TECHNOLOGY LANDSCAPE AND FUTURE DIRECTION FOR TRANSPORTATION EMISSIONS, ENERGY, AND HEALTH

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16. Abstract This report presents a roadmap for technology development and implementation in transportation emissions, energy, and health, in the context of emerging transportation sector trends. Specifically, the project focuses on vehicle electrification. The report identifies technologies currently available or under development in both software and hardware. Further, the report notes transition partners and stakeholders in private and public sectors. The technology landscape will also reveal gaps in research and development and in technology transfer. The report concludes with an action plan for modeling, testing, and measuring regarding vehicle electrification.		
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Table of Contents

List of Figures ..... **v**
List of Tables ..... **v**
Background and Introduction **1**
Problem **1**
Approach **4**
Findings **5**
Research Gaps 6
Research Questions by Sector 6
Research Questions by Vehicle Type 6
Action Plan **7**
Modeling and Simulation 8
Testing and Measuring 9

List of Figures

Figure 1. The e-mobility ecosystem. 3
Figure 2. Envisioned transportation-grid co-simulation framework. 8

List of Tables

Table 1. Testing Facility Sample Use Cases 9

Background and Introduction

Vehicle energy consumption and emissions have long been linked with public health effects, which are also key issues in equity and environmental justice. Emissions and their disparate impacts on low income, and black and brown communities, are at the core of the health and equity issues that exist in the transportation sector. These communities are more likely to be located near high emitting industrial facilities, ports, and transportation hubs. As such, improving energy efficiency and reducing emissions are indispensable components of any discussions related to public health and equity in transportation.

These issues are especially relevant in Texas because it is the largest energy-producing and energy-consuming state in the nation. According to the U.S. Energy Information Administration, Texas produced 41% of the nation's crude production in 2019. Additionally, 25% of the natural gas marketed in the United States was produced in Texas. The state's 30 refineries processed 5.8 million barrels of oil per day, 31% of the nation's total refining capacity. Texas also consumed 12% of the nation's electricity, which was twice that of Florida, the second highest electricity consumption state in the country. The oil and gas industry in Texas consumes approximately 50% of the state's electricity. More vehicles are operated in Texas than every other state except CA, a key factor that has caused the transportation sector to become the largest in-state emitter of Nitrogen Oxides (NOx) and second largest for greenhouse gases (GHGs). Transportation accounts for 2/3 of these emissions in Texas' largest urban metropolitan areas, including Houston–Galveston–Brazoria, Dallas–Fort Worth, and San Antonio–Bexar County, and is primarily responsible for their ozone non-attainment designation.

Priority pollutants are responsible for various health ailments, including respiratory, heart and lung diseases, and premature deaths. Many scientists have concluded that GHGs are causing climate change and will result in catastrophic societal outcomes if GHGs are not substantially reduced. Objective polls show strong public support for actions that would reduce pollutants that have health and climate consequences. Government officials and corporate executives are increasingly embracing actions and technologies to reduce these emissions. In this report, we focus primarily on electric vehicles (EVs) because they are so far the most promising in technology readiness and environmental benefits.

Problem

The key challenge related to EVs is that the ecosystem has many stakeholders with split incentives and siloed information. Figure 1 illustrates the stakeholder groups in the ecosystem and their respective needs and challenges. Using the medium- and heavy-duty truck fleet segment as an example, electric truck (ET) deployments are difficult due to three factors:

1. The power grid dynamically changes with renewable generation investments with grid stakeholders as decision-makers and ET fleet deployment with transportation stakeholders as decision-makers, each with explicit cost and payback requirements.

2. The grid-fleet-manufacturer ecosystem consists of many-to-many relationships, resulting in mismatching operating regions across systems. For example, Oncor, a Texas utility, has 21,600 fleets with two or more vehicles in its service territory, whereas the FedEx Express fleet must work with more than 3,000 utilities in the United States. Public incentives are specific to a political jurisdiction with many utilities and fleets supplied by multiple truck manufacturers. The mismatches among territories make it difficult to define an optimization system boundary.

3. Real-world data are scarce and opaque for both grid and truck operations.

Because EV adoption requires complex changes in regulatory and business models, innovative research and development can play a pivotal role in orchestration and acceleration.

