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Getting the Most Out of Electric Vehicle Subsidies

The electrification of passenger vehicles has the potential to address three of the most critical challenges of our time: Plug-in vehicles may produce fewer greenhouse gas emissions when powered by electricity instead of gasoline, depending on the electricity source; reduce and displace tailpipe emissions, which affect people and the environment; and reduce gasoline consumption, helping to diminish dependence on imported oil and diversify transportation energy sources.

Several electrification technologies exist for helping to achieve these goals. Hybrid electric vehicles (HEVs), such as the Toyota Prius and the Ford Fusion Hybrid, don't plug in. They still use gasoline for net propulsion energy, but they also use an electric motor and a small battery pack to improve fuel efficiency.

Plug-in hybrid electric vehicles (PHEVs), such as the GM Volt, charge an onboard battery via a wall outlet. They use electricity for propulsion when the battery is charged but also have a gasoline engine for use when the battery is depleted. Larger PHEV batteries enable longer electric travel between charges. The PHEV version of the Prius has an 11-mile battery pack; the GM Volt has a 35-mile battery pack.

Battery electric vehicles (BEVs), such as the Nissan Leaf, plug in to charge an onboard battery. They have no gasoline backup, so they require large battery packs to enable longer trips, and they require higher-power charging equipment to refill the battery overnight. The Nissan Leaf has a 73-mile battery pack; the Ford Focus Electric has a 76-mile battery pack.

Current federal policy intended to encourage the development and deployment of plug-in vehicles includes tax subsidies established in the 2009 American Recovery and Reinvestment Act of up to $7,500 per vehicle. Some members of Congress have proposed extending this tax credit, others have proposed eliminating it, and President Obama proposed increasing the credit to $10,000 to help meet his administration's target of one million plug-in vehicles on the road by 2015. Both existing and proposed subsidies provide larger payments for vehicles with larger battery packs.

Larger battery packs enable vehicles to displace more gasoline, so at first glance one might think that subsidizing larger battery packs is better for the environment and for oil security. But large battery packs are also expensive; the added weight reduces efficiency; they are underused when the battery capacity is larger than needed for a typical trip; they have greater charging infrastructure requirements; and they produce more emissions during manufacturing. Whether larger battery packs offer more benefits on balance depends on their net impacts from cradle to grave.

Running the numbers

Using ranges of values from the academic literature and government studies, it is possible to quantify lifetime externality costs, including greenhouse gases, human health effects, agricultural losses, and infrastructure degradation, caused by air emissions from conventional and electrified vehicles. Many of these damages vary with the location of air-emission releases, so it is important to account for the existing and

potential future locations of vehicle tailpipes, power plants, oil refineries, vehicle and battery production facilities, and upstream supply chain entities, such as mines for raw material extraction. It is also possible to estimate the extra U.S. costs of oil consumption beyond the market price paid, including increased vulnerability to oil supply disruptions, increases in world oil prices due to U.S. demand, and military spending related to oil security.

If we add up all of these costs, which we did in a study published in 2012 in the *Proceedings of the National Academy of Sciences*, we find thousands of dollars of damages per vehicle (gasoline or electric) that are paid by the overall population rather than only by those releasing the emissions and consuming the oil. These costs are substantial. But, importantly, the potential of plug-in vehicles to reduce these costs is modest: much lower than the $7,500 tax credit and small compared to ownership costs. This is because the damages caused over the life cycle of a vehicle are caused not only by gasoline consumption, which is reduced with plug-in vehicles, but also by emissions from battery and electricity production, which are increased with plug-in vehicles.

Today's policies provide larger subsidies for vehicles with larger battery packs, but those large battery packs do not generally offer more benefits, even in optimistic scenarios. For example, as a base case assume that the battery will last the life of the vehicle and take average U.S. estimates for electricity production, oil refining, vehicle and battery production, driving location, upstream supply chain emissions, and greenhouse gas emission costs. In this case, HEVs and PHEVs with small battery packs cause lower damages than conventional gasoline vehicles, but BEVs with large battery packs actually increase net damages. In an optimistic scenario where plug-in vehicles receive all of their charging electricity from zero-emission sources, the lifetime benefits of plug-in vehicles exceeds the benefits of HEVs by about $1,000. In contrast, if plug-in vehicles are charged using coal-generated electricity, they could cause several thousands of dollars more damage per vehicle.

HEVs, PHEVs, and BEVs are all expected to provide some benefits over conventional vehicles on average, but those benefits do not necessarily increase with battery size, and even in the most optimistic scenarios the large subsidies for vehicles with large battery packs are not justified by their air-emission and oil-displacement potential.

