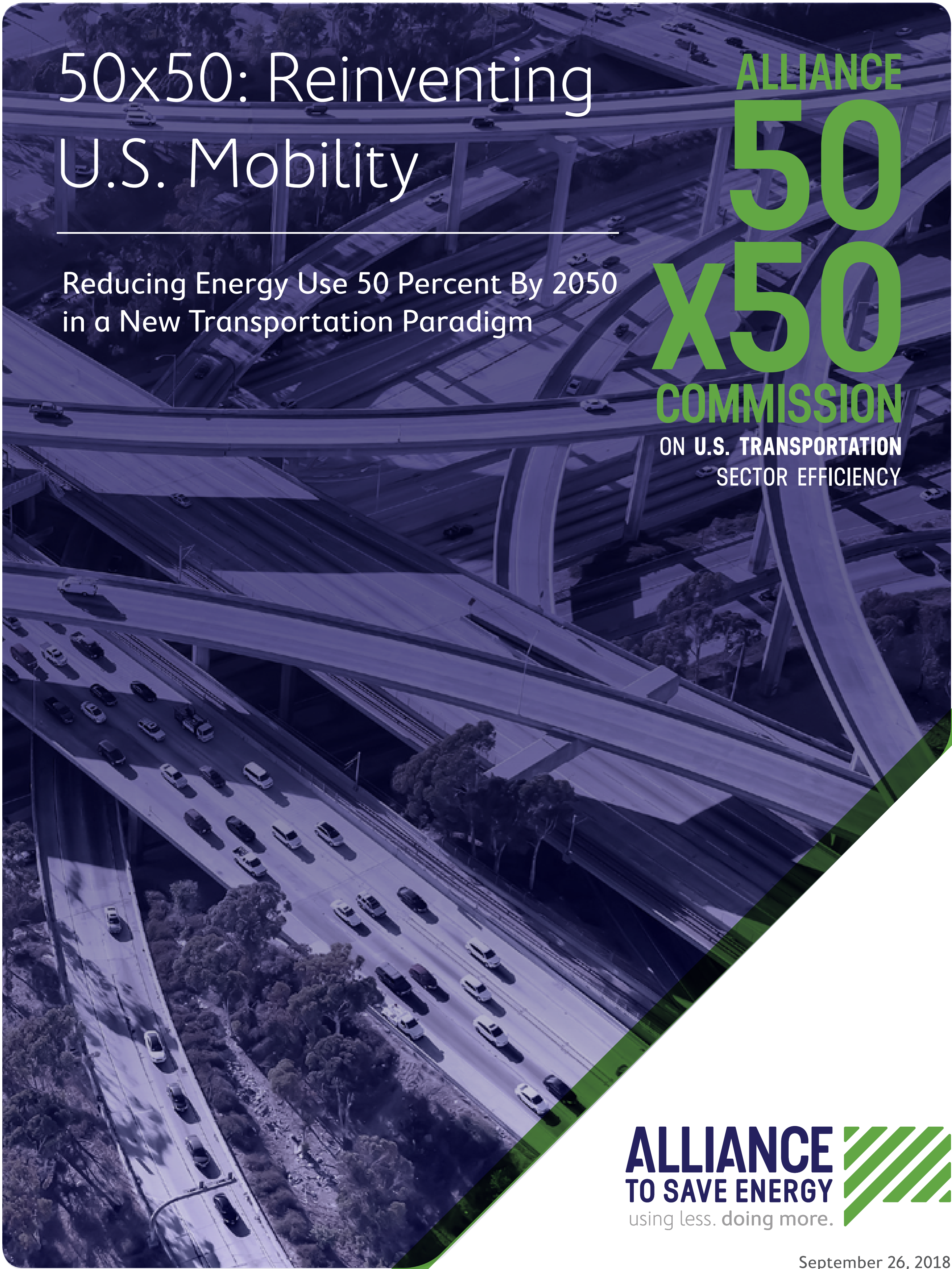

50x50: Reinventing U.S. Mobility

Reducing Energy Use 50 Percent By 2050
in a New Transportation Paradigm

ALLIANCE 50x50 COMMISSION
ON U.S. TRANSPORTATION
SECTOR EFFICIENCY

ALLIANCE
TO SAVE ENERGY
using less. doing more.

September 26, 2018

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EXECUTIVE SUMMARY

The United States transportation sector is on the verge of a major transformation. And with this transformation comes an opportunity to ensure energy efficiency is a cornerstone of mobility in the 21st century.

A confluence of new technologies, business models, and other innovations are rapidly emerging.

More efficient vehicle types, including electric vehicles, hybrids, and highly efficient vehicles running on renewable natural gas are emerging to serve different needs, ranging from cars to buses, heavy-duty trucks and other non-road vehicles like forklifts and cranes.

Advanced vehicle technologies, such as lightweighting, downspeed powertrains, aerodynamics, and anti-idle solutions are quickly integrating into all vehicle types.

Automation has the potential to enhance the efficiency of vehicle use and revolutionize the economics of mobility, especially when combined with ridesharing and electrification.

Information and communications technologies, including big data, artificial intelligence, and machine learning are quickly evolving to enable the dynamic integration of mobility, with positive impacts on public transportation, freight logistics, ride-hailing services, and bikesharing.

This technological revolution allows us to reinvent mobility for a smarter, more integrated system. It is also creating an urgent need to address energy consumption in the transportation sector, as these technologies could move energy use dramatically up or down depending on how the transformation unfolds.

If the public and private sectors work together to construct a new transportation paradigm that prioritizes energy efficiency, the opportunities for positive societal impacts – reduced dependency on oil, lower household transportation costs, reduced vehicle air pollution and greenhouse gas emissions, decreased traffic congestion, improved public transit systems, equality in mobility access, job growth, and American leadership in innovation – will be tremendous.

To capitalize on these unprecedented opportunities, the Alliance to Save Energy (the Alliance) convened the 50x50 Commission on U.S. Transportation Sector Efficiency (50x50 Commission), a partnership of public and private stakeholders including automakers, utilities, public interest groups, product manufacturers, and technology providers.

The 50x50 Commission articulated the goal to meet evolving transportation needs while reducing energy use 50 percent by 2050* – or, to put it simply, "50x50." This goal not only reduces energy use, but also drives co-benefits ranging from transportation affordability and environmental stewardship, to convenience and equity.

The 50x50 Commission worked for a year to identify the most impactful bipartisan policy solutions to move America toward achieving this goal. The result of their effort is "50x50: Reinventing U.S. Mobility," a set of consensus recommendations that urges the private sector and policymakers at all levels—local, state, and federal—to act in three key areas: transform, innovate, and invest.

**Relative to a 2016 baseline on a pump-to-wheel (PTW) basis, which includes the energy used in fueling and operating vehicles. While the goal is framed on a PTW basis to provide a clear foundation with extensive data availability and accountability, the Commission affirms that all steps forward should be consistent with a path that enhances energy productivity across the full lifecycle of fuel production, delivery, and use.*

TRANSFORM our sector into a more energy-efficient, integrated, coordinated, and modern transportation system.

Transportation Services Model: Transition toward an integrated "transportation services" model, where the most efficient transportation modes (e.g. public transit, rail, biking, and walking) are integrated into a system-wide approach with other vehicle options. This will require strengthening public transportation systems; enhancing freight system efficiencies; reducing passenger vehicle miles traveled; facilitating transitions among different transportation modes; and enhancing integrated systems at transportation hubs such as ports, airports, and distribution centers.

Address Barriers to Reaching 50x50: A system-wide approach will require multi-stakeholder coordination and technology development to address major uncertainties, especially for fast-evolving data and analytical capabilities and vehicle automation. Addressing inconsistencies across the U.S. policy and regulatory landscape that directly hinder the 50x50 goal is also imperative.

INNOVATE solutions to existing and future challenges.

Research, Development, Demonstration, and Deployment (RDD&D): Pursue federal and private RDD&D for a wide range of transportation innovations, while optimizing how it is performed and filling gaps in data collection.

INVEST in the foundation to get us there.

Enhance the Efficiency of All Vehicles: Support policies that improve the efficiency of all vehicle types, i.e., fuel economy standards, accelerating inefficient vehicle turnover, and encouraging interagency collaborations to advance key technologies.

Deploy More Efficient Vehicles: Incentivize the deployment of, and infrastructure for, vehicles that have enhanced energy efficiency relative to conventional vehicles, including plug-in electric vehicles, hybrid vehicles, hydrogen fuel cell vehicles, and highly efficient vehicles running on renewable natural gas. Also, redesign the Highway Trust Fund to balance the growth of key markets and the need for equitably-funded infrastructure investments.

Support Plug-In Electric Vehicle (PEV) Markets: Address key weaknesses in PEV markets through incentives to enhance deployment of PEVs and develop charging infrastructure, interoperability standards, a streamlined customer experience, and charging behaviors that increase efficient use of the energy grid.

Foster Equity and Jobs: Focus on creating equitable solutions that provide low-income, disabled, and other under-served consumers with access to the benefits of efficient vehicle markets and ensure a well-prepared workforce through the sector's transitions.

First Movers Matter: Affirm the importance of 'first movers' in governments and corporations as they lead by example and develop strategies that support the 50x50 goal.

The Commission's goal of reducing energy use in transportation 50 percent by 2050 is an aggressive, yet achievable, goal. Reinventing mobility is a worthy and necessary pursuit, with a litany of positive impacts on American consumers, businesses, and the environment. The recommendations outlined in this report provide the direction for federal, state, and local officials to make policy decisions that will chart our course to secure efficient, safe, clean, and improved mobility for all. If you are not yet part of the 50x50 initiative, please join us. By working together, we can make today's challenge of reinventing mobility tomorrow's reality.

NOTES

This report is a product of the Alliance 50x50 Commission on U.S. Transportation Sector Efficiency.

While the development of this work was consensus-based, it represents a collaborative approach among stakeholders from diverse sectors and perspectives. Consequently, this work is intended to highlight a shared path forward, and not every recommendation reflects the precise views of every institution.

Scope

The scope of the transportation sector addressed in this report includes all highway light-, medium-, and heavy-duty vehicles and non-road vehicles such as cranes, forklifts, shuttles, and airport ground support equipment. Marine and aviation vehicles (ships or planes), while critical contributors to the sector's energy consumption, were excluded, as they involve a different set of stakeholders and respond to a different regulatory and policy framework.

Definitions and Acronyms

Alternative Fuel Vehicle (AFV): a vehicle that has the capability to deploy a fuel other than traditional petroleum fuels (gasoline, diesel, and approved low-level biofuel blends with these fuels), including plug-in electric vehicles, fuel cell electric vehicles, natural gas, propane, and flex-fuel vehicles.

Annual Energy Outlook (AEO): the U.S. Energy Information Administration's report of annual modeled projections of domestic energy markets through 2050.

Battery Electric Vehicle (BEV): a type of electric vehicle that uses chemical energy stored in rechargeable battery packs to power an electric motor.

