Electrification Coalition

Analysis

Analysis: Valuation of plug-in vehicle life-cycle air emissions and oil displacement benefits

SUMMARY

The October 4 edition of the Proceedings of the National Academies of Science contained a detailed analysis of the lifecycle economic costs of various automotive drivetrain technologies. The article, entitled "Valuation of plug-in vehicle life-cycle air emissions and oil displacement benefits" was submitted by researchers from Carnegie Mellon University, Arizona State University, and the RAND Corporation. The article has received notable coverage in digital media for its conclusion that:

> "[P]lug-in vehicles with large battery packs may either reduce or create more life-cycle damages than [hybrid electric vehicles] depending largely on [greenhouse gas] and SO_2 emissions from electricity and battery production. But even if future marginal electricity production and battery manufacturing processes have substantially lower emissions than today's averages, the emission damage and oil premium reduction potential of plug-in vehicles is small compared to ownership cost…"

More generally, the study finds that the oil savings and emissions reduction potential of electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) with large batteries (for example, batteries that provide roughly 40 miles of charge depleting range) do not justify the lifecycle ownership cost premium when compared to efficient internal combustion vehicles (CVs), hybrid electric vehicles (HEVs) or PHEVs with smaller battery packs. This conclusion, if true, could have important implications for public policy in the United States and elsewhere as national leaders work to address energy security and environmental issues associated with oil consumption in the transportation sector.

However, there are a number of assumptions and other characteristics of the study's approach that should raise questions about its conclusions. In some cases, there may simply be differences in opinion regarding the appropriate way to measure costs and to determine which costs should be attributable to various technologies. In other cases, some of the authors' assumptions depart significantly from other research published by respected experts.

ASSUMPTIONS

Battery Cost and Capacity: In any assessment of the cost-effectiveness of plug-in electric vehicles, assumptions about battery prices will play a large role in determining outcomes. This particular analysis assumes the lithium-ion battery powering an EV-240 (kilometers) will cost nearly $32,000 in 2015. In referring to the authors' supporting materials, it appears that the battery cost assumed in this analysis is $450 per kWh for an EV and $500 per kWh for a large-battery PHEV. These estimates of factory-gate pricing seem reasonable. However, at $32,000, they appear to result in an EV-240 battery that is rated at more than 70 kWh. It is not clear why an EV-240 would need such a large battery pack, unless it were a very large, inefficient passenger sedan, a model that may not be competitive as a full EV by 2015.

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Motor Efficiency: For the EV-240, the model's base case assumes an efficiency of 2.73 mi/kWh; however, the Nissan Leaf – the very first generation of mass market BEV—already achieves far greater than 3.0 mi/kWh with the expectation that subsequent generations of vehicles will improve efficiency.[1]

Charge Depleting Range Usage: The study's model assumes a charge-depleting mode utility factor for PHEV-20s and PHEV-60s to be 28 percent and 47 percent respectively. GM's real world data for the Volt already demonstrates a utility factor of 67 percent after customers' first 2 million miles.[2] Utility factor estimates developed by the Society of Automotive Engineers for use in EPA fuel-economy analyses produced similar figures.

Gasoline Costs: For their base case, the authors simply use the average U.S. retail gasoline price for the period 2008-2010. This appears to be approximately $2.75 per gallon, a price that seems out of line with the general direction of future petroleum prices. Most analysts would readily admit that a $2.75 per gallon gasoline price will make advanced powertrain vehicles uncompetitive. For their optimistic case, the authors use the more reasonable $4.05 per gallon; though a case that purports to be 'aggressive' could certainly reasonably use a much higher price. For example, the Department of Energy's 'High Oil Price Case' assumes $4.27/gallon in 2015.[3]

Battery Production Emissions: To estimate emissions from EV battery production, the study linearly scales HEV battery production emissions by the estimated weight of the larger battery pack—a massive simplification that assumes every unit of production emissions is a variable unit without any fixed components of emissions to the production. Not only is this estimation nonsensical from a technical point of view, but it also means that the study assumes that as the battery packs get larger, incidentals such as the lights in the factory and the number of times the vacuum cleaner is run scale linearly.

Charging Equipment Costs: The authors assume the equipment and installation costs of a home charger average $2,400. The charging equipment including installation for the Ford Focus BEV will be sold at Best Buy for an average of $1,499and Nissan has announced aggressive price targets for future versions of charging equipment. [4, 5]

SCENARIO DEFINITION

In reporting on the output of the model, the study presents the case in a way that obscures some very important insights on how best to mitigate emissions in transportation. The summary views in the journal article are construed in a way that arguably misses the real emissions reduction opportunities offered by the different propulsion technologies.

