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Issue Brief

Autonomous Vehicles: State of the Technology and Potential Role as a Climate Solution

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Autonomous vehicles (AVs) are an emerging technology in surface transportation with tremendous potential to change the way individuals and communities interact with the built environment. The widespread use of AVs could also have a substantial impact on greenhouse gas emissions from the transportation sector, which is responsible for the largest share of emissions in the United States at 28 percent.[1] The vast majority of those transportation emissions—82 percent—are from cars and trucks,[1] many of which could be replaced with AVs. A recent study suggests that half of new vehicles could be autonomous by 2050, and half of the entire vehicle fleet by the 2060s.[2] Another, related key trend in transportation is electrification: more than half of all new passenger vehicles will be electric by 2040, according to a BloombergNEF study,[3] and most AVs are expected to be electric.[4] Whether AVs increase or reduce greenhouse gas emissions could help make or break efforts at keeping climate change in check. This issue brief reviews the projected environmental impacts of AVs, the benefits AVs could provide as a form of mass transit, and an overview of AV development, testing, and policies in the United States as well as internationally.

Potential Impacts of Autonomous Vehicle Technology

Several automakers have been bullish about AV technology, predicting its imminent, broad deployment in the United States.[6] They also note several synergies between AV and EV (electric vehicle) technology, so that AV deployment could find itself accelerated as governments across the world increasingly phase out vehicles powered by fossil fuels (see next page for details).[4,7] Multiple issues remain, however, and some experts have cautioned that the development of reliable, safe, and affordable autonomous vehicles will take many more years than advocates claim.[8]

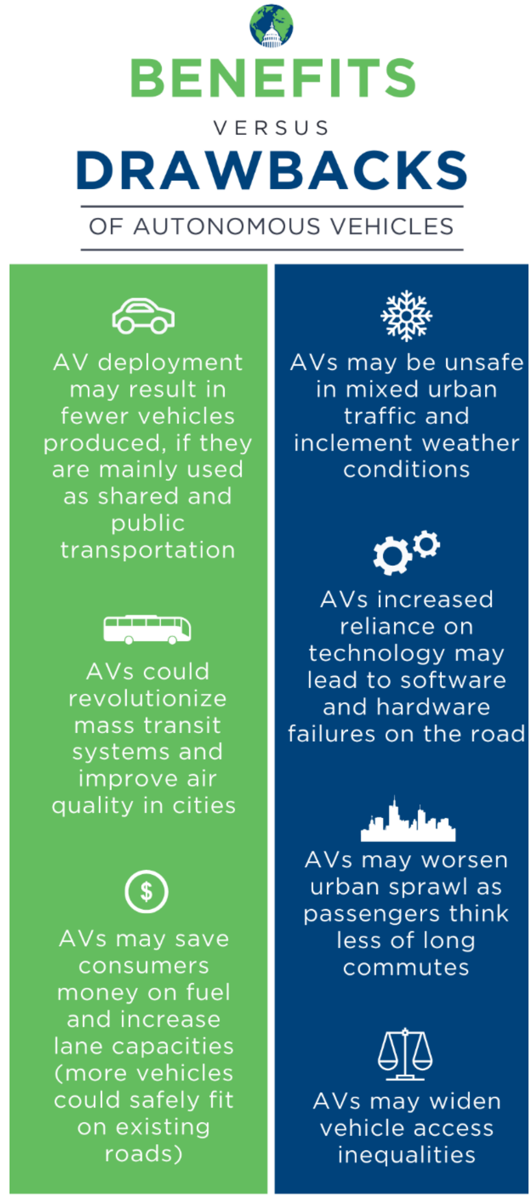
Most of the AVs currently in use are considered "level 3," which means that a human driver must be available to take over in some traffic circumstances (see table). A few AV shuttles are designated as "level 4," meaning the vehicle can complete a trip autonomously on mapped, pre-planned routes.

