Technical Highlights

A Wedge Analysis of the U.S. Transportation Sector

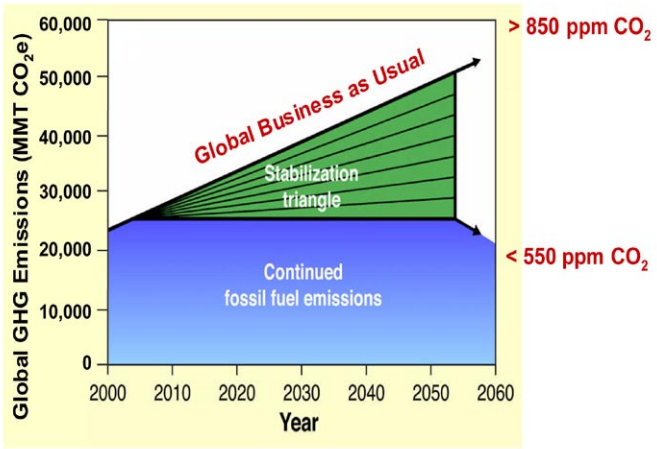
Greenhouse Gas Emissions from the Transportation Sector

The U.S. transportation sector represents approximately 10% of all energy-related greenhouse gas emissions worldwide. Over the next 50 years, rising numbers and use of vehicles could increase greenhouse gas emissions from U.S. transportation by 80% above current levels. However, many current and anticipated vehicle and fuel technologies, as well as approaches for reducing vehicle use, could be deployed to slow or halt the increase in accumulated greenhouse gasses in the atmosphere from transportation. This fact sheet provides a summary of a number of these approaches from a recent EPA study, "A Wedge Analysis of the U.S. Transportation Sector" . www.epa.gov/otaq/climate/420r07007.pdf

Stabilization Wedge Approach

EPA's analysis uses the "stabilization wedge" concept first developed by Rob Socolow and Stephen Pacala at Princeton University. This approaches focuses on ways to reduce emissions from a business-as-usual scenario in which atmospheric carbon dioxide (CO2) concentrations reach 850 parts per million (ppm) over the next 50 years to a scenario that stabilizes global concentrations at 550 ppm, which is less than twice the preindustrial concentration of atmospheric CO2 (see Figure 1).[1] The difference between these two scenarios is the "stabilization triangle." Socolow and Pacala slice this triangle into seven "stabilization wedges," each representing an activity that over the next 50 years could

Figure 1: Global-scale Stabilization Wedge



[1] Figure 1 is reproduced from Stephen Pacala and Robert Socolow (2004), "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies." *Science*, 305, 968.

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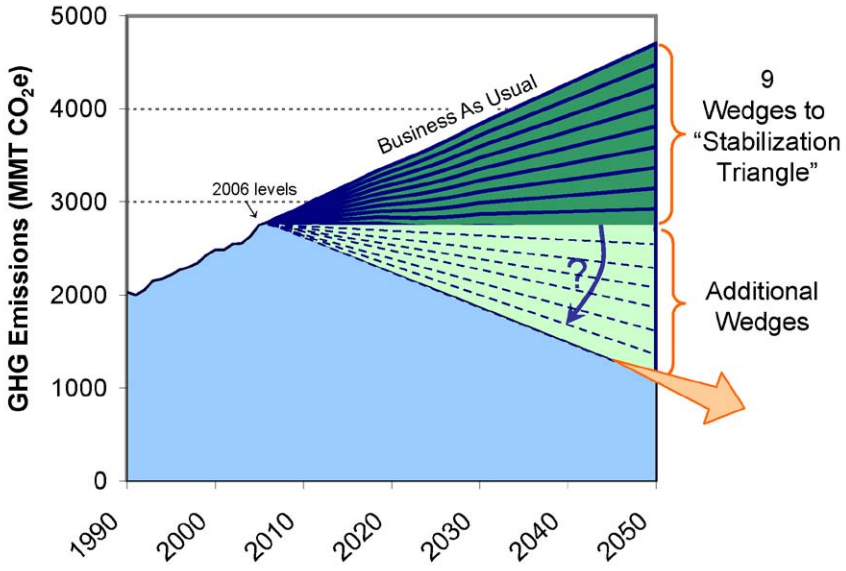
reduce 92,000 million metric tons (MMT) of CO2e on a global level.[2] Eliminating all seven of these wedges would allow global emissions to be flattened (or kept at today's level) over the next 50 years, helping to maintain an atmospheric CO2 concentration of 550 ppm.