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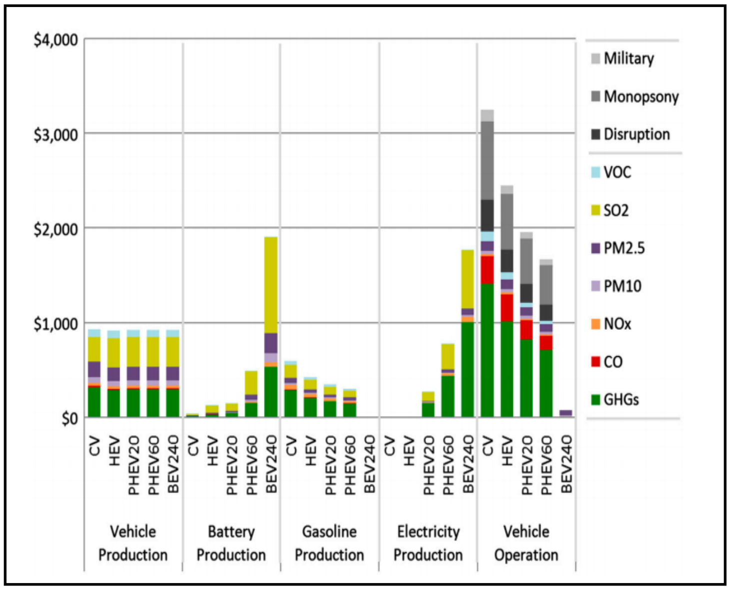
1 Nick Bunkley, "Nissan Says Its Electric Leaf Gets Equivalent of 99 M.P.G," New York Times, November 22, 2010
2 Nauman Farooq, "Chevy Volt Owners Clock 2 Million Miles, Two-Thirds on Electric Power," Auto Guide November 7, 2011
3 U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2011*, Table A.12
4 Nick Chambers, "Best Buy to provide Ford Focus electric charging stations at lower prices than competition," Plug-in Cars.com, January 7, 2011
5 Eric Loveday, "Nissan looks to corner quick-charge industry with half-price unit," AutoBlog Green, September 28, 2011

As demonstrated in the study's own Figure S5 shown at right, battery electric vehicles demonstrate far superior performance in reducing emissions in all 'fixed' categories of emissions production, such as Vehicle Production, Gasoline Production, and Vehicle Operation where there is little opportunity to change the emissions levels associated with any of the different propulsions' emission levels.



Where EVs struggle are areas where there is ample opportunity to affect change, most notably Electricity Production. In their own words, the study's authors provide important insight on the best means for addressing emissions and challenges related to EVs:

> "EVs have the potential to offer the greatest reductions in emissions and oil consumption at competitive cost if air emissions from electricity generation are substantially reduced, battery prices drop dramatically, gasoline prices rise, high-power charging infrastructure is sufficiently deployed, and battery life is increased beyond vehicle life."

These are arguably the exact goals of current public policy in the United States—and elsewhere—as it relates to plug-in electric vehicles.

MARKET DYNAMICS

In their Optimistic Scenario, the authors acknowledge that market forces under their defined optimistic conditions would drive adoption were they to materialize. However their defined Optimistic Scenario is a scenario that will almost certainly eventually materialize, and the purpose of policy to support plug-in electric vehicles is to hasten the conditions needed for commercialization in the United States. Without these incentives, such a scenario will arrive quicker in high fuel cost countries (Europe) and those with aggressive policy support (China). A late response domestically will diminish U.S. competitiveness.

The authors acknowledge that their Optimistic Scenario does demonstrate superior performance for battery electric vehicles in all of their critical criteria:

> "Although large battery packs offer the largest emissions and oil consumption reductions at lowest cost in the most optimistic scenarios, they result in high costs and increased damages if not all of the right factors fall into place, including high gasoline prices and achievement of low battery costs, long battery life, and low electricity production emissions."

The "right factors" that their Optimistic Scenario requires are arguably quite feasible, and the public policy instituted to date has tried to hasten the advent of those factors which the government can reasonably affect. (Out of their list, the only factor the U.S. has not addressed through policy is encouraging higher gasoline prices.)

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Additionally, the purely academic nature of this exercise is divorced from market realities regarding marginal usage versus capacity requirements. One of the author's strongest arguments is that HEVs and small-battery PHEVs are more optimal because of the higher utilization of their expensive batteries. This may seem true from a purely mathematical model point of view. However, it is roughly equivalent to arguing that all families should buy compact cars since 90 percent of their trips are with one or two people and their mini-vans—which use their entire cargo capacity only 10 percent of the time—are wasteful since compact cars "with small [cargo space] offer more [cargo] benefits per dollar spent." Relying on only the actual utilization as a metric for overall utility ignores the required capacity for consumer acceptance as a key driver of utility.

OIL PREMIUM

The authors calculate an oil premium that should be added to the market price of gasoline when calculating the cost-effectiveness of plug-in vehicles as compared to gasoline vehicles. Their premium includes the cost of externalities (oil security and dislocation costs) and a monopsony premium, which reflects the extent to which oil prices include a component that accounts for the United States' large share of the oil market. The authors decided, however, not to include costs imposed on the U.S. economy as a result of dependence on a market dominated by a group of suppliers engaging in anti-competitive behavior, making the market more akin to a monopolized (or partially-monopolized) market than a competitive one. In doing so, they noted that "[t]hese costs . . . are not externality costs and are not likely to be substantially changed by marginal changes in US consumption."

That, however, could be said about many of the costs associated with oil consumption. For instance, reducing U.S. oil demand by five percent is unlikely to reduce the security premium at all. Our economy bears a heavy burden because we are so dependent on a large non-competitive oil market, which makes us particularly vulnerable to high and volatile oil costs. A more complete analysis should have accounted for the immense costs imposed on our economy as a result of OPEC's exercise of monopoly power in world oil markets.