TR NEWS

September–October 2022 NUMBER 341

DECARBONIZING TRANSPORTATION

Challenges and Pathways to 2050

PLUS

Decarbonizing the U.S. Power Grid with Battery Electric Vehicles

Research Needs for Reducing Carbon in Aviation

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COVER The drive to decarbonize all modes of transportation has become urgent, but each "fill-up" with electric energy rather than carbon fuel offers the assurance that, worldwide, the transportation sector is moving with determination toward a goal of zero emissions by 2050. (iStock)

ALSO IN THIS ISSUE

Coming Next Issue

The November–December 2022 issue of *TR News* features articles covering a variety of topics. Authors look at the most effective infrastructure approaches to keeping wildlife and traffic safely separated; integrated warning and response systems to lessen the negative effects of flooding, as well as to predict the extent and severity of a flood event; and how five state departments of transportation are training staff on and implementing a toolkit that measures the effectiveness of public involvement in transportation planning.

Camelia TWU, Flickr

Elevated trains, city buses, and taxis serve the transportation needs of residents in Chicago, Illinois. More and more, state departments of transportation are looking at—and testing—ways to engage the public in transportation planning.

TRB COVID-19 Resources

Agencies and organizations can use TRB publications and online resources for useful and timely information to help address issues related to the COVID-19 pandemic. To read about TRB's current research and activities, and for a list of relevant publications, visit www.nationalacademies.org/trb/blog/transportation-in-the-face-of-communicable-disease.

The *TR News* Editorial Board thanks Christine Gerencher, TRB, for her work assembling and developing this issue.

TR NEWS

features articles on innovative and timely research and development activities in all modes of transportation. Brief news items of interest to the transportation community are also included, along with profiles of transportation professionals, meeting announcements, summaries of new publications, and news of Transportation Research Board activities.

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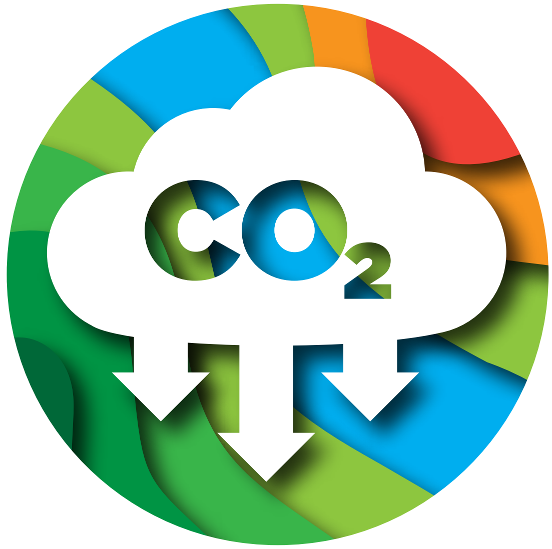

Letter from the *TR News* Editorial Board

Dear *TR News* Readers,

This issue of *TR News* focuses on addressing climate change, one of the greatest challenges facing the world today. Carbon emissions continue to increase, and the global effects are becoming more visible each year. The scientific consensus is that action to decarbonize is not happening quickly enough. The TRB standing committees on Air Quality and Greenhouse Gas Mitigation, Transportation Energy, and Alternative Fuels and Technologies helped curate this collection of articles, which cover research, policy proposals, and potential pathways to decarbonizing transportation.

The topic is challenging. There is no single or simple solution, and it is easy to feel discouraged. You may find some of the ideas discussed in these articles compelling, or you may disagree with them. Whatever your views, TRB invites you to join the conversation. Volunteer to participate on one or more of the TRB standing committees, panels, and task forces. Interact with TRB on Facebook and Twitter @NASEMTRB. Consider attending the next TRB Annual Meeting, January 8–12, 2023, in Washington, DC, where researchers, thought leaders, practitioners, and many others will discuss decarbonization from a wide range of perspectives and areas of expertise.

By joining TRB in pursuing our mission to spark progress and innovation, you can work with us to confront challenging issues and find solutions for the benefit of society.

Thank you for reading! We look forward to continuing the dialogue.

—The *TR News* Editorial Board

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DECARBONIZING TRANSPORTATION

CHALLENGES AND PATHWAYS TO 2050

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CHRIS PORTER AND STEPHEN ZOEPF

Porter is a principal at Cambridge Systematics in Medford, Massachusetts. Zoepf is chief of Policy and Development at Ellis and Associates in Redwood City, California.

Above: Queued curbside, a fleet of electric car-sharing vehicles will ferry passengers around the streets of Paris. Increased use of electric cars is only one of the ways that municipal to international governments are working toward their goal to reach zero emissions by 2050.

The numbers say it all. More than 90 percent of the total energy used to move people and freight comes from petroleum. As a result, the transportation sector is directly responsible for 29 percent of U.S. carbon dioxide (CO_2) emissions (*1*) and one-quarter of global CO_2 emissions (*2*). Upstream and embedded emissions associated with vehicles, fuels, and infrastructure could add more than 60 percent to direct emissions from on-road sources (*3*). Furthermore, due to expected population growth, greater use of personal vehicles, and increased freight demand, researchers anticipate that global transportation emissions will grow by 75 percent between 2020 and 2050 under a baseline scenario that still heavily relies on petroleum fuels (*4*).

At the 2015 United Nations Conference of the Parties in Paris, 196 countries agreed on a goal to limit global warming to well below 2°C—preferably to 1.5°C—compared with pre-Industrial Revolution levels, those deemed necessary to avoid the most drastic effects of climate change. Many state and local governments, as well as private companies, have set their own aggressive decarbonization targets, mirroring and supporting national and international efforts. Decarbonizing transportation will be one of the greatest challenges to meeting these local and international goals for carbon reduction.

One widely recognized framework for structuring thinking around transportation emissions is Lee Schipper's ASIF model (Figure 1), which explains the basic mechanisms by which transportation emissions may be reduced (*5*). In this framework, emissions can be lowered through the following four pathways:

- Travel Activity: Emissions can be reduced by limiting the need for travel. The opportunities to accomplish activity reduction are broad and include approaches as diverse as mixed-use urban development that allows people to accomplish their work

Emissions = Travel **A**ctivity × Modal **S**tructure × Modal Energy **I**ntensity × Carbon Content of **F**uels

FIGURE 1 ASIF model.

and personal needs while traveling shorter distances; infrastructure investments supporting less energy-intensive modes such as mass transit, walking, and bicycling; and travel demand management policies that encourage mode shift and travel reduction. Activity reduction also can encompass trip-chaining (combining errands into a single loop, rather than taking each trip individually) or replacing physical travel with virtual meetings or electronic communications.

- Modal Structure: Emissions reductions also can be accomplished by shifting travel from energy-intensive modes (such as private cars or freight trucks) to lower-emissions modes (such as walking, bicycling, public transportation, or freight rail). Modal structure also encompasses operational improvements within these modes, including route changes or schedule shifts that enable modes to carry more passengers or freight per vehicle, thus reducing the emissions burden that each traveler imposes.
- Modal Energy Intensity: Within a mode, emissions reductions can be accomplished by improving the efficiency of vehicles, including powertrain efficiency enhancements or vehicle efficiency advancements, such as weight reduction or improved aerodynamics. Emissions also can be reduced by allowing existing vehicles to operate more efficiently per mile; for example, by reducing congestion or unnecessary acceleration and braking.
- Carbon Content of Fuels: Emissions reductions also can be accomplished by shifting a vehicle from the use of carbon-intensive fuels (such as gasoline, diesel, or heavy fuel oil) to lower-carbon fuels (such as electricity, hydrogen, or liquid fuels generated from renewable sources).

National and local approaches to transportation greenhouse gas reduction vary based on context and opportunities. However, a recent TRB National Cooperative Highway Research Program (NCHRP) guide for state transportation agencies to reduce greenhouse gas emissions provides some general findings in the U.S. context (*6*).

Scenario analyses have consistently shown that clean vehicle and fuel technologies—including vehicle efficiency, greenhouse gas emissions standards, electrification, and other low-carbon fuels (affecting the "I" and "F" in ASIF)—collectively have the largest emission reduction potential. For example, the Carbon Free Boston study (for an urban location with strong travel alternatives) found that even relatively aggressive measures to manage transportation demand would only contribute to about 20 percent of greenhouse gas reductions needed to achieve carbon neutrality by 2050, compared to 70 percent for clean vehicle and grid decarbonization strategies (Figure 2) (*7*).

Different strategies may be needed for different parts of the transportation sector. Electrification—with decarbonized electricity—is emerging as the most likely path for light- and medium-duty vehicles (*4*), whereas other alternative fuels could play an important role in the heavy-duty and nonroad sectors, such as aviation, maritime, and rail.

The shift to low-carbon fuels, such as renewable electricity, presents a unique challenge: It requires simultaneous activity and coordination among numerous stakeholders. Vehicle manufacturers must shift their design expertise, production, and supply chains to accommodate a change from internal-combustion powertrains to battery electric or hydrogen fuel cell powertrains. Utilities must accommodate new loads on the electric grid, which affect generation, distribution, and regulation. Distribution networks for nonpetroleum fuels must be created. Consumers must become comfortable with vehicles with different performance characteristics, and other

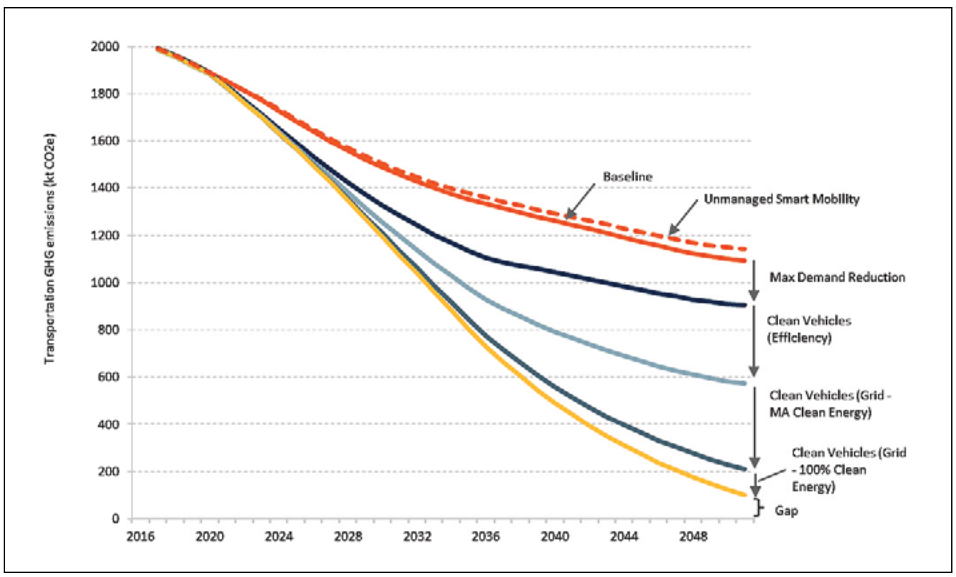

FIGURE 2 Carbon Free Boston trajectory toward zero-carbon transportation in 2050.

public and private entities must provide new facilities for users to recharge or refuel their vehicles. At the same time, these interconnections open up synergistic opportunities to improve systems and reduce costs (*8*).

Vehicle travel demand reduction—affecting the "A" and "S" in ASIF—and traffic efficiency strategies—affecting the "I" in ASIF—also can play an important role in reducing greenhouse gas emissions. The estimated reduction potential ranges from modest (a few percentage points) to significant (tens of percentage points), depending on the strategies that are included and the level of aggressiveness assumed. Some of the more optimistic estimates of reduction potential rely on technologies or policies that are not yet ready for implementation, such as higher levels of road or parking pricing or connected vehicles supporting "eco-driving", (i.e., driving to minimize fuel consumption and carbon dioxide emissions).

Most activity reduction strategies present a challenge in that they presume that humans will modify their behavior. Furthermore, behavioral shifts that—on their face—seem to promote reductions in emissions may create rebound effects in other places. For example, teleworking may directly reduce the emissions from commuting trips. However, evidence suggests that people engage in additional nonwork travel that partially offsets their reduction in commuting. Over the long run, teleworking also can induce workers to relocate farther from their jobs. Some studies have found that the rebound effect from teleworking can be close to or even exceed 100 percent, meaning there would be no carbon reduction benefit in the long run (*9*).

An additional concern about relying on activity reduction is a potential interaction effect between policies that promote transportation equity and those that promote activity reduction. For example, public transportation and ride-hailing services could increase or decrease emissions, depending on vehicle occupancies, technology characteristics, and how riders previously traveled (*7*, *10*). Services in low-income travel markets are more likely to serve new trips or substitute for other public or active transportation trips, whereas higher income users are more likely to displace automobile travel. Equity concerns are especially acute in the many areas of the United States, where low-density development patterns make it difficult or impossible to travel anywhere by means other than personal vehicles. Land use strategies to provide more compact and walkable development—that more easily serves public transportation and nonmotorized trips—provide an important complement to transportation-side travel reduction measures. However, the pace of land use change is slow, and authority is highly decentralized—with land use decisions largely in the hands of numerous municipal governments and private landowners and developers.

Traffic efficiency strategies, such as signal coordination to improve traffic flow and capacity and operations improvements to reduce congestion at bottlenecks, also can have unintended consequences. Studies have found a significant rebound effect related to capacity expansion—to the degree that most or all of the emissions benefits of congestion reduction could be offset by increased vehicle travel (*11*). The evidence on the rebound effect related to operations strategies is less clear-cut, but some studies found that long-term benefits can be much smaller or even fully negated by induced demand as travel becomes quicker and easier. Simply smoothing traffic flow (through strategies such as roundabouts, signal synchronization, or vehicle automation) rather than making it faster, also can have emissions benefits without creating additional vehicle travel (*6*).

Finally, transportation agencies can play a modest but important role by decarbonizing their own operations through the use of low-carbon materials and vehicle fleets. Researchers estimate that emissions generated by a typical state transportation agency's activities represent around 5 percent to 6 percent of surface transportation emissions generated by vehicles. About two-fifths of these

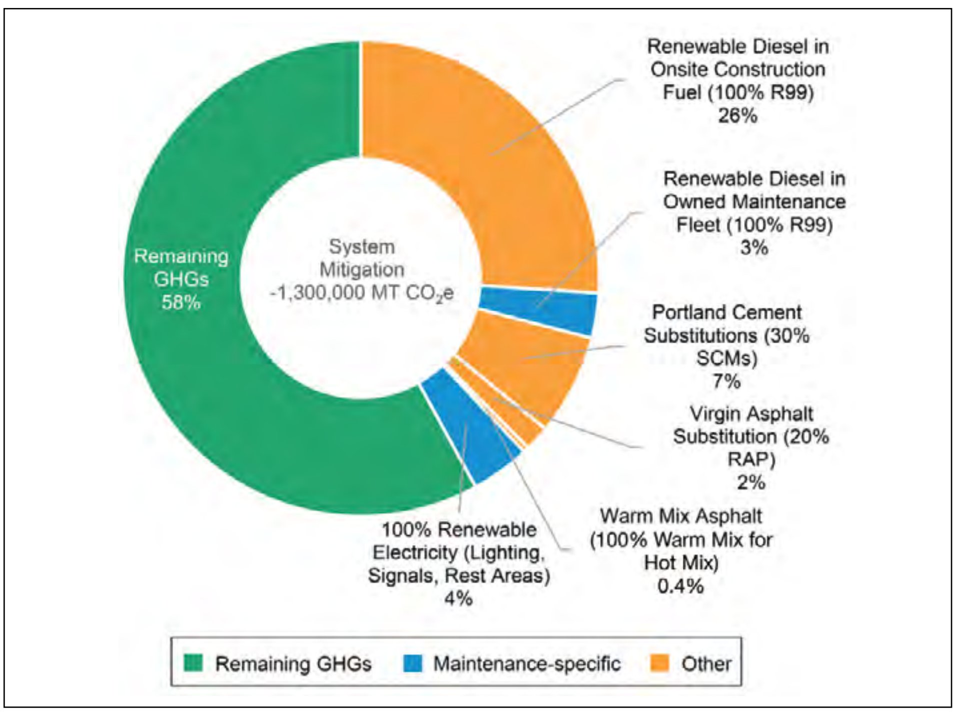

FIGURE 3 **Example of mitigation potential for highway system construction and maintenance. (GHGs = greenhouse gases; SCMs = supplementary cementious materials; RAP = reclaimed asphalt pavement.)**

emissions could be mitigated using current technologies (Figure 3) (*6*).

Even with aggressive implementation of all of these strategies, it is challenging to meet targets of 75 percent to 80 percent or more greenhouse gas reduction by 2050. Studies are in general agreement that doing so will require widespread electrification, decarbonization of the electric grid, large volumes of low-carbon liquid fuels, and policies to manage vehicle travel demand. To be fully effective, most strategies require implementation at national, state, regional, and local levels, as well as across multiple agencies and organizations, such as executive, transportation, environmental, and community development agencies, as well as utilities.

Transportation agencies cannot go it alone when it comes to reducing transportation emissions, but they can make important contributions through policy, planning, and investment decisions. These contributions can include the following:

- Revising transportation planning goals and project evaluation and selection criteria to emphasize greenhouse gas reductions;
- Shifting investments from those that favor vehicle travel to those that favor less carbon-intensive travel modes;
- Supporting the planning, design, and build-out of electric and alternative-fuel vehicle charging and refueling infrastructure;
- Improving the efficiency of traffic flow in ways that reduce emissions without creating substantial new demand for travel;
- Using low-carbon materials and vehicle fleets for their own construction and maintenance activities; and
- Ensuring that emissions-reducing investments and services support travel equity and improve conditions for underserved communities.

Through concerted and coordinated actions across all sectors and levels of government, including transportation, the world may yet have a chance to achieve net zero by 2050.

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VOLUNTEER VOICES

Frankly, I hope to get a lot of transit built, for both sustainability and equity reasons. I'd like to reduce the amount of driving modern life requires, through changes to both transportation and land use planning. I feel my attendance at the TRB Annual Meeting and committee activities helps to support that vision through sharing knowledge. That's the impact I hope to have.

—MATT MILLER
Operations Manager, Metro Analytics
Charlotte, North Carolina

POINT OF VIEW

Decarbonizing the U.S. Power Grid

Are Battery Electric Vehicles Part of the Solution?

Tony Webster, Wikimedia Commons, CC BY-SA 2.0

CHASE P. DOWLING

The author is a former principal applied scientist at Pacific Northwest National Laboratory in Seattle, Washington.