In the EPA study, the wedge analysis approach was scaled down and applied to the U.S. transportation sector. Figure 2 illustrates the triangle necessary to flatten emissions from the U.S. transportation sector from now until 2050. The cumulative emissions embodied by the upper "stabilization triangle" are approximately 45,000 MMT CO2e—roughly half of one of Socolow and Pacala's seven wedges. To better evaluate the possible strategies to reduce these emissions, the EPA study divided the transportation-specific triangle into nine wedges of 5,000 MMT CO2e each. Elimination of all nine of these wedges would be needed to flatten the sector's emissions by 2050.

Figure 2: U.S. Transportation Stabilization Wedge



Options for Reducing Greenhouse Gas "Wedges" from the U.S. Transportation Sector

There are three general approaches for reducing greenhouse gases in the transportation sector: 1) adopting advanced vehicle technologies, 2) switching to low-greenhouse gas fuels, and 3) reducing vehicle miles traveled. The EPA wedge analysis examined numerous scenarios for implementing these options separately and in combination.

The analysis focused only on passenger vehicles, which contribute approximately half of all U.S. transportation sector emissions. Over the next 50 years, emissions growth from just passenger vehicles is expected to contribute half of transportation emissions under a business-as-usual scenario (the other emissions come from emissions growth of trucks, airplanes, rail, and other modes of transportation). A number of different examples are shown that can reduce anywhere from 4 to 9 wedges—just from passenger vehicles. Incorporating other transportation sources

[2]In their analysis, Scolow and Pacala measure emissions in billions of tons. This paper uses millions of metric tons (MMT). One of the seven 92,000 MMT wedges described by Socolow and Pacala is equivalent to 25 billion tons. CO_2e, or "CO_2 equivalent" emissions, represent emissions of all greenhouse gasses converted to units of CO_2 based on their relative global warming potential.

into the analysis would yield many more possible approaches for reducing emissions and could yield much larger reductions than those from passenger vehicles alone.

What if We Just Changed One Thing? Scenarios Focused on Stand-alone Changes to the Transportation Sector

EPA analyzed the effect of a number of stand-alone changes to vehicle technologies, fuels, or vehicle use that would reduce greenhouse gasses. The scenarios focused on changing vehicle technology examined what would happen if various types of vehicles reached a market share in 2025 that was 30 percentage points above their current market share and then maintained the new market share until 2050. A vehicle that currently has 10% of the market would, for example, have 40% of the market from 2025 to 2050. Figure 3 illustrates that such a boost in market share for gasoline-hybrid electric vehicles (HEV) would reduce emissions by one wedge. The results of other vehicle technology scenarios and their wedge counts are shown in the figure's inset box. (The ranges of GHG reductions shown account for low and high estimates for fuel-cycle emissions depending, for example, on what technologies are used to generate electricity for plug-in hybrid electric vehicles or to produce ethanol.)

Figure 3: Potential Emissions Reductions from Vehicle Technology Scenarios

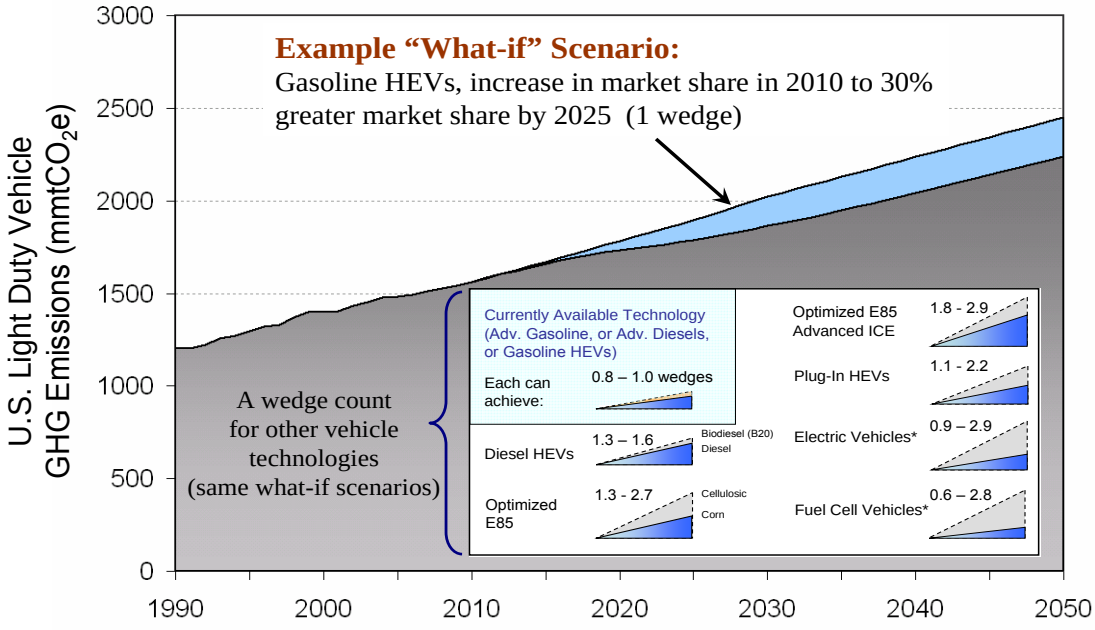


Figure notes: HEV=hybrid electric vehicle; ICE=internal combustion engine. *For electric vehicle and fuel cell vehicles, the "what-if" market share reaches 30% five years later (2030) due to large technical hurdles remaining.

