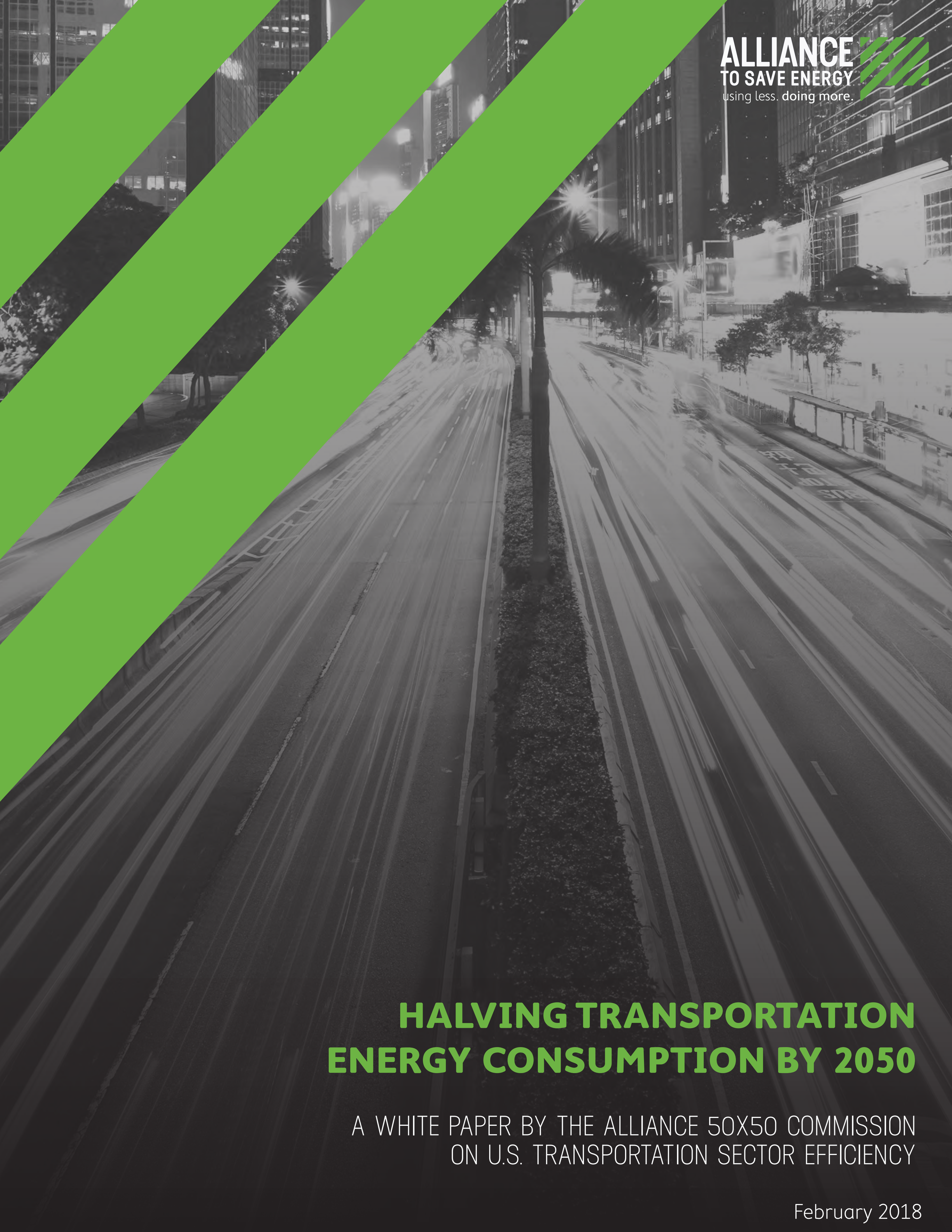


ALLIANCE TO SAVE ENERGY
using less. doing more.

# HALVING TRANSPORTATION ENERGY CONSUMPTION BY 2050

A WHITE PAPER BY THE ALLIANCE 50X50 COMMISSION ON U.S. TRANSPORTATION SECTOR EFFICIENCY

February 2018

# FROM THE COMMISSION CO-CHAIRS

Scott Keogh

Dean Seavers

As co-chairs of the Alliance to Save Energy's "50x50 Commission," we are pleased to present the Commission's foundational white paper, *Halving Transportation Energy Consumption by 2050.*

Transportation offers the single largest opportunity for energy efficiency improvement among all energy end-uses in the United States. New transportation technologies are quickly being introduced to the market and have the potential to create new opportunities, while reinventing the paradigm of our transportation system.

*Halving Transportation Energy Consumption by 2050* serves as the first step in this exciting conversation. It details the Commission's objective to achieve a more efficient transportation system by pursuing a clear goal: halving the energy used in the U.S. transportation sector by 2050. This goal is ambitious, yet achievable. The paper describes how the 50x50 goal was developed, and how it will ensure that we remain at the forefront of a changing industry, leveraging existing and fast-emerging opportunities for energy efficiency.

The white paper also details the structure of the 50x50 Commission itself, as well as the supporting technical committees, which represent a diverse group of national leaders from both the public and private sectors who are generously donating their time and expertise to this bipartisan effort. Over the course of the coming months, our Commission will develop a suite of policy recommendations – at all levels of government – that will put us on a path to achieve the 50x50 goal.

In the paper, we identify a number of possible paths that the 50x50 Commission and the technical committees are considering to answer the ultimate question before us, "How do we get there?" We look forward to working collaboratively with this dynamic, diverse and thoughtful community to explore the opportunities and challenges to making this ambitious goal a reality, and to make recommendations that can move us from thought to action.

Let the conversation begin!

Scott Keogh
*President*
*Audi of America*

Dean Seavers
*U.S. President*
*National Grid*

# Executive Summary

*"We're at a fascinating time in the transportation industry: the way in which vehicles are powered and how they're driven is evolving. We're at an inflection point and we have an opportunity, as an industry and a sector, to leverage that transformation for the benefit of society."*

*-- Scott Keogh, President, Audi of America*

*"As our region shifts its attention to efficiency in the transportation sector, we must be ready to support our customers and communities in that transition with services, infrastructure, and affordable solutions."*

*-- Dean Seavers, U.S. President, National Grid*

The transportation sector has been identified as the energy end-use in the U.S. economy where the greatest efficiency gains can be achieved.[1,2] It is also the largest consumer of fossil fuels in the United States. These points, combined with the fact that the transportation sector is undergoing a period of transformational change – ranging from the increased viability of alternative fuels[a] such as electrification to advanced vehicle technologies, automation, and shared mobility – offer enormous opportunities to improve the energy efficiency of the sector. The *Alliance 50x50 Commission on U.S. Transportation Sector Efficiency* (50x50 Commission) comprises corporate executives and public sector leaders who hold the keys to unlocking the power of improved energy efficiency across the transportation sector.

At the Initiative launch, the Commission approved the following ambitious, but achievable goal:

**50x50: meeting tomorrow's transportation needs with half the energy by 2050 (pump-to-wheels, relative to a 2016 baseline).**

Although the goal is technology-neutral and not prescriptive, it will require a creative and sustained national effort to implement the necessary policy, market enablers, and innovation to drive the sector and consumers beyond minor adjustments and into transformational change.

To identify a roadmap and develop recommendations for transportation sector stakeholders, the Commission will direct the work of six Technical Committees (TCs) that will each explore a different mode or cross-cutting transportation theme, including:

- ***Light-Duty Vehicles*****:** Electrification, advanced vehicle technologies, vehicle-level aspects related to shared mobility and automation;

[a] Consistent with its usage elsewhere, "alternative fuels" includes electrification, unless otherwise specified.