Direct Current Fast Charging (DCFC): a high-voltage charging station that allows for rapid charging of plug-in electric vehicles (often at 480 V).

Electric Vehicle (EV): a vehicle powered by an electric motor, including battery electric vehicles, plug-in hybrid electric vehicles, and fuel cell electric vehicles.

Electric Vehicle Supply Equipment (EVSE): the infrastructure that recharges an electric vehicle, also known as a charging station.

Enhanced Energy Efficiency Vehicle (E3V): a vehicle that uses energy more efficiently (measured in energy units per mile on a well-to-wheel basis) than its most energy-efficient conventional internal combustion engine equivalent when viewed over the full lifecycle of its energy production and use.

Flex Fuel Vehicle (FFV): a vehicle that can run on a broad array of alternative fuels or fuel blends with conventional fuels to power an internal combustion engine; typically uses biofuels such as ethanol or biodiesel.

Fuel Cell Electric Vehicle (FCEV): a type of electric vehicle that runs on hydrogen fuel, which is converted to electricity by a fuel cell to power an electric motor.

Greenhouse Gases (GHGs): gases (such as carbon dioxide, nitrous oxide, methane, ozone, and fluorocarbons) that absorb infrared radiation and radiate heat, leading to a warming effect on the earth and its atmosphere.

Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET® Model): a computation model developed by Argonne National Laboratory to perform well-to-wheel analysis of transportation vehicles based on a number of assumptions regarding the vehicle type, fuel type, and fuel production pathway.

Gross Vehicle Weight Rating (GVWR): the maximum operating weight of a vehicle, including the weight of passengers and/or cargo, as defined by the manufacturer.

Heavy-duty Vehicle (HDV): in the Federal Highway Administration definition, vehicles weighing over 26,001 lbs, including class 7 and class 8 long-haul trucks.

Hybrid Electric Vehicle (HEV): a vehicle powered by an internal combustion engine in combination with one or more electric motors. The electric motor portion runs on electricity generated from regenerative breaking and the internal combustion engine.

Information and Communication Technologies (ICT): the integration of telecommunications, computer systems, and any other software, middleware, storage, and audio-visual systems that enable users to access, store, transmit, and manipulate information, including the Internet, wireless networks, and other communication mediums.

Internal Combustion Engine (ICE) vehicle: a vehicle that typically runs on traditional petroleum fuels (including conventional gasoline, gasoline blended with low levels of ethanol, or conventional diesel, and conventional diesel blended with 5% biodiesel). The internal combustion engine operates by capturing energy from the combustion/burning of the fuel (through spark ignition or compression ignition).

Internet of Things (IoT): a network of items embedded with electronics, software, sensors, actuators, and connectivity which enables them to connect and exchange data, creating opportunities for more direct integration of the physical world into computer-based systems.

Light-duty Vehicle (LDV): vehicles weighing under 10,000 lbs (i.e., passenger cars, SUVs, light trucks).

Medium-duty Vehicle (MDV): vehicles weighing between 10,001-26,000 lbs, including class 3-6 vehicles.

Partial Zero-emission Vehicle (pZEV): a conventional ICE vehicle that has zero evaporative emissions, includes a 15-year or 150,000-mile warranty on the emissions system, and meets the Super Ultra Low Emission Vehicle exhaust emission standard.

Plug-in Electric Vehicle (PEV): a vehicle that has a rechargeable battery pack that powers its electric motor, and recharges by plugging in to a port connected to the electric grid. PEVs include both battery electric vehicles and plug-in hybrid electric vehicles.

Plug-in Hybrid Electric Vehicle (PHEV): a vehicle powered by an internal combustion engine in combination with an electric motor. The battery pack that powers the electric motor charges by plugging in to a port connected to the electric grid.

Power-to-Gas: the conversion of electrical power into a gaseous energy carrier, usually including an electrolytic process to produce hydrogen and/or natural gas. When synthetic gases are produced from this process using renewable power generation (e.g., wind, solar), they are often classified as renewable gases (e.g., renewable hydrogen, renewable natural gas). *See also Renewable Natural Gas.*

Pump-to-Wheel (PTW) Analysis: in vehicle lifecycle analysis, the analysis of energy, emissions, or other aspects of the downstream fuel use processes involved in the fueling and operation of the vehicle.

Renewable Fuel Standard (RFS): a federal program that requires transportation fuel sold in the U.S. to contain a minimum volume of renewable fuels, including conventional biofuel and advanced biofuel.

Renewable Natural Gas (RNG): According to the definition used by the U.S. Department of Energy, the gaseous byproduct of the decomposition of organic matter that has been processed for purity standards, which can be used as a transportation fuel in the form of compressed natural gas or liquefied natural gas. RNG has also been defined to include both biologically-derived natural gas and synthetic natural gas produced from renewable power-to-gas processes. *See also Power-to-Gas.*

Research, Development, Demonstration, and Deployment (RDD&D): a process by which an entity works to obtain new knowledge that it might use to create new technology, products, services, or systems.

Transportation Network Company (TNC): a company that arranges rides between passengers and drivers and provides these mobility services through a digital platform; usually via a website and/or mobile application ("app").

Vehicle Inventory and Use Survey (VIUS): survey conducted by the U.S. Census Bureau that collects data on the physical and operational characteristics of the U.S. truck population (including light-, medium-, and heavy-duty trucks).

Vehicle Miles Traveled (VMT): a measure of the amount of travel performed by a vehicle, usually in a specified geographic region over a specified period of time, typically over a one-year period.

Well-to-Pump (WTP) Analysis: in vehicle lifecycle analysis, the analysis of energy, emissions or other aspects of upstream processes including fuel extraction, production, refinement, and distribution of fuels.

Well-to-Wheel (WTW) Analysis: in vehicle lifecycle analysis, the analysis of energy, emissions or other aspects of full lifecycle processes including fuel extraction, production, refinement, and distribution of fuels, as well as their use in the operation of the vehicles (also known as the sum of the "well-to-pump" and "pump-to-wheel" aspects of the lifecycle).

Zero-emission Vehicle (ZEV): a vehicle that has no emissions from the onboard source of power.

Acronyms used for various U.S. Federal Government Agencies and National Laboratories include:

- Argonne National Laboratory (ANL)
- Energy Information Administration (EIA)
- Federal Aviation Administration (FAA)
- Federal Transit Administration (FTA)
- National Highway Traffic Safety Administration (NHTSA)
- National Renewable Energy Laboratory (NREL)
- U.S. Department of Commerce (DOC)
- U.S. Department of Defense (DOD)
- U.S. Department of Energy (DOE)
- U.S. Department of Transportation (DOT)
- U.S. Environmental Protection Agency (EPA)

INTRODUCTION

Current Trends

In 1917, New York's Bleeker Street retired its last horse-drawn trolley, one of the many milestones that marked the beginning of the automobile era. In the following 100 years, the automobile evolved into the backbone of American life. Throughout the century, few other forms of mobility have achieved the popularity and cultural impact of the internal combustion engine (ICE). But the current transportation system also has challenges, many of which have grown in recent decades, and may grow further in coming years. A selection of these challenges is highlighted in Box 1.

Box 1. A Selection of Transportation Challenges

- **High Expenditures:** Transportation expenditures have become the second greatest expense for the average American household, after housing, with the average annual cost of vehicle ownership reaching $8,500, or $705 per month.[1,2]
- **Increasing Vehicles and Congestion:** The number of cars and trucks on U.S. roads has risen from 188 million in 1990 to 260 million in 2016, leading to increases in energy use; congestion; degraded quality of highway infrastructure, requiring investment; and the dedication of significant real estate to parking and roads.[3,4,5,6]
- **Weakening Public Transit:** Defection from public transportation services is undermining a primary tool for equitable and affordable transportation access for low-income and disabled communities, as well as a key tool to manage urban congestion.[7,8]
- **Freight Energy:** Highway freight trucks (over 10,000 pounds gross vehicle weight rating (GVWR)) accounted for only 8 percent of the vehicle miles traveled (VMT), but consumed 25 percent of highway vehicle energy in 2016.[9] Freight and commercial truck (8,501-10,000 GVWR) travel demand is also expected to grow faster than any other highway transportation mode in the coming decades, increasing their VMT by more than 50 percent by 2050.[10]
- **Petroleum Dependence:** Petroleum products account for approximately 92 percent of transportation energy sources.[11] Petroleum fuel prices, while currently low, are historically volatile, with well-established negative economic consequences for families and the U.S. economy.[12,13,14]
- **Carbon Emissions:** In 2016, the transportation sector surpassed the electric power sector to become the greatest source of U.S. greenhouse gas (GHG) emissions.[15]

There was a time when solutions to many of these challenges weren't readily available. But today, approximately 100 years after the retirement of the Bleeker Street's last horse-drawn trolley, a variety of new tools are emerging that can enable a new caliber of solutions and are set to drive us into the next transformation.

Such tools include new technologies, business models, and innovations that are upending decades of assumptions around American preferences for personal mobility, optimal city design and freight routes, and the public policy that provides the sector's foundation.

Many intersecting trends are at play. U.S. demographics are shifting toward urbanization, with urban dwellers accounting for 82 percent of the U.S. population in 2017, compared to 70 percent in 1960.[16] Developments in information and communication technologies (ICT) open new possibilities to optimize when, where, and how people and freight reach their destinations. Transportation network companies (TNCs) such as Uber and Lyft are using these new tools to provide on-demand and shared-ride services, and they are increasingly serving as integrated cogs of the public transportation system.[17,18] Freight providers can design and deploy applications to optimize and synchronize movements along their routes and supply chains. Plug-in electric vehicle (PEV) sales continue to grow: there are now close to one million PEVs on the road in the U.S. and customers can choose from 20 all-electric and 33 plug-in hybrid electric vehicle (PHEV) models in U.S. markets.[19] A growing used PEV market is offering broader access to these technologies at lower prices.[20] In addition, electric transit buses have already gained a foothold: 9 percent of all public transit agencies either have electric buses in service or on order.[21] The need to address GHG emissions and air pollutants also has spurred innovations and created opportunities for vehicles running on electricity, hydrogen, or renewable natural gas (RNG). The popularity of bike-sharing is also growing quickly, with an estimated 35 million trips taken in 2017, an increase of 25 percent over 2016.[22] Finally, automation, especially when paired with electrification, may put several of these trends toward integrated systems into hyperdrive, generating extraordinary new levels of data, upending the sector's economics, and ratcheting up new customer expectations for convenience, access, affordability, and safety. These trends will likely have far-reaching effects across the sector, from personal mobility and freight to ports and distribution centers, which serve as key testing grounds to optimize the movement of goods and people.

A Call to Action

Society faces an exciting opportunity to secure efficient, safe, clean, and improved mobility for all. Unfortunately, it will not happen on its own—we must act now to perform the necessary changes that will unlock the potential and remove the barriers.