EPA also analyzed other stand-alone changes to the transportation sector that would reduce greenhouse gas emissions. Some of these changes involved switching to low greenhouse gas fuels while others reduced vehicle miles traveled (VMT). For fuels, the analysis revealed that substituting 60 billion gallons of ethanol for gasoline by 2050 (25% from corn ethanol and 75% from cellulosic ethanol and no changes in vehicle technology) would achieve 1.4 wedges. An alternative

case, involving 90 billion gallons of ethanol, would achieve 2.3 wedges. Reducing vehicle miles traveled by 5%, 10%, and 15% by 2050 through land use planning, shifting travel modes, and other approaches would achieve 0.5, 0.9, and 1.3 wedges respectively.

What if We Changed Many Things? Scenarios That Use a "Systems Approach" to Analyze Multiple Inter-related Changes to the Transportation Sector

By far, the greatest reductions in greenhouse gasses come from a "systems approach" that accounts for the important relationships among strategies for advanced vehicle technologies, low greenhouse gas fuels, and/or reducing VMT. Figure 4 shows the result of a deployment of a "systems approach" that includes both advanced vehicles and low-GHG fuels with a strong emphasis on hybrid electric vehicles. This scenario results in 5 wedges (the inset shows how the components of this systems scenario add up to the total). A large variety of other scenarios is possible. Three of these are described in Table 1, and additional scenarios are described in the full paper. The most aggressive scenario—achieving up to 9 wedges—involves extensive deployment of near-zero emission vehicle technologies and fuels (e.g. cellulosic ethanol and electricity from nuclear or renewable sources), as well as travel demand management approaches for reducing VMT (see Sceanrio 3 in Table 1, "Emphasis on Near-zero Emissions Vehicles and Fuels and Aggressive Travel Demand Management").

Figure 4: A "Systems" Scenario Assuming Predominantly Hybrid Electric Vehicles, Including Plug-in Hybrids, by 2050

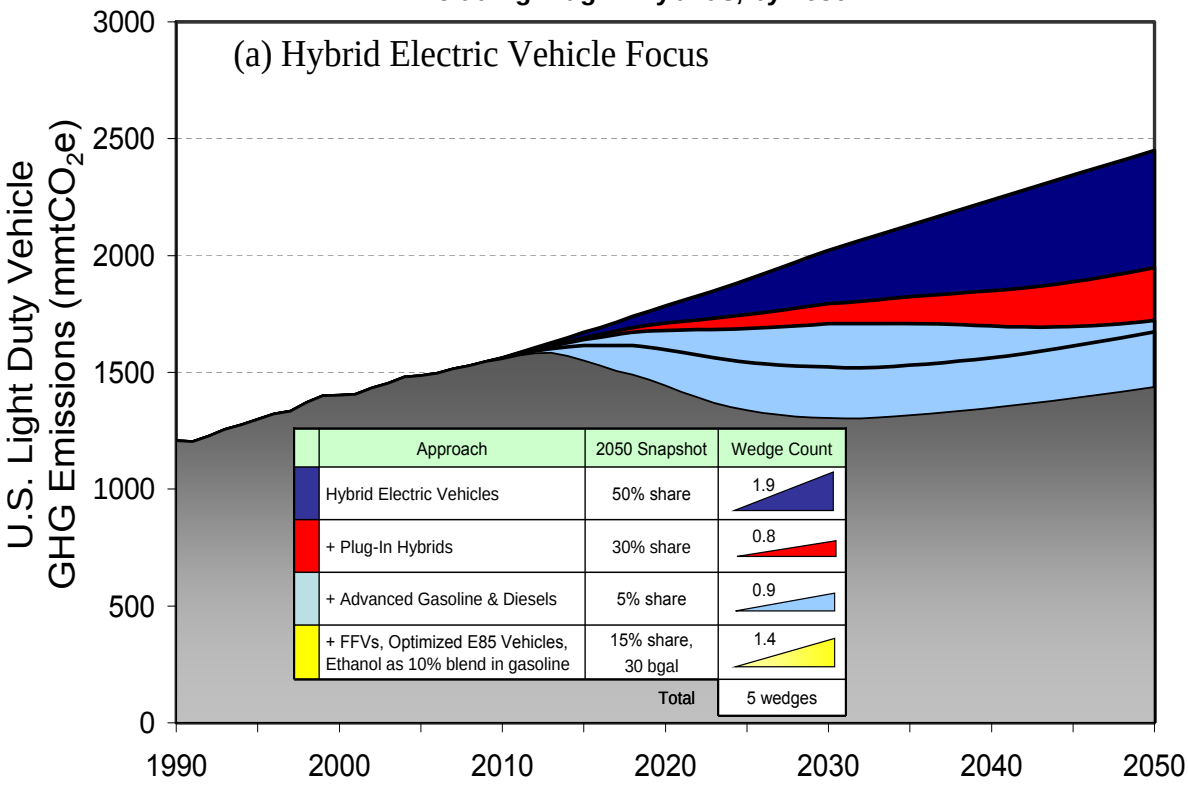
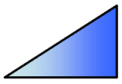
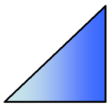
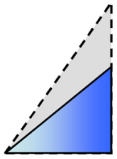