- ***Heavy-Duty Vehicles and Freight*** (medium-duty vehicles (MDVs), heavy-duty vehicles (HDVs), and transit buses): Engine hybridization, alternative fuels, electrification, and advanced vehicle technologies;
- ***Non-Road Vehicles*** (vehicles and infrastructure associated with transport hubs such as seaports, airports, and distribution centers): Energy-efficient technologies for support equipment (forklifts, shuttles, belt loaders, yard hostlers, tugs, cranes, etc.);
- ***Enabling Infrastructure:*** Alternative fuel distribution systems (natural gas, hydrogen, electricity, as well as grid modernization and reliability issues), fueling stations (including natural gas dispensers, electrolysis and reformation hydrogen stations, and Level 2 and DC Fast Charging stations), and power system aspects (smartgrid and grid reliability/resiliency);
- ***Information and Communications Technology (ICT), Shared Mobility, and Automation*****:** New software solutions that permit a range of technological improvements, ranging from vehicle automation to shared mobility while meeting security and privacy requirements;
- ***Outreach and Implementation*****:** Identify audiences and partners with whom to share the goals and findings of the Commission and ensure that the recommendations are targeted to opinion leaders and decision makers who can both influence and deploy them effectively to drive market transformation.

The Technical Committees will issue reports and suggest policy recommendations (including federal, state, or local policies, as well as financial and nonfinancial[b] incentives), seek peer review on the recommendations to gain a broader market perspective, and then submit them for the consideration and approval of the Commission. Policy recommendations will be tested against key tenets held by the Alliance to Save Energy: the recommendations must be non-partisan; proven and actionable; consensus-based; impactful; and cost-effective.

## Commission Task and Scope Boundaries

The transportation sector is both diverse and complex. To ensure the best use of the expertise within the Commission and the Technical Committees and to focus on areas where analysis can provide impactful recommendations, the Commission has agreed the initiative will focus on a subset of transportation technologies, including “grounded, wheeled transport with associated infrastructure.” The Initiative will abbreviate this “GTransport,” and it includes:

- Light-duty passenger vehicles, medium- and heavy-duty transport (including trucks and buses);
- Non-road vehicles associated with energy transformation hubs such as seaports, airports, warehouses, and distribution facilities (e.g., shuttles, forklifts, belt loaders, yard hostlers, tugs, cranes, etc.); and,
- Stationary infrastructure that supports alternative fuel vehicles and/or alternative fuel distribution (i.e. shore power, airport electrification, truck stop electrification, fleet warehouses, etc.).

[b] Nonfinancial incentives can include aspects such as high-occupancy-vehicle (HOV) commuter lanes and preferred parking.

GTransport does *not* include:

- Aviation
- Marine transport
- Locomotive efficiency
- Pipelines

This work will primarily focus on efficiency improvements in the operation, selection, and deployment of vehicles. However, where relevant to policy recommendations, the Commission and Technical Committees may explore system-wide opportunities to improve transportation use, and the movement toward a more integrated transportation services system. This may include exploring the improvement of public transportation modes (i.e. bus electrification, optimization of transit routes) and the shift from less efficient to more efficient transport modes (e.g., rightsizing public transit, shifting truck freight to rail shipment, encouraging walking and bicycling, and urban planning). The initiative will also consider data management and how this data is aligned with the overall regional data needs to implement a broader smart mobility future. The initiative will take a limited view of electric power utility policy and business models, focusing only on those areas where shifts in transportation policy could have direct impacts on system reliability (such as charging strategies for wide-scale vehicle electrification).

The Alliance affirms that many areas omitted from this scope are of critical importance to transportation sector efficiency, and the Alliance applauds the exploration of these topics that is being performed by other parties.[3,4,5] Their omission is a practical choice intended to channel the experience of the Commission and Technical Committee participants and focus the discussion on areas where clear, cogent, and sector-specific opportunities and policy recommendations could be identified within the transportation technology space.

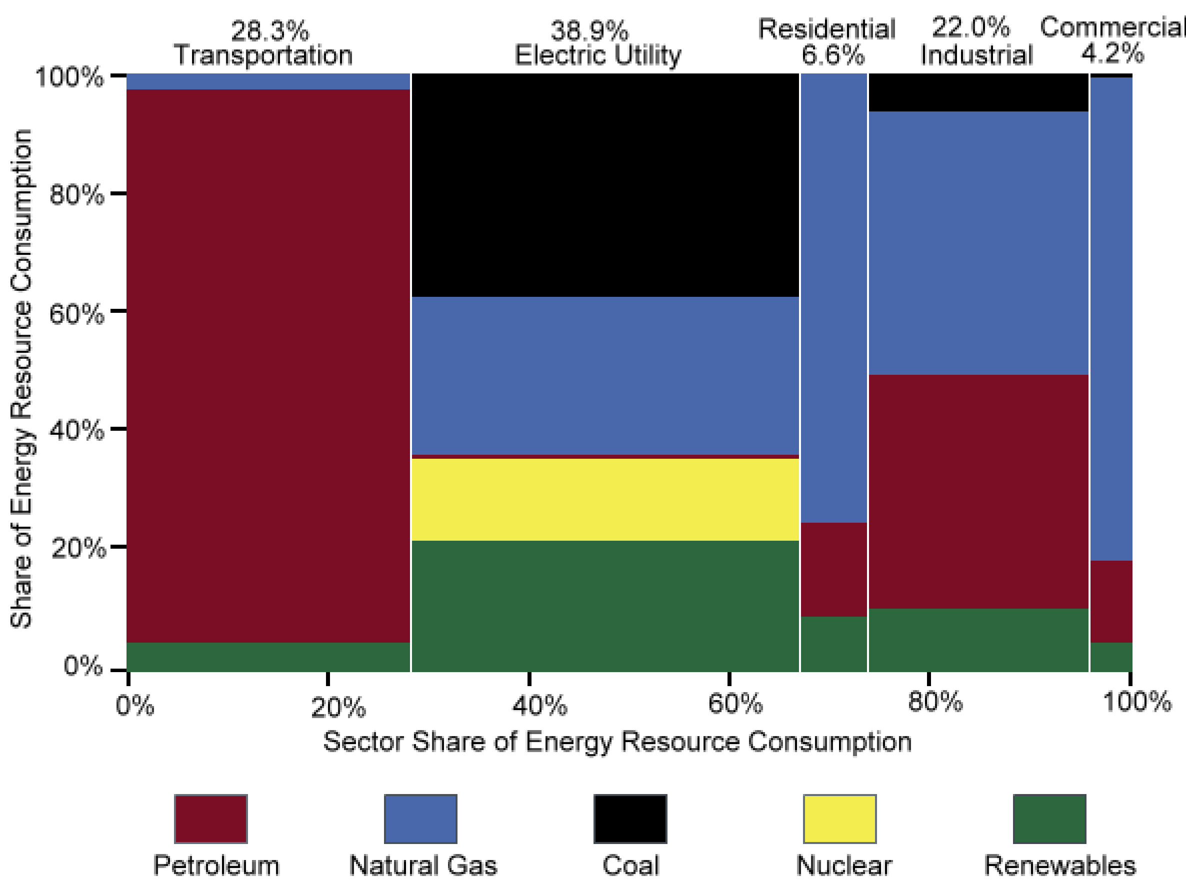
## Introduction: A Technology-Neutral Vision for the Future