The policy and regulatory framework for transportation across the U.S. is—at best—complex, fragmented, and evolved from an older paradigm. At its worst, it is contradictory, confusing, and wasteful. Embracing the opportunity requires a national vision for the future, and a collaborative effort to design the regulatory and policy frameworks to deliver it.

If we passively let these trends unfold, we will lose an irreplaceable opportunity to guide the transformation of the transportation sector. If we go to the opposite extreme and try to control them in an inflexible and uncoordinated manner, we may undermine our ability to innovate and therefore inhibit the very markets that will move us forward. However, if we are able to work together to pursue a clear vision to reinvent mobility while using less energy, we could see enhanced access to mobility services, reduced lifetime transportation costs, enhanced economic prosperity, less reliance on imported petroleum resources, and a cleaner, less polluting transportation sector. Many other countries, from China to Norway, are harnessing these opportunities through forward-looking strategies that provide successful models – and creating a competitive urgency to ensure we remain leaders in this transition.

50x50

With so much at stake, what principles should define the path forward, and how should progress be measured? The transportation revolution will have impacts across society, the economy, and the environment, and while these impacts are diverse and seemingly unconnected, nearly all of them are closely tied to energy use. Energy consumption is the key enabler of mobility, but it is also the primary cause of most of its negative impacts, including household costs of vehicle ownership, the cost of doing business, volatility in our economic growth, and environmental degradation. **As a result, our objective can be represented simply through a single, broad concept: to enhance energy productivity – which can be described as the efficiency with which energy is converted into economic benefit for society.** Use energy more productively, and it generates greater prosperity, less pollution, and greater energy security. Use it less productively and our communities, economies, and environment suffer needlessly.[23]

With an eye to defining a future that maximizes our energy productivity, the Alliance Commission on U.S. Transportation Sector Efficiency has articulated a goal of reducing U.S. pump-to-wheel (PTW) energy use in the transportation sector 50 percent by 2050, relative to a 2016 baseline. Done right, reducing energy consumption will also enhance the very economic stimulants that have always driven U.S. prosperity in times of change: a clear vision, innovation, collaboration across public and private sectors, and the power of markets.

The "50x50" goal is framed to focus on PTW energy reduction—defined as the energy transferred to and consumed in the vehicles themselves—to ensure it can be supported, measured and monitored by public metrics and data, and to capture progress in not only enhancing the energy-efficiency of vehicles, but also avoiding unnecessary miles traveled.[a,24]

It is worth noting that defining 'energy use in transportation' is an exercise in nuance. Transportation energy includes not just the "PTW" use of the fuel in the vehicle, but also the "well-to-pump (WTP)" upstream production and distribution of those fuels. One can also include the energy involved in the manufacturing and disposal of the vehicles, their components, supporting infrastructure in their use and manufacture, and so on. However, the further upstream and the more indirect the impact, the more difficult these energy costs are to estimate without extensive – and at times contentious – assumptions. The 50x50 Commission has addressed this nuance by defining the goal on a PTW basis to drive our vision forward with transparency and accountability based on extensive public data. However, the 50x50 Commission also affirms the importance of complementing this approach with a recognition of upstream energy use. Just as a driver behind the wheel may focus his or her eyes on the horizon while absorbing the full context of the scene, the policy recommendations in this report identify opportunities to achieve the 50x50 goal in accordance with the best path to enhance energy productivity over the full lifecycle of fuel production, distribution, and use.

The Path Forward

This report articulates principles and concrete actions to begin our journey to the 50x50 goal, grouped into three areas:

TRANSFORM – Today's innovations provide a new opportunity to not only improve specific aspects of the transportation sector, but integrate its many services into a coordinated, optimized system with seamless transitions. Integration, however, will require creativity and coordination among a broad array of stakeholders, including federal, state, and local governments; automakers; utilities; technology companies; and public interest organizations. It will also require greater clarity around wild-card uncertainties, like new data and analytical capabilities and automation.

INNOVATE – Innovation defines the breadth of our creativity and the range of our future opportunities, and at times of transformation it is a necessity. Advancing our understanding of automation, alternative fuel vehicles (AFVs) and their infrastructure, and potential 'game changing' technologies will require public and private research, development, demonstration, and deployment (RDD&D) supported by robust data resources. The governance of innovation is also important to ensure that the best solutions are productively applied.

INVEST – Reaching the 50x50 goal will not be possible without investing in a strong foundation to make this vision a reality. It includes enhancing the efficiency and availability of improved vehicles and incentivizing their purchase; developing alternative fuels and their transport, distribution, and fueling infrastructure; and optimizing transit and city planning. Such investments, which can be long-term and capital-intensive, are necessary to reach the tipping point where emerging efficiency technologies are driven by markets. There are critical roles for both public and private sector leaders to reach this point.

By **transforming** the transportation sector to use resources more efficiently while delivering better services to customers, **innovating** new technologies to advance our vision, and **investing** in the foundation that will make such a future possible, we will harness an engine of American economic growth and security, while creating leaps forward for the environment and quality of life for all.

a A key opportunity to enhance the energy productivity of transportation is to reduce the number of unnecessary miles traveled overall. This can be accomplished through shifts to active modes (walking, biking), increasing the number of passengers per vehicle, or reducing the need to travel altogether (e.g., telework, urban design).

TRANSFORM

TRANSFORM

Findings Summary

Finding 1: Efficiency gains can be achieved at the system level by maximizing the use of the most efficient transportation modes in personal mobility and freight transit.

- Recommendation 1.1 Enhance Public Transit
- Recommendation 1.2 Design Policies and City/Commuter Travel Plans to Optimize Passenger Travel
- Recommendation 1.3 Smooth Transitions Among Modes by Supporting Mobility Marketplaces
- Recommendation 1.4 Support Freight System Efficiency
- Recommendation 1.5 Support New Opportunities for Energy Efficiency at Ports

Finding 2: Transitioning to a "Transportation Services" model can bring a new level of energy efficiency opportunities, as well as integrated and improved services.

- Recommendation 2.1 Support Public-Private Partnerships to Articulate a Vision for Big Data and Beyond
- Recommendation 2.2 Work Together to Clarify an Automated Future

Finding 3: Policy inconsistency is a barrier to achieving the 50x50 Goal.

- Recommendation 3.1 Establish a Dialogue to Strive for Policy Consistency Towards 50x50

Moving Toward an Integrated Transportation Services Model

Enhancing the energy efficiency of transportation requires meeting two objectives: delivering the best-quality experience for the consumer, and providing that service in the most efficient and cost-effective way.

What do consumers need? While there is great diversity across the U.S. regarding how consumers use transportation services, in the light-duty sector, most trips taken are relatively short: studies show only 5 percent of all drivers travel more than 30 miles per day on average, and 58 percent travel fewer than five miles per day.[25] In the heavy-duty sector, there is diversity as well: trucking often requires long-distance travel, while "last-mile delivery" services, refuse trucks, and school buses tend to operate in smaller territories. Across the board, however, there are common consumer requirements: affordability, reliability, and convenience.

What is the most efficient way to meet these needs? The energy efficiency of specific transportation modes (e.g., trains, cars, trucks, buses) varies widely based on the technology and usage. For the most part, freight rail, public transportation options, and so-called 'active modes' (e.g., walking and biking) are the most energy-efficient in terms of the energy required to move one passenger or ton of freight a specific distance.[26] However, these modes are not always the most attractive to consumers. For example, many transit services have been criticized for a lack of reliability and consistency, sometimes leading to a vicious cycle – the "Transit Death Spiral" – of low ridership, budget shortfalls, and worsening service.[27,28,29] Additionally, a number of U.S. cities have only just begun investment in biking and walking paths, which are critical for the popularity of these options.[30,31] In freight transportation, barriers to the greater use of rail – a more efficient transportation mode per ton-mile than trucks – include congestion on freight rail corridors, the high costs of rail infrastructure, and a business model that tends to be less flexible and rely on longer asset lifetimes.[32,33,34,35]

For decades, conventional cars and trucks have won out as the most popular mode of transportation. In the U.S. in 2016, three trillion passenger-miles were traveled by passenger cars, while 50 times fewer—57 billion—were traveled by all transit options combined.[36] For many consumers, the costs of vehicle ownership and maintenance (estimated at approximately $8,500 per year in 2017), safety risks, and environmental impacts have been a necessary price to pay in exchange for the freedom of personal mobility.[37]

However, this formula may shift if other options become more competitive. Traffic congestion has increased across the country, and the average American driver experiences more driving inconveniences, such as spending an average of 41 hours stuck in peak traffic and 17 hours finding parking each year.[38,39,40,41] Transportation has also risen to the second-highest household expenditure (after housing).[42] And while energy prices remain at record low levels of approximately $70 per barrel, extensive historical precedent reaffirms that oil prices are volatile and consumers tend to respond to higher oil prices by reducing driving and preferring more efficient vehicle.[43,44] From the city perspective, vehicles also require costly real estate—the U.S. hosts one billion parking spaces (approximately four for every car) across the country, and informal estimates suggest that downtown areas of American cities devote 50-60 percent of city surface area to vehicles, which could otherwise be spent on other uses.[45,46] It is also valuable to note that transportation services tend to have significant impacts on development patterns—as a result, establishing strong and well-designed public transportation networks could bring could bring greater prosperity to urban areas.[47]

Big Data, the Cloud, the Internet of Things, Artificial Intelligence, and Beyond

One of the key challenges for these highly efficient transportation modes is their lack of integration: a passenger moving from car to train to bicycle may require long wait times, long walks, and a different payment mechanism for each step. However, a variety of evolving and cross-fertilizing innovations in ICT, including Big Data, the Cloud, artificial intelligence and machine learning, and the internet of things (IoT), could connect and coordinate these systems by enabling the dynamic collection and analysis of new data streams. Further, the ability to translate those real-time data streams into insights allows for increasingly sophisticated optimizations—and even predictive solutions—for asset management, traffic, infrastructure investments, and supply chains, all while providing an increasingly convenient experience to the customer.[48,49]

These tools are already giving collective transportation options (such as public transportation, ridesharing, and ride-hailing) a more competitive advantage by improving their convenience and providing greater integration of multiple options into an optimized and seamlessly-connected service. The potential opportunities based on these evolving capabilities are enormous, for example:

- Bus services could be right-sized to the number of riders and weather conditions;
- Greater connectivity between passengers and transportation alternatives could enable more accurate predictions of customer demand and facilitate better coordination;
- Commuters could hop from personal car to a train, bus, or a shared bicycle/scooter with ease, safety, and security;
- Truck drivers could pre-reserve city parking and unloading spots to avoid hours spent 'circling the block' or stalling the flow of traffic when double-parked;
- Utilities and policymakers could better understand where to place PEV charging stations and which type to deploy;
- Automated on-demand fleets, especially when electrified and optimally shared, could enhance the efficiency and convenience of automotive transportation and fill critical gaps between existing transit options. Such services could also lead to decreases in urban traffic congestion.[50]