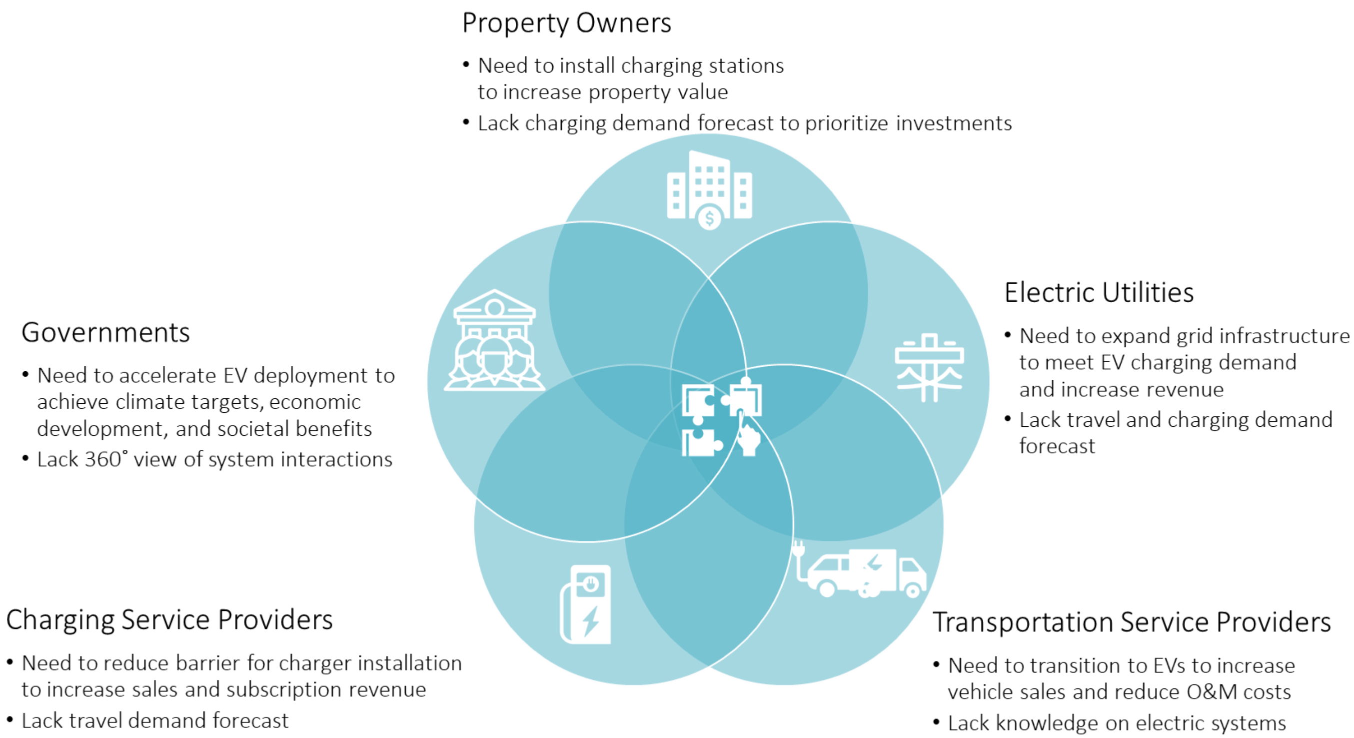

Figure 1. The e-mobility ecosystem.

Approach

To ensure that we gathered timely information about the rapidly changing e-mobility ecosystem, we conducted extensive market research through direct interactions with stakeholders within each stakeholder group. Many of these interactions were in-depth interviews. Other interactions involved attending presentations made by these stakeholders. In particular, we took systematic notes from the U.S. Department of Energy's "An EV Future"[1] workshop series. Below are sample customers from whom we have gathered insights:

- Governments:
  - Public Utility Commission of Texas.
  - Texas Commission on Environmental Quality.
  - California Air Resources Board.
  - U.S. Environmental Protection Agency.
- Electric utilities:
  - Exelon.
  - CenterPoint.
  - Pacific Gas & Electric.
  - Austin Energy.
  - Oncor.
  - CoServ.
- Property owners/managers:
  - IKEA.
  - Cap Metro.
- Charging service providers:
  - Electrify America.
  - Volta.
- Transportation service providers:
  - Fleets:
    - H-E-B.
    - PepsiCo.
  - Original equipment manufacturers:
    - Peterbilt.
    - Volvo.

