THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

TECHNICAL REPORT 0-6902-3
TxDOT PROJECT NUMBER 0-6902

Recommended Transition Plan for the Texas Technology Task Force

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July 2018; Published November 2019

http://library.ctr.utexas.edu/ctr-publications/0-6902-3.pdf

Technical Report Documentation Page

1. Report No. FHWA/TX-19/0-6902-3	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Recommended Transition Plan for the Texas Technology Task Force		5. Report Date July 2018; Published November 2019 6. Performing Organization Code
7. Author(s) Andrea Gold, Kristie Chin, Robert Evans, Amy Fong, C. Michael Walton		8. Performing Organization Report No. 0-6902-3
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3925 W. Braker Lane, 4th floor Austin, TX 78759		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 0-6902
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Division P.O. Box 5080 Austin, TX 78763-5080		13. Type of Report and Period Covered Technical Report September 2017 – July 2018 14. Sponsoring Agency Code
15. Supplementary Notes Project performed in cooperation with the Texas Department of Transportation.		
16. Abstract This research report provides an overview of the research team's activities from September 2017 through July 2018. Major activities include continued and increased stakeholder engagement as well as new technology discovery of the Texas Technology Task Force (TTTF). This report provides a brief history of TTTF activities and proposes activities for the project's next phase including technology discovery and technical learning, forming subcommittees on critical technologies, developing a comprehensive and unified communication strategy, and developing a Technology Utilization Plan to advance safe, coordinated technology adoption across the state.		
17. Key Words emerging technology, strategy and innovation, automated vehicles, connected vehicles, communication, technology adoption	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161; www.ntis.gov.	

19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 132	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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CTR Technical Report:	0-6902-3
Report Date:	Submitted: July 2018
Project:	0-6902
Project Title:	Texas Technology Task Force
Sponsoring Agency:	Texas Department of Transportation
Performing Agency:	Center for Transportation Research at The University of Texas at Austin

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

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Acknowledgments

The authors would like to thank members of the Texas Technology Task Force (TTTF) for their continued support in providing timely expertise and guidance during this study. The research team also appreciates and values the insights and support from our invited subject matter experts who participate in meetings and key person interviews. The authors would also like to thank the Texas Department of Transportation for their support, especially from the following:

Darran Anderson, Chief Strategy and Innovation Officer

The Office of Strategic Planning

Kent Marquardt, Director

Stacey Strittmatter, Deputy Director

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Preface

The transportation needs of Texas are evolving at a rapid pace with an expected doubling of population by 2050. When coupled with traditional transportation efforts, advanced and emerging technologies present the opportunity to enhance operations, achieve cost savings, reduce traffic congestion, promote safety, and increase economic activity. To ensure that TxDOT remains at the forefront of innovative transportation, the Task Force continue to evolve as a cross-functional body of transportation thought leaders and subject matter experts (SMEs), serving as an expert advisory body dedicated to transportation technology, to equip TxDOT with essential strategy, innovation, and communication tools. Key deliverables of the next phase of the Task Force project include, but are not limited to, an Emerging & Advanced Technology Portfolio, white papers on critical technologies, a comprehensive communications strategy, and a Technology Utilization Plan that will serve as the fulcrum between technology discovery and implementation. TxDOT and other public agency participants will benefit from insights into industry trends, partnership opportunities, and potential areas for research, as well as strategic deployments, in order to help develop its innovative transportation innovation strategy.

The dynamic and collaborative model outlined in this proposed transition plan will provide insights, offer strategic guidance, and make tactical recommendations regarding a broad portfolio of emerging technologies—paying dividends for the state of Texas.

1 Introduction

This report provides a brief introduction to the Texas Technology Task Force (TTTF) and its activities and outlines recommended next steps for the Task Force as it transitions to its next phase. This report recaps key meetings and activities of the Task Force and puts forth recommendations for the continuation of the Task Force by transitioning to the activities described in the following sections.

Texas is expected to grow by 12 million people in the next 30 years, bringing the total population to 40 million. The increased population will have greater needs for goods and services, which will all potentially contribute to increased congestion. A 21st century transportation system will have an increasingly important role in enabling a vibrant, growing economy. While emerging technologies promise safety benefits, improved quality of life, and increased economic activity, there are also unknown risks associated with these advances. A trusted and neutral group of advisors, forming a task force dedicated to transportation technology, offers TxDOT outside expertise that will enable the agency to safely navigate these risks. Formed independently and not biased toward a particular solution, the Task Force and research team will foster collaboration with industry and research teams, strategically asses emerging technologies, deliver innovative research & technology applications, and position Texas as a leader. This Task Force already has a history of success that will continue into the next phase of work.

Inception: Authorized by Texas's 83rd Legislature, General Appropriations Bill S.B. No. 1 Item 44 VII-31, the Texas Department of Transportation (TxDOT) established the TTTF in early 2013 to develop a vision for the future of Texas's transportation system.

Phase I: (February to August 2013) Began with a core knowledge group that sought experts in various transportation technologies. The initial Emerging Technology Portfolio was presented and a public-private consortium was established to further develop key emerging technologies.

Phase II: (September 2013 to December 2013) Focused on the background research pertaining to the Strategic and Innovation Plan (S+IP) and outlined steps for completion in the next phases.

Phase III: (September 2014 to December 2015) Dedicated to updating the Emerging Technology Portfolio, developing white papers on critical technologies, and drafting initial chapters of the STBP.

Phase IV: (January 2015 to August 2016) Concerned with engaging industry, research, and public partners in order solicit guidance and input for the completion of the Strategy and Innovation Plan.

Phase V: (September 2016 to March 2017) Committed to empowering teams from across the state and engaging stakeholders in the development of a collective mobility-focused agenda for action.

Phase VI: (April 2017 to August 2018) Building upon past achievements, developing a comprehensive stakeholder engagement and communications strategy, and continuing to serve TxDOT by positioning Texas as a leader in mobility and innovation.

At the end of Phase VI of the Task Force, the Task Force is refreshing its membership and reviewing its goals to continue to provide value for TxDOT and the state. So far, it has successfully identified emerging technologies and how they can best be put to use to serve TxDOT's mission. The Task Force will continue to evolve its structure in accordance with recommendations from existing members and needs identified thus far, but the core services of *People*, *Portfolio*, and *Plan* will remain. The Task Force will focus on system readiness and integration and plan activities to advance its mission and develop deliverables such as the Emerging Technology Portfolio, White Papers on critical technologies, and Technology Utilization Plan to continue to provide unparalleled value to TxDOT and the state.

In order to anticipate change, act proactively, and invest in strategic opportunities, the Task Force and research team must have the right combination of independent industry experts, knowledgeable researchers, and the personal connections required to find new subject matter experts (SMEs). TxDOT has developed a strong foundation of innovative research and implementation programs. The next phase of Task Force work should continue the history of collaboration with TxDOT to optimize resources. In short, the existing Task Force membership has a track record of proven success upon which to build. The network of trusted relationships and understanding of TxDOT's technology discovery programs have been cultivated through experience and hard work, and another team would be duplicating efforts to achieve the same results.

Below are proposed recommended steps that the Task Force can take to continue delivering a high level of value to TxDOT and the state while transitioning to the next phase:

Update Emerging Technology Portfolio: Created in Phase I and last updated in Phase III, the emerging technology portfolio is a crucial part of technology discovery at TxDOT. The forum builds institutional knowledge throughout TxDOT and other stakeholders regarding emerging trends and technologies, their potential impacts to Texas, and opportunities for action.

Refresh Membership: New members will provide a different perspective, helping to identify strategic investment opportunities and providing trusted insights. A group of trusted advisors and a network of SMEs will benefit TxDOT.

Create Subcommittees: Subcommittees will allow trusted advisors to focus on key technologies in order to advance technology discovery to utilization and build awareness

of emerging trends and technologies. Incorporating industry experts will help to strengthen key partnerships and relationships.

Develop a Communications Strategy: A solid communications strategy will help to build awareness of emerging trends and technologies across the state, while acting as a vehicle to identify strategic opportunities and provide insights. Making white papers and subcommittee reports available online will provide a unified resource for anyone in the state to follow for guidance.

Develop White Papers on Critical Technologies: The development of white papers will help to monitor and provide awareness of the most up-to-date information on critical technologies, innovative policies, and novel programs while also highlighting opportunities for Texas.

Develop a Technology Utilization Plan: The Technology Utilization Plan developed in order to provide strategic guidance on the anticipation and inclusion of advanced technologies for the Texas transportation system and within the TxDOT. The Task Force shall form the plan through a multi-step process that draws from all activities of the project and includes, but is not limited to, elements such as technology market forecasting, evaluation of benefits and barriers, technology maturation requirements and planning, lessons learned from early trials, and technology adoption strategies. The Technology Utilization Plan shall be developed to define a technical end-state enabled by technology adoption over time. The plan should also identify opportunities for TxDOT to use advanced technology to advance transportation and organizational goals in the near and long term.

2 Emerging Technology Portfolio

The three-step portfolio development and management process outlined below is critical to advancing the Task Force's goals regarding technology discovery and identification of strategic investment opportunities for Texas.

2.1 Technology Identification

Interviews with Task Force members and subcommittees will be conducted at the same time as literature reviews, with feedback between the two processes. Technologies relevant to the future of transportation and aligned with TxDOT's goals will be identified and carried into the next step. Examples from past work include connected, automated, and electric vehicles; unmanned aerial vehicles; cloud computing; location-based services; and transportation subscription services.

2.2 Technology Assessment

Items in the initial technology list will then be assessed for viability based on four dimensions: Strategic Goal Alignment, Deployment Barriers, Mode-Specific System Enhancement, and User Group Enhancement. Each technology from step one will be ranked on a scaled matrix based on the four dimensions and a final consensus will be determined. High-ranking technologies will then proceed to the next step.

2.3 Portfolio Assessment

In the final step, high-ranking critical technologies from the previous technology assessment will be rigorously assessed. A comprehensive portfolio assessment framework will be used to gain a deeper, highly technical understanding of the technologies. This step will focus on a comprehensive perspective incorporating the full technology lifecycle.

2.4 Suggested Elements

The following elements are either currently part of the Emerging Technology Portfolio and should remain, or should be considered for addition to the portfolio. Each of these technologies can make Texas stand out nationally and requires thoughtful consideration by TxDOT.

2.4.1 Connected, Automated, and Electric Vehicles

Alone, each of these technologies has the potential to revolutionize transportation. However, the benefits multiply when all three technologies are combined. The Task Force should keep an eye on these three technologies and their interactions going forward. Connected vehicles can increase the safety and efficiency of transportation systems, while automated vehicles have safety and environmental implications. Electric vehicles can reduce environmental impacts and increase resiliency of both the electric grid and transportation system.

2.4.2 Cloud and Edge Computing

Processing data where it is generated in the field can significantly reduce the infrastructure required to transmit raw data back to a central location and the storage

costs. Cloud and Edge providers can turn data into actionable information, enabling some of the other technologies on this list, saving money for TxDOT via reduced infrastructure requirements.

2.4.3 Data Management as a Service

Big data needs to be stored somewhere, and public agencies are increasingly finding that it is more cost effective to utilize cloud providers such as Amazon Web Services. A cost/benefit analysis and legal implications of these services would identify and remove roadblocks before implementation.

2.4.4 Real-Time Data and Information Management

Real-time incident management has implications from automated vehicles to freight operations. The Task Force should continue to monitor strategies for collecting and distributing real-time data about traffic operations to increase safety and operational efficiency of the transportation system.

2.4.5 Next-Gen Communications

Both 5G cellular and dedicated short-range communications (DSRC) could have a place in a connected transportation ecosystem. The Task Force should continue to monitor active deployments and make recommendations on which technology is most effective under which circumstances so that Texas can make strategic investments.

2.4.6 Artificial Intelligence (AI)

AI is changing how data is analyzed, unlocking computerized applications that were not possible before. From machine vision to business intelligence, AI can revolutionize safety and transportation planning in Texas.

2.4.7 Blockchain

Blockchain enables security and data integrity in environments where trust is not guaranteed, such as automated vehicles reporting on incidents and road conditions. Other applications where data integrity is paramount should be investigated to increase operational security of ITS deployments.

2.5 Relevance of Emerging Technology Portfolio

The emerging technology portfolio will be used to inform the composition of the Task Force, formation and topics of subcommittees, the communications strategy, and which SMEs are invited to meetings. Critical technologies such as connected and automated vehicles and AI shape the transportation landscape and require unique planning considerations. SMEs can clarify aspects of the technology, see through any hype associated with emerging technology, and identify its potential.

3 Refresh Task Force Membership

The Task Force has continually identified and engaged the relevant SMEs to guide specific activities, such a considering technology market projections, understanding its applications and uses, exploring supportive and limiting policies and regulation, etc. TTTF membership evolves as its work progresses through various phases so that the right expertise is always present for the task at hand. In its current state, the TTTF is comprised of eight external industry, research, and public agency professionals. On-going engagement occurs with necessary leadership within TxDOT that serve in administrative, decision making roles or staff from various divisions as well as including other public sector stakeholders outside of TxDOT. Finally, the TTTF regularly engages SMEs to present on select topics or to serve as advisers on specific tasks. Past SMEs have included representatives from Verizon & Alcatel-Lucent, Xerox, ESRI, Volvo, Toyota, General Motors, Port of Houston Lone Star UAS Center of Excellence, and Lyft. Current Task Force members are listed below:

C. Michael Walton (Chair)
Cockrell Centennial Chair in Engineering |
Department of Civil, Architectural &
Environmental Engineering
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Executive Advisor
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Steve Dellenback
Executive Director of R&D
Southwest Research Institute

Tom Lambert
President and CEO
Houston METRO

Mike Heiligenstein
Executive Director
Central Texas Regional Mobility Authority

JD Stanley
Chief Strategy Officer & Co-Founder
IoTAI

The Task Force should consider new members that have expertise in areas not currently represented, such as original equipment manufacturers (OEMs), the insurance industry, freight, and data management and mining, or entrepreneurship and business development.

4 Create Subcommittees

The Task Force should consider establishing subcommittees to conduct deeper discovery into critical technology topics. The subcommittees would be intended to be a dynamic, short-term mechanism to serve specialized needs and supplement the Task Force, rather than develop into standing independent bodies. Subcommittees would form to investigate particular questions or topics that arise out of Task Force meetings. Potential examples include the readiness of 5G versus DSRC telecommunications, applications of blockchain in transportation systems, or regulatory needs for automated vehicles. Each subcommittee would be best led by a Task Force member, TxDOT staff, and/or a member of the research team and is thought to benefit from limited participation from industry SMEs, or members of other research institutions who may provide technical guidance or recommendations on topic areas. The need for any particular subcommittees will be determined by the Task Force and the TxDOT staff following the identification of critical topics at meetings. Subcommittees will convene via conference calls, online meetings, or email and shall be in effect in between Task Force meetings. Subcommittees will report on activities and findings at each Task Force meeting where the full Task Force and TxDOT can work together to determine if the subcommittee has completed its investigation and dissolve or if there is a need for it to continue. Outcomes of subcommittees may include recommendations for technical sessions at meetings, development of research problem statements, white papers, or opportunities in the Technology Utilization Plan.

5 Develop White Papers on Critical Technologies

The Task Force should develop white papers each year in order to provide timely information on innovative technologies, policies, or programs. Topics should rotate and be selected based on input from TxDOT and Task Force members, focusing on areas in which there is critical interest and a number of outstanding questions (example topics include virtual and augmented reality, road usage charges, and vehicle-to-infrastructure applications). The white papers should be designed to serve as a mechanism to bring the most-up-to-date information to the Task Force and interested stakeholders. Content and findings from the white papers will inform strategies in the Technology Utilization Plan. Elements of the white papers may contain (but are not limited to) information on technical details of technologies and their real-world applications, potential business models or markets, political and societal trends bearing an impact on technologies, identification of opportunities for utilization and adoption in Texas, and case studies on ongoing trials or pilots, when possible.

6 Communications Strategy

The Task Force should develop collaboration and communication materials throughout the next phase in order to identify and implement a variety of communications activities. These activities should outline the strategy and opportunities to be used for project communications, information distribution, feedback, and stakeholder engagement. These activities are described in more detail in the tasks listed below.

Stakeholder Mapping: The Task Force should develop a stakeholder map that characterizes stakeholder groups, such as elected officials, other state agencies, the divisions of TxDOT, industry sectors, the public, etc., and defines appropriate messages, informational materials, and communication channels.

Dedicated Website: The Task Force should develop and maintain a dedicated website with background information, up-to-date materials, visions, mission, values, goals, objectives, and additional resources. The website will serve as a central repository of information and details of activities to share with interested stakeholders.

Library of Presentations and Talking Points: The Task Force should work with TxDOT's communications team, Strategic Planning, and other divisions to prepare and deliver presentations and talking points for use during conference presentations, media interviews, council, committee, legislative, and commission meetings, or other public forums. The Task Force research staff and supporting TxDOT leadership has been selected several times to present on emerging technology activities at professional society and research conferences, such as those hosted by TRB, AASHTO, ITS America, etc., and should continue to pursue these opportunities. Materials will also be developed for use by TxDOT staff in similar presentation or public forum opportunities.

7 Develop Technology Utilization Plan

The Technology Utilization Plan should be developed under the guidance of the Task Force and designed to serve as a strategic guide on the anticipation and inclusion of advanced technologies for the Texas transportation system and within TxDOT. Under the guidance of the Task Force and TxDOT, the research team should form the plan through a multi-step process that draws from all activities of the Project and includes, but is not limited to, elements such as technology market forecasting, evaluation of benefits and barriers, technology maturation requirements and planning, lessons learned from early trials, and technology adoption strategies. The Technology Utilization Plan should define a technical end-state enabled by technology adoption over time. The plan also identify opportunities for TxDOT to use advanced technology to advance agency and transportation goals in the near and long term. Critical components of the plan are described below.

Evaluate Benefits and Barriers to Technology Adoption: Under the guidance of the Task Force and TxDOT, the research team should conduct an evaluation of impacts to TxDOT, the Texas transportation system, and the public from the adoption of the emerging technologies identified in the Technology Utilization Plan. Using information gathered during the Project activities, the research team should conduct a high level assessment of benefits such as expected safety improvements, reduced congestion, environmental impacts, cost savings, and increased accessibility. An assessment of barriers to adoption such as policy and regulatory challenges, funding, user acceptance, and security should also be conducted. The evaluation should describe changes or uncertainty in the economic, political, and organizational spheres that need to be taken into account when planning for technology utilization.

Synthesize Best Practices and Lessons Learned: The research team should develop a synthesis of best practices, including, but not limited to, a compilation of technical information on the state of practice in developing or testing advanced technologies. The synthesis should provide examples of applications, techniques, tools, policies, and funding, reported and illustrated through specific case studies. It should also compile lessons learned from ongoing pilot programs and/or model deployments. The synthesis will draw from information gathered during model deployment site visits, key person interviews, attending deep-dive sessions, and Task Force expertise.

Policy Toolkit: A policy toolkit could assist TxDOT and the Texas Legislature with identifying and resolving barriers to critical transportation issues. The toolkit could identify key issues or outcomes that are aligned with Task Force activities and other outcomes desired by TxDOT. Examples for issues to be addressed by the toolkit include pollution and congestion reduction, economic development, connected and automated vehicles, and next-generation communications. Elements in the toolkit could be put

together by a subcommittee or the research team, depending on need. Once issues and desired outcomes have been identified, the Task Force could identify examples of success and pull out implementation challenges, resolution, and the methodology used to resolve the issue

Deliver Technology Utilization Plan: Under the guidance of the Task Force and TxDOT the research team should develop the Technology Utilization Plan to serve as a guide to the anticipation, adoption, and promotion of advanced technologies. In addition to the elements described above, the full plan should include, but not be limited to, the following:

- A Utilization Roadmap identifying the phasing, insertion points, associated R&D investments, and work plans or packages for core technologies, and then sequencing the activities within each functional and major program area in the tactical plan to form the roadmap.
- Recommended resources to be allocated as well as tasks and priorities for action with timelines.
- Assessment of the life-cycle costs of technology
- Recommended strategies for maximizing research and resource allocation
- Creation of a framework to measure progress toward implementation

8 Next Steps

The transportation needs of Texas are evolving at a rapid pace, and there is still much uncertainty around the realization of emerging technologies. Continuing the activities of the Task Force with trusted advisors and SMEs who provide insights, offer strategic guidance, and make tactical recommendations regarding a broad portfolio of emerging technologies will pay dividends for the state of Texas.

Guidance from the Task Force will be essential to helping the state of Texas identify viable technologies, assess their barriers and benefits, and recommend strategic investment decisions to TxDOT. Furthermore, stakeholder engagement will open dialogue with the companies, start-ups, other public agencies, and policymakers to prepare Texas to anticipate the ways emerging technologies will change how we move people, deliver goods, and exchange information.

The Task Force, research team, TxDOT supporting staff, and dedicated participants have a track record of proven success upon which to build. With an extensive network of trusted relationships and deep understanding of TxDOT's innovative programs, the Task Force and research is committed to delivering a collaborative and dynamic technology discovery program. Ultimately, a cohesive and collaborative transportation innovation strategy will be realized for Texas and serve as a catalyst for future innovative programs.

9 Appendices

White Paper: Texas Economic & Environmental Sustainability—Top-Down & Bottom-Up Transportation Strategies

White Paper: Improving Freight Operations in Texas—Operational and Policy Recommendations

Materials from the June 13, 2018 meeting of the TTTF

1. Agenda
2. Meeting Notes
3. PowerPoints:
    - TTTF Overview, Update, and Agenda
    - Small Cell Telecommunications in State Rights of Way (Beverly West, TxDOT)
    - Proterra – Leading the Way to the Electrification of Transit (Dale Hill, Proterra)
    - The Standards-Driven Path to 5G (Jim Misener, Qualcomm)
    - Resilient Grid: Electric Vehicle-Grid Integration (Michael Legatt, Resilient Grid)

Texas Economic & Environmental Sustainability

White Paper

Top-Down & Bottom-Up Transportation Strategies

How can transportation agencies leverage technology to maintain Texas's economic sustainability and promote environmentally responsible travel to secure economic competitiveness and quality of life for generations to come?

A major threat to the state of Texas in the 21st century is the impact that extreme weather events and severe drought will have on the Texas workforce, agricultural industry, livability, and overall economic attraction. Texas has the opportunity to establish leadership in advocating for the environmental sustainability of our transportation and infrastructure systems while bolstering their resiliency and economic sustainability. Actions, policies, and strategies designed to mitigate the transportation system's contribution to anthropogenic climate change moving forward will pay dividends for Texans in the present and for future generations. This paper explores policy actions that can take either a top-down approach to greenhouse gas emissions reduction (through policies that reduce vehicle emissions) or a bottom-up approach (with policies that encourage more sustainable travel behavior)

Texas Economic & Environmental Sustainability

White Paper

Top-Down & Bottom-Up Transportation Strategies

KEY STRATEGIES

Facilitate Zero- and Low-Emissions Vehicle Adoption

Electric and hybrid-electric vehicles are becoming increasingly cost-competitive relative to traditional vehicles, but agencies must alleviate range anxiety by meeting charging infrastructure demand and coordinating efficient fleet procurement options to enhance overall fleet

Incentivize and Improve Multi-Modal Travel

Mobile applications hold great promise for enhancing real-time travel information; increasingly sophisticated applications also enable the provision of personalized incentives that are effective at encouraging individuals to make sustainable mode and time-of-day shifts.

Encourage Alternative Commutes and Travel to Reduce Peak Travel Demand

Transportation agencies can also mediate excessive travel demand by promoting telework programs and educational campaigns to benefit air quality and reduce pollution. Early implementations in other states have been well-received.

Leverage Volkswagen Mitigation Trust Funds Strategically

Use trust funds as local match requirements for external grant programs to maximize funding streams to Texas, allow localities to use funds to meet their specific needs, and continue pursuing appropriations for existing emissions reduction programs in the upcoming legislative session.

Consider Economic and Environmental Interdependencies

Texas's natural and human resources are critically linked to the state's long-term economic growth, but declining air quality, climate change, and federal policies can pose barriers to economic development unless all sectors take

Texas Economic & Environmental Sustainability

White Paper

Top-Down & Bottom-Up Transportation Strategies

INTRODUCTION

Texas has the second-largest economy in the United States, with a $1.6 trillion gross state product [1]. Although energy is the largest industry in Texas, the state owes its economic stability to the diversity of industries and regional economies that call it home. For instance, the health, information technology and telecommunications, business and financial services, and recreation and food services industries have all reported marked growth in employment in Texas since 2006 [2]. Furthermore, the agriculture industry employs 1 out of 7 Texans and Texas leads the nation in value of farm real estate [3]. However, climate change and the extreme weather events associated with it threaten Texas's burgeoning cities and rural homelands alike. A recent study found that the effects of climate change are forecasted to lead to significant economic damages in the United States by the end of the century, with Texas and nearby states bearing the brunt of the damage. These states are predicted to experience 10 to 20% loss of their gross domestic product (GDP), whereas the northern part of the country may be impacted relatively little. This is because the change in climate conditions could lead to migration of labor and economic productivity out of Texas and into northern states, as agricultural productivity climbs in more temperate regions and stagnates in Texas. Much of the damage to the Texas economy is expected to be in the form of deaths due to increasingly severe heat waves, lost labor productivity in industries such as agriculture that depend on outside labor and environmental conditions, and escalating utilities costs [4].

However, the economic impact of climate change is not merely predicted; it has already begun to show its teeth in Texas with the multi-year drought from 2010 to 2015 (with 2011 being Texas's driest year on record), and the increasing intensity of extreme weather events such as Hurricane Harvey in 2017. The 2011 Texas drought was the most expensive drought in history, leading to $8 billion in losses in the agricultural industry alone [5]. Crops that were severely impacted included cotton, peanuts, corn, and wheat. As Texas provides 10% of the world's cotton, global markets and economies will be affected by the impacts of drought and global warming realized in Texas alone [6]. Texas's state climatologist John Nielsen-Gammon named increased evaporation due to warmer temperatures as a cause of the drought, with evidence that the global rise in temperature is in part due to anthropogenic greenhouse gas emissions [7]. More recently, Hurricane Harvey is estimated to have cost the Texas economy $190 billion, due to business disruptions, transportation and infrastructure damages, crop loss, increased fuel prices, and property damages, making it costlier than Hurricane Katrina in 2005 [8]. A recent study that examined climactic effects on Hurricane Harvey found that global warming, primarily associated with greenhouse gas emissions, has increased both the intensity of rainfall events in the

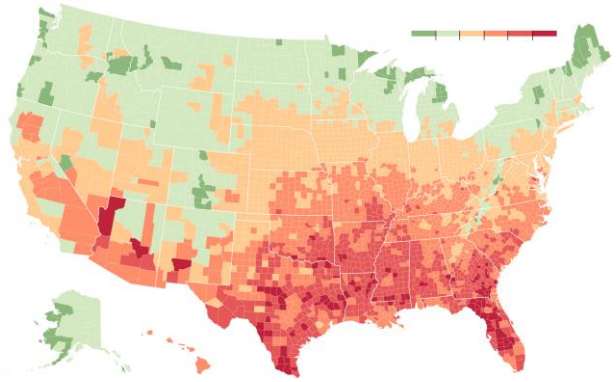


Figure 1: Predicted Damage by County from 2080 to 2099, Percent GDP per year, ranging from -5% (green, increased GDP) to 15% (red, decreased GDP), Source: NYTimes [4]

Gulf Coast as well as their probability of occurring [9].