In an integrated system, familiar inconveniences such as waiting for a bus, looking for parking, or becoming stranded at a train station could become a thing of the past, and the Transportation Services model could convert a vicious cycle to a virtuous one that improves quality of life for travelers and city dwellers alike. Public transportation systems could be a key beneficiary, with significant benefits for society writ-large, and especially low-income communities that typically have a greater reliance on such services.[51] And while this report focuses on mobility as a societal good, it is worth noting that teleworking, the co-location of residential areas and workplaces, and a variety of other urban design options also have helped enable 'the trip not taken,' which is often considered the most desirable trip of all, and which can enhance mobility for other customers by reducing congestion.[52,53]

Parallel opportunities exist in the freight sector, where data capabilities can optimize the capacity of freight vehicles and avoid 'empty miles.'[54] In urban areas as well as on highways, truck speeds have been decreasing with increased congestion; U.S. Department of Transportation (DOT) projects that, without additional network capacity, increases in truck and passenger VMT will extend "recurring peak-period congestion" from 8 percent to 35 percent of the national highway system from 2012-2045.[55] Transportation hubs such as airports, seaports, and distribution centers – where people and freight movements are blended in complex, time-sensitive environments – present a clear business case and ideal testing ground for Transportation Services models.[56]

However, these data and analytical tools are still emerging and characterized by uncertainties, including which stakeholders should have the ability to generate, own, and/or access the data, and how to keep it safe and secure in an era of cyberthreats.[57]

Automation

Automation is another wildcard for the U.S. regulatory framework, as it could lead to more efficient driving (e.g., "platooning" in the trucking industry and smoothing congestion behaviors in light-duty fleets) and greater deployment of shared ride services.[58,59] However, it could also result in massive increases in VMT, especially for personal travel, as vehicle owners can cheaply send vehicles on errands or summon them over long distances. Studies have suggested automation's energy impacts could range from energy savings of 60 percent to energy increases of 300 percent depending on technological, policy, and behavioral variables.[60] Achieving greater clarity on the impacts of these technologies will require cross-sectoral collaboration to understand the scale and scope of the challenges, and to identify and implement solutions.[61]

Finding 1: Efficiency gains can be achieved at the system level by maximizing the use of the most efficient transportation modes in personal mobility and freight transit.[62]

- **Recommendation 1.1**
  Enhance Public Transit: Governments at all levels should work to enhance the impact, effectiveness, affordability, and attractiveness of public transit systems by optimizing their design, customer service and maintenance, performance and reliability, as well as sustaining/appropriating funding for their development and operation. This includes providing support for public transportation services (e.g., metro rail, bus, shuttles) and investing in bike lanes and pedestrian walkways, especially those with physical separation from vehicle roads.

- **Recommendation 1.2**
  Design Policies and City and Commuter Travel Plans to Optimize Passenger Travel: Consistent with their geographical and demographic needs and context, cities should work to optimize overall VMTs —especially per passenger—to reduce overall energy use, congestion, and air pollution; enhance affordable transportation access for all, especially low-income communities; and optimize the use of city spaces. They can achieve this through 1) coordinated planning of public transportation, shared mobility, land use (e.g., curb access), and active modes (e.g., bike rentals, biking/walking paths) to ensure comprehensive and affordable transportation services with convenient "transfers"; and 2) policies that encourage the use of the most energy-efficient modes, through options such as high-occupancy vehicle (HOV) lane access on commuter routes or the development of biking/walking paths.

- **Recommendation 1.3**
  Smooth Transitions Among Modes by Supporting Mobility Marketplaces: State and local governments should support the private sector in developing "mobility marketplaces"—mobile applications that allow users to find and pay for a range of transportation options in real time and in one place (e.g., integrated wayfinding, integrated payment solutions), while prioritizing low-energy or high energy-efficiency modes (e.g., walking, biking, and public transit).

Recommendation 1.4

Support Freight System Efficiency: The private sector and federal, state, and local governments should work together to enhance system-wide efficiencies that reduce energy consumption in the freight sector. Options include establishing a Freight Clearinghouse to enhance the load occupancy of vehicles and reduce "deadheading;" establishing multimodal freight centers to facilitate the most efficient and affordable mode choice (e.g., among class 8 trucks, rail, last-mile delivery options); and developing freight efficiency corridors to ensure freight routes support the needs of maximally efficient freight vehicles, reduce congestion, and reduce energy waste.[b]

Recommendation 1.5

Support New Opportunities for Energy Efficiency at Ports: Ports and transit hubs represent integrated systems of transportation services that have the potential to make significant improvements in energy efficiency and serve as a model for cities and states exploring system-wide approaches.[63] Congress should leverage this leadership at airports, seaports, inland ports, and other logistics and transit hubs by expanding funding for programs that provide grants and loans for projects that drive the development and deployment of energy-efficient practices and technologies; examples include highly-efficient vehicle acquisitions, the development of alternative fueling infrastructure, the energy-efficient use of automation, and shore power. Relevant programs include authorizations for the Voluntary Airport Low Emissions (VALE) grants, the Zero Emissions Program, the Federal Transit Administration (FTA) "No-Low" program, the Federal Aviation Administration's (FAA's) Airport Improvement program, and Airport Environmental Program grants.

Finding 2: Transitioning to a "Transportation Services" model can bring a new level of integrated, improved, and energy-efficient transportation services.[64,65,66] Doing so requires us to define and clarify certain foundational aspects for such a transition.

Recommendation 2.1

Support Public-Private Partnerships to Articulate a Vision for Big Data and Beyond: Congress and the federal government agencies—including the DOT, the Department of Energy (DOE), the Department of Commerce (DOC), and the Department of Defense (DOD)—should work with the private sector to explore the role of fast-growing data and analytical capabilities in the future transportation paradigm. This effort would need to address several interrelated topics, including the beneficial uses of data to enhance transportation sector efficiency; how to protect data privacy and security (including cybersecurity); the development of common standardized data platforms that could be used by all vehicles; and clearer definitions relating to how data are owned, managed, and shared among private parties, governments, and the public. If deployed appropriately, these partnerships could provide guidance on smart city data architectures to enable energy efficiency; greater resources for electric utilities and municipalities for planning purposes (e.g., EV charging locations and use, parking, transit options); and opportunities for the private sector to streamline personal and freight travel.

Recommendation 2.2

Work Together to Clarify an Automated Future: Given the enormous policy uncertainty and regulatory complexity surrounding automated vehicles, a stakeholder group should be formed to establish a dialogue to clarify the regulatory framework for automated vehicles.[67] This effort should include federal agencies – including the National Highway Traffic Safety Administration (NHTSA), DOT, U.S. Environmental Protection Agency (EPA), and DOE – as well as state and local governments, industry, and public interest groups. The group should develop a holistic set of principles and policy goals to ensure the regulatory framework is well-designed, clear, and consistent; that innovation can proceed nimbly and effectively; that vehicles are ultimately deployed energy efficiently (both in terms of vehicle efficiency and with optimal levels of occupancy) and safely; and that automation supports positive impacts for the environment and transportation access.

b "Deadheading" describes the situation when a vehicle, such as a class 8 truck, is pulling an empty trailer without cargo.

Finding 3: Strive for Policy Consistency at All Levels to Address Barriers to the 50x50 Goal: A number of the 50x50 Commissioners and Technical Committee participants commented on the difficulties presented by policy inconsistency – for example, where policies incentivize contradictory pathways, use incompatible metrics, lack consistent compliance mechanisms, or directly conflict with one another in such a way as to undermine our path to the 50x50 goal. We should strive to address such issues and support a more streamlined policy framework that delivers clarity to all stakeholders while allowing for differences in each market to spur innovation or to meet specific needs.

Recommendation 3.1

Establish a Dialogue to Strive For Policy Consistency Towards 50x50: Federal, state, and local government representatives, as well as other public and private sector stakeholders, should establish a dialogue to identify inconsistent or conflicting policies that inhibit our path to the 50x50 goal and explore collaborative solutions to address them.

INNOVATE

INNOVATE

Findings Summary

Finding 4: The United States' leadership in innovation and RDD&D has led to many of the technologies and innovations that are driving today's transformation, and will become increasingly important in the coming decades.

- Recommendation 4.1 Research New Mobility
- Recommendation 4.2 Enhance Fuel Economy
- Recommendation 4.3 Support Development of Electric Vehicles (EVs)
- Recommendation 4.4 Drive Infrastructure Development
- Recommendation 4.5 Support Advancements in Emerging Carbon-Neutral Fuel Technologies
- Recommendation 4.6 Understand Consumer Behaviors

Finding 5: The structure and design of RDD&D could be optimized for deeper impact.

- Recommendation 5.1 Promote Public-Private Partnerships
- Recommendation 5.2 Strengthen Inter-Agency Collaboration on RDD&D
- Recommendation 5.3 Define Better Mobility Metrics

Finding 6: Close transportation data gaps.

- Recommendation 6.1 Update the Vehicle and Inventory Use Survey (VIUS)
- Recommendation 6.2 Collect Data on Household Mobility
- Recommendation 6.3 Collect Data for Transportation Hubs
- Recommendation 6.4 Incorporate Well-to-Wheel (WTW) Analysis in the Annual Energy Outlook (AEO)
- Recommendation 6.5 Expand Research in Medium-duty and Heavy-duty Vehicles (MDVs/HDVs)

Leading through RDD&D

Innovation by public and private stakeholders stretches the boundaries of our ability to transform the transportation sector. RDD&D gives us tools to make pragmatic improvements or create game changers.[68] The dazzling opportunities we have today are the result of decades of innovation, and as we navigate the path forward, RDD&D will remain critical for developing and supporting emerging technologies, business models, and behavioral models to enhance the efficiency of the sector.[69]

Finding 4: The United States' leadership in innovation and RDD&D has led to many of the technologies and innovations that are driving today's transformation, and will become increasingly important in the coming decades.

The U.S. should continue to prioritize its leadership in innovation and RDD&D to address the full range of transportation opportunities. Sufficient and appropriate funding should be maintained, additionally appropriated, and/or otherwise prioritized by Congress, for the DOE, (within the Energy Efficiency and Renewable Energy Office and the Vehicle Technologies Office), EPA (Office of Transportation and Air Quality and the National Vehicle and Fuel

Emissions Laboratory), DOT, DOD, and the DOC's National Institute of Standards and Technology (NIST), as well as the National Laboratories, in the following key research areas:

- **Recommendation 4.1**
  Research New Mobility: Additional research at all levels—from technology development and consumer experience and behaviors to proof-of-concept and demonstration projects—should be supported to better understand how to safely and fairly integrate EVs, automation, and shared mobility into a new, energy-efficient transportation paradigm together with transit, biking, walking, and improved land use.

- **Recommendation 4.2**
  Enhance Fuel Economy: Congress and the federal agencies, in collaboration with private industry, should continue RDD&D on conventional vehicles (of all vehicle classes) to develop new and affordable technologies (e.g., lightweight materials and advanced drivetrain components, variable and high compression engines) that improve vehicle fuel economy.