[1] https://www.evplusgridworkshop.com/

Findings

The extensive stakeholder engagement process has revealed that EVs are feasible from a technology standpoint. In the light-duty vehicle sector, the rapidly increasing battery range that is commercially available is giving rise to aggressive market adoption projections and goals. The Biden Administration, for example, has set the goal of 50% EV sales by 2030.

Regarding medium- and heavy-duty vehicles, technological challenges still remain to reduce the cost and weight of the batteries and increase the range. The general sentiment is that medium-duty short-haul operations are going to electrify first, with depot charging. Long-haul trucking is still in question whether battery electric or hydrogen is more feasible.

In light of the technological feasibility of EVs, stakeholders are coming together to discuss issues they collectively face in the EV transition. The transportation electrification ecosystem consists of five customer groups:

- Government:
    - Municipalities.
    - State-wide entities: For example, in Texas, relevant agencies include the Public Utility Commission; Electric Reliability Council of Texas; Texas Department of Transportation; Texas Department of Licensing and Regulation; Texas Commission on Environmental Quality; Texas Department of Motor Vehicles; Texas Department of Housing and Community Affairs; Texas State Affordable Housing Corporation; Texas Division of Emergency Management; and Texas Economic Development and Tourism Office within the Office of the Governor.
    - Federal agencies.
- Electric utilities:
    - Generators.
    - Transmission and distribution system operators.
    - Retail electricity providers.
    - Vertically integrated utilities:
        - Municipal utilities.
        - Electric utility co-operatives.
        - Investor-owned utilities.
- Property owners/managers, such as apartment managers and retail chains.
- Charging service providers, such as ChargePoint, EVGo, and Greenlots.
- Transportation service providers:
    - Auto manufacturers, such as Tesla and Peterbilt.
    - Fleet owners:
        - Government fleets.
        - Public transit.
        - Goods movement, such as H-E-B, PepsiCo, and Jetco.
        - Uber and Lyft.

Research Gaps

Research Questions by Sector

Transportation Sector

- Percent and types of EVs in the fleet over time under different sales assumptions.
- When and where public charging needs will likely arise:
  - In urban and suburban areas.
  - Along major intercity corridors.
- Where to prioritize charging stations to:
  - Meet EV public charging demand.
  - Maximize air quality improvements.

Electric Power Sector

There is a set of EV-related questions for long-term system planning in the electric power sector. The questions concern the operational reliability of the electric grid under normal operating conditions. A few selected questions include:

- The energy and power demand under the EV penetration scenarios noted above.
- Time and place of charging, and the requisite grid infrastructure to support such charging.
- Potential impacts to the power system operations from several minutes to several days.
- Long-term investment requirements in the charging and grid infrastructure.
- Opportunity for EVs to be grid assets through optimized and coordinated charging (V1G) and vehicle to grid (V2G).

While it is important to simulate coupled infrastructure systems with a focus on minimizing costs or similar parameters or finding optimal charging strategies under normal operating conditions, one cannot neglect to investigate a variety of situations where one cannot always assume ideal charging behavior from consumers, especially in case of extreme events. Research on infrastructure resilience in an EV future is a critical need.

Research Questions by Vehicle Type

Light-Duty Vehicles

For light-duty vehicles, there is a rich body of literature on household passenger EVs in their daily travel. However, significant gaps remain such as:

- Where to place chargers for fleets, both regarding traditional fleets and shared vehicles such as Uber and Lyft.
- How to enable EV adoption at multi-unit dwellings.
- How to ensure an equitable EV transition for disadvantaged communities.

Medium- and Heavy-Duty Vehicles—Buses

Buses are a complex segment including transit, intercity, and school buses. Due to the public nature of transit and school buses, they tend to receive more attention regarding electrification. For example, the Metropolitan Transit Authority of Harris County (Houston METRO) recently announced[2] a goal to transition the urban area's entire

[2] https://uspirg.org/news/usp/houston-breathes-easier-metro-adopts-goal-all-electric-public-transit-over-next-decade

public transit fleet to zero-emission vehicles by 2030. Montgomery County, MD, plans to replace its fleet of more than 300 school buses with electric buses over the next four years[3].

Challenges remain to implement and scale these transitions. For transit buses, the operating schedules are such that buses have a very short refueling/charging window. This constraint means that transit buses need very high-power chargers, which, in turn, requires grid-side upgrades, which will take months, if not years, to plan, design, and build. School buses, on the other hand, tend to have more charging opportunities. Research is needed to investigate the potential for V2G applications such that school bus batteries can serve as grid assets.

