Climate Solutions Series

Decarbonizing Global Transport

By Stephen Naimoli and Nikos Tsafos

THE ISSUE
This brief is the third in a series on achieving net-zero global greenhouse gas emissions by 2050. The CSIS Energy Security and Climate Change Program is hosting six events that will be followed by resource briefs related to each event. For more information on the series, see our website.

THE CHALLENGE
The transportation sector is a large and diverse sector that encompasses road, aviation, rail, and marine transport. Transportation includes both the movement of passengers and the movement of goods. In 2018, the global transportation sector emitted approximately 8 billion tons of carbon dioxide (CO₂), or 24 percent of CO₂ emissions from fuel combustion.¹ As shown in Figure 1, 45 percent of total transportation emissions came from passenger vehicles, 29 percent from road freight vehicles, 12 percent from aviation, 11 percent from international shipping, less than 1 percent from rail, and the final 2 percent from other sources. Transportation is the second-largest source of CO₂ emissions worldwide and the largest source in the United States. Transportation emissions have grown steadily over the past few decades, largely due to increased travel related to economic growth and delivery services but also due to an increasing trend toward larger cars, SUVs, and pickup trucks. Absent significant action, aviation and shipping will be responsible for an increasing share of emissions from transport. Oil demand is expected to continue increasing through at least 2040 in a business-as-usual scenario, and while increasing efficiency and electrification in passenger vehicles is expected to mitigate the increase in that segment, increased oil use in aviation and shipping will cause emissions to grow at a faster rate.²

Figure 1: Transport Emissions by Mode, 2018 (billion tons CO₂)

Data source: “Transport,” International Energy Agency, 2020, https://www.iea.org/topics/transport. Each component of the transportation system has unique challenges to reduce emissions. One common issue is that decarbonizing transportation requires consumer adoption. Decarbonizing the transportation sector requires decisions from individuals, fleet owners, shipping company managers, and so on. This requires convincing stakeholders
to make different purchasing and behavioral decisions. In personal transportation alone, there are over 1.3 billion cars on roads around the world. Just dealing with the emissions from cars will require replacing virtually all of these with zero-emissions vehicles or encouraging passengers to travel via other modes of transport. Even a complete ban on the sale of new fossil fuel-powered vehicles would take years to reduce emissions from cars in use to zero, as a significant number of older cars not affected by the ban would remain in use for 10 to 15 years given current patterns of fleet turnover. While technological solutions exist to replace conventional internal combustion vehicles with lower emitting options, reducing the costs and creating the enabling infrastructure to facilitate mass deployment and zero emissions is still a long way from where it needs to be.

This does not begin to address the other segments of the transportation sector, such as aviation and marine shipping and travel, for which there are not yet viable solutions at scale. Decarbonizing these segments will require more technological breakthroughs, whether they are solutions that allow for new drop-in liquid fuels to replace carbon-intensive fuels or innovative ways to power transportation using electricity or hydrogen. Unfortunately, it is likely to take decades to develop these technologies, so significant investment in identifying these solutions will be necessary.

While technological solutions exist to replace conventional internal combustion vehicles with lower emitting options, reducing the costs and creating the enabling infrastructure to facilitate mass deployment and zero emissions is still a long way from where it needs to be.

GETTING FROM HERE TO THERE

TECHNOLOGY

Electric vehicles (EVs) are the most prominent solution in the transportation sector. Versions of EVs have been developed and released since the 1800s, beginning with early electric alternatives to horse and buggy wagons such as William Morrison’s electric wagon in 1896. The latest iteration and the technology that generates the most attention is the lithium-ion battery-powered electric car. Tesla Energy, then Tesla Motors, released the first mass-produced electric car in 2008 with the Tesla Roadster. Now, there are several EV offerings from Tesla as well as the traditional automakers, with many more models on the way. As of mid-2020, there are 7 million passenger EVs, half a million electric buses, and about 400,000 electric delivery vans and trucks on the road. The upfront cost of EVs is still higher than that of internal combustion engine (ICE) vehicles, but energy consultancy BloombergNEF predicts that will change by 2030 as EVs meet price parity with ICE vehicles around the world, largely due to economies of scale and decreases in battery costs. It is important to note, however, that consumers do not always buy cars based on price alone; there are many factors that go into buying a new car and, when complexity is introduced into the equation, as it may with EVs, they are more likely to default to what is familiar. Therefore, price parity may not drive deployment on its own.

Although the car is the most popular mode of personal transport in the United States, that is not the case in many other countries. In India, for example, two-wheeled vehicles such as scooters and mopeds are much more common and are ripe for electrification. Three-wheeled auto rickshaws, which are a common last-mile solution in India, see fewer sales but are also easy to electrify because they can use smaller batteries and do not require specialized charging infrastructure. As shown in Figure 2, of the approximately 26 million vehicles sold in India in fiscal year 2019, 80 percent were two-wheelers, 13 percent were cars, and 3 percent were three-wheelers. Only about 760,000 of those 26 million were EVs, but as shown in Figure 3, 83 percent of EV sales were three-wheelers, just under 17 percent were two-wheelers, and electric cars and commercial vehicles made up the remaining less than 1 percent. Clearly, some see a quicker path to the electrification of two- and three-wheelers in India than of passenger cars—a report from Rocky Mountain Institute and Indian government think tank NITI Aayog suggests that the success of current policy interventions could push EVs to 80 percent market share in both two-wheelers and three-wheelers by 2030.
Some automakers, most notably Toyota, believe that the **hydrogen fuel cell vehicle** (HFCV) will emerge as a viable alternative to the battery EV. An HFCV is similar to the battery EV, but the electric motor is powered by a fuel cell that converts hydrogen and oxygen to electricity rather than a battery. A combination of unfavorable economics and a lack of fueling infrastructure has impeded the expansion that HFCV manufacturers want in personal transport, but the technology may find better success in other segments.

Personal transport is not the only segment of transportation seeing growing electrification; low-emissions short-haul and long-haul vans and trucks as well as buses will also be key to decarbonizing the sector.

Electric long-haul trucks are not yet widely available, but some experts and manufacturers of heavy-duty trucks are optimistic that solutions are emerging. Some experts believe that HFCVs may become the preferred solution for zero-emissions long-haul trucking because it may allow for a longer range and it could eliminate the problem of added weight that batteries can cause for this segment. Electric buses are gaining adoption in a number of countries, but particularly in China, where aggressive policy decisions have spurred deployment of most of the world’s 500,000 electric buses.

Regardless of the segment or the technology, the success of zero-emissions transport requires **charging or fueling infrastructure**. Many EV owners can charge their cars overnight at home. The International Energy Agency (IEA) has found that in 2019, 6.5 million of the world’s 7.3 million EV charging points were private chargers at homes, apartment buildings, and offices. However, “range anxiety,” or the fear that an EV will run out of charge before reaching its destination or a charging point, necessitates publicly available charging infrastructure along roads and highways.

A 2019 survey in the United States found that 58 percent of drivers were concerned about an EV running out of power and 49 percent were afraid there were not enough charging stations. A similar study in the United Kingdom found that 57 percent of drivers were concerned about switching to an EV because of range concerns and 69 percent felt there were not enough charging stations. Interestingly, a 2016 study found that, at least in the United States, 87 percent of daily car use could be met with an EV, and a 2020 survey from AAA found that 91 percent of EV owners had range anxiety concerns before buying and 77 percent became less or no longer concerned after buying and driving their EVs.

EV chargers are categorized by their “level,” which describes how quickly they can charge a vehicle. Level 1 chargers can provide 2 to 5 miles per hour, Level 2 chargers can provide 10 to 60 miles per hour, and Level 3 chargers (also known as direct current fast chargers, or DCFC) can typically provide 60 to 100 miles in 20 minutes. The latest EV offerings can reach well over 300 miles per charge, so charging time is important. Publicly available DCFC infrastructure is considered necessary for widespread adoption of EVs, but it is very capital intensive and incurs demand costs for the electricity it uses, so it is difficult to make profitable. In addition, there is debate over whether electric utilities or other private companies should own the infrastructure. All of
these issues will need to be resolved for EV charging to become more widely available.