The Levels of Driving Automation[5]	
Level 0	**No driving automation**
Level 1	**Driver assistance** (e.g., cruise control)
Level 2	**Partial driving automation** (e.g., self parallel parking)
Level 3	**Conditional driving automation** (environmental detection capabilities)
Level 4	**High driving automation** (self-driving in specific environments)
Level 5	**Full driving automation**

Safety and Security

Advocates argue that autonomous vehicles will be far safer than vehicles driven by humans. According to the National Highway Traffic Safety Administration, 94 percent of serious crashes are due to human error, and in 2018 alone, 36,560 people died in car crashes in the United States.[9] Reducing the scope for human error could help save lives. However, considerable progress is needed in artificial intelligence (AI) technology before AVs can operate reliably in mixed urban traffic, heavy rain and snow, unpaved and unmapped roads, and in areas with weak wireless connectivity.[10] AVs rely on AI to identify and respond to traffic signals, signs, pedestrians, and other vehicles while keeping their occupants safe. At the moment, AI has great difficulty reacting to the often unpredictable movements of pedestrians and bicyclists on roads, thus placing people engaging in active transportation at greater risk.[11] Several deadly AV accidents have already occurred due to faulty AI, raising concerns among policymakers and community advocates.[12,13,14]

Malicious hacking and surveillance are likely to present challenges to the successful deployment of self-driving cars in the coming decade.[15] AVs increase the vulnerability of vehicles to hacking and unwanted location tracking and data sharing.[2] These safety and security concerns will require further testing and regulatory approval before AVs can be extensively deployed.[16]



Graphic By: Sydney O'Shaughnessy

The Environment

Many car manufacturers and technology companies are currently developing electric and hybrid AVs.[17] Commercially-available AVs are all likely to be electric vehicles (EVs) for three key reasons: emission-free and quieter vehicles are more likely to be adopted in dense cities and in a world that is seeking to reduce its carbon emissions; AV sensors and computers need a lot of reliable electricity, which batteries are better able to provide than combustion engines; and electric vehicles are much more responsive, which makes them safer and easier for artificial intelligence systems to control.[4] It will also potentially be easier for electric AVs to recharge themselves without human intervention (versus gasoline refueling).

Electric vehicles—including electric AVs—do not emit carbon or other pollutants at the tailpipe. Because of the efficiency of electric motors, electric vehicles have lower emissions than gasoline-powered vehicles, even if they use electricity from a grid relying on fossil fuel plants. Electric vehicles in the United States emit as much carbon (indirectly, by using grid electricity) as a gasoline-fueled vehicle getting 88 miles per gallon (mpg).[18] In comparison, the most efficient gasoline car manages about 58 miles per gallon, and the average new gasoline car does 31 mpg.[19] Though a significant share of U.S. electricity will come from fossil fuels for the foreseeable future (in 2019, fossil fuels—mostly natural gas—accounted for 63 percent of electricity generation in the United States),[20] an increasing share of renewable energy in electricity generation means that electric vehicles will continue to reduce their greenhouse gas emissions, on a per vehicle basis. But if we build and drive more cars, overall GHG emissions from vehicles—even if most are EVs—could increase. An overall increase in emissions could also occur if people take longer trips and spend more time in their vehicles (see below for details).

If AVs become sufficiently widespread and advanced, driving could become much less risky and many safety features in cars could become superfluous. The National Renewable Energy Laboratory estimates removing safety features that are no longer necessary could make AVs up to 75 percent lighter than conventional vehicles, which could make them significantly more energy efficient.[21]

According to the National Renewable Energy Laboratory, AVs could lead to more efficient driving and routing, with smoother stops and starts and better traffic avoidance, which would also make them more energy efficient.[21] AVs, with their sensors and artificial intelligence, could also make full use of a technique called platooning, or flocking, in which the distance between cars is drastically reduced.[2] By sticking close together, the cars benefit from each other's slipstreams, reducing air resistance and increasing efficiency. Platooning could also help fit more cars on existing roads without causing congestion. But an accident could result in a chain reaction.

Despite these potential environmental benefits, the broad deployment of single-occupancy AVs could have a net negative environmental impact. If people are able to spend more time working or relaxing in their cars, they may decide to travel more. This would cause vehicle miles traveled (VMT) to increase due to AV use, thereby increasing pollution as well. Testing also shows that more than half of an electric vehicle's battery storage could be consumed by the computing power required by an AV's sensors and computers, as well as the cabin comfort and entertainment systems.[17] This would negatively impact the vehicle's energy efficiency and lead to higher electricity consumption.