Table 1: Summary of Selected "Systems" Scenarios for Reducing Transportation-Related Greenhouse Gas Emissions

Scenario and Assumptions (Snapshot of Vehicle Sales, Fuels, and Travel Demand Management in 2050)	Wedge Count
1. Emphasis on Advanced Internal Combustion Technologies and Traditional Fuels ▫ 80% market share in 2050 for advanced gasoline, advanced diesel, and gas-hybrid vehicles ▫ 20% market share for optimized E85 vehicles ▫ Use of 50 billion gallons (bgal) per year of ethanol (15 bgal from corn, 35 bgal from cellulose) ▫ No travel demand management	4.0 wedges 
2. Emphasis on E85 Vehicles and Ethanol Fuels and Aggressive Travel Demand Management ▫ 60% market share in 2050 for advanced gasoline and advanced diesel vehicles ▫ 40% market share for optimized and advanced optimized E85 vehicles ▫ Use of 80 bgal per year of ethanol (15 bgal from corn, 65 bgal from cellulose) ▫ 15% reduction in vehicle miles traveled (VMT) from travel demand management	6.0 wedges 
3. Emphasis on Near-zero Emissions Vehicles and Fuels and Aggressive Travel Demand Management ▫ 40% market share in 2050 for electric vehicles ▫ 30% market share for hydrogen fuel cell vehicles ▫ 30% market share for advanced optimized E85 vehicles ▫ Use of 40 bgal per year of ethanol (15 bgal from corn, 25 bgal from cellulose) ▫ 15% reduction in VMT from travel demand management	5.2 to 9.0 wedges (depending on the sources of electricity & hydrogen for vehicles) 

Conclusions

Overall, the analysis showed that with aggressive combined improvements in vehicle technologies, fuels, and vehicle miles traveled, the future contribution of U.S. transportation to accumulated greenhouse gasses in the atmosphere could be reduced or flattened. It also suggested the following additional conclusions:

- By themselves, individual approaches incorporating vehicle technologies, fuels, or transportation demand management (TDM) approaches could moderately reduce, but not flatten, the nine transportation-related wedges from now until 2050. "Systems approaches" that combine all three approaches, however, could yield the 4.3 wedges needed to flatten passenger vehicle emissions and even up to all nine wedges under aggressive scenarios.
- If efforts are limited to only passenger vehicles, the task of achieving nine wedges will be a challenging one. Incorporating solutions that involve commercial trucks, marine vessels, railroads, airplanes, and non-road vehicle sources would yield much larger possible reductions that could more easily eliminate nine or more wedges.

- Near-term vehicle technologies can have as much an impact in terms of GHG reductions as future, longer-term technologies because their reductions begin to accrue sooner. To achieve the most wedges, however, the reductions achievable only though longer-term technologies are needed.
- Nearly all the approaches discussed also reduce petroleum use, which would have benefits beyond GHG reductions. For example, achieving five wedges could result in saving 7 to 8 million barrels of petroleum per day in 2050.

For More Information

You can access the full study on EPA's Office of Transportation and Air Quality (OTAQ) Web site at:

www.epa.gov/otaq/greenhousegases.htm

References

Stephen Pacala and Robert Socolow (2004), "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies." Science, 305, 968.

Simon Mui, Jeff Alson, Benjamin Ellies, David Ganss (2007). "A Wedge Analysis of the U.S. Transportation Sector." Transportation and Climate Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency.