

POLICIES THAT WORK: HOW VEHICLE STANDARDS AND FUEL FEES CAN CUT CO₂ EMISSIONS AND BOOST THE ECONOMY





Policies That Work analyzes energy, transportation, and climate policies from around the world to determine which work, which don't, and why. Written by leading policy and technical experts in the ClimateWorks Network, the Policies That Work reports provide an analytical framework to help government leaders evaluate proposed policies in terms of their economic benefits and effectiveness in reducing greenhouse gas emissions.

Policies That Work focuses on the sectors responsible for the vast majority of the world's energy use and greenhouse gas emissions, including vehicles and fuels, appliances, power, industry, and buildings. Policies That Work is published by the ClimateWorks Foundation.



The International Council on Clean Transportation is an independent nonprofit organization that works directly with regulatory agencies and policymakers to control greenhouse gas emissions and conventional pollution in the transportation sector. Part of the ClimateWorks Network, the ICCT provides scientifically sound, technically rigorous analysis to inform the design, implementation, and enforcement of vehicle efficiency and fuel standards in countries accounting for 80 percent of the global automotive market, including China, the European Union, the United States, India, Brazil, South Korea, and Mexico.

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How vehicle standards and fuel fees can cut CO₂ emissions and boost the economy

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Government policies to improve energy efficiency and reduce air pollution from motor vehicles have reaped outstanding benefits: They have decreased oil consumption, lowered greenhouse gas emissions, and increased investment in innovative technologies—all at a net savings to society.

Road transportation contributes a sixth of the world's energy-related greenhouse gas emissions. As car ownership in China, India, and developing countries continues to explode, vehicle emissions and oil consumption will skyrocket unless nations adopt effective policies to rein them in.

If policymakers are to succeed in their efforts to foster economic growth, improve public health, and protect the environment, they need to know which policies work, which don't, and why. Various modeling efforts have tried to determine which *technologies* can increase vehicle efficiency, but comparatively little research has focused on the effectiveness of *policies* aimed at achieving that goal. This report, part of the "Policies That Work" series, fills the gap by analyzing the results of vehicle performance standards and fuel and vehicle levies from around the world. (Other transportation policies, such as smart urban planning and support for high-quality transit, will be addressed in a forthcoming Policies That Work report.)

This concise analysis provides an analytical framework for evaluating policies to curb greenhouse gas emissions from road transportation. Each policy is evaluated in terms of its design strengths and flaws, its net socioeconomic costs and benefits, and its success in reducing carbon emissions.

Executive summary

In 2007 the transportation sector emitted almost 7 gigatonnes (Gt), or billion metric tons, of carbon dioxide—roughly a quarter of the world's total energy-related emissions. Road transportation, with 5 Gt of CO_2 , made up the lion's share of the sector's emissions. CO_2 emissions from road transport are expected to grow by more than 2 percent per year between 2010 and 2030,¹ largely spurred by the dramatic increase in the number of automobiles hitting the roads in China, India, and other developing economies.

Two policies have proved most effective at significantly reducing emissions from road transportation:

- Vehicle performance standards establish minimum requirements based on fuel consumption or greenhouse gas emissions per unit of distance traveled.
- Economic signals such as fuel and vehicle fees provide clear monetary incentives to consumers (to drive less and purchase more-efficient vehicles) and automakers (to improve vehicle efficiency beyond the minimum requirement set by performance standards).

When designed and implemented correctly, these policies can save significant amounts of fuel and associated CO_2 emissions.

Five steps to successful vehicle and fuel policies

- 1. Set goals and let the market work out the best solutions
- Establish performance standards and levies to reduce emissions.
 Don't mandate a particular technology solution, such as electric cars or biofuels; instead, set overarching policy goals and let the market find the most costeffective solutions.
- Base standards and fees on greenhouse gas emissions. Vehicle performance standards based on greenhouse gas emissions are more effective than fuel economy standards because they cover non-CO₂ gases and address the different carbon intensities of different fuels. By the same token, fuel and vehicle fees should be linked to emissions rather than to vehicle attributes, such as weight or engine displacement, so that they can be applied across a range of technologies and fuels.

2. Require consistent, predictable performance improvements

Continuously tighten vehicle performance standards and raise fuel levies.
 Standards should be made more stringent on a constant, steady basis over several product development cycles—by 3 to 6 percent annually—to encourage ongoing innovation.

3. Go upstream in the manufacturing process and capture 100 percent of the market

 Cover all vehicles and fuels. Emissions performance standards should apply to all vehicles, including medium- and heavy-duty, agricultural and construction, and two- and three-wheel vehicles. To prevent manufacturers and consumers from circumventing the standards or fees, no model or fuel should be exempt.

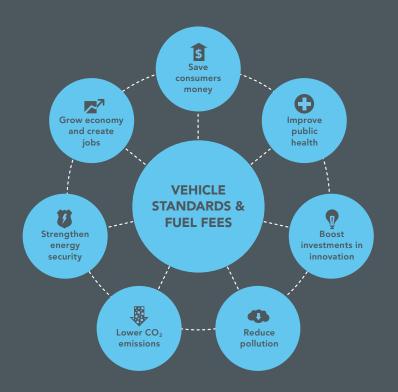
4. Facilitate private sector investment and innovation

- Send long-term signals. Manufacturers need stable market signals to invest in new technology. Vehicle standards and fuel and vehicle fee rates should be predictable and well publicized to provide a meaningful signal to automakers and consumers.
- Combine fees with rebates. When appropriate, such as for vehicle fees, create "feebates" that offset charges with rebates, so that the pricing structure does not just penalize highemissions vehicles but also rewards low-emissions models.
- Adjust fees to meet revenue goals. Increased fuel and vehicle levies need not translate into higher overall tax rates. The pivot point (the point at which rebates become fees) can be adjusted to meet the revenue target of fiscal policies.

5. Reward performance, not investment, and beware of unintended consequences

- Avoid weight-based vehicle performance standards. Such standards typically shift fleets toward bigger or heavier models.
- Increase standards and fees on a continual, rather than a stepwise, basis across vehicle classes. Requirements that become more stringent a step at a time, from one vehicle class or size range to the next, encourage manufacturers to meet only the minimum for each class. Standards and levies that use a continuous curve across classes push automakers to develop more-efficient products and maximize emissions reductions.
- Improve testing techniques and rules. Procedures to test vehicle emissions and efficiency should closely approximate real-world conditions.