As Texas's industries and exports have grown to global significance, Texas must also be a steward of its natural resources and environment in light of the value the Texas economy derives from them, and the impact the Texas economy has on those of other major world powers. It's clear that TxDOT's mission to enable economic opportunity and enhance quality of life for all Texans is now deeply intertwined with the impacts that the transportation sector has locally and globally on economies and the population's well-being. The transportation sector contributed to 27% of all US greenhouse gas emissions, second only to electricity production, and 83% of all transportation emissions were produced by light-duty vehicles and trucks [10]. The transportation sector will thus be instrumental in reducing global greenhouse gas emissions in order to lessen the extremity of the climate change that has already begun to affect Texas. Moreover, the transportation sector is responsible for over 50% of nitrogen oxides (NOx), volatile organic compounds (VOCs), and particulate matter emissions across all sectors in the US, all pollutants known to have negative impacts on the health and welfare of those exposed [11]. For instance, smog or ground-level ozone produced as a result of NOx and VOCs can make it difficult to breathe, damage airways, and make the lungs more susceptible to infection. In the long term VOCs can even cause chronic diseases and conditions such as asthma and chronic obstructive pulmonary disease. Similarly, particle pollution from particulate matter is associated with premature death in people with heart or lung disease, nonfatal heart attacks, decreased lung function, and more [12]. Based on the value of a statistical life, the internationally based Organisation for Economic Co-operation and Development estimated that the economic cost of deaths from ambient air pollution in the United States totaled US$496 billion in 2010, with surface transportation emissions responsible for about 50% of the damage [13].

TxDOT is presented with the opportunity to be a leader in promoting environmental sustainability for the benefit of Texas's economic sustainability. This aligns handily with other goals to enhance the multi-modal mobility of Texas residents and reduce congestion that negatively impacts the industries that rely on mobility through major Texas corridors. Some emerging policy and technological interventions seek a balance between regulation and behavior change in order to facilitate economic development for years to come. The most effective and equitable solutions will likely draw on synergies between travel demand management, reduced vehicle-miles traveled, and increasingly efficient vehicle technology and fuel sources. This will maximize the benefit to the highly interconnected spheres of economic and environmental prosperity in Texas while simultaneously leading to enhanced multimodal mobility, planting the seeds for the continued growth of diverse economies in Texas, and improving conditions for communities whose public health has been most impacted by pollution.

VOLKSWAGEN TRUST

A catalyst that is set to mobilize the transportation sector towards reduced emissions is the establishment of a $2.7 billion environmental mitigation trust for the states or beneficiaries that were exposed to excess NOx emissions due to the Volkswagen (VW) emissions cheating scandal. Beneficiaries must each develop and publish for public comment a "beneficiary mitigation plan" that summarizes how they intend to spend their allocated funds in order to reduce NOx emissions

from the transportation sector [14]. As of December 2017, all 50 states and the District of Columbia have named the designated lead agency that will allocate and administer the funds throughout their areas for approved projects.

Eighty percent of the beneficiaries have designated an agency that is responsible for ensuring the public health and resource conservation of their state. The Texas Commission on Environmental Quality is the lead agency to manage the trust funds in Texas.

Most project types that are eligible for funding through this trust must involve the replacement of diesel engines with more efficient engines. These can be powered by diesel, including biodiesel and renewable diesel, or by natural gas, including CNG (compressed natural gas), LNG (liquefied natural gas), RNG (renewable natural gas), and propane (liquid propane gas). They can also be some variation of an electricity-powered vehicle such as a hybrid electric (HEV, which combines an internal combustion engine with a battery and electric motor and may be plug-in) or a battery electric (BEV—powered exclusively by electricity provided by a battery, fuel cell, or the grid). Additionally, the types of vehicles or infrastructure that are eligible for investment are primarily freight and port drayage trucks; school, shuttle, and transit buses; freight switchers, ferries, and tugs; oceangoing vessels; shorepower, airport ground support equipment, forklifts, and port cargo handling equipment; and light-duty zero emission vehicle (ZEV) equipment. Finally, the funds may also be used as a local match toward Diesel Emission Reduction Act (DERA) projects, which are awarded through national grant programs administered by the US Environmental Protection Agency (EPA) and are often similar in scope to the VW settlement-eligible projects. For instance, the 2017 EPA Clean Diesel Funding Assistant Program request for proposals named eligible diesel emission reduction solutions that included verified emission control technologies such as exhaust controls, cleaner fuels, and engine upgrades; verified idle reduction technologies; verified aerodynamic technologies and low rolling resistance tires; certified engine replacements; and/or certified vehicle or equipment replacement [15].

As of December 2017, a number of these states have already published draft mitigation plans for public comment. Rather than naming very specific projects or even specific types of projects, most draft plans available propose to choose projects that are most cost-effective (most emissions reduced per dollar spent) or that most benefit populations and communities in areas with the worst air quality [16].

Some of the unique aspects of different states' priorities include the emphasis on electric vehicles (EVs) and infrastructure in Washington state and ZEVs in Delaware (rather than investing in new diesel engines that, although more efficient, would

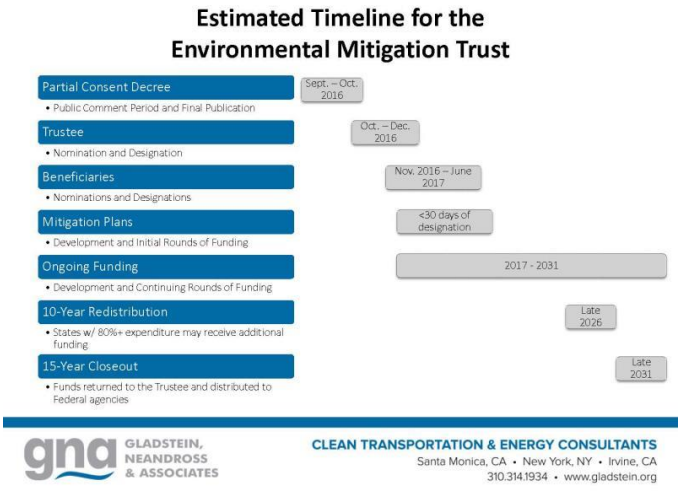


Figure 2: VW Trust Distribution Timeline, Source: Gladstein, Neandross & Associates [46]

still have air pollutant emissions associated with their operation).

Considerations: Life-Cycle & Evaluations

Cost-effectiveness is a common goal in emissions reductions actions. It is cited as a top priority in the EPA DERA request for proposals as well as in many of the already available VW settlement draft mitigation plans. However, the comparison across different vehicles is not straightforward. Some life-cycle costs that fleet operators must consider include vehicle lifespan, maintenance costs, fuel costs and their respective volatility, emissions profiles, and infrastructure and vehicle local availability. For instance, the *Pike Research Total Cost of Ownership of Alternative Fuel Vehicles for Fleet Operators* finds in its analysis that in the mid-size vehicle class, HEVs, diesel vehicles, and BEVs with an offsetting tax credit all have lower total cost of ownership than the pure gasoline vehicle at low gas prices (with battery electric being lowest in cost and hybrid electric and diesel being roughly equal in cost). However, the report makes it clear that the cost of ownership calculated is based on assumptions of vehicle and infrastructure availability; for instance, installing EV infrastructure could add thousands of dollars to the total cost of ownership [17].

Evidently, a careful and comprehensive life-cycle must be considered in order to capture the full cost of fleet investments and truly inform funding decisions. However, other considerations are more difficult to operationalize, such as the value of the reduction of dependence on foreign energy and the associated price volatility or the positive image effect of implementing ZEVs. Public agencies in Texas will need to incorporate life-cycle calculations that consider a wide range of variables in order to invest in the right technology to maximize environmental benefit and minimize long-term operator cost.

LOCAL & REGIONAL CLIMATE ACTION IN TEXAS

Some city and regional governments in Texas have already been recognized for their leadership in sustainability or climate action. For instance, both Dallas and Houston were praised in 2017 for demonstrated climate action among the likes of San Francisco, New York City, and Miami. The Guardian noted Houston's efforts to use renewable energy and energy-efficient municipal buildings, with Dallas being a close second among Texas cities [18]. Furthermore, Corpus Christi was recognized in 2014 for their leadership in climate planning with the Gulf of Mexico Spirit of Community Award. The Gulf of Mexico Climate Outreach Community of Practice lauded their Integrated Community Sustainability Plan, which utilized extensive stakeholder engagement and multidisciplinary collaboration [19]. The figure on the next page details several local achievements or commitments to climate action and sustainability in Texas.

Texas Economic & Environmental Sustainability

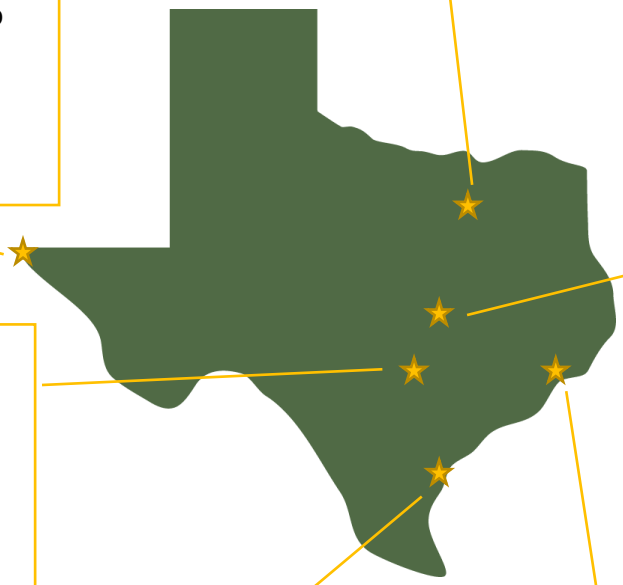
White Paper

Top-Down & Bottom-Up Transportation Strategies

Local Transportation Sustainability Initiatives in Texas, [20]-[25]

The **North Central Texas Council of Governments (NCTCOG)** adopted the Mobility 2035 Plan in 2011, with a chapter on sustainable development. Their livability principles recognize that multimodal transportation, mixed-use land use, and affordable housing will bolster economic competitiveness while improving air quality.

El Paso's Livable City Sustainability Plan calls out their need to power public fleets with lower emissions fuels such as natural gas, reduce fleet size, and invest in local transit in order to meet their goal of becoming the least car-dependent city in the Southwest.



Austin's 2015 Community Climate Plan highlights numerous strategies in transportation and land use planning to reduce greenhouse gas emissions, including transportation demand management, electric/alternative vehicle adoption and infrastructure, parking management and road pricing, and telecommuting.

San Antonio developed a SA Tomorrow Sustainability plan in 2016 in preparation for the ongoing development of a Climate Action and Adoption Plan, targeting increased transit ridership, decreased transportation pollution per capita, and more miles of Complete Streets.

Corpus Christi released the Integrated Community Sustainability Plan in 2011. Their mobility goals emphasize Complete Streets and multimodal accessibility in recognition of synergistic benefits in emissions reductions, public health, and equity.

Houston released their most recent Emissions Reduction Plan in 2008, and in a 2009 update reported they met goals of replacing aging public fleets and maintenance vehicles with hybrid vehicles.

Texas Economic & Environmental Sustainability

White Paper

Top-Down & Bottom-Up Transportation Strategies

POLICY & PROGRAMS

Numerous policy approaches have been implemented in the past to curtail transportation sector emissions, ranging from fuel efficiency standards enforced at the federal or state level to incentives for high occupancy vehicles or alternate modes to vehicles, which may be implemented at a state, regional, or local level. These policies can be characterized as one of two methods for reducing transportation sector environmental impacts: those that make the technology itself more efficient and those that shift travelers to more efficient choices. At the state-agency level is the flexibility to implement and support both types of policies. For instance, many states have adopted fuel efficiency standards more stringent than the federal standard or provided additional subsidies and rebates to ZEV purchases. At the same time, mobility improvements at the state level can be coordinated to maximize effectiveness in encouraging mode shifts across all population segments, such as the deployment of a single payment platform that facilitates multimodal travel throughout the state.

The rest of this paper provides a scan of noteworthy policies and programs that state or federal agencies have implemented or performed extensive research on with greenhouse gas and air pollutant emissions reduction goals in mind. The two broad strategies that address transportation's environmental impacts from the top down and bottom up are presented. Top-down policies and programs aim to reduce emissions generated by the transportation sector passively by increasing overall fuel efficiency of public and private fleets or personal automobiles. Meanwhile, bottom-up policies and programs aim to reduce emissions by actively encouraging changes in people's travel decisions.

Strategy: Improved Transportation Fleet Efficiency

Some analysts argue that imposing strict standards for vehicle efficiency and incentivizing the adoption of ZEVs are more effective than policies that target traveler behavior. This position acknowledges the challenge of motivating long-term behavioral shifts within the population, such as driving less or taking more transit. Furthermore, behaviors that are favorable in terms of greenhouse gas reductions typically reduce the traveling public's mobility, by shifting them to modes with typically longer relative travel times and perceived reductions in flexibility and personal agency. As a result, some argue that vehicle miles traveled (VMT) reduction policies intended to change traveler behavior are more intrusive to the traveling public than the implementation of stricter emissions standards, which do not have direct impacts on people's lifestyles but still reduce transportation sector emissions [26]. Finally, it is necessary to establish that not only do EVs produce fewer greenhouse gas emissions even when all of their electricity is generated by coal-fired power plants, but the Texas renewable energy portfolio is expected to expand in the next 15 years based on the Electric Reliability Council of Texas' (ERCOT) Long Term System Assessment, which anticipates that solar additions and coal retirement will provide the most reliable and efficient electricity generation under a robust suite of scenarios [27] [28].

Alternative Fuel Vehicle Adoption: Incentivizing and Enabling Individual Adoption

In addition to the federal income tax credit of $7,500 that was left intact in the December 2017 tax overhaul, numerous states offer incentives for PHEVs and BEVs in hopes of increasing their value to consumers. These benefits include direct rebates on the purchase cost of a vehicle; high-occupancy vehicle lane, parking, and toll exemptions; and reduced electricity rates for at-home charging. In a 2014 study on state incentives for EV adoption, the International Council for Clean Transportation (ICCT) noted that states with the largest EV incentives relative to the rest of the country also had EV sales shares approximately two to four times greater than the national average, providing evidence that such incentives are effective at increasing consumers' appetite for EVs [29]. Some states with notable incentive programs include California, Georgia, Hawaii, Oregon, Louisiana, Illinois, and Washington: the ICCT estimated that in these states the consumer benefit per vehicle ranged from $2,000 to upwards of $6,000, whereas the national average in 2013 was roughly $1,000 per vehicle. Of the variety of consumer incentives represented above, the ICCT found that the most effective incentives were direct subsidies, carpool lane access, and emissions testing exemptions.

Some of the benefits that each of these states provide to their citizens to incentivize the adoption of more efficient vehicles as of December 2017 are summarized below.

Building Coalitions to Address Range Anxiety

Range anxiety—a concern that EVs do not have sufficient range for common uses—has long been recognized as a common barrier to EV adoption. Some federal and regional initiatives have been implemented to promote investment and strategies to overcome this adoption barrier. For instance, in 2017 the Federal Highway Administration (FHWA) designated its first set of Alternative Fuels Corridors with the ultimate goal of building out a national network of alternative fueling and charging infrastructure along national highway system corridors. Furthermore, with these designations the FHWA hopes to accelerate public interest in and awareness of alternative fuel vehicles through national highway signage branding. Such a network would also help identify collaboration opportunities at the state and local level amongst those with interstate highways targeted for investment in the first 30-month investment cycle using VW settlement Electrify America funds. Designated corridors may even be considered for priority Congestion Mitigation and Air Quality Improvement (CMAQ) Program funding [30].

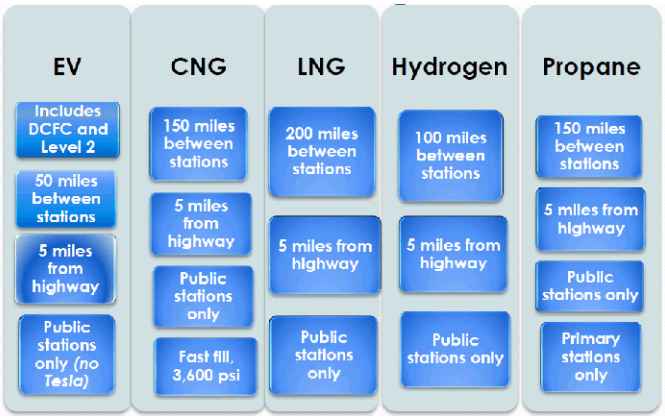


Figure 3: Criteria for "Signage-Ready" (Already Equipped with Sufficient Infrastructure) Corridors for Each of Five Alternative Fuels, Source: FHWA Office of Planning, Environment, and Realty [30]

Another recent movement to unify multiple states towards EV adoption is the memorandum of understanding announced in October 2017 for the Regional Electric Vehicle Plan (REV West). The plan, signed by governors of Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming, spans more than 5,000 miles of highway across east-west

Interstates 10, 40, 70, 76, 80, 84, 86, 90, and 94, and north-south Interstates 15 and 25. Primarily, this collaborative effort will ensure that EV charging infrastructure can be efficiently deployed along the aforementioned corridors across state lines, rather than through decentralized state-level efforts that would lead to redundant or unnecessarily frequent charging stations [31].

As the federal government begins to designate corridors within the national highway system that run through multiple contiguous states and states themselves begin entering into coalitions, opportunities arise for cross-agency coordination in order to install the necessary alternative fuel infrastructure efficiently across borders and jurisdictions.

Implementing Provisions to Make EVs Readily Accessible

The state of California pioneered the ZEV program, a credit-based system that requires auto manufacturers to sell ZEVs (plug-in HEV, BEV, or hydrogen fuel cell). Nine other states (Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont) have joined California in adopting the ZEV program. An exemption in effect until the end of 2017 allowed auto manufacturers to earn more credits in one state in order to meet their credits in all other states; the result is that not all states under the ZEV program have accelerated ZEV deployment and accessibility as quickly as California did. However, as this exemption ended in 2017, affordable ZEVs should become increasingly available in other states that adopt the mandate [32]. Thus, although California was able to promote ZEVs earlier than other states, 2018 marks a new period in which states that adopt a similar program will finally be able to benefit from new vehicle fuel technologies to the same extent that California has.

Zero & Low Emissions Vehicles Benefits Span Multiple Sectors

MJ Bradley & Associates performed an analysis of the costs and benefits of different plug-in electric hybrid vehicles (PHEV) market share scenarios. The results identified economic benefits for PHEV owners, utility providers, and all utility customers regardless of whether they themselves owned an EV. This finding implies that increased market shares of alternative fuel vehicles will have benefits across the population, and thus policy interventions that incentivize their adoption will not only benefit those who can afford to buy a new low emissions vehicle but our communities in general. It is projected that a high market penetration of EVs coupled with incentives to shift electric demands to certain times of the day have the potential to make electricity demand on utilities providers more uniform, which decreases their operating costs and lowers the price they must charge electricity customers. Furthermore, the generally increased electricity demand will increase utility providers' revenue, which will enable them to maintain and operate the existing electricity distribution infrastructure, further stabilizing and reducing present electricity costs. Ultimately, the authors of the report estimate that societal benefits measured in 2016 dollars will range from $100 to $265 dollars per PEV, and that these benefits will be experienced by all utility customers, but especially PEV owners [33].

As a supplement to the aforementioned project benefits, MJ Bradley quantified the benefits potentially realized in Massachusetts, one of the nine states that adopted California's ZEV program. Despite some negative economic impact on jobs due to decreased spending on gasoline and vehicle maintenance, the net economic impact was estimated as positive due to increased spending on

electricity and new, more fuel-efficient vehicles, and PEV ownership savings compared to the cost of owning a fuel combustion vehicle. Ultimately this would result in thousands of jobs created and billions of dollars in gross state product, state tax revenue, and personal income [34]. This analysis makes a strong case for the potential economic benefit that could be realized statewide as well as by individual Texans.

Alternative Fuel Vehicle Adoption: Reducing Organizational Barriers

Public agencies that operate their own fleets have the potential to save public money on maintenance, fueling, and other life-cycle costs when they convert part or all of their fleet to EVs. However, the initial investment is high, which has prompted federal and state initiatives designed to reduce a local agency's financial burden. One example of a state initiative was California's 2015 Public Fleet Pilot Project, which provided rebates to agencies in disadvantaged communities, which were disproportionately affected by poor air quality. The Center for Sustainable Energy, in a feasibility analysis, reported that if each eligible fleet replaced all the recommended vehicles with appropriate PEVs, each fleet would save an average of approximately $75,000, or nearly 25% of the estimated total cost of ownership over the life of the vehicles. Further, these recommended replacements would reduce each fleet's modeled vehicle emissions by an average of 67% [35].

Fortunately, the burden on state agencies to finance programs that increase cities' and localities' access to new, more efficient vehicles may be lessened soon by the VW Settlement trust. Most of the eligible projects are similar use cases. As of December 2017, several states have shared their Draft Mitigation Plans for public comment. Of these, Oregon, Delaware, Washington, Pennsylvania, and Colorado have all stated in their plans that their investment priorities lie in areas with vulnerable or disadvantaged populations that are disproportionately exposed to poor air quality, as well as in replacing aging diesel-fueled public fleets. For instance, Washington State has proposed to use their funds to convert their bus and ferry fleets from diesel to all-electric. Similarly, Colorado has proposed to prioritize local freight and port drayage trucks and transit and school bus fleets. Oregon too has proposed to replace older diesel school buses across the state with clean diesel-powered buses [36].

Finally, an oft-cited organizational barrier to alternative fuel vehicle adoption has been the burden of initiating a competitive procurement process for new fleets. A collaboration between Fleets for the Future and the National Joint Powers Alliance (NJPA) has aimed to dismantle this barrier by developing a national competitive solicitation for EVs.

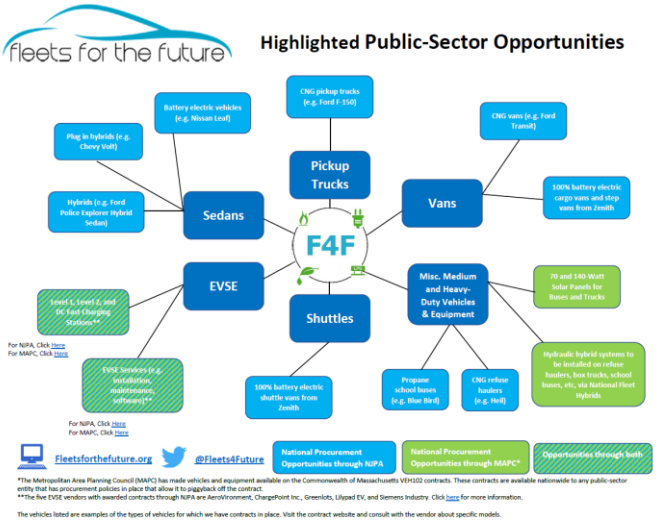


Figure 4: Varieties of Vehicles Available for Procurement through the Fleets for the Future National Contract, Source: Fleets for the Future [49]

The first procurement window took place in October 2017, where public agency members of the NJPA (membership is free) not only had access to discounts on PHEVs, BEVs, CNG-powered vehicles, and charging infrastructure and installation but also were able to conserve their own staffing resources by leveraging the collection contracting and procurement processes already developed by Fleets for the Future and the NJPA.

Strategy: Behavior Shift to More Efficient Travel Patterns

A common argument against solely implementing vehicle emissions regulations to reduce emissions is that as alternative fuel sources are adopted and the cost of transportation fuels decreases, travel demand and VMT will increase accordingly. This could increase congestion, crashes, or even vehicle emissions from present amounts. As such, some suggest that travel demand management in tandem with regulatory action is crucial to meeting reduction goals. In order to achieve this, travelers need to be shifted to more efficient modes of transportation, such as transit and shared rides, and active transportation modes like walking and bicycling. There are new ideas and technologies that change how public agencies can implement incentives to mode shift or improve alternative modes in order to nudge the traveling public towards fewer single-occupancy VMT and hence reduced emissions per capita.

Reduce VMT: Incentivize Multimodal Transportation

Public agencies and researchers are becoming increasingly interested in leveraging personalized incentives to create significant mode and travel departure time shifts among the traveling public. Transportation analysts have long known that people's travel decisions are far from socially optimal, resulting in negative externalities such as traffic congestion and air pollution. However, never before has there been a feasible way to orchestrate transportation system-level coordination among travelers in order to reduce the negative byproducts of transportation systems. Now, such large-scale coordination is possible, and the US Department of Energy (DOE) and FHWA are both supporting the investigation of technologies that would result in a more efficient transportation network—without requiring capital investments in new infrastructure or improved modal efficiency, or a degradation in quality-of-service or reliability of the system.

For the first time, high-speed communications technologies have made this idea feasible for implementation, as widespread adoption of smartphones and 4G-LTE connectivity give agencies the ability to communicate with travelers directly and in real time. A research project to watch is the Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation (TRANSNET) program funded by the DOE [37]. This project, initiated in 2016 and running through July 2018, engages five different research teams to leverage newly available communications channels such as cellphone applications or connected vehicles to coordinate travel behavior in transportation networks. For instance, the National Renewable Energy Laboratory is partnering with Metropia on the Connected Traveler project to design and develop personal signaling associated with various energy-efficient and contextually relevant commuting options to present to Metropia users [38]. The team will use behavioral modeling to identify the right incentives at the individual level to encourage app users to change their departure time, route choice, or destination choice, as well as their mode choice, vehicle occupancy, or decision to make a trip at all. Ultimately, they will deploy in a major US city in

order to prove the efficacy of their system for systemic travel behavior coordination using real-time sensor data streams and estimated travel demand.

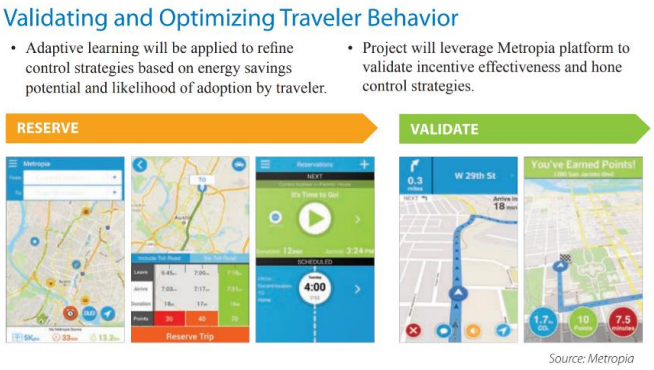


Figure 5: Metropia In-App Experience, Source: NREL [36]

These projects are laying the groundwork for regional and state-scale deployments of personalized incentives in an informed, data-driven effort to reduce congestion and transportation emissions, and results from early proof of concept deployments may give rise to an entirely new way to manage and operate transportation systems.

Another unique effort is taking place in Utah to incentivize travel choices that can ultimately reduce vehicle emissions and promote shifts towards multimodal travel, active transportation, higher-occupancy driving, or reduced vehicle trips in general. The Utah DOT (UDOT) identified eight strategies that can reduce energy consumption, optimize mobility, and ultimately improve the quality of life in Utah: carpooling/vanpooling, public transit, "skip the trip", teleworking, trip chaining, planning ahead, active transportation, and alternative work schedules [39]. To promote these eight strategies, in 2008 UDOT launched an educational campaign called TravelWise.

The program realized measurable and significant benefits by engaging individuals and businesses in a statewide annual competition, the Clear the Air Challenge, which is slated to take place again in 2018. With a primary goal of improving air quality, the challenge also aspires to educate participants on drive-alone alternatives and produce long-term travel behavioral change. Some tactics the program uses to reach as many participants as possible include encouraging businesses to serve as intermediary influencers; engaging key local political, community, and faith leaders, as well as popular public figures such as lifestyle bloggers; and advertising weekly and grand prizes to participants. In the first seven years of its implementation, UDOT estimates that 11,700,000 vehicle miles have been saved; 900,000 vehicle trips eliminated; and $5,500,000 in gas, vehicle maintenance, and wear-and-tear saved for participants [40]. With this program, UDOT demonstrates strategies to shift travel behavior that don't rely on engineering solutions (which could take great effort to fund or procure) or policy solutions (which may require years of research and demonstration before implementation).