Policy adjustment

Under current federal policy, plug-in vehicles with battery packs at least as large as the Chevy Volt's [16 kilowatt-hours (kWh), providing about 35 electric miles per charge] receive the full $7,500 tax credit, while vehicles with smaller battery packs, such as the Toyota Prius Plug-in Hybrid (4.4 kWh, providing about 11 electric miles per charge) receive only $2,500. At first glance, tripling the subsidy may seem justified because the electric range is tripled. But tripling the range does not mean tripling the amount of gasoline displaced or emissions reduced: Increasing battery size has diminishing returns. In fact, when we consider U.S. driving patterns (many short trips, where the larger battery is only dead weight), U.S. average emissions from battery and electricity production, and the other factors described above, the small 4.4-kWh battery actually has more net benefits than the larger 16-kWh battery. Even in the most optimistic scenarios where vehicles are charged with zero-emission electricity, the larger battery packs offer only comparable or slightly greater net benefits, not double or triple. Public funds are limited, and because today's policy consumes more resources when subsidizing large-battery vehicles, fewer of them can be supported under a fixed budget. Allocating a fixed budget to a flat $2,500 subsidy for all plug-in vehicles would more than triple the potential air-emissions and oil-displacement benefits of the subsidized vehicles as compared to subsidizing one-third as many large-battery vehicles at $7,500 each.

It is important to note that in the future, plug-in vehicles with large battery packs might be able to offer the largest benefits at the lowest costs if all the right factors fall into place, including low-cost batteries, low-emissions electricity, long battery life, and high gasoline prices. Policies supporting R&D for battery improvements and large emissions reductions from electricity generation can help move the country in this direction. But such a future may take decades to realize and is not guaranteed because of uncertain technical, economic, and political factors. In the near term, HEVs and PHEVs with small battery packs are more robust, offering more air-emission and oil-displacement benefits per dollar spent. And although some characteristics of longer-range batteries are different, the production of small-battery vehicles in the near term will create demand for batteries that will help drive learning and innovation to lower the costs of all electrified vehicles.

There are myriad other arguments for supporting vehicle electrification beyond human health, environmental, and oil-displacement effects. This long list might include job creation, reducing the trade deficit by shifting from foreign to domestic fuel sources, enabling a distributed storage resource to support the integration of intermittent renewable electricity generation, reducing oil revenues to states hostile to U.S. interests, hedging against an anticipated oil-scarce or car-

bon-constrained future, improving regulatory control over emissions associated with poor vehicle maintenance, generating positive externalities by encouraging innovation, encouraging domestic development of strategic technical competency and intellectual property, reducing nonfinancial political and human suffering effects from war and political instability, and promoting international environmental justice. However, because HEVs and PHEVs with smaller battery packs provide more air-emissions reduction and oil displacement per dollar spent and offer lifetime costs competitive with conventional vehicles, it is not clear that directing near-term subsidies toward vehicles with large battery packs would produce superior results on any of these objectives.

We should not forget that the most efficient policies would target externalities directly, through mechanisms such as an economywide carbon price, cap-and-trade policies, and gasoline taxes. Such policies are generally understood to be far more efficient than technology-specific subsidies, and we should consider subsidies as an inferior substitute given the political difficulties of implementing efficient market-based policies that address the problem directly. In the absence of such policies, federal subsidies and policies designed to encourage electrified vehicle adoption would produce more benefit at lower cost for the foreseeable future by targeting the purchase of vehicles with small battery packs.

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CHRISTOPHER WILSON

U.S. Competitiveness: The Mexican Connection

A "giant sucking sound" was the memorable description made by presidential candidate Ross Perot during the 1992 campaign of the impact that the North American Free Trade Agreement (NAFTA) would have, as business and jobs moved from the United States to Mexico. The reality is that economic cooperation with Mexico has been a boon for U.S. industry and has strengthened the country's competitive position in ways that have produced broad economic benefits. Today, as China and other Asian countries have emerged as major economic challengers, expanding economic cooperation with Mexico is one of the best ways for the United States to improve its global competitiveness.

Regional integration between the United States and Mexico is already vast and deep. As the United States' second largest export market and third largest trading partner, Mexico is clearly important to the U.S. economy. Merchandise trade has more than quintupled since NAFTA went into effect in 1994, and in 2011, bilateral goods and services trade reached approximately a half-trillion dollars for the first time. The U.S. Chamber of Commerce has calculated that the jobs of six million American workers depend on U.S.-Mexico trade. Many of those jobs are in border states, which have especially close ties to Mexico, but Mexico is also the top buyer of exports from states as far away as New Hampshire (mostly computers and electronics). In fact, 20 states, from Michigan to Florida, sell more than a billion dollars' worth of goods to Mexico each year, and Mexico is the first or second most important export market for 21 states.

The United States and Mexico are also major investors in one another. In fact, combined foreign direct investment holdings now total more than $100 billion. According to the most recent count by the Department of Commerce, U.S.-owned companies operating in Mexico created $25 billion in value added and employed nearly a million workers. Mexican investment in the United States is less than U.S. investment in Mexico, but it is has been growing rapidly in recent years. Several of Mexico's top companies, which