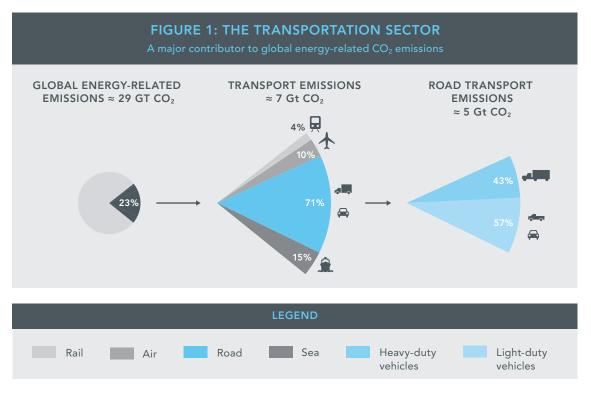
Effective vehicle emissions performance standards, coordinated with revenue-neutral fuel fees, can significantly reduce nations' annual CO₂ emissions—and save a substantial amount of money. Vehicle efficiency improvements require increased up-front investments, which spark economic growth and create jobs. In addition, by slashing fuel use, these improvements strengthen national security and result in significant net savings to consumers. This frees them to purchase other goods and services, further boosting the economy. By reducing conventional pollutants, these policies also improve public health. The best practices outlined in this report can help nations reap all of these climate and socioeconomic benefits.



Why focus on transportation?

Overall, the transport sector accounts for almost a quarter of global energy-related greenhouse gas emissions. Road transportation contributes the largest portion (over 70 percent), with marine (15 percent) and aviation transport (10 percent) the next biggest emitters. Most road transportation emissions come from light-duty vehicles and trucks.

Vehicle ownership continues to grow worldwide. China, for example, added more than 18 million vehicles in 2010, over a quarter of global sales, and is forecast to have up to 250 million vehicles clogging its roads by 2025. Road emissions are projected to grow more than 2 percent annually, reaching 8.4 Gt CO_2 in 2030.² The U.S., China, and the E.U. are expected to remain the top three emitters, responsible for more than 60 percent of global road emissions, so our analysis focuses on these regions.



Source: International Energy Agency, International Council on Clean Transportation

Road transport contributes a sizable fraction of global CO₂ emissions. Of that, light-duty passenger vehicles account for the majority, with medium- and heavy-duty trucks adding a significant portion.

² McKinsey & Co., global greenhouse gas abatement cost curve version 2.1.

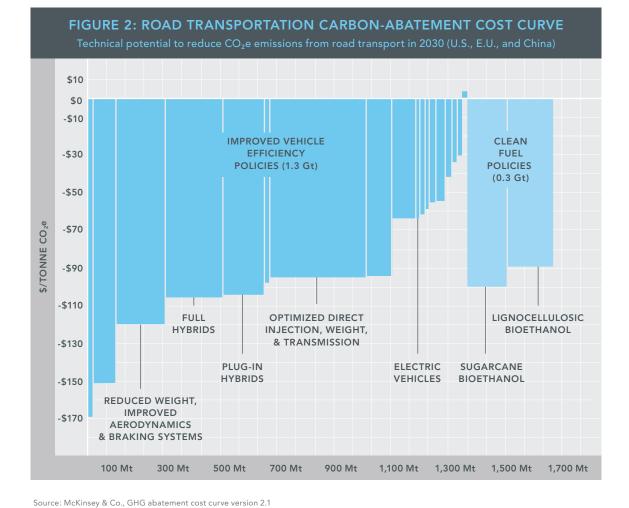
Improvements in vehicle technology could significantly reduce CO₂ emissions from road transportation — most at a net cost savings. Promising gains can be achieved with advanced internal combustion engines; lightweight materials; advanced biofuels; and hybrid, electric, and compressed natural gas models. In the U.S., the standards covering model years 2012–16 are expected to reduce CO₂ emissions by 18 percent while saving each car owner about \$3,000 over the life of the vehicle.³ A 2009 study identified ways to reduce CO₂ emissions from heavy-duty long-haul combination trucks by as much as 50 percent, also at a net economic benefit.⁴ And a series of National Research Council studies spanning two decades have consistently shown substantial opportunities to cut emissions at a net savings through vehicle efficiency improvements.⁵

Current technologies will slash greenhouse gas emissions from U.S. passenger vehicles by almost 20 percent while saving each car owner about \$3,000 over the life of the vehicle.

⁴ Northeast States Center for a Clean Air Future, International Council on Clean Transportation, et al, "Reducing Heavy-Duty Long-Haul Combination Truck Fuel Consumption and CO, Emissions," 2009.

⁵ National Research Council, "Automotive Fuel Economy: How Far Can We Go?" 1992; "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards," 2002; "Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy," 2011.

³ U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule," 2010.



Each rectangle in the cost curve represents an option for reducing emissions. The width measures the

option's technically achievable emissions reduction, in megatonnes (Mt), or millions of metric tons, of CO_2 equivalent; the height measures its cost per tonne, in U.S. dollars. Options that save money appear below the "\$0" line.

Vehicle efficiency improvements could reduce annual CO_2e emissions from the U.S., China, and the E.U. by 1.3 Gt at a savings of about \$135 billion per year by 2030. Effective vehicle standards and fuel fees can capture the vast majority of this technical potential.

7

Standards and fees: Proven in the marketplace

The two policies that have shown the greatest potential to reduce emissions from road transportation are vehicle emissions performance standards and fuel and vehicle fees.⁶

Both create demand for technology innovation. Performance standards produce predictable results because they require manufacturers to build more-efficient products, usually at very low cost—but in doing so, they make driving less expensive, which encourages consumers to drive more. Also, performance standards generally do not incentivize automakers to surpass the minimum requirements.