Above: Smokestacks send plumes of exhaust skyward at the Sherco Generating Station near Becker, Minnesota. Fueled by coal, it is one of more than 3,400 fossil fuel–fired power plants in the United States that could potentially benefit from renewable energy generated by electric vehicle batteries.

Transportation electrification is playing a growing role in decarbonization. However, despite having lower emissions overall, in the absence of usable renewable energy generation, electric vehicles simply move tailpipe emissions to the exhaust stacks of power plants (*1*). Even with aggressive renewable deployment timelines, the effects of renewable generation intermittency are increasingly felt and—for the time being—remain generally insufficient to handle peak energy needs. Energy storage is key to enabling renewable wind and solar, yet year-over-year growth in grid-scale energy capacity has been slow to make up for the frequent time gaps between peak renewable energy production and peak energy demand. The net result is that the U.S. energy generation portfolio remains considerably dependent on fossil fuels.

A key piece of the solution to both increasing power needs and further decarbonization may come, in part, from growth in transportation electrification. Net energy storage within battery electric vehicles—powered solely by an electric battery with zero tailpipe emissions—will quickly eclipse grid-scale storage projects. Figure 1 combines data from the Department of Energy Alternative Fuels Data Center and the National Renewable Energy Laboratory to compare true total U.S. grid storage to a conservative estimate of net battery electric vehicle storage. Assuming battery electric vehicles are limited to smaller 30 kilowatt-hour batteries,[1] their combined storage capacity is on track to double net grid storage capacity in 2022, including stationary grid batteries and pumped storage hydropower.

[1] For reference, the 2021 Chevy Bolt has a 66 kilowatt-hour battery. Tesla's Model 3 has batteries ranging between 50 and 83 kilowatt-hours. The battery electric vehicle with the smallest battery included in the data set is the 2011 Nissan Leaf with a 24 kilowatt-hour battery. However, the 2021 Nissan Leaf has a battery size between 40 and 62 kilowatt-hours.

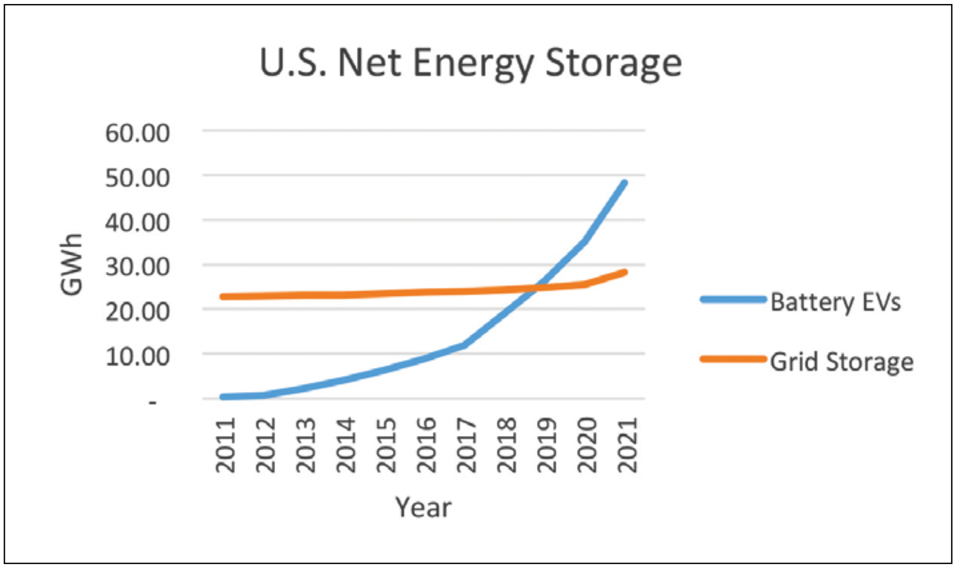

FIGURE 1 **Year-over-year U.S. net energy storage in gigawatt hours comparing static grid-scale storage (including pumped hydro and battery storage) with estimated net U.S. battery electric vehicle storage, assuming smaller 30 kilowatt-hour batteries and based on sales of plug-in electric vehicles (excluding hybrids). (EVs = electric vehicles.)**

The often-lamented fact that personal vehicles are parked 95 percent of the time—taking up space and not generating revenue—can suddenly be viewed as a blessing rather than a curse (*2*). What if all of this mobile energy storage could be deployed as power available to the grid while an electric vehicle is otherwise not in use? Fleets of electric vehicles can potentially exceed the overall value of grid-storage projects by providing critical personal and commercial mobility for the periods when not parked. Thus, the onboard storage of electric vehicles can—and should—be viewed as a means to help decarbonize the power system by enabling the effective use of renewable energy resources (*3*). Two challenges effectively tap this storage capacity: scale and coordination.

In the United States, there are approximately 200 million personal vehicles in use. If 30 percent of these vehicles were replaced with battery electric models with conservative storage capacities of 30 kilowatt hours, then their combined storage would represent 1.8 terawatt hours of power. This is equivalent to about 90 minutes' worth of the entire nation's generating capacity, a scale unimaginable for current grid-scale storage capacity projects (*4*). Arrival's and Stellantis' battery electric delivery vans have storage capacities on the order of 100 kilowatt hours, and major orders from UPS and Amazon will further speed up the growth of operational battery storage capacity on U.S. roadways (*5*, *6*). Thus, the key is the coordination of these resources as a means for energy storage.

Coordinating and accessing even a fraction of the total storage available to an electrified transportation system will have enormous benefits for decarbonizing the United States' energy generation portfolio. Significant technical headway has been made on the flexible use of individual electric vehicles for reducing peak demand and shifting load to other times of day (*7*), and some manufacturers (such as Ford, which manufactures the Lightning battery electric pickup), have visibly leaned into this capability for individual home use. However, while already a demonstrated peak demand curtailment or backup power as a part of varied demand response programs, this only provides half the benefit by merely reducing demand. The converse: Exporting power back to the grid through pooling and coordinating fleets of electric vehicles is not a trivial task as hurdles facing coordination of electric vehicle battery energy storage are regulatory, as well as technical.

The United States is host to multiple types of transmission system

Eric Demarcq, Flickr, CC BY-NC-ND 2.0

Stop-and-go traffic clogs a Los Angeles, California, thoroughfare, involving mostly automobiles that represent a fraction of the roughly 200 million personal vehicles in use in the United States.

operators—known as balancing authorities—that ensure the reliability of the power system. Among balancing authorities, independent system operators (ISOs) and regional transmission organizations (RTOs)[2] whose responsibility zones are illustrated in Figure 2, operate bulk power systems over high-voltage transmission. They also perform the important function of maintaining and clearing power markets open to qualified generators, distribution utilities, and large industrial consumers. Distribution utilities—public and private—bid for power on markets operated by ISOs and RTOs and sell this power to end consumers. Simultaneously, some distribution utilities are vertically integrated and also operate transmission networks as a balancing authority in regions not covered by an ISO or RTO. This complex mix of power-system operator types creates an overlapping hierarchy of regulatory compliance. At the top, the Federal Energy Regulatory Commission oversees balancing authorities that cross state lines. This regulatory hierarchy flows down to local public utilities overseen by individual municipalities. Operating constraints, pricing mechanisms,[3] and available communications infrastructure vary greatly across power-system operators.

Figure 3 illustrates how these entities are related by way of power-system infrastructure and where various electric vehicle service operators will likely participate in power markets as a function of fleet size, geographic distribution, and total power demands. This paints a challenging picture, as useful or valuable solutions for certain utilities and certain electric vehicle operators will not be uniformly replicable across the United States. The challenge for electric vehicle

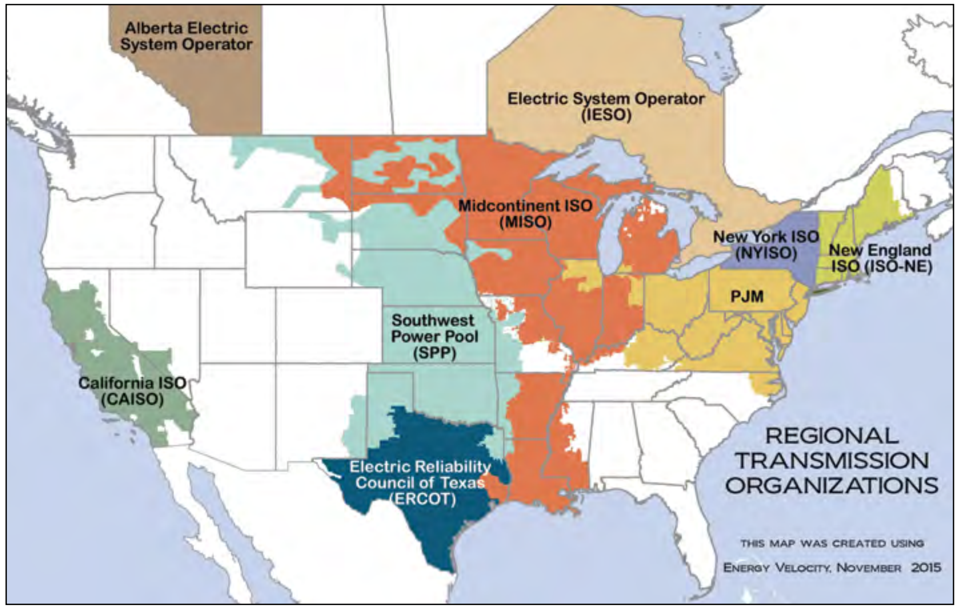

FIGURE 2 Areas of responsibility for ISOs and RTOs in the United States and Canada. (Source: Federal Energy Regulatory Commission)

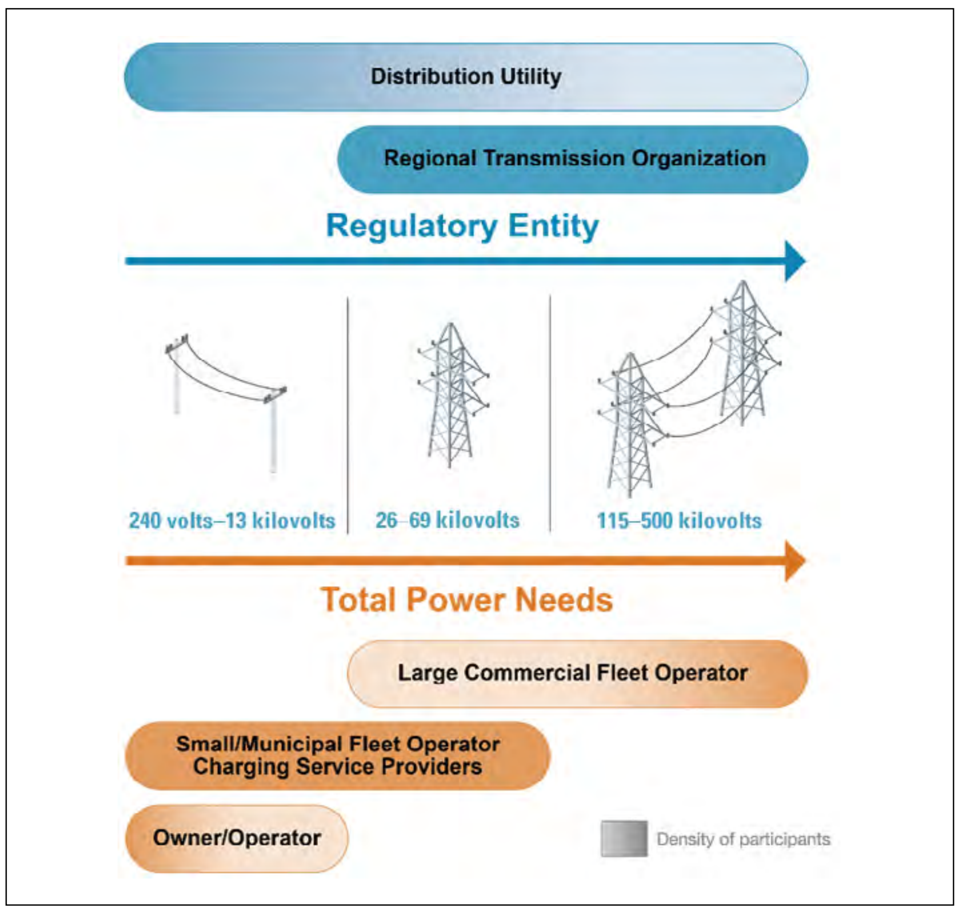

FIGURE 3 Power-system operators answer to stratified levels of regulatory governance that generally tend to align with the size of the system they operate: distribution (240 volts–13 kilovolts), subtransmission (26–69 kilovolts), and transmission (115–500 kilovolts) systems.

[2] ISOs and RTOs can be treated—conceptually—very similarly. However, RTOs have stricter responsibilities and requirements than do ISOs, as outlined by the Federal Energy Regulatory Commission.

[3] This includes how distributed energy resources (e.g., home rooftop solar as opposed to a larger central power plant) are fairly compensated relative to the value of the energy generated.

fleet operators will be to develop flexible coordination systems that can readily adapt to where in the U.S. their electric vehicle resources are located, particularly for those with national footprints. This could be accomplished by creating virtual power plants (VPPs).

A relatively new concept for most policy makers, VPPs federate distributed energy resources to form what is essentially a large, grid-system–scale generator or power plant by pooling and coordinating the collective power of many small, distributed energy resources. VPPs include—but are not limited to—resources such as rooftop solar panels, home flexible loads (e.g., air conditioning), behind-the-meter storage (e.g., home batteries), and electric vehicle–managed or smart charging systems. These are often geographically distributed and used on disaggregated schedules, but they need to be carefully coordinated to realize increased performance and greater value than each energy resource could achieve individually. Coordinating these resources via combinations of Internet and power-system controls communication as if they were one large generator—that is, virtualization—would help overcome discontinuities introduced by the levels of market interaction and electric vehicle fleet sizes across disjoint geographic regions and can be accomplished by software-defined control and participation.

In dealing with regulatory challenges as vehicles move from one region to the next, infrastructure or market regulation differences can be accounted for with software-defined control. ISOs, such as the Electric Reliability Council of Texas, use what is known as coincident peak pricing,[4] which covers transmission system costs and can account for 20 percent of a commercial power consumer's annual electric bill (*8*). In contrast, the Bonneville Power Administration, a large balancing authority in the Pacific Northwest, does not.[5] Coincident peak pricing is just one example of a fairly complicated power pricing mechanism that isn't used everywhere in the United States, but electric vehicle operators would be heavily incentivized to be responsive in electric markets where it *is* used.

VPPs also address the technical challenges introduced by efforts to coordinate the net energy storage of electric vehicles fleets. In this context, "fleet" loosely refers to any collection of electric vehicles participating in the same VPP that does not need to be centrally located or dispatched (e.g., registered electric vehicles on a VPP operated by a local distribution utility, electric vehicles operated by a commercial logistics company, or electric vehicles from a single original equipment manufacturer providing VPP services to its owners). In the United States, distribution utilities have sometimes struggled to accept power exports from small retail consumers with distributed energy resources such as home solar panels, primarily because of a unified lack of coordination[6] and, in the absence of coordination, individual electric vehicles will be no exception. In short, without coordination, power provided by a home solar panel, for example, does not offer the same grid-conforming stability that large power plants do simply by nature of their enormous size.[7] With coordination, a VPP can broker deals with local utilities on behalf of electric vehicle fleets (and other constituent distributed energy resources). This results in greater economic welfare to the grid with, for example, reduced overhead costs, decreased line congestion, and better frequency control. VPPs also may participate directly in bulk power markets, depending on the location and connectivity status of the energy resources. The coordination of these resources overcomes some of the issues caused by uncoordinated distributed energy resources that otherwise go untapped. It also creates opportunities for these resources to provide important ancillary grid services in addition to supplying power.

Industry has already begun to converge on this approach because the incentives are already in place. The location and time-dependent wholesale price of electricity in bulk power markets are highly variable by time of day and location. Figure 4 is a screen

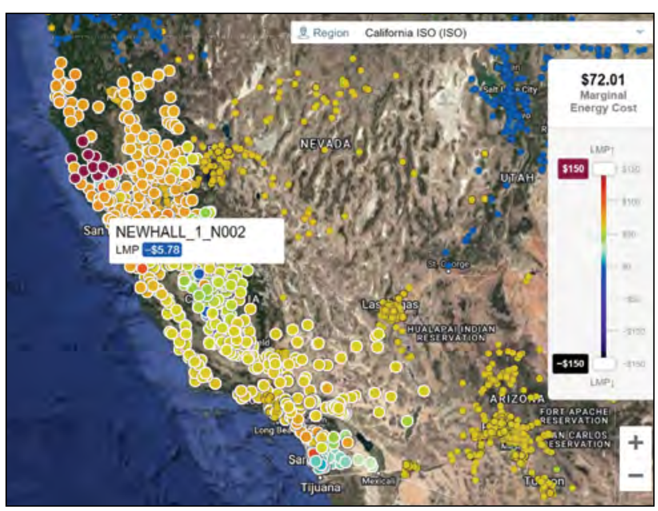

FIGURE 4 Day-ahead locational marginal prices of electricity in dollars per megawatt hour over the California segment of the Western Interconnection, a network of 136,000 miles of transmission lines, on May 4, 2022. CAISO transmission nodes are highlighted. (Source: CAISO)

[4] "Coincident peak pricing" is a heavy post-hoc surcharge determined retrospectively by a large (typically commercial) consumer's demand when the system was at peak generation.

[5] Further complicating matters, there are even examples of local distribution utilities—such as the Fort Collins Public Utility District—using coincident peak pricing.

[6] Various utilities manage consumer solar power differently, based on the control resources available and the topology of the grid they operate. Many utilities do not accept consumer solar power exports back to the grid. However, others are mandated to buy excess solar power at retail rates. The latter is called "net metering"—when power is bought back at retail rates—and varies from state to state.

[7] Large hydro and thermal generators introduce a considerable amount of rotational inertia that helps maintain grid-frequency stability, somewhat similar to a flywheel.

capture of day-ahead bulk power prices on the California Independent System Operator (CAISO) transmission market and shows incredibly high prices north of San Francisco and very low prices in the Central Valley region. The ability to simply store and discharge power at will gives a battery owner the ability to arbitrage these market prices and is a market feature that is already heavily leveraged by grid-scale battery storage sites. Figure 5 shows the geographic distribution of grid-scale storage sites by state.