Medium- and Heavy-Duty Vehicles—Trucks

Widespread truck electrification requires strategically planned public and private charging infrastructure. Among on-road vehicles, electric trucks provide the highest climate and environmental benefits. The 2014 National Emissions Inventory reported that heavy-duty on-road vehicles emitted 30% of mobile source black carbon, a heat-trapping pollutant, compared to 8% from light-duty on-road vehicles. Truck electrification also poses the biggest threat to the grid, due to its high, concentrated, and inflexible charging demand. According to Oncor, a Texas utility, a few customers electrifying only a few vehicles each simultaneously could overload substations; yet there are 21,600 fleets with two or more vehicles that operate in Oncor's service area.

No solutions currently exist to forecast truck charging demand for grid planning by funding several transportation-energy system simulation models. Traditional commercial travel models do not have energy components. Integrated urban models such as POLARIS and Behavior, Energy, Autonomy, and Mobility (BEAM) are not for state- or national-level analysis, which is required for freight corridor planning. National-level models such as Transportation Energy & Mobility Pathway Options and the Freight Analysis Framework are spatially resolved at the county level, which is not detailed enough for grid planning. Fine-grained truck charging demand forecast is challenging because truck data are scarce. Scaling urban models to regional and state levels is also cost prohibitive for data acquisition and technical development.

Action Plan

The electrification of the mobility system and a decarbonized, reliable, and resilient power grid are crucial elements in a sustainable and equitable future. Despite the rapid technological advances in grid, energy storage, vehicles, and transportation networks, the respective research communities and industry sectors remain siloed, resulting in the lack of integrated research and development and holistic testing and evaluation capabilities across disciplinary boundaries. Several stakeholders have taken the initiative to address this gap. For example, the U.S. Department of Energy announced close to $30 million of funding to advance research in batteries and electrification of vehicles in May of 2018[4]. The National Science Foundation has declared Convergence Research and Mid-scale Research Infrastructure as two of its 10 big ideas[5]. From the private sector, the integration of transportation to the grid is taking place in pilot form, as demonstrated by a recently announced partnership between eMotorWerks and LO3 Energy[6]. Observing such trends, it is imperative that the units within The Texas A&M University System anticipate the need for convergent research infrastructure to address the needs of private and public sponsors and strengthen the research community.

[3] https://news.montgomeryschoolsmd.org/staff-bulletin/mcps-replacing-326-diesel-school-buses-with-electric-buses-over-next-four-years/
[4] https://www.greencarcongress.com/2018/05/20180501-doe.html
[5] https://www.nsf.gov/news/special_reports/big_ideas/
[6] https://www.energycentral.com/news/emotorwerks-and-lo3-energy-partner-local-energy-trading-platform-between-electric-vehicles-and

Modeling and Simulation

Until recently, no software solutions existed to forecast EV charging demand for grid planning or to simultaneously optimize vehicle charging and grid asset management. The challenge arises from the requisite modeling scale to couple the largest machine ever built—the North American power grid—with the largest infrastructure project in American history—the interstate highway system—at sufficient spatio-temporal resolution. Traditional commercial travel models do not have energy components. Integrated urban models such as POLARIS and BEAM are not for state- or national-level analysis. National-level models such as Transportation Energy & Mobility Pathway Options and the Freight Analysis Framework are spatially resolved at the county level, too coarse for grid planning.

The ultimate vision is to build a comprehensive shared view between transportation and grid so that EVs truly become grid assets, adopted in an equitable fashion that minimizes societal costs. As such, we recommend the following activities to enhance simulation capabilities for the coupled infrastructure systems, especially in cases of extreme events and disasters:

- Creating coupled (synthetic) models of the two infrastructure networks.
- Developing simulation techniques and tools for these coupled models with appropriate methods adapted from each domain.
- Incorporating hazard analysis tailoring to these networks.

Once a co-simulation framework is in place, it can serve as the foundation of additional much-needed modeling efforts in emissions and health, including:

- Joint Mobile and Stationary Source Emissions Modeling.
- Integrated Energy, Emissions, and Health Assessment.

Figure **2** illustrates the transportation-grid co-simulation modeling framework.