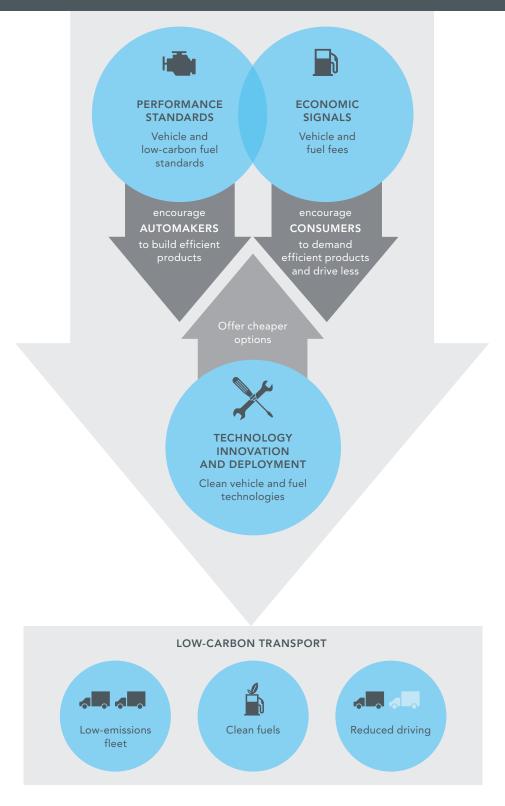
Fuel and vehicle fees, on the other hand, encourage consumers to buy the most efficient models and thus nudge automakers to continuously improve efficiency beyond the minimum mandated levels. But they do not guarantee improvement, and they are subject to some market failures: For instance, most consumers severely discount fuel savings when purchasing a car or truck. (Feebates, which combine fees on high-emitting vehicles with rebates for buyers of low-emissions vehicles, can address this market failure.)

If well designed and coordinated, these two policies complement and reinforce each other; the shortcomings of one offset the other's. For example, consumers respond to the increased cost of driving due to high fuel fees not only by choosing more-efficient vehicles and driving less but also by choosing to live closer to work and public transit. These choices ultimately affect urban planning and land use patterns, with even bigger benefits to global greenhouse gas emissions.

As these policies boost demand for lower-carbon technologies, innovation creates a positive feedback loop: Technological advances lower the cost to reduce emissions and thus make more-stringent policy options feasible and cost-effective.

⁶ This report does not intend to underplay the importance of other policies aimed at decarbonizing the fuel supply, such as low-carbon fuel standards. However, the track record of such policies is too short to definitively assess their effectiveness. But they can complement vehicle performance standards and fuel taxes, especially as the world shifts to multiple fuel options.

FIGURE 3: PERFORMANCE STANDARDS, ECONOMIC SIGNALS, AND TECHNOLOGICAL INNOVATION COMPLEMENT EACH OTHER



Vehicle performance standards and fuel and vehicle fees create demand for innovation, which lowers the cost of new technologies.

Policy benefits outweigh costs

Over the past 50 years, a quiet transformation has taken place in the environmental performance of motor vehicles and the fuels they burn. Before government regulation, passenger cars and trucks emitted roughly 30 times more carbon monoxide (CO) and 110 times more nitrogen oxides (NO_x) per kilometer traveled than they do today.⁷ This air pollution caused acid rain, damaged crops, contaminated water bodies, and contributed to premature mortality and respiratory diseases including chronic bronchitis. Nowadays—at least in the E.U., the U.S., and Japan—vehicles emit a tiny fraction of these conventional pollutants,⁸ at a modest cost to the consumer of roughly \$500,⁹ or less than 2 percent of the average cost of a new gasoline-fueled vehicle. The social benefits—such as reduced smog, improved public health, and higher crop production—outweigh the costs on the order of two to five times, according to the U.S. Environmental Protection Agency.¹⁰

The types of government policies that led to this transformation are now being harnessed to spur a similar reduction in greenhouse gas emissions (primarily CO_2 , but also nitrous oxide, or N_2O , and air conditioner refrigerants including hydrofluorocarbons and chlorofluorocarbons). In addition, most conventional pollutants, such as ground-level ozone and fine particulates, contribute to climate change directly or indirectly. Fine particle emissions create regional haze and are a serious health concern in urban areas; black carbon, a major component of fine particulates, has significant climate change impacts.

⁷ Passenger vehicles sold in the U.S. before 1975 had average emissions of 60 grams per kilometer of CO, 9 g/km of hydrocarbons (HC), and 4.4 g/km of NO_x under the federal test cycle. R. Heck, R. Farrauto, and S. Gulati, *Catalytic Air Pollution Control: Commercial Technology* (Hoboken, New Jersey: John Wiley & Sons, 2009).

 $^{^8}$ Current U.S., E.U., and Japanese emissions standards are, respectively: 2.6, 1.0, and 1.92 g/km of CO; 0.06, 0.10, and 0.08 g/km of HC; and 0.04, 0.06, and 0.08 g/km of NO_x.

⁹ F. Posada, A. Bandivadekar, and J. German, "Estimated Costs of Emission Reduction Technologies for Light Duty Vehicles," International Council on Clean Transportation, Washington, D.C., 2012.

¹⁰ U.S. Environmental Protection Agency, "Regulatory Impact Analysis—Control of Air Pollution From New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements," 1999.

The history of vehicle regulations: A global perspective

The United States and Europe have a long history of regulating vehicle pollution and fuel efficiency. The first U.S. emissions regulations were established in 1966 in California, where air pollution was a major public concern, to control hydrocarbon (HC) and CO emissions from passenger cars and trucks. The federal government instituted similar controls two years later. Manufacturers met these requirements by modifying engine components, such as adding positive crank-case ventilation and air injection systems and adjusting the spark timing, at a cost of less than \$100 per vehicle.¹¹ Over the following decades, more-stringent California and U.S. requirements were adopted, leading to remarkable technological innovations.

Early German and French initiatives to implement national emissions regulations were seen as barriers to free trade by other E.U. members and thus opposed.¹² As a result, European emissions regulations were delayed until the Euro 1 and 2 standards were introduced in the 1990s. These were followed by Euro 3 levels in 2000, which led to cold-start emissions and self-diagnosis technologies. Euro 4 and 5 levels required roughly 50 percent reductions in NO_x, HC, and CO emissions from Euro 3 levels.

Vehicle CO_2 emissions can also be trimmed indirectly through fuel efficiency standards. In the 1970s, for example, the U.S. adopted corporate average fuel economy (CAFE) standards for autos and light trucks, partially in response to the Arab oil embargo. The program was extremely successful at reducing reliance on imported oil. Between 1975 and 2005, the standards slashed oil consumption by 3 million barrels per day and lowered petroleum imports by almost a quarter, greatly enhancing the country's energy security. The standards also reduced CO_2 emissions by roughly 25 percent over the same period. In Germany, where voluntary fuel efficiency targets were also adopted at the end of the '70s, vehicle CO_2 emissions dropped by approximately 10 percent, compared with business-as-usual trends, between 1978 and 2005.

¹¹ J. Lee et al, "Forcing Technological Change: A Case of Automobile Emissions Control Technology Development in the U.S.," *Technovation*, 2010.