Authorities may determine AVs can safely be run at higher speeds and increase speed limits on certain roads, which would increase energy consumption over the same distance. Car manufacturers may also begin to design larger, less energy-efficient electric vehicles to accommodate mobile offices and bedrooms.[22,23] Bigger vehicles with bigger batteries would produce more carbon emissions as a byproduct of manufacturing.[24] When considering the vehicle's entire lifecycle, from manufacturing to disposal, researchers have predicted that the widespread use of private electric AVs could increase carbon emissions by up to 200 percent.[25]

Urban Infrastructure

Autonomous cars that can be summoned at will could make car ownership obsolete, at least in urban areas. If such cars were also shared (rather than used by a single person per ride), fewer vehicles would be required to serve the needs of the same number of people, and parking spaces could be eliminated, providing more space for other uses.

However, an increased number of AVs being used as personal vehicles or rideshares could actually have negative impacts on urban sprawl, road congestion, parking, and public transit in large cities.[26] If AVs become a widely available option for private vehicles or rideshares, commuters may prefer them over public transportation. Decreased use of mass transit in favor of these AVs, in turn, would increase congestion on roads and could cause mass transit system operators to raise fares or reduce the number of available routes for regular riders (making mass transit even less appealing and potentially creating a vicious circle). AVs, which allow passengers to work or relax rather than focus on the road, could also make long commutes seem less daunting, pushing people further out into the suburbs. This would cause more urban sprawl, with all the negative environmental impacts that entails.[27]

Many AV visions call for road systems free of traffic lights, which would reduce the space for cyclists and pedestrians.[28] Widespread use of AVs could also lead to increased costs for roadway infrastructure and maintenance.[2] Roads may need to be kept free of any small debris and uneven or irregular pavement lest they be misread by AV sensors, as any sensor errors could endanger passengers, property, pedestrians, and other vehicles.

Integrating AVs with Mass Transit and in Urban Areas

Deploying AVs as bus and shuttle services could have a positive impact on the environment and urban transit. Prototype AV shuttle services are being tested on campuses and in cities around the world (including one at National Harbor, Maryland, just outside of Washington, D.C.).[29] These AV services typically run in confined geographical areas on downtown roads—not highways—and are restricted to very low speeds (usually 10-25 miles per hour). Often, these shuttles seat four to eight passengers per vehicle and are used to provide the first or last mile connections to other public transportation networks, such as buses or light rails.

If AVs are shared (i.e., used as public transportation) and integrated into a multimodal, electric, urban transportation system, urban transportation pollution could be reduced by 80 percent by 2050, and substantial congestion increases could be avoided.[30] Vehicle miles traveled (VMT) would decline by 25 percent, contrasted with a 50 percent increase in VMT if the automobile industry is allowed to pursue its current focus on single-occupancy vehicle trips.[31] Without intervention to require pooling, people might opt to take AVs rather than public transportation, leading to increased congestion and greenhouse gas (GHG) emissions.

The National Association of City Transportation Officials (NACTO), representing 81 North American cities, published a second edition of its *Blueprint for Autonomous Urbanism*, which predicts how AVs could help or hurt cities.[32] The report suggests that cities should engage with automobile manufacturers, mobility companies, and other stakeholders to ensure that AV technology is used to decrease VMT and GHG emissions. The blueprint recommends:

- High-capacity, on-street transit (buses, streetcars, and street-level light rail) is essential for growth without congestion. Privately-owned AVs should not take street space at the expense of such on-street transit;
- AVs operating in urban areas should be limited to speeds of 25 mph or less and should be able to demonstrate their ability to protect all right-of-way users;
- Walking, biking, and green spaces should be given priority for street space and resource investments (walking and biking are healthier and less polluting than even the most efficient AVs and so should be encouraged by public authorities);
- Freight distribution should be consolidated to increase efficiency and reduce the number of large vehicles—including AVs—in and around urban areas;
- Location delivery vehicles—including AVs—should be downsized whenever possible to allow deliveries via e-bikes or other small, high-efficiency modes (several companies are testing small, autonomous delivery robots, including some that could use sidewalks instead of roads);[33]
- Private vehicles and parking should be de-prioritized by implementing programs such as congestion pricing, dedicated lanes for mass transit, and green infrastructure in spaces reclaimed from parking; and
- Cities should have access to information about how ride-hail services and other new transportation service providers impact congestion and VMT.