Recent analyses have found that transportation offers the largest opportunity for energy efficiency improvement among all energy end-uses in the United States.[6,7] In 2016, 29 percent of U.S. energy was used for transportation; of that, 92 percent derived from petroleum products (Figure 1). As a result, the transportation sector alone consumes roughly three-quarters of all petroleum products in the United States.[8] Biofuels and natural gas were minor contributors, making up about 5 percent and 3 percent of the total transport energy, respectively,[9] and electricity provided less than 1 percent of the total energy used in transportation. Light-duty vehicles (LDVs) were the largest energy consumers in transportation, consuming 58.6 percent of total energy use, with medium- and heavy-duty trucks coming in second at 22.7 percent (Figure 2). U.S. usage is globally relevant as well: the United States was responsible for a quarter (28 quadrillion BTU) of global energy use in transportation in 2016.[10]

The transportation sector is undergoing a rapid transformation. While it can be difficult to produce a significant “leap forward” in energy efficiency through minor adjustments to traditional internal combustion engine technologies, especially in the LDV market,[11] the rapid pace of technological change is opening new avenues for improvement. New vehicle technologies, such as lighter, more durable materials, are reducing the energy required to manufacture and propel a vehicle. Vehicle electrification and the use of additional alternative fuels (e.g. hydrogen, natural gas, and biofuels) are becoming increasingly viable both technologically and commercially. The rising sophistication of data analysis, information technology (IT), automotive software, and user applications are changing the way we use transportation altogether. And new tools, such as vehicle automation and shared mobility, have the potential to increase safety, lower costs, and deliver new user benefits while requiring less energy.

However, the diversity of these opportunities also creates a challenge in identifying the path forward: timing, planning, coordination, markets, and innovation all have a role to play. Technologies relevant to facilitating different powertrain selections, for example, require investments in fuel delivery infrastructure (e.g., for electricity, hydrogen, natural gas, or biofuels) to ensure that they are universally accessible. This infrastructure is costly and may take decades to implement. It is also likely that multiple pathways will be necessary to bring about timely energy efficiency improvements across the sector. In the end, the technologies that dominate the transport sector of the future will likely be influenced by a combination of policy, innovations, evolving business models, and global prices of legacy fuels.

*Figure 1: U.S. Energy Consumption by Sector and Energy Source. (2016 EIA Monthly Energy Review data, reproduced in the ORNL 2017 Vehicle Technologies Report.)*



These changes carry important implications for U.S. competitiveness. Regardless of the United States' stated intention to withdraw from the Paris Climate Accords, nearly every other country in the world, as well as key states and Governors here in the United States, remain committed to the agreement. The global appetite for low carbon and low-emissions technologies is particularly strong in European, Chinese, and Indian markets, and the increasingly international nature of supply chains suggest that U.S. companies have much to gain by maintaining leadership in transportation technology, manufacturing, and design. This requires mastering climate-friendly global market trends.[12] This link between global markets and U.S. competitiveness can be observed in nearly all aspects of the transportation sector.

Recent trends in electric vehicle (EV) markets provide one specific illustration. While 61 percent of passenger cars and commercial vehicles worldwide were produced in the United States in 1961, this number had fallen to 13.4 percent by 2015.[13] In 2016, the countries with the highest EV market shares were Norway (29 percent), Netherlands (6.4 percent), and Sweden (3.4 percent). China's EV market share was roughly the same as that of France, the UK, and the United States (1.5 percent); however, in terms of overall stock, China had the largest electric car market in 2016, accounting for twice the number of electric cars sold in the United States, and more than 40 percent of electric cars sold in the world.[14] These leading countries all have sustained policy and incentive structures in place to ensure the continued adoption of EVs and their own companies' competitiveness. The International Energy Agency has noted that, as of April 2017, 35 international original equipment manufacturers (OEMs) had made announcements on their electric car ambitions: three were American (Chevrolet (GM), Ford, and Tesla); six were from other Organization for Economic Cooperation and Development (OECD) countries (BMW, Daimler, Honda, Renault-Nissan, Volkswagen, and Volvo), and twenty-six companies were Chinese. [15,c]

Achieving our goals for U.S. competitiveness, prosperity, energy security, climate, and environment will require advances across the board utilizing a variety of technologies, infrastructures, and behaviors. With so many choices ahead, this is a moment for leadership.

The benefits of "getting it right" are significant: enhanced energy and national security, superior business competitiveness, technology leadership, the creation of jobs and advancement of U.S. prosperity, increased transport safety and quality of life, and a significant reduction in carbon emissions and other environmental pollutants. By taking a technology-neutral lens and charting a path to meet an ambitious but achievable end-goal, the Commission seeks to not only identify those opportunities to move the sector forward, but also to build a coalition to act and achieve the vision of a more modern, more secure, cleaner, and more effective transportation system in the United States.

[c] Including BYD, BJEV-BAIC Changzhou factory, BJEV-BAIC Qingdao factory, JAC Motors, SAIC Motor, Great Wall Motor, GEELY Auto Yiwu factory, GEELY Auto Hangzhou factory, GEELY Auto Nanchong factory, Chery New Energy, Changan Automobile, GAC Group, Jiangling Motors, Lifan Auto, MIN AN Auto, Wanxiang Group, YUDO Auto, Chongqing Sokon Industrial Group, ZTE, National Electric Vehicle, LeSEE, NextEV, Chehejia, SINGULATO Motors, Ai Chi Yi Wei and WM Motor.

## The 50x50 Goal

The Commission will explore a path to achieve the following ambitious and achievable goal for the United States GTransport sector:

**Fifty by fifty: meeting tomorrow's transportation needs with half the energy by 2050 (pump-to-wheels, relative to a 2016 baseline).**