¹² M. P. Walsh, "Automobile Emissions Motor Vehicle Pollution Control in the United States and Europe," in The Reality of Precaution: Comparing Risk Regulation in the United States and Europe (RFF Press, 2010).

Between 1975 and 2005, U.S. fuel economy standards saved 3 million barrels of oil per day and cut petroleum imports and CO_2 emissions by about a quarter, at a net savings of about \$30 per tonne of CO_2 .

When examined more closely, however, U.S. fuel economy standards offer a cautionary lesson. From 1975 to 1985, the standards were strengthened annually. As a result, automobile and light truck fuel economy nearly doubled during that decade. From 1985 to 2010, however, the standards plateaued, stagnating at about 28 miles per gallon for cars and 20 mpg for light trucks (8.4 liters per 100 kilometers and 11.8 liters/100 km, respectively). This standstill cost the U.S. economy some 12 billion barrels of oil by 2010.¹³ In addition, the more-lenient truck standards boosted demand for trucks and contributed to a 42 percent increase in average vehicle weight from 1985 to 2005, hampering the potential efficiency gains.

China has experienced similar results since it adopted a weight-based fuel economy standard for autos and light trucks in 2005. Nationwide new vehicle fuel economy improved by 10 percent, but over the past three years, that improvement has halted due to the trend toward heavier cars.

These experiences have identified two characteristics of effective vehicle performance standards: They should be based on vehicle size (footprint) or greenhouse gas emissions, not weight, and they should be tightened consistently. Since 2005 the United States has renewed its commitment to fuel economy standards, raising the requirements for cars and light trucks and establishing standards for heavy-duty vehicles. China's central government is currently drafting regulations to require at least a 14 percent increase in automobile fuel efficiency between 2010 and 2015 within each weight category.

The timeline on page 14 charts the major policy milestones and technological solutions developed over the past five decades.

¹³ Calculation based on the total U.S. fleet (per U.S. Department of Transportation) traveling 11,500-11,800 miles per year (per McKinsey & Co.) with an average 27-mpg starting point. It assumes forfeited fuel efficiency improvements of 2 percent per year for new vehicles, with a roughly 10-year lag before the fleet average reflects the higher fuel economy. Savings start to accrue in 1996, becoming bigger each subsequent year.



33B

barrels of oil saved by U.S. fuel economy standards, 1975–2005



of conventional vehicle pollutants eliminated by E.U., U.S., and Japanese standards

Timeline of selected vehicle performance standards

late 1960s

PROGRAM

First emissions regulations, covering hydrocarbons (HC) and carbon monoxide (CO) from passenger vehicles

California, United States

TECHNOLOGY

Positive crank-case ventilation, secondary air injection, adjusted spark timing

COST <\$100/vehicle*



PROGRAM

Clean Air Act amendments: 75% reductions in HC and CO, 70% reduction in NO_x

Lead in gasoline phased out, with major health benefits

United States

TECHNOLOGY

Three-way catalytic system and exhaust oxygen sensors; electronic systems to precisely control airfuel mix, including engine control unit, electronic air sensing, fuel metering via fuel injection, and electronic spark ignition timing

COST ~\$300/vehicle*

1970s

PROGRAM

Clean Air Act: 60% reduction in HC and CO emissions from passenger vehicles, introduced control of nitrogen oxides (NO_x) emissions

First fuel economy (corporate average fuel economy, or CAFE) standards

United States

TECHNOLOGY Catalytic converters (led to phaseout of le

(led to phaseout of lead in gasoline), exhaust gas recirculation **PROGRAM** Tier 1 levels:

60% reduction in NO_x emissions

United States

TECHNOLOGY

Catalyst and fuel injection improvements, including multipoint fuel injection, improved airfuel control with single oxygen (O₂) sensor selfdiagnosis technology

COST \$80-\$100/vehicle*

PROGRAM Euro 1 and 2 standards

European Union

 $^{
m *}$ Dollars listed are initial costs as of the regulation date. The costs are much lower now.

PROGRAM Top Runner program introduced

Japan

PROGRAM First voluntary CO₂ emissions standards

European Union

PROGRAM Low-emission vehicle (LEV) levels

California

2005

PROGRAM Fuel economy standards

China

PROGRAM Euro 4 levels: 50% reductions in NO_x, HC, and CO

European Union

PROGRAM First mandatory greenhouse gas rules

California, European Union

2000s

PROGRAM Tier 2 levels: 65% reduction in NO_x emissions

United States

TECHNOLOGY

Sequential multipoint fuel injection, variable spark timing, double O₂ sensor, advances in three-way catalytic systems, cold-start emissions

COST \$70-\$120/vehicle*

PROGRAM

Euro 3 levels: 25% reduction in NO_x emissions

European Union

PROGRAM First heavy-duty vehicle standards Japan

2010s

2000

PROGRAM Euro 5 levels: 25% reductions in NO_x

European Union

PROGRAM

Higher fuel economy standards for passenger vehicles, greenhouse gas emissions standards, fuel economy standards for heavy-duty vehicles

United States

TECHNOLOGY

Advanced direct injection, turbochargers, engine downsizing, low-rolling-resistance tires, improved aerodynamics and transmissions, lightweight materials

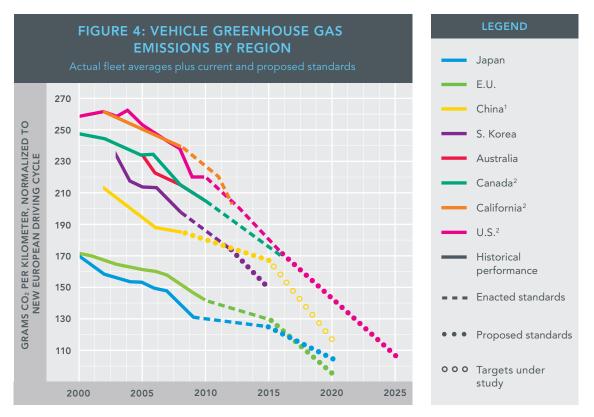
Standards as a vehicle for innovation and savings

Despite their imperfections, fuel economy standards have been a net economic boon, because the cost of the new technology has been more than offset by the fuel savings. Between 1975 and 2005, for example, U.S. vehicle fuel economy regulations resulted in a net savings of approximately \$30 per tonne of avoided CO_2 emissions. In addition, the standards improved energy security by reducing the country's reliance on foreign oil. The money consumers save on imported gasoline can be spent on goods and services that fuel domestic economic growth. And reduced pollution from emissions standards also yields substantial health benefits.