The transportation system will simultaneously feel the federation of electric vehicles as a VPP. Observing that transmission congestion creates negative spot prices of electricity, a sufficiently flexible electric vehicle fleet operator could route and schedule charging of their vehicles to times that wouldn't simply be cheap to fuel their fleet, but potentially profitable. What electric vehicles do that grid-scale battery storage projects do not, however, is compound the value that the battery can provide, whether to a commercial fleet operator or an individual vehicle owner. An electric vehicle provides value or revenue when used for mobility. Then, a VPP—for example, in the form of a co-op of electric vehicle owners, a municipal utility with access to connected electric vehicles, an electric vehicle manufacturer that provides monetization services to their constituent owners, or electric vehicle commercial fleet operators—can pool parked electric vehicle energy resources, coordinate charging and discharging, and benefit from all the time the vehicles remain parked. In doing so, this would generate revenue and compensate VPP membership for co-ops of electric vehicle owners. Alternatively, it would reduce fueling costs for a commercial electric vehicle fleet operator. Environmental benefits would stem from a VPP procuring charging power when the sun is shining or wind is blowing and realizing these renewable generation benefits by discharging back into the power system, either when power demand is high late in the evening, when the wind is calm, or by expending clean power when

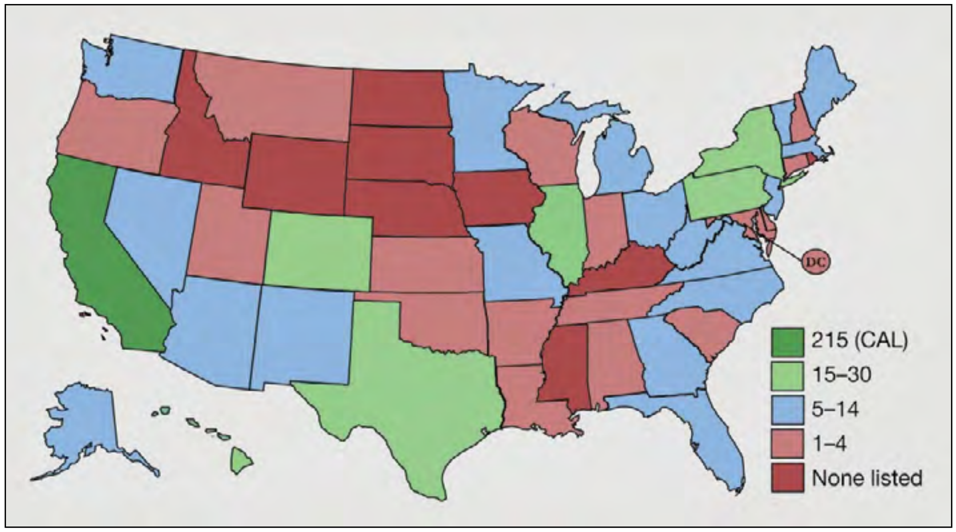

FIGURE 5 **Number of grid-connected energy storage projects by state, 2021. (Source: U.S. Department of Energy)**

providing mobility services. Companies such as Tesla are already registered VPPs on some ISOs. However, in the United States, Tesla's VPP currently only trades power via their Powerwall home batteries, as opposed to their vehicles' onboard batteries. Domestically, the Federal Energy Regulatory Commission has begun to steer ISO- and RTO-managed wholesale power markets toward recognition of the electric vehicle–size batteries as distributed energy resources, as well.[8] Internationally, the inclusion of electric vehicles in VPPs is being accomplished by companies such as the United Kingdom's Octopus Energy, providing power export coordination services for electric vehicles (*9*).

The biggest long-term cost of electric vehicles participating in a VPP is a shortened battery lifespan with each charge–discharge cycle, but this tradeoff is readily quantifiable. That is why a diversity of emerging VPPs should be fostered, such that vehicle use incentives align with this tradeoff in battery lifespan. These VPPs would range from commercial or logistics electric vehicle fleet operators to co-ops of electric vehicle owners on a distribution utility. Although diversity of VPPs will make more efficient use of the resources to build the battery, long-term battery reuse and recycling programs (e.g., reuse as grid-scale storage) must also be on the horizon for transportation industry stakeholders who are serious about decarbonization.

If electric vehicles' growing net storage capacity is exposed to increasingly direct grid participation through coordination of a VPP, their use will become—in part—a balancing act of when mobility is monetarily more valuable than providing grid services. Driving patterns will change, as will daily power demand, provided that wholesale and retail electrical markets can continue to move toward a more uniform regulatory environment. With that, electric vehicles could someday be a key player in decarbonizing tailpipes and power plant exhaust stacks.

[8] Federal Energy Regulatory Commission Order 2222 enables distributed energy resources (small-scale generation or storage technologies between 1 and 10,000 kilowatts) "to participate alongside traditional resources in the regional organized wholesale markets through aggregations."

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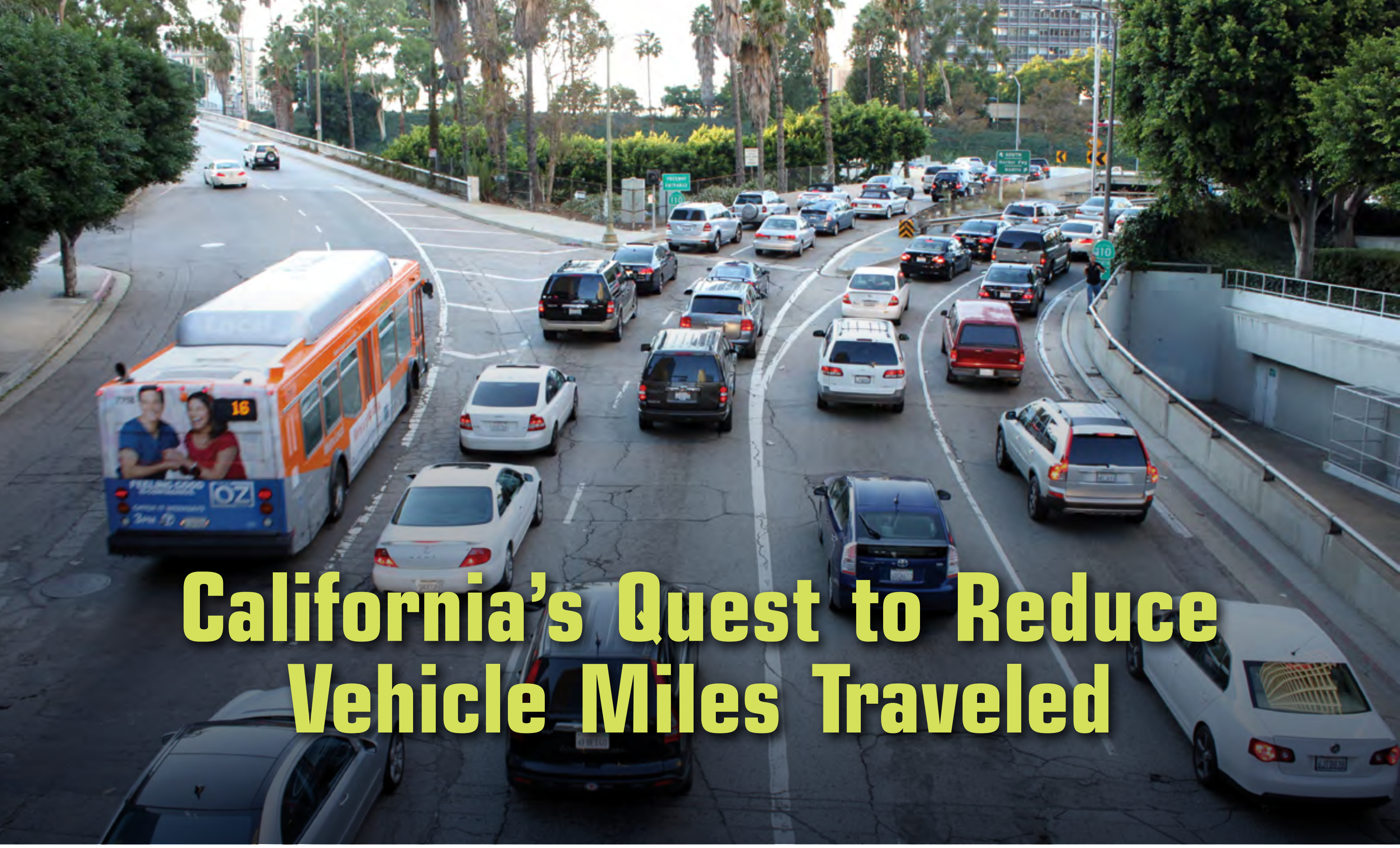

California's Quest to Reduce Vehicle Miles Traveled

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SUSAN HANDY

The author is a distinguished professor of environmental science and policy at the University of California, Davis.

Above: Traffic jams (such as this one in Los Angeles, California), the culture that promotes them, and policies that continue to enlarge roads to accommodate more traffic make it difficult for states like California to succeed in reducing greenhouse gas emissions by 40 percent of 1990 levels by 2030.

California has been on a quest to reduce vehicle miles traveled ever since the passage of the Sustainable Communities and Climate Protection Act of 2008, Senate Bill 375, known in transportation circles as SB 375. This legislation was one of several important steps taken by the state legislature to implement the landmark California Global Warming Solutions Act of 2006, or Assembly Bill 32. Although the electrification of the vehicle fleet will get the state much of the way toward its ambitious goals for reducing greenhouse gas emissions (40 percent of 1990 levels by 2030 and to 80 percent below 1990 levels by 2050), the analysis done by the California Air Resources Board and the academic community shows that electrification is not enough. For the state to meet its targets, Californians will have to drive less (*1*, *2*).

That is a big request in a state so well known for its freeways. California has more than 26,000 lane miles of freeways that carry more than 340 billion vehicle miles of travel each year, serving more than 27 million licensed drivers in a state with 30 million registered cars and trucks (*3*). The state's residents averaged 8,600 vehicle miles traveled per capita per year in 2019. This amount was actually somewhat lower than the national average of nearly 9,800 vehicle miles traveled per capita per year and quite a bit lower than 20 years earlier when Californians averaged more than 11,000 vehicle miles traveled per capita per year. But the state still has a long way to go.

How to Meet Reduction Targets

A decade ago, a team of researchers[1] reviewed the empirical evidence for 18 potential strategies (see box) for reducing vehicle miles traveled in a project for the California Air Resources Board (*4*). The evidence supported the conclusion

[1] This research was led by the author and Marlon Boarnet, a professor at the University of Southern California.

Reduction Strategies for Which Evidence Was Reviewed

- Transit Service
- Bicycle
- Pedestrian
- Parking Pricing
- Highway Capacity and Induced Travel
- Road User Pricing
- Employer-Based Trip Reduction
- Car Sharing
- Gas Price
- Voluntary Travel Behavior Change Program
- Telecommuting
- Land Use Mix
- Jobs–Housing Balance
- Residential Density
- Employment Density
- Distance to Transit (Transit Access)
- Network Connectivity
- Regional Accessibility

that each one of the strategies could be effective in reducing vehicle miles traveled, although usually the effects were small. Often, the available studies showed a wide range of possible effects, which always were likely to depend on the context in which the strategy was implemented. The research team focused on the highest quality studies available, especially those relevant to the California context, but found many methodological limitations. Most importantly, much of the research was cross-sectional (meaning that it compared travel in places with and without the strategy), rather than longitudinal, measuring changes in travel that occur when a strategy is implemented. When compared with a cross-sectional study, a longitudinal study provides more convincing evidence that a given strategy causes a change in vehicle miles traveled. The researchers will be updating their reviews of the evidence on these and other strategies in the coming year.

Meanwhile, the evidence is sufficiently strong to conclude that a multifaceted approach that implements a broad set of complementary strategies is needed and could work. Most of the strategies reviewed are complementary and may even be synergistic, meaning that the total effect could be greater than the sum of each strategy's individual effects. Combining strategies also is a way to ensure equitable outcomes and could yield many other benefits beyond reductions in greenhouse gas emissions—less noise, fewer crashes, better health, reduced costs, and more travel options, among others (*5*). Here is a four-step way to think about how to fit these strategies together.

1. *Make it possible to drive less.*

   Many Americans feel that they have no choice but to drive. This can be remedied through investments in transit service, as well as bicycle and pedestrian infrastructure. Micromobility services like bike sharing and e-scooter sharing, often provided by the private sector, have helped expand alternatives to driving one's own car. But changes in land use policies are needed to ensure that development is of sufficient density to support high-quality transit service and that more destinations are within reasonable walking, bicycling, and scooting distances (*6*).

2. *Help people see how to drive less.*

   Providing alternatives to driving will have little impact if people either do not know those alternatives are available or are unsure of how to use them. One strategy is to offer training programs for riding transit and for bicycling that are targeted to specific segments of the population, such as the young, the elderly, or recent immigrants. Such programs, which are often run by community organizations, could benefit from increased public funding. Improved maps and signage also can help.

3. *Help people* want *to drive less.*

   The proverbial carrot and stick are relevant here. Although social marketing campaigns can influence transportation choices, monetary rewards—perhaps in the form of free-fare programs and subsidies for e-bike purchases—often get better results. Building on the success of several small-scale programs, California is implementing a statewide e-bike subsidy program in 2022. Disincentives could be any increase in the cost of driving, including congestion charges and parking pricing. New York City, San Francisco, and Los Angeles are exploring congestion charging schemes. Strategies that simply make driving less convenient, including reducing parking and closing streets to cars, also can be effective.

4. *Stop encouraging people to drive more.*

   If California and other places are serious about reducing vehicle miles traveled, they have to get serious about not adding vehicle capacity. Any form of capacity expansion that reduces travel times is likely to induce additional vehicle travel (*7*). Much of the new capacity being added in the state is in the form of managed lanes, which have the advantage of potentially encouraging transit ridership and carpooling. However, they, too, are likely to induce additional vehicle travel.

Although further studies, especially natural experiments and evaluation studies, could strengthen the evidence backing up these suggestions, the evidence in hand is sufficient to support action, particularly given the gravity of the problem. The next frontier for transportation researchers will involve determining how to make these policies and programs happen. Studies of successful—and unsuccessful—cases, drawing on theories of the policy process, can help get the train moving.

The Covid-19 pandemic heightened the uncertainty around the state's reduction efforts for vehicle miles traveled. On the bright side, the pandemic led to a surge in bicycle purchases, especially of e-bikes, and many cities moved relatively quickly to install new bicycle infrastructure. On the other hand, transit ridership has yet to fully bounce back, although transit agencies may be learning important lessons that will lead to more efficient and effective service in the long run. The future of remote work remains a question. While a sizable portion of the workforce is likely to work remotely, at least for part of the time going forward, the impact on vehicle miles traveled will depend on their choices regarding travel for purposes other than commuting and where to live. What is known is that a more diverse transportation system—one that offers people alternatives and that is not solely dependent on cars—will be a more resilient system in the face of pandemics, natural disasters, disruptions to the global oil market, or other events that are bound to come our way.

Conclusions

Reducing vehicle miles traveled does not mean taking away cars or putting limits on their use. It does mean putting transit, walking, and biking on equal footing with cars, and that means rethinking policies and practices that have favored cars for more than a century. Reducing vehicle miles traveled will be a long, slow process, but where there's a will, there's a way.

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People like this e-biker, who is struggling during a 2021 King Tide (when high tides and stormy weather coincided in Marin County, California), are biking more as gasoline prices increase. Although concerns about climate change and the increasing cost of using a private vehicle are motivators for moving to an alternative, incentive programs also can encourage the use of bicycles, e-bikes, scooters, and other means of transportation.

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For the state to meet its targets, Californians will have to drive less. That is a big request in a state so well known for its freeways.

POINT OF VIEW

Shifting Gears to Zero Emissions

Five Strategies for U.S. Trucks and Buses

Jess Rodriguez, Adobe Stock Photos

RAY MINJARES

The author is director of the Heavy-Duty Vehicles Program at the International Council on Clean Transportation in San Francisco, California.

Above: Skies are clearing on the road ahead for a heavy-duty truck driver. However, diesel fuel used in such trucks—and buses—is producing nitrogen dioxide emissions that disproportionately affect the health of residents in racially and ethnically diverse areas. As a result, federal and state authorities are executing strategies to drive the nation's fleet down to zero emissions.

There is a need for trucks and buses in the United States to shift away from diesel engines to fully zero-emission engines. These vehicles account for roughly 5 percent of the U.S. transportation fleet but 43 percent of an estimated 22,000 traffic-related air pollution deaths each year (*1*). Researchers studying disparities in exposure to transportation-related air pollution have found heavy-duty vehicles to be primarily responsible for a 2.6-times-greater baseline level in traffic-related nitrogen dioxide (NO_2) emissions exposure in the least-white census tracts when compared to the most-white census tracts in the United States (*2*). Exposure disparities are associated with higher densities of highways and Interstates in racially and ethnically diverse areas, a function of historical housing segregation (*3*).

The impacts of climate change call special attention to the urgency of this technological shift. A zero-emission bus powered by batteries, for example, consumes an estimated 29 percent of the energy used by a diesel bus following an identical route (*4*). These efficiencies translate into the potential for zero-emission trucks and buses to deliver as much as 47.5 billion tons of cumulative carbon dioxide (CO_2) emission reductions through 2050, which is equal to about half of what the transportation sector as a whole needs to deliver globally to remain within a 2°C warming pathway (*5*). Even more reductions are needed to align with a 1.5°C pathway.

Key actions that represent the most effective strategies to accelerate this transition include the following:

1. Setting clear goals,
2. Developing sales requirements or performance standards to increase zero-emission vehicle supply,
3. Using fiscal incentives to lower cost barriers,
4. Establishing clear infrastructure plans and investments, and
5. Stimulating demand for zero-emission trucks and buses.

Setting Clear Goals

In 2020, California Governor Gavin Newsom set a series of statewide goals, including 100 percent zero-emission of the following:

- Passenger car sales by 2035;
- Drayage operations by 2035;
- Off-road equipment operations by 2035; and
- Medium- and heavy-duty vehicle operations, where feasible, by 2045 (*6*).

The following year, 15 U.S. states, joined by the District of Columbia and the Province of Quebec, endorsed the goal of 30 percent zero-emission truck sales in 2030 and 100 percent in 2050 (*7*). New York Governor Kathy Hochul was the first to sign legislation requiring 100 percent of all truck sales to be zero-emission vehicles in 2045.[1] Fourteen countries have endorsed the goal of 100 percent zero-emission heavy-duty vehicle sales by 2040 (*8*).

To align with the Paris Agreement—also known as the Paris Accords or the Paris Climate Accords—and to maintain warming within 2°C, the goal for the U.S. truck fleet will need to include at least 46 percent zero-emission vehicle sales in 2030 and 100 percent no later than 2040 (*5, 9*). Faster action is achievable in key market segments that can rely on battery-electric depot charging (e.g., transit buses, local delivery vans, and short-haul tractor trailers).