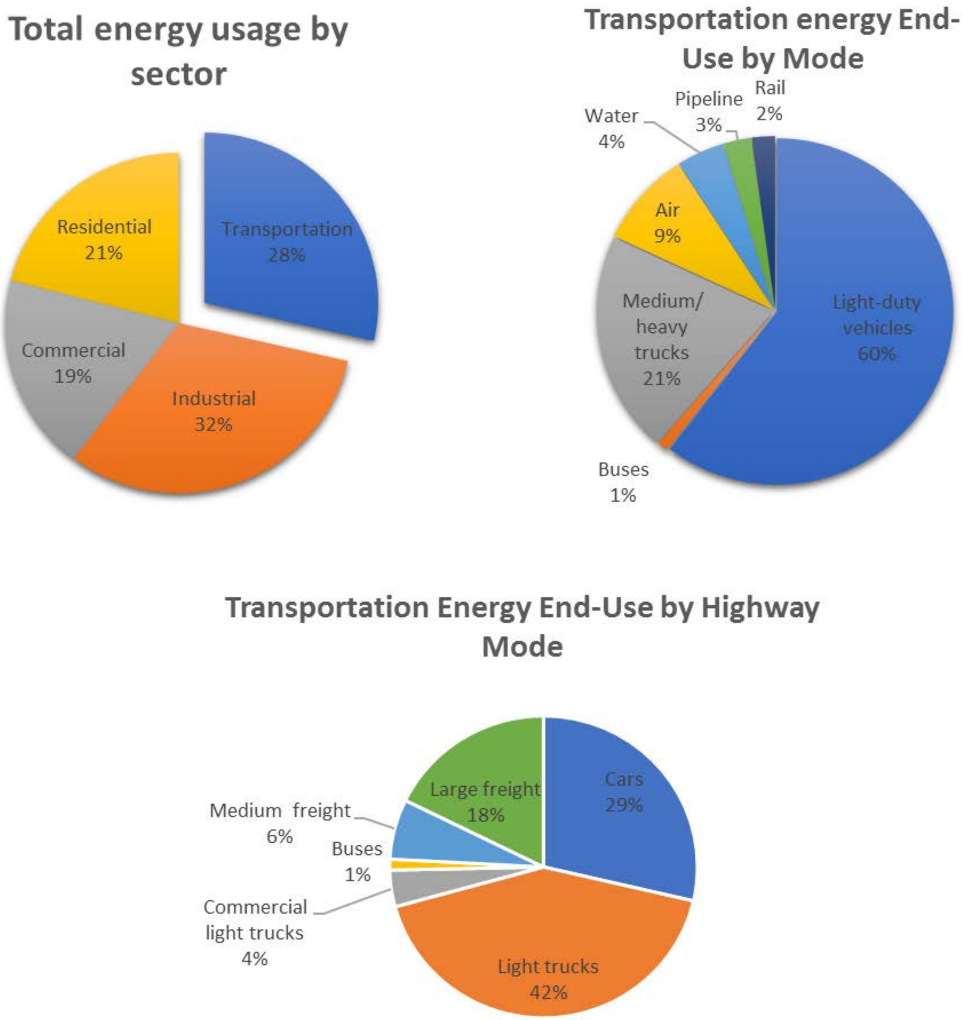
This goal seeks to meet energy demand for an increased number of vehicle miles traveled, as projected in 2050 by the Energy Information Administration's (EIA's) 2017 Annual Energy Outlook (AEO), while reducing total energy consumption (in British thermal units, BTUs) by 50 percent across the GTransport sector by 2050 (relative to 2016 levels), on a pump-to-wheel (PTW) basis. It will serve as a guiding light to direct a deeper, subsector-specific analysis (based on PTW as well as well-to-wheel and full-system considerations, discussed below) to develop a series of consensus recommendations to drive the United States toward greater efficiency, prosperity, equity, and environmental stewardship in the transportation sector.

**Why this metric**: Where possible, the Alliance prefers to use energy productivity as the metric, defined as economic output per unit of energy consumption. For economy-wide goals, energy productivity is easily calculated by taking the ratio of GDP to energy consumption (in quadrillion Btu, or quads). However, in the case of a sector of the economy such as transportation, economic output is not as clearly defined: it could include access to destinations, services, goods, jobs created, and/or miles traveled, making this definition difficult and open to interpretation. Even when restrained to the simplest "miles per gallon" metric – which, it could be argued, is a kind of energy productivity metric – does not capture the value afforded by reducing the number of miles traveled altogether (known in the field as "avoided miles traveled"), which becomes especially relevant when discussing shared mobility or the optimization of freight routes. For this reason, the Commission has decided to use the most straightforward and measurable variable – total energy consumption – as the key metric.

Rather than halving energy consumption relative to today's usage, the goal could have also been framed in reference to the AEO's projected energy consumption in 2050 (as a "business as usual," or BAU, scenario). The Alliance explored both possibilities, and chose 2016 as the reference year to minimize the number of assumptions necessary to reach and measure the goal. It also helps reduce the potential for double-counting efficiency gains that are already included in other estimates.

Finally, the Commission confirmed that the goal be articulated on a "pump-to-wheel" (PTW) basis, which quantifies the energy placed in a vehicle and consumed in operation (i.e., miles per gallon equivalent); rather than on a "well-to-wheel" (WTW) basis, which additionally includes the energy consumed in producing, refining, and transporting fuels to the point of sale. There is broad consensus that WTW calculations more effectively capture the full energy impacts of transportation energy use, as it most fairly accounts for energy consumption across the fuel production and supply lifecycle. For example, electric, biofuel, and fuel cell vehicles have proportionally more energy usage in their upstream pathways (i.e. electricity generation, agricultural feedstock production, and hydrogen production, respectively), causing an important energy consuming step to lie "outside" the window of PTW analysis. Argonne National Laboratory has created the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model, which allows for the calculation of WTW energy consumption and emissions for a wide variety of vehicles and different fuel source pathways.

*Figure 2: Transportation Energy Usage by Sector, Mode, and Highway Vehicles. EIA; Total energy usage statistics from the Monthly Energy Outlook (2016), others from the AEO (2017; 2016 data used for comparison)*




However, the PTW metric reflects the portion of the lifecycle where the Commission's main policy recommendations will be made. Seeking energy efficiency gains across the WTW lifecycle would necessarily include improved efficiency of fuel extraction and refining, electricity generation and transmission losses, agricultural practices to produce biofuels feedstocks, and other elements that lie beyond the scope of the Commission. Additionally, many sources of high-quality transportation data – especially forward-looking projections, such as the AEO -- are based on PTW measurements. Converting these values to WTW values is viable through GREET, but requires assumptions that may generate discussion and distract from the primary goal. For these reasons, the Commission confirmed a PTW basis for the overarching goal, but also affirmed that: 1) some of the final recommendations would center on topics relating to the WTW lifecycle, 2) WTW equivalents would be jointly referenced with PTW data as often as possible throughout the initiative,[d] and 3) the importance of relying on WTW data and analyses will grow over time.

**Why it's ambitious**: As the demand for vehicle miles traveled is expected to increase in the future, meeting this demand with half the energy by 2050 requires us to move from short-term, minor adjustments to transformational changes. The goal translates into *more than* doubling the energy efficiency of the sector,[e] and would require the U.S. GTransport sector to revert to energy consumption levels in 2050 last seen in the 1960s,[16] while traveling up to 580 billion more vehicle miles. For comparison, the energy efficiency of cars nearly doubled from 1970 to 2014;[17] the Goal will require similar levels of system-wide reductions in fuel use across all highway transport modes in nearly half the timeframe.

Such dramatic changes to the sector also require action far before 2050, due to the long lag time for new vehicles to replace older vehicle stocks and the decades needed to build new infrastructure. One informal U.S. Department of Energy (DOE) estimate suggested that it takes 20 years to bring new technology to market, and 20 years to "get all the old technology out of all vehicles." By other estimates, from 2010 to 2050, approximately 77-93 percent of the LDV fleet could potentially turn over.[18]

Figure 3, Figure 4, and

Figure 5 provide a view of our current trajectory, according to the 2017 AEO Reference Scenario, which we will refer to as the "business as usual" (BAU) scenario. As shown in Figure 3, the demand for vehicle miles traveled (VMTs) in transport are assumed to increase slightly across all vehicle classes (with the exception of a temporary downward trend in LDV VMTs). Figure 4 shows the projected energy consumption of different vehicle modes, illustrating the expected efficiency gains in the short-term in the LDV and freight stocks through vehicle standards. However, over time, all vehicle classes are assumed to be on a path to gradually increase energy consumption by 2050.

Figure 5 shows the BAU projections of car vehicle stocks to 2050, with 18 percent penetration of electric vehicles and 3 percent penetration of other alternative fuel vehicles (biofuel, natural gas, fuel cell) in the car stocks by 2050. By contrast, the AEO estimates that the VMTs by the heavy-duty sector (including light heavy duty (LHD); medium heavy duty (MHD); and heavy heavy duty (HHD)) will remain largely unchanged, with a continued, almost exclusive reliance on gasoline and diesel and only minor gains in flex fuel vehicles (LHD, MHD) or natural gas (HHD).[f]

[d] This effort will explore the possibility of using a "PTW(WTW)" format for data to ensure clarity and transparency, and ensure that WTW is used for any comparisons among technologies.
[e] Assuming AEO estimates for 2050 vehicle miles traveled.
[f] The one exception is in LHDs, in which flex-fuel vehicles are projected to perform as many VMTs (30 billion) as diesel (42 million) and motor gasoline (26 million) in 2050. AEO 2017 Freight Transportation Data.