Since the late 1990s, concerns about climate change have led to an increased focus on lowering CO_2 emissions and improving energy efficiency. Europe established the first voluntary standards for CO_2 emissions in 1998; California and the U.S. adopted mandatory greenhouse gas rules in late 2009 and early 2010, respectively.

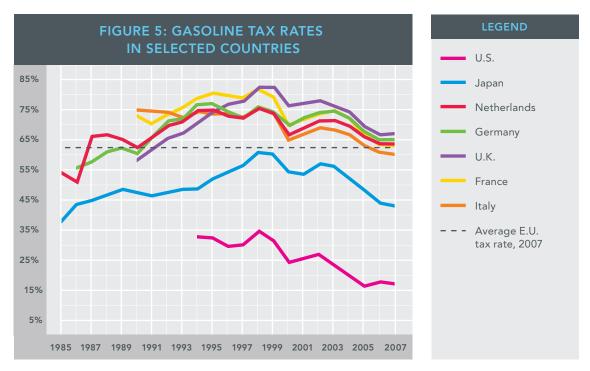
Technological innovation has followed two routes to improve fuel economy and reduce CO_2 emissions:

- Engine and vehicle modifications—including engine downsizing, cylinder deactivation, auto start-stop, lighter-weight cars and trucks, better aerodynamics, and low-rolling-resistance tires—provide immediate benefits.
- Electric, hybrid, and fuel cell vehicles have the potential to address long-term, large-scale climate change goals. Hybrids gained market share during the mid-2000s and opened the door for plug-in and electric models. Hydrogen fuel cells have made significant progress, although they face substantial technical and fueling-infrastructure challenges. Such zero-tailpipe-emissions vehicles generally offer considerable air quality and CO₂ benefits, depending on the upstream emissions from production of electricity or hydrogen.



Passenger vehicle fuel economy standards have substantially reduced CO_2 emissions. ¹ China's target reflects a gasoline fleet scenario. If other fuel types are included, the target will be lower.

² U.S. and Canadian light-duty vehicles include light commercial vehicles.



Source: International Energy Agency and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

The higher fuel economy in Japan and Europe illustrates the benefits of long-standing high fuel and vehicle fees.

These innovations not only reduce fuel use and emissions; they can also boost profits and create jobs, from the U.S. Rust Belt to Europe to southern China. Recent research shows that the shift to greater fuel economy can trigger demand for additional manufactured components, which promotes investment and greater labor content per vehicle.

Specifically, the research found that "supplying the U.S. automobile market with more-efficient cars could provide a net gain of over 190,000 new jobs" by 2020.¹⁴ However, the location of those jobs largely depends on policy decisions, including fuel economy standards and domestic production incentives. Anecdotal evidence also demonstrates the jobs created by vehicle performance standards:

- In May 2010 Toyota and Tesla Motors announced a joint venture to reopen the shuttered NUMMI plant in Fremont, California, and employ 1,000 workers to produce electric sedans and SUVs.
- BMW AG began recruiting 2,600 new employees in 2010 to develop models with lower CO₂ emissions to meet regulators' demands for cleaner-running cars.
- In Cleveland, Ohio, Ford reopened a mothballed plant in 2009 to build its efficient EcoBoost engines, investing \$55 million and hiring 250 workers. As it expands production of the EcoBoost and other efficient engines, Ford is hiring thousands more assembly workers as well as engineers specializing in electrification.
- General Motors announced plans in 2010 to hire 1,000 engineers to work on its electric vehicles.

¹⁴ A. Baum and D. Luria, "Driving Growth: How Clean Cars and Climate Policy Can Create Jobs," March 2010, www.uaw.org/sites/default/files/Driving Growth Paper_CAP_NRDC_UAW_Mar2010_FINAL.pdf.

- Bosch, which invests roughly €400 million each year in engineering electric drives, has hired some 700 workers since 2004 to develop technology for hybrid and electric vehicles; it employs another 650 to work on lithium-ion battery technology for vehicles through its joint venture with Samsung SDI.
- In China, BYD Auto, which makes a plug-in hybrid and is developing an all-electric model, has received a \$230 million investment from Warren Buffett and an \$88 million co-investment from Daimler.

In sum, over the past 50 years, government-set performance-based standards have driven new technologies into the marketplace that transformed the environmental performance of passenger vehicles. Incremental progress, sparked by increasingly stringent standards, allowed for new ideas to build on previous technologies. No one could have foreseen the full suite of emissions controls now featured in motor vehicles. Similar policies can trigger comparable innovations to reduce greenhouse gas emissions.

> Technological innovations to reduce greenhouse gas emissions also cut fuel use, enhance energy security, boost economic growth, and create jobs.

Results of fuel and vehicle levies

Fees can be assessed on fuel or vehicles to encourage consumers to drive less and buy more-efficient cars and trucks, and to nudge manufacturers to produce more-efficient models. Vehicle fees can be charged as a lump sum at time of purchase or annually as registration fees. Regardless of when fees are levied, whether on fuel or vehicles, the goal is the same: Prices should take into account the full costs of emissions.

Fuel fees and high fuel prices have proved extremely effective at increasing vehicle energy efficiency. In the aftermath of the '70s oil crisis, a 1980 study identified fuel prices as the most important factor in determining the fuel economy of the new car fleet.¹⁵ Thanks in part to high fuel fees, the average fuel economy of passenger vehicle fleets in Europe and Japan is more than 50 percent greater than the U.S. average: 45 mpg (5.6 liters per 100 kilometers) in Japan and 42 mpg (6.2 liters/100 km) in Europe versus 28 mpg (8.4 liters/100 km) in the U.S. This higher fuel efficiency results in much lower CO₂ emissions. European motorists also typically drive about 50 percent less than their U.S. counterparts, according to McKinsey & Co.

Individual countries assess charges on transportation fuels very differently. Figure 5 shows that European fees are fairly harmonized, and fuel levies in the E.U. and Japan are significantly higher than in the U.S.

Several studies have demonstrated the effects of higher fuel prices: Consumers drive less, vehicle fuel efficiency improves, and some people shift to public transit. According to research by economists Ian Perry and Kenneth Small, if U.S. gasoline taxes were roughly doubled, to about \$1 per gallon, about half of the drop in gasoline use would be due to reduced driving; the rest would result from improved average fleet fuel efficiency.¹⁶ Their analysis shows that well-designed fuel fees can be

¹⁵ R. S. Pyndick, The Structure of World Energy Demand (Cambridge, Massachusetts: MIT Press, 1980).