Developing Sales Requirements or Performance Standards to Increase Zero-Emissions Vehicle Supply

While setting clear goals sends a market signal, production and sales requirements translate these goals into actions. A key barrier to electrification is the absence of a diverse supply of commercially available heavy-duty vehicle

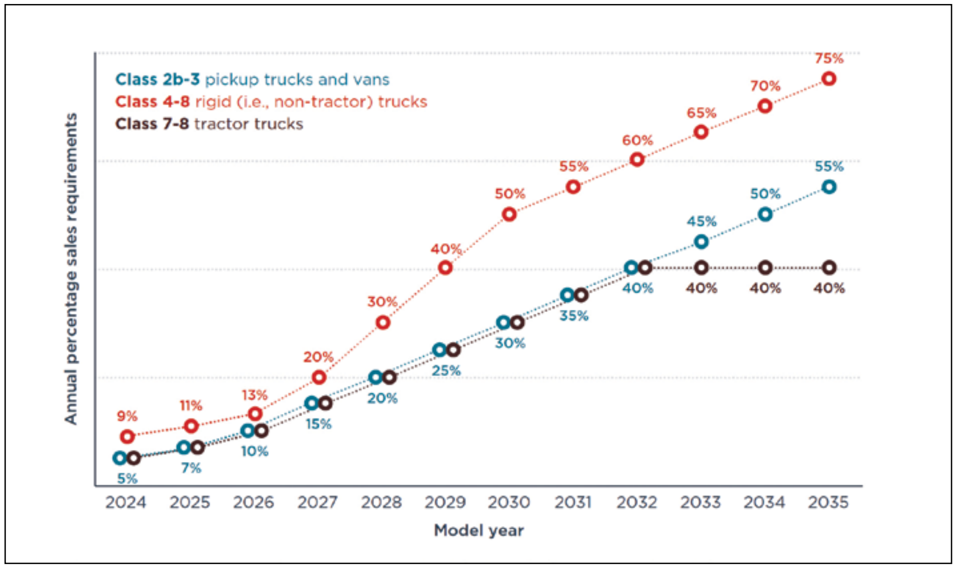


FIGURE 1 **Zero-emission sales percentage schedule by vehicle group and model year. (Source: International Council on Clean Transportation)**

models. Sales requirements or performance-based standards increase supply and product availability, and that leads to downward price pressure. California has introduced regulatory innovations on sales requirements that date as far back as 1990.

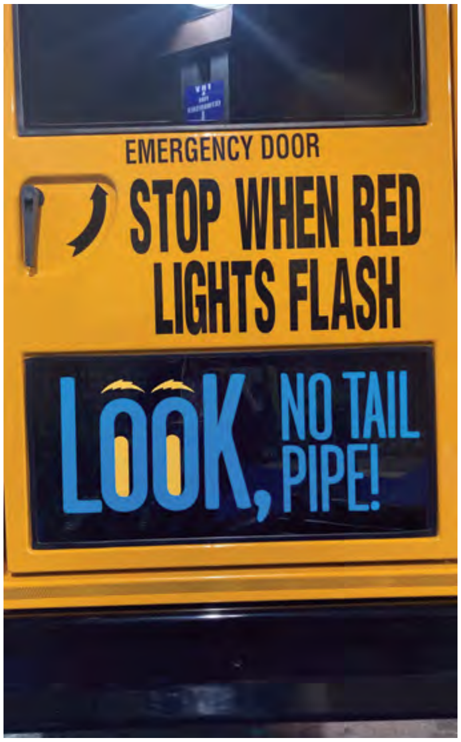
In 2020, the California Air Resources Board adopted the Advanced Clean Trucks (ACT) Program to require the sale of zero-emission trucks across all weight categories sold in each model year between 2024 and 2035 (Figure 1). Five U.S. states—Massachusetts, New Jersey, New York, Oregon, and Washington—joined the ACT Program in 2021. More states are in the process of joining. As of mid-2022, 145 zero-emission truck models are commercially available in the United States and many more are expected in the coming year (*10*). Meanwhile, EPA has proposed revising performance-based Phase II greenhouse gas emission standards for medium- and heavy-duty vehicles (*11*). However, analysis by the International Council on Clean Transportation shows these new standards will likely neither require any more zero-emission vehicle production than the market already intends to supply nor generate significant enough carbon reductions to limit future warming to within 2°C (*12*). At the same time, manufacturers are opposed to any changes to existing greenhouse gas standards through model year 2029 (*13*).

Using Fiscal Incentives to Lower Cost Barriers

Fiscal incentives can provide an initial market stimulus to jump-start demand. Although the total cost of owning certain electric truck or bus models today may already be lower than it is for their diesel equivalents, the upfront cost of purchase can be two or three times greater than that of a diesel version. Purchase incentives provide a mechanism to stimulate demand from customers who are more sensitive to upfront cost. Fiscal incentives that reduce operating costs provide another form of stimulus. Fiscal incentives are a public investment, but not all governments have the balance sheet that can support such programs. However, these incentives can be temporary, since they typically serve their purpose once upfront cost parity is reached.

Vehicle manufacturers and fleet owners have been supportive of programs that provide purchase incentives to immediately reduce upfront costs. California operates the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project. This project provides point-of-sale

[1] Read New York State Senate Bill S2758 at https://www.nysenate.gov/legislation/bills/2021/s2758.



Ray Minjares, International Council on Clean Transportation

A sign on the rear door of a battery-electric school bus on display at the 2022 Advanced Clean Transport Expo in Long Beach, California, ensures that the zero-emissions message reaches the public—of all ages.

discounts to purchasers of zero-emission trucks and buses of between $7,500 and $120,000, with the largest amounts reserved for the heaviest weight classes. Additional amounts are given to applicants who represent drayage truck operators, disadvantaged communities, fuel cell tractor operators, public transit agencies, and public school districts. These incentives have directly funded as many as 438 of the 730 zero-emission trucks on California roads as of January 2022 (*14*).

In-use fiscal incentive schemes provide another path to reduce costs. An analysis of new battery-electric tractor trailers operating in Europe suggests that these trucks can achieve total-cost-of-ownership parity with diesel equivalent vehicles in this decade without any new policies (*15*). In Germany, France, and the Netherlands, total-cost-of-ownership parity is already in reach for 2022. Without any zero-emission truck requirement, Switzerland has deployed dozens of fuel cell truck tractors and has a goal of 1,600 by 2025. The business case for the Swiss investment is supported by a road toll that is based on the distance driven, the weight of the vehicle, and its emission performance (*16*). Examples of other in-use fiscal policies can include reduced annual vehicle registration fees, lower parking fees, and certain exemptions from business or personal taxes.

Establishing Clear Infrastructure Plans and Investments

Vehicles and fuels are a single system. Without the infrastructure to deliver the fuels—whether it be the electricity to charge the battery or the hydrogen to power the fuel cell—a market for zero-emission vehicles cannot exist.

A subset of vehicles—those with the longest daily range, the highest payloads, and trips predominantly outside of urban areas driven by long-haul tractor trailers—requires a network of publicly accessible infrastructure. Certain vehicle manufacturers and other infrastructure providers are investing in this space. Daimler Trucks has established a joint venture with BlackRock and Next Energy to build out three regional infrastructure networks in the United States (*17*). In Europe, Volvo Trucks—together with Daimler and Traton—is constructing a high-speed charging network (*18*). Tesla intends to have a megacharger network worldwide (*19*). The density and distribution of the publicly accessible infrastructure will, in large part, determine how quickly the market for this subset of vehicles can reach maturity.

In 2021, President Joe Biden signed the Infrastructure Investment and Jobs Act. This legislation established a Joint Office of Energy and Transportation to study, plan, and coordinate the deployment of zero-emission vehicle infrastructure. The legislation also provides $5 billion in funding from FY 2022–2026 to support the National Electric Vehicle Infrastructure Formula Program. This program provides grants to states to deploy publicly accessible electric vehicle charging infrastructure along designated alternative fuel corridors. The legislation requires the U.S. Department of Transportation (U.S. DOT) to designate national electric vehicle charging corridors for the location of charging infrastructure to support freight along the National Highway Freight Network, at ports, intermodal centers, and warehouses. However, no funds from this program are required to be spent on freight charging infrastructure, and U.S. DOT guidance does not require states to make any new infrastructure accessible to freight vehicles.

The European Commission's Fit for 55 includes a proposed alternative fuels infrastructure regulation. As proposed, the regulation would require individual European member states to deploy infrastructure for charging and hydrogen refueling for both light- and heavy-duty vehicles. For heavy-duty vehicles, the proposed regulation would require this infrastructure across the Trans-European Network for Transport. The proposal includes a minimum installed charging capacity every 60 kilometers (40 miles) for the core network and 100 kilometers (60 miles) for the larger comprehensive network, a minimum charging speed of the highest-powered charger at each location, and minimum distances and fueling speeds of hydrogen stations by 2030. The proposal will remain under discussion as it makes its way through the Council of the European Union and European Parliament in the coming months.

One emerging take-away from research on heavy-duty vehicles is the extent to which most vehicles—transit buses, school buses, refuse trucks, last-mile delivery trucks, and short-haul combination tractors—can be electrified before a publicly accessible national infrastructure network is deployed. Batteries work well in vehicles that are parked overnight and return to their dedicated base of operations at the end of each day. Generally, fleet owners and operators of these vehicles can purchase their own electric vehicle charging equipment and install it on their property before they take ownership of the vehicle. Operational requirements dictate infrastructure needs,

Ray Minjares, International Council on Clean Transportation

As clean inside as it is outside, the Kenworth T680 fuel cell electric tractor transforms the chemical energy from compressed hydrogen gas into electrical energy. In Los Angeles, California, a fleet of such vehicles is used to transport supplies to underserved communities.

and infrastructure for battery-electric depot charging is generally within reach for many fleet owners or operators.

Stimulating Demand for Zero-Emission Trucks and Buses

The final set of measures to accelerate electrification are those designed to stimulate the demand for zero-emission vehicles. Purchase requirements place obligations on fleets to buy these vehicles, while operations requirements grant road access to zero-emission fleets and limit road access for all other fleets. These measures either strongly require or create strong nonfiscal incentives for vehicle owners and operators to choose a zero-emission vehicle the next time they buy.

Purchase requirements provide a demand stimulus to match production or sales requirements on manufacturers. Fleets financed or owned primarily with public funds are common initial targets of purchase requirements. For example, California adopted the Innovative Clean Transit Regulation in 2018 to require 100 percent of transit bus purchases in the state to be zero-emissions vehicles in 2029 (*20*). As of mid-2022, the staff of the California Air Resources Board proposed extending purchase requirements to government vehicles and large private fleets as part of a new Advanced Clean Fleets Rule (*21*). Similarly, five major transit agencies in New York State have agreed to fully electrify their fleets, and New York Governor Hochul has committed to electrify all school bus purchases by 2027 and operations by 2035.[2] At the federal level, President Biden has committed to 100 percent zero-emission government purchases of medium- and heavy-duty vehicles.

Vehicle access restrictions provide another path to stimulating demand. The California Air Resources Board staff proposed disallowing any new diesel trucks from joining the state drayage registry and restricting their access to marine terminals. The government of the Netherlands has identified dozens of cities where it will require zero emissions in certain transit buses and delivery trucks. In London, Mayor Sadiq Aman Khan intends to have a zero-emission zone in place by 2030.

[2] Governor Hochul's 2022 State of the State address includes the commitment, "[the] state is moving forward with regulations to require 100 percent of all school bus purchases to be zero-emission starting in 2027 and by 2035, all school buses on the road will be zero-emission." Learn more at https://www.governor.ny.gov/sites/default/files/2022-01/2022StateoftheStateBook.pdf.

San Joaquin Regional Transit District, Wikimedia Commons, CC-BY-SA-3.0

In only 10 minutes, an all-electric bus will power up at a fast-charging station and get back on route in California's San Joaquin County. Part of the San Joaquin Valley Transit Electrification Project, zero-emissions public transit vehicles like this Proterra BE35 relieve communities from the effects of diesel fumes and improve air quality at bus stations and along routes.

Marc A. Hermann, Wikimedia Commons, CC-BY-2.0

Rolling through the streets of New York, an all-electric articulated bus ferries passengers along one of the city's longest routes. Introduced in a 2020 Metropolitan Transportation Authority pilot program, such buses are modernizing the fleet with clean energy and will eventually serve all five boroughs.

Summary

International experience has revealed five effective policies to accelerate the electrification of medium- and heavy-duty fleets in the United States. These policies and the actions to put them in place represent the level of effort we need to accelerate the transition to a national zero-emissions truck and bus fleet in the United States.

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CARBON REDUCTION IN AVIATION

What Are the Research Needs?

Ross Parmly, Unsplash

KATE ANDRUS AND CARLY SHANNON

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Above: Every day, airplanes criss-cross the skies, leaving emissions in their wake. The aviation sector's share of global carbon emissions—expected to increase along with the growing demand for air travel—has led the industry and the federal government to invest in research on ways to decarbonize and decouple activity growth from emissions.

The aviation industry and federal government are investing significant resources to better understand and minimize the potential environmental impacts related to aviation. For example, in 2021, the Airports Council International committed to net-zero emissions by 2050, thus solidifying a target for airports. In addition, FAA set a goal to achieve net-zero emissions from the U.S. aviation sector by 2050, as part of FAA's *United States 2021 Aviation Climate Action Plan*.

Transportation Research Circular E-C271: Critical Issues in Aviation and the Environment 2021 is an update to previous E-Circulars that the TRB Standing Committee on Environmental Issues in Aviation produced to summarize the insight and progress made on many environmental concerns specific to the aviation industry. This publication provides recommendations for additional research to help achieve and mitigate environmental impacts.

The following is an excerpt from the E-Circular, developed in coordination with the committee's climate change and sustainability subcommittee with contributions from industry experts, regulatory agencies, and other stakeholders. The E-Circular describes decarbonization progress and trends, including advancements in technological, operational, and infrastructure improvements. The TRB Airport Cooperative Research Program (ACRP) supports many of these efforts, historically focusing on the reduction and management of greenhouse gas emissions.[1]

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[1] To learn more, see *ACRP Report 57: The Carbon Market—A Primer for Airports* at https://nap.nationalacademies.org/catalog/14607/the-carbon-market-a-primer-for-aiports; *ACRP Research Report 220: Guidebook for Developing a Zero- or Low-Emissions Roadmap at Airports* at https://nap.nationalacademies.org/catalog/25677/guidebook-for-developingo-a-zero-or-low-emissions-roadmap-at-airports; and *ACRP Synthesis 100: Airport Greenhouse Gas Reduction Efforts* at https://nap.nationalacademies.org/catalog/25609/airport-greenhouse-gas-reduction-efforts.

Notably, slowing the pace of climate change requires continual improvement and innovation. Even since the publication of the E-Circular, additional research gaps have been identified relative to carbon removal. For example, the most recent version of the Intergovernmental Panel on Climate Change (IPCC) report, *Climate Change 2022: Mitigation of Climate Change,* highlights the need for permanent removal to limit the rise in global temperatures.[2] Carbon removal must be a vital part of the overall climate mitigation strategy in order for aviation to meet these goals. ACRP Project 02-100, "Carbon Removal and Reduction to Support Airport Net-Zero Goals" will help to fill some of these gaps by bridging reductions and removal needs to provide a comprehensive roadmap to zero emissions. This rapidly evolving landscape underscores the importance of research entities like TRB.

[2] Read the full report at https://www.ipcc.ch/report/ar6/wg3/.

Excerpt from E-C271, Chapter 2

Sustainable Solutions to Address Environmental Challenges—Carbon Reduction and Management

Veronica Bradley, Mary Johnson, Prem Lobo, and Robert M. Peterson, Editor

Updates to reflect progress have not been made since publication in 2021.

Introduction

Aviation's contribution to global carbon emissions was approximately 2 percent as of 2017. It is projected to grow as demands in travel and air freight increase, particularly in emerging markets (*1*). In addition, while air carriers have decoupled their carbon emissions from the growth in number of passengers served and amount of cargo transported, the entire industry seeks to further reduce its carbon footprint and contribute to collective efforts to further mitigate climate change impacts (*2*).

The majority of aviation-related carbon emissions come from aircraft; however, air travel can induce emissions from surface access (mainly via road vehicles travelling to/from airports) and activities on site at airports (e.g., heating and lighting of infrastructure and GSE [or ground support equipment]). This chapter focuses primarily on aircraft emissions, which are the bulk of the aviation-related carbon emissions, with some discussion of reducing emissions from ground transportation and equipment.

In 2009, the industry, through the Air Transport Action Group (*3*), committed to three carbon reduction goals to: (1) improve average fuel efficiency 1.5 percent per year from 2009 to 2020, (2) keep growth carbon neutral from 2020, and (3) halve net aviation CO_2 emissions by 2050, relative to 2005 levels (*4*).

For their part, airports are also working to reduce their carbon footprints, and many have committed to becoming carbon neutral. For example, Dallas–Fort Worth International Airport (DFW) and San Diego International Airport (SAN) have already been accredited as carbon neutral airports (*5*).

Current State

The aviation industry has taken a four-pronged approach to fulfilling its carbon reduction goals noted above. To meet these targets, the industry is pursuing technological, operational, and infrastructure improvements as well as establishing a carbon offsetting mechanism to be used as a backstop to ensure success [Figure 1]. Progress has been made in recent years in each of these categories as detailed below.