- **Recommendation 4.3**
  Support Development of PEVs: Battery electric vehicles (BEVs), where available for a specific vehicle class, are currently estimated to be the most efficient vehicle type on the market on both PTW and WTW bases, usually by a significant margin.[70,71,72] As such, their extensive deployment is critical to enhance the sector's energy efficiency and achieve the 50x50 goal.[73,74] Congress and the federal agencies should continue to prioritize RDD&D to enhance these technologies, their performance, and deployment.

- **Recommendation 4.4**
  Drive Infrastructure Development: Fuel production, transport, and distribution infrastructure can be as important an enabler for AFVs as the vehicles themselves. Congress and the federal agencies should assess needs for enabling infrastructure for AFVs and business models to advance infrastructure development.

- **Recommendation 4.5**
  Support Advancements in Emerging Carbon-Neutral Fuel Technologies: Ongoing research and pilot studies have demonstrated that it is technologically feasible to produce fuels with attributes similar to conventional fuels—such as gasoline or natural gas—through zero-carbon, highly energy-efficient mechanisms.[75,76] Making these technologies more widely available and affordable would provide opportunities for rapid improvements in the transportation system while leveraging our existing energy delivery infrastructure assets. Congress and the federal agencies should prioritize RDD&D to improve the economics and performance of these advanced technologies, together with their deployment to maximize the achievement of the 50x50 Commission's goal.

- **Recommendation 4.6**
  Understand Consumer Behaviors: Carry out research on consumer behaviors that could enhance transportation sector efficiency (e.g., preferences for AFVs, more efficient driving behaviors, ridesharing, mode shifting).

Finding 5: The structure and design of RDD&D could be optimized for deeper impact. While U.S. RDD&D is among the best in the world, there are opportunities to optimize its structure.[77,78,79] This includes enhancing collaboration with the private sector and within federal government agencies for development and deployment, and establishing stronger metrics to track progress.

- **Recommendation 5.1**
  Promote Public-Private Partnerships: Collaborative pre-competitive and continuing research efforts between government and industry should be pursued and encouraged. Specifically, public-private partnerships should play a key role in government efforts to stimulate research into market-transformational efficient transportation technologies.

Recommendation 5.2

Strengthen Inter-Agency Collaboration on RDD&D: Federal government inter-agency collaboration is important and should be pursued with greater regularity. As such, the federal government should perform more cost-driven and goal-oriented collaborative projects to leverage the specific RDD&D capabilities and expertise of each agency and identify robust solutions. Wherever possible, federal agencies should utilize well-established collaboration mechanisms such as the US DRIVE and 21st Century Truck Partnership to achieve this enhanced collaboration.

Recommendation 5.3

Define Better Mobility Metrics: While many sectors can measure their primary outputs with a single metric (kilowatt-hour (kWh), quantity of a product, or number of jobs), the diverse outputs and value streams of the transportation sector make the definition of such metrics challenging. The administration should direct federal government agencies to develop clear, standardized metrics to measure progress in energy consumption, safety, economic impact, environmental impact, and impacts of mobility services provided (including by TNCs), establishing a common language for progress assessment and target-setting within and beyond the federal government.

Finding 6: Close Transportation Data Gaps: Progress requires a clear understanding of the challenges facing the U.S. transportation sector and which solutions can deliver the most positive impact. However, the sector has significant data gaps that inhibit these assessments.[80] Congress and the administration should close these data gaps, including:

Recommendation 6.1

Update VIUS: The DOT and/or Census Bureau and DOE should be required to regularly update the VIUS (last published in 2002) and modernize and enhance the availability of data on all passenger and freight vehicle classes.

Recommendation 6.2

Collect Data on Household Mobility: The DOT and/or Census Bureau should close gaps on key data regarding household expenditures on transportation, mode choices, and VMT.

Recommendation 6.3

Collect Data for Transportation Hubs: The DOT should collect and publish detailed data on energy use at transportation hubs (airports, seaports, distribution centers), including the energy use of electrified functions and associated classes of non-road vehicles (e.g., forklifts, cranes, conveyers, ground support equipment, shuttles), as well as the impacts of automation.

Recommendation 6.4

Incorporate WTW Analysis in the AEO: The Energy Information Administration (EIA) should incorporate WTW analysis, PTW analysis, in the transportation module for the AEO.

Recommendation 6.5

Expand Research in MDV/HDVs: The administration should enhance research efforts relating to non-light-duty vehicle (LDV) classes.

INVEST

Findings Summary

Finding 7: Vehicles should be operated more efficiently across all vehicle classes.

- Recommendation 7.1 Facilitate Critical Efficiency Technologies

Finding 8: Vehicle efficiency should be enhanced across the full U.S. vehicle stock.

- Recommendation 8.1 Strengthen Fuel Economy/Emissions Standards
- Recommendation 8.2 Accelerate Inefficient Fleet Turnover
- Recommendation 8.3 Improve Interagency Collaboration to Reduce Regulatory Barriers to Key Technologies

Finding 9: Enhanced Energy Efficiency Vehicles (E3Vs) constitute a class of vehicles that provide a significant improvement in energy efficiency and should be extensively deployed.

- Recommendation 9.1 Enhance E3V Deployments Broadly
- Recommendation 9.2 Establish Non-Purchase Incentives for E3Vs
- Recommendation 9.3 Establish MDV/HDV Purchase Incentives

Finding 10: Infrastructure investments are critical to facilitate E3V deployments.

- Recommendation 10.1 Support the 30C Tax Credit
- Recommendation 10.2 Develop Public Hubs for Fleet Refueling/Charging
- Recommendation 10.3 Provide Grants for Infrastructure for MDV/HDV E3Vs

Finding 11: Utilities play a key role in infrastructure investments.

- Recommendation 11.1 Enhance Utility Role in Charging/Refueling Investments

Finding 12: RNG can be utilized for benefit in vehicles and power.

- Recommendation 12.1 Recognize Benefits of RNG
- Recommendation 12.2 Collectively Work on RNG Gas Quality Standards
- Recommendation 12.3 Recognize Benefits of Electricity from RNG

Finding 13: The Highway Trust Fund requires a change in design to ensure sufficient funding without hindering the path to 50x50.

- Recommendation 13.1 Adjust the Design of the Highway Trust Fund

Finding 14: The Qualified Plug-In Electric Vehicle Tax Credit is critical as a tool to consistently drive PEV markets over the near- and long-term.

- Recommendation 14.1 Change the Automaker Vehicle Sales Cap Under the Qualified Plug-in Electric Vehicle Federal Tax Credit to an Industry-Wide Market Penetration Phase-Out
- Recommendation 14.2 Convert the Qualified Plug-in Electric Vehicle Federal Tax Credit to a Point-of-Sale Incentive

Finding 15: Electricity is not consistently treated as a fuel in federal policies.

- Recommendation 15.1 Include Electricity in the Alternative Fuel Tax Credit

Finding 16: Integrating PEV charging infrastructure into homes and workplaces will support PEV markets.

- Recommendation 16.1 Develop Model Building Codes for Charging
- Recommendation 16.2 Incentivize Workplace EVSE

Finding 17: Markets should provide a seamless PEV charging experience for customers.

- Recommendation 17.1 Standardize the Customer Experience (e.g. universal credit card payments, open access to stations without a membership)
- Recommendation 17.2 Collaborate Toward Hardware Standardization
- Recommendation 17.3 Develop Direct Current Fast Charging (DCFC) Adaptors to Facilitate Interoperable Charging

Finding 18: Utilities and other stakeholders should plan for the future needs of the grid.

- Recommendation 18.1 Plan for Off-Peak and Managed Charging

Finding 19: The 50x50 goal is an opportunity to rewrite the status quo on transportation equity.

- Recommendation 19.1 Support Research on AFV Integration into Low-income Communities

Finding 20: Electrification strategies can be designed to optimize equity.

- Recommendation 20.1 Ensure Affordable and Accessible Charging

Finding 21: Labor markets may undergo significant changes over the course of this transformation, which presents an opportunity to plan for and develop the workforce of the future.

- Recommendation 21.1 Research Workforce Impacts
- Recommendation 21.2 Provide Workforce Training and Certification
- Recommendation 21.3 Offer Retraining for Displaced Workers

Finding 22: Leadership by corporate and government first-movers drives action.

- Recommendation 22.1 Federal, State, and Local Governments Should Demonstrate Leadership for Fleet Efficiency
- Recommendation 22.2 Enhance Corporate Leadership in Deploying and Fueling Energy-Efficient Fleets
- Recommendation 22.3 Enhance Corporate Leadership for HDV/MDV Fleet Management

While transformation and innovation open opportunities to engineer benefits at the system level, it is also critical to improve the sector's backbone: the vehicles themselves, and the infrastructure that enables their use. This is an area that is primarily challenged by inertia.[81,82] Raising the efficiency of U.S. vehicle stocks across the board requires the urgent advancement of markets for the most efficient vehicle types and the comprehensive application of best practices (fuel economy, operation, maintenance, and end-use) throughout the sector.[83] Significant long-term investments are required to underpin these options— enhancing the efficiency and availability of the vehicles and vehicle technologies, fuel production, transport, distribution, and retail infrastructure.[84] This is a responsibility that has been, and must continue to be shared among the private and public sectors.

Enhance the Energy Efficiency of the Full U.S. Vehicle Stock

In 2016, the U.S. had approximately 260 million highway-rated vehicles on the road, 97 percent of which were ICE vehicles running on conventional petroleum-based fuel.[85,86] To maximize the efficiency of this base stock, it is important to ensure these vehicles: 1) are appropriately operated and maintained; 2) turn over after an appropriate useful life; and 3) have high fuel economy.

The average age of LDVs on U.S. roads has risen from 8.4 years in 1995 to 11.6 years today, and IHS Markit estimates that the volume of vehicles that are 12 years or older will grow 10 percent by 2021.[87] This trend of aging of vehicle stocks is present for HDVs, too: the number of trucks (classes 3-8) in operation that were 15 years or older rose from 15 percent to 21 percent of vehicle stocks from 1970 to 2013.[88] Slow turnover rates keep outdated vehicles on roads for longer, and slows the adoption of improved vehicles to the scale of decades. In contrast, policies that encourage faster turnover of private vehicles and fleets can yield significant energy savings.[c] There are also many opportunities to encourage enhanced operation of vehicles, ranging from appropriate tire inflation and observing speed limits to strategies that reduce idling.

Finally, some key technologies could have notable benefits across the full range of vehicles. For example, advanced technologies to reduce the mass of a vehicle, also known as lightweighting, allows vehicles to use smaller, more fuel-efficient engines, extending the fuel economy for any vehicle and enhancing the range of BEVs, and can be deployed without sacrificing safety if safety-relevant components (airbags, sensors, seatbelts) are used.[89,90] Identifying circumstances where vehicle lightweighting can satisfy market demands and enhance the energy-efficiency of vehicles is a key opportunity.