¹⁶ I. W. H. Perry and K. A. Small, "Does Britain or the United States Have the Right Gasoline Tax?" American Economic Review 95, no. 4 (2005): 1276–1289.

combined with other policies to lighten the impact on low-income drivers, and that gasoline fees efficiently address climate externalities such as congestion, air pollution, and greenhouse gas emissions. Fuel fees also raise public awareness of such externalities.¹⁷

Vehicle levies have not demonstrated a strong track record for CO_2 abatement, but this failure was mostly due to poor design.¹⁸ Since 1991, for example, the U.S. has charged a gas-guzzler tax on cars with a fuel economy rating below 22.5 mpg. Because it applied to cars but not light trucks, the tax had the inadvertent effect of shifting sales to SUVs. And a 1997 study found that fuel fees have significantly more impact on fuel economy than purchase-registration fees.¹⁹

Historically, European countries and Japan have adopted fees that indirectly tax vehicle CO_2 emissions as a function of engine displacement or power rating, applying lower fees to smaller engines and charging more for larger ones. Over the past couple of years, France, Germany, and the U.K. have adopted annual registration fees for cars based on CO_2 emissions. Japan assesses purchase taxes based on vehicle class and annual fees based on vehicle weight and engine displacement; it has also introduced tax breaks for highly efficient models. Some recent experiments, such as France's feebate mechanism, have shown considerable potential to reduce CO_2 emissions.

Overall, fuel and vehicle levies make economic sense, as the revenue they raise can fund mass transit, infrastructure improvements, clean energy research, or social programs. They can also be returned to consumers via income or payroll tax reductions; this would result in a better macro-economic outcome, as income and payroll taxes are associated with very high deadweight losses.²⁰ Finally, fuel fees make strategic sense, since they reduce reliance on expensive, unstable oil imports.

¹⁷ K. Hirota and J. Poot, "Taxes and the Environmental Impact of Private Car Use: Evidence From 68 Cities," in Methods and Models in Transport and Telecommunications: Cross Atlantic Perspectives (Springer Press, 2005).

¹⁸ ICCT, "Global Review and Comparison of Fiscal Policies to Influence Passenger Vehicle CO₂ Emissions," 2010.

¹⁹ O. Johansson and L. Schipper, "Measuring the Long-Run Fuel Demand of Cars: Separate Estimations of Vehicle Stock, Mean Fuel Intensity, and Mean Annual Driving Distance," *Journal of Transport Economics and Policy* 31 (1997): 277–292.

²⁰ I. W. H. Parry, "How Much Should Highway Fuels Be Taxed?" Resources for the Future, 2009.

What defines effective vehicle standards and fuel fees?

Performance standards and fuel fees are both extremely effective at increasing vehicle fuel efficiency and reducing emissions, but even greater advances can be achieved by implementing the two policies together. Over the next 20 years, performance standards alone will be unlikely to mitigate the emissions from the projected increase in vehicle use associated with global economic and population growth. Both policies must be adopted to achieve the necessary reductions.

Japan provides an apt example: By combining performance standards with fees, it has been able to keep levies lower than in Europe and still achieve the world's most fuel efficient vehicle fleet.

Based on an extensive review of the vehicle standards and fuel fees implemented so far, we have identified several criteria for effective policy design. Below we describe these best practices and the potential economic benefits and reductions in CO_2 emissions these policies can achieve.

Best practices: Vehicle emissions performance standards

As discussed above, regulations aimed at improving vehicle efficiency and emissions have been one of the most effective carbon-reduction policies worldwide. Vehicle performance standards have been successful because they follow two policy best practices:

Set goals and let the market work out the best solutions: Let the market choose the most cost-effective technologies to achieve the prescribed performance improvements.

Go upstream: Target a small number of market players—automakers—rather than try to influence millions of consumers.

However, vehicle performance standards sometimes failed to promote additional technological innovation because regulators and political leaders allowed them to stagnate. Trial and error over the past two decades

Compared with model year 2008 vehicles			
	Technology	Reduction in CO ₂ emissions	Incremental price per vehicle
Engine	Low-friction lubricants	0.5%	\$3
	Engine friction reduction	1–3%	\$50-100
	Variable valve timing and lift	3–4%	\$125-259
	Cylinder deactivation	6%	\$150–169
	Turbocharged downsized engine	5–7%	\$149–1,099
	Camless valve actuation	5–15%	\$501
	Gasoline direct injection (stoichiometric)	1–2%	\$209–346
Transmission	Continuously variable transmission	6%	\$192–224
	Six-speed automatic	4.5-6.5%	\$99
	Six-speed dual clutch	5.5–13%	\$47–92
Vehicle	Aerodynamic drag reduction (20% cars, 10% trucks)	2–3%	\$42
	10% reduction in tire-rolling resistance	1–2%	\$6
	10% reduction in weight	6.5%	\$518-666
	High-efficiency alternator and electrified accessories	1–2%	\$76
	Electric power steering	1.5–2%	\$94
	Integrated stop-start system	7.5%	\$351-437
	Hybrid motor assist	20–30%	\$2,854-4,431

FIGURE 6: EFFICIENCY GAINS AND COSTS

Source: U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards: Joint Technical Support Document," April 2010, www.epa.gov/otaq/climate/regulations/420r10901.pdf.

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has unearthed some unintended but predictable consequences of poorly designed standards, including a considerable increase in automotive weight and power (the U.S. is the most flagrant example) and a steady growth in driving distances. In addition, vehicle standards have traditionally covered only a fraction of the transportation sector, ignoring heavy trucks and other vehicles that together represent about 45 percent of global road transportation emissions.

The good news is that these shortcomings can be remedied through improvements in policy design. The following six best practices would significantly curb vehicle CO_2 emissions at a net savings to society:

Avoid weight-based vehicle performance standards. Because weightbased standards are more lenient for heavier models, they foster a shift to heavier vehicles and give manufacturers little incentive to use lightweight materials. Emissions- or footprint-based standards encourage development of high-strength steel, aluminum, plastics, magnesium, and other materials that reduce weight and boost fuel economy.

Use greenhouse gas emissions as the metric. Standards based on greenhouse gas emissions have two advantages over a fuel economy rule: They accommodate the different carbon intensities of various fuels such as diesel and gasoline; they also cover non-CO₂ gases, such as the fluorocarbons in air-conditioning, so they have the potential to reduce emissions up to another 5 percent.