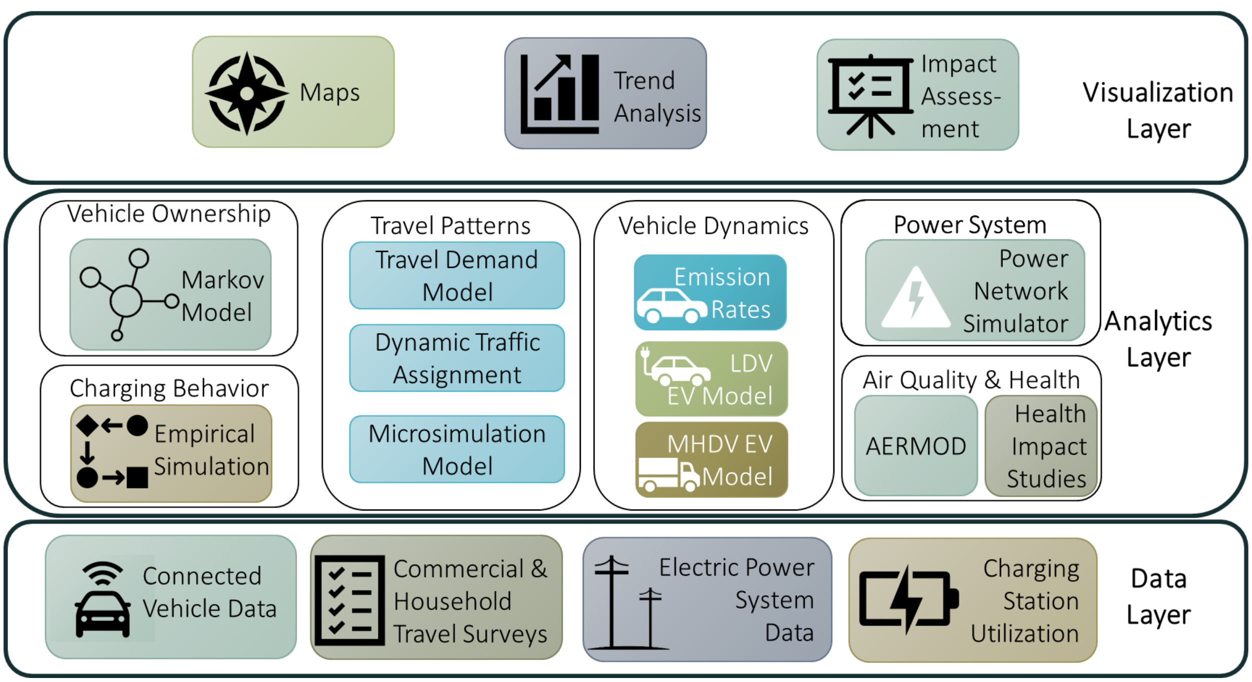

Figure 2. Envisioned transportation-grid co-simulation framework.

Testing and Measuring

From a hardware perspective, the key technological barriers that remain are mostly related to 1) medium- and heavy-duty vehicles and 2) vehicle and grid interaction at operational scale. As such, it is imperative to establish a state-of-the-art research facility for medium- and heavy-duty electric vehicle testing for:

- Vehicle performance.
- Vehicle-grid interaction.
- Off-grid configurations, such as microgrids.

Such a facility can be applied to various use cases as showcased in Table 1. At its core, such a testing environment allows:

- Commercial entities (e.g., electric utilities, fleet owners, technology startups, etc.) to research, develop, test, and evaluate new algorithms and software for EVs' integration with the grid.
- Policy makers to evaluate "what-if" scenarios associated with EV/grid integration to enable evidence-based decision-making.
- The public and corporations to understand personal and societal implications of vehicle choices such as vehicle purchase and energy storage/generation installations.

Table 1. Testing Facility Sample Use Cases

Use Case	Innovation Process*	Topic Area	Target Customers	Capabilities Utilized						
				Grid Model	Transp. Model	Chamber	Dyn0	Driving Simulator	Electricals	Air Instruments
Rapid prototyping of a blockchain marketplace for smart EV charging	R&D	Grid, Transportation	Electric Utilities	✓	✓		✓	✓	✓	
Evaluate grid vulnerability of cyber-attacks through EV charging	T&E	Cybersecurity, Grid, Transportation	U.S. Department of Homeland Security, U.S. Department of Energy	✓	✓				✓	
Demonstrate air quality and health benefits of EVs	TT&O	Transportation, Health	Consumers	✓	✓	✓	✓	✓	✓	✓

Note: *R&D: research and development; T&E: testing and evaluation; TT&O: tech transfer and outreach.