GETTING THERE

THE TEXAS ELECTRIC TRANSPORTATION ROADMAP

TxETRA
EDUCATION FUND

GETTING THERE

THE TEXAS ELECTRIC TRANSPORTATION ROADMAP

MICHAEL J. OSBORNE, TOM 'SMITTY' SMITH, KEVIN DOUGLASS, DAVID TUTTLE, STEPHEN BROWN, LAURA MORRISON, ROGER DUNCAN, ROSS CROW, HANNAH SMOTHERS

TxETRA
EDUCATION FUND

Published in the United States by TxETRA Education Fund Publishing, a subsidiary of the Texas Electric Transportation Resource Alliance Education Fund.

Library of Congress Cataloging-in-Publication Data is available upon request.

ISBN 979-8-218-14416-6
Published in the United States of America

Edited by Gail Vittori
Art Direction by Logan Stewart
Print Management by Jane Pulaski

Library of Congress Control Number: 2023901411

First Edition

GETTING THERE

The Making of the Roadmap

In December 2021, The Texas Electric Transportation Resources Alliance Education Fund received a grant to conduct a process to develop and prepare a Roadmap for the Electrification of Texas Transportation. Working with TxETRA, a series of meetings was developed around the platforms selected to shape such a document with the Industry and other TxETRA members.

The platforms—TECH, Futureproofing, Justice, Market, Owners—were led by Dr. David Tuttle, Roger Duncan, Stephen Brown, Michael Conklin, and Kevin Douglass, respectively. We are most indebted for their contributions to this process, and for their contributions to this plan.

And there were many others, including input from our utility members, our OEMs, our charging company members, and our owners/drivers.

This book and its companion website are designed to work together. Thus, we have added a QR code that will direct the reader to the website (Gettingthere.info). It will provide a detailed charging map and the graphs and charts associated with the respective chapters.

We hope these tools will accelerate and help shape Electric Transportation in Texas.

SCAN QR CODE
TO VISIT WEBSITE

TABLE OF CONTENTS:

1

Why E.T. Matters

MICHAEL J. OSBORNE

With all the hubbub about electric cars these days, it's not surprising that some of us wonder why. Why do we need to replace our existing infrastructure of cars, trucks, filling stations, and oil change centers? We have seen our transportation system improve and modernize over the last 100 years to become a very reliable way to get from home to office, or from hometown to your favorite ocean side beach.

It's reliable, you can buy hats while you fill up with gas, and you can load up with sugar and starch while you do it. Many of us have experiences where the car heats up, or the AC breaks, or the fuel pump goes out; in the vast majority of experiences, things work out. We find a mechanic after asking around, we call AAA, or in the worst case, we call a wrecker and simply rent a car at a fairly reasonable price while the car is getting repaired.

The system works.

But the transportation system doesn't work with the rest of our infrastructure. You can't power your house with your car with this system. And you can't power your car with your house. When you park 40,000 cars into several square miles of asphalt, they can't power the lights at the football stadium. We can't use our cars to power the grid when a snow storm freezes the gas fields, which shuts down the power plants.

So, we have two very large systems in our advanced world and they don't communicate or share with each other. Electric transportation (ET) solves that problem.

Even though electric cars seem new to most of us, they've been around longer than our gas-powered cars. Here is what the U. S. Department of Energy has

to say about the early days of ET.

> It's hard to pinpoint the invention of the electric car to one inventor or country. Instead, it was a series of breakthroughs—from the battery to the electric motor—in the 1800s that led to the first electric vehicle on the road.
>
> In the early part of the century, innovators in Hungary, the Netherlands and the United States—including a blacksmith from Vermont—began toying with the concept of a battery-powered vehicle and created some of the first small-scale electric cars. And while Robert Anderson, a British inventor, developed the first crude electric carriage around this same time, it wasn't until the second half of the 19th century that French and English inventors built some of the first practical electric cars.
>
> Here in the U.S., the first successful electric car made its debut around 1890 thanks to William Morrison, a chemist who lived in Des Moines, Iowa. His six-passenger vehicle, capable of a

top speed of 14 miles per hour, was little more than an electrified wagon, but it helped spark interest in electric vehicles.

Over the next few years, electric vehicles from different automakers began popping up across the U.S. New York City even had a fleet of more than 60 electric taxis. By 1900, electric cars were at their heyday, accounting for around a third of all vehicles on the road. During the next 10 years, they continued to show strong sales.

To understand the popularity of electric vehicles circa 1900, it is also important to understand the development of the personal-use vehicle and the other options available. At the turn of the 20th century, the horse was still the primary mode of transportation….

Yet, it was Henry Ford's mass-produced Model T that dealt a blow to the electric car. Introduced in 1908, the Model T made gasoline-powered cars widely available and af-

fordable. By 1912, the gasoline car cost only $650, while an electric roadster sold for $1,750. That same year, Charles Kettering introduced the electric starter, eliminating the need for the hand crank and giving rise to more gasoline-powered vehicle sales.

In 1905, Henry Ford sold 500 cars. In 1915, he sold 500,000. Take a look at any photograph of a western city and the change in our cities is profound. In 1905, there were no cars, and in 1915, there were no horses.

So electric vehicles have been around a very long time.

But besides unifying the global energy system, why else would we supplant our existing transportation system which arguably performs well enough?

It's the carbon.

When Edwin Drake drilled his breakthrough well in Pennsylvania in 1859, change was on the horizon. But when Captain Anthony F. Lucas drilled through the overburden in East Texas in 1901 and his Lucas Geyser blew oil 150 feet into the air at a rate of 100,000 barrels per day, change had come. Rock oil became plentiful and cheap. No longer would we need to send New Englanders out to spear whales for oil for our lamps. We literally had oil to burn.

And oil was cheap: cheap enough to drive electric vehicle technology into a 100-year slumber.

But now, by burning all that carbon that was sequestered deep in our geologic inheritance and releasing the carbon dioxide that is formed in the process, our climate is changing. And we simply have to stop doing it or our children will be harmed and our grandchildren will suffer.

Why do we need to transition to electric vehicles? We simply must.

Only electric vehicles can run on our gigantic solar and wind plants that now can be seen throughout Texas. They also run on non-carbon emitting nucle-

ar generators. And even if they run on Texas lignite, in most cases they still emit less carbon than internal combustion engines (ICEs). In Texas, where 30% of our electric generation is wind and solar, electric vehicles clearly beat the best ICE vehicles.

Only electric vehicles can be charged at night by underutilized electric generation capacity so that you wake up every morning with a proverbial full tank.

But carbon isn't the only issue; it's also the pollution. And that means our health.

Multiple studies link vehicle exhaust to increased rates of cancer, heart and lung disease, and asthma. Fine particle pollution can cause coughing, wheezing, and decreased lung function in otherwise healthy children and adults. It's well known that vehicle emissions are major contributors to pediatric asthma. According to studies in Dallas, there is a persistent linkage with poor air quality and pediatric asthma. The Nature Conservancy's Nancy Jack underscored the concern:

"What we do know here in Dallas is that we've had a persistent problem with poor air quality and pediatric asthma for many years. Our region has never met federal regulations for ozone. And we have sufficient evidence that links ozone and other pollutants, like particulate matter, with childhood asthma and asthma at large."

The American Lung Association's 2022 "State of the Air" report finds that despite decades of progress on cleaning up sources of air pollution, more than 40% of Americans—over 137 million people—are living in places with failing grades for unhealthy levels of particulate pollution or ozone.

While intuitively we understand that air pollution damages the lungs, research is continually uncovering how it truly impacts nearly every organ in the human body. Air polluting particles can be small enough to enter the bloodstream, and from there they cause systemic inflammation and wreak havoc on our natural bodily functions.

It's easy to imagine what our air might look like with very few gasoline-powered vehicles in our air supply. We saw it during the pandemic. Moving to electric transportation, especially in our school buses, will provide substantial health benefits to those young lungs that ride in them.

It is odd that all of us get it that running your engine in your garage with the door closed is a sure, somewhat painless method to check yourself out. Why we think opening the garage door will lead to a different end is a mystery.

Moving away from internal combustion engines to electric drivetrains provides another benefit.

It saves us all money.

We save money when we buy electric transportation, both in the cost of the fuel and in the maintenance of the vehicle.

A recently released U.S. Department of Energy analysis found that battery-powered EV owners generally spend less than $1,000 per year on the electricity for their vehicles, versus average fuel prices between $2,000 and $7,000 for gas-powered vehicles.

If electricity costs 10.7¢ per kilowatt-hour (kWh) and the vehicle consumes 27 kWh to travel 100 miles, the cost per mile is about $0.03. If electricity costs 10.7¢ per kilowatt-hour, charging an EV with a 200-mile range (assuming a fully depleted 54 kWh battery) will cost about $6 to reach a full charge.

Overall, as of March 2022, driving an EV is dramatically cheaper per mile than driving a gas-powered vehicle. Nationally, EVs are three to five times cheaper to drive per mile than gas-powered vehicles. The fact that electric vehicles are more efficient and less costly to operate than their gas-powered counterparts is not new information, but it is becoming more apparent, and it is on more people's minds with fluctuating gas prices.

So, even though electric vehicles have a higher up-front cost than gas cars, many are less expensive over the course of their lifetime primarily due to cheaper fuel. Several studies break down this total cost of ownership, but as the cost of batteries continues to drop, more and more vehicles are becoming affordable for more and more buyers.

This trend can be seen in the skyrocketing sales figures all over the world.

As reported by the International Energy Agency, "Electric car sales reached a record high in 2021, despite supply chain bottlenecks and the ongoing Covid-19 pandemic. Compared with 2020, sales nearly doubled to 6.6 million (a sales share of nearly 9%), bringing the total number of electric cars on the road to 16.5 million. The sales share of electric cars increased by four percentage points in 2021. The "Net Zero Emissions by 2050 Scenario" sees an electric car fleet of over 300 million in 2030 and electric cars accounting for 60% of new car sales."

And it's not just car sales: decisions to procure electric trucks and buses are becoming commonplace in board meetings and executive offices around the globe. Here in Texas, the Austin ISD just announced their intent to move to 100% electric school buses.

In a historic vote, California state regulators in October 2022 agreed to ban the sale of any new gasoline-powered cars by 2035. Because California is the largest auto market in the U.S., the move could spur a faster nationwide shift to electric vehicles. Following in California's footsteps, New York will require all new vehicles sold in the state to be electric vehicles by 2035, reports *The Wall Street Journal*. The requirements would apply to all new cars, pickup trucks, and SUVs.

The number of EVs on U.S. roads is projected to reach 26.4 million in 2030, up from the projected 18.7 million as cited in a 2018 report. The projected 26.4 million EVs will make up nearly 10% of the 259 million light-duty vehicles (cars and light trucks) expected to be on U.S. roads in 2030.

We can expect Texas to be 10% of that number or more, giving us somewhere close to three million vehicles by 2030. As of October 2022, Travis County leads Texas counties with over 21,000 EV registrations. Harris, Dallas, Collin, Bexar, and Tarrant counties follow behind. If all that sounds like a pittance, it should be noted that just 12 years ago, the number of registered EVs in Texas was about 100.

Clearly, the EV growth rate here is spectacular.

Moving to electric transportation will unify all of our energy systems, thus making our energy infrastructure more efficient, more practical, stronger, and more resilient. It will substantially reduce the amount of carbon emitted by the transportation sector in our communities, both local and global. It will clean our air supply and improve the health of us all, but especially our children and our elderly. And reduced health costs will be good for our wallets at home and in Washington.

And it will evolve us.

Electric transportation is the door to a new future that we can only partially imagine. Not only does it allow us all to ride on the wind or the sun, it presents to us the possibility of transportation devices with communication and geospatial capabilities that are orders of scale beyond our present system of material delivery.

Every year 1.35 million citizens of Earth die in car crashes. Here in the U.S., the number is just over 36,000. Perhaps more importantly, 94% of the crashes are the result of human error.

A self-driving car, also known as an autonomous car, driver-less car, or robotic car is a car incorporating vehicular automation; that is, a ground vehicle capable of sensing its environment and moving safely with little or no human input.

Self-driving cars combine a variety of sensors to perceive their surroundings, such as thermographic cameras, radar, LIDAR, sonar, GPS, odometry, and inertial measurement units. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage. As a future technology, they are predicted to have a comprehensive impact on the automobile industry, health, welfare, urban planning, traffic, insurance, labor market, and other fields.

Whether or not you and I get in a self-driving vehicle, only time will tell. But our grandchildren may not have any issues with it. Besides, they will be able to watch their screens with relative abandon. My grandfather didn't like the idea of getting in an elevator without

an operator on board. It never bothered me.

Personally, like many in my generation, I like to drive. It's good for my concentration, my creativity, and blowing the bad ideas out of my bubba mind. But now I drive electric, and driving my third electric vehicle right now. My first lease was an electric long range (ELR) plug-in-hybrid which I liked a lot. It would send me text messages if I hadn't plugged it in by 11:00 PM. It even sent me text messages after I traded it in. My next electric car was a Tesla S. The "S" is a nice luxury sedan with remarkable acceleration and driving enjoyment. It will ruin you. My third EV is a Tesla 3. It has a very clean interior, and the control monitor in the middle of the console is horizontal instead of vertical like in the "S." It's faster than my GTO that I owned while at UT. And it handles like a fine sports car on Hill Country curves and grades. It is a computer with wheels and a great big battery. If I drive the speed limit, my range is around 260 miles. My lease payment is $450.00/month, the same amount I paid for my last Chevrolet Impala.

When we had the super storm, it was an office for both my physician partner and myself.

Once you drive electric, few go back to the old ways.

The purpose of GETTING THERE is to get you there.

The next chapter is written by Tom Smith. He describes the details of the Texas Electric Transportation Resource Alliance's (TxETRA) plan to electrify Texas. The chapters that follow are derived from the PLATFORM discussions we held over the last six months addressing Environmental and Social Equity, Market, TECH, Owners, and Futureproofing.

And since the mission of TxETRA is to promote transportation electrification in all its forms, we have provided a chapter on aviation, marine, and land technologies.

Also, you will notice that each chapter has a QR code that will open up the graphics and webpages that accompany this book.

Thanks for coming on board.

2

How E.T. Happens

TOM 'SMITTY' SMITH

We'd like to ask you to join us on a journey into the future–and it will be electrified. When you begin any journey, you choose a destination and then figure out how to get there–and for that you need a roadmap. As you begin this journey, you may ask several questions:

How soon do we want to get there, and how many people will be traveling with us? President Biden posed a challenge for EVs to reach 50% of new car sales by 2030; we Texans expect to cross that point by 2033.

How many vehicles will be on this journey? Estimates vary from a low of 930,000 by 2029 to 2.5 million. Some estimate as many as three million EVs will be on the roads based on the current rate of growth in sales. Texas is just beginning to accelerate up the adoption bell curve of EV ownership. The adoption curve can be divided into five segments: 2.5% innovators; 14% early adopters; 34% early majority; 34% late majority; 15% laggards. As of this writing, EVs represent almost 2% of new car sales in Texas. If by 2030 about 50% of car sales are EVs, we'll be shifting from the early adopter phase into the beginning of the early majority era.