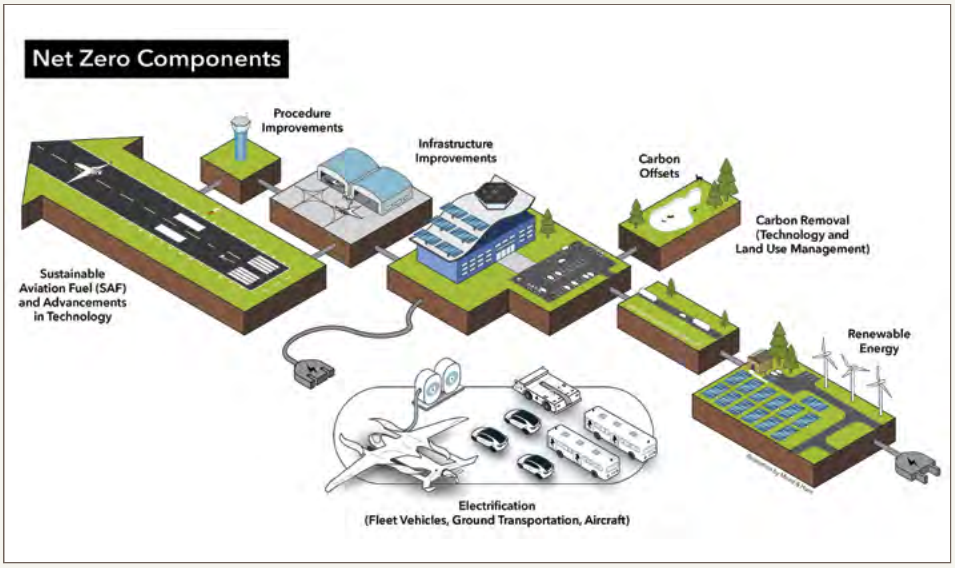

FIGURE 1 **Many components will need to be addressed to reach aviation's zero carbon emissions goal, including furthering research in carbon reduction and carbon removal. (Source: Mead & Hunt)**

Advancements in Technology

Aircraft manufacturers and airlines have been working in recent years to reduce the aviation industry's carbon footprint [Figure 2]. Because CO_2 emissions are directly proportional to fuel burn, these stakeholders have worked to improve fuel efficiency. Aircraft manufacturers have improved the fuel efficiency of their fleet offerings year over year by focusing on engine design as

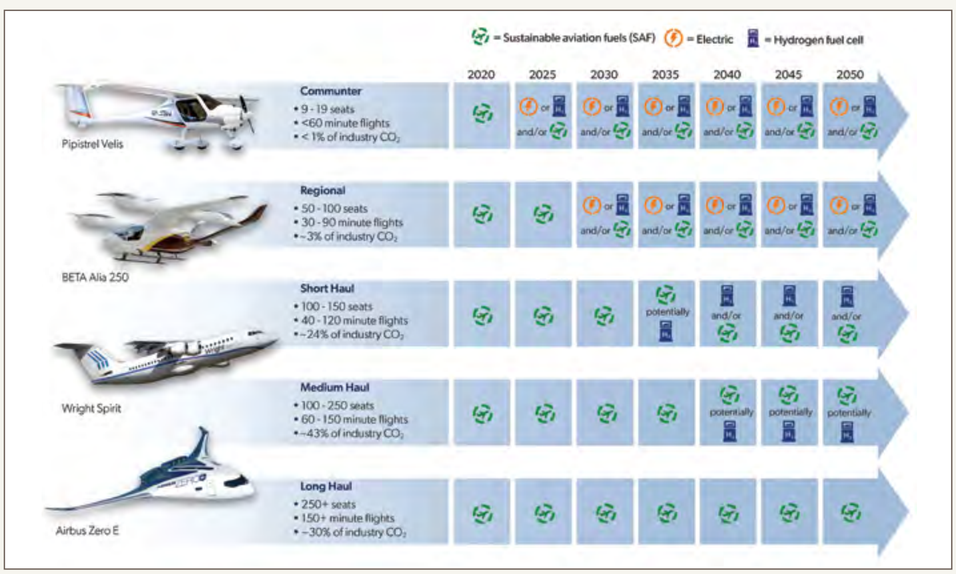

FIGURE 2 **Advancements in the use of SAF, hydrogen fuel cells, and electrification of aircraft will be an important part of meeting net zero goals. (Source: Mead & Hunt)**

well as the weight of every aspect of the aircraft. In 2018, U.S. airlines carried 42 percent more passengers and cargo than in 2000 with only a 3 percent increase in total CO_2 emissions (*6*).

In 2015, Boeing introduced the new 787-9s (the Dreamliner) with fuel-efficient engines that reduce CO_2 emissions by at least 20 percent compared to the aircraft they replaced (*7*). In addition, manufacturers are replacing the traditional aluminum in the aircraft bodies with lighter weight carbon fiber and also offer lighter weight seats, cargo nets, and exterior paints for airline liveries to save on fuel burn. Reducing the weight of aircraft seats by 1 pound each saves nearly 7,000 gallons of jet fuel per year for a single-aisle aircraft.

Pacific Northwest National Laboratory

Displaying his contribution to decreasing CO_2 emissions in aviation, Pacific Northwest National Laboratory researcher Rich Hallen partnered with LanzaTech to develop a process that converts ethanol into sustainable jet fuel.

New aircraft designs have also resulted in reduced carbon emissions. Improved three-dimensional airflow modeling has enabled manufacturers to enhance aircraft aerodynamics. These and other technological advancements spurred ICAO CAEP [or International Civil Aviation Organization Committee on Aviation Environmental Protection] to agree to a CO_2 emissions regulatory standard for commercial aircraft in February 2016.

Since the last edition of this E-Circular, the aviation industry has also been investing in the commercial advancement of sustainable aviation fuels [SAF] as another means to reduce carbon emissions. SAF are jet fuels produced from alternative sources of hydrocarbons rather than conventional petroleum. Through coordinated aviation community efforts under initiatives such as CAAFI® [or Commercial Aviation Alternative Fuels Initiative], significant advances have been made on multiple fronts including environmental sustainability analyses, flight demonstrations and efforts to identify and employ fuel production pathways [Figure 3].

On the ground, airlines and airports are working together to reduce their carbon footprints by converting diesel-powered GSE and vehicle fleets to all-electric equivalents where economically practicable and commercially available. While airlines are usually the owners of electric GSE (eGSE), airports often own the charging infrastructure airlines use to charge the eGSE batteries. For years, airports have been leveraging federal funds through the FAA Voluntary Airport Low Emissions (VALE) program (*8*) to install GSE charging stations.

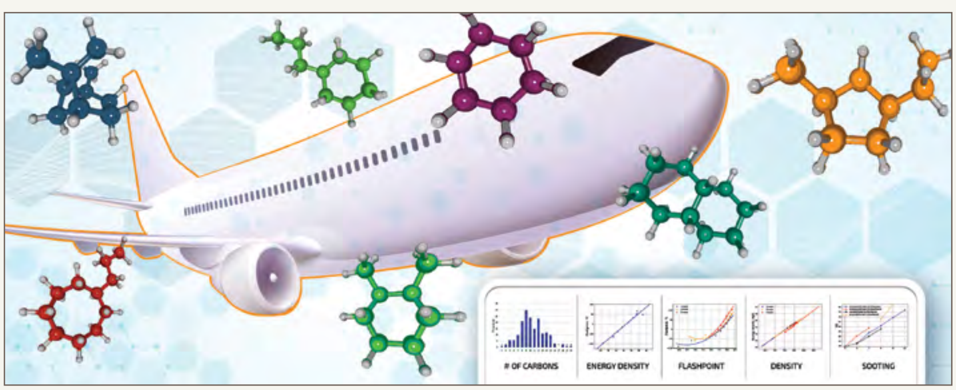

FIGURE 3 **The physical properties of cycloalkanes, produced from feedstock or renewable biological material, could play an important role in reducing aviation emissions. (Jami Butler, Sandia National Laboratory)**

Operational Improvements

In addition to the technological advancements assisting the industry in managing aviation's carbon footprint, the sector is also focused on achieving operational improvements to reduce emissions. In particular, airlines have deployed techniques like ground power unit (GPU) and pre-conditioned air (PCA) usage, improved maintenance programs, and single-engine taxiing to reduce their CO_2 emissions. Conventionally, when an aircraft is parked at the gate, it continues to burn jet fuel through its APU [or auxiliary power units] to keep the lights on and the heating, cooling, and ventilation system running between flights. To reduce carbon emissions, airlines can use GPU and PCA to power and cool/heat the aircraft while at the gate.

Infrastructure Improvements

The third prong of the industry's efforts to manage its carbon emissions is infrastructure improvements. Air Navigation Service Providers (ANSP) manage air traffic patterns across the world. As technological advances in global positioning systems have come online, ANSPs have been able to replace the traditional vector flight paths (i.e., point-to-point flying) with global positioning system (GPS)-based flight paths, which allow for more efficient flying. This GPS-based system of flying, known as NextGen, not only allows aircraft to travel the most efficient path geographically between two city-pairs, but it also allows aircraft to fly more efficiently in relation to each other.

Carbon Offsetting

In addition to the carbon reduction measures already noted, the industry, through ICAO, agreed to a global market-based measure for international aviation. The ICAO Assembly adopted CORSIA [or Carbon Offsetting and Reduction Scheme for International Aviation] in 2016 (*9*). Under CORSIA, airlines will be required to buy carbon offsets to compensate for their growth in CO_2 emissions starting in 2021. Starting in 2019, all airlines operating international flights began monitoring and reporting their fuel consumption on their international flights to their national authorities.

Future Vision

The goals and future vision of the aircraft industry as they relate to deeper CO_2 emission reductions can be summarized by the following:

- Continued collaboration among interested stakeholders to meet the ICAO goals
- Petroleum-based, price parity for SAF
- Achieving long-term SAF production levels that can contribute significantly to the industry's 2050 goal of 50 percent reduction in net CO_2 compared to 2005 levels
- Significant research and development of hybrid and electric battery aircraft technologies
- Commercial deployment of electric taxiing
- Further improvements in engine efficiency, aerodynamics, lightweight materials and structures
- Research and development of new aircraft configurations to minimize CO_2 and other air pollutant emissions

Research Needs

While substantial progress has been made in recent years to understand and mitigate carbon emissions from the aviation sector, more research is needed. Particular research needs can be summarized by the following:

- SAF for turbine aircraft need to continue to be assessed for potential reductions in emissions of GHGs [or greenhouse gases].
- Additional techno-economic analysis of SAF is needed to assess the potential for SAF to reach price parity with petroleum-based jet fuel.
- APU emissions profiles need to be further assessed. APU efficiencies have been improved in response to the changing price of fuel. The exhaust models for the newer APUs need to be studied and updated.
- Updated emission factors for non-aircraft emission sources at airports, such as GSE and motor vehicles, need to be developed. As electric vehicles become more prevalent, the emissions modeling for those vehicles will also need to consider the effects of shifting the burden of emissions from the airport to the power generation and delivery companies.
- Emission estimates and emission factors for aircraft landing emissions associated with brake and tire wear need continued research and development.
- Recent airport data regarding the impacts of carbon reduction due to airport operations need to be synthesized.
- Ways to include the carbon reduction or carbon 'cost' in airport decision-making models and methods for structures, buildings, and roadways should be pursued.
- Planning process and organizational behavior tools should be analyzed for their potential impact to reducing the sector's carbon emissions.

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The complete E-Circular, Critical Issues in Aviation and the Environment 2021, *can be found at https://www.trb.org/Publications/Blurbs/182198.aspx.*

POINT OF VIEW

CO_2 Emissions from International Shipping

How a Global National Allocation System Addresses the Problem

PxHere

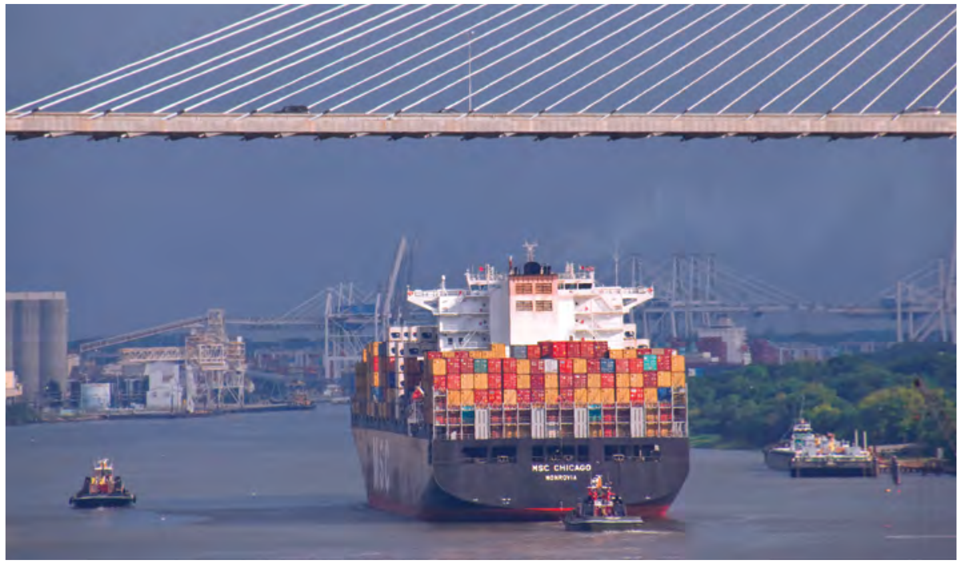
HENRIK SELIN

The author is an associate professor and associate dean for studies at the Frederick S. Pardee School of Global Studies at Boston University in Massachusetts.

Above: The *Maersk Laguna* pulls away from one of several international ports where it loads and unloads its cargo. The bunker fuel that powers maritime shipping vessels contributes to global CO_2 emissions. However, CO_2 emissions from international maritime shipping are excluded from national carbon budgets and domestic efforts to reduce greenhouse gases. Could a worldwide national allocation system be the answer?

A deep reduction in transport-related carbon dioxide (CO_2) emissions, including those from the maritime shipping sector, remains a challenge and a necessity. Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are obligated to include CO_2 emissions from intracountry shipping in their national carbon budgets and to reduce domestic CO_2 emissions in line with national laws and international commitments. These commitments include those under the Paris Agreement. In contrast, CO_2 emissions from international shipping are not included in national carbon budgets and are, thus, not part of domestic efforts to reduce greenhouse gas emissions. The International Maritime Organization (IMO) estimates that international maritime transport was responsible for roughly 2 percent of global annual CO_2 emissions in the 2010s (*1*), a number that is roughly on par with all of Germany.

One way to further address CO_2 emissions from international shipping is to establish a global system of national allocation. Such an allocation system would mean that these emissions are added to national carbon budgets of total annual emissions, which would create stronger incentives for governments to take steps to reduce them. If included in national carbon budgets, the emissions would become part of a country's greenhouse gas reduction targets. Then, national governments could engage with domestically located actors in the international shipping industry to support emission reduction efforts, as well as set their own specific reduction targets for those actors. Governments also could increase funding for research and development of zero-carbon fuels, electric ships, or both. In addition, governments would have the option to expand mitigation in nonshipping sectors to meet national reduction targets, which would result in a greater overall reduction in global CO_2 emissions.



Ron Cogswell, Flickr, CC BY 2.0

Registered in Monrovia, Liberia, the *MSC Chicago* heads into Georgia's Savannah Harbor. Growth in international trade could see a marked increase in CO_2 emission levels, adding urgency to global emissions reduction efforts.

An open-access research article in *Environmental Research Letters* explored the option to establish an international system of national allocation CO_2 emissions from international shipping (*2*). This *TR News* article presents the main findings and conclusions of the journal article to stimulate further discussions on how to accelerate efforts to reduce and eventually phase out CO_2 emissions from the shipping sector. In short, the case for a national allocation scheme is outlined—based on the geographic location of ship owners, operated under the UNFCCC, and using the Paris Agreement's system of nationally determined contributions for stimulating national-level actions by country parties, as well as by the European Union. The journal article includes the full analysis, and all data are available online as part of the supplementary material.

The analysis is based on a unique data set of ship movements combined with data on bunker fuel sales from the International Energy Agency as a bottom-up way to estimate annual CO_2 emissions. The different data were used to analyze how the carbon budgets of individual countries and the European Union would be affected if international shipping emissions were allocated to them, based on the national location of one of five of the following central shipping industry actors:

- Flag country,
- Ship owners,
- Ship managers,
- Ship operators, and
- Bunker fuel sellers.

Findings showed that the selection of a national allocation option can have widely varying implications for the national carbon budgets, particularly for some smaller countries.

The UNFCCC parties first raised the question of how to address CO_2 emissions from international shipping in the 1990s, but the parties delegated this issue to the IMO because of the organization's central role in multilateral decision making on issues related to international shipping. However, it was not until 2016 that the IMO first adopted mandatory energy efficiency and fuel reporting measures. In 2018, the IMO agreed on an initial strategy for reducing greenhouse gas emissions from international shipping with the goal that emissions should peak as soon as possible and—by 2050—be reduced by at least 50 percent from 2008 levels, with the ultimate goal to phase them out completely. However, in its fourth greenhouse gas study (published in 2020), the IMO states that—if additional emissions reduction efforts are not taken—CO_2 emissions from international shipping may increase by up to 50 percent above 2018 levels by 2050 as a result of growth in international trade (*1*).

As a first step, analysis of the journal article suggested that the UNFCCC and the Paris Agreement were better forums for discussions about a national allocation scheme for CO_2 emissions than was the IMO, based on comparing the objectives, principles for decision making, and geographical coverage of the two forums. The UNFCCC and the Paris Agreement have clear objectives of reducing CO_2 emissions, while the IMO has only a partial focus on reducing maritime pollution. Both the UNFCCC and the Paris Agreement recognize that parties can take on varying commitments (albeit in two slightly different ways), whereas the IMO has a strong adherence to the equal treatment principle. In addition, the UNFCCC has a larger membership than the IMO (195 versus 174 member states, with the European Union also being a UNFCCC party but not an IMO member), which helps reduce the possibility of shipping actors getting a free ride by moving to countries outside a collective allocation and governance mechanism.

Under each of the five allocation options examined (based on the location of shipping industry actors), a clear majority of CO_2 emissions would be distributed to fewer countries. Between 69 percent and 75 percent of total CO_2 emissions would be allocated to the top 10 countries under each option, while between 88 percent and 90 percent of emissions would go to the top 20 countries. The individual countries in the top 10 and 20 vary across the five options, and national allocation would result in widely diverging percentage increases to the countries' carbon budgets. The flag country option is the one allocation option that would most heavily affect the national carbon budgets of smaller countries, with the Marshall Islands seeing an increase of 51,203 percent, followed by Liberia

Five Allocation Options

Allocation Option	Description
Flag Country	The country where a ship is officially registered. A ship flies the flag of the country where it is registered.
Ship Owner	The owner is the asset owner, or the entity that ultimately benefits financially from the vessel's employment.
Ship Operator	The operator is the commercial decision maker concerning the employment of the vessel and, therefore, decides how and where that asset is employed.
Ship Manager	The manager is the entity responsible for the daily running of the vessel. Management may be subcontracted by a third party or undertaken as an internal function by the owner or operator.
Bunker Fuel Seller	Bunker fuel sellers are typically located near major ports.

Learn more at https://www.iopscience.iop.org/article/10.1088/1748-9326/abec02.