There is evidence that, at least in some countries, EV charging infrastructure is not being deployed at a sufficient pace to keep up with expected deployment of EVs. The International Council on Clean Transportation assessed the availability of public and workplace charging in the 100 most populous metropolitan areas of the United States as of 2017 and compared it to the charging needs of what they expect will be 3 million EVs on the road by 2025. They found that only about 25 percent of the chargers necessary for those 3 million EVs across these metropolitan areas were in place, and 88 of the 100 areas had less than half the charging infrastructure they would need by 2025. While this does not pose an immediate problem, it implies that if EV sales maintain the rate assumed in the study’s scenario, many of these areas will need to ensure infrastructure development keeps up. Notably, even while increasing the number of charging points to meet EV owners’ projected need, utilization of charging infrastructure would increase in their scenario, helping to make the business case for installing chargers more attractive.

Hydrogen fueling infrastructure is much less common. At the end of 2019, there were 432 hydrogen fueling stations around the world and another 226 in development. Unlike EVs, HFCVs cannot be fueled at home. Building hydrogen fueling stations is much more expensive than building EV charging stations—by one estimate, $1-3 million compared to $200,000 for an ultra-fast EV charging station—but a station can fuel an HFCV in 3 to 5 minutes, compared to over half an hour for an EV with a similar range on an ultra-fast station.

Automated vehicles, also referred to as self-driving cars or autonomous vehicles, may be part of the decarbonization solution. Proponents argue that because they do not need a driver, they can replace much of private car ownership. Some experts have argued that AVs will need to be all-electric because of the power requirements to make AVs work. If a large-scale shift from privately-owned ICE vehicles to shared, electric AVs occurred, it would drive a decrease in emissions from on-road vehicles—potentially an 80 percent reduction by 2050, according to the Institute of Transportation Studies at the University of California-Davis and the Institute for Transportation and Development Policy. If the world embraces AVs without a shift to shared mobility, traffic could increase by 15 or 20 percent, and if AVs are not electric, CO₂ emissions would increase. Opponents of AVs are skeptical that they will meet their technological potential while maintaining safety and addressing congestion.

Alternative fuels may have a role in many different segments of the transportation sector but are likely to play a larger role in those segments that are more difficult to electrify, such as aviation or heavy-duty trucking. In these segments, the power, distance, and weight requirements make it difficult to install battery power, at least with current technology. Alternative fuels that can be substituted for fossil fuels but have lower or zero emissions can be useful for these segments, but the technological breakthroughs required to make them cheap and easy to produce are still elusive.

In addition, the creation of these fuels, especially those from food crops, can indirectly influence land use and inadvertently drive up emissions from other sources or impact the other markets for those feedstocks, including food. For example, palm oil can be used as a biodiesel feedstock, and it releases less CO₂ than fossil diesel when burned. However, when accounting for the CO₂ released from trees and lands cleared for palm oil production, palm oil biodiesel is more carbon-intensive than fossil diesel—by one estimate, three times as much. It should be noted, however, that a cursory search of academic literature on biofuels reveals that there is much debate in the scientific community about their exact CO₂ impacts. There are other methods of creating alternative fuels, including advanced biofuels from waste oils or algae or liquid fuels made from renewable energy, but on the whole, these solutions have either not yet reached commercialization or are very expensive.

Alternative fuels will likely be necessary for zero-emissions ships as well, although as the fossil-based liquid fuels are different for cars and ships, so will be the alternative fuels. Zero-emissions fuels for ships may include methanol and gas oil substitutes made from biomass, hydrogen and ammonia made from natural gas with carbon capture and sequestration, and fuels produced directly from renewable electricity. Batteries may play some small role in the decarbonization of maritime shipping, but the power requirement is likely to make it economically impossible to fully electrify ships. Fuels made from renewable energy, also called electrofuels, may prove to be useful in the future but are currently early in their development, and business models for their production have not yet been established.

Although they will not get us to net-zero emissions alone, efficiency improvements will likely be a key strategy to provide an easier glide path to decarbonize transportation. Improvements in the fuel efficiency of cars have fallen in recent years, from 1.85 percent per year between 2005 and 2016 to just 0.7 percent in 2017. The IEA suggests that a 3.7 percent annual increase through 2030 will be
necessary to meet climate goals. Decreasing vehicle weight and increasing the use of hybrid powertrains can help improve the efficiency of road vehicles. In maritime shipping, there are operational and technical efficiency changes that can decrease greenhouse gas (GHG) emissions, including decreasing sailing speed or installing waste heat recovery systems. There are some similar operational and technical efficiency improvements to be made in aviation as well, including optimizing maintenance of current jets, electrifying some ground operations, and using composite materials and more efficient engines to design new planes.