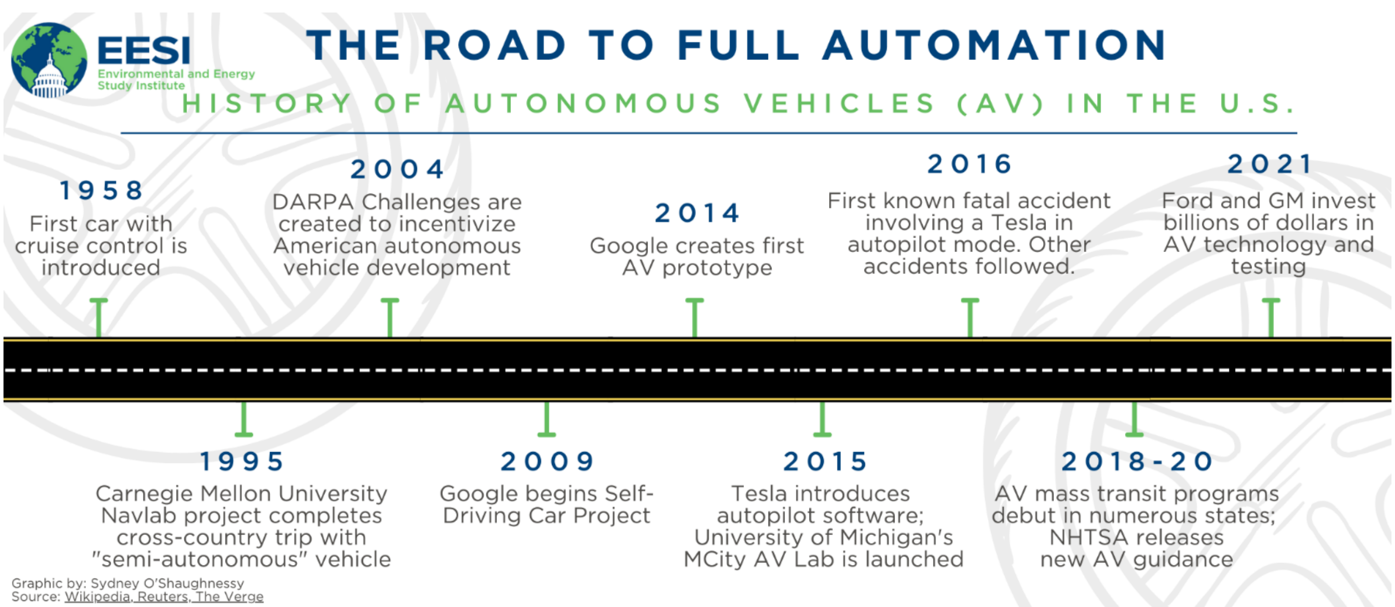
These recommendations indicate that city governments will need to work to change how street space is designed and allocated to decrease VMT and reduce GHG emissions through making transit, biking, and walking more reliable and appealing by prioritizing those transportation modes over single-occupancy vehicles. In particular, cities will need to act proactively to ensure that AVs are used in ways that reduce congestion and pollution rather than the reverse.

Autonomous Vehicle Policy, Development, and Testing in the United States

In January 2020, the National Highway Traffic Safety Administration (NHTSA, part of the U.S. Department of Transportation) released *Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0*, which builds upon its previous policy guidance for AVs, and expands the scope to all surface on-road transportation systems.[34] NHTSA is currently working on changing the Federal Motor Vehicle Safety Standards for AVs to include, among other provisions, recommending voluntary action by AV manufacturers and developers in lieu of regulation.[35] NHTSA had previously issued federal exemptions for testing purposes to allow AVs to be deployed on public roads without steering wheels, brake pedals, or rear or side mirrors. Critics argue that the technology is being deployed without common standards or terminology, which creates confusion about what the systems can safely do.[36]

Several Congressional efforts are seeking to use AVs to bring down GHG emissions. The majority staff of the House Select Committee on the Climate Crisis released a report in 2020 that included a set of recommendations related to AV technology to help reduce CO2 emissions.[37] It recommends that Congress direct the Environmental Protection Agency and Department of Transportation to develop a national autonomous vehicle strategy focused on climate change, complementing ongoing federal efforts to develop strong safety standards. During the 116th Congress, Rep. Blumenauer (D-Ore.) introduced the *Preparing Localities for an Autonomous and Connected Environment (PLACE) Act* (H.R. 2542), to study the social and environmental impacts of AVs.[38] The bill would establish a federally-funded clearinghouse at a higher education institution to collect, conduct, and fund research to understand how AVs will affect land use, transportation, municipal budgets, the environment, and social equity.