(8,143 percent), Tuvalu (2,450 percent), and Malta (2,061 percent). Under the bunker fuel sellers option, some countries—including Malta, Singapore, and Panama—would also see relatively large percentage increases to their carbon budgets at 281 percent, 232 percent, and 121 percent, respectively.

If CO_2 emissions were allocated according to the location of the ship operator and ship manager, then they would predominantly add to the carbon budgets of wealthier members of the Organisation for Economic Co-operation and Development (OECD). However, the Marshall Islands' carbon budget would increase by nearly 400 percent under either of these options. Both the ship operator (making decisions on operational issues, including a ship's routing) and the ship manager (having responsibility for the day-to-day running of a ship, including ship speeds and fuel oil purchases) make decisions that influence the amount of CO_2 emissions coming from an individual ship. However, these decisions have less of an effect on the total amount of CO_2 emission reductions than the capital investment choices in engine upgrades and the purchase of new vessels in the future that can run on zero-carbon energy—determinations made by ship owners.

The analysis in the research article concluded that the influence of ship owners on modifications to existing ship engines and the purchase of future ships makes them the most effective industry actors for carrying out a transition to zero CO_2 emissions. Allocating emissions to countries—based on ship owners—also incorporates an equity dimension in that most CO_2 emissions would be allocated to the carbon budgets of OECD countries. As these emissions are incorporated into national carbon budgets, they would—for the first time—be part of national mitigation efforts and also increase the incentives for national governments to more actively engage with efforts to reduce these emissions. Yet, under the owner option, the Marshall Islands' carbon budget would also increase by 610 percent. Addressing this situation, for example, could involve allocating the vast majority of the CO_2 emissions that would go to the Marshall Islands to other larger countries' carbon budgets using a collectively agreed-upon distribution formula.

Rather than relying on IMO processes to produce sufficient decarbonization outcomes, other options should be considered. These options include the possible creation of a national allocation scheme for CO_2 emissions from international shipping—based on the geographical location of the ship owners—to be operated under the UNFCCC and linked to the Paris Agreement's nationally determined contributions. However, this would depend on agreement among the world's countries to create such a scheme and governments instructing their respective national delegations to the UNFCCC and the IMO to take the necessary steps. Reaching such an agreement would likely be challenging. It requires political will, especially from countries that are leaders in international trade and shipping. When they finally commit to making the reduction of greenhouse gas emissions—from all sectors—a true priority, the answer to how to phase out CO_2 emissions from shipping will be much clearer.

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RESEARCH PAYS OFF

SEAHIVE

Coastal Infrastructure Protection from Hurricanes and Storm Surge

paulbr75, Pixabay

LANDOLF RHODE-BARBARIGOS

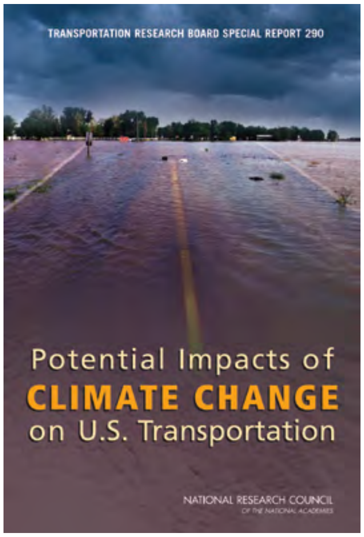
The author is an assistant professor of civil and architectural engineering at the University of Miami in Coral Gables, Florida.

Above: Beachside property stands perilously close to an eroded edge, the result of repeated storm surge and wave action along the coast of St. Augustine, Florida. SEAHIVE, a sustainable alternative to revetment, breakwaters, and seawalls, may help revive and protect vulnerable coastlines from destruction.

With annual temperatures projected to increase and coastal population density continuously growing, coastlines will likely experience stronger storms and potentially more devastating disasters. These events include tropical cyclones and hurricanes, which bring extreme winds, rain, storm surge, and waves to the built environment and coastal infrastructure.

Assessing the Problem

Storm surge and wave action induce destructive forces to coastal communities that can result in loss of life, shoreline erosion, and structural damage to the built environment and transportation network. According to TRB's *Special Report 290: Potential Impacts of Climate Change on U.S. Transportation*, more than 60,000 miles of coastal highways are under threat. Revetments, breakwaters, and seawalls serve as barriers against storm flooding and wave action. However, revetments and breakwaters (sloping protective structures) may require large footprints, while seawalls (vertical protective structures) do not always dissipate wave energy. Such structures also decrease natural habitat, an effect associated with their geometry and materials used.



Read the full report at https://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.

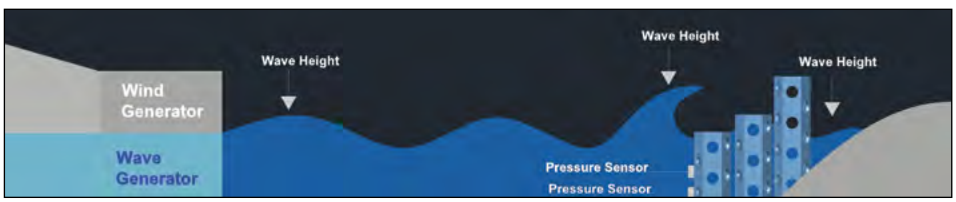
Solving the Problem

To address the coastal infrastructure protection issue, National Cooperative Highway Research Program (NCHRP) Project 20-30/Innovations Deserving Exploratory Analysis (IDEA) 213 researchers at the University of Miami—with support from the Florida Department of Transportation—developed SEAHIVE, a sustainable estuarine and marine revetment system. The system's design is based on results of tests carried out at the University of Miami Surge Structure Atmosphere Interaction (SUSTAIN) Laboratory.[1] The facility allowed for the evaluation of system performance against a series of water and wave conditions prior to its full-scale implementation.[2]

[1] Learn more about the SUSTAIN Laboratory at https://www.sustain.earth.miami.edu.
[2] Read the project final report at https://www.onlinepubs.trb.org/onlinepubs/IDEA/FinalReports/Highway/NCHRP213.pdf.

The SEAHIVE research and development began with a morphological investigation—dealing with form, shape, or structure—that related the shape of the system's elements to aspects such as material efficiency, stability, and ease of manufacture. Elements with circular, square, and hexagonal cross-sectional profiles were explored. Elements with circular and square cross-sectional profiles are commonly used in construction with applications such as concrete piles and pipes. A hexagonal cross-sectional profile was considered because of the geometrical properties associated with this shape, as hexagons—along with squares and triangles—are the only shapes that can cover a surface without gaps between the units (continuous tiling). SEAHIVE prototype elements of three cross-sectional profiles with varying perforation configurations were fabricated and tested in the SUSTAIN Laboratory under different water–wave conditions. Pressure profiles, or measured pressure values, varied significantly among prototype elements with different cross-sectional profiles, void configurations (i.e., the number, size, and position of the perforations), and water–wave conditions. Hexagonal units were selected for the final system design because their geometry increased stability and reflected waves in multiple directions. They also maximized the volume for a given amount of material, similar to a beehive. Thus, the SEAHIVE system refers to a cluster of hexagonal perforated elements reflecting the beehive design.

System-design testing focused on the hydrodynamic performance of the SEAHIVE system, beginning with testing a vertical SEAHIVE wall section in the SUSTAIN tank. Figure 1 illustrates the experimental setup for the test. Performance was evaluated on the basis of the water-level measurements, as they allow calculation of wave reflection and wave-energy dissipation. Comparison of



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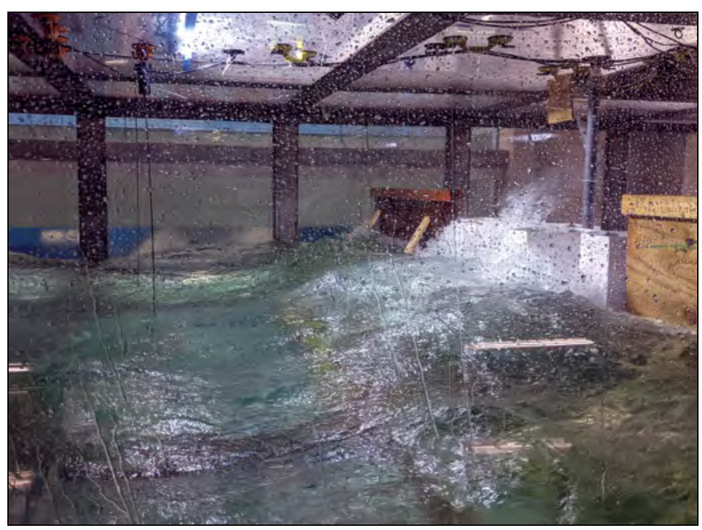

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FIGURE 1 The experimental setup for testing a vertical SEAHIVE system model in the SUSTAIN Laboratory tank is shown as (*a*) an illustration, (*b*) the front of a SEAHIVE scale model, and (*c*) the model under wave testing. (Landolf Rhode-Barbarigos)

the reflection coefficient for the vertical SEAHIVE system model with that of the flat vertical wall model revealed that the SEAHIVE system model significantly decreased wave reflection (up to 60 percent, depending on the configuration and the water–wave conditions) while dissipating up to three times more energy. Similarly, a comparison between a submerged horizontal SEAHIVE system model and a flat trapezoidal reef model revealed similar trends with the SEAHIVE model, presenting lower reflection and dissipating more wave energy.

Applying Solutions

The SEAHIVE system can be used as revetment, breakwater, and seawall alternative, providing protection from storm surge and wave action in marine and estuarine environments. Three SEAHIVE pilot installations are ongoing in Southeast Florida.

- A riprap installation, in collaboration with the City of North Bay Village. Riprap is a sloped layer of angular stones placed at the foot of vertical seawalls to enhance shoreline protection from the waves. SEAHIVE replaces those stones.
- A hybrid coral reef installation, in partnership with the City of Miami Beach and the University of Miami Laboratory for Integrative Knowledge.
- A seawall–mangrove planter installation, in collaboration with Shipwreck Park (a nonprofit organization), the City of Pompano Beach, and Broward County. The system will be part of a newly established educational marine park named Wahoo Bay (Figure 2).

In all three cases, SEAHIVE also was selected because it promoted habitat creation. All three installations will be monitored to assess the engineering and ecological performance of the system, as well as to obtain important technoeconomic data for further developments.

Overall Benefits

Laboratory tests on SEAHIVE models show that the system provides better protection against storm surge and wave action—lower wave reflection and higher wave energy dissipation—than vertical seawalls and trapezoidal submerged breakwaters. Perforations on the side faces of SEAHIVE units form interconnected channels, allowing water and dissipating wave energy through turbulence. Furthermore, the structural complexity of the SEAHIVE system (provided by its faceted perforated geometry)—combined with the use of ecofriendly materials—is expected to increase the system's potential for habitat creation. The SEAHIVE elements are being manufactured using biophilic concrete—in this case, promoting habitat for marine life—and noncorrosive reinforcements that minimize environmental impacts and extend service life. Manufacturing is achieved using conventional concrete casting techniques, without need of new equipment or additional cost.

With adaptive features for various applications and topography and the potential for habitat creation, the SEAHIVE system provides an efficient and cost-effective ecoengineering alternative for protecting the transportation network and the built environment that can be tuned for low- and high-energy areas. The cost of coastal protection in the United States is projected to skyrocket to $400 billion by 2040, making the proposed SEAHIVE system a great payoff potential (*1*).

The SEAHIVE system has received significant media attention from local and national television and print media, including a segment in the Weather Channel's Weather Underground.[3]

For more information, contact Landolf Rhode-Barbarigos, University of Miami, at landolfrb@miami.edu.

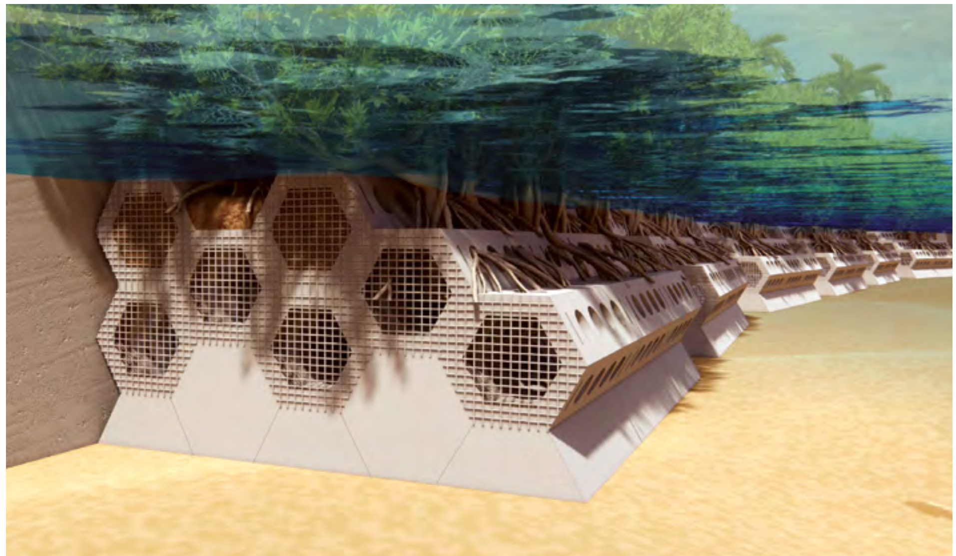

FIGURE 2 **Currently under construction, the Wahoo Bay SEAHIVE system will feature a planter integrated with live mangroves. (D. Jalfon, University of Miami)**

[3] See the science behind SEAHIVE and the Weather Underground interview with the author at https://miami.app.box.com/s/xkkzgz5m034oc50ici86cxzo1ytegaxx.

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Appreciation is expressed to Nancy Whiting, Transportation Research Board, for her efforts in developing this article.

Marianne Mintz

Principal Transportation Analyst, Argonne National Laboratory

Marianne Mintz is a forward thinker. In her more than 40 years at Argonne National Laboratory in Lemont, Illinois, Mintz has directed analyses of transportation energy technologies and policies primarily involving hydrogen, electricity, and renewable natural gas. Today, at the forefront of the transportation sector's energy retooling, she notes, "an increasing focus of my work is in response to the Infrastructure Investment and Jobs Act and the Inflation Reduction Act of 2022, which are enabling a transition to a low-carbon energy future."

After Mintz earned her master's degree in Transportation Systems Planning and Policy from the University of California, Los Angeles (UCLA), she worked for local government and gained experience as a consultant. Her next job influenced her entire career. "When I arrived at Argonne, I got involved in the nascent TRB Transportation Energy Committee and worked closely with the committee's founders." Mintz went on to serve two terms as committee chair, and then co-chaired a combined Transportation Energy and Alternative Fuels Committee. When the latter was spun off to create the Special Task Force on Climate Change and Energy, Mintz served on that committee and was the liaison between it and the Transportation Energy Committee. During that time, she also was involved with the semiannual Asilomar Conference on Transportation and Climate Change, which was hosted by the University of California, Davis, and cosponsored by TRB's standing committees on Transportation Energy and Alternative Fuels and Technologies. "Looking back," Mintz admits, "I feel truly fortunate to have worked with such an amazing group of professionals from Argonne, the Department of Energy, and the many organizations involved in TRB."

At Argonne National Laboratory, Mintz focused on the big picture. She worked to introduce alternative or flexibly fueled vehicles and fuels into the U.S. transportation fleet; directed model development, vehicle characterization, and data preparation to project activity and energy consumption for all U.S. transport modes; and produced alternative sociotechnological scenarios. Drilling down into the details helped her quantify important energy-related factors like the gap between EPA test data and actual on-road fuel economy; the amount of transportation energy consumption associated with curbside recycling; racial and demographic differences in rates of vehicle ownership and fuel use; and the impact of exempting alternative fueled vehicles from transportation control measures adopted to meet Clean Air Act standards. In approximately 150 publications, she analyzed, calculated, and quantified past and present energy use. She also projected, suggested, and postulated the future of transportation energy. She has documented industry perspectives, and examined refinery and refined-product trends as they affect worldwide supply and demand.

"Looking back, I feel truly fortunate to have worked with such an amazing group of professionals."

Mintz's experience stretches beyond U.S. borders. For example, she assessed transportation energy issues in South Korea for the World Bank and led transportation demand analyses in Argentina, Portugal, and South Korea for Argonne's Cooperative Energy Assessment Program. In 1987, and again in 1995, she received the Argonne National Laboratory Pacesetter Award.

Today, as Mintz is scrutinizing how best to deploy infrastructure for electrification and renewable natural gas, she is assessing the impact of that infrastructure. "Consumer satisfaction with electric vehicle charging is likely to be higher if the infrastructure is deployed ubiquitously," she mentions, "unlike today. Current charging infrastructure tends to be concentrated in areas with high incomes or at locations frequented by high-income drivers." She notes that researchers are seeing a diverse set of economic impacts from deploying new infrastructure. "These are not just direct effects from producing, installing, and maintaining equipment, and providing the power to operate it, but also *induced* effects associated with consumer spending while charging vehicles. Potentially, this is significant new spending on dining, shopping, or entertainment."

Mintz's involvement with TRB dates to when Martin Wachs—well known to the TRB community—was her undergraduate advisor. "Marty spoke almost reverently of TRB and urged his students to become involved in the research community—not only by attending the Annual Meeting but by submitting and reviewing papers, serving on committees, and volunteering for committee tasks." Mintz's continuous TRB committee involvement began in 1988. Currently, she is a member emeritus of the Standing Committee on Transportation Energy.

She commends the TRB community for welcoming young professionals. "TRB has come a long way in providing opportunities for young members in the research community. I applaud those efforts," she adds, pointing out the young members' reception at the Annual Meeting, additional committee membership "slots" for researchers younger than 35 years of age, paper awards, opportunities for committee "friends," and training to assist young members seeking greater TRB involvement.

"The sky's the limit when it comes to opportunities for colleagues starting out," Mintz observes. "I see government agencies, consulting firms, and equipment suppliers hiring on an almost daily basis. I also see great opportunities for professional growth." The future is bright.

Timothy Sexton

Assistant Commissioner, Minnesota Department of Transportation

Ever since his college days at the University of Iowa in Iowa City, **Timothy Sexton** has been passionate about public health. Sexton earned two master's degrees: one in public, environmental, and occupational health and another in urban and regional planning.