*Figure 3. BAU Vehicle Miles Traveled by vehicle type, LDVs. 2017 AEO.*

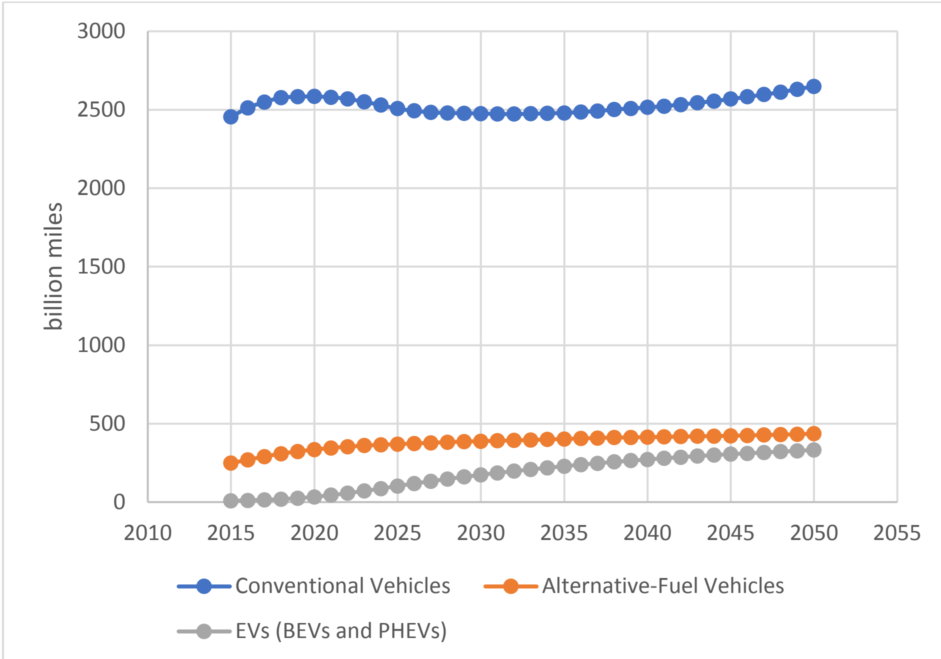



*Figure 4. BAU Projected energy use by vehicle mode. AEO 2017.*

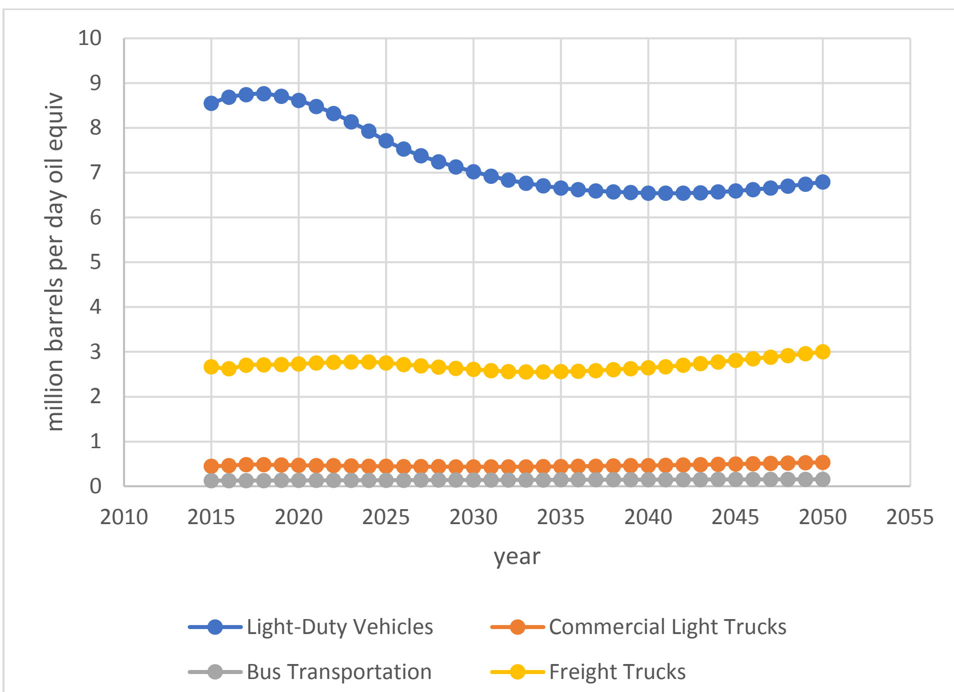
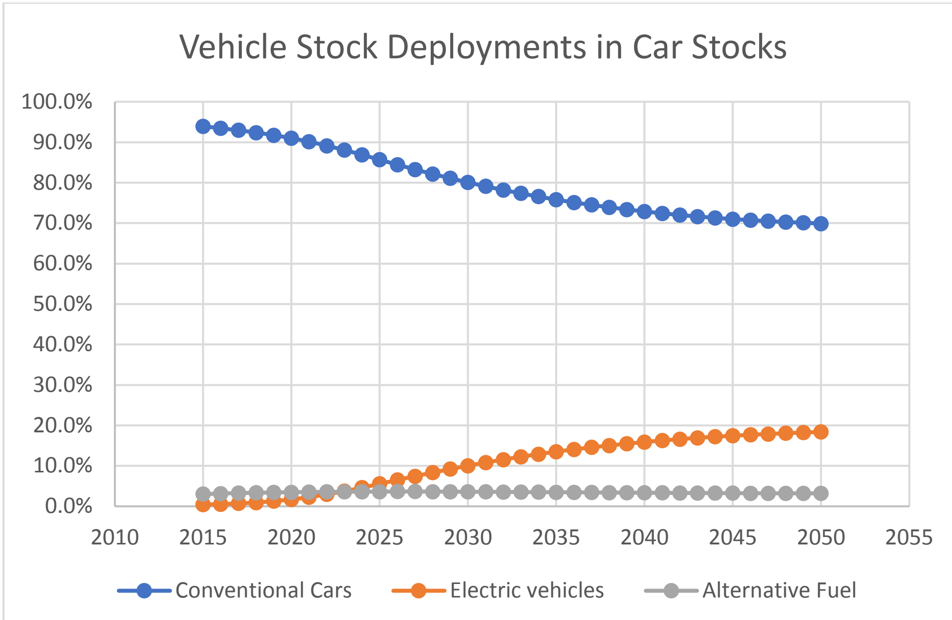


*Figure 5: BAU Vehicle Stock Deployments in Car Stocks. AEO 2017.*




**Why it's achievable**: While the BAU scenario shows some growth in new technologies (such as electrification), many other significant players – international, state, and local governments, companies ranging from automakers to utilities, think tanks, financial analysts, and advocacy groups – are predicting a much more enterprising future may be possible, if the policy environment evolves with the trends. Some believe the overhaul is already beginning, and that it's accelerating.[19,20,21] Simultaneous trends (e.g., alternative fuels, advanced vehicle technologies, and information and communications technology (ICT)) enable users to both improve the efficiency of existing transportation modes and explore transportation system redesign and altered usage.