**POLICY**

Governments around the world have a suite of policies in place to incentivize consumers to buy EVs. The policy that is most visible to consumers is the subsidy, which is typically either given as a tax credit, such as a federal tax credit of up to $7,500 available in the United States, or a cash rebate, such as the up to €12,000 (approximately $13,000) rebate recently announced in France. Other incentives include tax breaks, exemptions from registration fees and taxes, and exemptions from driving restrictions meant to curb air pollution. A potentially viable policy is a scrappage program to trade in old ICE vehicles for financial compensation that can help contribute toward the price of a new EV. This program idea is modeled after previous efforts in various countries to shift consumers from older cars to newer, more efficient cars, but an attempt to use it to incentivize EV purchases would need to reckon with issues with past programs. The 2009 experiment in the United States did not particularly stimulate the economy or have a large impact on GHG emissions, but it did exacerbate economic inequality. Lawmakers in the United States and the United Kingdom have floated the idea, but so far the only programs are Spain’s effort to replace older cars with low- or zero-emission vehicles and London’s scheme aimed at electrifying businesses’ van fleets.

Leveraging government procurement power is also a common strategy to help build markets and stimulate demand for zero-emission vehicles. China has made use of this strategy by buying taxis, buses, and public service vehicles and is requiring the central government’s fleet to be 50 percent electric by 2021. India’s Energy Efficiency Services Limited is using its procurement power to purchase vehicles for the government’s fleet. Many cities around the world have begun buying electric buses to replace diesel buses in their jurisdictions.

Governments can also provide incentives and supportive policies for installing EV charging infrastructure. Most directly, they can provide tax breaks or rebates to property owners who install charge points on their premises or authorize regulated electric utilities to make investments in charging infrastructure that are eligible for cost recovery through their regulated rates. Several countries, including the United States and a number of European countries, offer tax benefits to defray a percentage of the cost of installing EV charging equipment. However, there are other policy options, such as cities incorporating EV charging into their building codes, streamlining permitting processes for installing EV charging, and instituting policies that favor EV charging in parking.

On the supply side, the primary incentive is the EV sales mandate. In the EV market, the sales mandate requires automakers to ensure that a percentage of their vehicle sales are electric by a set date. Since 1990, California has been iterating on its Zero-Emissions Vehicles (ZEV) Program, which requires sales of low- or zero-emissions vehicles in the state. The most recent version of the program awards credit to vehicles based on their range and requires major automakers to hold credits equal to 4.5 percent of sales in 2018 and 22 percent of sales in 2025. As of this writing, 11 other U.S. states have adopted California’s ZEV program and more are considering doing the same. In 2019, China implemented a new quota system modeled after California’s program, requiring 25 percent of new light-duty vehicle sales to be “new energy vehicles” (plug-in hybrids, EVs, or HFCVs) by 2025. Europe has instituted a voluntary version of the credit program. The sales mandate has not yet spread to other countries.

In recent years, a growing number of national, state, and local governments have announced they intend to move beyond just requiring sales of EVs and begin to phase out sales of ICE vehicles. As of June 2020, this is largely limited to a few countries in Western Europe and several of their cities, but some U.S. states have considered making similar commitments. It is worth noting that, with the exception of France, all of the announcements have yet to be enacted as binding legislation, so it remains to be seen whether these jurisdictions will follow through with their pledges once their compliance dates arrive.

Not all transportation policy aims to simply electrify the modes of transportation currently in use. A strain of transportation policy generally associated with urbanism aims to decrease car use in favor of mass transit, biking, and walking. Urbanist advocates argue that smarter city planning and a more efficient allocation of space can reduce private car use, which would reduce CO₂ emissions.
without having to sell as many EVs. These policies are not necessarily aimed directly at reducing CO\textsubscript{2}, but at other issues important to many who work on transportation issues, including traffic and pedestrian deaths on city roads, that can correlate with CO\textsubscript{2} emissions.