In his role as Chief Sustainability Officer and Assistant Commissioner for Sustainability and Public Health at the Minnesota Department of Transportation (DOT), Sexton led Pathways to Decarbonizing Transportation, a multiagency initiative that created a blueprint for sustainable transportation in the state. Over approximately three months, national transportation experts researched and strategized to achieve state greenhouse gas reduction goals and obtain feedback and input. Their efforts resulted in the Minnesota DOT, the Minnesota Pollution Control Agency, the Minnesota Department of Agriculture, Minnesota DOT's Sustainable Transportation Advisory Council (STAC), and the Governor's Office adopting low- and zero-emission vehicle standards, creating the Governor's Council on Biofuels, and developing the first U.S. electric vehicle incentive for managed lanes. Sexton led Minnesota's multiagency electric vehicle plans, including electric vehicle adoption goals and equity strategies in 2019, 2021, and 2022. He also led coordination with other state agencies to engage the public and external stakeholders in identifying electric vehicle charging needs and supporting state funding for chargers. "For newer fields of transportation practice, like sustainability, clean transportation, climate resilience, and health, research helps build a foundation for informing decisions and building new programs," he states.

Since 2019, when Sexton helped create STAC, the group has developed new partnerships to advance transportation climate and equity goals. "STAC invites leaders from public, private, and nonprofit sectors—as well as elected officials—to spearhead development of strategies and recommendations to help Minnesota DOT decarbonize

"For newer fields of transportation practice, research helps build a foundation for informing decisions and building new programs."

transportation," he explains. "The council is facilitated by Minnesota DOT but directed by external members. The department has advanced a number of challenging recommendations from STAC, including a goal to reduce vehicle miles traveled across the state to support public health, safety, and equity, and to decrease carbon pollution."

Sexton's career continues to grow. In July 2022, he took on a new role that uses his previous experience in the Office of Sustainability and Public Health and in the division responsible for multimodal planning and program management. This multimodal planning and program experience benefitted the Offices of Aeronautics, Freight, and Commercial Vehicles; Research and Innovation; Transit and Active Transportation; Transportation System Management; as well as the Asset Management Project Office.

Sexton, who currently chairs TRB's Transportation and Sustainability Committee, also has served on the Standing Committee on Extreme Weather and Climate Change, as well as several NCHRP project panels. He has strengthened his professional relationships—and air quality and climate pollution knowledge—through his work with what is now the Standing Committee on Air Quality and Greenhouse Gas Mitigation. Earlier, while at Washington State DOT, Sexton's role expanded to focus on greenhouse gas mitigation. Soon he began participating in committee sessions and meetings at TRB Annual Meetings. "I was so impressed by the complexity of modeling, testing, and other highly technical challenges being tackled by researchers," he reflects. "Attending the Annual Meetings allowed me to talk with academic and private-sector researchers to understand how their work could translate to applicable uses by a state DOT. Meanwhile, professional relationships led to development of a multistate transportation pooled fund focused on near-road air quality."

His dedication to the field has earned Sexton several awards, including the FHWA Environmental Excellence Award for Project Lead: Pathways to Decarbonizing Transportation, 2022; the National Conference of State Legislatures Notable Document Award, 2020; and *Midwest Energy News*' 40 Under 40 Award, 2018.

Sexton has found valuable learning opportunities throughout his career, as well as through his TRB involvement. "I've been fortunate to work for leaders who recognize the importance of transportation research and support external collaboration to help us think differently about how transportation can help the economy and connect people and communities," he adds. "Relationships and research supported by TRB are more important than ever as new technologies and changing public expectations around transportation access, equity, safety, and climate action continue to drive changes in our profession."

TRANSPORTATION INFLUENCER

Milena Rangelov

Milena Rangelov is a research engineer with Engineering & Software Consultants in Centreville, Virginia. She also is a contractor on the Sustainable Pavements Program for FHWA, where she worked as a postdoctoral candidate. She chairs the Younger Member Subcommittee for the Transportation Infrastructure Group's Pavements Section.

What is your role for the Section on Pavements of the Younger Member Subcommittee?

As chair of the Younger Member Subcommittee under the Section on Pavements, I help young members get involved with TRB's activities and meet their peers for knowledge exchange and networking. These activities include the development of research need statements, workshops, and sessions, as well as collaboration with other committees. All these activities are meant to help young members gain valuable professional development opportunities and become active TRB members.

How does your Younger Member Subcommittee interact with other groups or committees and the Young Members Coordinating Council?

The Younger Member Subcommittee is a new group; however, there are several key areas of collaboration with other committees and subcommittees under the Section on Pavements. For example, our subcommittee has collaborated on the development of several workshop proposals and cosponsored workshops and sessions. Through the joint work on research need statements, our subcommittee is strengthening the collaboration with other committees. We are also cosponsoring a 3-minute thesis competition. All these efforts enable our members to hone their technical and communication skills, while learning about TRB processes.

What is helping you to be successful in this role?

I was fortunate to receive immense support from Section on Pavements Chair Bouzid Choubane, as well as from other committee chairs. It is very helpful to get support from the colleagues who are more experienced. Their advice and assistance was indispensable as I was building up the subcommittee and trying to bring new ideas to life. Also, this subcommittee's members are very proactive and innovative, which makes my role quite enjoyable and rewarding.

How has TRB influenced your career so far?

Ever since I was a student, TRB has been an important organization for learning and research dissemination, as well as for networking with peers and colleagues. Work with TRB committees helped me learn about the postdoctoral opportunity I enjoyed at FHWA, which was transformational for my career and opened many new doors. I am hoping that through the work of my subcommittee, I can help young professionals gain similar benefits and become the thought leaders in transportation.

Transportation Influencer highlights the journey of young professionals active in TRB. Have someone to nominate? Send an e-mail to TRNews@nas.edu.

Let's Hear from You!

In each issue, we pose a sometimes light and fun transportation-related question that allows you to share your thoughts with other readers. To answer, **click here** or e-mail us at **TRNews@nas.edu** and follow these simple steps:

1. In the subject line, include **"Volunteer Voices: [the question you're answering]"**;
2. Answer the question thoughtfully, but keep it brief—up to about 150 words;
3. Add whether you are a TRB member or volunteer, and list the committees you are involved with; and
4. Add TRNews@nas.edu to your contacts so we avoid your spam folder when we tell you you're going to be published.

That's it! Like all *TR News* content, your response may be edited for grammar, length, and TRB style. When the issue with your quote is published, you'll get a PDF of the page featuring your response and photo.

Now that you have the details, here's the question:
What form of transportation do you think most changed the world, and why?

TRB Executive Committee Adopts Revised Strategic Plan

In January 2018, the TRB Executive Committee first adopted a Diversity and Inclusion Strategic Plan. The TRB Special Committee on Diversity and Inclusion was established and charged with monitoring implementation of this plan and proposing revisions as appropriate. In fall 2020, the name of the committee was changed to include the word "equity" and became the Special Committee on Diversity, Equity, and Inclusion (DE&I). The committee's membership is representative of TRB's major oversight committees and stakeholders, and every effort is made to ensure racial, ethnic, gender, and ability diversity of the committee.

Significant progress has been made in implementing the strategies contained in the 2018 plan. Since TRB began implementing its plan, the National Academies of Sciences, Engineering, and Medicine also developed a DE&I strategic plan and has created its Office of Diversity and Inclusion (ODI). It also established two employee-led groups in 2022—the Academies' DEI Council and the DEI Program Advisory Group. TRB staff have collaborated in the development and monitoring of the Academies' DE&I Strategic Plan to ensure alignment of the work of ODI and the employee groups, as well as with TRB's DE&I Strategic Plan.

The DE&I Committee recently recommended a revision of its strategic plan to better reflect recent TRB work, accomplishments, societal changes, new priorities, alignment with the Academies' DE&I priorities, and alignment with the Executive Committee's priorities. A new DE&I strategic plan was adopted at the June 2022 TRB Executive Committee meeting. The revised strategies and associated actions for each of the strategies below are continuously updated to reflect their progress and to add or delete actions based on priorities and resource availability.


Risdon Photography

Engaged in a session at the 2022 TRB Annual Meeting, members of the Standing Committee on Equity in Transportation are a good example of inclusion. TRB's revised plan and its strategies reflect the value the organization places on ensuring diversity, equity, and inclusion.

Revised Strategies and Associated Actions

Strategy 1. Ensure equitable opportunities for all involved in TRB, and implement strategies and resources that are used to recruit, welcome, and actively involve more diverse committee and panel members.

Strategy 2. Engage with transportation-related organizations and other appropriate organizations that serve groups that are under-represented in TRB (e.g., cultural minority groups, women, and people with disabilities) to increase their members' awareness of and participation in TRB.

Strategy 3. Create opportunities for everyone to make connections and feel included, welcomed, and able to participate equitably at the TRB Annual Meeting, specialty conferences, and committee meetings.

Strategy 4. Achieve greater diversity among TRB contractors and their lead staff, whether they are research consultants or suppliers.

Strategy 5. Identify and minimize barriers to achieving greater TRB staff diversity and assure opportunities for career advancement for diverse staff.

Strategy 6. Ensure that TRB's programmatic activities—such as, convening and other technical activities, consensus activities, and research projects—address diversity, equity, and inclusion, and ensure results are disseminated.

Strategy 7. Improve existing data, information, and communication mechanisms to support all strategies.

The new DE&I Strategic Plan lays out a roadmap for strategies and actions that will guide TRB's continuous progress in this critical area well into the future. "The TRB Executive Committee and I have placed a high priority on advancing the values of diversity, equity, and inclusion in TRB and throughout the transportation industry," noted TRB Executive Director Neil Pedersen. "I ask that everyone who is involved in TRB join us in our commitment to diversity, equity, and inclusion."

The updated Diversity, Equity, and Inclusion Strategic Plan can be found at https://onlinepubs.trb.org/onlinepubs/general/TRB_Diversity_Equity_Inclusion_Strategic_Plan_2022.pdf.

NCHRP WEBRESOURCE 1

A Guide to Reducing Greenhouse Gas Emissions

CHRIS PORTER

The author is a principal at Cambridge Systematics in Medford, Massachusetts.

Increasingly, state departments of transportation (DOTs) are being tasked with supporting state policies and targets aimed at reducing greenhouse gas emissions. Enacted in 2021, the Infrastructure Investment and Jobs Act will provide state DOTs with Federal-Aid Highway Program funding specifically directed at carbon reduction.

NCHRP WebResource 1: Reducing Greenhouse Gas Emissions: A Guide for State DOTs is meant to assist DOTs with greenhouse gas reduction activities. This guide discusses technical and institutional issues related to greenhouse gas estimation and reduction across the spectrum of an agency's activities—starting with planning and continuing through programming, design, environmental review, construction, maintenance, and operations.

NCHRP WebResource 1 can be used by individual functional units contributing to an integrated agency effort. Each of the guide's functional unit sections provides information to help staff understand and shape greenhouse gas reduction strategies (Table 1). Each section of the guide provides a self-assessment worksheet that staff can use to evaluate current activities and plan future actions. To characterize DOT activities, the self-assessments are based on a level-of-engagement framework that ranges from Level 1 (just getting started) to Level 4 (comprehensive approach).

The guide describes institutional considerations involved in working to reduce greenhouse gas emissions, such as

- Setting overall policy,
- Coordinating internally across the agency,
- Working with external partners, and
- Measuring and communicating progress.

Sample materials, such as a greenhouse gas working group charter and meeting agendas are provided, as is technical information on data, tools, and other available resources for developing greenhouse gas inventories and forecasts, and for identifying and evaluating greenhouse gas reduction measures.

The guide is the first NCHRP publication to be developed entirely in the online WebResources format. Extensive user input, including workshops hosted by the Colorado, Delaware, Hawaii, Minnesota, Nevada, Texas, and Washington State DOTs during guide development, informed the creation of the guide. Many of these workshops involved DOT partners, including state energy and environmental agencies, metropolitan planning organizations, transit agencies, municipalities, and university researchers.

An indicator of its importance and timeliness in helping transportation

This web-only product was designed to assist state DOTs and their partner organizations as they grapple with reducing greenhouse gas emissions.

TABLE 1 DOT Functional Unit Roles in Greenhouse Gas Reduction.

	Functional Area									
GHG Step	Execs and Whole Agency	Planning	Programming	Env Analysis	Design	Construction	Maintenance	Operations	Administration	Regions/ Districts
Policy	●	●		●						
Institutional Alignment	●	●		●			●	●	●	●
Partnerships	●	●		●			●	●	●	●
Communication and Public Engagement	●	●		●	●					●
Inventory	●	●		●		●	●	●	●	●
Strategy Identification	●	●	●	●	●	●	●	●	●	●
Strategy Assessment	●	●	●	●	●	●	●	●	●	●
Implementation	●		●	●	●	●	●	●	●	●
Monitoring, Evaluation, and Reporting	●	●		●			●	●	●	●

GHG = greenhouse gas, Execs = executives, Env = environmental.

agencies address climate change can be seen in the popularity of *NCHRP Web-Only Document 308*. This document describes the research and engagement activities that supported the development of *NCHRP WebResource 1*, and has set a new record for the most downloaded NCHRP publication during its first month of release.

NCHRP WebResource 1: Reducing Greenhouse Gas Emissions: A Guide for State DOTs may be found at https://crp.trb.org/nchrpwebresource1/. To view *NCHRP Web-Only Document 308: Methods for State DOTs to Reduce Greenhouse Gas Emissions from the Transportation Sector,* visit https://www.trb.org/Main/Blurbs/182696.aspx.

TRB Staff

Gathered at the 2022 TRB Annual Meeting in Washington, DC, winners of the 2021–2022 ACRP Graduate Research Award Program—and staff from the support program—are (*front row, left to right*) Mary Sandy, Virginia Space Grant Consortium; Lamiya Noor, Oregon State University; Maryssa Loehr, Washington University in St. Louis; Ebenezer Duah, Arizona State University; Mingu Kang, University of Illinois at Urbana–Champaign; and Sarah Pauls, Virginia Space Grant Consortium. In the back row are (*left to right*) Chuyang Yang, Purdue University; Mark Kotwicz Herniczek, Georgia Institute of Technology; Javier García Mainieri, University of Illinois at Urbana–Champaign; Pengyu Xie, Rutgers University; Christopher Cummings, Northwestern University; and Matthew Griffin, ACRP. Awardees not pictured are Daniela Betancourt Jiminez, Purdue University; Fiona Greer, University of California, Berkeley; and Drew Taplin, Arizona State University.

Making a Difference

ACRP Graduate Research Award Program

ANTHONY P. AVERY

The author is a senior program assistant for the Cooperative Research Programs at the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine in Washington, DC.

A web-based, electronic survey was recently distributed to solicit both attitudes and assessments from past participants of the Graduate Research Award Program on Public-Sector Aviation Issues, which is administered by the Airport Cooperative Research Program (ACRP). ACRP annually recruits up to 12 graduate students for the program to produce a paper for publication consideration in the *Transportation Research Record: Journal of the Transportation Research Board* and to present this paper at the TRB Annual Meeting, in coordination with TRB's Aviation Group standing committees. Preparation includes active support from advisors and a panel of mentors assigned to work with the student based on a particular expertise. In the 13 years during which the program has been active, more than 120 students—representing in excess of 80 universities—have participated.

The survey was intended to determine the perceptions and long-term impacts of the program on students' professional personas and development. There was particular interest in whether the participants believed the program affected their graduate efforts and helped them realize their career objectives.

Out of the 50 requests made, 20 past participants representing seven program years promptly responded to the e-survey—a 40 percent response rate. Overall, the participants perceived the program as having played a significant role in enhancing their education and having a positive long-term impact on the participants' professional careers.

Regarding program recommendations for future consideration, participants expressed support for addressing a need for greater publicity to help increase interest in the program. For example, they suggested using social networking outreach as a potentially easy and cost-effective way to advertise the program to a wider audience.

For more information about the survey results and the ACRP Graduate Research Award Program, visit http://www.trb.org/ACRP.

COOPERATIVE RESEARCH PROGRAMS NEWS

AIRPORT PROGRAMS THAT REDUCE LANDSIDE VEHICLE CARBON EMISSIONS

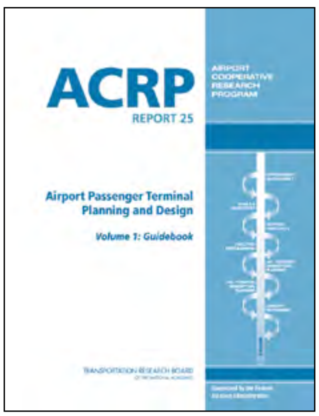
InterVISTAS Consulting received a $45,000, 18-month contract [Airport Cooperative Research Program (ACRP) Synthesis Project 11-03/Topic S02-22] to provide information on airport programs or initiatives that reduce carbon emissions from vehicles accessing the airport. The study team will conduct a literature review; document airport programs or initiatives that influence carbon emissions; identify funding mechanisms that support advancement toward sustainability; conduct interviews with airport staff; provide at least four case studies that include at least one international airport; and describe additional research needed.

For further information, contact Jordan Christensen, TRB, at 202-334-2317 or JChristensen@nas.edu.

UPDATE TO ACRP REPORT 25: AIRPORT PASSENGER TERMINAL PLANNING AND DESIGN

Ricondo & Associates received a $499,880, 14-month contract (ACRP Project 07-19) to update *ACRP Report 25*. The new edition will be more user-friendly, with Volumes 1 and 2 consolidated. This research will cover the terminal area from the terminal frontage/terminal entry to the aircraft gate apron and return. This update will consider all types and sizes of airports and will reference *ACRP WebResource 2: Airport Passenger Terminal Design Library.*

For further information, contact Edward McDonald, TRB, at 202-334-2934 or EMcDonald@nas.edu.



Published 12 years ago in two volumes with a CD-ROM, *ACRP Report 25* is getting an update.

VERIFYING QUANTITIES OF MATERIALS USED IN ASPHALT MIXTURES

The University of Nevada at Reno has received a $350,000, 28-month contract [National Cooperative Highway Research Program (NCHRP) Project 09-69] to recommend procedures for verifying quantities of materials used in asphalt mixtures at production facilities and to prepare guidelines for the application of these procedures. The procedures and guidelines shall be prepared as a standalone document suitable for AASHTO's consideration and adoption.

For further information, contact Amir Hanna, TRB, at 202-334-1432 or AHanna@nas.edu.

David Prasad, Flickr, CC BY-SA 2.0

Are Indian treaties that were adopted when states were territories but never abrogated by Congress still in effect? According to a 2020 U.S. Supreme Court ruling, *yes*. A new legal research digest will help state DOTs to address this issue throughout the nation for roads like this one near Warm Springs Indian Reservation in north–central Oregon.