The viability and value-add of these opportunities vary for each subsector (light-duty vehicles, heavy-duty vehicles, non-road vehicles, transportation-related stationary infrastructure). The energy impacts of key elements, such as automation and shared mobility, are also accompanied by enormous levels of uncertainty.[22] The ultimate impact of each of these options will depend on a number of areas, including technological innovation, vehicle deployments, infrastructure development, and the policy/regulatory framework in the United States and globally.

While advances along many fronts will be necessary to achieve the goal, a few areas will require a priority focus. Given that the LDV, MDV, and HDV vehicle classes account for 82 percent of all transportation fuel consumption (2016)[23] – the majority of the energy consumed in GTransport -- advances in efficiency in these classes can have the greatest overall impact on the sector's energy consumption. Three main tools appear most relevant to achieving the goal:

1) *Alternative fuels:* The electrification of vehicles appears extremely favorable for energy efficiency, constituting the most efficient powertrain even on a WTW basis, with nearly double the efficiency

of a traditional E10 gasoline internal combustion engine under typical fuel pathway assumptions (Figure 6).

Markets for electric vehicles are also accelerating. Vehicle battery prices fell 77 percent in the last six years,[24] and Bloomberg New Energy Finance (BNEF) projects that they will fall another 77 percent between 2016 and 2030.[25] Along with the emergence of new vehicle models with longer ranges and greater affordability, BNEF estimates that the electric vehicle market (including battery electric vehicles, BEVs, and plug-in electric hybrid vehicles, PHEVs) is likely to reach an inflection point between 2025 and 2030, resulting in EVs becoming economical (on an unsubsidized, total cost of ownership basis) across mass-market vehicle classes. BNEF further estimates that EVs will account for 54 percent of new car sales and 33 percent of the LDV fleet globally by 2040.

Other alternative fuels are also likely to be part of the solution. While the energy efficiency benefit of these alternative fuels appears minor relative to gasoline in national averages for passenger cars (figure 6), they are also highly variable based on source, production, transport, geography, and end-use vehicles, and require consideration in context. For example, hydrogen fuel cells carry zero tailpipe emissions (enabling their deployment indoors without human health impacts), run on highly efficient electric motors, and can be produced from natural gas or renewable fuels. Renewable natural gas (e.g. biogas from landfills, wastewater) is easily transported, viable in many conventional vehicle types, and results in the highest reductions in greenhouse gas emissions per mile of any fuel[g] -- California sourced 60 percent of its natural gas for vehicles from renewable forms in 2017, and Southern California Gas Co. expects this number to rise to 90 percent in 2018.[26] Liquid biofuels also exhibit enormous variability in WTW energy efficiency depending on the feedstock: GREET estimates that a transit bus running on 100 percent renewable diesel could have WTW energy consumption ranging from 67 to 24 megajoules per mile (MJ/mi), depending on whether the diesel is generated from pyrolysis of forest residues or soybeans.[h]

2) *Advanced vehicle technologies* reduce the fuel needed to propel a vehicle. This includes internal combustion engine (ICE)-specific elements such as start-stop systems, cylinder deactivation, turbocharging, and advanced transmissions. Advanced vehicle technologies also carry opportunities for *all* vehicle types, including improved aerodynamics, low rolling resistance tires and vehicle light-weighting.

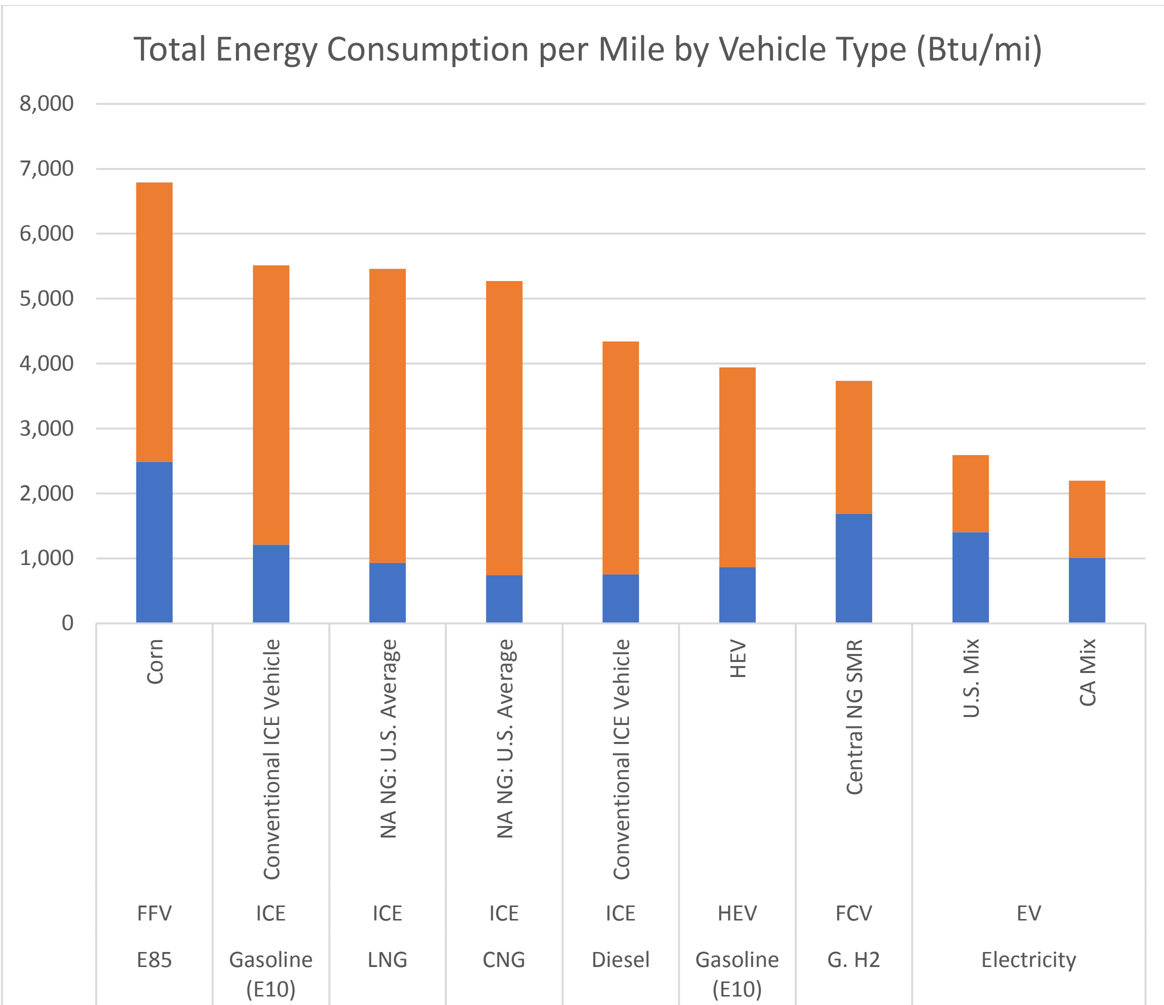
3) *Enabling technologies,* such as vehicle automation and shared mobility capabilities, allow travelers to use vehicles more energy efficiently and effectively, eliminating unnecessary vehicle miles traveled while enhancing economic output and environmental gains.