The most commonly proposed policies in this area can broadly be characterized as reducing driving, increasing density, and reallocating urban space. The policies to reduce driving include increasing the gas tax to make driving more expensive, implementing congestion taxes to disincentivize driving in high-traffic areas and during high-traffic times, and limiting parking. There has been some evidence that these policies have worked—for example, a pilot congestion fee in downtown Stockholm, Sweden, in 2006 decreased vehicle kilometers travelled by 14 percent from the previous year and increased public transit use by 6 percent.\textsuperscript{55} In Copenhagen, Denmark, charging higher parking fees in the city center than the outskirts helped decrease traffic downtown by 6 percent from 2005 to 2011.\textsuperscript{56} Increasing density is not directly a transportation policy; rather, it would be a change to city planning. The direct link between density and GHG emissions is not perfectly clear, but there is evidence that increased density can provide greater access to public transit and decrease vehicle miles traveled, leading to lower GHG emissions from car travel.\textsuperscript{57} Closing streets to vehicles and reallocating the space to pedestrians and cyclists is even less tested as a climate strategy. New York City converted Times Square to a pedestrian plaza in 2014 to decrease pedestrian deaths, and Seattle closed some streets to traffic in 2020 to make more room for walking and cycling.\textsuperscript{58} This is likely to be a very contentious issue if it becomes a more common practice around the world.

Mass transit, including heavy- and light-rail trains as well as buses, is a much more efficient way of moving passengers than single-occupancy vehicles or ridesharing. In the United States, subway and metro trains in 2008 produced 76 percent less CO\textsubscript{2} than single-occupancy vehicles, while light-rail transit emitted 62 percent less and buses emitted 33 percent less.\textsuperscript{59} As described earlier in this brief, buses are ripe for electrification and about 75 percent of passenger rail is already electrified, so the decreasing carbon intensity of electricity will deliver even greater benefits for electrified mass transit.\textsuperscript{60} Building more mass transit and encouraging drivers to take the bus or train could be key policy decisions to decarbonize transportation.

Mass transit projects can be very capital intensive—particularly rail projects, which can cost anywhere from $10 million to $500 million—and often face political headwinds in the spending, siting, and building phases.\textsuperscript{61} The IEA suggests optimizing operational and technical efficiency of transit, and implementing a “polluter pays” principle in transportation funding through road fees and congestion charges can help minimize cost concerns.\textsuperscript{62}

Building more mass transit and encouraging drivers to take the bus or train could be key policy decisions to decarbonize transportation.

---

**COVID-19 AND THE FUTURE OF TRANSPORT**

At the time of this writing, the world is in the midst of the Covid-19 pandemic. This crisis has the potential to shake up the future of transportation, especially public transit. Publicly available data indicate that Covid-19 has forced a larger decline in transit usage than in walking or driving, as would-be commuters have stayed home and avoided crowded areas.\textsuperscript{63} Cities around the world are temporarily closing streets to make more room for walking and biking.\textsuperscript{64} Teleworking has become the norm for many office workers around the world, while many other “non-essential” businesses have closed, leaving millions more workers unemployed. Eventually, the threat of Covid-19 will go away, but the time spent dealing with it and the measures taken could have profound effects on how people get around.

Some countries have issued economic relief for carbon-intensive transportation with conditions on decarbonizing or mode shifting. In France, for example, Air France will be required to eliminate short-haul flights where rail service is available, and in the United Kingdom, the government has formed a “Jet Zero” council in an effort to begin a “greener restart” from the Covid-19 crisis.\textsuperscript{65} Many others, such as the United States, have opted not to add these conditions. No one is equipped to predict what the long-term
effects of this pandemic will be, but here are a few questions that this situation raises:

- How will Covid-19 and future pandemics affect public transit usage in the long run? Will fears about public transit persist and change long-term behavior after the pandemic has been addressed? Will this push already cash-strapped transit systems into insolvency? How will this affect those for whom public transit is the only viable mode of transportation?

- Social distancing has necessitated teleworking for many non-essential workers. Will learnings from this period inspire more or less teleworking in the future?

- Most of the road closures around the world for more walking and biking are temporary. Will this trend last beyond the worries about the pandemic?