How are we going to prepare given that level of uncertainty? You're likely to get closer to your destination if you have a plan and end up being slightly off course, than to have never taken the first steps and be left behind and 100% wrong. Road building projects offer some lessons: First you build the major interconnecting highways, then the secondary roads interconnecting the businesses, and, finally, the roads to everybody's home. In every road project, there are al-

ways the first movers that have already blazed the trail. They, eventually, will have to be interconnected for the system to function.

What's driving this change?

- Twenty Asian, European, and North American countries have banned the sale of gas and diesel vehicles because of choking air pollution and climate concerns.
- Emerging economies are looking at EVs as their "Henry Ford" moment where they can jump ahead and build EV plants to meet future demand in the U.S. and elsewhere.
- Recent federal legislation has funded the building of a border-to-border, urban and rural charging network and provided for significant tax incentives for buying and manufacturing EVs.
- EVs are far cheaper to own and operate than gas-powered vehicles: *Consumer Reports* found that EV owners save $6,000 over 200,000 miles of driving.

We are beginning to drive the transformation of our transportation system and industry, and in doing so, creating the opportunity for a new, just transportation and industrial system.

On every journey there are a number of hills to climb.

Charging is the first hill. The number one reason people don't buy an EV is range anxiety. If you leave town and want to go to Grandma's, because of a shortage of charging stations you might not get there. Those that exist are hard to find, even with an app, and are often broken or unable to connect to the internet. Today, there are 63 fast charging stations in Texas that will recharge your car within an hour, mainly along highways near major cities, but that's not enough to get into rural Texas.

The recently passed federal Infrastructure Investment and Jobs Act provides $5 billion to develop a border-to-border charging network across the country, of which Texas will receive $408 million. These funds will add 55 new fast chargers along Texas interstates to the 63 existing chargers for a total of 118; they will be installed about 50 miles apart. On less traveled rural roads, the chargers will be installed about 70 miles

apart. About 40% of the remaining funds will be used to install charging stations in each of Texas' 254 county seats.

Rural charging stations offer big opportunities to revitalize downtowns in smaller county seats. Since EV charging takes 20-60 minutes, EV drivers tend to spend money while waiting. They will often have a sit-down meal rather than buy fast food, and will spend more in downtown shops. According to the retailer Target, EV owners typically spend about $1 per minute shopping while their car is charging.

Many other opportunities exist to increase access to EV charging stations:

- **Parks** Texas should set aside funds to put charging stations in every state park, or allow private companies to lease land to provide that charging service.
- **Signage** Placing signs to help you find the EV charging stations once you leave the major highways are helpful in two ways: they ensure the traveler gets to the charger, and signal to non-EV drivers that there are ample chargers to

meet their needs.

- **Charging for renters** Eighty percent of current EV users charge at home, overnight. They use a 120V wall plug, or 240V power from a dryer circuit. However, since more than 50% of the urban population lives in rental properties, installing a charger isn't always possible. Special programs will need to be developed to ensure access to charging stations in these areas.
- **Disadvantaged communities** Forty percent of the National Electric Vehicle Infrastructure (NEVI) funds are for charging infrastructure, and are designated to benefit urban and rural disadvantaged communities to ensure that EV charging infrastructure is available to all. This can be accomplished by setting metro-wide goals, tax policies, making unused city lands available for leases to charging companies, installing street side parking powered by streetlamp circuits, and through requirements on developers and utility providers.
- **EV-ready codes** Twenty-four cities and one state have adopted EV-ready building codes to ensure that new single- and multi-family homes are EV ready; this requires adding an extra charging circuit and conduit to the electric wir-

ing at the time of construction. Futureproofing new buildings in this manner costs about $900 per unit, or one-quarter the cost of the $3,900 needed to install these circuits later.

- **Charging up office and commercial parking spaces** Charging at work is a good solution for those unable to charge at home or with long commutes. Adding charging infrastructure to existing office buildings is expensive, though those costs can be recouped through imposing higher parking fees for EVs, leasing spaces to commercial charging companies, or by using bidirectional energy flow to help offset peak energy costs. Some companies offer EV parking as a perk. Free or at-cost EV charging can also reduce employee commuter costs in a tax-free way, and can attract customers. Indeed, several retail chains, including Target and Walmart, offer EV charging in their parking lots to attract customers. Moreover, in October 2022, Diversified Restaurant Group announced that more than 100 Taco Bell restaurants are set to be "electrified" over the next year with ChargeNet DC fast-charging stations, offering what the operators said on average will amount to 100 miles of additional range in just 20 minutes—about the time it takes to sample some Nacho Fries and take a bathroom break. These stations, powered by solar and grid energy, will be able to charge rapidly because of a battery booster.

- **Convenience stores and gas stations are getting charged up** Texas' EV charging plan is designed to serve one million EVs, but if the number of EVs on the road is two and-a-half or three times more than predicted, we'll need a lot more. According to a 2022 study by Boston Consulting Group, the good news is that about 95% of U.S. fuel retailers surveyed said they're currently offering or planning to offer EV charging stations, while 70% said they're planning to expand their fuel network in the coming years. The bad news: unless Texas has a universal access to charging plan, these charging stations may not be available in all areas of the state, reflecting the economic and geographic challenges associated with providing universal access to broadband.

A second hill is to ensure the benefits of low cost EVs are available to all. EVs can help reduce the transportation-related portion of a low-income family's

budget, from 28% to 13%, as a result of lower fuel and repair costs. New EVs are typically $10-15,000 more expensive than traditional gas-powered cars, though 10 EV models on the market today are less expensive than the average new gas car. However, the price of previously owned EVs now exceeds the average cost of comparable used gas-powered cars.

What can be done to increase EV use in low-income communities? In some metro areas, programs such as rent-on-demand and subscription car rental services that allow the use of EVs on an as-needed basis, versus requiring a regular monthly payment, are working well. Another strategy is to provide low-cost loans to buy new or used EVs. The recently passed Inflation Reduction Act provides $27 billion to the U.S. EPA to award competitive grants for clean energy and climate projects that reduce greenhouse gas emissions. These include funds to underwrite loans for EVs. The Texas Clean Energy Fund is planning a pilot program to test these types of loans.

A third hill we have to climb is putting tools in place to ensure that excess energy stored in EV batteries can be used to support the grid, and that

thoughtless charging doesn't stress the grid. The grid is a term loosely used to describe the electric transmission and distribution network that interconnects electricity to our buildings and to the myriad things we plug into it.

Historically, the power has flowed one way. New internet technology enables electrical demand to be reduced when the grid is short, allowing the amount of power you consume to be reduced, or for the grid to be operated as a two-way street so that the solar on your roof, batteries in your EV or on a garage wall can be dispatched to provide back-up power. Dispatching energy can be rewarding: the Battle Group estimates that it could be a $1.3 B business in Texas by 2030, with the value coming from avoided generation, energy, transmission and distribution costs, and ancillary services.

A fourth hill is ensuring *reliable* charging. A recent study found that more than one quarter of all chargers in the Bay Area were found to be nonfunctional when tested. Of these, the cable was too short to reach the EV inlet for 4.9% of the EVSEs, and 22.7% were unresponsive or had unavailable screens, payment

system failures, charge initiation failures, network failures, or broken connectors.

A fifth hill is training the workforce needed to install half a billion dollars in charging infrastructure and maintain it. The federal government has required that the stations it funds be operational 97% of the time, and so trained diagnosticians and technicians will be needed. This further requires that electricians complete the Electric Vehicle Infrastructure Training Program (EVITP) to ensure they can undertake site assessments and load calculations, comply with the National Electric Code, adhere to jobsite safety practices, have access to and properly use personal protection equipment, and other installation and maintenance best practices. Community colleges in Texas are beginning to offer this EVITP certification.

Texas has 14 manufacturing facilities making EVs or components. By 2024 it's estimated that nearly 14,000 Texans will be working in those industries, located in 203 Texas counties. Governor Abbott's top industrial development priority is luring EV manufacturing to Texas. For Texas to become a larger EV manufacturing hub, it would be wise to develop a consortium of industry, research, and educational institutions similar to the seminal Microelectronics and Computer Technology Consortium (MCC) that led to Texas becoming a leader in high tech manufacturing.

The sixth hill is educating dealers and salespeople. EVs are a new type of car and there a lot of misconceptions about them. Salespeople need to answer basic questions about the extent and types of charging infrastructure, battery longevity, power sources, relative efficiency, and battery recycling. Salespeople find that they sell two to three times as many EVs once they are trained. Most manufacturers offer training, but it's often not comprehensive or localized to address state or local EV charging grants. Several non-profits and cities are stepping in to offer training.

But before we address the final hill to climb, let's look at some of the downhill challenges: electric vehicles used in transit and freight. The reasons are simple: economics and the environment.

EV trucks reduce costs. When you look around the world, the first adopters of electric vehicles are metro and school buses. They enjoy lower fuel

costs, reduced brake costs due to regenerative braking, and the simplicity of battery engines. EV trucks and buses are far cheaper to own and operate than gas-powered options. Peterbilt has a graphic that compares the cost of a 200-truck mile trip, illustrating that it would cost $118 in diesel fuel to cover that distance, but just $25 in electricity for an EV truck.

EV trucks are good for the environment, too. The Dallas–Fort Worth and Houston-Galveston metro areas have been declared severe non-attainment areas for ozone. Fifty-seven percent of the ozone emissions in DFW and 63% in Houston come from vehicles. Existing emissions reduction strategies won't be enough to reduce air pollution to safe levels. Under the Clean Air Act's Section 185, the U.S. EPA can force industries in non-attainment areas to make further reductions.

Electric trucks can come rolling to the rescue of our cities from air pollution. Heavy-duty trucks represent only 4% of vehicles on Texas roads, but account for 90% of NOx emissions. Eight-five percent of heavy-duty truck traffic travels less than 500 miles, leaving plenty of opportunity for zero-emission vehicle investments, especially in and around ports. In the most recent Texas Clean Fleet Program period, the Texas Commission on Environmental Quality (TCEQ) set aside 50% of funds ($8 million of the $16 million) for zero-emission trucks. Staff have said the program exceeded those targets.

University of Houston researchers have found that replacing at least 35% of Houston's gasoline cars and diesel trucks with electric vehicles by 2040 will reduce pollution and improve air quality by 50%.

Why is pollution from trucking highest around Texas sea, rail, and airports and along our borders? A lot of diesel engine vehicles wait for their loads for hours and idle to cool and heat their cabs. Pollution controls don't work, or don't work efficiently at idle. Heat maps show the plumes of pollution radiating like spokes on a wheel toward warehouse and distribution centers, to industries and shopping centers, and then for home delivery. Electric vehicles can heat and cool their cabs far more efficiently than diesel. A last mile delivery vehicle will run 8-12 hours in a day, but is driven less than 65 miles. That's a perfect range for an electric

delivery vehicle with a small battery.

Texas has an opportunity to flip the switch, rapidly reduce costs, and reduce pollution by electrifying its trucking fleet. The Texas Emission Reduction Program gives fleet operators incentives to switch early enough to meet U.S. EPA deadlines for air quality standards.

What role does hydrogen play and how can we assure it's "green"? Hydrogen fuel cells are promoted as a way to power trucks with electricity without the weight of batteries. While these fuel cells work well, building hydrogen reformers and pipelines is very expensive, and likely to thrive only on interstates where there is a lot of truck traffic, or in areas near refineries where hydrogen is produced as a by-product. According to a 2014 report published by the National Renewable Energy Laboratory, total fuel costs per mile for an electric battery vehicle were 21% lower than for a hydrogen fuel cell electric vehicle. Both gray and blue hydrogen emit pollution during processing. Blue hydrogen captures carbon and injects it underground in a process called carbon capture and underground storage

(CCUS), but a recent study of 13 of the largest CCUS projects totaling 55% of the world's capacity found that of these, seven underperformed, two failed (the Sahal plant in Saudi Arabia was shut down due to concerns about containment failure), and one was mothballed.

The seventh and final hill: What happens when EV batteries wear down? Won't we have a big waste disposal problem? The federal government requires electric vehicle batteries to be warrantied for 100,000 miles or eight years. As the battery ages and its range is reduced below 80%, the battery gets replaced. It's estimated that 80% of batteries can be repurposed and reused as energy storage devices. Batteries that are damaged or are too worn for reuse will need to be recycled: the precious metals used to manufacture them can be resold for new batteries or to the high-tech industry. The Texas Commission on Environmental Quality has appointed a task force to develop standards for battery reuse and recycling.

Texas is beginning to experience a series of electrifying changes that will play out over the next five to 10 years. Texas can either lead or follow. Leaders

will get the benefit of new jobs, lower costs, and cleaner air. Followers will pay higher prices and lose out on potential economic growth.

Let's get rolling on our journey into the future with our roadmap in hand.

SCAN QR CODE
TO VISIT WEBSITE

3

Driving Electric

KEVIN DOUGLASS

I'm Kevin Douglass. I'm an airline pilot and serial EV owner. I've owned four EVs and built one. (I also own an electric plane.) I've been asked to share my experiences and those of other TxETRA owners and drivers to outline problems and solutions facing EV owners.

I drive EVs because they are simply better: they are cheaper to own and operate, they last longer, they are easier to repair, and they pollute less. You don't create heat while driving or idling, the impact of the extraction of the minerals needed for a battery is a fraction of the ongoing cost of extraction of crude oil and refining it into gas and oil, and you don't drip oil and gas as you drive.

Like most drivers and EV owners, I drive back and forth to work and run a few errands daily—usually less than 40 miles per day. I charge my EVs at home at night. It becomes a habit to plug in, like charging your cell phone. And I don't have to go get gas once a week and waste 10 minutes while being gassed with fumes.

But EVs aren't just for driving around town. I go on frequent road trips to see my grandkids in Tennessee. It's about a 600-mile trip and takes several stops to charge. The time needed to charge the car benefits me in terms of exercise and exploration: I go for walks in places I have never been, and follow medical advice and stretch my legs and mind.

It's not just cars and trucks that are electrifying. I recently bought an electric airplane called a glider. I use the motor to gain altitude and glide home. Prototype electric planes are being tested for short commuter flights by major manufacturers that show promise. EV ferries are working every day in New York harbor, and

fishing and pleasure boats are becoming common.

In the rest of the world, the most common EVs are electric bikes and three-wheeled delivery and passenger vehicles.

I'd like to take you on a recent road trip that shows some of the problems EV drivers run into. Recently, I drove my Chevy Bolt from my home in Houston to San Marcos to go canoeing with my nephew. I left for the trip two-thirds charged. We turned over in the canoe; I went swimming with my phone and it died. I went looking for a place to charge the car and stopped at several nearby charging stations. Those charging networks would only work with a phone app, not with a credit card. So, I drove very slowly to a charging station in San Antonio that accepted credit cards. My experience was just like that of driving a gas car: when you're low on fuel you drive more slowly to get to where you can refuel.