Finding 7: Vehicles should be operated more efficiently across all vehicle classes. Where straightforward and available best practices for vehicle equipment and operation exist, their use should be maximized.

- **Recommendation 7.1**
  Facilitate Critical Efficiency Technologies: To ensure critical vehicle efficiency technologies (e.g., lightweighting, downspeed powertrains, aerodynamics, optimized cruise control and vehicle speed, anti-idle solutions, and the use of low-rolling resistance tires) move forward, interagency support should be coordinated and advanced across the federal government to efficiently identify barriers and enhance deployment.

Finding 8: Vehicle efficiency should be enhanced across the full U.S. vehicle stock. The energy-efficiency of all vehicles should be maximized, regardless of vehicle size or powertrain. Effective levers to enhance vehicle energy-efficiency include fuel economy standards, accelerating turnover of inefficient vehicles, and policy support to minimize barriers to development and deployment of advanced vehicle technologies.

- **Recommendation 8.1**
  Strengthen Fuel Economy/Emissions Standards: The NHTSA, EPA, states, automakers, and other stakeholders should work together to continue to progressively strengthen national fuel economy and emissions standards for LDVs, MDVs, and HDVs in the coming decades at levels necessary to reach the 50x50 goal. EPA GHG emissions standards also should include specific accounting for PEVs as a component of the compliance fleet.

- **Recommendation 8.2**
  Accelerate Inefficient Fleet Turnover: The federal government (and states and cities, where possible), should explore opportunities to accelerate turnover for the oldest and least-efficient LDVs, MDVs, and HDVs, in national vehicle fleets to more efficient vehicles or alternative efficient modes of transportation. This includes identifying and addressing flexibility in federal regulations and agency circulars that perpetuate long turnover times and can

c e.g., tax credits for donated cars, or the "Cash for Clunkers" program create unnecessary financial burdens for public transit agencies.[d] Other potential actions include the study, design, and implementation of a turnover program to eliminate the oldest and most inefficient vehicles and incentivize the uptake of efficient vehicles or alternative modes of transportation.

Recommendation 8.3

Improve Interagency Collaboration to Reduce Regulatory Barriers to Key Technologies: Federal funding should be allocated to support the creation of an interagency (DOE, DOT, EPA, NHTSA) task force to promote collaboration across the government regarding the elimination of barriers to lightweighting and other advanced vehicle technologies.

Identify High-Energy-Efficiency Vehicles and Incentivize Their Deployment

All vehicles can be made more efficient; however, some vehicle types, due to their design and powertrain, can provide a significant 'step-up' in vehicle efficiency. For example, a battery electric car is on average 70 percent more efficient than a comparable diesel car, while a fuel cell electric vehicle (FCEV) running on hydrogen produced by steam methane reforming is 20 percent more energy-efficient on a lifecycle basis.[e,91] This strong performance is even more pronounced on a PTW basis. Efficient vehicles running on RNG provide additional benefits by preventing methane gas, a potent greenhouse gas, from being vented to the atmosphere at sites such as landfills and waste treatment plants.[92] Non-plug-in hybrid vehicles enhance efficiency as well. Markets may determine that certain vehicles "win out" over the long term or may evolve to accommodate a combination of them; as a result, given the fast pace of change, the diversity of the sector, and the different stages of development of key technologies, it is important to explore multiple technologies that could drive meaningful progress.

However, there currently exists no definition describing a broad class of vehicles that enhances energy efficiency relative to conventional vehicle types and fuels. As such, this report introduces a new term, **Enhanced Energy-Efficiency Vehicle (E3V). An E3V is defined as a vehicle that uses energy more efficiently (measured in energy units per mile) than its most energy-efficient conventional equivalent, when viewed over the full lifecycle of energy production and use (i.e., a WTW basis).** The Argonne National Laboratory Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET®) Model is used to determine the relative efficiency of fuel sources and power train technologies available in the U.S. market.[93] Because the line is drawn at diesel engines—the most efficient conventional vehicle on the market—the powertrain technologies that qualify as E3Vs **include BEVs, PHEVs, non-plug-in hybrid vehicles, FCEVs, and highly efficient vehicles running on RNG.** This definition is intended to encourage the 'best next option' available in any given vehicle class, from LDVs and forklifts to class 8 trucks. The definition is discussed in detail in the Appendix.

Finding 9: E3Vs constitute a class of vehicles that provide a significant improvement in energy efficiency, and should be extensively deployed. Including PEVs, hydrogen fuel cell vehicles, hybrids, and highly efficient vehicles running on RNG, E3Vs should be deployed to the maximum extent possible, relative to their ability to improve a specific vehicle's fuel economy. This will require clear articulation of the benefits of E3Vs, as well as incentives to drive their deployment.

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d Agency Circulars are defined as instructions or information issued by the Office of Management and Budget to Federal agencies, expected to have a continuing effect of two years or more. e.g., the FTA mandates a 12-year "useful life" for heavy-duty transit buses (35'-40'); should a Federal Agency dispose of the vehicle before 12 years, it forfeits its entitlement to its share of the remaining financial interest. https://www.whitehouse.gov/omb/circulars/

e These calculations are for passenger cars, based on the following pathways: BEV running on the average U.S. electricity mix; FCEV running on hydrogen produced through centralized steam methane reforming with North American natural gas as the feedstock. In the case of FCEVs, different hydrogen production pathways can have markedly different energy impacts: for example, if hydrogen is produced by distributed electrolysis with the California electricity mix, the FCEV qualifies as 32 percent less efficient than a diesel engine on a WTW basis. Calculated using the GREET® WTW calculator. The difference between BEV and conventional vehicle efficiency is also more pronounced when considered on a PTW basis: for example, an EV with an efficiency of 3.3 miles/kWh has a miles-per-gallon equivalent (MPGe) rating of 111.2 MPGe, compared to a diesel vehicle at 27.8 miles per gallon.

Recommendation 9.1

Enhance E3V Deployments Broadly: To ensure every consumer has access to E3V mobility options by 2030, Congress should support E3V deployments through sustained: a) infrastructure investments; b) education/awareness campaigns; and c) vehicle purchase incentives that reach all vehicle consumers.

Recommendation 9.2

Establish Non-Purchase Incentives for E3Vs: Federal, state, and local governments should increase the use of non-purchase incentives to incentivize more efficient vehicles, such as HOV lane access for single-occupancy use of E3Vs; reduced vehicle registration fees and ownership taxes for E3Vs; and expedited permitting for alternative fueling infrastructure. These incentives should be temporary, with a planned phase-out tied to a market tipping point, such as when E3V penetrations reach a certain threshold by sales or penetration in vehicle stocks.

Recommendation 9.3

Establish MDV/HDV Purchase Incentives: Using existing state-level voucher programs as a model, Congress should implement medium- and heavy-duty E3V purchase incentives through a mixture of tax credits and point-of-sale vouchers for medium- and heavy-duty E3Vs.[f]

Finding 10: Infrastructure investments are critical to facilitate E3V deployments. All vehicle types require infrastructure for fuel production, storage, transport, and distribution to users, whether the fuel is electricity, hydrogen, RNG, or conventional fuels. For emerging alternative vehicle markets, especially PEVs, hydrogen fuel cell vehicles, and RNG, the lack of such infrastructure presents a market barrier, as some consumers experience "range anxiety" that discourages the purchase and use of E3Vs.[94] Such infrastructure developments are long-term and often capital-intensive. To achieve the 50x50 goal, a plan for infrastructure investment must be developed and incentivized in the very near future.

Recommendation 10.1

Support the 30C Tax Credit: Congress should extend the 30C Alternative Fuel Vehicle Refueling Property Tax Credit, which provides a 30 percent federal tax credit of up to $1,000 for residential and $30,000 for commercial property.

Recommendation 10.2

Develop Public Hubs for Fleet Refueling/Charging: Local governments should re-examine zoning and other permitting processes and develop strategies to facilitate the creation of central charging/alternative refueling hubs for taxi or shuttle fleets, including hubs that could be used to service autonomous vehicles.

Recommendation 10.3

Provide Grants for Infrastructure for MDV/HDV E3Vs: The DOE and DOT should establish grant programs for freight companies and truck stop site hosts to stimulate E3V deployment by designing facilities (e.g., alternative fueling infrastructure, electrified truck stops) to support E3Vs in the future.

Finding 11: Utilities Play a Key Role in Infrastructure Investments. Creating the infrastructure network to support E3V fueling is a significant investment, and it requires the involvement of many new stakeholders, from utilities to automakers and third-party providers. The extent to which utilities should be allowed to develop, own, and operate charging/fueling infrastructure is a complex topic that will necessarily include full consideration of every jurisdiction's context. However, utility involvement may constitute a critical lever to enhance E3V infrastructure developments and stimulate E3V markets.

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f e.g., California's Hybrid and Zero-emission Truck and Bus Voucher Incentive Project; the New York State Energy Research and Development Authority New York Truck Voucher Incentive Program; the Chicago Department of Transportation Drive Clean Truck Voucher Program; the Maryland Energy Administration Maryland Freedom Fleet Voucher Program; and the Colorado Energy Office ALT Fuels Colorado program.

Recommendation 11.1

Enhance Utility Role in Charging/Refueling Investments: Utility regulators should support utility involvement in the development of E3V charging/refueling infrastructure (where the utility's involvement accelerates infrastructure development and expands customer access). This includes the opportunities to conduct education campaigns and support energy grid reliability and safety that contributes to a growing competitive market.

Finding 12: RNG Can Be Utilized for Benefit in Vehicles and Power. RNG stands out as a fuel source with significant environmental benefits when harnessed from waste streams, such as agricultural facilities, wastewater treatment plants, or landfills. When locally-sourced, it provides economic value for the producer and prevents the unnecessary venting of methane to the atmosphere.

Recommendation 12.1

Recognize Benefits of RNG: States should explore strategies to recognize the carbon emission reduction benefits of RNG derived from sustainably sourced biomass feedstocks. Vehicles using these RNG resources should be highly efficient, utilize an advanced or electric drive train to the maximum extent possible, and meet ultra-low nitrogen oxides (NOx) requirements or lower emissions levels.

Recommendation 12.2

Collectively Work on RNG Gas Quality Standards: RNG quality is currently handled on a case-by-case basis and does not have an established standard (with the exception of some recently established rules in California).[95] Federal, state, utility, and industry stakeholders should work together to establish a quality standard to provide clear and consistent rules for project developers and facilitate its deployment.