AIRFIELD TURF AND VEGETATION MANAGEMENT

DPrather Aviation Solutions received a $45,000, 18-month contract (ACRP Synthesis Project 11-03/Topic S09-10) to provide guidance on current airfield practices for turf and vegetation management given the various constraints of staffing, equipment, safety, funding, climate, and regulations. Tasks resulting in the creation of this synthesis will include a literature review, survey of geographically and size-diverse airports regarding their practices and techniques, equipment, staffing, and operational methods; and the provision of case examples and sample practices.

For further information, contact Jordan Christensen, TRB, at 202-334-2317 or JChristensen@nas.edu.

EFFECTS OF INDIAN TREATIES ON TRANSPORTATION FACILITY DEVELOPMENT AND OPERATION

Kaplan Kirsch & Rockwell received a $100,000, 14-month contract (NCHRP Project 20-06/Topic 26-01) to research and produce a legal research digest that addresses how state departments of transportation (DOTs) perform due diligence on the existence of Indian treaties that may be in force and affect development and operation of transportation facilities; the ways in which treaties that may still be in force are related to today's federally recognized Indian tribes; how such treaties could be interpreted to affect transportation facilities; and what the administrative mechanism would be for resolution of treaty rights against developers and operators of transportation facilities.

For further information, contact Gwen Chisholm-Smith, TRB, at 202-334-3246 or GSmith@nas.edu.

NCHRP RESEARCH REPORT 948 IMPLEMENTATION: GUIDE FOR PEDESTRIAN AND BICYCLE SAFETY

Kittelson and Associates received a $249,950, 18-month contract [NCHRP Project 20-44(35)] to implement *NCHRP Research Report 948*, in which guidance was provided to transportation practitioners working to improve and integrate pedestrian and bicycle safety considerations at alternative intersections and interchanges through planning, design, and operational treatments. The implementation project's objective is to share and disseminate the results of the research with public agencies and to provide hands-on technology transfer assistance to these agencies.

For further information, contact Trey Wadsworth, TRB, at 202-334-2307 or TWadsworth@nas.edu.

IN MEMORIAM

Frederic D. Hejl 1944–2022

Fred Hejl was a senior program officer for many years in what was the Design and Construction Group and is now the Transportation Infrastructure Group. When he joined TRB, he was responsible for materials—concrete and asphalt—and construction of transportation facilities, an area in which his leadership excelled.

For nearly 25 years of his 26-year TRB career, he was secretary of the Design and Construction Group, where he managed the logistics of programming sessions, workshops, and committee meetings for the TRB Annual Meeting. As associate division director, he coordinated the work of the Technical Activities Division. He helped launch the Annual Meeting's Distinguished Lecture (now called the Deen Lecture), as well as the Dialogue with Leaders in the Design and Construction of Transportation Facilities Lecture. He championed the creation of emeritus committee members and the Research Needs Database.

With his reputation for fostering ways in which to involve and engage members of the TRB community, he was often recognized for excellence, innovation, and going above and beyond. In 2012, Fred received the Distinguished Service Award for outstanding contributions to the work of the National Academies.

In a manner that augmented but never diminished his professionalism, Fred was well known for his dry sense of humor and a few Annual Meeting rituals. Many remember how he would wear a salmon-colored shirt as his reminder that the Annual Meeting was about to happen—regardless of whatever else was going on, it would occur, and there would be no delaying or avoiding it. He also was known as the creator of Black Tuesday, a day when he would wear black to the Annual Meeting. This happened without explanation but occurred for years. In 2016, at the last Annual Meeting Fred attended before he retired, members of the Technical Activities Division surprised him when they all conspired and wore black in a show of solidarity (*top*).

TR News has a special connection to Fred. He served on the *TR News* Editorial Board for more than two decades—from his 1993 appointment by then Executive Director Thomas B. Deen until the end of 2016. His stewardship as Editorial Board chair began in 2009 and continued beyond his May 2016 retirement until the end of that year. While Editorial Board member and chair, nearly 150 issues of *TR News* were published under his watchful eye. During his tenure, he envisioned *TR News* issues that were topic-focused and presented collections of feature articles concentrated on a particular research theme. Over the years, he influenced many and surely left his mark here, between the pages.

TRB Staff

For many years at TRB, Fred Hejl (*right*) and G.P. "Jay" Jayaparakash (*left*) literally worked side-by-side—their offices in Keck were next to each other. "We had a 26-year career together," Jay recalls. "I believe we made some major contributions for the good of TRB, volunteers who worked with us, and the transportation community in the U.S., as well as worldwide." TRB agreed and honored Fred and Jay at the 2016 Annual Meeting, where they were granted emeritus member status in the TRB Design and Construction Group.

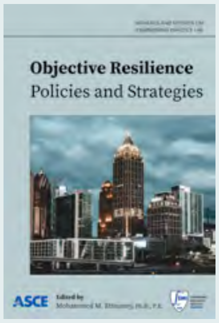
Risdon Photography

Those who know TRB often remark on that collegial synergy that is ever present at meetings and other gatherings. Fred nurtured this spirit. "Everyone learned a lot, and we laughed a lot," remembers Ann Brach, director of the Technical Activities Division. Pictured (*left to right*) are Claire Randall, Jay Jayaprakash, Mark Norman, Scott Babcock, Michael DeCarmine, Rosa Allen, Mary Kissi, Christine Gerencher, Brie Schwartz, Kim Fisher, Angela Christian, Mai Le, Frank Lisle, Javy Awan, Fred Hejl, Stephen Maher, Steve Andrle, Ann Brach, Joanice Johnson, James Bryant, Brittney Gick, Scott Brotemarkle, Tom Palmerlee, Monica Starnes, Bernardo Kleiner, and Lea Camarda.

TRB Staff

"He was the father of the theme issue," notes current *TR News* Editorial Board Chair Christine Gerencher. "In fact, it is very like Fred that this remembrance of him appears in a theme issue." At a 2016 Editorial Board meeting are (*left to right*) Javy Awan, Lea Camarda, Katherine Kortum, Russell Houston, Fred Hejl, Tom Menzies, Chris Hedges, Ed Harrigan, and Christine Gerencher.

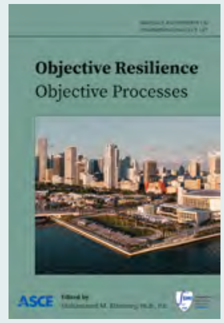
American Society of Civil Engineers (ASCE) Objective Resilience Series



Objective Resilience: Policies and Strategies

ASCE, 2022, 272 pp., $100, 978-0-7844-1588-7. Edited by Mohammed M. Ettouney.

This new manual of practice (MOP) 146 examines policies and strategies related to community and asset resilience. It will be of interest to policy makers; owners and managers of civil infrastructures; and local, state, and federal legislators.



Objective Resilience: Objective Processes

ASCE, 2022, 378 pp., $100, 978-0-7844-1589-4. Edited by Mohammed M. Ettouney.

MOP 147 illustrates some of the objective processes used to manage community and asset resilience. This manual will be of particular interest to researchers, educators, engineering consultants, and practitioners.

Objective Resilience: Technology

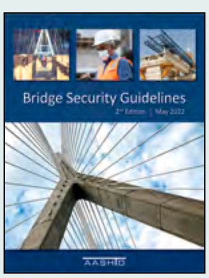
ASCE, 2022, 288 pp., $100, 978-0-7844-1590-0. Edited by Mohammed M. Ettouney.

MOP 148 examines the use of different technologies to enhance community and asset resilience. Individuals and organizations in the construction, as well as the sensor and monitoring communities; health care facilities; and disaster preparedness and response fields will find this manual to be a useful guide.

Objective Resilience: Applications

ASCE, 2022, 348 pp., $100, 978-0-7844-1591-7. Edited by Mohammed M. Ettouney.

MOP 149 provides different applications that aim to enhance community and asset resilience from the community viewpoint. The manual of practice will be of interest to groups focusing on pandemic mitigation and response, blast protection, public and private transit organizations, and natural hazards.



Bridge Security Guidelines, 2nd Edition

AASHTO, 2022, 101 pp., AASHTO members, $83; nonmembers, $112; 978-1-56051-789-4.

This downloadable PDF offers guidance on bridge design for human-induced extreme events, such as the response of concrete bridge columns subjected to blast loads, blast-resistant design, and detailing guidelines and analytical models of blast load distribution. Also included are guidelines on reducing risk to other structural bridge components and intentional hazards to consider for threat vulnerability risk assessments.

The titles in this section are not TRB publications. To order, contact the publisher listed.

TRB PUBLICATIONS

Transportation Research Record 2676
Issue 4

This issue includes research on fixed-time traffic control, train derailments in Canada, safety evaluation of pedestrian countdown signals, flexible notice-to-proceed provisions, and why commuters pay for autonomous vehicles.

2022; 800 pp. For more information, visit http://journals.sagepub.com/home/trr.

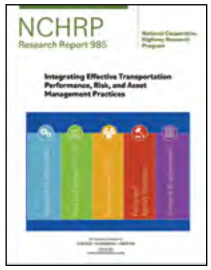
Transportation Research Record 2676
Issue 5

Environmentally tuning asphalt pavements, departure timing preference during extreme weather events, traffic noise impact prediction, asymmetric gasoline price effects on public transit ridership, and more topics are examined in this issue.

2022; 830 pp. For more information, visit http://journals.sagepub.com/home/trr.

SAGE is the publisher of the *Transportation Research Record: Journal of the Transportation Research Board* (TRR) series. To search for TRR articles, visit http://journals.sagepub.com/home/trr. To subscribe to the TRR, visit https://us.sagepub.com/en-us/nam/transportation-research-record/journal203503#subscribe.

To order the TRB titles described in Bookshelf, visit the TRB online bookstore, https://www.mytrb.org/MyTRB/Store, or contact the Business Office at 202-334-3213.



Integrating Effective Transportation Performance, Risk, and Asset Management Practices
NCHRP Research Report 985

This report is designed as a resilient process framework for the expected evolution of an agency as it matures in its management integration.

2022; 74 pp.; TRB affiliates, $51; TRB nonaffiliates, $68. Subscriber categories: administration and management, data and information technology, planning and forecasting.

Implementation of the AASHTO Guide for Enterprise Risk Management
NCHRP Research Report 986

This report documents how several state departments of transportation are adopting AASHTO's risk management principles and practices.

2022; 412 pp.; TRB affiliates, $88.50; TRB nonaffiliates, $118. Subscriber category: administration and management.

Ruggedness of Laboratory Tests for Asphalt Mixture Cracking Resistance
NCHRP Research Report 987

This report presents the results of ruggedness testing of eight laboratory tests for the cracking resistance of asphalt mixes and proposes revisions to the test methods based on these results.

2022; 114 pp.; TRB affiliates, $60.75; TRB nonaffiliates, $81. Subscriber category: materials.

Guide to Pedestrian Analysis
NCHRP Research Report 992

This report presents a state-of-the-art guide to conducting pedestrian traffic analysis on the basis of volume, safety, operations, and quality of service.

2022; 124 pp.; TRB affiliates, $60.75; TRB nonaffiliates, $81. Subscriber categories: highways, pedestrians and bicyclists.

Public Liabilities Relating to Driveway Permits
NCHRP Legal Research Digest 85

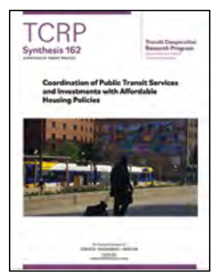
This digest evaluates the circumstances under which transportation agencies are held liable by property owners for the regulatory function of permitted and unpermitted driveways.

2022; 128 pp.; TRB affiliates, $126; TRB nonaffiliates, $168. Subscriber categories: law, highways.

Agricultural Operations on Airport Grounds
ACRP Synthesis 117

This synthesis compiles literature and practices at airports to initiate and manage agricultural operations on airport grounds.

2022; 94 pp.; TRB affiliates, $57.75; TRB nonaffiliates, $77. Subscriber category: aviation.



Coordination of Public Transit Services and Investments with Affordable Housing Policies
TCRP Synthesis 162

This synthesis looks at the current body of published works focused on the affordable housing and transit nexus. This information is supplemented by a national survey completed by 51 diverse transit agencies and five case examples that explore not only ways transit agencies are coordinating with affordable housing initiatives, but also the ways regional planning agencies, local governments, and affordable housing partners are helping to bridge housing and transit to realize the full potential of each.

2022; 96 pp.; TRB affiliates, $39; TRB nonaffiliates, $52. Subscriber categories: policy, public transportation.

MEETINGS, WEBINARS, AND WORKSHOPS

October

27 **TRB Webinar: Protocols for Macrotexture Measurement to Prevent Wet Weather Crashes**

November

1–2 **Marine Board Fall Meeting 2022: Maritime Infrastructure Investments**
Washington, DC
For more information, contact Scott Brotemarkle, TRB, at 202-334-2167 or SBrotemarkle@nas.edu.

3 **TRB Webinar: Six Minute Pitch—A Transportation Startup Challenge**

3–4 **10th International Symposium on Visualization in Transportation**
Washington, DC
For more information, contact Thomas Palmerlee, TRB at 202-334-2030 or TPalmerlee@nas.edu.

15–17 **13th Annual Maritime Risk Symposium***
Lemont, Illinois
For more information, contact Scott Brotemarkle, TRB, at 202-334-2167 or SBrotemarkle@nas.edu.

17 **TRB Webinar: Cybersecurity Trends in Transportation**

22 **TRB Webinar: Legal Considerations of Renewable Energy Production in State Right-of-Way**

29 **TRB Webinar: Managing Severe Storms and Environmental Impacts**

30 **TRB Webinar: State DOTs Perspective on Pavement Resilience**

December

12 **TRB Webinar: Expanding Microtransit Services and Improving the Rider Experience**

12–14 **Advances in Materials and Pavement Performance Prediction***
Hong Kong
For more information, contact Nelson Gibson, TRB, 202-334-2953, NGibson@nas.edu.

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*TRB is co-sponsor of the meeting.

Please contact TRB for up-to-date information on meeting cancellations or postponements. For Technical Activities meetings, visit www.TRB.org/calendar/calendar or e-mail TRBMeetings@nas.edu. For more information on a TRB webinar, contact TRBwebinar@nas.edu. For information on all other events or deadlines, inquire with the listed contact.

To subscribe to the TRB E-Newsletter and keep up to date on upcoming activities, go to www.trb.org/Publications/PubsTRBENewsletter.aspx and click on "Subscribe."

VOLUNTEER VOICES

I always appreciate receiving the TRB weekly e-newsletter. The transport material included in it helps me to imagine the future of transport in the United States. It also allows me to define new lines of study. As a project manager in reserved lanes at Cerema, I also distribute reports to my colleagues. With the COVID-19 crisis, I started to follow the TRB webinars and they are a great complement! All this enriches my professional life.

—ALEXIS BACELAR
ITS Project Manager, Cerema
Lyon, France

INFORMATION FOR CONTRIBUTORS TO TR NEWS

TR News welcomes the submission of articles for possible publication in the categories listed below. All articles submitted are subject to review by the Editorial Board and other reviewers to determine suitability for *TR News*; authors will be advised of acceptance of articles with or without revision. All articles accepted for publication are subject to editing for conciseness and appropriate language and style. Authors review and approve the edited version of the article before publication. All authors are asked to review our policy to prevent discrimination, harassment, and bullying behavior, available at https://www.nationalacademies.org/about/institutional-policies-and-procedures/policy-of-harrassment.

ARTICLES

FEATURES are timely articles of interest to transportation professionals, including administrators, planners, researchers, and practitioners in government, academia, and industry. Articles are encouraged on innovations and state-of-the-art practices pertaining to transportation research and development in all modes (highways and bridges, public transit, aviation, rail, marine, and others, such as pipelines, bicycles, pedestrians, etc.) and in all subject areas (planning and administration, design, materials and construction, facility maintenance, traffic control, safety, security, logistics, geology, law, environmental concerns, energy, technology, etc.). Manuscripts should be no longer than 3,000 words. Authors also should provide tables and graphics with corresponding captions (see Submission Requirements). Prospective authors are encouraged to submit a summary or outline of a proposed article for preliminary review.

MINIFEATURES are concise feature articles, typically 1,500 words in length. These can accompany feature articles as a supporting or related topic or can address a standalone topic.

SIDEBARS generally are embedded in a feature or minifeature article, going into additional detail on a topic addressed in the main article or highlighting important additional information related to that article. Sidebars are usually up to 750 words in length.

POINT OF VIEW is an occasional series of authored opinions on current transportation issues. Articles (1,000 to 2,000 words) may be submitted with appropriate, high-quality graphics, and are subject to review and editing.

RESEARCH PAYS OFF highlights research projects, studies, demonstrations, and improved methods or processes that provide innovative, cost-effective solutions to important transportation-related problems in all modes. Research Pays Off articles should describe cases in which the application of project findings has resulted in benefits to transportation agencies or to the public, or in which substantial benefits are expected. Articles (approximately 750 to 1,000 words) should delineate the problem, research, and benefits, and be accompanied by the logo of the agency or organization submitting the article, as well as one or two photos or graphics. Research Pays Off topics must be approved by the RPO Task Force; to submit a topic for consideration, contact Nancy Whiting at 202-334-2956 or nwhiting@nas.edu.

OTHER CONTENT

TRB HIGHLIGHTS are short (500- to 750-word) articles about TRB-specific news, initiatives, deliverables, or projects. Cooperative Research Programs project announcements and write-ups are welcomed, as are news from other divisions of the National Academies of Sciences, Engineering, and Medicine.

BOOKSHELF announces publications in the transportation field. Abstracts (100 to 200 words) should include title, author, publisher, address at which publication may be obtained, number of pages, price, Web link, and DOI or ISBN. Publishers are invited to submit copies of new publications for announcement (see contact information below).

SUBMISSION REQUIREMENTS:

- **Articles** submitted for possible publication in *TR News* and any correspondence on editorial matters should be sent to the *TR News* Editor, Cassandra Franklin-Barbajosa, cfranklin-barbajosa@nas.edu, 202-334-2278.
- Submit **graphic** elements—photos, illustrations, tables, and figures—to complement the text. Photos must be submitted as JPEG or TIFF files and must be at least 3 in. by 5 in. and 2 megabytes with a resolution of 300 dpi. Large photos (8 in. by 11 in. with a minimum of 4 megabytes at 300 dpi) are welcome for possible use as magazine cover images. A detailed caption must be supplied for each graphic element.

Note: Authors are responsible for the authenticity of their articles and for obtaining written permissions from publishers or persons who own the copyright to any previously published or copyrighted material used in the articles, **as well as any copyrighted images** submitted as graphics.

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