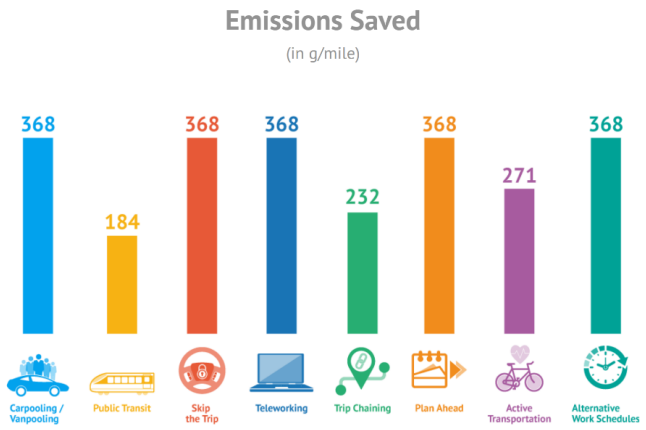


Figure 6: Emissions Saved from the Clear the Air Challenge in Utah, Source: UDOT [40]

Furthermore, the success of Clear the Air demonstrates that members of the public are willing to try new modes of transportation and understand the benefits of reducing single-occupancy vehicle use.

Reduce VMT: Limit Recurring Demands due to Commuting

Another cost-effective method to reduce VMT is to promote the implementation of telework policies. The Minnesota Department of Transportation demonstrated how effective teleworking programs can be at reducing VMT in 2012 with the eWorkPlace project. They showed that teleworking as a solution for travel demand management can be achieved, without any new physical infrastructure or long-term investment. By engaging 48 companies and 4,000 employees in Minnesota, they were able to reduce VMT by an estimated 7.4 million miles per year. The program was successful because it garnered true employer support and commitment, resulting in a behavioral shift amongst employees. In return, program administrators provided employee training, business strategy development, and IT support during the pilot. This pilot was a demonstration of policy intervention that yielded benefits on many fronts, thus enabling sustainable participation from employers and employees, and measurable reductions in areas of crucial importance to the public sector, such as VMT and transportation emissions [41].

Reduce VMT: Tax Road Usage Proportionately

Vehicle technology has evolved since the gas tax was first implemented. Because vehicle fuel efficiency has improved drastically, road use is not proportional to fuel taxes. Moreover, raising the existing fuel taxes to meet the average increased efficiency of the fleet disproportionately affects rural drivers who are more likely to own less fuel-efficient vehicles or those who can't afford newer fuel-efficient vehicles. On the other hand, implementing a mileage-based tax would likely result in little change in the cost of driving for rural drivers but would increase fees for urban drivers with fuel-efficient vehicles, which would help equalize the discrepancies that are growing between rural and urban drivers' tax contributions to infrastructure maintenance and investment.

The first American agency to pilot a mileage-based tax was the Oregon Department of Transportation (ODOT), first in 2006 and again in 2012. In the second pilot, the tax was set at 1.5¢ per mile driven, and ODOT contracted with private companies to administer the pilot study participant's accounts. Participants self-installed a mileage reporting device in their vehicles and were given the choice between GPS and non-GPS enabled devices. However, a key takeaway from the pilot was that in order for the program to be sustainable the means of tracking an individual's mileage will need to change, because the devices couldn't operate accurately in certain vehicles and can be easily removed. Such devices were sufficient for the purpose of proof of concept, but will not be suitable for a statewide deployment. Another conclusion from the pilot was that mileage-based fees will present an opportunity to utilize business partnerships, as the private sector can drive innovation in administering the tax through increasingly efficient support services or technologies [42].

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Top-Down & Bottom-Up Transportation Strategies

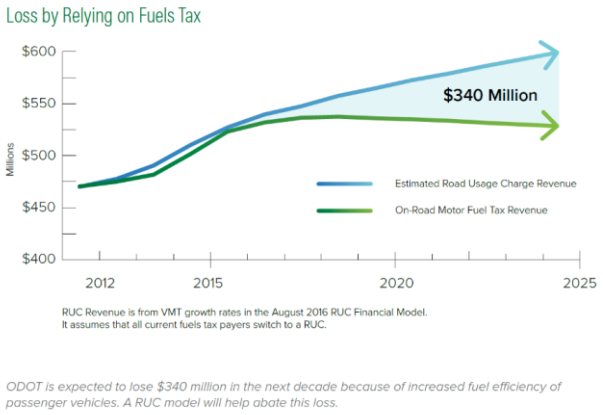

Figure 7: Projected Revenue Recovery in Oregon through Road Use Charge Implementation, Source: ODOT [42]

The OreGO pilot spurred the recommendation to the Oregon Legislature for a per-mile fee for all new vehicles rated at 20 miles per gallon or better beginning in 2025 [43]. They have also identified that the road usage fee will be a key opportunity for cross-state collaboration, as the program may be increasingly effective when enforced across state lines.

Pilots have also taken place or are underway in California, Washington, Hawaii, and Colorado. The California pilot, which released findings from their pilot in mid-2017, found that 80% of participants opted for automated mileage reporting options as opposed to odometer readings or pre-paid mileage permits, and the most common technology chosen to report mileage was a vehicle plug-in device that gave participants the choice of whether or not to use location and GPS to measure mileage more accurately [44].

Another prominent initiative is the Western Road Usage Change Consortium (RUC West). It is composed of 14 member states, including Texas, that have each demonstrated varying levels of commitment to testing and implementing road usage fees. RUC West serves to enhance the investigation of road usage fees through inter-agency collaboration and as a funding source for research projects pertaining to road usage fees [45]. As of 2017 they have funded 14 different projects that explore public perceptions of the fee, setting appropriate fees, effects of rural residents, driver privacy, and more [46].

Road usage fees and road pricing present an opportunity to address transportation sector emissions. An analysis performed by Cambridge Systematics indicated a road usage charge would decrease greenhouse gas emissions by up to 2.5% due to reduced VMT—a more significant reduction than for nearly every other strategy evaluated, such as transit improvements, carpooling and ridesharing, and idle reduction. Furthermore, the analysis presumed a road usage fee that would generate the equivalent revenue as gas taxes do presently. Therefore, if road usage fees are implemented to recover decreasing revenue from gas taxes, the price signal to reduce VMT by personal vehicles may become even stronger. Future analyses must consider the competing outcomes that arise when reduced VMT as a result of increased costs of driving produce reduced fee revenue to public agencies. There is certainly an opportunity to continue investigating how specific populations in Texas and their traveling behaviors will respond to road usage fees in order to determine whether or not pricing VMT will produce sustainable funding streams for Texas infrastructure and support emissions reduction goals.

Texas Economic & Environmental Sustainability

White Paper

Top-Down & Bottom-Up Transportation Strategies

OPPORTUNITIES FOR TEXAS

Texas can leverage the findings and lessons learned from the pilots and studies over the last decade to implement policies and programs that best suit its diverse and growing population. Following are the most important insights:

- Reducing the environmental impacts of transportation is not only becoming a key business strategy for modern state departments of transportation, but also necessary action in order to protect the millions of American livelihoods linked to the success of industries built around natural resources such as agriculture. Many of the technologies and new ideas in transportation system operations that tout benefits for the environment through travel demand management are also techniques for reducing reliance on foreign energy, stimulating innovation in growing markets like electric and other alternative fuel vehicles, the growing renewables industry in Texas, and advanced and coordinated travel demand management through the state.
- Low-emission vehicles and ZEVs are becoming increasingly accessible and useful for the motoring public and fleet operators. As a result, mobility can now increase without the adverse impacts of air pollution and greenhouse gas emissions. Past limitations on economic growth in freight and logistics due to transportation costs will be lessened by increasingly efficient vehicles, expanding Texas's economic competitiveness. Furthermore, Texas drivers can access more job, health, education, and recreation opportunities through lower transportation costs.
- Forward-thinking states are encouraging the adoption of new vehicle technologies by adapting policies to foster their public acceptance, ensuring long-term sustainable transportation funding mechanisms, and addressing organizational barriers to adoption. Early implementations and subsequent evaluations of policies that promote their adoption have been successful, and states are increasingly recognizing the demand amongst their citizens for lower-emitting vehicle choices. Estimates project that one in five cars sold in 2025 will be EVs, and numerous American and foreign automakers have announced initiatives to provide increasingly diverse electrified vehicle offerings to the American market. Fostering their adoption among Texans will yield economic benefits to consumers, Texas utilities providers, and their communities at large.
- Rural, low-income, and otherwise underserved populations can benefit greatly as a result of the policy implementations that curb single-occupancy vehicle travel and overall VMT. Several states are investigating road usage charges that would shift the disproportionate burden of paying for infrastructure through the gas tax away from rural drivers while promoting alternate modes in urban areas. Furthermore, the 24 Texas counties with US EPA nonattainment status in 2018 across all criteria pollutants will benefit from reduced vehicle exhaust emissions, especially in historically disenfranchised communities near high volume roads and highways.

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Improving Freight Operations in Texas

White Paper

Operational and Policy Recommendations

How can states and localities improve the freight ecosystem to keep pace with technology, get the most out of existing infrastructure, reduce harmful side effects of pollution, and boost the economy?

By re-examining the way the freight infrastructure operates, cities and states can prepare for a more robust economy. They can prepare themselves to accommodate an upswing in freight demand or be better prepared for reduced demand due to economic downturns. Implementing key programs that are already being tried in other areas will allow states to move faster with less risk. These enhancements can also improve operational efficiency, reduce cost to consumers, and reduce emissions. Policy changes could ease rollouts of these new systems and maximize their benefit. Updated regulations around right-of-way, drive time for truckers, and use of urban space will unlock advantages and multiply the effects of other advances. Implementing these policy and operational changes can have a positive ripple effect on the state.

Improving Freight Operations in Texas

White Paper

Operational and Policy Recommendations

KEY STRATEGIES

Learn Fast from Others

Other public agencies are already testing connected and automated freight applications. Texas can leverage lessons learned in Europe and Wyoming to jump-start truck platooning and harness safety and efficiency benefits.

Examine Alternate Uses of Right-of-Way

Technology continues to develop at breakneck pace, but industry has started moving towards DSRC and 5G technology. Public entities in Texas should continue to lease right-of-way and install flexible frameworks to remain up to date and enabling.

Partner with Industry to Match Technology Advances

Technology and the private sector are moving quickly. Public agencies should ensure that regulations enable procurement for pilot projects, innovative parking solutions, and connective technologies to achieve the full benefits of advances in these areas.

Enhance Ports and Border Crossings

Existing bottlenecks at ports and land borders need to be addressed to maintain Texas's competitive edge. Position related activities near one another within the port and eliminate multimodal bottlenecks to enhance economic growth and decrease harmful effects of pollution.

Urban Delivery Improvements

The last leg of deliveries causes a disproportionate level of congestion and pollution. Urban areas should take a comprehensive approach to managing space for deliveries to make the most of a limited resource.

Improving Freight Operations in Texas

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INTRODUCTION

Freight operations are crucial to the operation of the Texas economy. From long-haul trucking within and through the state, to port operations, urban deliveries, and congestion, every Texan's life is impacted by the movement of goods. However, this essential operation is often invisible to citizens. Even people who are not concerned with day-to-day operations are affected by key advancements in platooning, first- and last-mile operations, and at ports and borders. Truck platooning (computer-assisted following at close distances, as shown in Figure 1) could reduce emissions, increase safety, and change the makeup of the workforce. Innovations in first- and last-mile delivery could lead to more effective use of curb space and faster package delivery with less environmental impact. And improvements in port operations could lead to less congestion, lower levels of emissions, and faster turnaround times for shippers and receivers. All of these improvements increase economic benefits and reduce harmful effects of pollution statewide. This can only be good news for a state that is expected to grow by 40% over the next 30 years.

LONG-HAUL INNOVATIONS

Platooning & Connectivity

Trucks are the primary method for freight movement in Texas, accounting for 54% of goods movement by tonnage, a number that is expected to grow as Texas's population continues to increase [26]. Further exacerbating that problem is the increased usage of online delivery services, especially with short turnaround times. Same-day and next-day deliveries require companies to set up more warehouses on the periphery of cities and make more frequent deliveries with trucks that are less than 100% full. This inefficiency increases vehicle miles travelled (VMT) and emissions and could only get worse as more customers expect this high level of service. However, it may be possible to counteract some of these negative effects using connected and automated technologies in the long-haul supply chain. Additionally, services like Uber Freight can increase the fill rate of trucks, further increasing efficiency.

European Truck Platooning Challenge

The European Truck Platooning Challenge attempted to solve this problem by discovering real-world barriers to the implementation of truck platooning. Established by the Netherlands in 2016, the challenge brought together key European governments with industry partners such as Volvo and Daimler. This multinational effort tested all aspects of running an automated platoon across borders, encompassing physical infrastructure; vehicle communications; and safety, legal, and policy considerations. The test took place on April 6, 2016, and involved driving platoons from Sweden, Denmark, Germany, and the Netherlands to Rotterdam. Scania, a subsidiary of Volkswagen, had the longest route at roughly 1,250 miles. This challenge tested SAE Level 1 automation [24], which is relatively new on open roads, and imparts few details regarding real-world performance capabilities. Each of the six participating companies used its own proprietary wireless connection to manage the platoons, so inter-company connectivity was not possible [6]. However, if truck platooning is to succeed at a larger scale, it must be possible for different manufacturers and operators to communicate with one another. The organizing committee recognized a need to develop a standard to ensure interoperability and security between competing manufacturers.

Several important lessons were learned from the event. For instance, each country required that the

platoons break up under certain circumstances, such as when entering tunnels, in heavy traffic, or near on-ramps. Analysis of driver behavior indicated that people would notice the larger gap in the broken-up platoon and merge in between trucks. This then required the trucks to pass the merged vehicles before they were able to re-form the platoon. When the platoon did not break up for on-ramps, drivers simply waited for the entire platoon to pass and merged after it [6]. Though the Dutch research team was unable to survey the drivers who merged into the middle of the broken-up platoon, they did conclude that the behavior around unbroken platoons was safer as it required fewer merges and risky passing maneuvers. Achieving freight platooning in the US would require policy changes as well as an effort to increase public acceptance of automated driving.

Figure 1: A Platoon of Volvo Trucks [6]

The regulatory differences between different European countries required that the platoons be broken at border crossings and re-formed with different characteristics. Almost every country has a different allowable following distance, and Germany required that the platoons activate their hazard flashers and have unique signage to indicate an unusual load. While the research team stated that these identifiers in Germany helped increase awareness of the platoon and reduced risky merge-ins, the EU as a whole would have to come up with standards regarding following distance and driver regulations to ease that aspect of the process. (The control transition was identified by drivers as the most difficult part of the entire process.) This problem could be mitigated in the US if the federal government established national standards for following distance, driver certification and rest time, and platoon identification. However, until that time, states should work together to enable platooning across state lines and reduce the overhead for trucking companies. Additionally, the US could work with Canada and Mexico to enhance existing cross-border operations.

Wyoming I-80 Connected Corridor Pilot

Connected vehicle (CV) technologies enable sharing of safety and other messages between vehicles beyond line-of-sight. 5G cellular and DSRC are the two leading technologies, but USDOT is focusing on DSRC. USDOT's CV Pilot is an example of CV testing taking place in the US. Two pilots through this program, in New York City and Tampa Bay, FL, are focused on taxis and passenger vehicles. The third, administered by the Wyoming Department of Transportation (WYDOT), is focused on connected corridors. WYDOT applications could have impacts for safety and reliability on I-80, a major national freight corridor. Freight traffic makes up roughly 30 to 55% of annual traffic on I-80, though this can spike to 70% seasonally. Additionally, the winter crash rate on the corridor is three to give times higher than the summer rate and the rough terrain makes responding to incidents difficult [14] [17]. This area's clear need for sharing accurate information about weather conditions, conditional speed limits, and other safety hazards makes it ideal for vehicle-to-everything (V2X) applications.

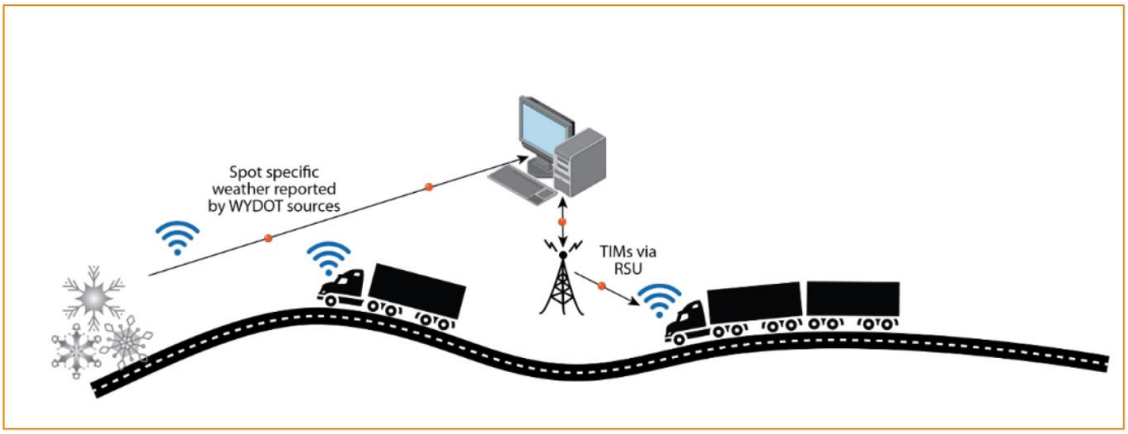

Figure 2: Wyoming DOT Concept of Operations [14]

After I-80 was identified as a pilot site in 2015, WYDOT began planning and developing the required concept of operations (ConOps); see Figure 2. Phase Three, real-world demonstrations, began in December of 2017. Snowplows and other state-owned vehicles equipped with sensors and communication devices will allow the DOT to collect information about current conditions on the road from a trustworthy source and disseminate it to interested parties. The vehicles will automatically collect data about weather, speed, and pavement condition that the DOT can use to evaluate conditions and adjust speed limits or close roads accordingly [14]. Data on safety conditions is coming from DOT-equipped vehicles, which limits the ways in which bad actors can manipulate the system and increases confidence in the data. Additionally, equipping police vehicles with connected technology will allow them to respond to "disabled vehicle" signals or other types of distress. Knowing the exact location of, and reason for, a disabled vehicle enables law enforcement to respond appropriately and in a timely fashion while reducing risks associated with traditional search-and-rescue operations.

The second key component of the ConOps plan is the Traffic Management Center (TMC). WYDOT's TMC will be upgraded to handle the increased amount of data produced by sensor-equipped vehicles. Upgraded facilities will allow them to dispatch maintenance, issue alerts and advisories, or even close roads. They will also be able to control the flow of information going out with tools like dynamic messaging signs, the WYDOT travel information site, and the commercial operator portal [14]. Increased information coming out of WYDOT will increase safety on the corridor. WYDOT can serve as a valuable, trustworthy source of information for all users of the corridor, regardless of whether they have adopted CV technology themselves.

Finally, WYDOT will need to upgrade its roadside infrastructure in order to handle the increased amount of data flowing from the roadside to the TMC. Facilities to be upgraded include speed sensors, CCTV cameras, dynamic message signs, telecommunication networks, and new DSRC facilities [14]. More sensors, cameras, and dynamic messaging signs have obvious safety applications. Upgrading telecommunications networks will allow for more data to flow through the corridor, which

is necessary due to the increased data generation and need for communication. WYDOT chose to go with DSRC because it is the current federal standard. Some original equipment manufacturers are also starting to move in this direction, while others continue to pursue 5G cellular [13].

Connected Infrastructure in Right-of-Way

While truck platooning can take place without any infrastructure components, deploying connected corridor technologies presents numerous advantages. As seen in the Wyoming I-80 pilot, adding roadside capacity can enhance safety for all road users by enabling weather, construction, and hazard notifications as well as distress signals from disabled vehicles. These advantages outweigh the costs associated with such infrastructure upgrades [14]. Another possible benefit of roadside hardware is enabling platooning service providers (PSPs), which can coordinate trips among different companies and ensure safety for all drivers involved in the platoon [20]. A PSP could be a government entity operating with the public good in mind or a private company contracting its operations to different trucking companies.

State DOTs have an opportunity here to license their right-of-way to telecommunications providers or PSPs. Multi-duct conduit or utility corridor structures [21] provide the most flexibility for the DOT in terms of future upgradability. Technology changes very quickly and it is important to have the flexibility required by changing CV systems. Because these systems do not require infrastructure to succeed, it is important that the DOT is able to accommodate their needs in order to derive value for both parties. Once these structures are in place, the DOT can lease its ROW to telecommunications providers in exchange for access to data or maintenance and upgrades to connected technology.

Workforce Considerations

Automation in the trucking industry is almost unquestionably better for safety and consumer considerations, but the situation is considerably more complex when considering drivers and those in the freight workforce. On one hand, there is a driver shortage of about 50,000 that is expected to increase to 174,000 over the next ten years [8]. Automation could relieve that shortage by enabling more efficient operation or replacing drivers altogether. For example, following drivers in a highly automated platoon could “clock out” and rest while the lead driver controls the entire stream. The drivers would then clock back in to separate from the platoon and make the last leg of their journey. Even higher levels of automation could potentially remove the need for drivers altogether, though industry and research partners do not agree on timelines. Today, SAE levels 1 and 2 [24] have completed real-world testing and can increase safety for drivers with features such as lane-departure warning and forward crash avoidance. Electronic logbooks have also dramatically reduced instances of driver exhaustion [8].

Despite benefits to the industry as a whole, automation has potentially negative effects for drivers. Truck drivers have a median age of 49 and are overwhelmingly male [8]. This segment of the population is less technologically inclined and may be unwilling to learn new skills just a few years before they become eligible for retirement. As the industry increases its use of automation, people who have traditionally held these jobs either no longer have the required skillset or are finding their jobs eliminated altogether. In this case, what is good for consumers and the large shipping companies is not good for drivers. It falls on policymakers, then, to determine how to make this

transition while respecting the history and traditional importance of truck drivers to the economy.

Another tricky issue for lawmakers is centered on electronic logbooks and maximum drive times when paired with automation. In the past, if a driver was out of time but close to a rest stop, it was simple and common to exceed the allowable drive time to complete a delivery or find a better place to pull over. Obviously, it is safer to prevent drivers from taking long shifts without breaks, which is why regulations existed in the first place. However, as the industry transitioned to electronic logbook devices (ELDs), drivers lost that flexibility. They now find themselves unable to finish a route or find a rest station once their time is up. ELD laws need to accommodate the needs of these drivers and allow them to find a better place to stop if they can do so safely.

Existing laws are also not caught up with the levels of automation that are currently possible. For example, trucks often queue up at ports and borders while waiting for inspections. This low-speed environment where the trucks are essentially waiting and following, and even idling for hours at a time, is the perfect environment for low-level automation. It is a comparatively simple task to have an automated driving system keep pace with the truck in front, especially in this low-speed environment. However, current legislation does not account for this situation and requires drivers to be on the clock the entire time. As a result, a driver may spend up to eight hours "on the clock" in an easily automated queue. Federal policymakers should consider updating legislation to allow drivers to clock out while automated driving modes are engaged, or at least to have automated queuing only count for a fraction of the actual time. This will enable drivers to complete more deliveries in less time and ultimately make more money. Automated queuing could also potentially enable drivers to rest or talk to family while the truck is moving at low speeds. These quality-of-life improvements may help to combat recruiting issues that the industry as a whole is facing by simplifying the complex task of driving a truck.

URBAN FIRST- & LAST-MILE DELIVERY

Curb Space Management for Parking & Delivery

The modern urban environment presents increasingly complex challenges as cities grow and citizens demand more amenities. Urban freight delivery tends to scale poorly as cities become denser, because existing policies have been focused on managing residential use of curb space, not commercial use. Further complicating the issue is that cities have a large number of deliveries, with few alternative modes available. For example, a single large residential tower can have hundreds of deliveries in a day. Without a single entity coordinating the activity in that building, the traffic is unpredictable and inefficient. And larger delivery companies simply account for parking tickets in their fees, making delivery prices higher for everyone while still blocking the road. Furthermore, a wide variety of stakeholders complicate any attempts to improve curb space management in a logical way. Any city hoping to change its curb use policy will have to contend with residents trying to park, delivery companies, local businesses, travelers who want unimpeded access to the road, transit operators, as well as ride-hailing and ride-sharing services, among others.

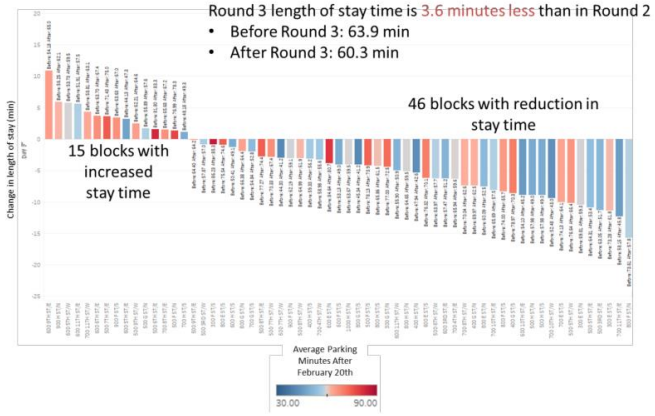

Figure 3: Length of Curbside Parking Stay in DC [11]

Most cities have an incremental or reactionary approach to urban freight deliveries, with layers of regulation built up over time as new problems arise. Despite being the most common, these types of regulation lack the context necessary to develop an urban delivery network that works for everyone. Instead, they tend to preserve the status quo and can compound problems that cities otherwise work hard to solve, such as congestion and pollution mitigation.

Large cities like New York City, where these problems are particularly prevalent, have started evaluating parking and curb space regulations with a framework [28]. The process begins by overhauling all existing regulation and aligning the new rules with the city's goals. As seen in NYC, streets are grouped by type and size, with allowable uses based on a predetermined set of factors. When these regulations are clear, it becomes much easier for delivery companies and local businesses to comply with the city's vision of reducing congestion and pollution. Delivery drivers can know based on the street design, even without having visited a location before, what the expectations are in terms of idling, allowable dwell time, and whether parking will be available or not. However, this approach takes more time up front from the city's transportation department and also requires systematic review to ensure that the allowed uses are still desirable as the city changes.

Another model for regulating curb use, proposed by Zalewski et al. in 2011, was largely theoretical at the time but may be coming in to its own as IoT and V2X technologies make their way into the world. The Performance Pricing Model effectively prices all curb space so that the available curb space is equal to the demand. While the potential benefits are immense, setting the price to achieve desired outcomes can be a difficult task. Washington, DC recently conducted a pilot for demand-based pricing of curbside parking (Figure 3). In contrast with other cities that have tried monitoring parking occupancy with cameras, inground sensors in every space, or manual counts, the DC pilot aimed to use as few components and as little manual intervention as possible in order to save costs [10]. After developing the physical infrastructure, rate structure, and rate schedule, the city began the pilot in a three-by-eight block area overlapping three neighborhoods with high parking demand. In addition to metered spaces for residents and tourists, the study area captured a number of loading zones that were illegally being used for passenger vehicle parking [11]. This caused delivery vehicles that wanted to use these spaces to double-park or look for a different space, in turn increasing emissions and reducing the effective capacity of the streets. It is not enough to price curb space and monitor usage of street parking. Enforcement of existing policies is key to ensuring that the outcomes intended by policy are happening in the real world. Without effective enforcement of curb usage, people will continue to use the available space for their own benefit to the detriment of the system as a whole. Nevertheless, high-tech solutions such as the DC pilot show that

effective changes can be made with low cost and high public acceptance.

Parking management is not the only way to improve use of curb space. The Regional Plan Association and Volvo developed a set of recommendations based on New York City and leading European cities. For example, urban consolidation centers (UCCs) bring trucks into the heart of the city, near demand, before redistributing packages for last-mile delivery. Despite the high costs involved with locating a package sorting facility in or near the center of the city, there are some real benefits to the public. By locating the UCC near demand hotspots, the actual distance of the "last mile" is reduced. The packages can then be delivered by a variety of means that are in line with the city's goals, including automated and/or electric vehicles, or "cargo cycles." While uncommon in the US, cargo cycles have been used to great effect in large European cities. Gothenburg in particular has made great use of a UCC and cargo cycles to reduce the number of deliveries per recipient by 14% [27]. This results in shorter, faster delivery times for companies, all with fewer emissions. While this may seem unrealistic in the United States, bold companies in NYC have had success with the technique and cite low upfront and operating costs, high flexibility, and increased safety as key benefits [27].