THE ROLE OF PRIVATE-SECTOR ENGAGEMENT

Automakers are increasingly introducing more EV models to the public. Research has shown that increased model availability typically correlates with higher EV adoption. EV charging companies such as ChargePoint, Electrify America (established by Volkswagen as part of a settlement with the U.S. government for selling cars that cheated on emissions tests), and EVgo are installing public EV chargers. Tesla has also installed a network of its “superchargers” around the world, but unlike the other companies’ infrastructure, its chargers will only fit Tesla cars.

Alongside automakers such as Daimler and Volkswagen, oil and gas majors are getting involved in transportation decarbonization, particularly EV charging, hydrogen fueling infrastructure, and alternative fuels. A few of the majors have acquired EV charging companies, including BP’s acquisition of Chargemaster, Shell’s acquisition of NewMotion and Greenlots, and Total’s acquisition of G2Mobility and PitPoint. Equinor and Shell have also invested in ChargePoint. Many of the oil and gas majors have alternative fuels programs, including BP’s sugarcane ethanol joint venture in Brazil, Eni’s biorefineries converting waste oils to fuel in Italy, and ExxonMobil’s longstanding algae biofuel research efforts in the United States.

The private sector can serve as a source of demand as well, particularly among fleet owners. Through the Climate Group’s EV100 campaign, 77 companies in various sectors have committed to accelerate EV adoption. Ride hailing companies have made big commitments as well. In 2017, Indian ride hailing company Ola formed Ola Electric, a project to deploy electric two-, three-, and four-wheelers on its platform. In 2019, Uber and charging network owner EVgo announced a partnership that would educate Uber drivers who currently drive EVs, increase access to EVgo charging stations for Uber drivers, and eventually help Uber drivers switch from ICE vehicles to EVs. In June 2020, Lyft committed to converting 100 percent of the cars on its platform to EVs by 2030, including by offering EVs for drivers to rent and by helping drivers swap their personal ICE vehicles for EVs.

Many delivery companies have begun to turn to electric trucks and vans—UPS has ordered 10,000 electric trucks from UK startup Arrival, and Amazon has ordered 100,000 electric vans from Rivian. Germany-based Deutsche Post DHL bought StreetScooter in 2014 and has integrated the company’s electric delivery trucks into their fleet. Unfortunately, DHL was unable to scale the business, and they announced in early 2020 that they would close the business and focus on buying EVs from other manufacturers.

CONCLUSION

Decarbonizing the transportation sector will mean addressing a disparate collection of transportation modes, some easier to decarbonize than others. Even in passenger vehicles, the easiest of the modes to decarbonize through electrification, replacing the over 1 billion cars on the road and meeting new demand for cars with EVs will be a very difficult challenge. In segments such as heavy-duty, long-haul trucking, aviation, and marine transport, new technology breakthroughs will be required to sufficiently decrease CO₂ emissions. The private sector will be deeply involved in the process to address transportation emissions given its role in manufacturing vehicles and their fueling infrastructure as well as serving as a source of demand. Policy will likely play a large role in determining the path for different technologies, enabling growth of zero-emissions options, and perhaps even changing behavior and the way people interact with cities.

Stephen Naimoli is a research associate with the Energy Security and Climate Change Program at the Center for Strategic and International Studies (CSIS) in Washington, D.C.

Nikos Tsafos is a senior fellow with the CSIS Energy Security
and Climate Change Program.

The authors would like to thank Howard Gruenspecht, Sarah Ladislaw, and Kartikeya Singh for their input on this brief and Dan McGrath, Shoshanna Saxe, Anand Shah, and Dan Sperling for participating in the event that informed this brief.

This brief is made possible by support from JPMorgan Chase & Co.


4. Ibid.


20. Ibid.


ev-turn-off-survey-finds/.


26. David Thill, “The need for charging stations is clear, but who should own them is not,” Energy News Network, February 15, 2019, https://energynews.us/2019/02/15/midwest/the-need-for-charging-stations-is-clear-but-who-should-own-them-is-not/.


39. Ibid.


Incentives in Europe: A Complete Guide for Businesses and Credits-Explained/


58. Tanay Warerkar, “Times Square’s transformation into a pedestrian-friendly space captured in photos,”


61. Ibid.

62. Ibid.