Tighten standards consistently and predictably. Automakers operate on a long time horizon. Efficiency standards send the most effective signal to the market when they're raised by a constant, predictable amount over several four- to five-year product development cycles, with sufficient lead time for manufacturers to synchronize investments with product retooling cycles. A good rule of thumb is that robust standards should improve vehicle efficiency by 3 to 6 percent annually.

Establish continual, rather than stepwise, improvements across vehicle classes. Standards that ratchet up from one class to another direct automakers to meet only the minimum requirements for each class. Improvements based on a continuous curve push manufacturers to maximize the efficiency improvements and emissions reductions across all models.

10%

improvement in fuel efficiency since China adopted standards in 2005



barrels of oil wasted by stagnating U.S. fuel efficiency standards, 1985–2010

190K

U.S. jobs could be created to build more-efficient cars by 2020

Expand coverage to all vehicles. Standards should cover medium- and heavy-duty vehicles; tractors, bulldozers, and other off-road vehicles; and two- and three-wheelers, especially in developing countries, where they are widely used. If standards don't cover all vehicle types, manufacturers can evade the rules by marketing unregulated models.

Improve testing techniques and rules. Results from the fuel efficiency test cycle differ substantially from real-world driving. This problem needs to be addressed, especially in those regions where emissions performance standards have been introduced only recently.

Our estimates suggest that vehicle emissions performance standards designed according to these best practices would reduce greenhouse gas emissions from road transportation in the United States, China, and the European Union by almost 40 percent, or more than 850 Mt, in 2030.

Best practices: Fuel and vehicle fees

As explained above, fiscal policies complement vehicle emissions performance standards. Fuel and vehicle fees in particular provide very clear monetary incentives for consumers to drive less and purchase moreefficient models and thus for automakers to improve vehicle efficiency beyond the minimum requirement set by performance standards.

High fuel prices have proved very effective at mitigating CO_2 emissions from passenger cars and trucks, partly because they follow a basic criterion for smart policies:

Set goals and let the market work out the best solutions: By simply providing economic incentives to consumers and manufacturers, fuel and vehicle fees act as a decentralized tool that allows the market to choose the cheapest technologies.

In some regions, however, fiscal policies have failed to send clear market signals because they were set too low and not directly linked to greenhouse gas emissions. The effectiveness of vehicle-pricing policies depends on three factors: the level at which they are set, how they relate to vehicle efficiency, and how much of the market they cover (the more vehicle classes, the better).

Based on an extensive review of the results of existing fuel and vehicle levies, we have identified seven policy best practices:

Base fees on greenhouse gas emissions. Fees based on emissions, such as an assessment per grams of greenhouse gas emissions per kilometer, can be applied across different vehicle technologies and fuel types.

Increase the fee rate annually and predictably. Consistently increased fuel levies exert continued pressure on the market to develop new technology and innovative solutions to reduce emissions.

Cover all vehicles and fuels. Fees that exempt some vehicles or fuels can shift consumer demand to untaxed options and circumvent policy goals.

Send a long-term price signal. Transparent, well-publicized fees provide a clear signal to consumers and allow automakers enough lead time to invest in new technologies.

Combine fees with rebates. When appropriate, such as for vehicle fees, create feebates that offset charges with rebates. The pricing structure should not just penalize high-emissions vehicles with fees but also reward low-emissions models with rebates.

Increase fees on a continual, rather than a stepwise, basis across vehicle classes. Stepwise fees encourage consumers to purchase (and manufacturers to produce) vehicles that only meet the minimum requirements for each class.

Adjust the fee structure to meet revenue targets. Increased fuel and vehicle levies need not translate into higher overall taxes. Vehicle and fuel fees could support development of mass transit or finance research on clean transportation, or they can be returned to consumers by decreasing income or payroll taxes. The pivot point (the point at which rebates become fees) can be adjusted without impairing the effectiveness of a feebate. Each country can adjust the pivot point to reach its own revenue goal: to raise money, invest in incentives or improvements, or be revenue neutral.

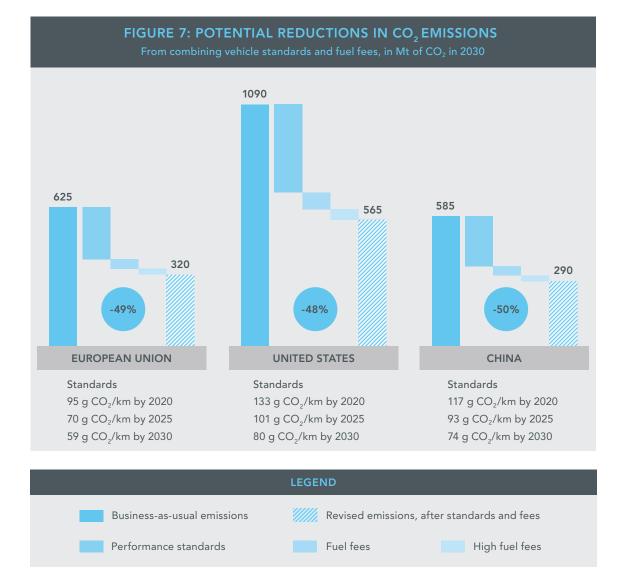
Our analysis estimates that fuel and vehicle fees designed according to these guidelines would reduce greenhouse gas emissions from road transportation in the U.S., China, and the E.U. by more than 250 Mt in 2030.

Best practices: Combine vehicle performance standards with fees

As effective as performance standards and fees are when implemented as stand-alone policies, their complementary nature makes a combination of the two an almost textbook-perfect climate policy. Performance standards increase the fuel efficiency of the fleet, while high fuel and vehicle levies offset the resulting lower cost of driving and encourage consumers and manufacturers to pursue ever more efficient technology options. When implemented together, they reduce greenhouse gas emissions significantly compared with business-as-usual practices.

Based on a conservative projection of the effects of combining stringent vehicle performance standards and high fuel fees, we estimate that the E.U., the U.S., and China could reduce their combined annual CO₂ emissions by more than 1 Gt in 2030; their cumulative reductions from 2010 through 2030 would total almost 10 Gt. That equates to approximately 2.5 billion barrels of oil conserved in 2030, or a cumulative reduction of 23 billion barrels.²¹ At \$100 per barrel, that would be a gross savings of some \$2.3 trillion over 20 years. Depending on the cost of additional investments in efficiency improvements, we estimate the net savings would amount to roughly \$130 billion in 2030 alone and would accumulate to approximately \$800 billion to \$1.5 trillion by 2030.