Off-hour deliveries are another solution that can improve freight operations within a city. Generally, retailers are the ones opposed to shifting delivery times to overnight hours because they may have to provide staff and a secure area to store goods until regular hours [27]. Additionally, some businesses require deliveries to be made at specific times or as soon as possible. However, time-shifting deliveries without these restrictions to overnight hours can still be beneficial to the city as a whole. In certain New York zip codes, shifting just 30% of deliveries to off-hours resulted in fewer areas where demand exceeded available spaces and effectively increased the number of parking spaces for people to use during peak hours [19]. Even a modest shift in demand has a drastic effect on curb space availability in the city.

Personal Delivery Devices

Personal delivery devices (PDDs) are an option similar to cargo cycles that several cities have explored. These are autonomous delivery robots that can safely deliver packages on sidewalks to people's homes or businesses (Figure 4). Due to their small, battery-operated nature, they are more environmentally friendly than small delivery trucks. However, cities have reacted with concern about having an autonomous robot on public sidewalks with vulnerable road users. In 2017, San Francisco passed legislation requiring permits to test these devices on public sidewalks. The rules are quite restrictive, allowing at most nine devices in the city, and only in certain industrial areas with low risk, as identified by their Vision Zero program [4]. The ordinance also specifies a maximum speed of 3 miles per hour, and a human operator must be within 30 feet of the device at all times. Contrast this regulation with the City of Austin, which has decided to use PDDs to benefit vulnerable populations. In February of 2018, the city's Transportation Department issued a request for information (RFI) for PDDs to "improve access to goods and services for residents in under-served areas" [9]. The RFI emphasizes access to healthy food, educational materials, and medical equipment. It also calls out specific low-income, high-density areas where the city would like to see tests performed and allows for speeds up to 10 MPH, without a human present. Structuring the RFI in this way may increase access to critical goods

and services for vulnerable populations in the city. Due to the recent timeline, the city has not yet published information about responses to the RFI.

Figure 4: Starship Technologies Personal Delivery Device [25]

PORTS & BORDER CROSSINGS

Case Studies

Port of Oakland. Alameda County California, where the Port of Oakland is located, has an innovative vision for simplifying operations, increasing multimodal mobility, and growing the regional economy. Currently, freight arriving in the port must be unloaded and travel by truck to a rail terminal, where it can be shipped to the rest of the US. Additionally, rail and truck traffic patterns cross, resulting in long delays, increased pollution, and spillback into the general traffic stream. As larger and larger ships become economically viable for shippers, ports around the world have had trouble keeping up. Already, so-called "megaships" (Figure 5) cause spikes in truck traffic as more containers than ever are unloaded onto the same land-side infrastructure. These spikes cause increased pollution and congestion and are only projected to increase as demand for megaships grows.

However, as part of their 2017 FASTLANE (now INFRA) and ATCMTD grants, Alameda County has re-designed large parts of the port, including traffic flows and a new Traffic Management Center [5]. The new vision allows freight arriving at the port to be placed directly on trains and eliminates conflict points between rail and trucks. These innovations will dramatically improve the throughput of the port, as well as providing pollution reductions and enabling just-in-time pickup. This future-proofs the port against ever-increasing freight volumes. By applying for, and receiving, multiple federal grants, Alameda County was able to leverage a significant amount of local money into a comprehensive redesign of the port.

It is clear that Alameda County is aware of the port's significance, both locally and nationally. By taking a broader view of the operations, Alameda County is able to pitch the port improvements as nationally critical, which was the key to their securing two national funding sources. In the application, the county makes it clear that they are uniquely equipped to serve the nation's freight needs and that the federal funding provided will allow them to overcome local challenges for national benefit. Using this framework, Alameda County also included additional components, such as bike paths, to enhance the traditional freight project to support community goals. Additionally, the modularity of the application allowed the county to seek separate funding for each component without fear that the project would collapse absent any given source. Stage A involves ITS upgrades and relocating utilities, which by itself will increase the efficiency of the port. Relocating utilities first also lowers the cost for later phases. Stage B is divided into two construction phases, one for the rail and another for roadway. Again, this division allows individual sections to proceed independent of funding for other sections. This

gives the county flexibility when they are seeking funds and during the construction phase. By re-framing their local goals with a national perspective and subdividing the project into independent parts, Alameda County set itself up for success.

Port of Rotterdam. Port of Rotterdam is the largest port in Europe by tons of cargo freight. Faced with lower-than-predicted growth and heavy competition from nearby ports, Rotterdam has identified ten success factors along with European and Global freight vision. They created two to six goals for each success factor, including increasing throughput and multimodal connections, clustering related activities, reducing bottlenecks, and optimizing schedules [23]. By aligning their measurable goals with their overall vision, the Port is able to improve operations intelligently while preparing to remain competitive during economic downturn. If trade increases, they are set up for increased activity without adversely affecting operations. Or, if trade volumes continue to be below predictions, they have increased efficiency, and will be more able to withstand the economic stress.

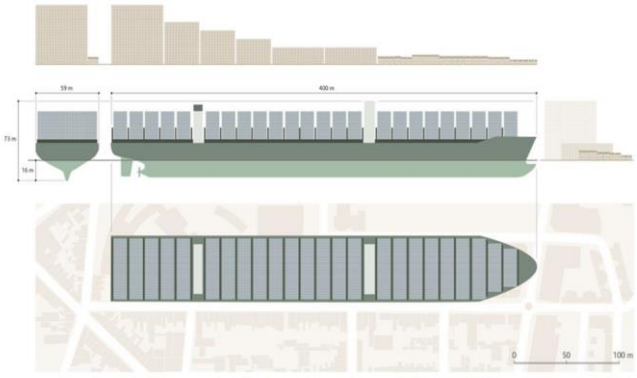

Figure 5: Size of a Mega-Ship Superimposed on a City Block [1]

One way the Port of Rotterdam is achieving its goals is by embracing a synchromodal freight transportation system. The Dutch government has defined "synchromodal" as an agreement between the shipper and service operator on cost, quality, and sustainability level, while leaving the other aspects up to the service provider [29]. This allows the service providers (of shipping services) to take advantage of real-time market efficiencies when choosing routing. Traditionally, when a shipper purchases services, date, time, route, and mode are all incorporated into the agreement. The synchromodal system allows the service provider to dynamically choose the most effective mode and route for the cargo. Zhang and Pel find that for Rotterdam, the total system costs are comparable, but throughput is higher and delivery time is lower. Additionally, they find a 28% reduction in carbon dioxide emissions related to freight movement through the port [29]. Synchromodal planning is an intriguing way to achieve multimodality and carbon emission reductions, though in the United States the correct incentive would be difficult to implement.

Applicability to Texas

As the second busiest port in the country by tonnage [7], the Port of Houston is critical to national economic strength. Additionally, local residents are concerned about the levels of pollution from trucks idling in queues. And, the State of Texas has identified serious bottlenecks in the unloading process at the Port. By adopting lessons learned from the Ports of Oakland and Rotterdam, Houston can spring into the 21st century while maintaining its competitive economic edge, reducing pollution, and eliminating multimodal bottlenecks that affect shippers. The Port of Houston can cluster related activity and implement stronger rail transfers to enable

synchromodal traffic. The Port can look at national and statewide goals when developing their freight improvement plans to help secure funding from multiple sources. And they can implement cutting-edge technologies to allow just-in-time delivery, reducing queues and pollution while increasing throughput. Any one of these strategies by itself would increase Port of Houston's competitive edge, but taken together they can make it a successful economic driver regardless of economic conditions.

CONCLUSION

Freight operations impact every aspect of daily life and are a key driver for economic activity. The industry is advancing quickly, though improvements are often invisible to average citizens. Advances in truck platooning, as seen in Europe, highlight the legal and cultural changes that need to occur before platoons can be deployed at large. However, the benefits from increased safety and reduced fuel consumption are promising. Similarly, connected technology, as demonstrated on I-80 in Wyoming, can increase safety for all road users as long as technical barriers are overcome. Departments of transportation should remain flexible as these connective technologies mature, though there does finally seem to be some consensus in the industry towards DSRC. State legislatures should also remain aware of issues facing truck drivers, as current laws have not kept pace with technology.

In urban environments, cities need to be more proactive about managing freight deliveries and curb space usage. Technology such as parking space monitors deployed in Washington, DC and last-mile delivery drones in Austin, TX are game changers with the potential to reshape the urban environment, but cities will need to be proactive to ensure that they are aligned with equity considerations.

Finally, new technologies at ports and border crossings are enabling more goods to be moved than ever before with fewer negative impacts. Eliminating bottlenecks at modal shifts and accommodating larger container ships means that goods get to people faster than ever before. And lower emissions mean that people who live near these industrial centers are not impacted as severely. As with all new technologies, changes in this space are happening fast. It is important for cities and states to remain aware of the impacts of new technologies in order to reap the most rewards and curb inequitable side effects. Otherwise, Texas may face growing pains as the economy and population continue to grow.

Improving Freight Operations in Texas

White Paper

Operational and Policy Recommendations

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Materials from the June 13, 2018 meeting of the TTTF

1. Agenda
2. Meeting Notes
3. PowerPoints:
    - TTTF Overview, Update, and Agenda
    - Small Cell Telecommunications in State Rights of Way (Beverly West, TxDOT)
    - Proterra – Leading the Way to the Electrification of Transit (Dale Hill, Proterra)
    - The Standards-Driven Path to 5G (Jim Misener, Qualcomm)
    - Resilient Grid: Electric Vehicle-Grid Integration (Michael Legatt, Resilient Grid)

TEXAS DEPARTMENT OF TRANSPORTATION

TEXAS TECHNOLOGY TASK FORCE

Agenda
TxDOT Greer Building | 125 E 11th St. | Austin, TX
June 13, 2018

Objectives:

1) Identify approaches and programs to support vehicle electrification and charging infrastructure investment
2) Develop a framework for coordinated automated vehicle testing in collaboration with other state agencies
3) Identify infrastructure investments and programs to enable telecommunications rollout in support of connected transportation

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9:00 AM | Welcome & Opening Remarks – *Darran Anderson, TxDOT & C. Michael Walton, UT Austin*

9:15 AM | Progress Update – *Kristie Chin & Andrea Gold, UT Austin*

9:30 AM | Panel Presentations: Electrification

Moderator: *Michael Webber, Deputy Director of the Energy Institute at The University of Texas at Austin*
While electric vehicle sales have been slowly but steadily climbing over the past decade, recent investments decisions from automotive manufacturers indicate a major shift in market share in the next 5 to 10 years. Advances in battery technology, reduced costs, and regulations serve as primary influences of these decisions; however, charging infrastructure could pose a challenge to quicker market adoption. This sessions will explore the future of electric vehicles by examining market projections, performance considerations for heavy duty vehicles, charging infrastructure, alternative energy sources, as well as regulations and policies.

David Raney, GM of Corporate Strategy and Planning, *Toyota Motor North America*
Michael E. Legatt, Chief Executive Officer & Founder, *Resilient Grid*
Dale Hill, Founder, *Proterra*
David Schatz, Director of Public Policy, *ChargePoint*
Michael Quinn, VP & CTO for Strategy, *Oncor Electric*

10:30 AM | Open Discussion: A Path Forward in Electrification

Moderator: *Michael Webber, Deputy Director of the Energy Institute at The University of Texas at Austin*

11:00 AM | Break

11:15 AM | Roundtable: Statewide Connected and Automated Vehicle Framework

Moderator: *Michael Morris, Director of Transportation, NCTCOG*
Representatives from public agencies and industry join the Task Force and TxDOT in a discussion on a coordinated approach to creating a strong Texas market for the deployment of emerging and advanced technologies. Prospective attendees include representatives from the Governor's office, key legislators, and the business and entrepreneurial community.

Chris Nordloh, Major, *Texas Department of Public Safety*
Caroline Love, Government & Strategic Communications Director, *Texas Department of Motor Vehicles*
Brian Moen, Assistant Director of Transportation, *City of Frisco, Texas*

12:30 PM | Lunch

Presentation: Artificial Intelligence for Smart Transportation
TBD*, NVIDIA*

1:30 PM |Panel Presentations: The Path to a V2X Ecosystem

Moderator*: Steve Dellenback, Vice President, ITS Division, Southwest Research Institute*

V2X, or vehicles-to-everything, is an encompassing term for a vehicle's communication system, where information from sensors and other sources travels via high-bandwidth, low-latency, high-reliability links, paving the way to fully connected transportation ecosystem. There are several components of V2X, including vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P), and vehicle-to-network (V2N) communications. In this multifaceted ecosystem, cars will talk to other one another, to infrastructure such as traffic lights or parking spaces, to pedestrians via smartphones, and to data centers. But there is still much uncertainty and debate about which standards and communication technology will underpin all this V2X communication. This session will aim to address a number of these debates and identify strategies for TxDOT to prepare its system while the technology continues to develop in the market. Topics for discussion include comparison of DSRC versus 5G telecommunications; right-of-way and data access; cybersecurity; infrastructure readiness and required supplemental digital infrastructure such as fiber backhaul; applications for safety, mobility, environment; and regulatory considerations.

Salam Akoum, Principal Member of Technical Staff, *AT&T*
Jim Misener, Senior Director, Technical Standards**,** *Qualcomm*
Sue Bai, Principal Engineer, ATR Division, *Honda R&D Americas, Inc.*
Roger Berg, VP North America Research and Development, *DENSO International America, Inc.*
Beverly West, Alternative Strategies Manager - Real Estate Management and Development*, TxDOT*

2:30 PM | Open Discussion: A Path Forward in a V2X Ecosystem

Moderator*: Steve Dellenback, Vice President, ITS Division, Southwest Research Institute*

3:30 PM | Closing remarks and Next Steps - *Darran Anderson, TxDOT & C. Michael Walton, UT Austin*

4:00 PM | Adjourn

Meeting Notes
TxDOT Greer Building | 125 E 11th St. | Austin, TX
June 13, 2018

Participants: See Attachment
Objectives: 1) Engage public and private stakeholders in critical discussions on advancing model deployments
2) Make recommendations for developing a cohesive freight and logistics innovation strategy for Texas
3) Make recommendations on structuring and funding a collaborative Proving Grounds Partnership Program

9:00 AM | Welcome, Opening Remarks, & Progress Update – *Darran Anderson, TxDOT & Dr. Walton, UT Austin*

- Darran Anderson from TxDOT and Dr. Walton from UT Austin kicked off the meeting by welcoming participants and asking for introductions. Darran highlighted the need to identify short-term questions that set up the long-range planning done by the Task Force and the partners in the room from other state agencies.
- Kristie Chin gave an overview of Task Force activities to date and brought up the importance of keeping the momentum going on technology discovery and stakeholder collaboration.
- Andrea Gold highlighted upcoming work from the Task Force, including three white papers on Freight & Logistics, Transportation Energy, Emissions, and the Environment, and Artificial Intelligence in transportation and public administration.

9:30 AM | Panel Presentations: Vehicle Electrification and Charging Infrastructure

- Dr. Michael Webber moderated a panel regarding vehicle electrification, air quality, and charging infrastructure. Electric vehicle adoption is increasing worldwide as demand for electric buses grows in China and the EU becomes more concerned about pollutants and noise in cities. Automobile manufacturers are also making more investments in battery electric vehicles and alternative fuels.
- Toyota has moved its headquarters to Texas and has been researching and manufacturing batteries for about 35 years. Toyota is now committed to hydrogen battery technologies. The technology exists but distribution is currently a challenge. As an example, Toyota has deployed a drayage vehicle at Long Beach that is in service with a 240-mile operating range.
- Panelist noted that there is currently a temporal mismatch in electricity demand and production, exacerbated by lessened control that operators have over peak generation from renewables like wind and solar. However, electric vehicles can improve grid operations by charging interactively. Switching the source of emissions from tailpipe to smokestack can bring 80% emissions reductions due to economies of scale and stricter regulation.
- Panelists spoke to concerns about internal combustion engine vehicle emissions and their impacts on public health. A case study revealed impacts that ultrafine particulates have on children's learning and developments. Air quality experts are hopeful that increased electric vehicle adoption could mitigate these effects.
- Battery electric buses are becoming a more popular choice for cities as they reach cost parity with diesel. One revenue model is to sell the bus at the same price as a diesel bus, then lease the battery for 12 years. This helps keep capital expenditures down and still provides cost savings in operating expenditures. Los Angeles, New York City, San Francisco, Seattle, Reno, and Canada have all committed to using 100% battery electric buses in their fleets. This implies that operational characteristics related to performance the drive train, power, and range have been addressed.
- There is a large and growing network of smart chargers for consumers to use with their electric vehicles. A revenue model in this space is to sell the hardware, then provide a subscription-based data analysis service. Consumers should be able to charge when and where it is convenient for them (when they are parked), which is slightly different from the gas station model. Consumer electric vehicles have been growing 34% year-over-year, and Texas is the 5th largest market in the nation. Texas is receiving money from the Volkswagen settlement, 15% of which could be used

towards charging infrastructure. Ramping up city and state fleets, clarifying regulations, and installing charging infrastructure in new developments are areas for improvemnet in Texas.

- Oncor Electric strives to be a trusted advisor to consumers, making information about charging and purchasing electric vehicles accessible. Oncor is converting its fleet to battery electric vehicles (BEVs) and estimate that a 150-mile range covers 92% of drivers' daily needs. Expected benefits to the state include cost savings, improved air quality and health outcomes, regaining attainment status, and economic development.

10:30 AM | Open Discussion: A Path Forward in Electrification

- Discussion shifted to CO_2 emissions and resilience. If done properly, BEVs can improve grid resilience; otherwise they will make it worse by increasing demand when the supply chain is broken due to disruption. Resilience comes with scale in cases such as when larger vehicle batteries can supply electricity back to the grid when it is offline in emergency scenarios. Storage of hydrogen and electrolysis of water can also have positive impacts on resiliency by providing additional means of backup power.
- Charging buses overnight to absorb excess wind power could be good for the grid and fleet operators. On average, electricity costs 11¢/kWh, but those costs drop to 2-4¢/kWh during the night due to low demand.
- Transportation resilience may also be bolstered by EVs: during and after hurricanes there is often no gas or electricity, but solar power can be used to charge EVs or electric buses may be used to power the grid. All ChargePoint stations in Houston and Florida survived hurricanes even after being inundated by up to three feet of water.
- The construction industry and building codes do not currently support electric vehicles adoption. Getting homes fitted for EV charging is much more expensive than a 240V or hydrogen dryer hookup, despite the same equipment behind each application. Large commercial developers in Dallas are only putting in 2-3 EV charging stations for every 500 parking spaces but putting the wiring in place from the outset would be much cheaper than after construction.
- Texas is a great market for hydrogen electric because it generates a lot of wind energy, which can be used for electrolysis to produce hydrogen. Texas also has the largest surplus of hydrogen in the US, along with significant pipelines to transport hydrogen and relevant industry experience. Traditional energy partners in the oil and gas industry are not necessarily opposed to the adoption of electric vehicles, since they see emerging markets that they can serve.
- A third party could lease land from TxDOT along the interstate and install solar EV chargers; both TxDOT and industry are open to this but neither wants to bear all the risk.
- Last-mile freight and package deliveries have the right fleet patterns for EVs; UPS is deploying 50 in Dallas.
- To address cybersecurity efforts to protect charging infrastructure, collecting Personally Identifiable Information (PII) is not required to analyze usage patterns of EV's, so it is not done.
- Given the demographics of typical first adopters, there may be equity concerns around the deployment of EVs. However, second-hand EVs are typically inexpensive and still serve most of a consumer's daily needs. This allows low-income consumers to purchase EVs and enjoy the benefits. In addition, transit vehicles typically traverse neighborhoods with equity concerns. Converting these to EVs will reduce pollution. Seeing charging stations on a map may drive economic activity to those locations.

11:00 AM | Break

11:15 AM | Roundtable: Statewide Connected and Automated Vehicle (CAV) Framework

- Michael Morris moderated a panel on a statewide connected and automated vehicle framework. Technological advances are being made today that affect nearly every aspect of our transportation system. Texas could benefit from coordinated testing, piloting, and shared learning to safely integrate these advances.
- The Department of Public Safety has a fairly straightforward mandate to enforce SB 2205 (the Texas legislation allowing for AV testing). DPS core functions are assisted by automated technologies. They are developing a "Fusion Center" to bring together several data streams and share critical information back out to the field. At weigh stations, technology like weigh-in-motion and thermal imaging acts as a force multiplier.
- The Texas Department of Motor Vehicles not have a specific mandate regarding CAVs but does release an annual report revealing the proportions of each type of vehicle on the road. Automated vehicles are more difficult to

identify, since that information is not encoded in the vehicle identification number (VIN). The Department of Motor Vehicles (DMV) appreciates notification from industry before testing begins though SB2205 does not mandate it.

- The City of Frisco is already sharing signal data via a Dedicated Short-Range Communication (DSRC) pilot and will begin an autonomed vehicle pilot with Drive.AI next month. The pilot is set up as a public-private partnership with Denton County Transportation Authority (DCTA), Frisco, and developers using a Memorandum of Understanding (MOU) and will take people from an office park to a nearby retail center.
- Current law encourages AV deployments, but without reporting requirements it is difficult to assess how well they are working. Industry has been cooperative so far, but they may not be in the future. Boston has implemented mandatory reporting; can this be used as a model for Texas?
- Other states have siloed agencies, or are not interested in cooperation to the same degree. It is important that Texas balance their reporting requirements to extract useful information without turning industry away.
- There are political, policy, and economic risks to CAV deployments. In the short-term, it may be better for cities to assume deployment risks because they can move quickly and keep the attention of industry. Longer term, as lessons coalesce, those risks can shift to a state level.
- The Texas Legislature showed statewide leadership by passing SB2205 and signaling to industry that Texas is open for business. The Task Force in collaboration with the Texas Innovation Alliance (TIA) is exploring processes to facilitate the demonstration and testing of CAVs.
- TX Representative Celia Israel stated that legislative action to require reporting would respect existing projects. The legislature wants to know who is planning projects and who is executing them. They may be more likely to respond to needs of projects that are underway than projects that have not started.
- Small agencies face different barriers than larger ones, specifically around Federal Communications Commission (FCC) licensing for DSRC and security key management. However, they can move faster with industry because they are typically implementing with respect to an immediate community need rather than in the context of long-range planning. TxDOT has a knowledge base and is able to assist cities that are having trouble in these areas.
- TxDOT could develop an Assisted Intelligence knowledge base to help with deployments. This aligns well with what the Texas Innovation Alliance is already doing.
- Two important questions arose: 1) How do we create a market for industry? And 2) How do cities pilot new technologies? Texas has uniquely unselfish cities that want other areas in Texas to succeed. The state can leverage that state spirit to share successes. AASHTO also has best practices for 5-10 year planning, including well-known use cases with research and more pilot-based use cases. TIA could contribute to this resource.

12:30 PM | Lunch

1:30 PM | Panel Presentations: The Path to a V2X Ecosystem

- Steve Dellenback moderated a panel on the path to a Vehicle-to-Everything (V2X) Ecosystem. These technologies are becoming increasingly prevalent as automobile manufacturers make investments in DSRC and 5G telecommunications for transportation applications. Toyota announced that all vehicles will have connectivity by 2021, and GM plans to offer V2X by 2023.
- 5G Cellular standards bring more network capacity and reliability for more devices. 5G devices can operate in mesh, or peer-to-peer (P2P) mode, as well as a traditional tower-device model, and in “licensed” and “unlicensed” bands. (The FCC reserves a portion of the wireless spectrum for LTE carriers, the “licensed band,” that corresponds with international norms and allows phones to work in the US and Europe. There is another part of the spectrum that the FCC has designated as “unlicensed,” which anyone can use. WiFi, microwaves, and wireless landlines all operate in this band.)
- LTE is evolving in parallel to 5G development. 5G enables, but does not require, device-to-device communications without a network operator, as requested by public safety officials after 9/11. C-V2X is the peer-to-peer implementation of 5G, which is competing with DSRC for space in the wireless spectrum. Public-private partnerships may be a good business model for roadside units (RSUs) in order to achieve the desired network density. At least two companies are already selling units that can operate in DSRC or 5G mode.

- Cooperative and connected vehicle communication has been proven with DSRC in Japan, where the standard is slightly different. Toyota has 100,000 DSRC vehicles on the road in Japan, but consumer wants may be outgrowing the capabilities of DSRC. These applications may be able to coexist.
- TxDOT is leasing Right-of-Way (ROW) for small cell (DSRC and 5G) deployments, but safety and project delivery are paramount. Partners can lease land or space on a pole during Phase 1. TxDOT is using SB1004 as a guideline for rules to keep the process consistent for industry, but also has their own statutes regarding what can be done with ROW. Even so, they have adopted the definitions, timelines, and fees from SB1004. TxDOT has a master lease agreement with the major telecommunications companies and have four approved permits that are expected to begin active testing in September. Communication with partners' subcontractors has been an unexpected barrier.
- The Society of Automotive Engineers (SAE) DSRC committee is over ten years old. They have seven subcommittees covering everything from toll collection to Vehicle-to-Human interaction. The Vehicle-to-Vehicle (V2V) standard is published but still waiting for the federal government to officially adopt. DSRC is highly developed and specific, but industry has not decisively moved in this direction yet. The committee is still learning from Japanese deployments and trying to match their success.

2:30 PM | Open Discussion: A Path Forward in a V2X Ecosystem

- C-V2X, DSRC, and WiFi all want to coexist in the same spectral band. DSRC has legal priority, but there are cases pending in court that may impact that standing. It would be difficult for these technologies to coexist in the same spectrum band. The US could follow Europe and subdivide the spectrum, but there may be safety and cost impacts from yielding this area to other applications. Different places within the US could establish different standards, but this may cause confusion for consumers.
- When considering how to build connected infrastructure, DOTs should plan for backhaul. Ohio has recently done this along US Route 33, and it allows them to be agnostic to 5G or DSRC technologies. There are roughly 300,000 signalized intersections in the US; outfitting each one with connective technology would be cost prohibitive. Focusing on data transmission allows for flexibility going forward.
- DSRC does not have recurring fees for end users, but 5G might depending on the application. 5G can operate without a SIM card for P2P connections, but would require a subscription for network access. Ford has committed to installing 5G radios for P2P communication in its vehicles. Both technologies would have operating expenses and maintenance costs. Remote driving and other non-safety applications that are enabled by 5G require more network resources and are likely to cost more. The cellular network will be installed and maintained by existing network providers, while DSRC backhaul would have to be maintained by the operator of the technology.
- Security mechanisms and costs are still somewhat of an open question. DSRC has certificate rotation that needs to be "refilled", which would cost. USDOT is funding pilots for implementations of this technique. 5G security and payment models are still being worked out.
- When cities deploy DSRC, they could own that data, but the data ownership, cost, and privacy implications are less clear in a 5G deployment. DSRC does not contain any PII, and anyone can "sniff" that traffic-this is how traffic studies could be done with the technology. One city's deployment may be better than another's in terms of maintenance and level of service, just like roads. Make sure the implementations are independently certified.
- Some areas are tired of waiting for DSRC and 5G to mature. They want to deploy now to save lives, even if the technology changes in the future. Business plans and data ownership are less important than saving lives, plus there could be benefits from redundant technology. What is reasonable to expect from industry regarding data ownership, locations, and technology, given that we could be saving lives right now? The point was made that every day we delay in providing connected vehicle safety benefits, it costs lives.
- Public agencies should focus on "Technology-to-Everything" (T2X) because the technology will continue to change. Meanwhile, they can scan available technology, uplift use cases, and learn by doing. 3rd parties may disrupt the entire sector so it would be wise to remain relatively technology-agnostic.
- There is an unpublished report regarding a proposed rule amendment for FCC licensing of DSRC. There may be security impacts or interference potential from allowing WiFi to occupy the same spectrum as DSRC.
- Backhaul technology is still significant regardless of the radio technology used. Fiber and 5G-enabled wireless backhaul are the two main technologies. 5G is newer, but potentially more flexible and installing it can unlock other

benefits of dense, small cells. Edge computing can reduce the amount of data that needs to be transmitted back to a central location, saving money. Focus on what the use case is: safety and security have different needs than ten-year planning.

- Texas has a statewide license for Signal Phasing and Timing (SPaT) /DSRC, but a second-layer license is required from the FCC to ensure the deployment will not cause interference. TxDOT has the resources to help cities with these deployments. Cities can leverage connectivity to deliver customized messages to citizens regarding weather, work zones, and crashes.
- TxDOT should be very specific about what it wants to learn regarding ongoing small cell deployments. This information could be shared nationally. Diversity in rural and urban use cases are an advantage to Texas. DPS is deploying a technology pilot on the interstate in Seguin, and TxDOT could run a small cell deployment there as well to maximize benefits for both agencies.
- Suggestions for the most immediate TxDOT use cases include intersections, pedestrian detection, red-light countdown, real-time travel information, emergency preemption, Transit Signal Priority, clustering traffic, high-collision areas, V2I, and safety. Start simple and get more complex: "If you don't start, you can't improve."

3:30 PM | Next Steps & Closing Remarks – *Darran Anderson, TxDOT & Dr. Walton, UT Austin*

- In conclusion, Darran Anderson highlighted the concept of a Fusion Center, Assisted Intelligence, more Artificial Intelligence, and focusing on the challenges like the TIA is doing. TxDOT is working on their budget for the upcoming biennium, and has included a technology strategy in their 2040 (long-range) plan for the first time.
- Dr. Walton encouraged the Task Force to continue to keep up with what other states and AASHTO are doing, and to share out information learned. He thanked the UT team, STR and RTI at TxDOT, Task Force Members, and TxDOT leadership.

4:30 PM | Adjourn

TEXAS TECHNOLOGY TASK FORCE

The Future of Transportation

Overview

Overview

Update

Agenda

HOW TO START A MOVEMENT


MOMENTUM
BEGETS
MOMENTUM

MOMENTUM BEGETS MOMENTUM

Overview

Overview

Update

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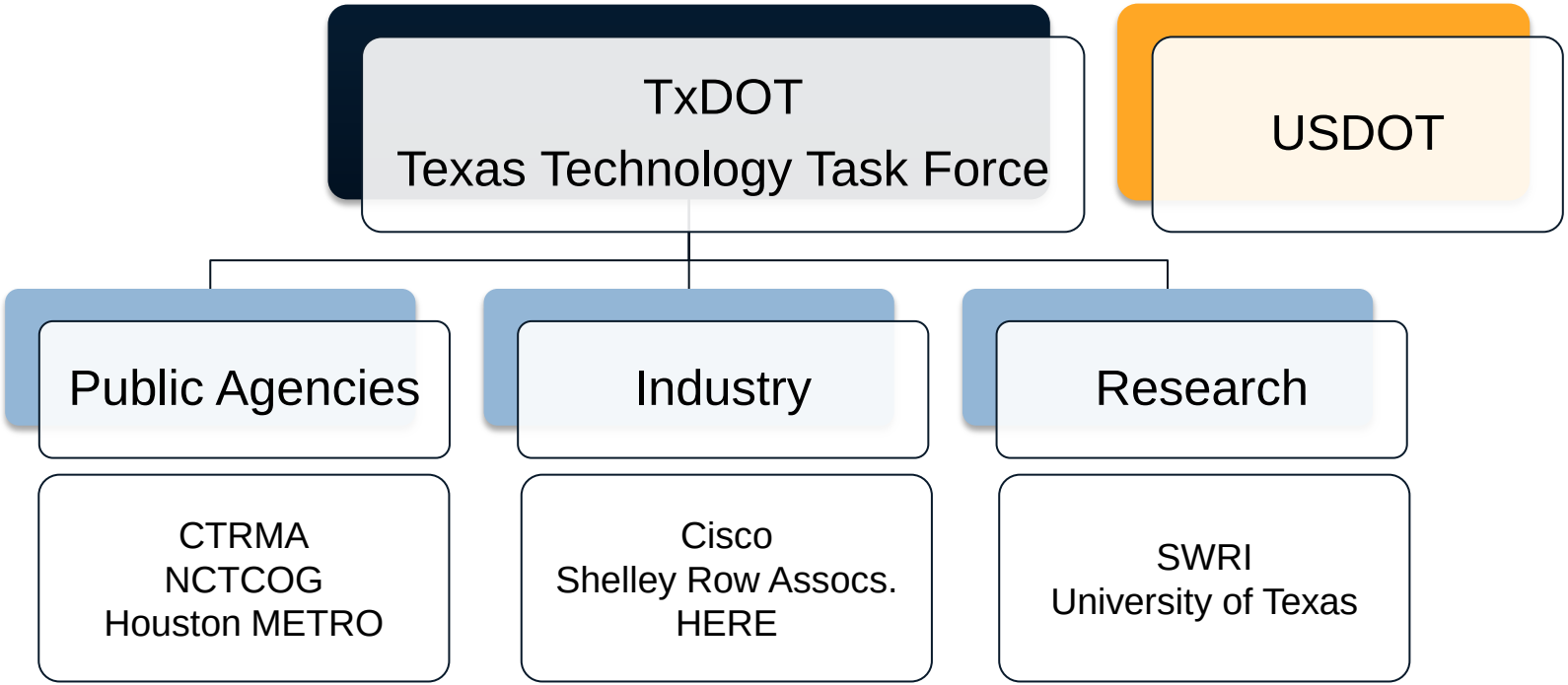
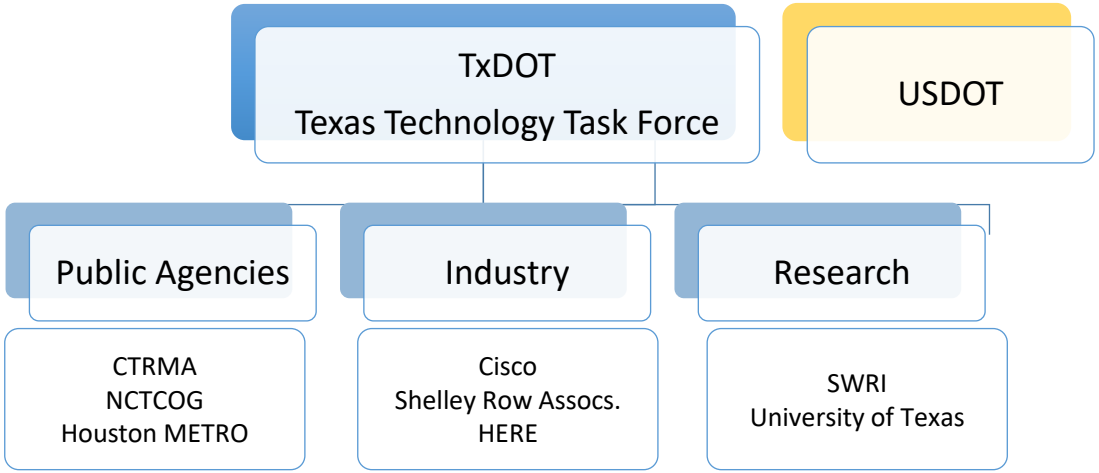
Overview: PEOPLE – Portfolio – Plan

Task Force Membership



PEOPLE – Portfolio – Plan

Task Force Membership



Subject Matter Experts

Verizon INRIX DFW Airport GM - Maven
Xerox Port of Houston Toyota UPS Walmart

Past Meeting Attendees

Industry and Research

30+

Public Agencies

17+

Legislation and Elected Officials

4

TxDOT Divisions

Texas Department of Transportation

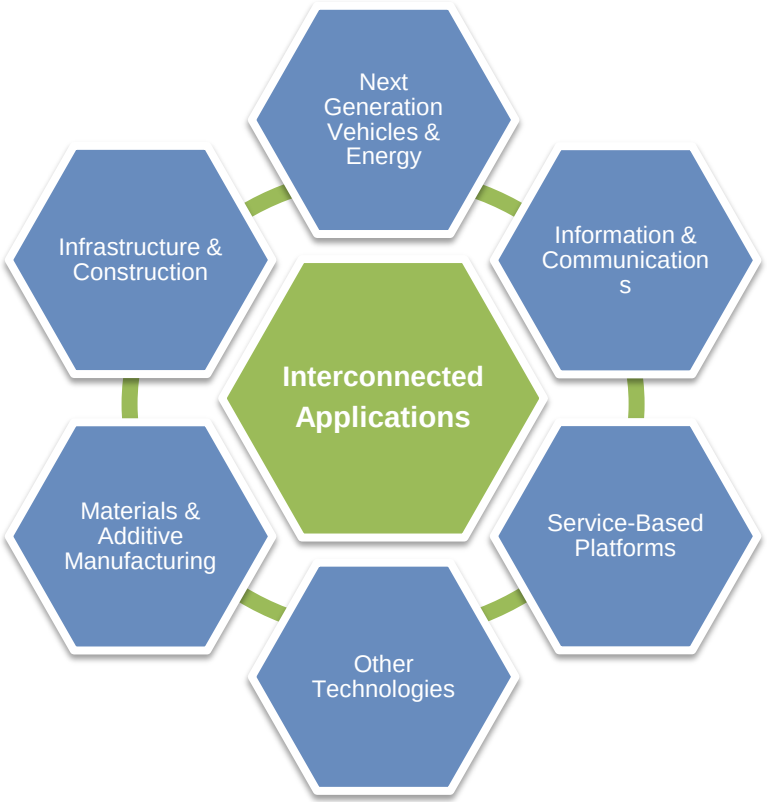
15+

People – PORTFOLIO – Plan

Next Generation Vehicles & Energy
Automated Vehicles
Connected Vehicles
Electric Vehicles
Unmanned Aerial Vehicles

Infrastructure & Construction
Infrastructure Enhancements
Construction Techniques
Equipment

Materials & Additive Manufacturing
Self-Healing Pavements
Nanotechnologies
3D Printing

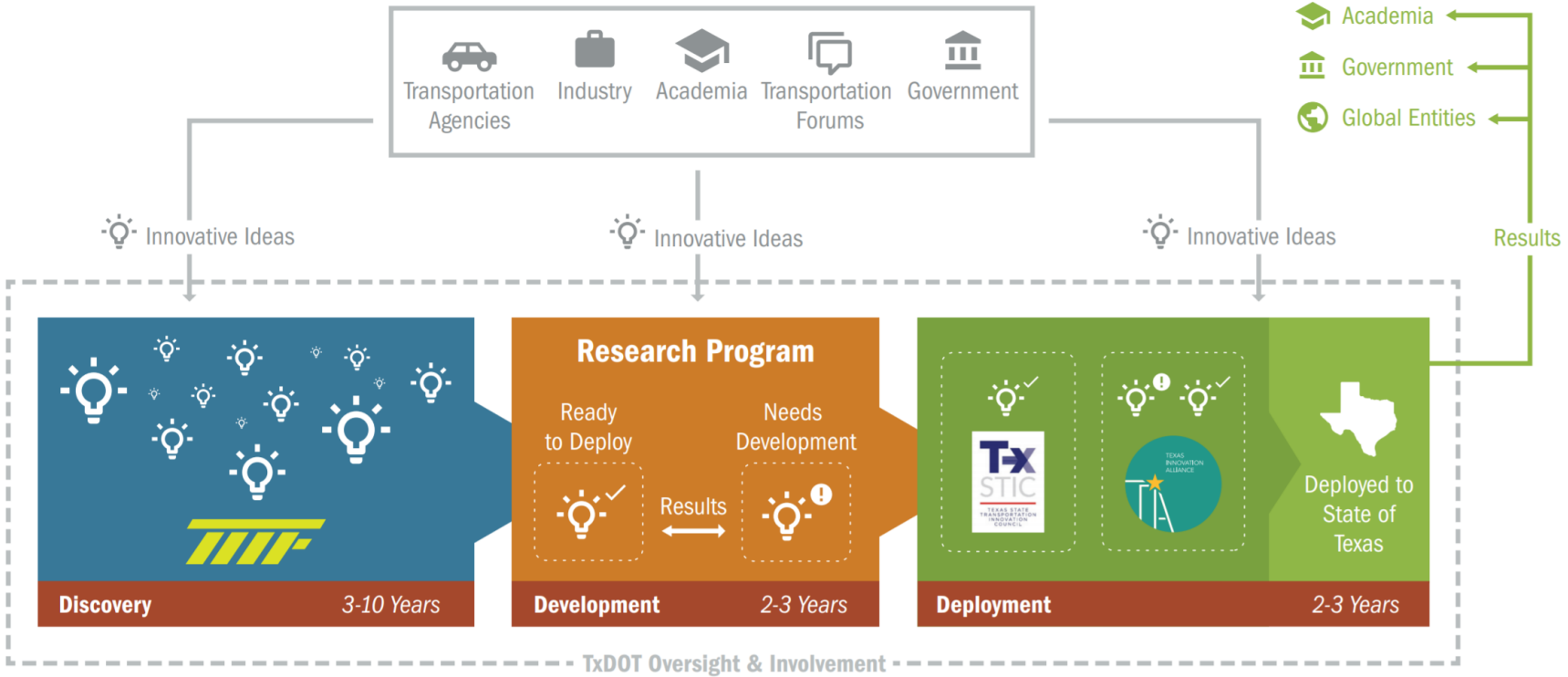


Information & Communications
Cloud Computing
Crowdsourcing
Blockchain
Big Data & Open Data
Cybersecurity
RFID

Service-Based Platforms
Location-Based Services
Transportation Subscription Services

Other Technologies
Robotics
Virtual/Augmented Reality
Hyperloop

People – Portfolio – PLAN



Overview

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Activities

- White Papers
- Technology Primers
- Strategic Plans
- Communications
- Key Conferences & Presentations
  - STIC
  - Smart Cities Connect
  - ITSAmerica

Overview

Overview

Update

Agenda

Today's Objectives

1. Identify approaches and programs to support vehicle electrification and charging infrastructure investment
2. Develop a framework for coordinated automated vehicle testing in collaboration with other state agencies
3. Identify infrastructure investments and programs to enable telecommunications rollout in support of connected transportation

Today's Agenda

9:00 AM | Welcome & Opening Remarks

9:15 AM | Progress Update

9:30 AM | Panel: Electric Vehicles and Charging Infrastructure

10:30 AM | Open Discussion: A Path Forward in Electrification

11:15 AM | Roundtable: Statewide Connected and Automated Vehicle Framework

12:30 PM | Lunch & Presentation on Artificial Intelligence for Smart Transportation

1:30 PM | Panel Presentations: The Path to a V2X Ecosystem

2:30 PM | Open Discussion: A Path Forward in a V2X Ecosystem

4:00 PM | Next Steps & Closing Remarks

4:30 PM | Adjourn

TEXAS DEPARTMENT OF TRANSPORTATION






SMALL CELL TELECOMMUNICATIONS IN STATE RIGHTS OF WAY

Texas Technology Taskforce

June 13, 2018

TxDOT's Goals for Right-of-Way Access

- TxDOT's primary goals in management of right-of-way assets are:
  - **Safety**: maintaining an appropriate and uncongested clear zone;
  - **Expeditious delivery of transportation projects:** ensuring occupying entities do not cause delays or incur costs to future projects; and
  - **Stewardship of public resources:** ensuring TxDOT receives the appropriate compensation for the use of taxpayer resources as required by law.

Senate Bill 1004 (85R, 2017)

- Senate Bill (SB) 1004, created a uniform framework to allow wireless network companies to place network nodes (small cell facilities) within the municipally owned public right of way (Chapter 284, Tex. Local Govt. Code).

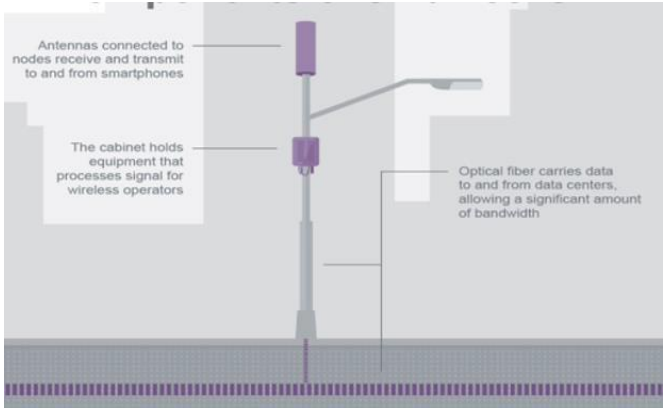
- SB 1004 does not apply to state (TxDOT) right of way.

- Sec. 202.052, Tex. Transportation Code, grants TxDOT exclusive authority over its rights of way and allows TxDOT to incorporate and apply many key components of SB 1004 to TxDOT's right of way.

Deployment in TxDOT Right of Way

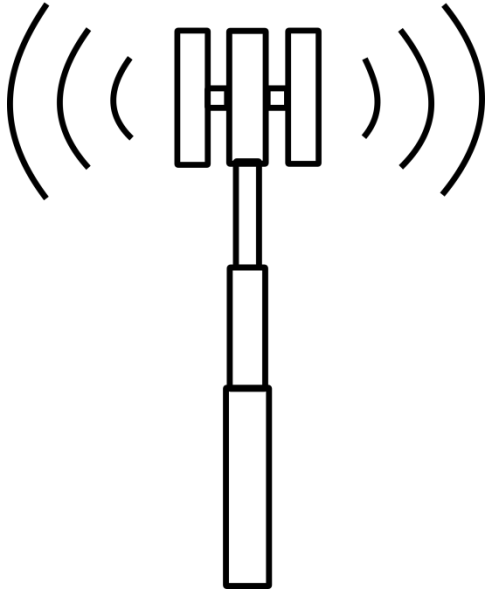
- TxDOT has taken a proactive approach to apply the framework of SB 1004 to TxDOT's rights of way and ensure the efficient and consistent deployment of small cell telecommunications infrastructure across the state.

- TxDOT is incorporating the framework provided by SB 1004 to:
  - adopt definitions and terms where applicable to ensure consistency with Local Government Code, Chapter 284;
  - ensure similar application and use process, including the application, submittal and initial review for application and final approval or denial of right-of-way access;
  - provide a fee structure; and
  - allow customer interaction throughout the review process.



TxDOT Partnership with the Telecommunications Industry

- TxDOT hosted a “Kickoff Workshop” in June 2017 and additional workshops in July, October, November and December 2017 and January 2018.
- Discussion topics were industry specific business models, equipment and siting requirements, fees, preferred time lines for processing and types of agreements.
- Confirmed that TxDOT Utility Accommodation Guidelines (UAG) will accommodate industry equipment and siting criteria.
- Configured the Utility Information Request (UIR) System to intake small cell lease applications.
  - Phase I - attachment to existing poles or new poles in the right of way
  - Phase II – consideration of attachment to TxDOT structures
- Establishment of Pilot Program in the Houston District for Phase I



Pilot Deployment in Houston District

Snapshot on June 11, 2018						
Site Application Submissions	**Awaiting Initial Review**	**Additional Information Needed From Applicant**	**TxDOT Field Review**	**Reviewed by FHWA (if applicable)**	**Approved**	**Average Processing Time (days)**
81	0	35	42	0	4	TBD

Pilot: March 2018

- Executed Master Lease Agreements (MLA)
  - March: Mobilitie, Crown Castle
  - April: AT&T, Verizon, Zayo
- Application intake for Individual Site Agreement (ISA) utilizing the UIR system
- Small cell layer on TxDOT Real Property Asset Map designating approved site agreements

NEXT STEPS

- Analyze pilot metrics
  - Procedures
  - Timelines
  - Staff requirements
- Industry roundtable June 18, 2018
  - Continued revision as needed
- Phased State-wide deployment

Questions?

Beverly.West@txdot.gov
512-486-5884

PROTERRA – LEADING THE WAY to the *ELECTRIFICATION OF TRANSIT*

Presentation to

TEXAS TECHNOLOGY TASK FORCE

June 13, 2018

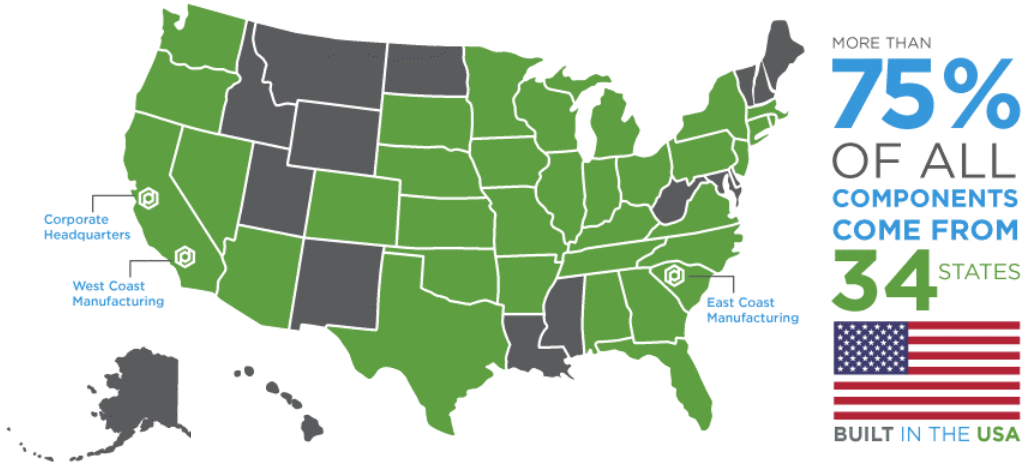
PROTERRA

PROTERRA

Proterra's Mission

Advancing electric vehicle technology to deliver the world's best-performing heavy-duty vehicles

- Offices and manufacturing in CA and SC
- 400+ employees, with strong transportation expertise
- >69 customers; >600 vehicles sold
- >200 vehicles delivered; >5,000,000 service miles
- >31,000,000 pounds of CO_2 emissions avoided



Strong Transportation Expertise

TESLA · GM · BMW · FREIGHTLINER · DENSO · NISSAN · ROUSHYATES · MICHELIN · TOYOTA · CHRYSLER · VW

World-Class Financial Partners

GM VENTURES · BMW i · EDISON INTERNATIONAL · Constellation. An Exelon Company · KPCB

HIGH-QUALITY, ADVANCED MANUFACTURING FOR RAPID EV ADOPTION AT SCALE

PROTERRA

Burlingame, California

Battery Manufacturing

Company HQ

Los Angeles, California

Bus Manufacturing

West Coast Operation

Greenville, South Carolina

Bus Manufacturing

East Coast Operation

OUR VISION: CLEAN QUIET TRANSPORTATION FOR ALL

Economics
Best TCO, lowest operating costs, least volatility

Performance
Highest MPGe, lowest weight, most torque

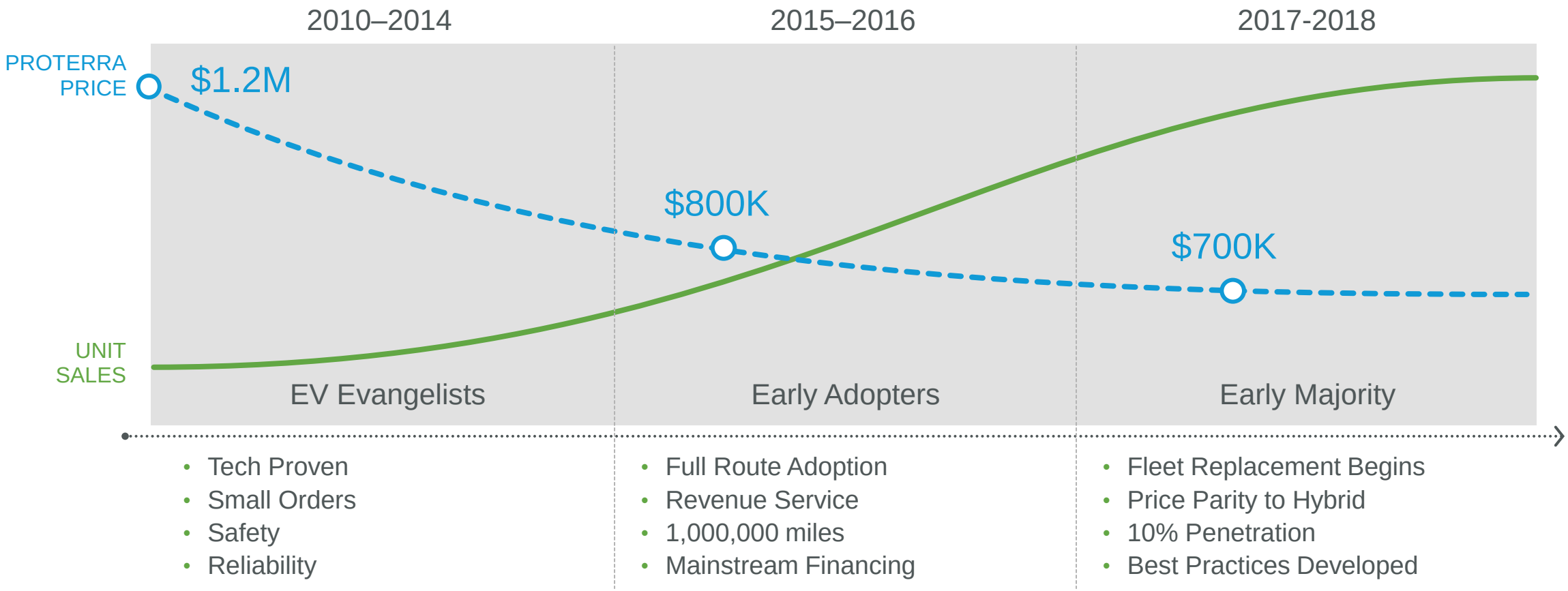
Customer Preferences
Clean, quiet, safe, modern

Policy/Regulation
Local health, air quality, climate change

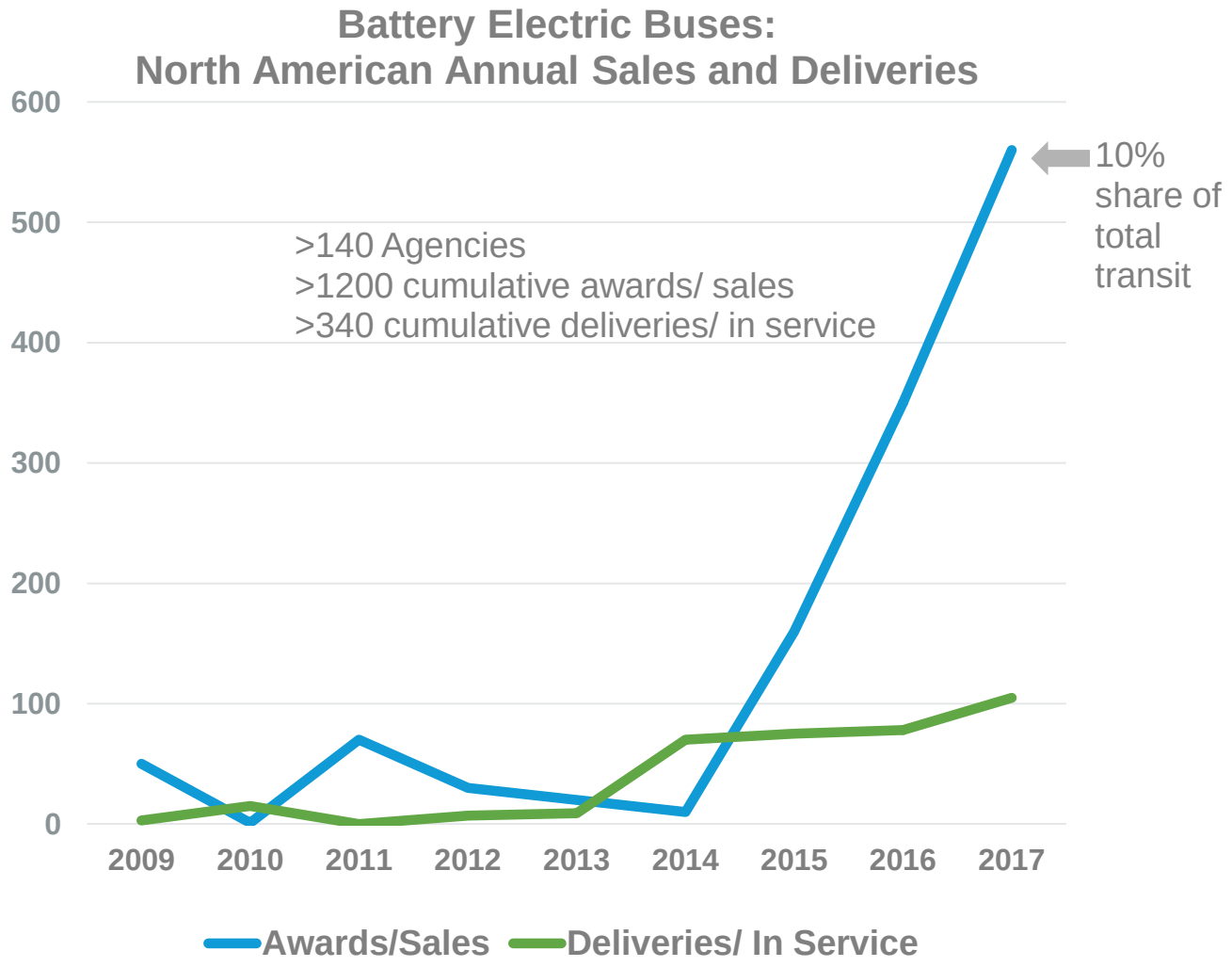
At Proterra, we believe that zero-emission electric vehicles are the smart choice for heavy-duty transit operations.

We hope you'll agree. Together, we can eliminate the need for fossil fuels in transit.

THE TRANSIT MARKET IS RAPIDLY SHIFTING TO EV



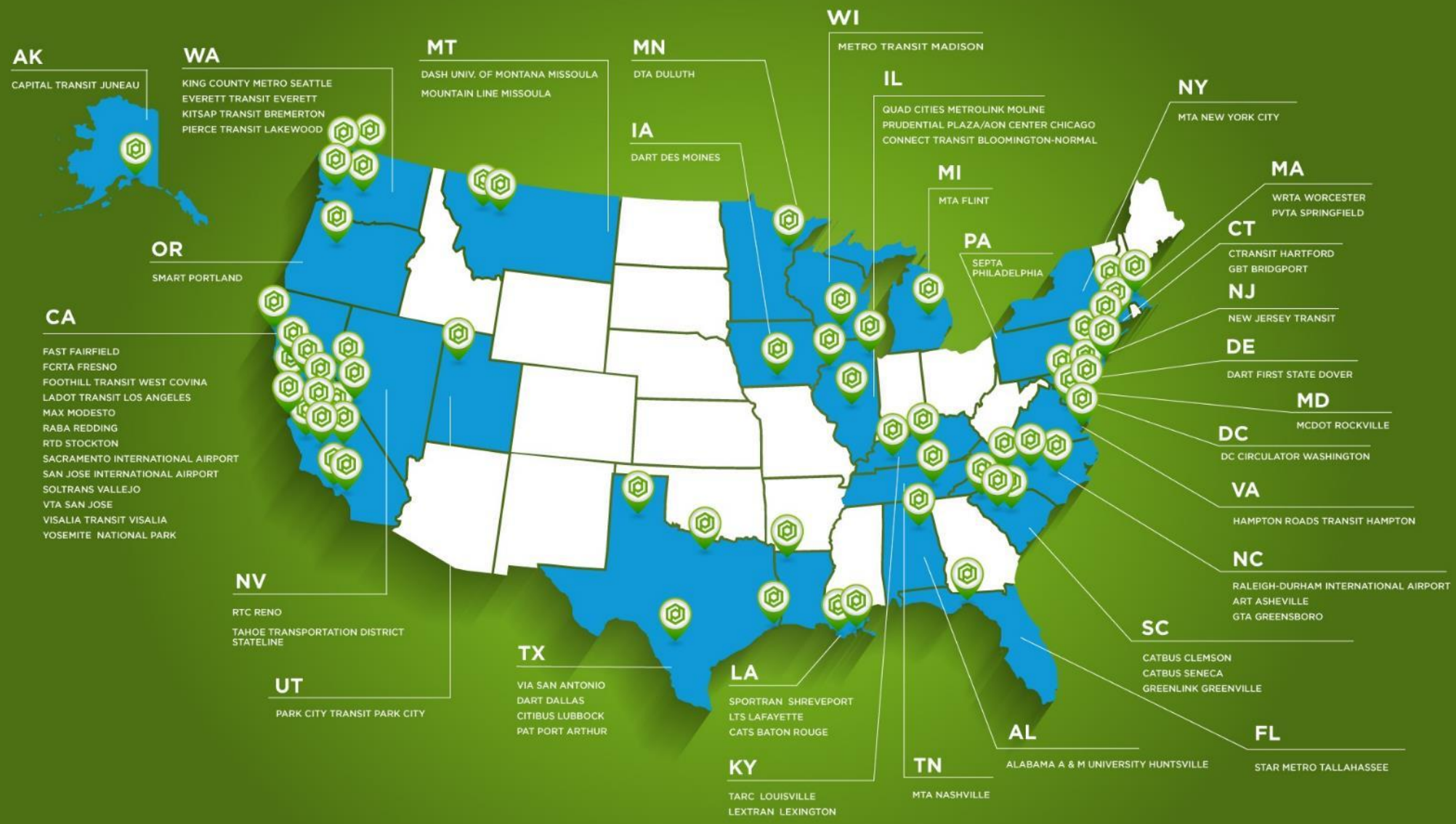
THE TRANSIT MARKET IS RAPIDLY SHIFTING TO EV



Source: CTE Center for Transportation and the Environment

- Moving toward **widespread industry adoption**
- **Purchase barriers eliminated** due to:
  - Improved range
  - Charging standardization
  - Sharp decline in battery costs
  - Service-proven performance

OUR CUSTOMERS



546 buses
sold to
67 customers
across
30 states

Additional
118 orders
not yet announced

OUR CUSTOMERS

PROTERRA

MAJOR CITIES ALREADY COMMITTED TO CONVERTING BUS FLEETS TO 100% BATTERY ELECTRIC OVER THE NEXT 12 YEARS

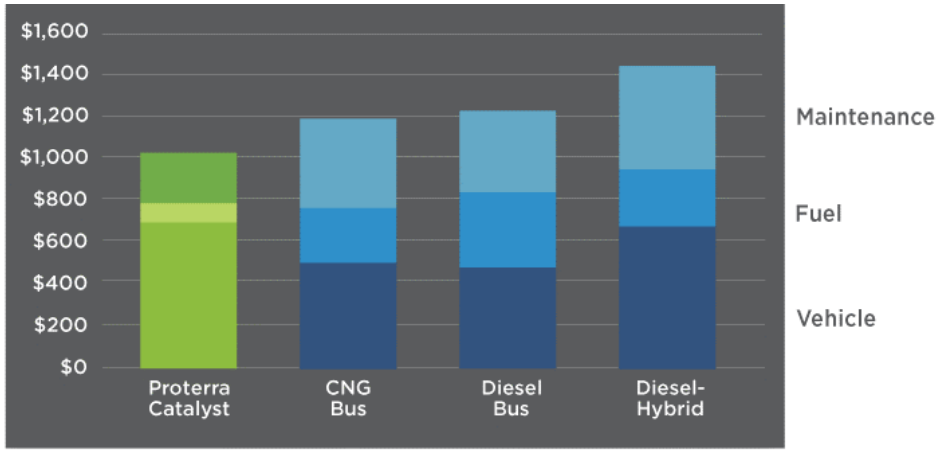
PROTERRA

- Los Angeles (LA Metro, LA DOT, Foothill Transit)
- New York City
- San Francisco
- Seattle
- Reno
- Nation of Canada

Projections by multiple International Research Firms indicate that by 2025 – 2030 80% of all bus purchases worldwide will be Battery Electric

CATALYST 40 FT. TOTAL COST OF OWNERSHIP ADVANTAGE

	Proterra EV	CNG Bus	Diesel Bus	Diesel Hybrid
Vehicle	$649	$470	$454	$650
Energy/Fuel	$81	$294	$378	$302
Maintenance	$238	$432	$389	$475
TCO	$967	$1,196	$1,221	$1,428
TCO $'s/Mile	$2.24	$2.77	$2.83	$3.30



est. over 12 year lifetime / $ in thousands, except TCO $'s/mile

- Battery-electric vehicles have the lowest operational lifecycle cost:
  - High EV energy efficiency, low electricity rates, and high annual vehicle mileage combine to create significant fuel savings
  - 30% fewer parts dramatically reduce maintenance and operating costs
  - Electricity prices far more stable and predictable than volatile fossil fuel prices

12-yr Operational Savings per Bus

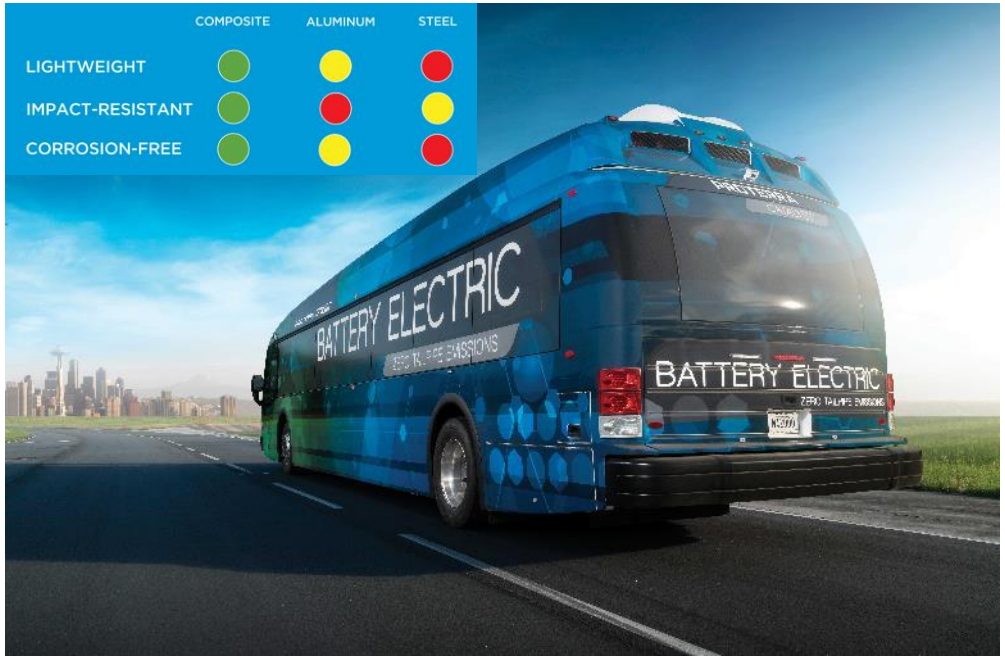
$448k vs. Diesel

$459k vs. Hybrid

$408k vs. CNG

THE PROTERRA CATALYST® PLATFORM

Proterra's use of advanced composite materials makes the Proterra Catalyst not only the lightest, most efficient vehicle, but the most durable and safe as well.



Lightest battery-electric bus on the market

- Increased passenger seating capacity
  - 40' vehicle: 40 seated passengers
  - 35' vehicle: 28 seated passengers
- Less damage to roadways

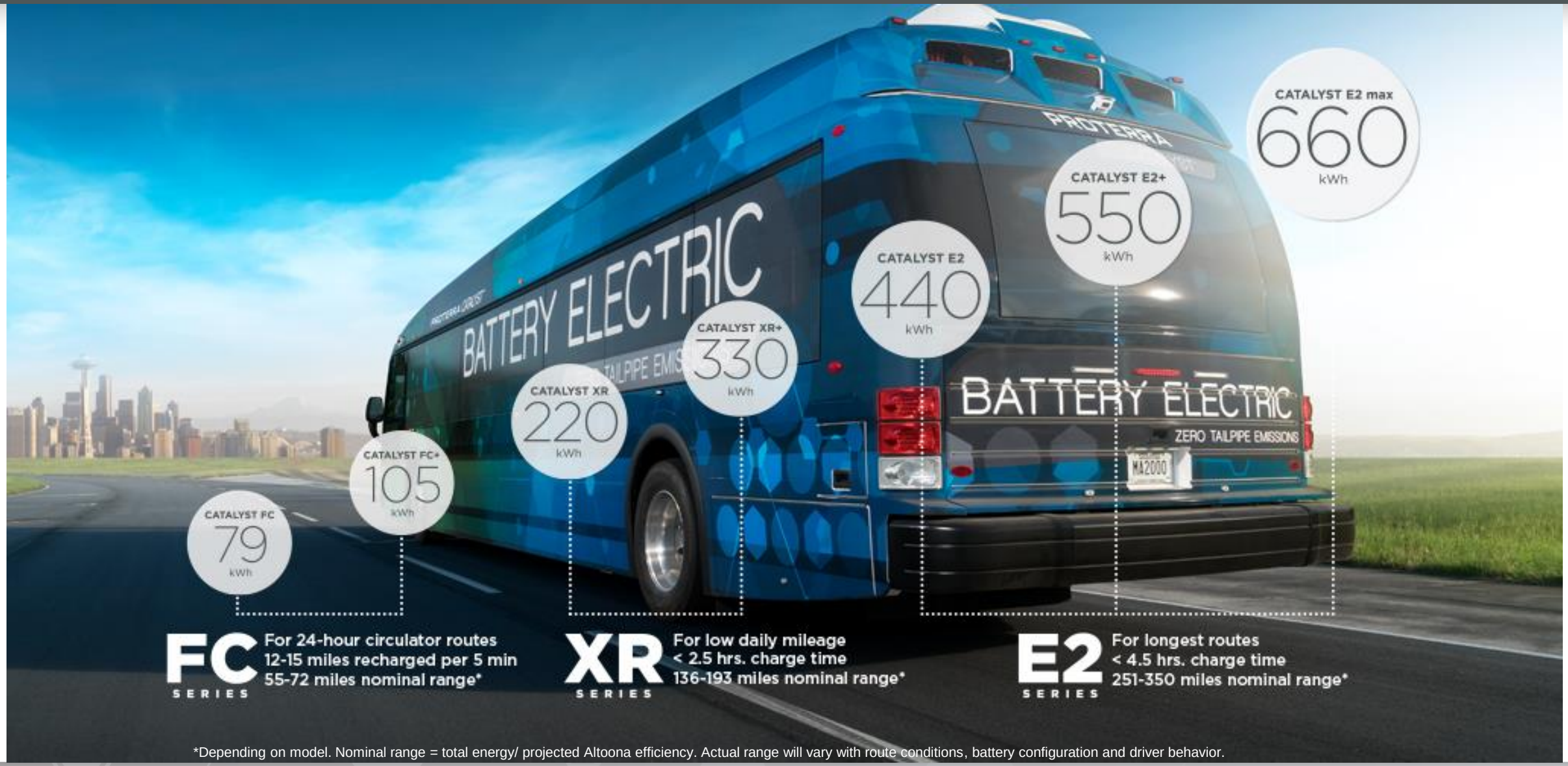
Most efficient in its class

- Highest efficiency of any vehicle in its class
- Longest range per kWh of energy storage
- Lowest fuel cost per mile
- 1.61 - 1.89 kWh/mile

Highly durable for greatest safety

- Advanced carbon-fiber-reinforced composite material
- Super strong, lightweight and impact-resistant
- Non-conductive and rust-resistant

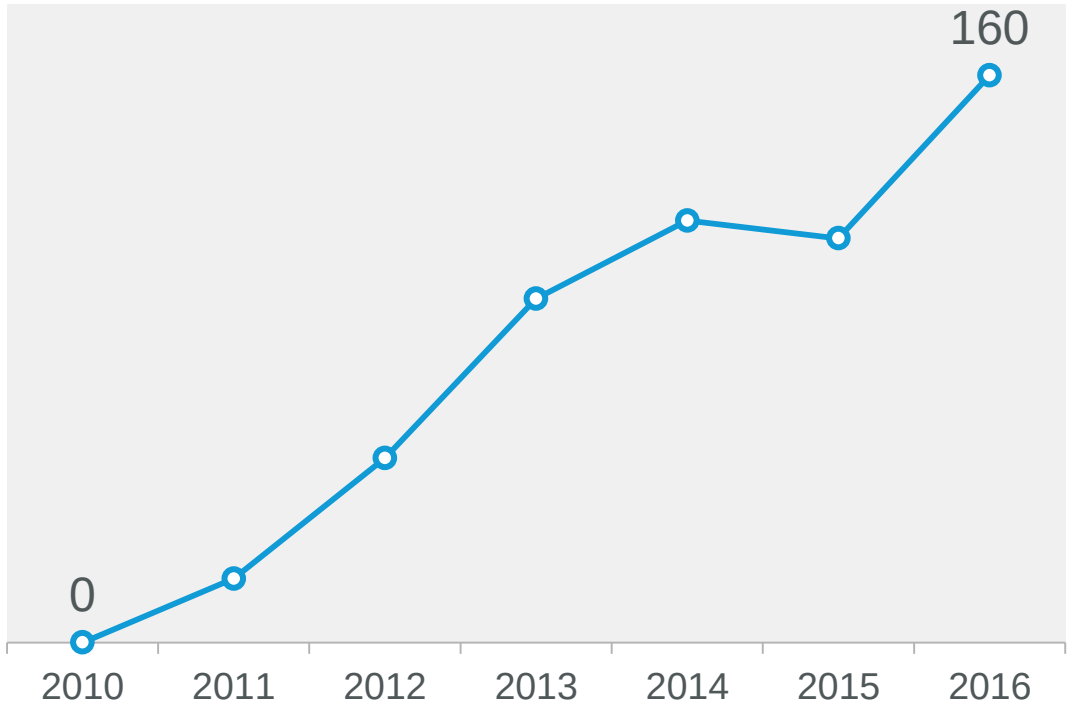
THE PROTERRA CATALYST'S RANGE



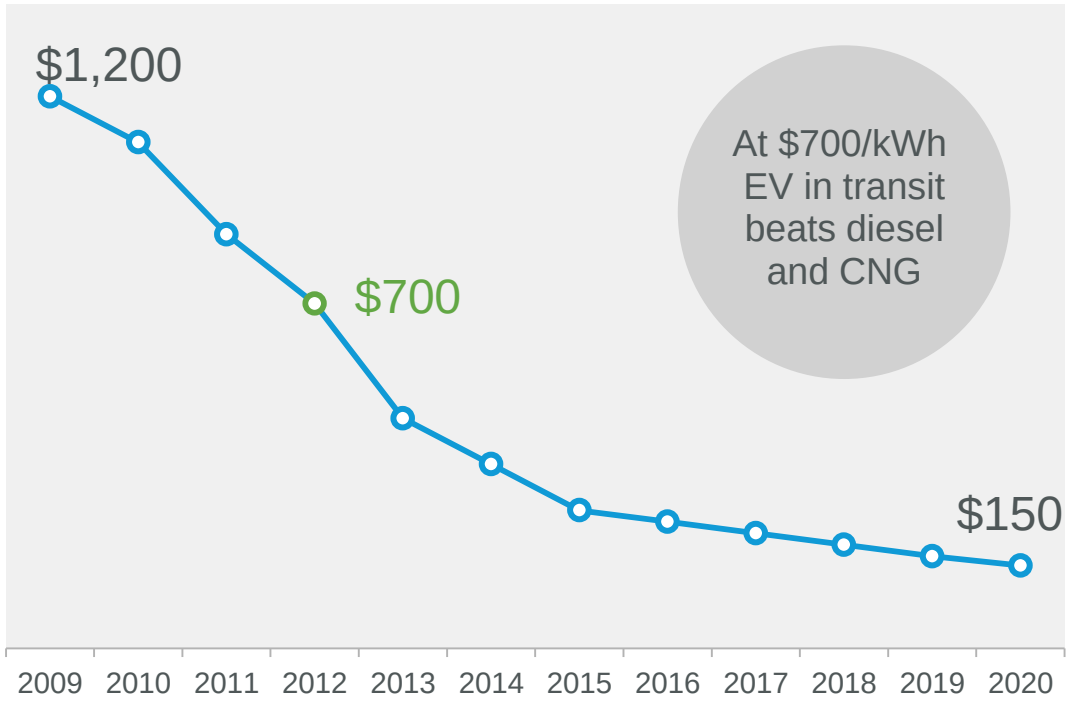
*Depending on model. Nominal range = total energy/ projected Altoona efficiency. Actual range will vary with route conditions, battery configuration and driver behavior.

EV ECONOMICS IMPROVING RAPIDLY - REVISIT

U.S. Electric Vehicle Sales (000s Units)



Proterra Battery Cost ($/kWh)

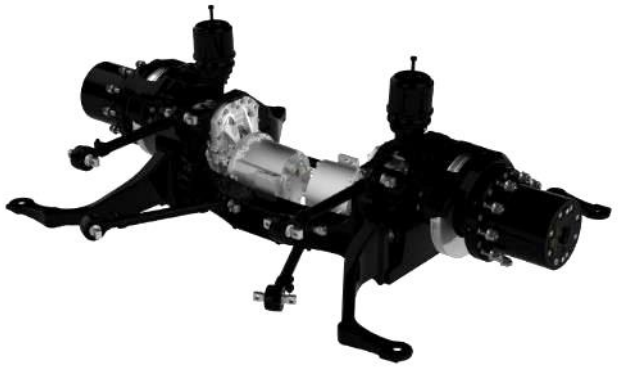


The sharp decline in battery costs is enabling a rapid shift to electric vehicles in the transit market.

Sources: Navigant Research, hybridcars.com, Electric Drive Transportation Association. xEV = PHEV and BEV.

DRIVETRAIN OPTONS: DUOPOWER and PRODRIVE

Designed for efficiency, power and durability, Proterra's drivetrains deliver unparalleled performance.



DuoPower

ProDrive

PERFORMANCE COMPARISON	Catalyst® E2 with ProDrive Drivetrain	Catalyst® E2 with DuoPower™ Drivetrain
ENERGY (kWh)	440	440
NOMINAL RANGE (miles) Total energy/projected Altoona Efficiency	251	305
EFFICIENCY (MPGe)	21.5	26.1
PEAK HORSEPOWER	295	510
ACCELERATION TIME @ SLW (seconds)		
0-20 MPH	6.7	4.5
20-50 MPH	32.8	15.5
MAX HILL CLIMB	20.0%	26.0%

THE DUOPOWER™ DRIVETRAIN

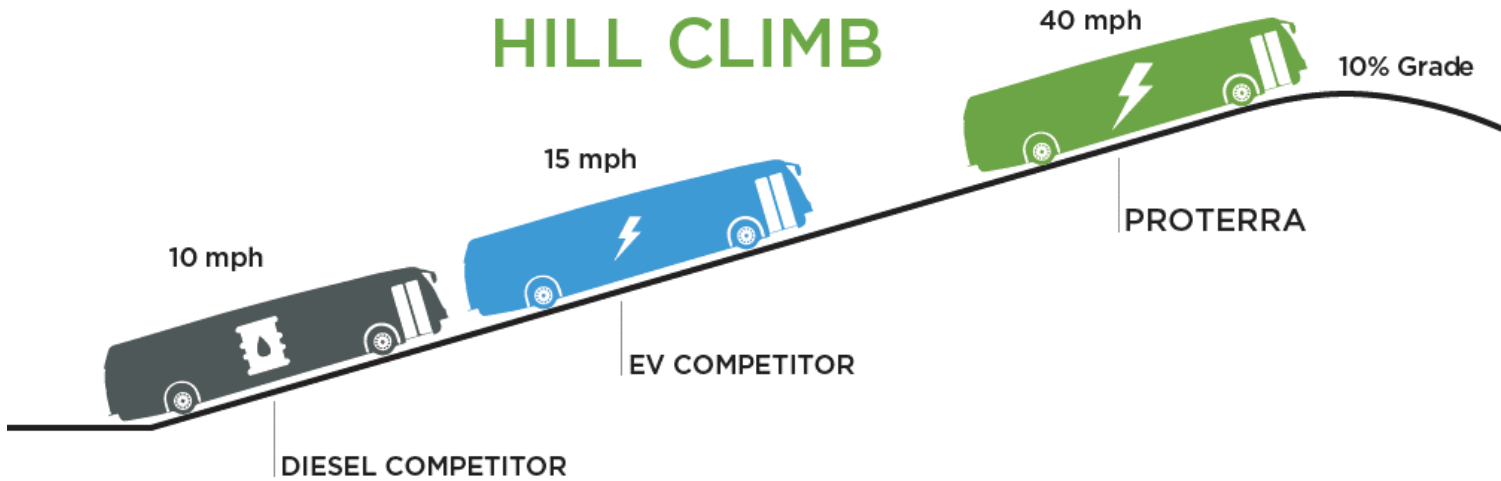
By combining the DuoPower drivetrain with Proterra's battery technology and lightweight composite bus body, the Catalyst delivers 26.1 MPGe—over 5X more fuel efficient than a diesel bus.

Enables a longest nominal range on the road

- A nominal range of 426 miles
- Tested at the Navistar Proving Grounds, achieving a world record range for an EV, traveling 1,101.2 miles on a single charge

Designed for best performance

- Propels a bus up a 26% grade, making it an ideal option for transit agencies with steep hills
- Enhances performance in extreme weather



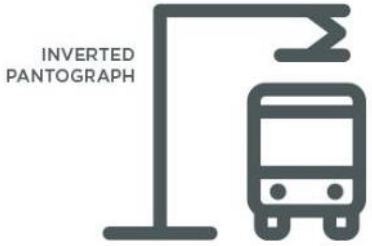
PERFORMANCE COMPARISON	Diesel Competitor	Electric Competitor	Proterra Catalyst® E2 with DuoPower™ Drivetrain
TOP SPEED ON HILLS			
5%	35 mph	33 mph	59 mph
10%	10 mph	15 mph	40 mph
15%	n/a	1 mph	27 mph
MAX HILL CLIMB	12.4%	15.1%	26.0%

2X The Horsepower, 2X The Acceleration, 5X More Efficient Than a Diesel Bus

SMARTER CHARGING
COMPATIBLE WITH INDUSTRY-STANDARD CHARGING SYSTEMS

OVERHEAD CHARGING
Keep your Catalyst buses rolling with easy depot or on-the-road charging, made simple by industry-standard SAE J3105 overhead systems.

- Charge on the road for longer routes or enable 24/7 circulator operations
- Low maintenance costs and high availability
- Compatible with roof-mounted pantographs as well as inverted pantograph systems, offered by Schunk and other suppliers



ADOPTED BY MAJOR OEMS

PROTERRA GILLIG NEW FLYER

PLUG IN CHARGING
Regardless of your fleet size, powering up your Proterra buses at the depot is as easy as plugging in a standard J1772-CCS Type 1 charger.

- Universal chargers are offered by Proterra and other suppliers
- Catalyst vehicles can be configured with two charge ports for flexibility at the depot
- Electric buses, utility vehicles and cars can share the same standardized chargers

ADOPTED BY MAJOR OEMS

GM CHRYSLER BMW Ford VW DAIMLER PROTERRA GILLIG NEW FLYER VANHOOL ALEXANDER DENNIS

CHARGING AT SCALE

Proterra works closely with customer to recommend the appropriate charging solution for fleets and facilities planning for scale as the demand for charging increases.

Proterra technologies enable:

- Efficient charge speed
- Dynamic power sharing
- Driver-friendly stations
- Cost-effective operations
- Universal compatibility
- Serviceability
- Low maintenance costs
- High availability

Our experts provide counsel on:

- Site layout
- Energy management
- Real-time energy monitoring
- Site configurations

SMART CHOICES
CHOOSE THE CHARGING SOLUTION THAT FITS YOUR FLEET

PROTERRA

Proterra offers a selection of charging options to match your available charge time to your vehicles' daily range and fleet parking space requirements, keeping your buses moving.