Recommendation 12.3

Recognize Benefits of Electricity from RNG: The federal government (through the EPA) should expeditiously review applications to use electricity from RNG under the Renewable Fuel Standard (RFS). The EPA's 2014 regulations established that electricity produced from RNG was a "cellulosic biofuel" under the RFS, and the regulations established a "pathway" to create RFS credits. However, all applications to use this pathway are still pending before EPA. Modeling by Oak Ridge National Laboratory has shown the potential of these credits in encouraging zero-emission vehicle (ZEV) adoption by providing savings to consumers in their total cost of ownership.[96]

Finding 13: The Highway Trust Fund requires a change in design to ensure sufficient funding without hindering the path to 50x50. The Highway Trust Fund currently lacks sufficient resources to support critical infrastructure needs, and the "gas tax" model is likely to become increasingly insufficient as AFVs increase in market penetration.[97,98] This is a central problem that requires a resolution, but it will be important to ensure that the resolution identified does not undermine the pathway to 50x50.

Recommendation 13.1

Highway Trust Fund: As Congress explores solutions for the Highway Trust Fund, such a program should not threaten the future growth of E3V markets, but rather should be structured to enhance revenues needed to sustain future transportation investments (including public transit) while recognizing increased fuel mileage, low weight vehicles, and electric/alternative fuel vehicles (EVs and AFVs respectively) to ensure adequate and equitable taxation as well as maximum societal benefits.

Incentivize PEVs

PEVs deserve special consideration, as they are the most efficient E3V on both PTW and WTW bases and produce low levels of carbon dioxide emissions, nitrogen oxides, and particulate matter.[99,100]

While the market for EVs is also still emerging (BEVs and plug-in hybrids constituted just 0.4 percent of U.S. car stocks and 1.3 percent of new car sales in 2016), it is growing rapidly.[101,102] U.S. PEV sales in 2017 reached 200,000 vehicles, a 26 percent increase over 2016, and PEVs reached 5 percent of new car sales in California in 2017.[103,104] Bloomberg

New Energy Finance estimates that global PEV sales are on pace to reach more than 1.6 million vehicles this year, and projects that they could reach 55 percent of the global LDV market by 2040.[105] The cost of lithium-ion batteries, the major cost component for the vehicles, has fallen a shocking 79 percent in seven years, and the average energy density of the batteries is improving at a rate of approximately 5-7 percent per year.[106]

However, PEV markets still face a number of fundamental challenges. PEVs are generally more expensive than equivalent conventional vehicles, pricing them out of reach for many consumers (though BNEF expects PEVs to reach price-parity with conventional vehicles by 2025).[107] Charging infrastructure (above readily available 120 Volt outlets) is also costly to develop, and direct current (DC) fast-charging stations—which provide the closest analogy to a 20-minute fueling stop for PEV owners—have a business model with an inherent chicken-and-egg dilemma: users will not buy the vehicles until the charging infrastructure is available, and the charging providers will not have a profitable business model until EV penetration increases. To overcome these challenges, simultaneous progress in vehicle deployments, charging infrastructure, and an increasingly convenient customer experience will be necessary.[108] A wide array of policies and incentives are needed to drive this forward.

Finding 14: The Qualified Plug-In Electric Vehicle Tax Credit is critical as a tool to consistently drive PEV markets over the near- and long-term. One of the key policies to incentivize PEV purchases is the Qualified Plug-in Electric Vehicle Federal Tax Credit, which provides consumers with up to $7,500 in a federal tax credit capped at the first 200,000 vehicles sold by each automaker. This credit remains critical, but would benefit from adjustment, since the market is still growing, certain first-moving automakers are already approaching their caps, and some consumers (such as low-income consumers, fleet owners, and purchasers of used vehicles) cannot take full advantage of the incentive as designed.[109,110,111]

Recommendation 14.1
Change the Automaker Vehicle Sales Cap Under the Qualified PEV Federal Tax Credit to an Industry-Wide Market Penetration Phase-Out: In the near term, Congress should continue to incentivize EVs through the Qualified Plug-In Electric Vehicle Federal Tax Credit, and the sales cap by automaker should be replaced with an industry-wide phase-out once PEV penetrations reach a certain threshold by sales or penetration in vehicle stocks.

Recommendation 14.2
Convert the Qualified Plug-in Electric Vehicle Federal Tax Credit to a Point-of-Sale Incentive: The Qualified Plug-in Electric Vehicle Federal Tax Credit can be made more accessible in the long-term. Provided it can be consistently implemented without risk of disruption, Congress should modify the existing tax incentive in two key ways: 1) by converting the tax credit to a point-of-sale incentive (e.g., a rebate) to make it more accessible for all customers; and 2) by developing a point-of-sale incentive for the purchase of used PEVs.[g]

Finding 15: Electricity is not consistently treated as a fuel in federal policies. This is a policy inconsistency that undermines those markets.

Recommendation 15.1
Include Electricity in the Alternative Fuel Tax Credit: Federal policies, such as the Alternative Fuel Tax Credit (26 USC sec. 6426(d)), should be amended to recognize the pathway for inclusion of electricity as a fuel.

Finding 16: Integrating PEV charging infrastructure into homes and workplaces will support PEV markets. Building PEV charging infrastructure into existing buildings can range from a modest expense to an exorbitant cost, depending on the building structure and level of charging required. Incorporating PEV-readiness into new building codes and standards and encouraging investments at workplaces can help prepare for the future and cost-effectively build charging infrastructure.[112]

g Such rebates should include precautions to avoid "dealer capture," which is when a vehicle dealership retains the rebate value instead of passing the value along to the customer.

Recommendation 16.1

Develop Model Building Codes for Charging: The DOE should work with stakeholders to develop model building energy codes and standards that facilitate the development of charging infrastructure (208-240 volts or higher, as needed) for new residential (both single-family and multi-unit dwellings) and commercial (e.g., workplaces, garages) projects. These model provisions should either be based on or integrated into codes such as the International Energy Conservation Code (IECC) and ASHRAE 90.1. States and localities should then adopt and implement these provisions into their codes and standards.

Recommendation 16.2

Incentivize Workplace EVSE: Congress and states should establish incentives for installation of EVSE infrastructure at workplaces and garages.

Finding 17: Markets should provide a seamless EV charging experience for customers. Even where EVSE infrastructure is available, other barriers exist to their convenient and seamless access by customers. Some charging providers still require monthly subscriptions, or do not accept credit cards; lack of standardization among chargers also means that not all customers can utilize all chargers.[113]

Recommendation 17.1

Standardize the Customer Experience: Through grants and preferential loans, federal government agencies should provide a near-term stimulus for the private sector to drive markets toward the standardization of the consumer experience at charging stations – i.e., ensuring that all PEV owners can have a uniform retail experience when purchasing fuel or electricity, such as a universal credit card payment mechanism and access to all stations without requiring memberships.

Recommendation 17.2

Collaborate Toward Hardware Standardization: DCFC stakeholders (e.g., automakers, equipment manufacturers, utilities) should collaborate to accelerate the standardization of EV charging equipment to ensure that all chargers can be accessed by all customers.

Recommendation 17.3

Develop DCFC Adaptors: In the interim while a DCFC standardization process is still underway, the National Laboratories should work to develop DCFC adaptors that allow vehicles to use other charging infrastructure interchangeably -- e.g., a SAE Combined Charging System (CCS) to Tesla adapter.

Finding 18: Utilities and other stakeholders should plan for the future needs of the grid. As markets for electrification grow and new innovations in ICT and other technologies provide more tools for a dynamic interaction between electricity consumers and suppliers, a range of new opportunities may emerge to deliver customer benefits while optimizing the efficient utilization of the electric grid. Planning for future charging needs requires thoughtful consideration of these future opportunities, ranging from new rate designs and automated charging schedules to vehicle-to-grid technologies. In the near term, policies and rate options can help incentivize electricity consumption in a manner that maximizes the positive impacts to power systems that could result from greater vehicle electrification.[114]

Recommendation 18.1

Plan for Off-Peak and Managed Charging: Utilities and utility regulators should plan for future grid needs and efficient charging. This includes programs and rates to incentivize off-peak charging and working with automakers and/or third-party infrastructure providers to support future enhanced managed charging strategies (e.g., smart charging, vehicle-to-grid capabilities). Rate designs and programs that encourage managed charging can improve the utilization of the electric grid and can maximize fuel cost savings.

Create Equitable Solutions for All

Transportation services have never been perfectly equitable.[115] Low-income communities typically spend a higher percentage of their income on transportation needs, have a lower ability to absorb price shocks, live in areas such as non-compliance zones with untenable levels of transportation-related pollution, and drive less efficient vehicles with higher fuel and maintenance costs.[116,117,118] The elderly and disabled communities (a significant portion of which are considered low-income) face an additional set of physical and logistical limitations that can make simple trips difficult. The transformational opportunities that lie ahead have the potential to bring greater service and a better quality of life to these communities. [119,120]

Additionally, every American's livelihood relies on high-quality and reliable jobs.[121] As the sector transitions toward the 50x50 goal, it will be important to clearly understand the implications of the changes in the job market and to ensure the workforce has the appropriate skills for the future.

Finding 19: The 50x50 goal is an opportunity to rewrite the status quo on transportation equity. Nearly every recommendation in this report can be considered and implemented with a focus on equity. In cities, a transportation services model could provide more affordable, more efficient, and cleaner connectivity to all parts of society. Strong public transportation systems are a well-established tool to enhance affordable transportation access across urban and rural areas.[122,123] In rural communities, access to an affordable EV and convenient charging infrastructure could make a difference in quality of life by enabling a lower cost of fueling and maintenance.[124] Greater efficiency in freight and port energy use through E3V deployments, trip optimization, and systems integration can reduce local air pollution, which disproportionately impacts health in low-income communities. And depending on how it is deployed and the cost structures utilized, automation has the potential to enhance access for those unable to drive, and to lower transportation prices for all.[125,126] To ensure such opportunities are utilized to the maximum extent, there is an urgent need for deeper analysis to understand how our current system can evolve to better support our most vulnerable communities.

Recommendation 19.1

Support Research on AFV Integration into Low-income Communities: Support research on the costs/benefits for low-income communities (e.g., energy affordability, access to mobility services, health impacts, jobs) of adopting greater numbers of AFVs.

Finding 20: Electrification can be designed equitably. Low-income communities require proactive consideration to ensure the resulting services provide equitable benefits. Ensuring that all communities have access to, and share in the benefits of, this transition is an important consideration for policymakers.

Recommendation 20.1

Ensure Affordable and Accessible Charging: Utilities are well-suited to expand access to charging. Utilities and their regulators should work together to ensure that electric utility investments and expenditures in PEV infrastructure result in customer benefits, especially for low-income communities, and efficient utilization of the grid. Electrification efforts could focus on enhanced EVSE development, greater availability of car-sharing programs, provision of electric buses and siting of charging stations at public transit locations, and developing utility pricing that supports development of public charging (especially ultra-fast charging) that can be provided affordably to the customer and economically sustainably for market participants, including the charging provider, utility, and site host.

Finding 21: Labor markets may undergo significant changes over the course of this transformation, which presents an opportunity to plan for and develop the workforce of the future. Achieving the 50x50 goal may lead to growth in some sectors, and adjustments in others. With current uncertainties relating to automation and the uptake of E3Vs, Congress and the states should work with private sector organizations and other stakeholders to support the workforce in preparing for the next step. Activities should include:

- **Recommendation 21.1**
  Research Workforce Impacts: Congress and the states should carry out research that quantifies the workforce-development impacts of alternative fuel and EV and infrastructure introductions, including automation technology.

