Published on *Pew Center on Global Climate Change* (http://www.pewclimate.org)

Understanding GHG Emissions from Plug-In Electric Vehicles

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Created *07/23/2010 - 09:09*

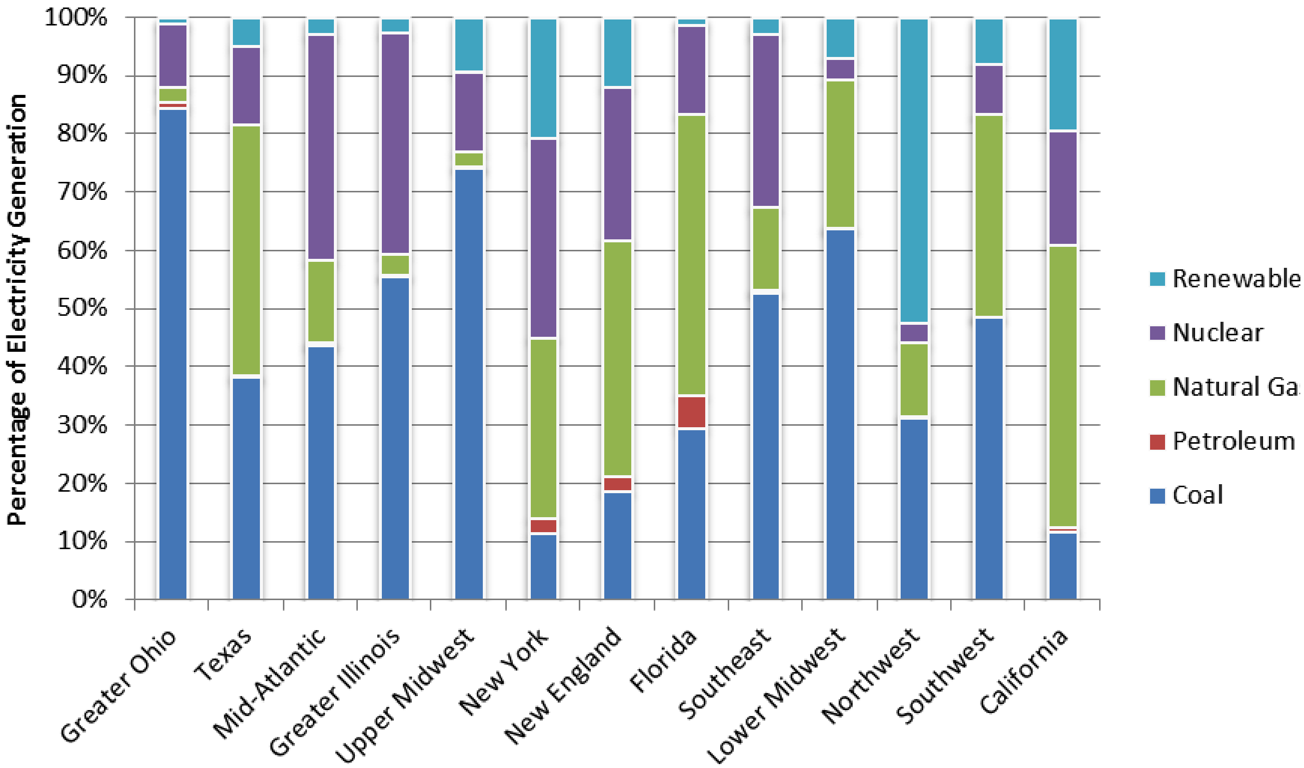
A hot topic in environmental circles lately has been the impact plug-in electric vehicles (PEVs) will have on reducing greenhouse gas (GHG) emissions. Some [1] are optimistic about PEVs' emission reduction potential, while others [2] are pessimistic. The truth is, not surprisingly, somewhere in between. In order to reduce emissions from the transportation sector, we must both move to low carbon fuels (including electricity, which has zero GHG emissions from the tailpipe) *and* reduce the carbon intensity of the electrical grid.

Abbreviation	**Definition**
Conventional Vehicle	Internal combustion engine vehicle fueled by gasoline
HEV	Hybrid Electric Vehicle; vehicle with both an internal combustion engine and an electric propulsion system
EV	Electric Vehicle; electric propulsion vehicle powered by a battery
PHEV-XX	Plug-in Hybrid Electric Vehicle where XX is the maximum amount of miles that can be driven on battery power; the remainder of miles are driven using an internal combustion engine fueled by gasoline
PEV	Plug-in Electric Vehicle; includes both PHEVs and EVs

To understand the impact of PEVs on the environment compared to alternatives, we have to consider the lifecycle GHG emissions from these vehicles. This kind of lifecycle analysis is commonly referred to as well-to-wheels emissions, and for PEVs that means we must consider the electricity generation source.

The figure below shows a breakdown of electricity generation by the 13 regions defined by the North American Electric Reliability Corporation (NERC) [3], a non-profit company set up by the utility industry to ensure the reliability of the bulk power system in North America. As you can see, the mix of sources of electricity varies greatly depending on the region and these differences influence the GHG emission from PEVs.

Figure 1: Electricity generation in by electricity market module in 2008 (ignore pumped storage generation for simplification)



[4]

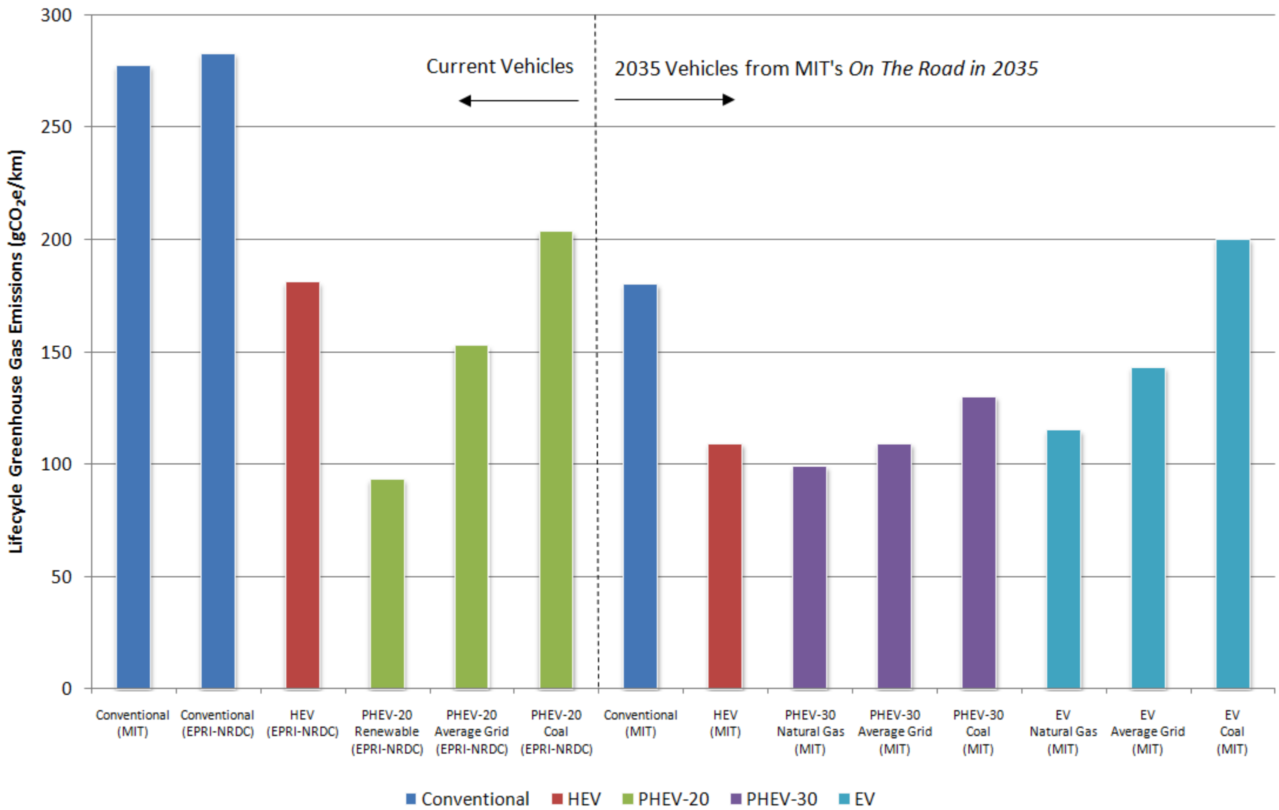
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2010*, 2010, http://www.eia.doe.gov/oiaf/aeo [5].

It is important to understand that the environmental benefit of using PEVs is not simply a function of which region has the highest amount of low-carbon electricity generation. The factor most important is *which* generation source is used to charge these new sources of demand for electricity. In particular, vehicles charged at night may have to rely on existing coal power in some regions since turning the units off and on (cycling) creates a lot of excess GHG emissions. It is therefore critical that electric grid management be optimized to allow for cleaner sources of energy to meet this new demand whenever possible. Since this optimization may not be the lowest cost with today's prices, public policy should play a role in leveling the playing field for cleaner sources of energy including correcting the price of traditional generation sources to account for harmful GHG emissions.

The environmental benefit also depends on the performance of PEVs versus conventional vehicles, and how much competing vehicles improve over time. Complex models of PEV usage and electricity generation management can assist in determining the impact on lifecycle GHG emissions from these vehicles compared to other vehicles. The figure below conveys the results of two studies that aimed to do just that. As you can see, the advantage of PEVs over conventional vehicles depends on the fuel efficiency of the conventional vehicle as well as the carbon intensity of the grid. In fact, in the future, improved conventional gasoline-powered vehicles could have lower lifecycle GHG emissions than PEVs if the electrical grid remains unchanged. So while a PEV when operated in all-electric mode will emit zero GHG emissions from the tailpipe, the lifecycle emissions of the vehicle are likely non-zero even out into the future.

The deployment of PEVs nationwide will not be instantaneous and may not seriously reduce GHG emissions from the transportation sector unless the electrical grid is decarbonized. Switching to electricity will certainly reduce oil consumption and thereby enhance national security, but it will not necessarily reduce GHG emissions to mitigate the impacts from climate change.

Figure 2: Lifecycle GHG emissions from various vehicles



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Source: Bandivadekar, Anup, et al. *On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG Emissions* [7]. Cambridge: Massachusetts Institute of Technology, 2008. Electric Power Research Institute. *Environmental Assessment of Plug-In Hybrid Electric Vehicles* [8]. Palo Alto: National Resource Defense Council, 2007.

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