Recently, TxETRA held a listening session where other EV owners shared their reasons for driving an EV and frustrations with some parts of the current system. These form the background for a number of the system improvements we suggest in other chapters.

One woman said she felt guilty about the pollution she was emitting when waiting in line to pick up or drop off her kids at school, and it was a joy to not have to pollute just to keep cool or warm. Another admitted that she snuck outside and sat in her temperature-controlled electric vehicle to make calls when the kids were too loud. Other drivers shared their reasons for driving EVs, including better technology, lower fuel costs, reliability, and less pollution.

A number of people shared their frustration with being unable to charge at their condo or apartment. About 50% of Texans live in apartments or condos, so this is a big problem. Some suggested streetside charging like you commonly see in Europe. Others suggested adopting building codes that require all rental or multi-family properties to install chargers.

Others found that charging stations frequently didn't work, and suggested the state should develop uptime standards. Many expressed frustration that

chargers required downloading an app to their phone to charge, and wanted all charging stations to accept credit cards.

Several people complained about rates. Most companies charge based on the energy consumed, while some charge based on the length of time it takes to charge. For those who drive cars that charge slowly, time-based rates can be a substantial added expense. Others complained about demand charges that increased the cost of charging at peak hours of the day.

Several people suggested that we were just in the first wave of electrification, and that we needed to plan ahead. In the near future we can expect plug-based charging to give way to inductive charging, and we need to plan for autonomous vehicles.

Consumers Union has found that 95% of those that own or drive an electric vehicle don't want to return to gas-powered vehicles.

I have seen the future: it is electric.

SCAN QR CODE
TO VISIT WEBSITE

4

Charging Ahead

DAVID TUTTLE

Electric vehicles are not a new concept. Thomas Edison and others were developing electrically driven vehicles over a century ago. However, throughout the 20^{th} century, the key technologies were not available to enable plug-in electric vehicles (PEVs) to offer competitive range, cost, and convenience of gasoline-powered internal combustion engine (ICE) vehicles. Over the past 20 years, lithium batteries, semiconductor-based power electronics, and software advanced sufficiently to enable mass-market viable and compelling PEVs such as battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). BEVs are the most conceptually simple PEVs to understand: a large on-board battery is charged from the grid; the energy stored in its battery is transformed from DC to AC via the power electronics based upon driver commands; and the output from the semiconductor-based power electronics is used by the electric traction AC motor to propel the vehicle down the road. As battery costs have declined substantially over the past decade, BEVs have become progressively more compelling with higher performance, much longer range, and far faster DC-Fast Charging (DC-FC) rates.

Plug-in hybrid vehicles use an innovative but somewhat more complex combination of a BEV's electric drive with an on-board gasoline generator or "range extender." The PHEV is also charged from the grid, and then driven on electricity until the battery is depleted. Once the battery is exhausted, computers seamlessly deploy the gasoline engine to power the vehicle in a fuel-efficient hybrid "charge sustaining" mode. This allows the driver to travel long distances without becoming stranded. With a long enough electric range, the PHEV driver can electrify most, if not all, of their daily local commuting trips, and leverage the existing gasoline infrastructure when taking a longer trip. Some

past implementations of PHEVs have had a relatively short all-electric-range (AER) that leads to less electrification of trips and reduction of emissions. Studies show that with longer AERs, far more vehicle miles traveled can be electrified, and drivers are more likely to charge from the grid instead of driving on gasoline. In August 2022, the California Air Resources Board adopted their Advanced Clean Car 2 (ACC2) regulations, requiring all vehicles to be BEVs, PHEV-50s, or hydrogen fuel cell vehicles (H2FCVs) by 2035. Up to 20% of these vehicles can be PHEVs as long as they have a minimum of 50 miles AER. This 50-mile electric range should comfortably cover the average daily commuting distance in the U.S. of about 35 miles. PHEVs eliminate the century-old range anxiety and charging infrastructure concerns. A range extender may be particularly valuable for vehicles such as pickups that haul heavy payloads, tow trailers, or for drivers in rural areas with sparse access to DC-Fast Charging infrastructure.

As hydrogen-related costs continue to improve, H2FCV technology will likely be adopted in larger trucks that consume considerable amounts of fuel, have the heaviest payloads or trailer, need fast refueling times, or travel very long distances. Large Class-8 semi-trucks for long distance hauling and heavy local refuse trucks are examples of applications where hydrogen has an advantage with its relatively high speed of refueling and high energy density of on-vehicle fuel storage tanks.

As a wider variety of compelling BEV and PHEV models have become available, adoption has substantially increased. Indeed, electric vehicle adoption is expected to continue to accelerate as battery technology further advances and becomes less expensive, more charging infrastructure is deployed, and a wider variety of models is available.

Charging Infrastructure

A charging infrastructure that is not only equivalent to, but better than, the existing gasoline/diesel infrastructure is critical to accelerate electric vehicle adoption. The “4 C’s of charging”—coverage, capacity, convenience, and cost—offer an essential focus when developing strategies to deploy charging infrastructure. Unlike the gas station model of conventional ICE vehicles that we’ve been accustomed to for many decades,

electric vehicle charging offers a far greater variety of charging options. These different charging scenarios are characterized by different charging speeds, costs, and locations.

The common terms for *charging speeds* for the light duty electric vehicles that most U.S. drivers use are: Level-1 charging at 120Vac providing about a 1.44kW (kilowatt) charge rate and the lowest cost; Level-2 charging at 240Vac yielding a 3.6kW to 19.2kW charge rate; and Level-3 charging or “DC-Fast Charging” at 400Vdc to 800Vdc offering charging at 50kW to 350kW but at the highest cost. The common *locations* for light duty vehicle charging infrastructure are: single- and multi-family residences; workplaces; public city/town Level-2/DC-FC; and public intercity DC-FC along highways.

For daily commuting, the driver can generally charge where they are going to naturally park during their daily routines, say at their home or workplace. While traveling on trips or if living in a multi-family residence, they can charge at far faster DC-Fast Chargers that approach (but don’t quite yet match) the refueling speed of a gas pump.

The most attractive and dominant use case is a PEV that is typically driven in daily commuting and charged at a single-family home overnight. Over 80% of charging is typically performed at the driver's home. PHEVs have smaller batteries and typically can be charged overnight with a 120Vac Level-1 charger plugged into the ubiquitous NEMA 5-15 receptacle that virtually all other home electrical devices plug into. A 240Vac Level-2 charger is typically installed for much faster charging of BEVs with larger batteries, or for PHEV drivers who wish to electrify more of their miles.

Level-1 charging is the lowest cost, the easiest to install, and creates virtually no additional stress on the grid. The driver simply plugs their mobile EV charging cord into a common 120Vac wall outlet as they do a vacuum cleaner, floor light, TV, or any other device in their home. While Level-1 may charge a PHEV overnight comfortably, it may not meet a driver's need for charging a longer-range BEV with a substantially larger battery.

The number of multi-family residences with overnight Level-1 or Level-2 charging infrastructure in their parking lot or garage is growing, but is still more limiting than the opportunity to install Level-1/2 at a driver's own single-family home. Other options for these drivers include charging at work or at a public urban Level-2/DC-Fast Charger. Innovative urban DC-FC locations are where the driver can park and plug-in their EV, and then walk a short distance to shopping, dining, or entertainment for the 30-60 minutes it may take to charge their battery. An example of a convenient arrangement is when a driver could gain enough charge to last for a week of commuting (say 300 miles) in less than an hour while they complete their weekly grocery shopping or dine out.

When traveling between cities, intercity DC-FC can now generally provide up to an 80% charge in 30 minutes or less on the most capable long range BEVs and today's DC-Fast Chargers. DC-FC equipment is most costly to deploy, and thus is generally the highest cost per kWh of energy for the driver to charge their battery. Many DC-FC deployment plans target a maximum of 50 miles between intercity DC-FC with a minimum of four bays for each station. On the most sophisticated DC-FC stations and networks, the driver can have a trip refueling experience that can be superior to an ICE vehicle. The driver can program their trip into their vehicle navigation system that then calculates the DC-FC locations to stop at along the route, shows the cost per kWh at each station and the number of stations available in real time, and the amount of time to optimally charge at each DC-FC. They can pull into the charging bay, plug in the vehicle, have the vehicle automatically bill their credit card, and leave the vehicle to have a coffee or meal, enjoy shopping, or take a needed break or invigorating walk.

The costs vary for each of these charging speeds and locations. Level-1 chargers are generally provided free with the vehicle and simply plug into a common 120Vac wall outlet. Level-2 chargers can cost $400 to $3,000 to install at a home. Multi-family Level-2 installations are somewhat higher in cost given they are meant to be more rugged, sometimes involve trenching to install, and may need payment or authorization systems. The cost to install and operate a DC-FC is substantially higher given it can provide charging

rates over 240 times faster than a Level-1 charger. Each DC-FC unit can cost $50,000 to $100,000, plus have higher grid charges from the utility; its business case is the most challenging to achieve profitability. Firms that deploy DC-FC will tend to achieve sufficient profitability as they learn how to reduce the up-front capital installation costs, achieve higher asset utilization from more charging session sales, and become creative with co-selling other profitable products while drivers are charging.

Multiple charging station networks are being installed in Texas through local utilities, auto manufacturers such as Tesla, and charging network companies such as evGO and Electrify America. In addition, the Texas Department of Transportation (TxDOT) has a multi-year plan to develop a charging network with funding from the National Electric Vehicle Infrastructure Formula Program (NEVI) to enable drivers to travel across the state and spur economic development. This plan intends to first install 4-bay DC-FCs along all the major intercity alternative fuel corridors in Texas, with a maximum of 50 miles spacing between stations within one mile from the interstate highway exit. Each of these stations will have a minimum of four 150kW chargers. Later, TxDOT will work with rural counties and cities to install DC-FCs at or near the county seats across each of the remaining 254 Texas counties.

Autonomous Vehicles

Self-driving or autonomous vehicles are an exciting development that can provide new options to those who are traditionally mobility challenged, extend the years of mobility freedom, and reduce transportation costs or real estate used for parking. There is some debate whether autonomous vehicles will reduce overall traffic, congestion, and emissions. The sensors, control hardware and software, and controls have substantially advanced since the pioneering days of the DARPA Grand Challenge and Urban Challenge (2004-2007) competitions that were created to nurture self-driving technology. Even with these advancements, vehicles that can provide full self-driving on all roadways and conditions are not yet available to the average consumer or fleet. Today, competitors are using different sensor suites with different combinations of cameras, sonar, radar, and LIDAR, as well as varied hardware accelerators and software algorithms in pursuit of ever higher

levels of functionality. While none have achieved SAE Level-5 autonomy capabilities, the technology is continuing to improve.

Today, much of the value in the related technology is being delivered in Automated Driver Assistance Systems (ADAS), with features such as automatic emergency braking, lane-keep assist, and adaptive cruise control. While not providing full autonomy, these features can help reduce injuries and fatalities while the self-driving technology progresses further.

The sensor, computing, and servo control of self-driving technology can create an additional load to a vehicle's electrical system. Electric and electrified vehicles, e.g., BEV, PHEV, HEV, H2FCV, have an advantage over ICE vehicles in supporting this extra electrical load given their considerable battery and power electronics capabilities. That said, autonomous technologies can be incorporated in conventional ICE vehicles, but at additional cost and complexity. Therefore, even though autonomous vehicle technology can sometimes get grouped together in categories such as CASE: Connected, Autonomous, Shared, Electric Vehicles, autonomous and electric vehicle technologies can mostly be considered as independent technologies.

We should expect to see continued improvements of the technology's cost and capability over time. Some particular highest-value added market segments are taking the lead in deployments. Improvements in safety, efficiency, and cost may lead commercial trucking or fleets to deploy the most advanced systems more rapidly.

Vehicle-to-Everything (V2X)

"V2X" is a generic term to describe a variety of vehicle-to-vehicle, -infrastructure, -load, -home, and -grid interactions. The term V2X can have different definitions based upon context: When V2X includes V2V (Vehicle-to-Vehicle) and V2I (Vehicle-to-Infrastructure), it generally implies communications (and not electric power flow) that can improve safety, congestion, and traffic flow.

When V2X includes V2L (Vehicle-to-Load), V2H (Vehicle-to-Home), or V2G (Vehicle-to-Grid), it involves electrical power flowing to or from the vehi-

cle. This bi-directional power flow to an isolated load or microgrid with V2L, V2H, or vehicle-grid interaction with V2G leverages the considerable battery, energy storage, and power output capability of a BEV, PHEV, or H2FCV.

Vehicle-to-Load (V2L)

Vehicle-to-Load is a capability in which the vehicle can provide power output to individual loads, such as power tools, pumps, fans, TVs, refrigerators, and communications equipment. V2L allows the vehicle to act as a quieter, more convenient, and lower emissions portable backup generator. It may be manually connected to a home for rudimentary critical home load backup if the home is configured with an input box, transfer switch, and critical load breaker panel. The vehicle simply incorporates power conversion devices and common receptacles that allow these loads to plug into the vehicle as they would at a typical home. Two examples are a simpler, lower power 120Vac outlet in the rear of an SUV, and a more capable 120Vac plus 240Vac V2L "ProPower Onboard" option offered on the Ford F-150 Lightning pickup.

Vehicle-to-Home (V2H)

Vehicle-to-Home is a capability in which the vehicle can provide more seamless and automatic power to back-up a home when the grid fails. The vehicle is charged and discharged through the power cord typically used to charge the PEV. One of the first examples offered is named "Intelligent Backup Power" (IBP), which uses an off-vehicle DC-AC inverter, transfer switch, dark-start battery, and bi-directionally capable electric vehicle supply equipment (EVSE) or charger. The system senses when the grid fails, and then automatically reconfigures the system to output power from the vehicle's battery. This function could be expanded in the future to include power from a PHEV range extender or hydrogen fuel cell to power the home. The transfer switch isolates the home from the grid; this is essential to safely create a microgrid that the vehicle can power. Once the grid is functional again, this IBP system switches back to the grid and disables power export from the vehicle.

Vehicle-to-Grid (V2G)

Vehicle-to-Grid uses the electric vehicle's battery to provide services to reduce grid costs, stress,

or emissions in return for compensation to the vehicle owner. The vehicle is charged or discharged through the power cord typically used to charge the PEV. While a dedicated V2G system without a transfer switch cannot provide power to back-up a home when the grid fails as a V2H system can, a V2G system can leverage a potentially huge pool of storage in the electric vehicle fleet. A rough estimate is that for every one million new PEVs on the road, a pool of 75GWh of storage could be tapped as a huge lower-cost flexible distributed energy resource (DER). V2G as a concept has been explored for several years. However, the number of electric vehicles on the road is only recently becoming significant enough to attract investment deployment beyond a pilot phase. While the vehicle storage is already purchased as part of the vehicle, other factors such as the cost and lack of availability of bi-directional charging infrastructure, challenges with utility supervisory control and data acquisition (SCADA)/back-office software integration, immaturity of common industry standards, and EV manufacturers' concern over battery degradation have impeded broader scale deployment. The exciting promise of V2G is the ability for electric vehicle charging and discharging to be very synergistic with the grid.