It is also relevant to note that the greatest, and most transformational gains would likely stem from a system-wide, integrative transportation sector optimization: incorporating high-impact vehicle technologies into a holistic system that maximizes the efficiency *and the utilization* of all vehicle modes. Early discussions of short-term opportunities regarding integrated systems have primarily

[g] This is due to the fact that vented methane is one of the most damaging greenhouse gas emissions; its recapture for energy uses doubles as an energy source and GHG fixation tool.
[h] As calculated through GREET 2017 Lifecycle tool, WTW analysis. For comparison, the same vehicle is estimated to consume 40 MJ/mi if running on low-sulfur diesel and 21 MJ/mi if electric.

focused on shared mobility and freight optimization (as referenced above in *enabling technologies*). However, moving to the next level – an integrated transportation services system with right-sized, highly efficient vehicles, well-designed systems infrastructure (including improved urban design, road networks, transportation hubs), and ICT technologies to manage and coordinate all elements – will require a systemic overhaul, including breakthroughs in innovation, public support for new markets, significant public and private infrastructural investments, and unprecedented political will and coordination across many stakeholders.

*Figure 6: GREET 2016 Calculator estimates for vehicle well-to-pump (blue) and pump-to-wheel (orange) energy use per mile.*[i]




**How we get there**: The Commission's goal is intentionally broad and flexible, allowing consideration of all technologies. For this reason, there is no one path to achieve the goal. Based on in-house

[i] Assumptions included in the GREET Well-to-wheel calculator (2016): flex-fuel vehicle (E85) with corn ethanol; gasoline (E10) used U.S. Average; CNG and LNG vehicles assume North American Natural Gas (U.S. Average); diesel vehicle uses U.S. average fuel supply; fuel cell vehicle (FCV) uses gaseous hydrogen from central Steam Methane Reforming (SMR) process with North American natural gas; and electric vehicles are shown with U.S. average electricity mix and California average electricity mix.

analysis and a thorough literature review, the Alliance concludes that achieving the 50x50 Goal will require many, if not all, of the following elements:

- Deployment of alternative fuels, including significant electrification of LDVs (both cars and light trucks) with battery electric vehicles (BEVs) and high mileage plug-in hybrid electric vehicles (PHEVs), accompanied by a nationwide network of charging infrastructure;
- Deployment of additional alternative fuels with demonstrated efficiency gains, including options such as fuel cell electric vehicles (FCEVs), renewable natural gas, and/or sustainable biofuels, along with their relevant fueling infrastructure;
- Fast-track deployment of high efficiency hybrid electric vehicles as the default internal combustion engine (ICE) vehicle of choice for LDVs (cars and light trucks);
- Aggressive hybridization in freight vehicle classes;
- Efficiency gains in vehicles across the board, especially in the medium- and heavy-duty sector through advanced vehicle technologies;
- More efficient selection of vehicle modes, such as an increase in the use of cars over light trucks for low-occupancy LDV use, and optimization of supply chains to match freight vehicle sizes to freight needs;
- Overall reductions in the per capita VMTs to achieve similar or increased levels of economic growth through information and communications technology (ICT) to optimize supply chain movements and shared mobility;
- Simultaneous electrification and automation of vehicles; and/or
- Simultaneous electrification, automation, and shared mobility that reduces the number of cars on the road and increases vehicle occupancy and vehicle utilization.
- Expansion of alternative fuel usage in transportation infrastructure in energy hubs (marine ports, airports, warehouses and distribution centers, truck stops) to reduce other fuel-use behaviors such as idling.
- Deployment of alternative fuels in other non-road vehicle types (forklifts, shuttles, ground support equipment) in energy hubs.
- Parallel to vehicle optimization described above, the development of big data management systems to coordinate and maximize the efficiencies of vehicle movement and infrastructure usage.
- Greater exploration of system-wide efficiency opportunities.

For the sake of illustration, the Alliance estimated the energy consumption of several scenarios regarding highway vehicle mixes[j] based on AEO 2017 projections for vehicle miles traveled (VMT) by highway vehicle mode and type, and vehicle efficiencies projected for 2050. According to these "back

[j] These estimates did not include electrification of stationary infrastructure, due to incomplete data. However, infrastructure electrification remains an important, high-opportunity area for the initiative.

of the envelope" calculations, the Alliance estimates the goal would likely be achieved in the following scenarios:

- **Efficiency:** An additional doubling of efficiency across the board beyond the AEO 2050 projections for energy efficiency improvements (without deviating from AEO 2050 increased levels of VMT required);
- **VMT reductions:** A 40 percent reduction of VMT across all vehicle modes relative to AEO 2050 projections (assuming AEO baseline improvements in vehicle efficiency); OR
- **Electrification/Hybridization:** Electrification of 80 percent of VMT traveled by cars and light trucks and hybridization of 50 percent of VMTs by freight vehicles (assuming AEO baseline improvements in vehicle efficiency).

It is likely that these scenarios would be challenging to achieve; however, a scenario that combines all elements is more accessible, reinforcing the view that hybridization, alternative fuels, additional efficiency gains, and reduced VMT are all needed to contribute to the solution. For illustration, the following "combination scenario" arbitrarily combines several of these elements and achieves the goal of reducing energy consumption by 50 percent in 2050:

- 60 percent of car and light truck VMT performed by EVs;
- 20-30 percent and 10 percent of VMT in freight vehicles performed by hybrids and fuel cells, respectively;
- All modes experience an additional 20 percent "across the board" efficiency gain (beyond AEO expected efficiency gains and the efficiency aspects of electrification/hybridization); AND
- A 5 percent reduction in VMT relative to AEO 2050 projections.

This exercise helps to clarify the opportunities available. Identifying the path forward, and the relative contributions of each element will be the responsibility of the Technical Committees, with support from the Commission.

**Milestones:** Given the long-term nature of the goal and its breadth, the Commission determined that the Technical Committees will also identify nearer-term *conditions* (for example, reduced cost point for electric vehicles, or the availability of charging/fueling infrastructure) that will be required to achieve the 50 by 50 goal. These conditions will inform specific action-oriented *milestones* to achieve the conditions and measure progress (such as specific levels of greenhouse gas emissions reductions or sales of more efficient/alternative vehicles). These conditions and milestones will be tailored to each Technical Committee's specific subsector, and include metrics that allow for an assessment of the progress on economic, environmental, and social benefits.

**How it compares to other goals**: The proposed goal of this Commission is better understood in comparison to, and in the context of, other existing goals and targets for energy efficiency and emissions reductions that affect the transportation sector directly or indirectly:

- Through the Accelerate Energy Productivity 2030 initiative, the U.S. Department of Energy, in collaboration with the Alliance and the Council on Competitiveness, set a goal of doubling U.S. energy productivity (U.S. GDP per unit of energy consumed) by 2030. Transportation was identified as the area of greatest opportunity for energy productivity improvement.[k]

- The IEA's Clean Energy Ministerial (CEM) has announced a global campaign called EV 30@30, to reach a 30 percent sales share for EVs by 2030, and deploy 20 million EVs by 2020.

- The Paris Declaration on Electromobility on Climate Change states that 20 percent of all global road vehicles (including LDVs and HDVs) should be electrically powered by 2030.

- California has announced an intent to produce 50 percent of the State's electricity from renewable sources by 2030 and to reduce GHG emissions to 80 percent below 1990 levels by 2050 ("80 by 50"). This goal assumes a rapid increase in near-zero and zero-emission vehicles (ZEVs) – electric or fuel cell-powered – by 2030, potentially resulting in 6-7 million ZEVs and plug-in hybrid vehicles (PHEVs) on the road in 2030.