PRODUCT	PROTERRA® POWER CONTROL SYSTEM 60KW	PROTERRA® POWER CONTROL SYSTEM 125KW	PROTERRA® POWER CONTROL SYSTEM 500KW
MAX POWER LEVEL AVAILABLE (kW)	60	125	500
PCS LOCATION	DEPOT	DEPOT	DEPOT / ONROUTE
DISPENSER TYPE	PLUG IN / OVERHEAD	PLUG IN / OVERHEAD	OVERHEAD
CONNECTION STANDARD	J1772 CCS PLUG IN J3105 INVERTED PANTOGRAPH J3105 BUS-UP PANTOGRAPH	J1772 CCS PLUG IN J3105 INVERTED PANTOGRAPH J3105 BUS-UP PANTOGRAPH	J3105 INVERTED PANTOGRAPH J3105 BUS-UP PANTOGRAPH
VEHICLES	CHARGING TIME OR MILEAGE PER CHARGE*		
FC	1.1 HOURS	0.9 HOURS	19 MILES PER 10 MINUTES
FC+	1.5 HOURS	0.7 HOURS	38 MILES PER 10 MINUTES
XR	2.9 HOURS	2.4 HOURS	9 MILES PER 10 MINUTES
XR+	4.4 HOURS	2.4 HOURS	13 MILES PER 10 MINUTES
E2	5.9 HOURS	2.8 HOURS	17 MILES PER 10 MINUTES
E2+	7.3 HOURS	3.5 HOURS	20 MILES PER 10 MINUTES
E2 MAX	8.8 HOURS	4.2 HOURS	24 MILES PER 10 MINUTES

* Efficiencies based on DuoPower drivetrain; FC series charges at max overhead power limit; XR/E2 series charges at continuous power limit for plug-in; all charge times are approximate.

- Modular, flexible and scalable
- Charging can be converted from plug-in to overhead or upgraded to higher charging power as your fleet grows.

SMARTER CHARGING
PROTERRA POWER CONTROL SYSTEMS

INTELLIGENT

Automated and rules-based vehicle charging

UNIVERSAL

Standards-based, OCPP 1.6 open communications protocol-compatible

REMOTE

Can be located up to 492 feet from dispenser

SCALABLE

Can be installed side-to-side and back-to-back for high-density charger banks

60KW
For fleets with longer available charge times.

Catalyst E2 charge time:
~6 hours, w/ J1772-CCS plug-in

125KW
For fleets with high uptime requirements

Catalyst E2 charge time:
~3 hours, w/ J1772-CCS plug-in

500KW
For fleets with extended operating hours and high mileage requirements

Catalyst FC+ charge time:
~38 miles per 10 minutes, w/ J3105 overhead

Open source communications protocol

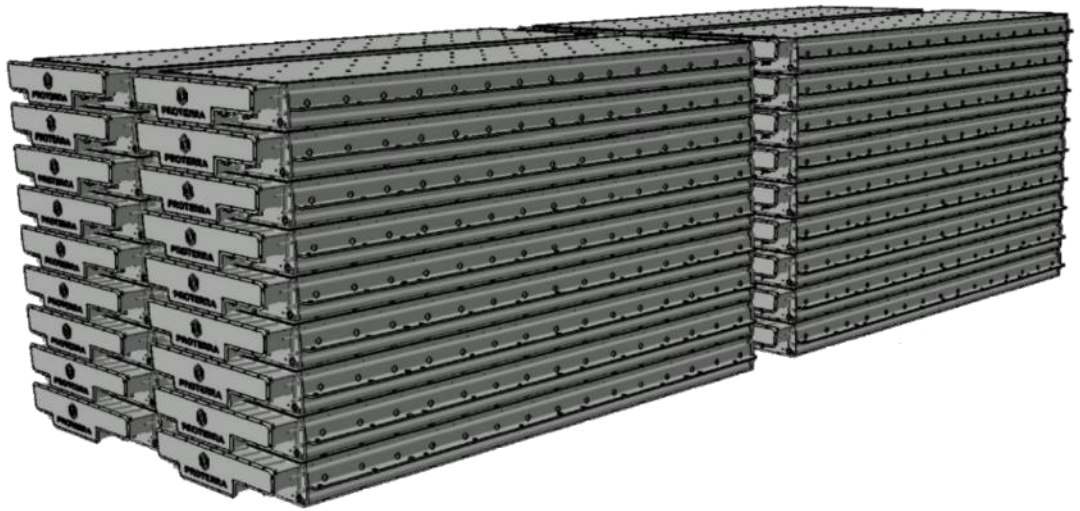
V2G Bi-directional V2G

Smart Grid Ready

Telematics-enabled

2 ACRES OF SOLAR WITH ENERGY STORAGE CAN POWER *6-8 BUSES* PER DAY IN TX

SECOND LIFE



~4 MWh shown

- Batteries will retain significant energy storage capability long after their first life in a transit bus
- Stackable design, retaining interface and safety features
- Hardware designed to exist >12 years in outdoor environmental conditions
- Capable of serving multiple storage requirements for renewable energy, grid services, demand management and emergency backup

FINANCING YOUR ELECTRIC FLEET

Proterra can help you find the right combination of financing tools that map to your procurement plans

Battery Lease

A battery lease enables you to buy a Catalyst vehicle for roughly the same price as a diesel bus, putting the operating savings toward the battery lease. Proterra is responsible for the performance of the batteries through the life of the lease, removing operator risk.

Municipal Capital Lease

A generally low-cost financing tool for local governments with investment-grade credits. Can be paid for with FTA funds. Offers structured ownership that enables you to own a Proterra bus at the end of the lease term.

Operating Lease

Operating leases allow you to pay for the use of a bus over time, with the option to permanently transition the bus into your fleet. No upfront capital costs.

Bus Rental Program

For fleet operators looking to “test drive” a Catalyst® bus before making a long-term commitment, Proterra offers the option to rent a bus for up to 12 months before making a long-term purchasing decision.

ALTERNATE MEANS OF FINANCE FOR BUSES AND CHARGING

- POWER PURCHASE AGREEMENTS FOR SOLAR AND CHARGING INSTALLATIONS IN STATES LIKE TEXAS, WHICH IS A NON-REGULATED UTILITY MARKET

Energy Savings Performance Contracting

Energy Savings Performance Contracting is a nationwide proven procurement vehicle which allows publi c entities to purchase improvements and modernization within their facilities utilizing energy savings and avoided costs to
pay for the improvements over a specific number of years. The energy and operational savings can be g uaranteed by the ESCO for the term of the agreement. Facility-based energy savings could be used to s ubsidize EV transit
vehicles, batteries and associated charging infrastructure achieved through avoided cost of fossil fuel (vs . kilowatt hours) and lowered overall maintenance and ownership costs. Program energy savings could also be used to
increase local match requirements for grant funding.

- Energy Services Company (ESCO) is an industry designation
- ESCO are formally recognized by NAESCO

NAESCO® National Association of Energy Service Companies

PROTERRA

THANK YOU.

INTRODUCING THE NEW PROTERRA INTELLIGENT DASHBOARD

Offers Information At-A-Glance
- Information for optimized readability
- Bold, simple dashboard provides situationally-relevant awareness
- Easy interface for maintenance teams

Encourages Better Driving
- Eco gauge encourages efficient driving
- Improves clarity around warnings and needed actions
- Improves driver situational awareness

Delivers Simple, Smart Interface
- Colors highlight important information and system status
- Look and feel of modern, smart electronics

COLLISION AVOIDANCE TECHNOLOGY
IMPROVING ROAD SAFETY WITH INTELLIGENT MOBILITY SOLUTIONS

PROTERRA

Proterra Catalyst vehicles are equipped with the Mobileye® Shield+ System

- Offers the latest technological advancement for preventing collisions between vehicles, pedestrians and cyclists
- Enhances visibility when operating the bus while approaching other vehicles, pedestrians and cyclists
- Helps eliminate blind spots in complex bus turning patterns on tight, busy city streets

Preventing Incidents Before They Happen:
Proterra Is Enabling Fleet Operators To Adapt To Changing And Complex Transportation Environments

June 13, 2018

Qualcomm

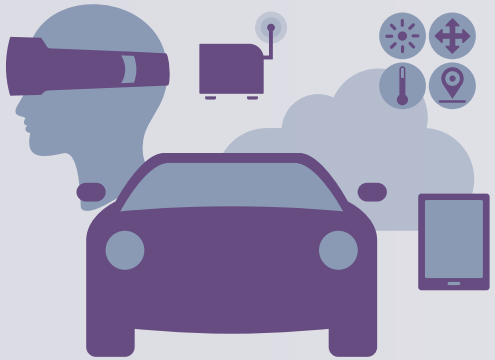
The Standards-Driven Automotive Path to 5G

Jim Misener

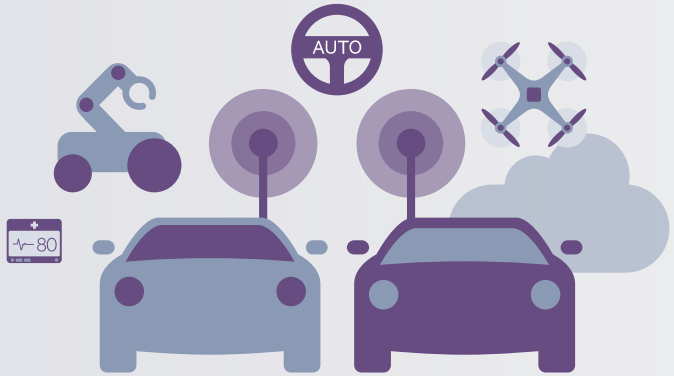
Senior Director, Technical Standards
Qualcomm Technologies, Inc.

5G is important for our automotive vision

Providing a unifying connectivity fabric for the autonomous vehicle of the future



Enhanced mobile broadband

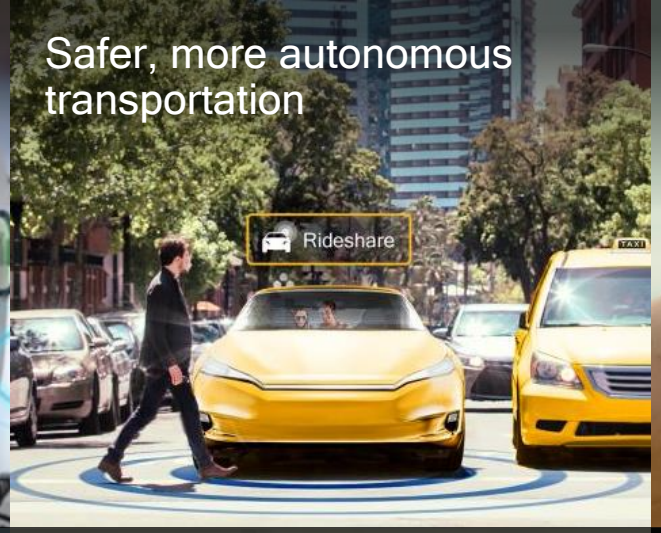


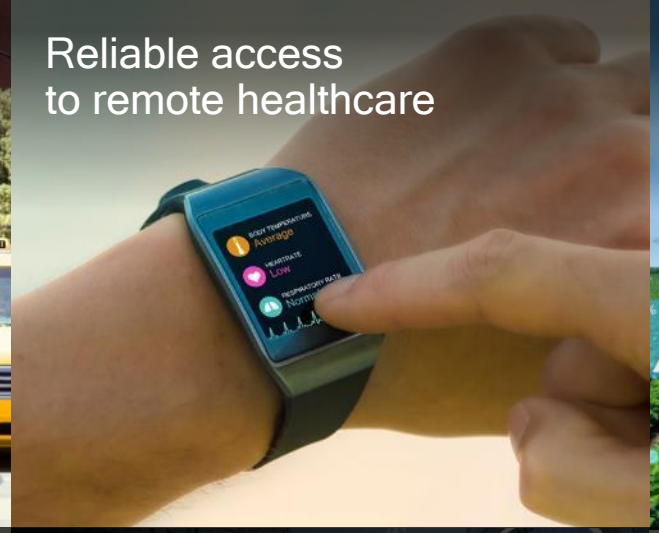
Mission-critical services

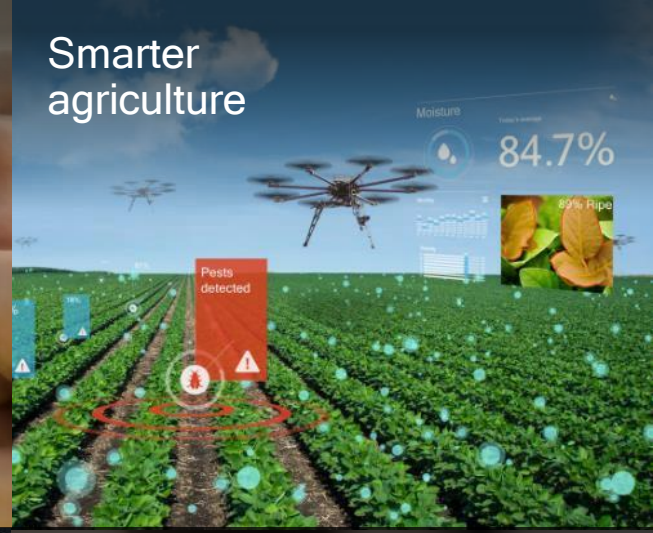
Massive Internet of Things

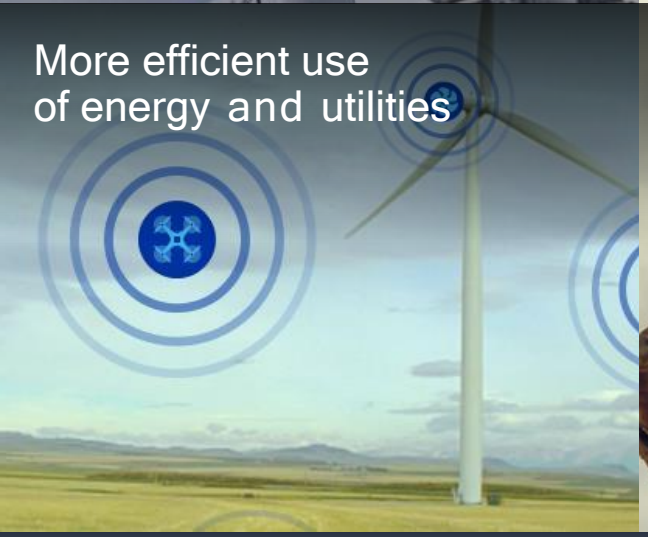
Unifying connectivity platform for future innovation

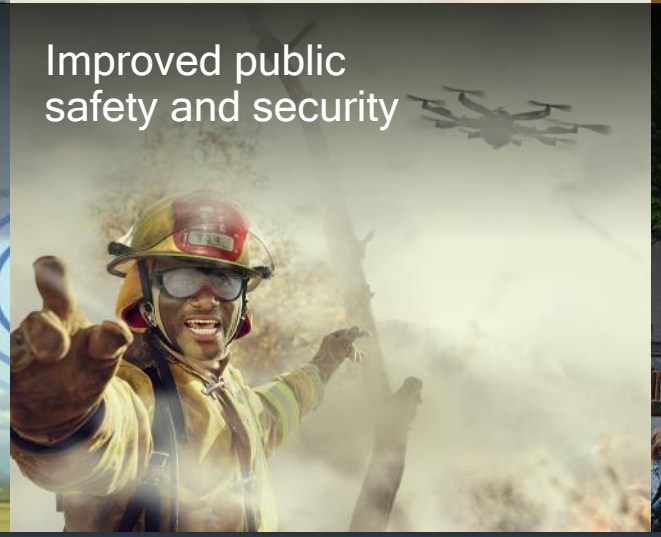
Starting today with Gigabit LTE, C-V2X Rel-14, and massive IoT deeper coverage











5G

5G will expand the mobile ecosystem to new industries

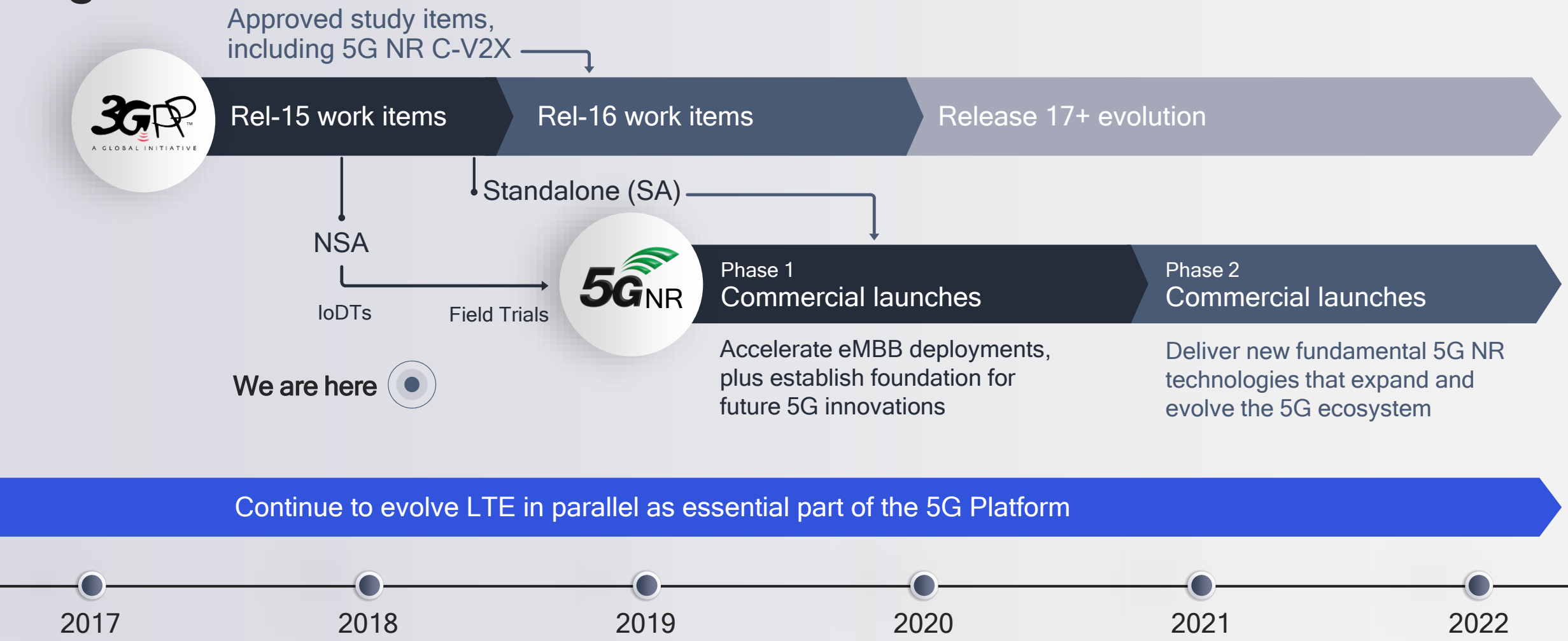
*The 5G Economy, an independent study from IHS Markit, Penn Schoen Berland and Berkeley Research Group, commissioned by Qualcomm

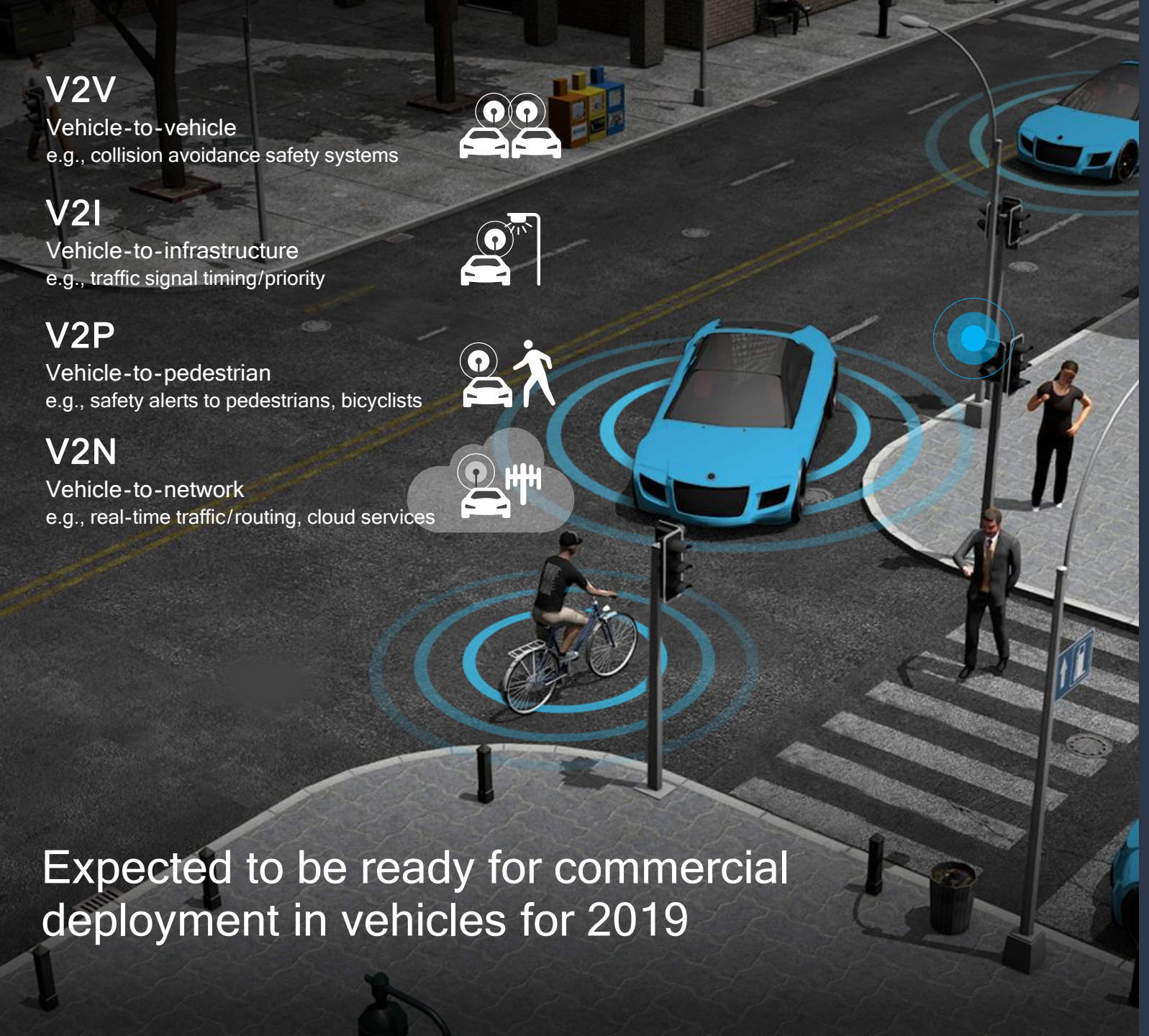
Powering the digital economy

>$12 Trillion

In goods and services by 2035*

Accelerating 5G NR to meet the ever-increasing global demand for mobile broadband





C-V2X

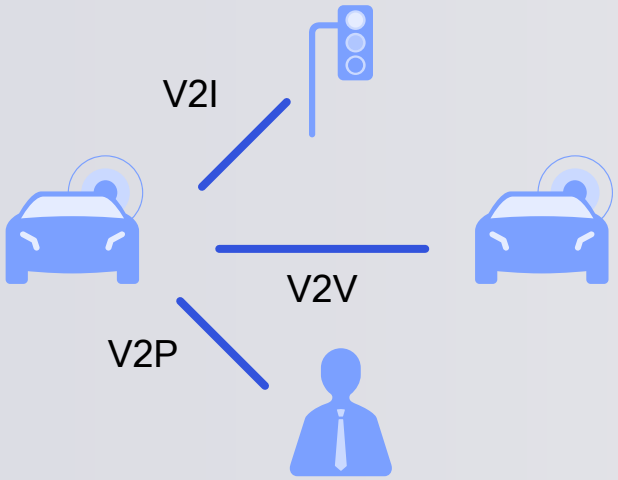
Establishes the foundation for safety use cases and a continued 5G NR C-V2X evolution for future autonomous vehicles

- Release 14 C-V2X completed in 2017
- Broad industry support – 5GAA
- Global trials started in 2017
- Our 1st announced C-V2X product in September, 2017

C-V2X defines two complementary transmission modes

Direct communications

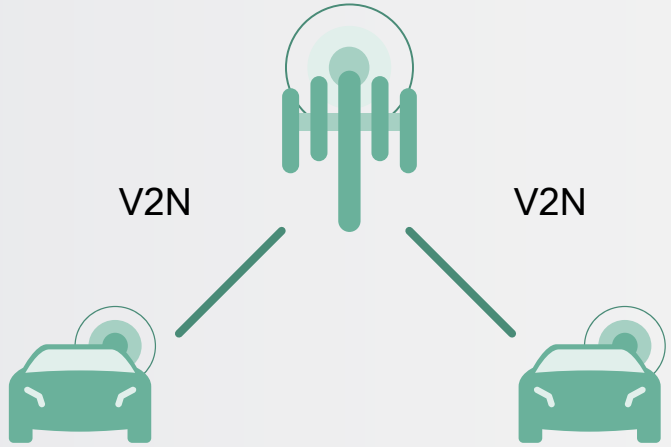
V2V, V2I, and V2P operating in 5.9 GHz ITS bands independent of cellular network or cellular subscription



Active safety
Latency-sensitive use cases, e.g. collision avoidance

Network communications

V2N operating in traditional mobile broadband licensed spectrum



Informational safety
More latency tolerant use cases, e.g. *accident 2 kilometers ahead*

C-V2X offers key advantages in multiple dimensions

Enhanced range and reliability

Up to 500km/h relative speed support

More cost efficient than other technologies

5G NR

Forward compatible evolution path to 5G

Enhanced range and reliability for direct communication without network assistance

Self managed for reduced cost and complexity

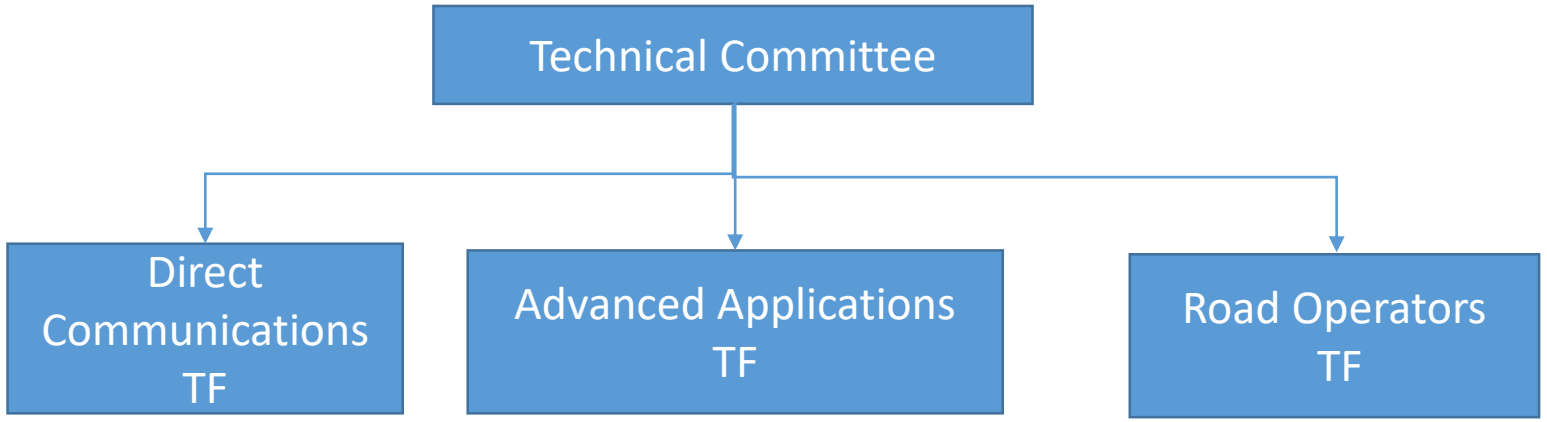
Synergistic with cellular modem

Leverage of cellular ecosystem

Reuse of SAE / ETSI upper layers

SAE C-V2X Technical Committee Scope

- **Established 2017 to fill the cellular (and 5G) void in hitherto 802.11p-focused ITS standards**: Primary SAE link to evolving, non-DSRC radio access technology. ~ 45 diverse members: auto, telecommunications, transportation applications
- **LSs sent to:** 3GPP, C-ITS, C-SAE, ISO TC204, IEEE 1609 WG, ETSI TC-ITS, IETF IPWAVE WG, ARIB, TTA, 5GAA, ITE, AASHTO (NTCIP Joint Committee, NEMA), ITU-T CITS, ITU-R SG5 WP5A SWG-ITS, ATIS, ITS Korea, ERTICO, ITS Japan, ITS Canada, IMT-2020PG, CAICT
- **Goal:** Jump start C-V2X deployment and establish basis 5G NR