Intelligent charging of the vehicle could be deployed when electricity prices, emissions, or stress are low. Opportunistic discharging could further reduce the grid's peak demand, help mitigate ramp rates from increasing amounts of renewable generation, and reduce electricity costs for both EV and non-EV drivers.

Utilities, auto, and charging equipment manufacturers, and customers will likely not jump from first charging their EV with only rudimentary levels of sophistication to V2G. V2G is the most sophisticated form of vehicle-to-grid interaction. There likely will be a progression of steps that make EV charging more intelligent, then enable bi-directional power charging, and then V2H/V2G.

In addition, customers may find great value in vehicle power export (VPE) with V2L and V2H. Note that some also may use the terminology vehicle-to-building (V2B). In this chapter, the author is differentiating when the vehicle is engaged with the grid with V1G (e.g., intelligent charging) or V2G, compared to when the vehicle and home/loads are isolated from the grid with V2L or V2H.

With vehicle power export, individual loads in remote areas, camping or tailgating, or emergency command centers can be powered in a more convenient, quieter, and lower emissions fashion than with a traditional portable or standby generator.

SCAN QR CODE
TO VISIT WEBSITE

5

Justice For All

STEPHEN BROWN & LAURA MORRISON

‘Equality’ is often used to imply that all people are given equal access to the same resources, regardless of the situation. Equity, meanwhile, is about ensuring everyone has what they need. That requires expending more effort on some communities than others to ensure they, too, end up with fair opportunities for a healthy life.

To have a common baseline, it’s useful to define some terms that are key to the concepts of energy and environmental justice. For instance, environmental justice is the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

Similarly, energy justice refers to the goal of achieving equity in both the social and economic participation in the energy system, while also remediating social, economic, and health burdens on marginalized communities. Energy justice explicitly centers the concerns of frontline communities, and aims to make energy more accessible, affordable, clean, and democratically managed for all communities. The common thread—justice—requires a commitment to systemic changes that facilitate equitable access to both opportunities and tools.

In this chapter, we'll explore opportunities to embed justice into Texas' electric transportation landscape and future. Three tenets of energy justice will be used to help add context for understanding and overcoming the obstacles to systemic change: procedural justice, distributional justice, and recognition-based justice.

These pillars encourage us to ask questions like:

- What is the decision-making process like? How transparent is it, who is included, etc.? It reflects the perceived fairness of the process.
- How do we allocate or distribute the resources or products? Is it by need, opportunity, location, or merit? It reflects the perceived fairness of the outcome.
- Who in the process or outcome is given respect or recognition? This reflects the perceived fairness of treatment.

All of these questions are subject to the context of a specific location and a specific history, both of which may have environmental or social harms. Recognizing the importance to not exacerbate these conditions, coupled with the ability to repair them, is crucial and must be realized and not just discussed.

Outcomes during Winter Storm Uri well illustrate this phenomenon. During this storm, it became evident that infrastructure in lower income communities was generally older, and had more problems due to historic disinvestment. As a result, these areas (which were also farther distanced from places to access food, complicated by a gasoline shortage) experienced worse outages and water main breaks. The combined effect left these communities more likely to be dealing with a need to boil water, while at the same time not having the electricity to do so and no way to get bottled water. There were stories of people weathering the storm in electric vehicles, which became a reliable mobile heat source.

Further, we'll discuss the challenges and opportunities related to electric transportation access and affordability. We'll conclude this chapter reinforcing the need to center justice in the work that we do to ensure that a decarbonized transportation sector is within reach of all Texans.

As we consider these topics, it is important to keep in mind the real people that will be impacted by these decisions. Consider a single parent transporting their kids, a recently-displaced community member who now commutes from a home 40 minutes outside of town, owners of an underutilized business that want to host a charging station, a resident living in a rural community with family hundreds of miles away, a neighborhood

apartment complex, a person with limited mobility dealing with the thick charging cables, a young person trying to get financing for an electric vehicle, a father working two jobs with no easy access to charging, and individuals trying to grow their generational wealth who want to invest in a new market.

These are the people who will be impacted by the policy decisions and investments made in electric mobility.

Justice Tenets

Procedural Justice concerns who is at the decision-making table, and whether, once at the table, everyone's voice is heard. It represents a call to involve all stakeholders in decision-making in a non-discriminatory way. It is strongly tied to the third pillar of Recognition, as it represents a call to involve all stakeholders in decision-making in a meaningful way. Although each of these three tenets are exceedingly important, our focus will be on Procedural Justice and how it can be applied to advance energy justice in the Texas electric transportation market.

Distributional Justice is outcome focused and speaks to whether all people equally share in the benefits and burdens of the energy system. Energy decisions can affect people unequally, starting from where coal plants or wind farms are located, to who shoulders the burden of rising energy prices. Distributional justice highlights the ways benefits, risks, and responsibilities are divided unequally throughout the energy system.

Recognition-based Justice asks the question who is justice for? Who enacts energy justice? When talking about energy issues, the language used is often technical, with very little recognition of the human beings affected. Recognition-based justice calls us to acknowledge who is being affected by energy decision-making and who is responsible for those decisions.

In this context, it is imperative that all Texans are exposed to the electric transportation arena to allow for meaningful community involvement in policy and program development, as well as in the experience of electric transportation itself. In the end, we should aspire to create community-driven solutions. Effective exposure across all communities requires outreach and

education by trusted individuals of the community, demystifying technical terms in discussions, ensuring that the language used is inclusive, and coordinating navigation programs.

Ensuring Equitable Opportunities in an Electric Transportation Future in Texas

Framing the opportunities in electric transportation requires a broad perspective that considers the spectrum of benefits of clean transportation, from cost savings on fuel maintenance for a personal-use vehicle and public health improvements from cleaner air, to job opportunities and community resilience. These opportunities can be categorized in four cross-cutting topics: Access to Electric Transportation; Access to Charging Infrastructure; Economic Opportunity and Just Transitions; and Building Healthy and Resilient Communities.

The TxETRA Equity Committee conducted several brainstorming sessions in 2022 to explore these topics. Their specific ideas are included below, with a brief discussion of each.

Access to Electric Transportation

Overcoming financial barriers or affordability issues of electric vehicle ownership/leasing is a key step in providing equitable access to electric transportation, and involves many aspects of the process, e.g., offering rebates and incentives where applicable, and leveraging financing through green banks where loan programs can be designed to be scalable through long term, patient capital.

However, alternatives to personal-use vehicles, such as electrified public transit, ride share, car share, and micro-mobility solutions. are also key in the transportation landscape, and can be successfully integrated with community-driven solutions.

Fleet and commercial transportation traditionally play significant roles in air quality issues; they should be prioritized for electrification in frontline communities that have been historically harmed by the cumulative effects of air pollution.

Alternatives to transportation per se also play a role in equitable access, ensuring that tele-work,

tele-marketing, tele-health, and tele-education opportunities are available and marketed to under-resourced communities.

The TxETRA Equity Committee suggested the following considerations to improve access to electric transportation:

- Align affordability of access with community needs
- Provide access to lower-cost, high-quality vehicles
- Develop and implement an equitable approach to electrifying public transportation and EV adoption in fleets
- Consider offsetting air pollution as a priority
- Ensure that people who are credit-challenged are able to purchase/lease EVs at fair interest rates, and have access to transportation-efficient loans
- Prevent predatory lending/financing practices
- Enact loan programs that scale relative to vehicle affordability, and innovative leasing programs that prioritize equal access to affordable

vehicles
- Establish green banks
- Provide rebates and incentives
- Promote equitable dealership experiences

Access to Charging Infrastructure

Charging infrastructure should be distributed in a way that's geographically just with public, residential, and workplace charging options.

Providing public charging options, both DC-fast charging and Level-2 charging, can be caught in a "which comes first, the chicken or the egg" quandary. It is, of course, necessary in areas already experiencing EV adoption. But it is also necessary in areas before EV adoption is common to instill a sense in the community that EV adoption is *possible*. Community-driven recommendations will identify culturally relevant and convenient locations to help avoid exacerbating gentrification forces.

Residential charging would generally be the most convenient location to charge an EV, but can be a challenge for residents of multi-family complexes, often

with a predominance of lower income families. Programs that encourage access to EV charging for apartment dwellers should be emphasized, with a particular focus to require installation in new affordable housing projects and retrofit existing affordable developments.

Workplace charging offers a highly convenient alternative to residential charging, and should also be emphasized with particular focus on employers with workers at the lower income scale.

The TxETRA Equity Committee suggested the following considerations to improve access to charging infrastructure:

- Prioritize communities that would traditionally not have infrastructure
- Emphasize culturally relevant sites (such as community centers)
- Assess how to ensure community members have access to new infrastructure, and that adding infrastructure does not facilitate displacement
- Address strategies to avoid EV gentrification

- Provide for charging access in rental properties
- Support charging-at-work strategies, and installing charging stations at challenging worksites such as construction sites

Economic Opportunity and Just Transitions

Billions of dollars in public and private funds are being deployed to develop the electric transportation future. This presents a unique and historic opportunity to create wealth and provide jobs and workforce training in disadvantaged communities.

Creating wealth can take the form of business development opportunities for existing and new small, local/regional, and historically underutilized enterprises, with equitable distribution of contracting opportunities and capacity-building resources.

The jobs created to support these investments offer an opportunity to participate in the economy of the future. Along with appropriate training, they can provide a pathway to thrive for groups that, historically, have experienced higher levels of employment barriers and challenges.

The TxETRA Equity Committee suggested the following considerations in economic opportunity and just transitions:

- Establish a wealth-building mindset; contracting opportunities for existing and new small, local/regional, and historically underutilized enterprises
- Prioritize plans that equalize distribution of contracts between large and small businesses
- Put Texas companies first
- Equalize the playing field; supplies should be vetted equally
- Consider defining "very small" business
- Create incentives for small businesses
- Gap-fill financial support
- Create jobs
- Address workforce training and maintenance

Building Healthy and Resilient Communities

The climate and health impacts of transportation-related emissions disproportionately effect disadvantaged communities. An electric transportation future creates a unique opportunity to build healthy and resilient communities. In fact, Texas is the largest contributor to transportation-related emissions in the U.S. With a clean transportation future, in 2050 Texas would avoid $6.7 billion in health impact costs, 582 premature deaths, 11,554 asthma attacks, and 46,914 lost workdays. In addition, the U.S. would avoid climate impacts of $113 billion in the "social cost of carbon."

Because historically disadvantaged groups, including racial/ethnic minorities and low-income populations, are exposed to higher levels of air pollution, prioritizing electric transportation solutions to these areas provides not only a just solution, but also a more efficient use of resources in general.

In addition, electric transportation can be leveraged to serve as resilience assets for communities more often impacted by climate disasters, providing backup power supply to individuals and shelters.

The TxETRA Equity Committee suggested the following considerations for healthy and resilient communities:

- Using EVs to address pollution hot spots
- Using EVs to bolster resilience in disadvantaged communities
- Using EVs to address logistical challenges during disasters
- Exploring how second-life battery uses can bolster resilience in disadvantaged communities

In conclusion, justice can be centered in the work that we do to advance and build out electric transportation throughout Texas. Justice should be procedural, recognition-based, and distributive in its application.

A just and equitable Texas Electric Transportation Future incorporates each of these tenets across all discussions, with justice and equity serving as a lens into the different platforms, as well as an individual focus area.

If done correctly, we should be able to develop a decarbonized transportation sector while also improving public health, strengthening our resilience, and creating wealth in areas of Texas that have been historically under-resourced.

SCAN QR CODE
TO VISIT WEBSITE

6

Planning the Future

ROGER DUNCAN

What does futureproofing the Roadmap mean? Futureproofing is the consideration of disruptive technology advancements and economic and social obstacles to implement the plan. It is considering the possibility that the assumptions underlying components of the Roadmap plan may not work out.

The purpose of futureproofing is to consider the feasibility and probability of such disruptions and possible solutions. In other words, to at least outline a "Plan B" in case assumptions in the Roadmap turn out to be wrong.

This chapter looks at a few areas of potential disruption. Technical advances, such as changes in charging technology and new battery developments, could disrupt the goals and targets of the Plan, as could economic and social/political changes.

Changes in Charging Infrastructure

This Roadmap focuses on a traditional charging infrastructure established throughout Texas by private and public sources. Naturally, there is an emphasis on installing charging stations along the state's highway system, and a concentration of charging stations in the cities that could accommodate EV users unable to conveniently charge their vehicles from their homes.

However, there could be a much greater variety of charging infrastructure than the plug-in stations currently being installed. Inductive charging, battery change-outs, and a hydrogen fueling infrastructure could all play a significant role in charging/fueling the future EV fleet.

Inductive charging will be a major new charging infrastructure feature, used as both a stationary

charging device and as an on-route charging technology. One could envision parking garages with inductive plates where vehicles are automatically charged as they park. Fleets could also be charged overnight with dedicated parking lots. Even home garages could be fitted with induction plates.

Several automakers are moving to inductive charging: Mercedes-Benz, Audi, Nissan, and Tesla either already have a wireless charging model or are planning one. The question is how automakers will integrate inductive charging into their models. Will there be dual-charging capabilities? Will certain models related to specific functions be targeted?

The China-based technology company BYD is using inductive charging for transit vehicles, and has delivered 10 K9S battery-electric buses, manufactured in Lancaster, California, to Link Transit in Wenatchee, Washington. In 2018, Link Transit commissioned the U.S.'s first 200-kilowatt wireless charging system, manufactured by Momentum Dynamics Corporation. In January 2022, they executed a new five-year agreement whereby Momentum will provide three new on-route inductive charging stations, each capable of delivering 300 kW/h.

While it is possible to build roadways so that vehicles are charged as they are driven, experience with “solar roads” has shown that it could prove to be very difficult to get working stretches of inductive charging embedded in roads subject to stresses, such as weather conditions and wear and tear from traffic. However, controlled conditions in parking garages or established transit routes *are* conducive to the widespread adoption of inductive charging.

Another change to the traditional plug-in charging infrastructure being planned involves the adoption of hydrogen fuel cell electric vehicles. Several niche areas of vehicles, like long haul trucking, port vehicles, forklifts, and others could prove to be the best choice for electrification. A hydrogen fueling infrastructure to support such vehicles must be planned in conjunction with the expanding charging infrastructure. Will there be combined charging/fueling locations? What considerations are needed to co-locate hydrogen fueling and electrical charging?

Battery change-out is also a possible new infrastructure to be developed, especially for two-wheeled vehicles. Although battery swapping has not proven economically competitive for cars and trucks, it could become very attractive for motorbike, scooter, and two-wheeled delivery service fleets.

Taken together, the multiplicity of charging and fueling options could become an issue for an expanding EV fleet. Planning for such diversity is prudent.

