POLICY BRIEF

Electric Vehicle Benefits and Costs in the United States

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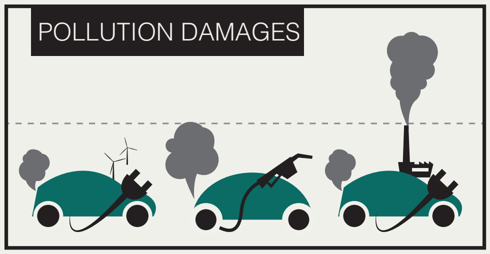
The US imports 5 million barrels of oil per day. Transportation accounts for 70%.

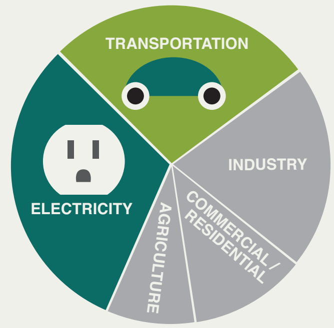
source: eia.gov

source: [1]



Each vehicle's air pollution causes thousands of dollars of damages to human health and the environment. Plug-in vehicles could increase or decrease air pollution damages, depending on the electricity source.

Transportation and electricity generation account for ~ 60% of greenhouse gas emissions in the U.S.



source: epa.gov

Motivations for vehicle electrification

Energy Security: Reduce our dependency on foreign oil.

Air Quality: Reduce air pollution and its effects on human health and the environment.

Climate Change: Reduce greenhouse gas emissions to slow climate change.

Economics: Reduce cost of driving, use local energy sources, and lead new technology innovation.

Electrification helps achieve these goals sometimes, but not always.

Benefits vary based on...

Vehicle Type

A typical gasoline vehicle may generate around $4,000 of costs to society over its life, in the form of human health costs, environmental damages, and other air pollution costs.

A hybrid electric (HEV) or plug-in hybrid electric (PHEV) vehicle could lower these costs by 15-30%, depending on the electricity source.

A pure battery electric vehicle (BEV) could either cut these costs in half or double them, depending on the electricity source.

HEVs and PHEVs tend to offer more air emissions and oil displacement benefits per dollar spent than pure BEVs with comparable range.[1]

Vehicle Electrification Comparison

Plug-in Electric Vehicles (PEVs): PHEV, BEV

increasing electrification →

		CV *Conventional*	HEV *Hybrid Electric*	PHEV *Plug-in Hybrid Electric*	BEV *Battery Electric*
DRIVETRAIN	battery	-	SMALL	MEDIUM	LARGE
	power converter	ENGINE	ENGINE & MOTOR	ENGINE & MOTOR	MOTOR
SOURCE	electricity	-	-	Y	Y
	gasoline	Y	Y	Y	-

Benefits vary based on...

How you drive

In stop-and-go city driving, HEVs and PEVs could cut greenhouse gas emissions in half while lowering lifetime costs. But for highway cruising, the same vehicles can cost more with marginal environmental benefit.[2,7]

Your climate

PEVs consume an average of 15% more electricity in extreme weather regions than on the balmy west coast. On the coldest or hottest days, PEV range can drop by 40% or more.[3,7]

How your electricity is generated

Charging in the northern Midwest can produce two to three times as much carbon dioxide as the same vehicle charged on the West Coast.

While an electric Nissan Leaf produces fewer greenhouse gas emissions than the gasoline Toyota Prius in the western U.S., the opposite is true in the coal-heavy northern Midwest.[4,7,8]

What time you charge

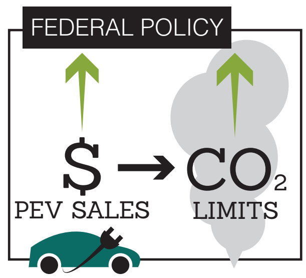
In places like Chicago, Washington, D.C., and Philadelphia, less expensive coal-fired power plants are available at night.

As a result, charging vehicles at night can lower electricity generation costs by 1/4 to 1/3, but the resulting emissions produce health costs that exceed any savings. This could change in a future with sufficient coal retirement and wind power.[5,8]

Fuel economy policy

Federal fuel economy standards allow automakers that sell PEVs to meet less-stringent fleet fuel efficiency standards through 2025. So, when one consumer opts for a PEV it allows other consumers to purchase higher-emitting vehicles, and net U.S. emissions and gasoline consumption increase.

Each time a PEV is sold in the United States, net vehicle fleet greenhouse gas emissions increase by up to 60 metric tons of CO_2, and U.S. gasoline consumption increases by up to 6,700 gallons.[6]



Implications

To achieve the best outcomes today, PEV adoption should typically be focused on HEVs and PHEVs by city drivers in mild-climate regions with a clean electricity grid, such as San Francisco or Los Angeles. And drivers should not be encouraged to charge at night in coal-heavy regions. However, because of federal fuel economy policy, even in the best scenario U.S. PEV adoption may result in increased emissions and gasoline consumption – at least through 2025.

The hope is that in the long run – as the electric power grid becomes cleaner, as electric vehicles become cheaper and faster to recharge with longer range, and as policies adjust – that electrification will offer benefits across the board. Electric vehicle technology is one of the few options capable of providing personal transportation with near-zero emission energy sources.

To achieve energy security, air quality, climate change and economic goals, policies that target these goals directly, rather favoring specific technologies, have the potential to be more efficient in managing the types of variations described here, while avoiding unintended consequences.

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[1] Michalek, J.J., M. Chester, P. Jaramillo, C. Samaras, C.S. Shiau, and L. Lave (2011) "Valuation of plug-in vehicle life cycle air emissions and oil displacement benefits" *Proceedings of the National Academy of Sciences*, v108 n40 p16554-16558.

[2] Karabasoglu, O. and J.J. Michalek (2013) "Influence of driving patterns on lifetime cost and life cycle emissions of hybrid and plug-in electric vehicle powertrains," *Energy Policy*, v60 p445-461.

[3] Yuksel, T. and J.J. Michalek (2015) "Effects of regional temperature on electric vehicle efficiency, range, and emissions in the United States," *Environmental Science & Technology*, v49 n6 p3974-3980.

[4] Tamayao, M., J.J. Michalek, C. Hendrickson and I. Azevedo (2015) "Regional variability and uncertainty of electric vehicle life cycle CO2 emissions across the United States," *Environmental Science & Technology*, v49 n14 p8844-8855.

[5] Weis, A., J.J Michalek, P. Jaramillo and R. Lueken (2015) "Emissions and cost implications of controlled electric vehicle charging in the US PJM interconnection," *Environmental Science & Technology* v49 n9 p5813-5819.

[6] Jenn, A., I.L. Azevedo and J.J. Michalek (2016) "Alternative fuel vehicle adoption increases fleet gasoline consumption and greenhouse gas emissions under United States corporate average fuel economy policy and greenhouse gas emissions standards," *Environmental Science & Technology*, v50 n5 p.2165-2174.

[7] Yuksel, T., M. Tamayao, C. Hendrickson, I. Azevedo and J.J. Michalek (2016) "Effect of regional grid mix, driving patterns and climate on the comparative carbon footprint of electric and gasoline vehicles," *Environmental Research Letters*, v11 n4 044007.

[8] Weis, A., P. Jaramillo and J.J. Michalek (2016) "Consequential life cycle air emissions externalities for plug-in electric vehicles in the PJM interconnection," *Environmental Research Letters*, v11 n2 024009.

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