²¹ U.S. Environmental Protection Agency Greenhouse Gas Equivalencies Calculator.



Source: Data on vehicle sales and kilometers traveled from McKinsey & Co., global greenhouse gas abatement cost curve version 2.1

By continuously tightening vehicle performance standards, nations can greatly reduce CO_2 emissions. (These emissions reductions were discounted by 10 percent to reflect that more-efficient models may encourage an increase in driving. Because fuel levies would counter this effect, those reductions are attributed to higher fuel fees.) The initial fuel fee is set at 10 percent of current fuel prices, equivalent to less than \$0.40/gallon in the U.S. and about 0.15/liter in the E.U. The high fee is set at 25 percent, or about \$1/gallon in the U.S. and 0.40/liter in the E.U. (Every 10 percent increase in fuel fees is estimated to reduce vehicle kilometers traveled by 5 percent.)

A combination of vehicle standards and fuel fees could reduce annual CO_2 emissions in the E.U., the U.S., and China by more than 1 Gt by 2030.

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As shown in Figure 7, these results are calculated based on existing and proposed target standards for each region, continuously tightened by about 4 percent per year, combined with higher fuel fees. These estimates are necessarily based on several assumptions; as with all projections, their accuracy versus real-world results will vary depending on many factors. For instance, because more-efficient vehicles cost less to operate, they can encourage more driving; thus we discounted these emissions reductions by 10 percent. High fuel fees, however, can counteract this effect, so we attributed that 10 percent reduction to higher fees.

Although high fuel fees can be a tough sell politically, especially in the current U.S. landscape, they can be structured as a shift from other less socially beneficial charges such as payroll taxes. By making driving more expensive, they discourage driving and support more-efficient vehicles. We estimate that every 10 percent increase in fuel fees will reduce fuel consumption by about 5 percent; because of differences in household income, fees will likely have less impact in the U.S. but more in China. In addition, the more efficient cars become, the less fuel they need, thus reducing revenue from fuel fees—and lowering the cost to consumers. Raising fuel fees over time moderates these effects.

These results are not limited to these three regions; nations worldwide can enjoy similar, substantial climate and economic benefits.

By combining performance standards with fees, Japan has kept levies lower than in Europe and still achieved the world's most fuel efficient vehicle fleet.

Accelerating smart vehicle standards and fuel fees

Designing effective policies that cost-effectively reduce emissions from motor vehicles requires extensive technical experience, knowledge of international results, sound economic analysis, and a deep understanding of local conditions. Badly designed transportation policies cost money, produce unintended results, fail to capture opportunities to trim emissions, and require further political effort to reform them. The United States, for example, designed its fuel economy standards for cars so that they plateaued 10 years after they were implemented—and then got stuck there for another 25 years, wasting vast amounts of oil and cash.

These challenges can and must be overcome, however. By following the best practices outlined in this report, government leaders can accelerate the design, adoption, and enforcement of the most important vehicle policies. To summarize:

- Emissions performance standards are key because they increase efficiency without dictating a specific technology solution.
- Fuel and vehicle fees complement performance standards and can align market forces with social benefits.
- Long-term policies are crucial to provide manufacturers and investors the reliable signals they need to boost R&D, deploy new technologies, and transform the market.

The potential benefits of adopting these policy best practices are impressive. Our conservative analysis shows that effective vehicle emissions performance standards, coordinated with revenue-neutral fuel levies, could reduce CO_2 emissions from the U.S., China, and the E.U. by more than 1 Gt in 2030—and at a net savings of roughly \$130 billion in 2030, or a cumulative savings of approximately \$800 billion to \$1.5 trillion by 2030. These policies can also reduce pollution, improve public health, enhance national security, and foster investment and job creation. The world cannot afford to wait to reap these climate and economic benefits.

The ClimateWorks Network

Regional Climate Foundations

The **China Sustainable Energy Program** (CSEP) supports China's transition to a sustainable energy future by promoting energy efficiency and renewable energy.

The **Climate and Land Use Alliance** (CLUA)—a collaborative initiative of the ClimateWorks, David and Lucile Packard, Ford, and Gordon and Betty Moore Foundations—works in Indonesia and Brazil to support the potential of forests and other land to provide climate, socioeconomic, and ecological benefits.

The **Energy Foundation** works in the United States to advance new energy technologies that enable economic growth with far less pollution.

The European Climate Foundation (ECF) promotes climate and energy policies that greatly reduce Europe's greenhouse gas emissions and helps Europe play an even stronger international leadership role in mitigating climate change.

ClimateWorks' Latin America Program works with the William and Flora Hewlett Foundation and others to provide analytical support for sector-specific policies that grow Latin American economies while reducing greenhouse gas emissions.

The Shakti Sustainable Energy Foundation

(Shakti) is helping to build a secure future for India's citizens by supporting policies that promote energy efficiency, sustainable transportation, and renewable energy.

Best Practice Networks

The **Collaborative Labeling and Appliance Standards Program** (CLASP) promotes appliance energy standards and labels that save consumers money, reduce power demand, and lower greenhouse gas emissions.

The **Global Buildings Performance Network** (GBPN) focuses on the design, implementation, and enforcement of building codes for new buildings, as well as retrofits of existing buildings.

The Institute for Industrial Productivity (IIP) provides analytical and research support for policies that reduce carbon emissions from industrial practices and improve companies' productivity.

The Institute for Transportation and Development Policy (ITDP) promotes sustainable, equitable transportation policies that offer alternatives to driving, reduce local air pollution, and limit carbon emissions.

The International Council on Clean Transportation (ICCT) provides regulators unbiased technical support, research, and analysis to improve the environmental performance and efficiency of vehicles and fuels.

The Regulatory Assistance Project

(RAP) focuses on the long-term economic and environmental sustainability of the power sector; its global experts provide technical and policy assistance to government officials on a broad range of energyrelated issues.

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The ClimateWorks Foundation supports public policies that prevent dangerous climate change and promote global prosperity.

ClimateWorks' goal is to limit annual global greenhouse gas emissions to 44 billion metric tons by the year 2020 (25 percent below business-as-usual projections) and 35 billion metric tons by 2030 (50 percent below projections).

These ambitious targets require the immediate and widespread adoption of smart energy and land use policies. ClimateWorks partners with an international network of affiliated organizations—the ClimateWorks Network—to promote these policies in the regions and sectors responsible for most greenhouse gas emissions.