Rare Earth Materials

Then there is the issue of the availability of rare earth metals and commodities. An enormous amount of rare earth metals is required to support the electric vehicle transition. It has been reported that the United States needs “ten times the amount of rare earth metals it currently has to meet President Biden’s ambitious 2030 EV goals.” Metals such as lithium and cobalt are used in batteries. Some EVs, such as the Tesla Model 3 Long Range, use permanent magnet motors which use neodymium, erbium, or dysprosium. Of course, use of rare earth metals is not unique to EVs, since fossil fuel cars also use such metals in production, and rely on parts such as catalytic converters which use palladium, rhodium, cerium, and/or platinum.

The concern is not just the availability of the raw materials, but also the fact that the processing of most of the rare earth elements takes place in China, with the U.S. and the rest of the world playing catch-up. Disruptions in the supply chain could significantly impact the goals and timelines of the Roadmap. We have already seen how supply chain disruptions during the pandemic have whipsawed the automotive industry due to the unavailability of computer chips. Ensuring a steady supply of materials has risen to the top of concerns for the future EV transition.

Solutions to the rare earth materials issue are recycling, substitution, and new mining, with opportunities and obstacles for each of these solutions. It is important that implementers of this Roadmap monitor progress in each of these areas and assist with programs where possible.

Recycling to recover raw materials should

quickly become a priority for the EV industry. Going beyond battery recycling, all major components of EVs need to be reused in some fashion. Although the focus now is on recycling used batteries, other materials in EVs, such as computer chips and chassis bodies, need to be recycled as well. Whole vehicle recycling should be the ultimate goal.

Recycling companies such as Redwood Materials, Li-Cycle, and Ascend Elements are quickly growing recycling capacity for batteries. Lithium-ion recycling companies report a material recovery rate of 95-98%. Recycling could meet a substantial portion of the EV industry's rare earth material needs. In the July 27, 2022 article "Are EV Batteries Recyclable?" author Jessica Dunn states, "Recent research has shown that by 2050 recycled materials could supply 45-52% of cobalt, 22-27% of lithium, and 40-46% of nickel used in the United States light- and heavy-duty vehicle fleet."

Batteries can also be reused for stationary storage. After completing their use in an EV, batteries can have an estimated 80% of the original rated capacity. Companies such as RePurpose Energy and B2U Storage

Solutions are using these batteries for renewable energy generation support. Banks of these batteries might also be used for grid support, and prove easier for utilities to manage than vehicle-to-grid battery use.

Substitution is one solution to address a shortage of rare earth materials. One of the current concerns is the use of cobalt, which is coming almost exclusively from the Democratic Republic of the Congo, where environmentally and socially damaging mining practices are reported. But substitutes for cobalt can be found. For instance, many of Tesla's cars do not use cobalt. Samsung and Panasonic are designing batteries without cobalt. And the U.S. Department of Energy plans to eliminate cobalt in electric car batteries by 2030.

Furthermore, much of the work that permanent magnet motors and generators can do can also be done by control software and power electronics.

But recovering materials through recycling will not be sufficient to meet demand. Mining will still be the principal means of acquiring the materials, and mines take a long lead time, even without obstacles.

And mining often raises significant social justice and environmental issues.

In Arizona, the proposed Resolution Copper mine by Rio Tinto has the potential to supply half the copper needs of U.S. electric vehicles for decades. It is one of the largest copper deposits in the world: 15 million metric tons.

But the land swap necessary to develop the mine is temporarily suspended by the U.S. Forest Service. The problem is that the reserve is the site of the Apache Nation's Sunrise Ceremony–an important indigenous religious ceremony. Additionally, the U.S. Department of the Interior cancelled a planned Twin Metals mine in northern Minnesota with nickel, cobalt, and copper deposits, citing an inadequate environmental analysis.

There are plenty of other examples where rare earth metal mining and processing necessary to supply electric vehicle production is being delayed or stopped due to environmental, social justice, or political opposition at local, state, and federal levels.

Chapter 5 of this book addresses social justice issues, providing a full discussion and TxETRA's recommendations. Suffice it to say that some EV goals may be affected to ensure that social justice is achieved.

Vehicle-to-Everything Connections

Another aspect of the Roadmap subject to technological and economic change is the transfer of electrical power to and from electric vehicles. This started with the concept of "vehicle-to-grid" or V2G, where EV batteries could supply power to the electric grid for ancillary services or backup power. Soon, many other possibilities of power transfer and communication became apparent, and the concept evolved to V2X or "vehicle-to-everything."

However, some serious caveats need to be made about the feasibility and practicality of some of these prospects. V2G has been demonstrated and discussed for several years, but has never really taken off. Pilot programs have not evolved to a real market opportunity for EV owners to contribute to grid power. And the problem is not just reluctance on the part of utilities.

There are legitimate questions about impacting the projected lifespan of EV batteries, as well as remaining distribution grid infrastructure issues. Furthermore, it is not at all clear that EV batteries will be able to compete economically with stationary batteries placed at strategic grid locations.

The technological advances in battery power and cost that have allowed the development of EVs has also lowered the cost and increased the power of small stationary batteries that are much better suited to provide grid support. The electric utility will find it much easier to manage a few larger batteries located near substations and critical grid points than coordinating thousands of parked car batteries. And the power provided by larger stationary batteries should be cheaper. When Tesla installed a 100 MW battery in Australia, it immediately took almost half of the regional ancillary market. It may be very difficult for EV batteries to compete in grid power markets.

But the application of EV batteries for back-up power to homes (V2H) and businesses (V2B) during emergencies may be a very strong selling point in the future. Nissan, Ford, and GM have either already demonstrated V2H or plan for their vehicles to have that capacity. We have seen Nissan distribute connections to EV owners in Japan after that country's nuclear accident shut down grid power. And the Ford F-150 Lightning EV and the Chevy Silverado EV are both going to have V2H capability.

Given the increasing number of weather-related grid disruptions due to climate change, V2H emergency backup power could be a major selling point for EVs in the future. And utility trucks capable of supplying temporary power to homes while repairs are being done could also be a welcome addition. While the current planning for EV owners around V2G may not work out, the option for a strong V2H and V2B emergency backup market is definitely a possibility.

Driverless Cars

Part of the future appeal of EVs is that they are often envisioned as driverless cars, whether delivering cargo or people. Indeed, Austin is now getting used to the electric pod navigating downtown sidewalks, and cars pulling up to stop signs without someone in the

driver's seat. In fact, part of the marketing pitch for the electrification of transportation in general is enhanced by the possibilities of AI-driven EVs that will be safer, more efficient, and quietly move our economy with driverless *and* electric vehicles of all sorts. The benefits of driverless cars extend to reducing the total number of vehicles on the roads, eliminating rush hour traffic jams, and reducing the need for parking space.

But we have seen over several decades now that driverless cars capable of moving freely on all our roads and highways is turning out to be much more difficult than first envisioned. The first driverless cars were demonstrated in the pilot stage 20 years ago. Yet there are still few vehicles on the road—all test vehicles. The road testing seems to be limited to the Sun Belt, since the driverless cars cannot seem to handle northern winter conditions. There are still basic driving problems, such as turning left into traffic. And the state of driverless AI does not seem on the verge of changing dramatically in the next decade or even decades.

While this may not impact the near future of EV sales and designs, it could certainly change the long-term prospects of how EVs would be designed and their features. Instead of completely autonomous vehicles, more electric vehicles may be designed for cargo movement on restricted routes, or even tracks with batteries and with charging requirements customized to the type of work. Specialized AI-controlled electric vehicles for industrial sites, mining, ports, and other operations could be a significant part of the future electric vehicle fleet.

Political Disruptions

Lastly, there could be disruptions in cost and deployment due to political actions. EVs are increasingly identified as a liberal, environmentally-friendly transportation system. There could be an increasing differential between how EVs are treated in red and blue states. State powers such as taxation, incentives, and regulatory approval could make it much easier to deploy and expand EV use in some states than others. We should plan accordingly, since Texas is currently a red state.

All these issues could affect the plans of this Roadmap. We can only keep in mind the possible disruptions, and be flexible enough to respond and change course as technologies and economic and social conditions change.

Perhaps the most important principle to keep in mind to futureproof the Roadmap is to maintain flexibility. We should try to avoid decisions that lock the plan into a specific technology or course of action. We need to keep in mind that the technology, economic, and political landscapes will continue to change, and keep as many options open as possible. With this in mind, we should be able to adapt the Roadmap as needed, and move forward to electrify Texas transportation.

SCAN QR CODE
TO VISIT WEBSITE

7

Making the Market

ROSS CROW & MICHAEL J. OSBORNE

The United States is well on its way to an electric vehicle future, and no place exemplifies this trend more than Texas. According to Ernst and Young, the sales of battery electric vehicles (BEVs) will outpace the sales of internal combustion engine (ICE) cars by 2033. That means 2.5 million electric vehicles on Texas roads in 10 years. In 2022, there were less than 200,000. And each one of those 2.5 million EVs are going to consume somewhere around four megawatt hours per year. That means about 12 terawatt hours a year of additional consumption. Now imagine five million vehicles a few years after that. The rise of BEVs is exciting, but it also comes as a double-edged sword, presenting a number of fiscal opportunities and risks. However, there are ways for Texas to turn these problems into solutions, for sound policies along with industry cooperation can resolve most issues and bolster job growth in the process.

The rapid increase in BEV sales is a forerunner for the other trends that follow, one of the most consequential being higher energy consumption. Texas faces a risk of unmanaged charging scenarios. This refers to when EV owners charge their vehicles from the grid with no consideration of its effect. Currently, most EV owners practice unmanaged charging, oblivious to how this habit affects the electric grid. While this tendency has little impact for now, it will have measurable effects as Texans continue purchasing EVs. In fact, as vehicle charging becomes more common, EVs may increase the load on the electric grid by 12 TWhs (terawatt hours) by 2033. Put in context, this increase is modest given that Texas' electrical consumption in 2022 was almost 482 TWhs. With these 2.5 million EVs, demand on the system is predicted to increase by 1.875 GWs. (Texas is about a 100 GW system.) As EV penetration grows to 50%, this increase becomes more significant. However,

much of this charging should and will occur at night when utility generation is plentiful, thus reducing the need for new generation.

If unmanaged charging continues, there's a risk that electric usage could jump by as much as 40-50% in different charging scenarios, such as in highway corridors, residential areas, and overnight stay hubs. While this increase may paint a dark picture for the Texas electric grid, not only is it preventable, it also has a silver lining. There are two key solutions to mediate the potential burden on electric utilities: managed charging practices and vehicle-to-everything (V2X) services.

With managed charging, EV operators aim for a balance between their charging needs without putting excessive strain on the charging site. This can be done by following simple rules of thumb, or with sophisticated communication. The first rule is to charge at night, since the electric grid in the sunbelt is driven by AC loads and night time generation is ample. The corollary is don't charge during the afternoon peak.

On the sophisticated side, EV drivers can program their vehicles to only charge based on price signals. Ultimately, with the development of V2X services, a network of digital communication and energy flows will exist between EVs and corresponding infrastructure that communicates with the vehicle's electronics, sending information to drivers such as energy prices, auto accidents, and traffic problems. Estimates indicate that by 2030, a combination of managed charging and V2X services will allow EVs to participate in a market worth $1.3 billion a year.

During this period, Texas is expected to spend $120 billion on new EVs and charging stations. Most of these funds will be used to purchase EVs, which will simply offset ICE vehicle purchases. Charging station infrastructure may add up to $15 billion.

However, this transition to electric transportation brings more benefits than burdens. If Texas policymakers encourage EV companies to join the state economy, this trend will promote job creation in both EV manufacturing and charging. The EV industry offers Texas with the potential for economic prosperity through professional training and employment, empow-

ering Texans through new jobs. Some Texas cities and colleges have already recognized this opportunity, with Austin Community College (ACC) now offering a technical course in Tesla manufacturing, the first community college to do so.

Five key stakeholders will streamline Texas' widespread adoption of BEVs: the federal government, states and cities, utilities, automakers, and customers. All of these groups hold their own slice of the pie, each having an effect on the EV industry and its economic development. Their decisions about EVs, be it at the political or economic level, hold the potential to offset consumer dependence on gas-powered cars.

The federal government defines the vision and provides the funding for electrification. The Infrastructure Investment and Jobs Act will put $10 billion toward EV development. While this stakeholder is not immune to political whims, assuming current legislation continues as planned, the federal government will also add 645,000 EVs to the federal fleet, with further plans to also add 500,000 public chargers across the country by 2030.

States and city governments provide political and legal support for electrification. Some jurisdictions have even considered banning ICE vehicles entirely. As of now, 11 states, including California and Washington, have committed to deploying 3.3 million zero emission vehicles (ZEVs) by as soon as 2025. Many cities have also incorporated electric buses into their fleets, with roughly 3,000 in use across the U.S. In Austin, both the city's school district and its public metro services have announced plans to electrify their bus fleets.

Utilities must develop the proper infrastructure for electrification. Major utilities in Texas are making the move to electric by adding new charging stations. Fourteen Texas-based utilities have joined together in the National Electric Highway Coalition, an effort to furnish a network of charging stations in West Texas, the Gulf of Mexico, and the Eastern Seaboard.

Automakers determine the type of fuel cars depend on. Most recognize the growing need for sustainable vehicles, with some announcing new electric models that will hit the market between 2023 to 2025.

General Motors (GM) has even committed to ending the production of ICE vehicles by 2035, a bold decision that may have ripples across the auto industry. In one sense, it already has. Ford made a similar promise, stating that by 2030, 33% of their pickup trucks and 70% of their buses and vans will be BEVs.

Customers buy electric vehicles and support the growth of the EV industry. While the year 2033 lingers in the air as being the inflection point where BEVs outsell ICEs, a future shift that is yet to come, there is precedent for the EV market to make rapid gains. In 2020, global EV sales increased 43%. In 2022, 90% of car sales in Norway were electric. More encouragingly, as the cost of batteries is expected to plummet, EVs will soon become the cheapest vehicle options for consumers.

Improved charging technology is a driver that can improve EV implementation in the commercial transportation sector. Medium- and heavy-duty ICE vehicles, such as cargo trucks, create significant emissions, affecting public health in poor communities where exposure to these vehicles is more prevalent.

The adoption of electric trucks would reduce pollution; however, this transition risks trading one problem for another, replacing air pollution with slow, costly charging times.

Fortunately, two key solutions exist to address this shortcoming: megawatt chargers and wireless charging. A megawatt charger can charge a vehicle's battery by a staggering four megawatts, fully charging a Class 8 truck in as little as 30 minutes. This fact is impressive, especially given that Class 8 trucks are the largest type of truck, including 18-wheelers and other large cargo vehicles. Tesla has recently released their new semi, and other Texas manufacturers are right there with them.

In addition to megawatt chargers, the implementation of wireless chargers can also be more efficient for large vehicle operators. For example, placing wireless chargers at bus stops would allow electric buses to charge while unloading and loading passengers. Large trucks could charge while waiting to load and unload their wares, not only saving time but allowing these vehicles to optimize their batteries. As the name

implies, wireless charging would also offset the need for operators to manage unwieldy cables. Typically, the faster the charge, the bigger the charging cable. But with the advantage of wireless charging, users can avoid this issue altogether.

The need to establish a circular economy to provide the context for recycling lithium stands out as one strategy that, while largely theoretical, represents a possible solution to a foreseeable issue. Currently, demand for lithium used to manufacture EV batteries is on a trajectory to exceed the available supply from mining companies. To compensate for the future lithium shortage, a proposal has emerged to recycle lithium from used EV batteries, and use the recovered lithium to manufacture new batteries. If this idea pans out and becomes a tenable reality, it will represent a "circular economy"—an economic model involving material reuse. This new circular economy can promote job growth, as facilities and workers would be needed to extract the lithium from used EV batteries, and use it to manufacture new ones. This model would also expand certain precedents in the developing EV economy, such as Austin Community College's Tesla manufacturing program, generating new skills and corresponding employment opportunities.

Texas currently has a state-wide battery recycling task force.

While the trend toward widespread BEV adoption appears likely in Texas, there are still several key opportunities and risks that will affect consumers' decisions to adopt EVs in the short term. Two important opportunities that improve the consumer's response to EVs are shared mobility and autonomous vehicles. Shared mobility's electrification depends on rideshare drivers, namely operators in transportation services such as Lyft or Uber. These workers use four times as much fuel as the average driver. While they consume more gas and create more pollution for this reason, if they retain the same energy demands but switch to electric, they will cut back gas sales and emissions and also boost the economic demand for EVs and chargers. The adoption of EVs as a rideshare driver's asset nurtures an economy based on charging demands, supporting growth in the charging sector while loosening the oil industry's monopoly on fuel choices. While the average driver gets 5% utilization, or use, from their personal vehicle, a rideshare driver gets 60%. If this 60% transfers from fossil fuels to electricity, this transition can stimulate growth on the part of charging companies, giving the EV industry more economic leverage.

Autonomous or self-driving electric vehicles represent another opportunity to cut back on emissions and lower transportation costs. Texas' autonomous vehicle laws and regulations are some of the friendliest in the U.S., allowing for frequent use of self-driving cars. As with rideshare vehicles, autonomous vehicles improve the business case for EV implementation. Since all available self-driving cars are electric or hybrid, the logic works out to where more reliance on autonomous vehicles results in more utilization of chargers, and thus further economic dependence placed on electric charging instead of gas.

Where positive opportunities may encourage EV purchases, there are also notable risks that can disillusion potential adopters. These risks include broken chargers, long charger queues, and grid constraints. Broken chargers frustrate would-be EV customers, discouraging them from switching to electric. In order to accommodate EV charging demand, chargers across the nation should be in good working condition, and, ideally, should also have 97% or higher uptime, the time these machines stay in operation. If total uptime for all chargers falls below 97%, this setback could sour public opinion of EV ownership; this is why proper charging maintenance is critical for the EV industry's long-term success.

There is a similar story for long charging queues. If lines for charging stations stretch too long, this may be a deal breaker for potential EV customers. There should be enough stations to meet public demand, and a way to communicate the status of a given station to potential users. Just as users can check Google to find out how busy a restaurant or business is at a given time, there should also be a system that alerts EV drivers as to how busy a charging station is. This concept is already in effect in the U.K., where public infrastructure and V2X services help EV users find out a given station's activity level, saving the customer time and battery life if one station is too crowded. Britain's model and its efficacy can serve as a template for a

similar system in Texas.

Grid constraints, or the electric grid's limited capacity, affect when EVs will be able to charge. As mentioned earlier, in order to prevent the negative effects of unmanaged charging scenarios, vehicle owners will have to be conscious of when they charge their EV. While this practice may ensure the electric grid's stability, it inconveniences drivers. However, this issue is amendable, and can change quickly if grid technology improves. Changes in the electric grid to accommodate EVs may become another part of the EV-Charging Infrastructure capex, the new electric technology incurring significant costs while also spurring job growth.

In Texas, the trend of BEV sales to surpass ICE vehicle sales in 2033 presents an opportunity. With Texas leading the national trend on electrification, the state faces a $120 billion economic boom in EVs and the accompanying charging infrastructure. As various stakeholders, from federal and state policymakers, automakers, and, importantly, customers, shape the political landscape for electrification, new technologies, such as wireless and superfast chargers will provide the convenience that users will adopt with enthusiasm. Creative solutions, such as recycling lithium from old batteries and using in new ones, will promote resource sustainability while creating new jobs.

Making the Market through a consortium of players and policy makers will pave the way to successfully integrate electric vehicles into the Texas market, and empower individuals and industry through a field of fresh economic opportunities.

8

Reaping the Rewards

HANNAH SMOTHERS

From the winding path of State Highway 71 to Interstate Highway 10, Texas has more road miles than any other state in the country, by far. Texas has more than 660,000 total lane-miles, compared to just under 400,000 in California, which ranks second. All that road underscores how important vehicles are to Texans. And to make it even clearer: vehicle registrations in Texas amount to 22 million, second only to California, the most populous state in the U.S. Suffice it to say, Texans predominately rely on cars, SUVs, and trucks to get around.

This means Texans have perhaps the most to gain in switching to EVs. Transportation-related greenhouse gas emissions account for about 27% of total greenhouse gas emissions in the U.S., making transportation the largest sector of total U.S. emissions. Of that 27%, the biggest contributors are cars, light trucks, and heavy-duty trucks like those we see across state highways. In a state that relies heavily on its roads and vehicles, reducing reliance on internal combustion engine (ICE) vehicles can significantly reduce greenhouse gas emissions, and create a more beautiful and healthful environment for all Texans.

Beyond the environmental benefits resulting from the adoption of electric vehicles, significant monetary benefits are realized. On a personal level, EVs cost far less to maintain than ICE vehicles and typically require less regular maintenance. Total cost of ownership for EVs is also significantly lower, with savings averaging between $6,000 and $10,000, compared to ICE vehicles.

And that's just for individual drivers. When utilized at the fleet level, EVs carry additional monetary benefits. Among top metropolitan areas, powering

light-duty electric vehicles is around 44% cheaper than fueling with gasoline. And switching from diesel-fueled buses to electric buses can yield a 63% cost savings.

To dive further into the data, let's walk through a breakdown of the numerous EV benefits by category.

Economic Development: Industry, Manufacturing, and Jobs

As of late November 2022, Texas is home to more than 16 extant and anticipated EV-related manufacturing facilities across the state. About eight of those manufacturers announced a Texas-based facility in 2022 alone, signaling a major growth area for Texas.

But if those numbers don't mean much, consider a couple of recent examples: In March 2022, Linear Labs, an electrification solutions company, announced it would build a facility in Fort Worth projected to create a minimum of 1,200 jobs. Later in 2022, SK Signet, a South Korea-based fast charger company, announced its first U. S. facility in Plano, anticipated to open in 2023. Once operational, the facility is expected to provide nearly 200 jobs.

There are many more examples, but the obvious economic benefit is clear: electric transportation is a growing provider of jobs across Texas. A December 2020 report by the Texas Advanced Energy Business Alliance (TAEBA) estimated there were more than 7,000 people involved in Texas' electric transportation supply chain; that number stands to grow immensely in the next two years based on the projected opening of new manufacturing facilities. The TAEBA report estimated that the number of jobs in electric transportation will nearly *double* by 2024 to include a projected 13,500 workers.

Continued manufacturing and job growth in Texas depends on a number of factors, including the availability of a workforce. As the TAEBA report notes:

> "There are more than 29,000 workers in 789 companies that are part of industries requiring similar skill and equipment to those needed for ET manufacturing. These industries lost 900 jobs statewide between 2014 and 2019. As such, there is a substantial workforce, which has seen some recent struggles, that could support a growing ET sector with relatively little reskilling or training and find new opportunities."

Furthermore, another 89,000 workers would require only short-term training or reskilling to transition to ET manufacturing roles.

Jobs are not just limited to urban centers, either. The TAEBA report states that ET workers make up a greater share of the labor force in several suburban and rural counties, including Titus, Cook, Lamar, Calhoun, and Dallam.

Beyond workforce opportunities, TAEBA estimated that ET activity contributed nearly $690 million to the Gross State Product (GSP) in 2019, a figure equivalent to the GSP contributions of convenience stores, and more than twice that of the Guided Missile and Space Vehicle Manufacturing industry. That annual GSP contribution will only grow as ET manufacturers open Texas facilities.

Texas has a history of robust manufacturing; the growth in the electric transportation sector continues in a tradition of manufacturing- and technology-related jobs across the state.

Cost Savings for Individuals and Businesses

While news media often focus on a vehicle's upfront costs, either new or used, total lifetime costs must be accounted for when considering the price of a car. And when it comes to a lifetime of ownership, electric vehicles beat out internal combustion engine vehicles across all major categories.

Research shows that fuel and maintenance costs for the average gas-powered vehicle can outprice the original purchase price of the vehicle over its lifetime. EVs, on the other hand, have remarkably lower fuel and maintenance costs, reducing their overall lifetime costs, and making electric vehicles more cost effective than gas-powered vehicles. Electric vehicle drivers encounter decreased fuel costs due to the relative price of electricity versus gas, as well as the average efficiency of EVs. Data show that even in cities where the cost of electricity is high, like Boston and San Francisco, EVs

still win out over gas-powered cars.

Using February 2022 data, Jeffries analyst David Kelley calculated that the total lifetime ownership cost of an EV is about $4,700 less than that of a gas-powered vehicle. That cost differential only stands to increase favorably for EVs, as more EVs come to market and as battery prices continue to fall over the next couple of years.

To break that number down further, consider that EV drivers pay about 60% less to travel the same distance as a gas-powered vehicle. *Consumer Reports* estimates that driving an EV in Texas, specifically, brings annual fuel cost savings of about $732 for drivers of sedans, $944 for drivers of SUVs, and $1,200 for drivers of pickup trucks.

But the savings don't stop at fuel costs: maintenance costs for EVs are also drastically lower when compared to gas-powered cars. Given that EVs have about one-tenth the moving parts of a gas-powered vehicle and do not require fluid changes, recent data from *Consumer Reports* shows that, over the lifetime of a vehicle, EV owners can expect to save an average of $4,600 on maintenance and repair costs. These savings only accelerate over the lifetime of the vehicle.

Data show that service costs for the first 36 months of ownership average about $514 for EV owners, compared to about $750 for gas-powered vehicle owners. But as more technicians are trained to service EVs, labor costs associated with EVs—currently high, compared to similar costs for gas-powered vehicles—will decrease, further lowering the lifetime ownership cost of an electric vehicle.

If the cost savings are impressive for individual EV drivers, the savings for electric fleets are even better. Businesses and public entities can enjoy lower transportation costs by adopting light-, medium-, and heavy-duty electric vehicles. With TxETRA's guidance, several Texas counties, including Bexar and Tarrant, have already begun the process of electrifying their fleets. In May 2022, Bexar County announced it would purchase 16 electric sedans and pickup trucks, and would spend a year studying operating costs and logistics before committing to a larger purchase. Officials said this could be the first step in electrifying the county's roughly 1,200-vehicle fleet.

As Bexar County studies operating costs, they'll find an abundance of savings opportunities. New York City analyzed the maintenance costs for light-duty EVs and found that they were about 25% lower than those for gas-powered vehicles. These savings increase as vehicle size increases. Delivery services, such as those used by Texas-based companies like H-E-B and PepsiCo, are rapidly electrifying their fleets. Medium- and heavy-duty EVs benefit from significant cost savings: the cost of fuel to drive 200 miles in a heavy-duty diesel truck is about $100; the same distance costs only $23 for an EV.

Electric school buses are also highly cost effective—and safer for drivers and children, as explained later on in this chapter. While upfront purchase prices for electric buses are currently higher than those of diesel-fueled buses, e-buses, like other electric vehicles, carry significant lifetime savings. More than 15 school districts in Texas—including Houston and Dallas, the two largest districts in the state—have applied for and been awarded federal funding via the Clean School Bus Program to purchase electric buses, offsetting the initial price tag.

But beyond the purchase of an electric bus, data show that savings can range from an estimated $4,000–$11,000 for each school bus per year, depending on labor costs, local electric utility rates, and the price of petroleum fuels. These savings mostly come from fueling and maintenance; as with personal EVs, e-buses are significantly cheaper to maintain over time. And these figures are based on the market as it exists today. As Clean Technica reported in February 2022, market experts expect that by the end of this decade, lifetime costs of electric school buses will be around the same as diesel buses, based on estimations of total cost of ownership.

Grid Stabilization and Cost Improvements

Not only is the myth that the electric grid cannot handle an electric vehicle future untrue, EVs can help provide additional grid stability and avoid grid overgeneration.

Texas and California consume more energy than any other state in the country, and provide a good metric for how an EV future may look. Based on expert estimates, the current Texas grid could charge and support a fully electrified vehicle fleet today if vehicles were charged during off-peak hours—a simple solution that would ask those with in-home chargers to charge at night, or when grid demand is at its lowest.

Beyond the ability to support an electric fleet, EVs can also provide grid benefits if utilized properly. EVs can actually improve the resilience and reliability of the grid by charging when electricity is plentiful (or, in other words, during off-peak hours) and by deploying technologies so that the batteries in EVs can provide back-up power to homes, and supply the grid during times of significant stress.

California, with its recently adopted Clean Car Standards that will put about 14 million zero-emissions vehicles on the road by 2035, provides an example of the possibilities that EVs create for the grid. If those 14 million EVs were capable of putting electricity back onto the grid via vehicle-to-grid, or V2G, technology, they would represent a collective battery that could power all the homes in California for three days.

If that sounds like science fiction to you, it isn't: V2G technology is a reality, and already integrated into vehicles like the Ford F-150 Lightning, which can and has been used as a backup generator in its limited time on the market. To use California as an example again: data show that between 2012 and 2019, California EV drivers contributed $806 million more in revenues than associated costs, which was automatically returned to utility customers in the form of rates and bills that were lower than they would have been, according to the National Resources Defense Council. And a separate study by Lawrence Berkeley National Laboratory found that enabling V2G technology could save $13–15 billion in stationary battery costs.

Environmental Improvements for Personal-Use Vehicles

If the state's anti-litter campaign motto "Don't Mess With Texas" is to be believed and followed, widespread adoption of electric vehicles is the most significant way to preserve the state's beauty, along

with the health of its residents. Switching to EVs carries unmatched positive environmental impacts.

Passenger cars and trucks are one of the largest sources of greenhouse gas emissions in the U.S. While manufacturing an EV results in more greenhouse gas emissions than manufacturing a comparable ICE vehicle, the reductions from driving an EV more than offset the manufacturing emissions. A July 2022 study found that, when comparing the average ICE sedan at 32 miles per gallon to the average-efficiency EV, the EV reduces total lifetime emissions by 52%. That figure is even higher for an EV pickup truck, which reduces lifetime emissions by 57% compared with the average ICE pickup truck.

Most of the emissions over the lifespan of any vehicle occur during its use, not its manufacturing, so the reductions from driving an EV more than level-off over its lifespan. Or, as the previously cited July 2022 study notes, another way to look at the eco-benefits of personal-use EVs is the "breakeven" point, or the point at which an EV's manufacturing debt breaks even in terms of total greenhouse gas emissions compared to an

ICE vehicle. This figure varies depending on regional emissions, but across the U.S., the average breakeven point for an EV with a 300-mile range compared with an ICE sedan is around 21,300 miles, or about 22 months of average annual driving.

But let's focus on Texas for a moment. While it's considerably cleaner for the environment to drive an EV anywhere you live, some states stand to benefit more than others. Texas is one such state. In Texas, the emissions of the average EV compare with those of an ICE vehicle achieving 76 miles per gallon—a feat no ICE vehicle on the market today is capable of.

Environmental Improvements for Electric School Buses

In September 2022, Austin Independent School District became the first school district in Texas to pass a resolution that commits to a 100% electric bus fleet by 2035. However, several districts throughout the state have also started trading in diesel-fueled buses for electric alternatives: thirteen districts, in fact, will add electric buses to their fleets, with assistance from the federal Clean School Bus Program. We'll get to the

monetary benefits of EVs later on in this chapter.

So why the switch to electric buses? School buses travel about four billion miles across the U.S. each year, providing transportation for more than 25 million schoolchildren. However, while those buses are safe in certain regards, they're particularly unsafe in others, such as the level of pollution they emit. Diesel exhaust from school buses is a contributor to ground-level ozone, which damages crops, trees, and other vegetation, and leads to the production of acid rain, which negatively impacts soil, lakes, and streams, and can enter the human food stream via water, produce, meat, and fish.

Buses are also major culprits of generating idling emissions, which, when parked outside of school buildings, means that diesel exhaust pollutants can enter schools through air intakes, doors, and windows.

But beyond these environmental impacts, the U.S. EPA classifies diesel exhaust as "likely to be carcinogenic to humans." Diesel exhaust particles can lodge in the lungs and heart and have been linked to premature death, aggravated asthma, and decreased lung function. Children are more susceptible to these symptoms because their respiratory systems are still developing.

All those negative impacts lead to an obvious solution: trading diesel-fueled buses for clean energy electric buses. Electric buses cut down on adverse health effects for children, who rely on the bus to get to and from school every day, and yield significant positive environmental impacts: they eliminate tailpipe pollution and, over the course of their lifespans, produce fewer greenhouse gas emissions than their diesel alternatives.

Air Quality Improvements

Not only does diminished air quality due to a surplus of greenhouse gases impact public health, it also impacts the Texas economy. EVs generate *zero* tailpipe emissions, and though the electricity used to charge EVs depends on a regional mix of generation resources, EVs result in a net reduction in all emissions.

How does that translate to Texans? For start-

ers, several Texas counties are currently designated as moderate- or severe-nonattainment zones by the U.S. Environmental Protection Agency. A recent report by the American Lung Association underscores the threat that living in a significantly polluted area has on personal health, and emphasizes that the shift to zero-emission transportation will not only help bring counties out of severe nonattainment, it will also save lives.

Beyond saving lives, living amid healthier air conditions reduces the need for sick time and the strain on public health systems. The same American Lung Association report showed that between 2020–2050, Texas could experience more than $104 billion in health benefits—second only to California—by implementing zero-emission transportation. Furthermore, Texas could avoid nearly 10,000 premature deaths, nearly 350,000 asthma attacks, and avoid 1.5 billion lost work days.

While this is explored extensively in Chapter 4, there is also an environmental justice element to improving air quality throughout Texas. The American Lung Association analysis found that the 100 U.S. counties with the highest percent populations of people of color could experience 13% of the cumulative health benefits of the transition to electric transportation, about $155 billion in benefits between 2020–2050.

The Greater Houston metroplex could alone experience $33.4 billion in health benefits if the region's air quality were improved by the switch to electric transportation. That would equate to about 568,000 lost days of work avoided. Those same numbers for Dallas-Fort Worth are about $28 billion in health benefits and 405,000 lost days of work avoided.

The benefits of switching to an electrified transportation system are innumerable. From cost savings and an improved public health, to an improved statewide economy, the transition to EVs is an obvious yes—and it's fully implementable with our current resources.

9 Air, Sea, & Land

ROSS CROW

Electric Aviation

While anxiety over the threat of climate change has spurred recent growth in the electric vehicle market, by contrast, the thought of electric aviation is almost void from the public consciousness. This difference in concern is ironic, as airline emissions alone account for 2.1% of all human-induced carbon dioxide (CO2) emissions. However, the lack of a media spotlight does not make electric aviation any less of a sleeping giant. In fact, numerous developments are underway from small companies offering their unique version of the electric aircraft dream.

In 2022, the National Renewable Energy Laboratory estimated that 170 projects worldwide are focused on developing electric planes or other aviation, double the number in 2018. Based on this trend, we can expect more EV aircraft models to burgeon in the coming years. While some projects linger in the conceptual clouds, many companies have already built working models ready for the skies. And although well-known aviation firms, such as Boeing, have yet to release any electric aircraft of their own, that doesn't mean the silent revolution has not gone unheard. Major plane companies, including American, United, and Mesa Air Group, have begun investing large sums of money toward various electric aircraft startups.

In June 2021, Fort Worth-based American Airlines announced a plan to pre-order 250 electric vehicle takeoff and landing (eVTOL) planes from British aviation firm Vertical Aerospace for $1 billion. An eVTOL aircraft is a new and exciting type of electric aircraft with aspects of both planes and helicopters: it has the wings of a plane and the propeller-driven takeoff motion of a helicopter. The newfangled aesthetic of eVTOL technology signals not only that the future of

aviation is changing course functionally, but also embracing a reinterpretation of aviation's cosmetic tradition. Various eVTOL models appear sleek and dynamic, flaunting sci-fi designs straight out of a James Cameron film. American Airline's deal with Vertical Aerospace includes 250 units of the firm's VA-X4 model, with the option to order 100 more. The company's willingness to invest a whopping $1 billion in electric aircraft demonstrates a surprising but reassuring confidence in eVTOLS' ability to reinvent the wheel of airborne transit.

The deal comes with a feeling of optimism, as American indicated sustainability was also a focus of its order. While the possibility of greenwashing their image is never off the table, the large expenditure expresses a commitment to utilize the new zero emission technology, and indicates that their purchase is more than a positive gesture. Globally, airplanes release around 500 million tons of carbon dioxide into the atmosphere each year. The choice to invest in electric aircraft is a step in the right direction, but the technology will need to be implemented quickly and commonly to reduce the impact of aviation-related emissions. Fortunately, Vertical Aerospace expects the VA-X4 to be certified for passenger flight by 2024, paving the way for commercial operation and, ideally, the decline of gas-powered aircraft.

American Airline's purchase of 250 eVTOLs presents the possibility of short, intercity rides in Texas between the state's major cities. Because current eVTOLs have little passenger space and limited battery life, different voices in the aviation industry have proposed using small EV planes for transporting small groups of passengers shorter distances, providing a level of service closer to buses than large passenger planes. Given that three of Texas' major cities—Austin, Houston, Dallas—suffer from some of the most severe traffic congestion in the U.S., electric aircraft would offer a means to reduce traffic without producing its own emissions. In effect, the implementation of short electric flights in Texas would cut down on emissions, while also widening the scope of transportation options in a state notorious for its dependence on cars.

Like with American Airlines and Vertical Aerospace, a similar deal was struck between United

Airlines and Mesa Air Group and Heart Aerospace, a Swedish aviation startup. In July 2021, the two major companies agreed to pay $35 million for 200 units of Heart Aerospace's ES-19 model, with the option to purchase another 100. The ES-19 features up to 19 seats and specializes in regional flights, relying on batteries and electric motors instead of fossil fuels. Heart Aerospace expects that the ES-19 will become commercially available by 2026. While the model will be limited to up to 250 miles in travel capacity based on current technology, United Airlines has already begun planning short intercity routes for the aircraft, realizing an economic strength from a technical weakness.

The main factor limiting both the transportation and commercial potential of electric aviation is the available battery technology. However, according to MIT researcher Qichao Hu, "…if we can make [plane] batteries lighter, then we can increase the energy savings and flying range of [electric] airplanes." Hu himself is playing an active role in the quest for a more effective battery. Recently, he invented a polymer ionic liquid, which, if placed in a battery, would hold twice as much power as a lithium-ion battery found in a smartphone. Ideally, this invention, when put into an electric plane's battery, would increase its ability to travel longer distances. Hu's ionic liquid inspires the possibility that electric aircraft in the future may not only rival traditional planes and helicopters, but even surpass them technologically. Electric engines would accomplish as much as fossil fuel ones, but more efficiently and with less hardware, with the potential to eliminate the world's dependence on clunky dinosaur engines.

One of the biggest milestones in electric aviation came in September 2022, with the flight of a prototype electric plane. Known as "Eviation Alice," a product of Israeli startup Eviation, the craft took its historic first flight in central Washington State. Like some of the developments mentioned earlier, Eviation Alice does not offer a high passenger capacity, with room only for nine passengers and two pilots. Its power comes from 21,500 small Tesla-style battery cells, roughly triple the amount found in a Tesla engine.

Where many electric aircraft remain on the drawing board, Eviation Alice is significant because it presents a working model that has already demonstrated

its ability to fly. As of October 19, 2022, German airline Evia Aero announced a plan to incorporate 25 all-electric commuter Alice aircraft into its fleet. A fledgling airline, Evia Aero holds a sustainable focus. The aim of their partnership with Eviation Alice is to establish zero emission regional flights between Germany, Denmark, Belgium, Austria, and the Netherlands.

Europe's success with this regional model may serve as an effective touchstone for Alice's implementation in the United States. If it passes federal regulations, it could become the first all-electric commercial airplane to transport passengers. Just as this aircraft may save on costs and emissions when flying between neighboring countries, it has the potential to streamline connections in large states like California or Texas for intercity passengers. Given Alice's rapid progress, it's possible that it may well begin commercial flights sooner than its counterparts, such as the different eVTOLS still under development.

Gas-powered planes are a major cause of carbon emissions, yet face less criticism than gas-powered cars. Likewise, electric cars steal thunder from electric aviation. But despite their obscurity, electric aircraft are well on their way and will likely shift the aviation paradigm in the coming decades, if not years. All U.S.-based major international airlines, with the exception of Delta, have put significant investments into the development of eVTOLs. The promise of electric aircraft implementation later this decade represents yet another nail in the coffin of the fossil fuel industry. While technological constraints may limit the possibility of long-distance flights in the near future, in the meantime, current EV aircraft could prove beneficial for densely populated states, such as Texas, in reducing traffic congestion.

Marine Electrification

The global shipping industry is deeply complicit in the world's total greenhouse emissions. Annually, container ships release around one billion metric tons of carbon dioxide into the air, roughly 3% of all greenhouse gas emissions, and more than the global aviation industry at 2%. Other types of watercraft, such as public ferries and speedboats, also pollute the air and water that surrounds them, adversely affecting human and animal health. The answer to addressing this issue lies

in the creation and implementation of electric-, solar-, and wind-powered maritime watercraft.

One of the biggest obstacles to developing electric watercraft is developing batteries with adequate capacity. According to authors Roger Duncan and Michael E. Webber in their book, "The Future of Buildings, Transportation, and Power," the global cargo ship industry will be "difficult to electrify." Based on what they describe, batteries in electric ships are good for short distances or as "auxiliary power while in port." Neither of these accounts suggests much promise in the future of electric watercraft. However, the book came out in 2020, and despite the authors' concerns over electric maritime batteries, the last two years have presented a flurry of exciting new developments.

In the U.S., Seattle is leading the movement toward electric watercraft. In April 2022, Washington State Governor Jay Inslee signed a nearly $17 billion transportation package, with $1.5 billion earmarked for a new ferry system. The state's new electrification program is expected to reduce Washington State's ferry emissions by 50%. With 2024 as the anticipated completion date for the new fleet, officials are hard at work preparing to release 16 new vessels alongside converting six existing ones to electric.

The electric watercraft movement in Seattle has gained public support and funding, and has also attracted private support. Major automobile company General Motors has invested $150 million in Seattle-based startup Pure Watercraft, taking a 25% stake in the company. While it's ironic that a car-and-truck-company should invest in electric boats before any known boat manufacturers, the investment is a crucial step. Ideally, GM's recognition of Pure Watercraft's potential will spur other big companies to support other electric maritime startups in the coming years.

While Seattle expects to see the switch to electric ferries in the next few years, in Stockholm, Sweden, the technology is already underway for public transportation. The Swedish transportation company Candela specializes in developing fast, quiet electric passenger watercraft. Their latest model, the Candela P-12, operates on a maximum speed of 30 knots (34.5 miles per hour). While this speed capacity may seem

limited, it is more than adequate to serve the needs of Stockholm's commuters. For a city replete with waterways, the Candela P-12 offers a faster, cleaner alternative to gas-powered ferries. The vessel sits on carbon fiber wings that remain submerged, while the boat itself stands suspended above the water. This design reduces the noise typically present in gas-powered speed boats, allowing it to glide near-silently above the currents.

While the future of maritime public transport looks bright based on the Seattle and Stockholm examples, there is still cause for concern from shipping freights, the main culprit in maritime emissions. Cargo ships cause significant air and water pollution, which has worsened with the global disruption to supply chains. Since the start of the Covid-19 pandemic, complications in shipping logistics have mired the speed with which container vessels can unload. The result leaves many ships to idle in place, producing severe levels of air and water pollution.

Fortunately, Japan is ahead of the game in developing the world's first electric cargo ship: the Asahi Tanker. Completed in March 2022, the Asahi

Tanker is 62-meters long (about 203 feet) and operates on a “battery capacity of 3,480 kilowatt hours (kWh) or about 100 batteries for a typical electric vehicle. The ship charges overnight and operates in Tokyo Bay in the daytime, delivering cargo to other ships. Typical cargo ship interiors are noisy due to their diesel engines, necessitating the use of ear protection. Fortunately, thanks to its all-electric design, the Asahi’s engine is much quieter by comparison, providing a calmer environment for workers inside the vessel. The company behind the ship and its namesake, Asahi Tanker Co., Ltd., anticipates releasing a second electric vessel by next year.

The Asahi tanker is a cause for hope, potentially serving as a viable replacement for diesel-powered container ships. However, the rate at which electric tankers replace diesel ships will, in part, depend on improvements in battery capacity. Due to this constraint, the Asahi is limited to short distances. Neither the Asahi nor any similar electric models will replace long-distance diesel ships until battery technology is improved. Fortunately, electric tankers address the pressing issue of harbor pollution, reducing emissions in a smaller, busier area.

In addition to electric options, the future of zero emission ships also hinges on the development and implementation of solar- and wind-powered vessels. While it may be some years before dependable, battery-powered ships hit the market, different wind and solar projects are closer at hand. As far as wind is concerned, designers are looking to the future and the past.

Oceanbird, a collaboration between Swedish companies Wallenius and Alfa Laval, is a concept for a modern ship with four wing sails. Like the Asahi, its creators aim for high cargo capacity. Its first vessel, scheduled for a 2026 release, will be a car-carrier able to transport around 7,000 cars with assistance from an auxiliary engine. Its sails will be 40 meters high and 14 meters wide, with testing of the sail technology to begin in 2023. The company is also considering placing these sails on existing vessels, which would streamline wind power’s ability to surpass and replace diesel ships. If this technology succeeds, it may provide a faster solution to creating a zero emission cargo fleet than waiting for more powerful batteries.

With reference to the past, the Costa Rican company SailCargo is reviving the schooner, an 18th-century wind-powered vessel with three masts and large sails. It has two models in construction: the Ceiba and the Vega. The Vega is scheduled for its first voyage in 2022, with an intended route from Colombia, South America to New Jersey to transport coffee. The Ceiba is also just around the corner, hitting the waves in 2023.

These models may seem strangely retroactive, but they circumvent many of diesel power's burdens. As the war in Ukraine continues, many diesel ships remain gridlocked at ports, an issue that does not affect SailCargo's historic models. These ships, in terms of travel speed, only go up to 14 knots, six knots slower than a conventional container ship. However, as the fiscal and environmental drawbacks of oil dependency begin to crystallize due to rising instability in both areas, SailCargo's ships' slowness seems less of an impediment. With fuel becoming more expensive, diesel ship operators have become more frugal, now driving at only half their typical speed. The increasing failures of diesel power necessitate reinvention, and while SailCargo's approach may seem out in left field, their strategy

opens one's eyes to the wisdom of past technologies.

A key development that synthesizes both wind and solar is the Japanese company Eco Marine Power's Aquarius MRE, a concept for a system of sails, each with photovoltaic panels, which can be installed on pre-existing ships. Its 14 solar-panel sails will be compatible with a range of ships, including coastal cargo vessels, bulkers, tankers, and cruise ships. This concept may prove more efficient than building new zero emission ships, as it saves on production costs for manufacturing vessels. Similar in design to the Oceanbird, both have the potential to rapidly change the face of shipping technology.

Electric maritime vehicles, be it passenger ferries or freight ships, present a quieter, cleaner alternative to the environmental and health effects of gas-powered watercraft. While current constraints on battery technology may limit the distance capacities of electric maritime vessels, that setback has not prevented various startups from taking initiatives. Short-distance electric watercraft are a crucial step in the right direction, as they eliminate emissions in densely-populated, urban environments. Solar and wind projects harness nature's forces using technologies, new and old, that provide alternative solutions in the wake of diesel power's waning viability.

Electrification on the Land

Few people appreciate the extent to which lawn mowers, leaf blowers, and other motorized lawn equipment contribute to greenhouse emissions. Yet, various studies suggest that they generate as much, if not in some cases more, emissions than gas-powered vehicles. Research from the U.S. EPA describes how "off-road gasoline-powered equipment, such as lawn mowers and leaf blowers, emit approximately 242 million tons of pollutants annually, just as much as cars and homes." Luckily, a number of electric alternatives have come out in recent years to offer quieter, zero emission substitutes in place of harmful gas-dependent lawn equipment.

A key reason lawn equipment is so hazardous is that it is subject to fewer environmental regulations than gas-powered cars. For example, motorized cars include a catalytic converter, a component that reduces the amount of harmful fumes cars emit. Since lawn

equipment is not subject to the same regulations as cars, most manufacturers do not equip their products with this technology. The absence of catalytic converters in lawn gear, when evaluated for its emissions impact, represents a brazen disregard for public and environmental health. When studied, the EPA found that gas-powered lawn mowers alone emit 5,000 times more carbon monoxide and more than twice the CO2 per hour of operation than electric lawn mowers.

Fortunately, there are electric alternatives. One key player, EGO, offers electric alternatives for most types of motorized lawn equipment. The company sells electric lawn mowers, weed whackers, chain saws, hedgers, etc., all of which share a common source: the EGO battery. All EGO products use the brand's unique battery, which comes in six varieties, ranging from 2.5 amp hours (Ah) to 12 Ah. The lower amperage versions serve lower-energy devices, such as weed whackers and leaf blowers, while the mid-range and higher amperage batteries meet the demands of larger products, like the EGO riding mower. Charging times vary widely for EGO batteries, from as little as 30 minutes to as much as 2 1/2 hours, depending on the total amperage.

Among the different varieties, the 2.5, 4.0, and 5.0 Ah versions feature a specialized “phase change” material (PCM) that keeps battery cells from overheating. The significance of the PCM is that it pushes heat away, reducing the buildup of thermal energy in the battery’s plastic shell.

While limited battery capacity remains an obstacle to advance electric aviation and watercraft, EGO’s batteries are more than adequate for consumer needs. A key example is their electric lawn mower, said to be capable of running up to 60 minutes on a single charge, enough to take care of quarter to half acre lots without recharging. It is worth mentioning that gas mowers run twice as long as EGO’s electric mowers (about two hours), but their longevity comes at the cost of public health, both to the operator and surrounding bystanders.

Unregulated emissions are not the only issue with gas-powered lawn gear, as noise pollution is another serious concern. Lawn mowers, leaf blowers, weed whackers, and hedge trimmers vary in noise production, reportedly from 82 to as much as 103 decibels

(dB), around the same range as a drum kit from 90 to 130 dB. For reference, noise levels greater than 80 decibels are considered potentially hazardous. Motorized lawn equipment is commonplace, exposing many to unwanted levels of harmful noise. Long-term exposure to noise from lawn equipment can lead to many physical and psychological issues, including hearing loss, tinnitus, sleep deprivation, cardiovascular disturbances, and chronic fatigue. While electric lawn equipment, including ECO’s products, still generates some noise, the noise is less severe than that from gas-powered tools, a point of significant value for the customer.

Greenworks is another brand selling similar products. One would not be remiss for confusing Greenworks with EGO, as the two share several intrinsic features, namely their black and green color palettes, use of brand-specific batteries, and similar selection of devices, including electric leaf blowers, weed whackers, and lawn mowers. However, Greenworks has been in the game longer, starting in 2002, while EGO began in 2012. Greenworks offers a more diverse selection including more niche items, such as electric pressure washers, snow blowers, skill saws, and even robotic lawn mowers, an apparatus that Greenworks shares with a more established lawn care brand, Husqvarna.

Husqvarna, based out of Sweden, is the first but not the last company to offer a robotic lawn mower. Like a Roomba for lawn care, the Automower is a small, two-wheeled machine that cuts grass automatically without an operator. It's all-electric, relying on an outdoor charging station instead of batteries like EGO or Greenworks. When low on charge, the Automower will even guide itself to its charging station, further minimizing the operator's involvement. The Automower's clever design has attracted the attention of competitors, with several brands, including STIHL, John Deere, Greenworks, and even Honda offering their own self-automated mowers.

Lawn gear is not alone in its shift to electric, as agricultural devices are also experiencing their own zero emission renaissance. One household name that's been making serious inroads in electrifying the agricultural industry is John Deere. The brand offers a plethora of all-electric devices, ranging from the "Zero emission compact utility tractor," which resembles a

conventional tractor (but with an electric engine), to the "Autonomous electric tractor," a minimalist tractor with two wheels or treads that runs automatically without a driver, much like the Husqvarna Automower. John Deere's zero emission machines give consumers many of the same perks as other electric alternatives, namely high performance, very low maintenance costs, and low noise levels. These advantages suggest that agricultural machines, like their counterparts in lawn care, are on the cusp of a paradigm shift, placing greater emphasis on customer convenience and health than before.

While gas-powered equipment remains the standard, electric lawn gear is taking a rapid foothold across the nation. According to the *Washington Post*, electric lawn equipment jumped from "32% to 44% percent of the overall lawn equipment market" in only five years, from 2015 to 2020. Unlike with electric cars, electric lawn gear maintains bipartisan appeal, with strong customer bases in states as politically different as Alabama and California. For example, the mayor of Mountain Brook, a town in Alabama that voted for Trump by a 50-point margin in the last election, announced his goal for the town to be "90% electric" in five years. In California, as much as one-half of household lawn and garden equipment in the state is already zero emission.

It is worth mentioning, however, that noise, not pollution, is the common motivator across the political aisle. With the Alabama example, Mountain Brook's mayor turned to electric alternatives only after the tumult of leaf blowers broke his concentration while playing tennis. Nonetheless, measures to cut back noise pollution are not a bad thing. And neither is the reduction of emissions, even if it is incidental.

Gas-powered lawn equipment, even in comparison to other carbon-emitting devices, causes inordinate harm in the form of severe noise and unfiltered pollution. However, brands such as EGO, Greenworks, and John Deere, among many others, offer substitutes that satisfy professional standards while avoiding the drawbacks of toxic fumes and undue noise levels. The growing trend toward electric lawn gear transcends political boundaries, suggesting a pervasive dissatisfaction with gas-powered equipment and its adverse effects on public health. The impressive variety of zero emission

products already available indicates a sea change in the standard of lawn care equipment, where products retain, if not enhance, the efficiencies that customers have come to expect while phasing out dependence on fossil fuels.

SCAN QR CODE
TO VISIT WEBSITE

10

Getting There

MICHAEL J. OSBORNE

Moving to a motive world that is primarily electric will be a monumental accomplishment. Some sectors will be transformed in the relative blink of an eye, much like the transformation that occurred 100 years ago when horses were replaced with horsepower. Others, for technological as well as historical reasons, will be slow to change. Aviation and Marine transport may be slow, but electric cars, scooters, and bikes are coming at a speed we would have never imagined just 10 years ago.

During the last months of 2022, TxETRA and the TxETRA Education Fund held a series of meetings to develop the Recommendations that our members, owners, and key constituents considered to be important to create an environment conducive to developing a robust electric transportation sector, while also managing this sea change efficiently.

These RECOMMENDATIONS, and the actors who must manage or bring them about, are important enough to single out.

The Texas Legislature:

1. The Texas Legislature should create a statewide electric transportation planning council. The planning council should plan charging buildout after federal funds are distributed.

2. The Texas Legislature should establish an electric vehicle consortium(s) similar to the consortium structures (National Cooperative Research Act) that accelerate the electric transportation industry by fostering a common technological architecture to create Texas jobs and manufacturing.

3. The Texas Legislature should amend the Texas Emissions Reduction Program to lift the cap on the number of electric vehicle incentives; allow rebates to be given as an incentive at the time of purchase; create two incentive levels and allow more for Vehicle-to-Grid (V2G) EVs (for grid resiliency); expand the number of grants for medium- and heavy-duty trucks; and fund the charging equipment necessary to power them.

4. The Texas Legislature should adopt goals and incentives for electric vehicle manufacturing jobs.

Texas Department of Transportation (TxDOT):

5. The Texas Department of Transportation should develop directional signs and regulations for charging equipment locations.

Texas Public Utilities Commission (PUC):

6. The Texas Public Utilities Commission should enable the development of industry standards, Vehicle-to-Home (V2H) and Vehicle-to-Grid (V2G) solutions/systems deployed in Texas, and empower the Electric Reliability Council of Texas (ERCOT) to develop protocols.

7. The PUC should allow mobile storage and stationary storage to powershift energy onto the electric grid at peak, and back into storage when generation exceeds load.

8. The PUC should encourage any public electric utility to offer programs to reduce charging during grid peak, and encourage charging during off-peak to lower costs and improve environmental and grid conditions.

9. Texas utilities should join other electric transportation compacts to ensure interstate electric travel.

Texas Commission on Environmental Quality (TCEQ):

10. The Texas Commission on Environmental Quality should be authorized to adopt battery recycling and reuse programs and establish goals.

Texas Department of Licensing and Regulation (TDLR):

11. The Texas Department of Licensing and Regulation should create an electric vehicle charger training program to certify charging and electric automotive technicians.

12. The TDLR should establish regulations to maintain high standards of charger reliability.

State Universities and Community Colleges:

13. State universities should compare the lifetime cost effectiveness of internal combustion engine vehicles versus electric vehicles in their procurement of buses and fleets, and provide electric vehicle charging facilities for faculty, staff, and students.

14. Community colleges should establish training programs for electric vehicle charging technicians and vehicle technicians.

Local Governments and Municipal Planning Organizations (MPOs):

15. Federal, state, and local governments and nonprofit organizations should provide funding and technical

assistance to community-based organizations to assist in developing grant and other funding opportunities.

16. Local governments should consider building codes that require new construction, including multi-family dwellings and workplaces, to be electric vehicle ready.

17. Local governments and/or public/private co-ops should create programs that help get affordable, reliable electric transportation in the hands of low- and moderate-income Texans.

18. Metropolitan planning organizations, city councils, and developers should ensure that affected communities are included in conversations about building electric transportation infrastructure and plans.

19. Independent school districts should transition their diesel fleets to electric transportation by 2035.

20. Public transportation agencies should transition their diesel fleets to electric transportation by 2035.

21. Cities and counties should transition their diesel

fleets to electric transportation by 2035.

22. To protect the public health, Texas cities and counties should be allowed to prepare for the regulation of internal combustion engines in their air sheds.

23. Cities should allow installation of wayfinding signs for electric vehicle charging on their right-of-way streets.

24. Municipalities should encourage programs and infrastructure that prioritize support for workplace and multi-family charging, and state agencies should prepare for electric vehicle sales and market penetration through 2033 (approximately 50% of sales by 2033).

Manufacturers:

25. Vehicle manufacturers should be incentivized to offer a wide variety of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) in rural Texas counties.

26. Early electric vehicle adopters should be considered as future technology arrives; for example: adapters for early electric vehicles should be available.

Getting Credit for Emissions Reductions:

27. Texas should adopt a regional carbon market so that carbon reductions achieved through electric transportation can be monetized.

28. Corporations and other business entities that reduce emissions through electrification of their fleets, telework, and electric transportation programs for their employees would be able to participate in the regional carbon market.

The Purpose of GETTING THERE is to get you there.

Electric transportation is the door to a new future that we can only partially imagine. Moving to electric transportation will unify all of our energy systems, thus making our energy infrastructure more efficient, more practical, stronger, and more resilient. It will substantially reduce the amount of carbon emitted by the transportation sector in our communities, both local and global. It will clean our air supply and improve the health of us all, but especially our children and our elderly. And reduced health costs will be good for our wallets at home and in Washington.

Not only does electric transportation allow us all to ride on the wind or the sun, it presents to us the possibility of transportation devices with communication and geospatial capabilities that are orders of scale beyond our present system of material delivery.

It will evolve us. -Michael J. Osborne

TxETRA
EDUCATION FUND

GETTING THERE
GETTINGTHERE.INFO
ISBN 979-8-218-14416-6

Cover Design: Logan Stewart

GETTING THERE | THE TEXAS ELETRIC TRANSPORTATION ROADMAP

TxETRA
EDUCATION FUND