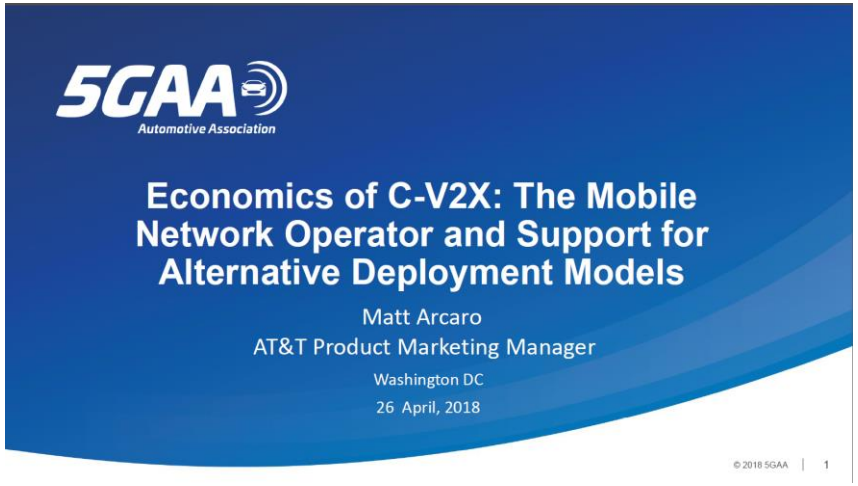


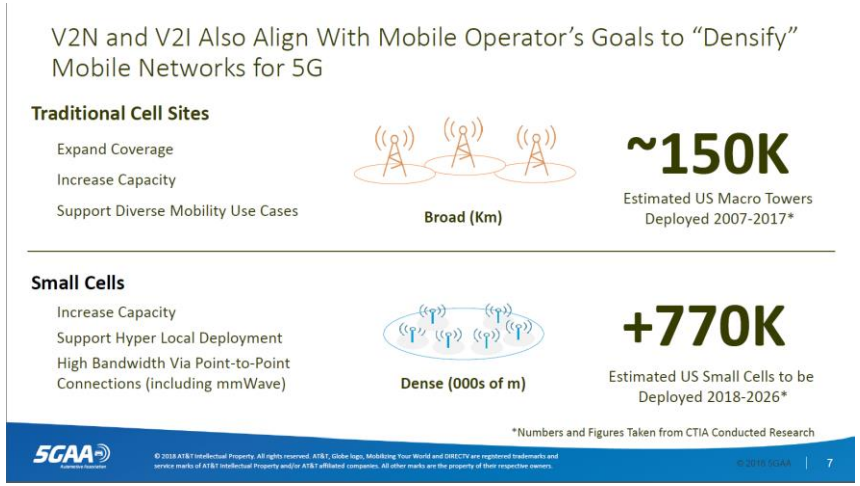
SAE J3161: *On-Board System Requirements for LTE V2X V2V Safety Communications*

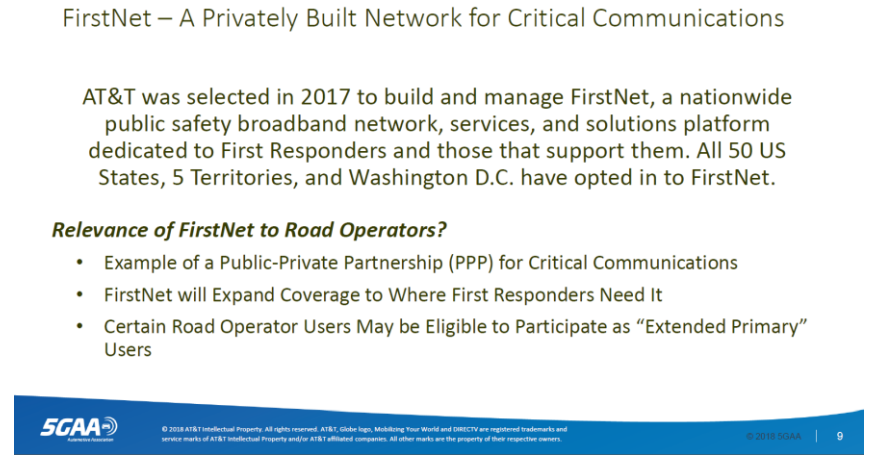
- Provides 3GPP-based alternative to SAE J2945/1
  - SAE J2945/1 pointed to in NHTSA V2V NPRM
- **Scope**: This standard specifies the system requirements for an on-board vehicle-to-vehicle (V2V) safety communications system for light vehicles , including standards profiles, functional requirements, and performance requirements. The system is capable of transmitting and receiving the SAE J2735-defined Basic Safety Message (BSM) [1] over a PC5 V2X wireless communications link as defined in 3GPP Release 14. The system uses Institute of Electrical and Electronics Engineers (IEEE) 1609 standards for network and transport layer communications, and for security.

AT&T recently presented on synergies between Cellular Infrastructure and RSUs – opportunity for Public-Private-Partnership

Source: http://5gaa.org/news/5gaa-presents-c-v2x-workshop-for-north-american-transportation-planning-and-north-american-road-operators/







C-V2X deployments now being announced

Reusing upper layer protocols to deliver safety applications

SAVARI®

June 4, 2018

Savari Adds C-V2X to Roadside Units for the U.S.

V2X technology leader plans development of its first RSU equipped with both DSRC and Cellular-V2X radio technologies to future-proof smart city infrastructure deployments

Qualcomm, Ford and Panasonic mark first US C-V2X deployment in C…

FierceWireless

commsignia

Commsignia Announces New C-V2X Roadside and Onboard Unit Product Line, Paving the Way for 5G-enabled Self-Driving Cars

Santa Clara, California – 06/05/2018 – In efforts to support the current Cellular Vehicle-to-Everything (C-V2X) and emerging 5G ecosystem, as well as roadside safety, Commsignia, a leader in the research, development and supply of V2X connectivity and collaborative systems for automotive, introduced today its new roadside units (RSUs) and onboard units (OBUs), which feature C-V2X direct communication technology. Building on the success of its existing ITS-RS4 and ITS-OB4 platforms, the new ITS-RS4-C and ITS-OB4-C will utilize the Qualcomm® 9150 C-

5G NR C-V2X

Communication augments autonomous driving

Perception

Sharing of high throughput sensor data and real world model

Path planning

Intention and trajectory sharing for faster, yet safe maneuvers

Real-time local updates

Real-time sharing of local data with infrastructure and other vehicles (e.g. 3D HD maps)

Coordinated driving

Exchanging intention and sensor data for more predictable, coordinated autonomous driving

Qualcomm

Thank you

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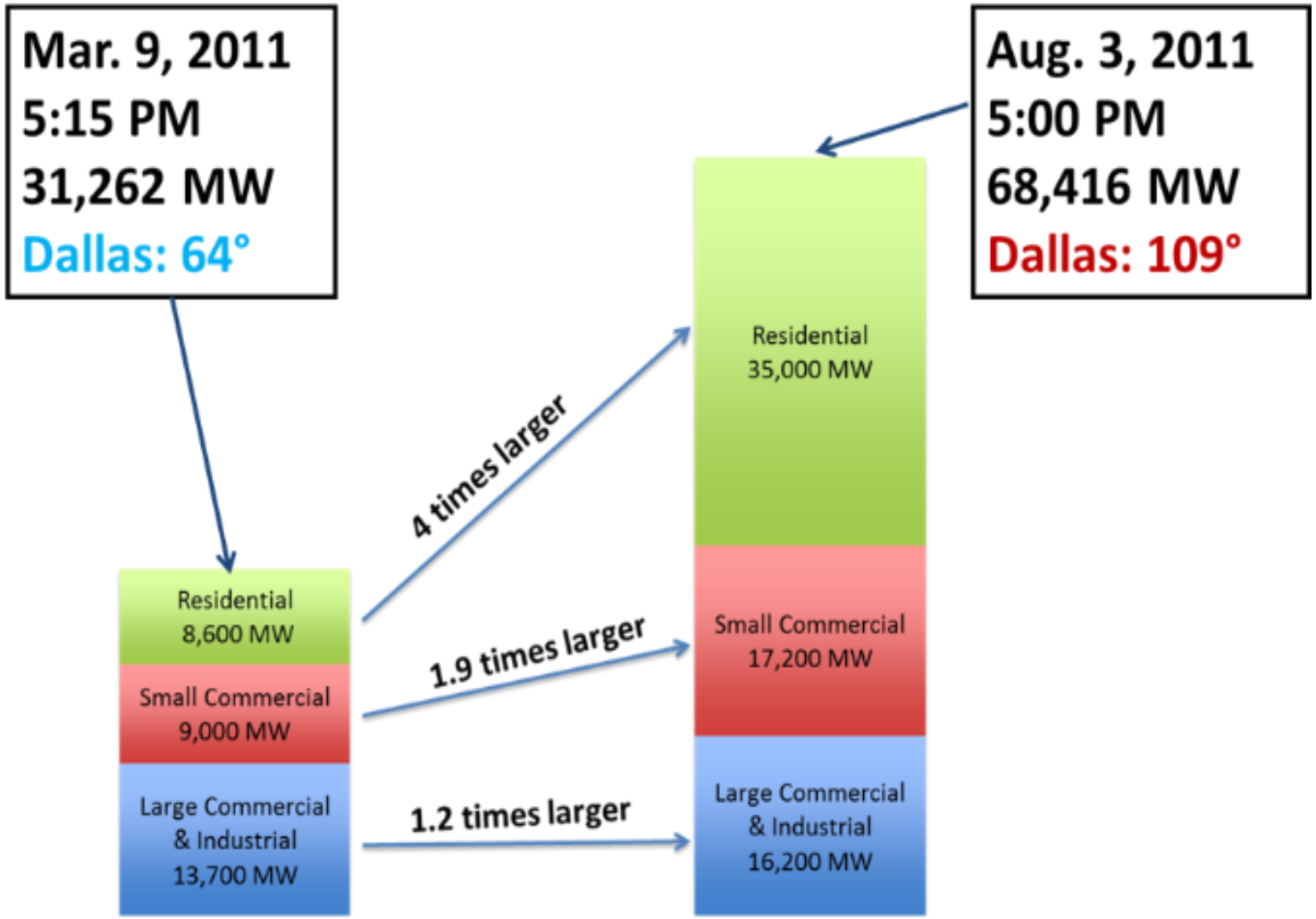
ResilientGrid

Electric Vehicle – Grid Integration
Texas Department of Transportation
Texas Technology Task Force

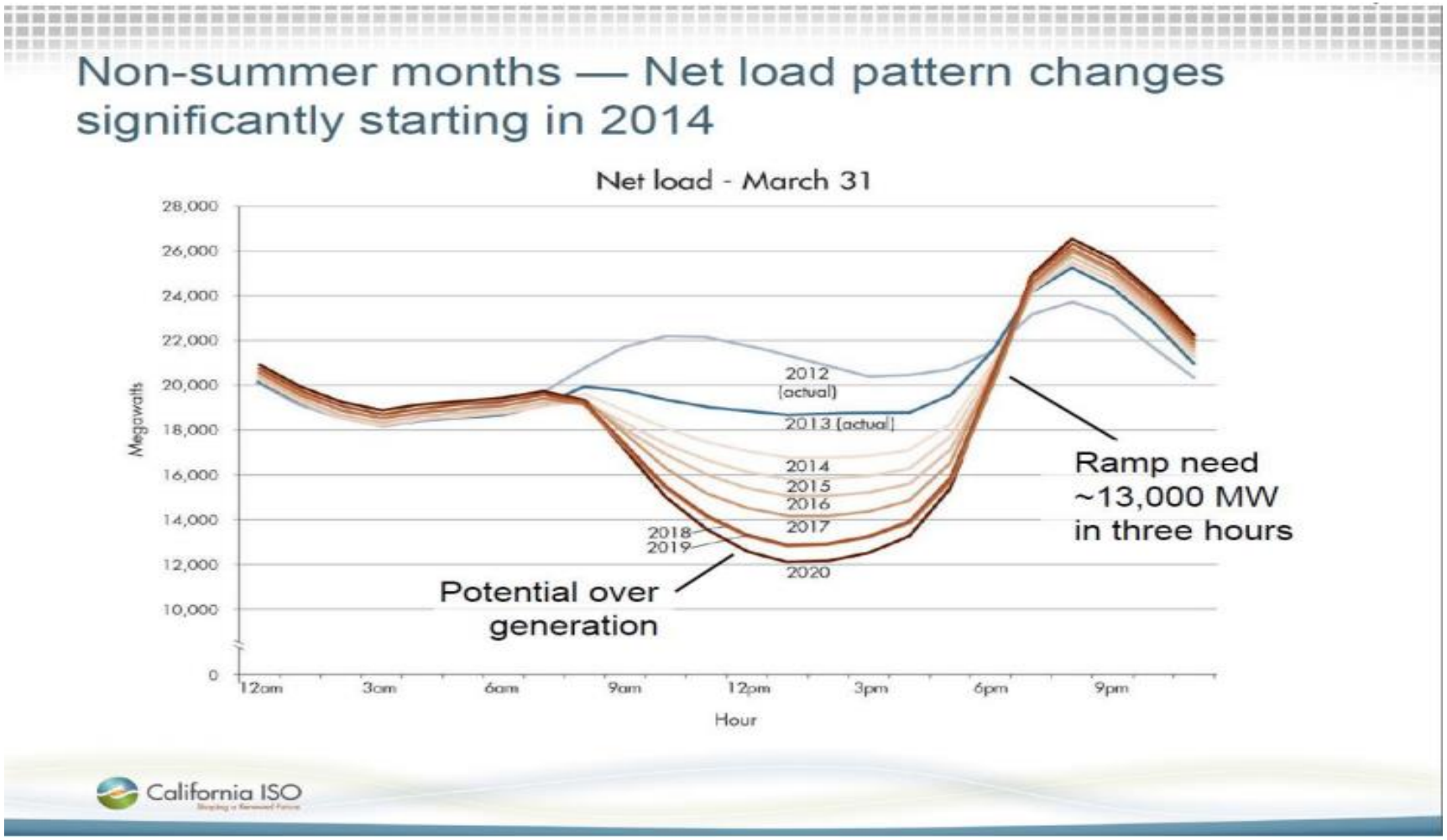
Mike Legatt, Ph.D., CPT
CEO and Founder
legatt@resilientgrid.com

The Grid: Temperature and Time



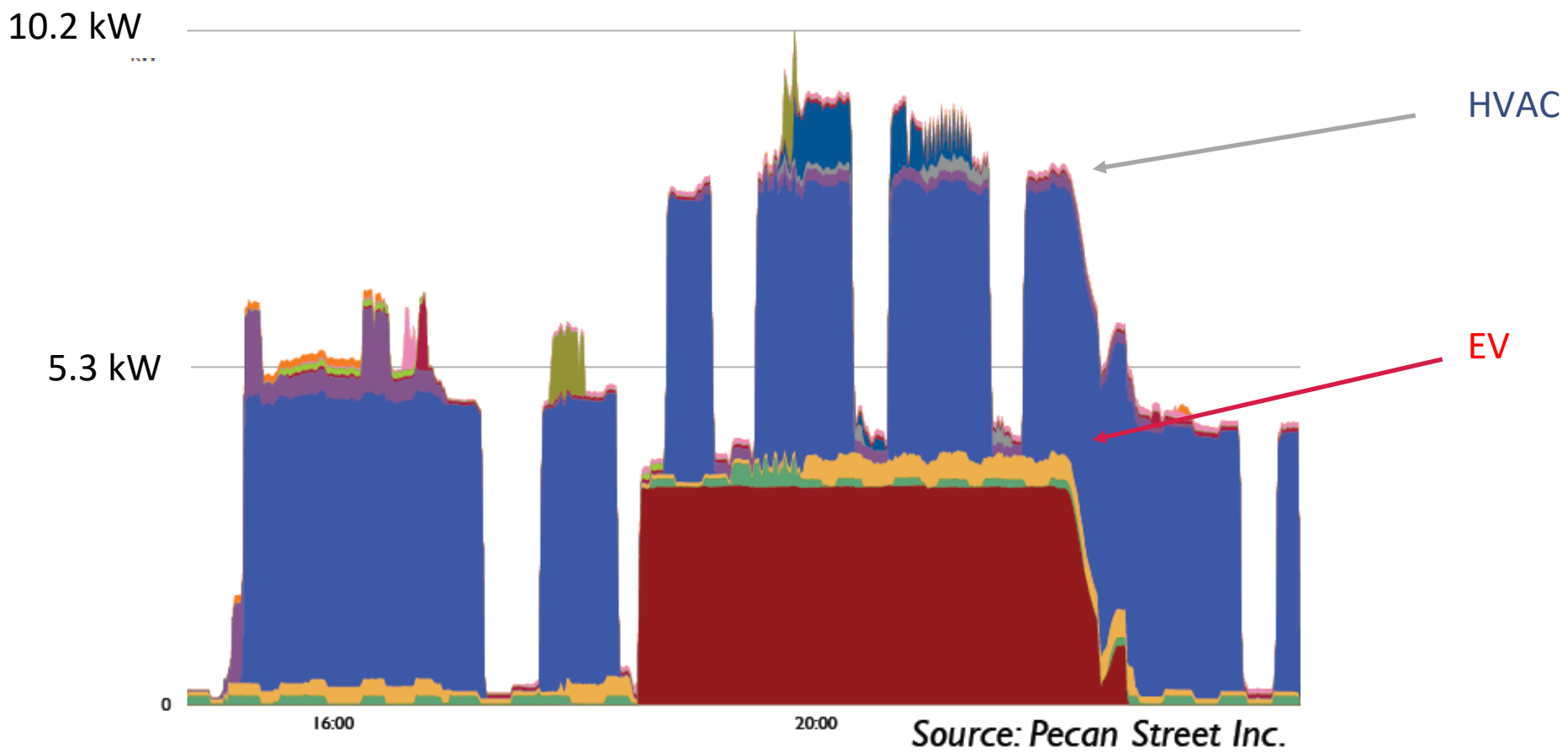
ResilientGrid

Growth of Distributed Energy Resources



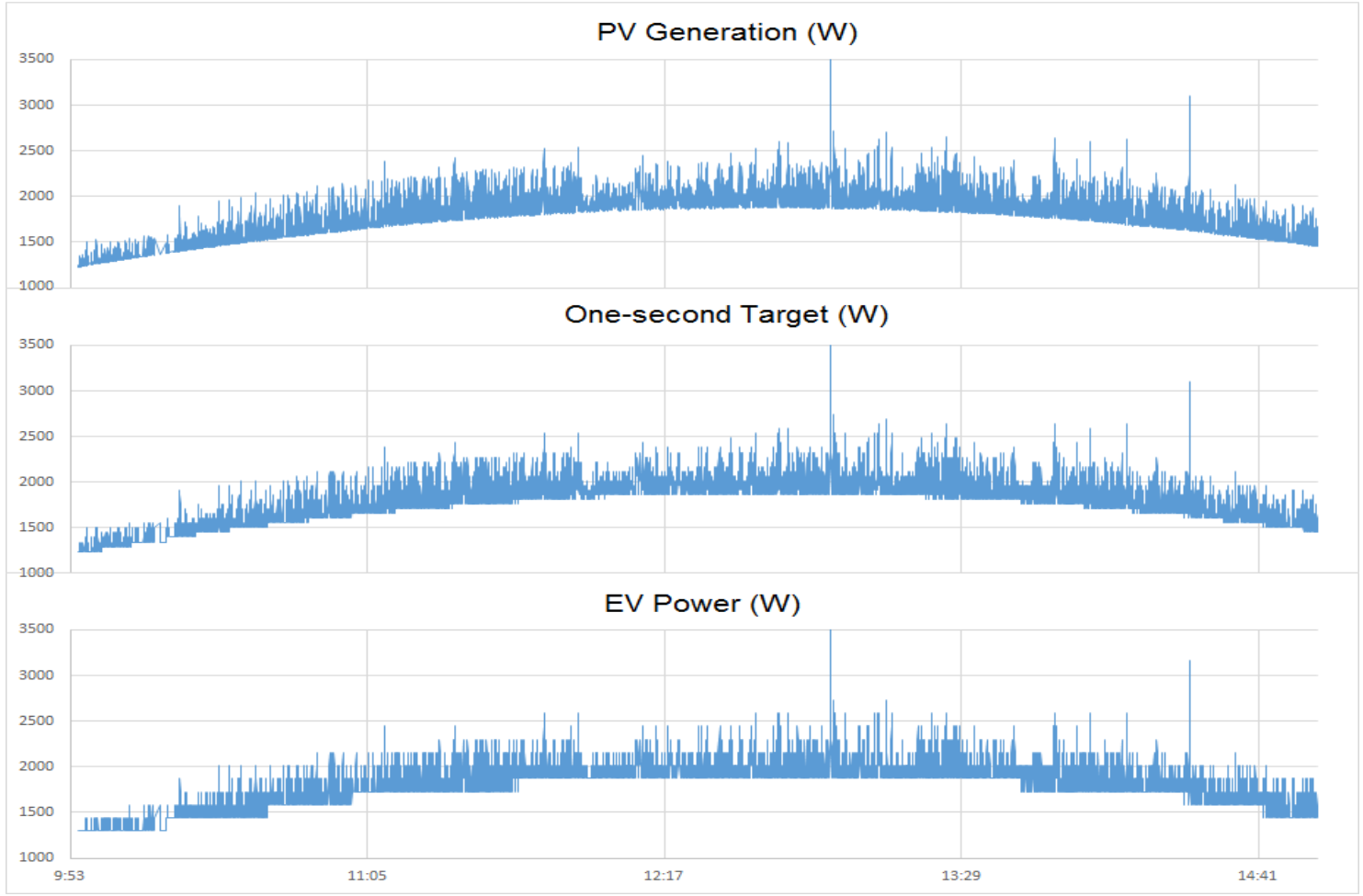
ResilientGrid

Electric Vehicles Making the Problem Worse



ResilientGrid

Electric Vehicles Making the Problem Better

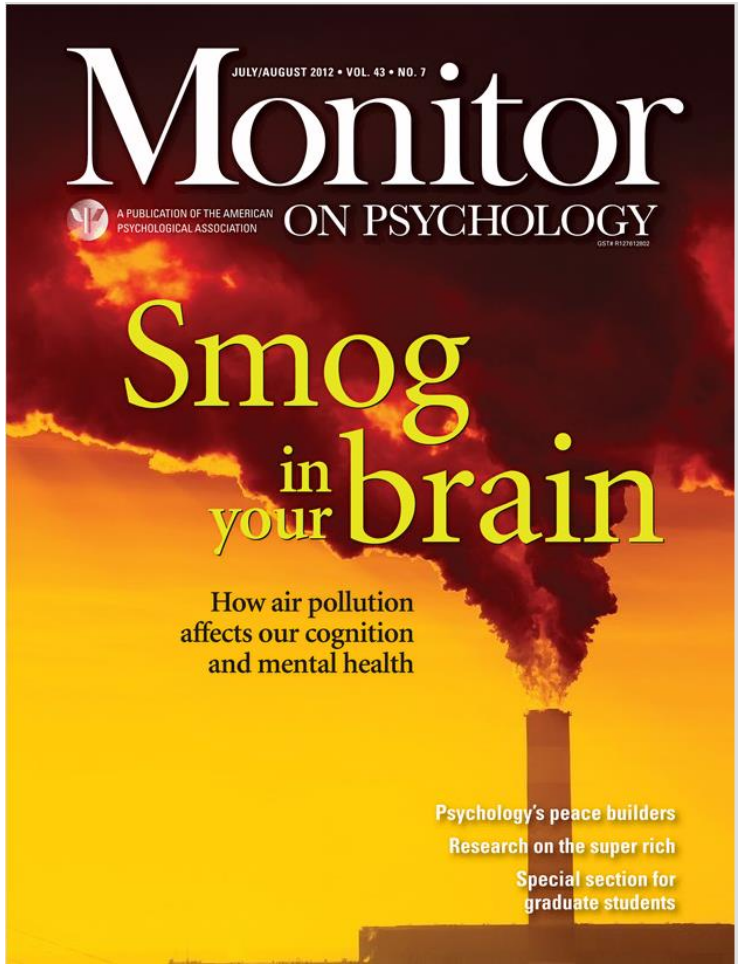


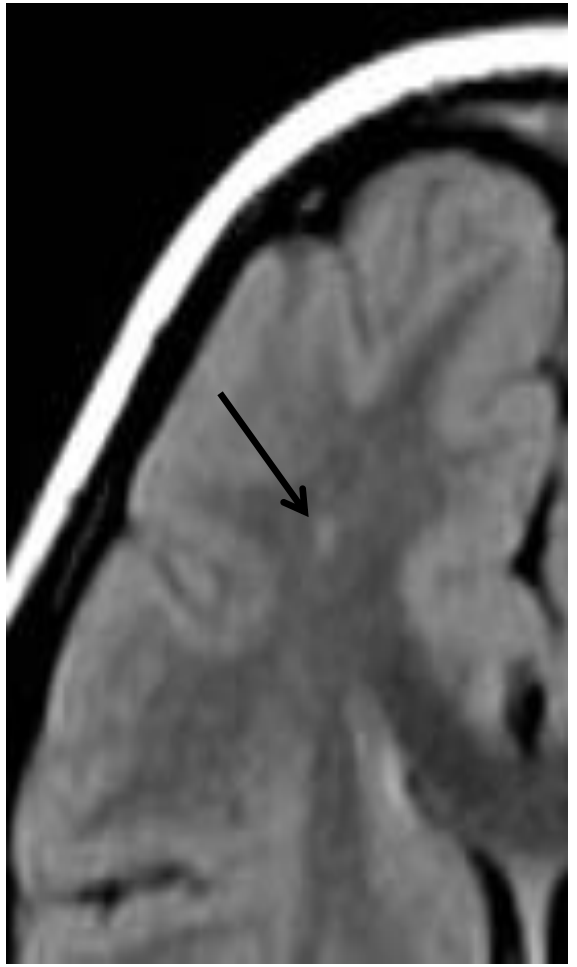
Emission	Per-Mile Emissions reduction
CO_2	80%
SO_2	128x larger
NO_X	41%
PM_{10}	73%
$PM_{2.5}$	62%
UFPM	62%

Cost-per-mile reductions from 10-15¢ to 2-4¢

ResilientGrid

Health Impacts of Vehicle Electrification





ResilientGrid

Behavioral and Societal Implications

- Need for strong planning (especially with autonomous vehicles, co-optimizing customer transportation and grid interfacing)
- Behavior change opportunities at the point of purchase
- Markets or autonomous systems can lead to local vehicle decisions that globally support the reliability of the grid
- There are several details of how this can work not yet decided (e.g., data link through EV or EVSE? MicroPMU integration? Scheduling cabin preconditioning)


ResilientGrid
Thank you
legatt@resilientgrid.com