Several states (such as Nevada, Florida, California, Virginia, Michigan, Maryland, and Arizona) have issued permits in recent years to allow pilot AV programs to begin on public roads.[39] In California, the state's public utility commission is currently considering how to regulate AVs in fleet services (e.g., taxis and ride hailing). The statewide pilot program began in 2018, and the current regulatory proceedings will consider issues of pooling, GHG emissions, and other environmental, safety, equity, compensation, accessibility, and privacy concerns.[40] Concurrently, the California Air Resources Board is working to reduce GHG emissions from ride-hail companies by setting a standard for allowed emissions,[41] but AV companies are concerned that such a standard would hamper innovation.



Car manufacturers and large information technology corporations have collectively spent tens of billions of dollars researching and developing AVs over the past decade. Waymo LLC, a self-driving technology development subsidiary of Alphabet, Inc., started a trial self-driving taxi service in Phoenix, Arizona, in 2017.[42] Another AV shuttle service is being tested at Ohio State University.[43] In 2019, an autonomous mobility solutions service, Beep, began a pilot of a self-driving shuttle bus in a suburb of Orlando, Florida. Every ride includes human attendants, and emergency personnel are available in case intervention is necessary. Vehicles operate over a fixed route and speeds are limited to 15 miles per hour. In February 2020, Beep expanded the trial to Peoria, Arizona.[44]

In 2019, a program in Columbus, Ohio, deployed six AV shuttles (each holding up to five passengers) operating over a circuit of designated roads. The program, run by May Mobility, has moved over 16,000 passengers around the city's downtown over a nine-month period. Grand Rapids, Michigan, is also testing an AV shuttle, which provides free service along a selected route.[45]

Autonomous Vehicle Development and Testing Internationally

Countries around the world are developing and starting to deploy AV technology; indeed, AV shuttle services in the United States appear to be lagging behind comparable programs in Europe and Asia. One study ranked the top ten European countries for AV development as: the Netherlands, Norway, Sweden, Finland, the United Kingdom, Germany, Austria, France, Spain, and Hungary.[46] The United Nations Economic and Social Commission for Asia and the Pacific ranked Singapore first in AV readiness because of its policies and laws governing AV deployment as well as its high consumer acceptance. The report also noted that South Korea has a facility intended to be the world's largest testbed for AVs.[47]

In Helsinki, Finland, a robot bus called GACHA, designed by Japanese retailer Muji, is able to navigate and detect obstacles in all weather conditions. The bus can seat 10 people and travel at 40 km (25 miles) per hour, with a range of 100 km (62 miles). It was commercially deployed in 2020.[48] Singapore began AV bus trials in 2019 and launched commercial autonomous bus services, on a trial basis, in January 2021.[49,50] A full size (40 passenger) AV bus is also being testing in the United Kingdom.[51]

Conclusion

With transportation accounting for the largest share of greenhouse gas emissions among economic sectors in the United States,[1] governments at all levels need to focus on planning for a more efficient and effective transportation system, in order to reduce its negative environmental effects and ensure maximum accessibility.

Autonomous vehicles hold a lot of potential, both to make roads safer by reducing the scope for human error and to reduce greenhouse gas emissions by accelerating the transition to electric and hybrid vehicles. However, AVs could also increase congestion and pollution if they become so popular that individuals switch to using private or shared vehicles instead of using mass transit, biking, or walking.

There is a strong bias in American culture towards car ownership, with cars representing freedom and autonomy. Cars are instantly available, can be used as mobile storage, and signal social status. But cars are also resource-hungry and, for the foreseeable future, greenhouse-gas emitting (if only because of the energy it takes to build them). In addition to harming the environment, America's prioritization of cars over public transportation, walking, and biking also worsens inequalities. The lack of investment in alternative means of transportation makes it more challenging for low-income workers who cannot afford private vehicles to access jobs, healthcare, social services, and other opportunities. Policymakers will need to take such considerations into account as they evaluate and respond to the likely impact of autonomous vehicles on transportation networks.

To achieve their climate goals and reduce congestion, cities, states, and the federal government will need to craft policies that ensure autonomous vehicles are fully integrated into multimodal, electric, urban transportation systems that favor mass transit, biking, and walking while discouraging single-occupancy rides. Making changes to transportation infrastructure is slow, expensive, and requires cooperation among many disparate groups. But such changes are necessary in the effort to decrease U.S. greenhouse gas emissions.

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This issue brief is available electronically (with hyperlinks and endnotes) at *www.eesi.org/papers*.

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