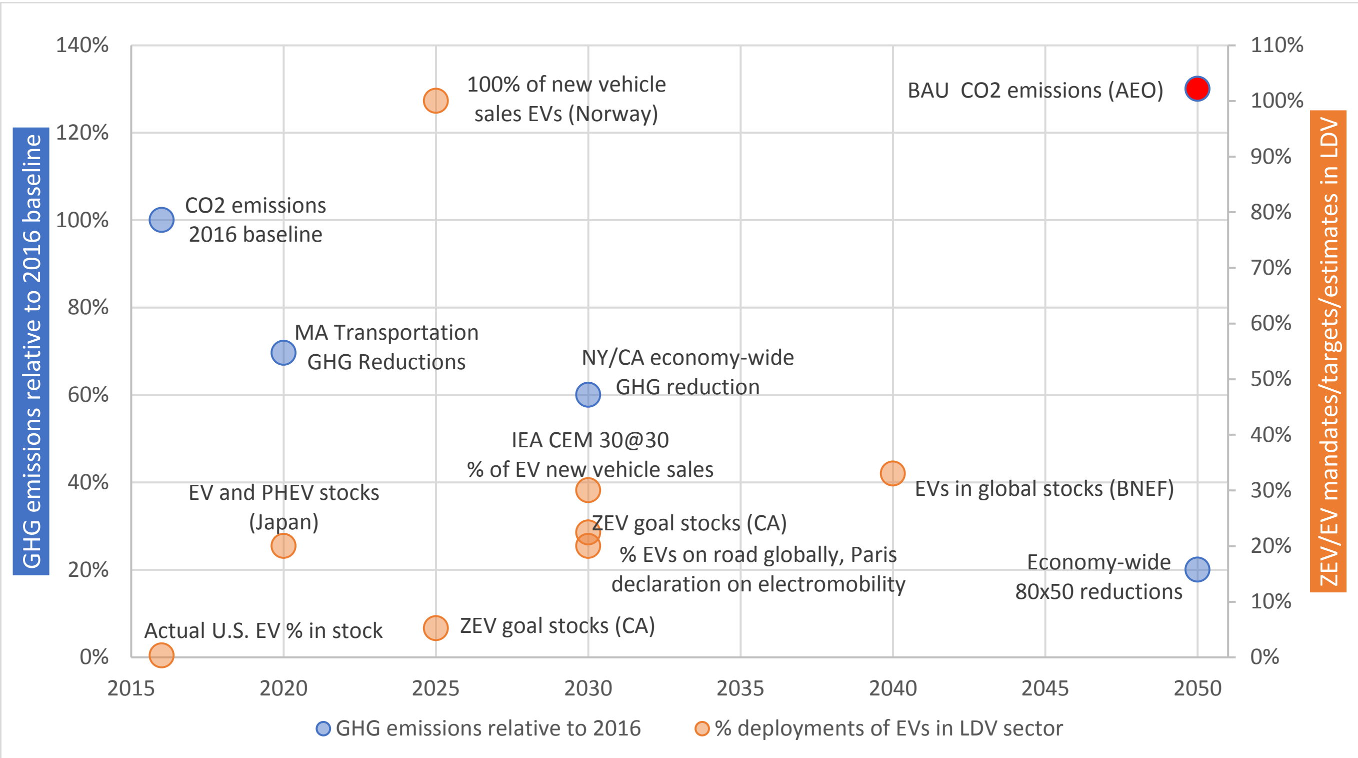
- California also implements a ZEV mandate requiring automobile companies to produce a certain percentage of ZEVs for sale (including electric and hydrogen fuel cell vehicles).[27] In 2012, Executive Order B-16-12 directed the state government to help accelerate the market for ZEVs, and called for 1.5 million ZEVs in California by 2025 (for comparison, California has approximately 29 million registered vehicles).[28] This would bring more ZEVs on the road at a rate nearly double that projected by BNEF.[29] The Governor's Interagency Working Group on ZEVs has noted that meeting the state's long-term climate goals essentially requires 100 percent of all new passenger vehicles in California to be ZEVs between 2040 and 2050.[30] As of May 2017, 300,000 ZEVs and plug-in hybrid electric vehicles (PHEVs) were sold in California, constituting half of the total 600,000 registered in the United States.[31]

- California's policy was adopted by other states, which joined the Multi-State Zero Emission Vehicle (ZEV) Initiative. Participants include Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont, which, together with California, collectively constitute 27 percent of the U.S. automobile market. The initiative aims to deploy 3.3 million ZEVs on the eight states' roads by 2025 and to make all passenger vehicle sales ZEVs by 2050.[32]

- Like California, New York has also established a path to achieve an 80 percent reduction in GHG emissions (from a 2005 baseline level) by 2050. It has been noted that this goal will likely only be achieved if it includes significant electrification of the transport sector.

[k] Though this initiative did not specify a goal for transportation per se, through modeling, it explored one scenario in which 16 quadrillion BTU could be avoided in the transportation sector by 2030, resulting in a reduction in transport energy use by 60 percent.

*Figure 7: Summary of Select GHG (blue) and EV deployment targets of nations and U.S. States (red) based on public announcements. This figure includes both economy-wide GHG reductions and transportation-specific reductions; and EV sales levels and EV stock penetration, for comparison.*




- Exploring the transportation impacts of "80 by 50" economy-wide greenhouse gas reduction goals, the Natural Resources Defense Council estimates that a 50 percent reduction in transportation energy use (relative to a 2050 business as usual scenario) would be required by 2050 to achieve an "80 by 50" GHG reduction. Their core modeling scenario includes a 24 percent reduction in vehicle miles traveled, significant electrification (such that EVs account for 60 percent of car vehicle-miles traveled), and significant vehicle efficiency gains relative to the AEO 2014-2050 baseline to achieve the reduction.[33]

- A number of transportation companies are setting ambitious goals as well: GM will bring two new EVs to market in the next 18 months, and at least 20 new all-electric vehicles (battery and/or fuel cell) by 2023;[34] Audi has announced an unveiling of three electric vehicles by 2020 and has committed to achieving 25 percent of U.S. sales from electric vehicles by 2025;[35] Nissan seeks to double annual sales of the Nissan Leaf by 2018;[36] Kia plans to increase fuel economy by 25 percent over 2014 levels by 2020 (through the use of more hybrids, electric, and fuel cell vehicles);[37] and Ford is considering electrification to 40 percent of its lineup and investing $4.5 billion in vehicle electrification by 2020.[38]

- Several countries – including the UK, France, Germany, Norway, India, Japan, and China – have made announcements relating to banning the sale of new diesel and gas cars by a target year in the future.[39]

- Given that many transportation goals in recent years are framed in terms of emissions reductions or the deployment of electric light duty vehicles, a selection of these targets are shown in Figure 7.

The proposed goal is ambitious relative to the BAU scenario, and consistent with the trends, policies and initiatives listed above. It is also important to emphasize that the Commission's goal encompasses the entire U.S. market, which represents fully one-quarter of the global energy consumption in the transport sector as noted above. Achieving the national goal will depend, in large measure, on aggressive actions in some markets to offset slower progress in others.

## Next Steps

With the launch of the 50x50 Commission, the Technical Committees will begin meeting regularly to set each Committee's detailed scope, explore potential milestones and metrics to chart progress, identify and pursue areas for necessary analysis and research, establish a series of recommendations for transportation sector stakeholders, and a strategy for outreach and implementation. The Commission will meet two more times over the course of the year to assess progress, guide the shape of the final recommendations, and explore ways to implement these efforts.

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