- **Recommendation 21.2**
  Provide Workforce Training and Certification: To ensure that the workforce of the future is prepared for technological advances in the transportation sector, public and private sector organizations, including unions, should collaborate to build the training and certification programs necessary to guarantee workers the relevant skill sets for the new economy.

- **Recommendation 21.3**
  Offer Retraining for Displaced Workers: Where transportation-related job displacement is found or predicted to occur, retraining programs should be leveraged to maximize employment and help workers develop new skills that will allow them to thrive in a changing economy.

Opportunities for Leadership

With so much work ahead of us, this is a moment for leadership. Corporate and government entities have the opportunity to demonstrate the first steps toward 50x50 in their own operations. Doing so also comes with the benefits of greater mobility and energy efficiency for their operations and employees. Demonstration, as well as vision, has the potential to drive progress.[127,128,129]

Finding 22: Leadership by corporate and government first-movers drives action.

- **Recommendation 22.1**
  Demonstrate Government Leadership for Fleet Efficiency: Federal, state, and local governments should set ambitious fleet efficiency targets to demonstrate government leadership in E3V deployments and the efficient operation of vehicles, ensuring programs are well-designed and sufficiently funded through appropriations to achieve measurable energy productivity improvements in government fleets.

- **Recommendation 22.2**
  Enhance Corporate Leadership in Deploying and Fueling Energy-Efficient Fleets: Corporations should make voluntary public leadership commitments to integrate efficient vehicles into their owned and leased LDV, MDV, and HDV fleets, including support for E3V fueling/charging infrastructure for use by employees and customers.

- **Recommendation 22.3**
  Enhance Corporate Leadership for HDV/MDV Fleet Management: The private sector should voluntarily commit to near-term, rigorous fleet efficiency targets, by: 1) prioritizing the immediate fuel efficiency gains that can be achieved with existing technologies and driving practices; and 2) participating in the EPA Smartway program, to report out efficiency data and improve performance.

CONCLUSION

There is much work ahead of us. Achieving the 50x50 goal will not happen without vision, coordination, leadership, and creativity. But the benefits of success will be lasting and extraordinary. Missing this opportunity could lead to stagnation, or far worse, as certain new innovations have the potential to exacerbate many of today's transportation challenges and propagate them for decades into the future.

Through **transformation, innovation,** and **investment,** we can arrive at 2050 with a new paradigm – one that boosts our prosperity, protects our environment, and creates a transportation system that works for all. Getting there will require that we take full advantage of every opportunity, join all stakeholders at the table, and work with urgency.

The Alliance 50x50 Commission on U.S. Transportation Sector Efficiency is committed to this path forward, both in our collective efforts, as well as our individual actions.

Join us.

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As of September 26, 2018

APPENDIX

Definition of Enhanced Energy Efficiency Vehicles (E3Vs)

There is a wide diversity of policy opportunities to enhance the energy efficiency of the transportation sector, ranging from vehicle lightweighting to powering vehicles with alternative fuels, from city design to influencing consumer behaviors. The Alliance 50x50 Commission is exploring policy recommendations to address all of these options in detail.

But for one of them – vehicle fuel sourcing – there appears to be a lack of clear language allowing us to distinguish which alternative fuel vehicles lead to a more energy-efficient transportation sector. The term "alternative fuel vehicle (AFV)" is a broad category of non-traditional vehicle technologies that includes electric vehicles (EVs), which include battery-electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and fuel cell electric vehicles (FCEVs). The AFV classification also includes natural gas, propane, and flex-fuel vehicles (FFVs). However, the AFV classification implies nothing about vehicle energy use.

To enable clear discussion of vehicles that directly address the 50x50 Commission's objective of greater efficiency and energy productivity, we propose a new term: "enhanced energy-efficiency vehicle" or E3V. **An E3V is defined as a vehicle that uses less energy per mile than the current "best-in-class" conventional ICE for a given size, usage and class of vehicle, as defined on a WTW basis through the Argonne National Laboratory Greenhouse gases, Regulated Emissions, and Energy use in Transportation model (GREET®).** As diesel vehicles are the most energy-efficient conventional vehicle operating on a traditional petroleum-based fuel, they constitute the threshold for E3V qualification.

Based on the GREET® tool national average estimates for today's vehicle technologies (Table 1), the following vehicle types qualify as E3Vs: most classes of plug-in electric vehicles (BEVs and PHEVs, known collectively as PEVs), FCEVs, and non-plug-in hybrid electric vehicles (HEVs). Best-in-class vehicles in other categories, like RNG vehicles or FFVs utilizing soybean-based biodiesel, may also qualify. As technology advances improve the efficiency of diesel, the threshold to qualify as an E3V will also increase, building in market and policy pressure for E3Vs to also improve their energy efficiency.

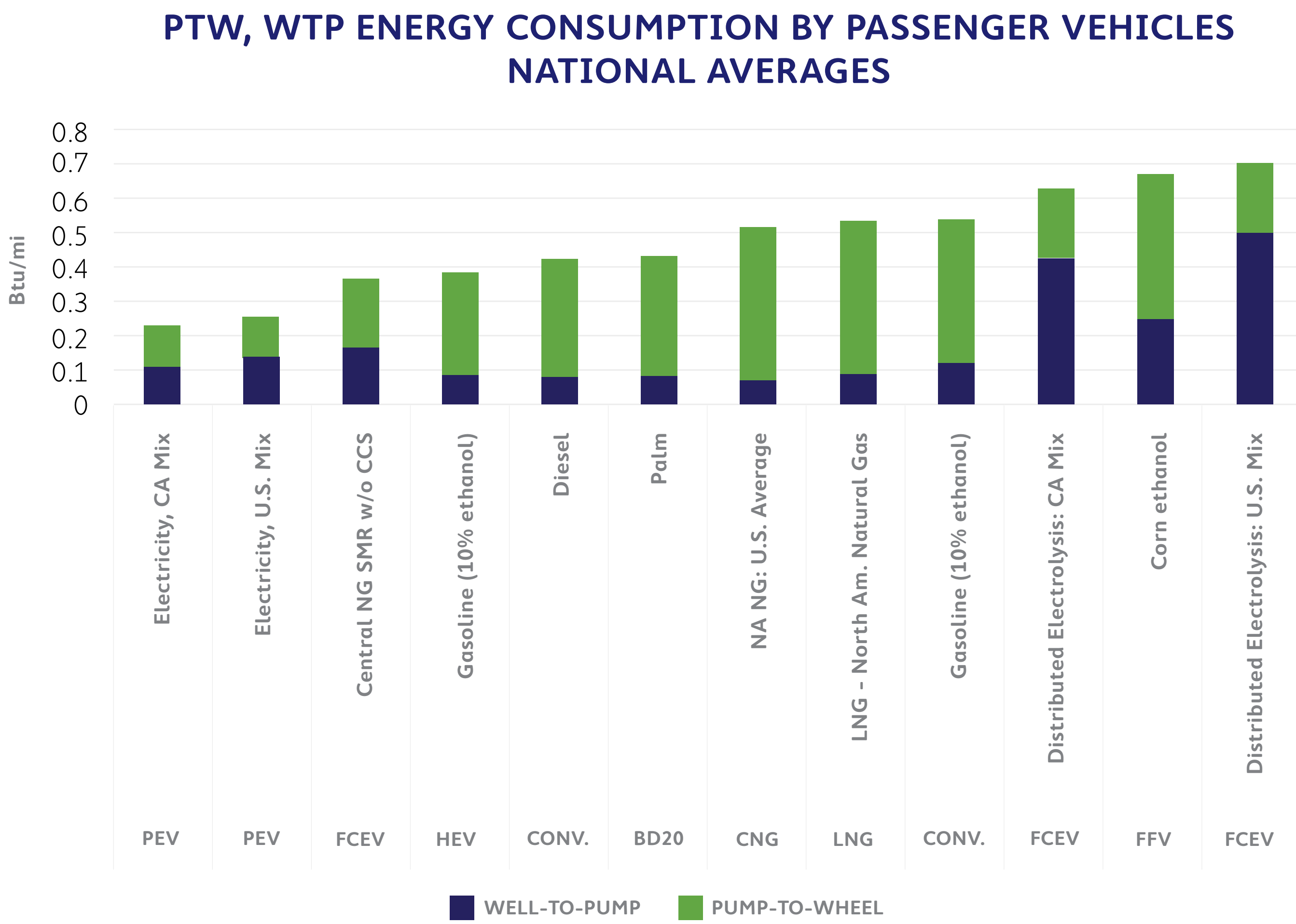
Why WTW?

A key question is whether it is better to assess the full lifecycle impact of a technology ("WTW") or take a more traditional approach and restrict discussions to the downstream vehicle energy consumption ("PTW"). While the overarching goal of the initiative is described on a PTW basis, the E3V definition is framed on a WTW basis to take a more comprehensive view of the vehicle's lifecycle energy use. This is a nuanced distinction, and in most cases, vehicles qualify for the E3V qualification equivalently in both PTW and WTW bases. However, there are specific fuel pathways that have extraordinary upstream energy costs – such as hydrogen production from non-renewable electrolysis or ethanol production from forest wastes. In these cases, the lifecycle energy consumption is considerably worse than for conventional vehicles, a point that merits acknowledgement in promoting such vehicles through policy.

WTW analysis is likely to become more relevant as the fuel profile of the transportation sector shifts towards E3Vs. EVs often, but not always, have greater energy costs in their upstream fuel production pathways than conventional fuels, due to the fact that the electricity generation (where most energy losses accrue) happens upstream and not in the engine. Biofuels also tend to have greater upstream energy consumption values, due to the requirements for agriculture and feedstock harvesting.

The E3V terminology can also be contrasted with that of Zero-emission Vehicles (ZEVs) and Partial Zero-emission Vehicles (pZEVs), derivation used in a number of U.S. states to describe vehicles with zero tailpipe emissions due to the use of an electric motor; ZEVs include all BEVs and FCEVs, and pZEVs include PHEVs. While ZEV/pZEV is an emissions-based derivation and E3V is an energy efficiency derivation, due to the coincident nature of the technology, as of 2018 most ZEVs/pZEVs also qualify as E3Vs. Therefore, ZEV policies are considered relevant for the advancement of E3Vs in this report.

Figure 1: National averages for upstream (WTP) and downstream (PTW) energy consumption (Btu/mile) of passenger cars of different vehicle types. The sum of green and purple bars is the "WTWl" value. On average, vehicles to the left of the diesel vehicle are registered as having lower energy consumption values per mile, and qualify as E3Vs. RNG, sourced from landfills and wastewater treatment plants, are modeled as having large negative WTP values and PTW values, due to upstream impacts in which RNG production avoids energy use in other sectors.



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