

Eight Reasons

Why Electric Cars Will Make Investment Sense

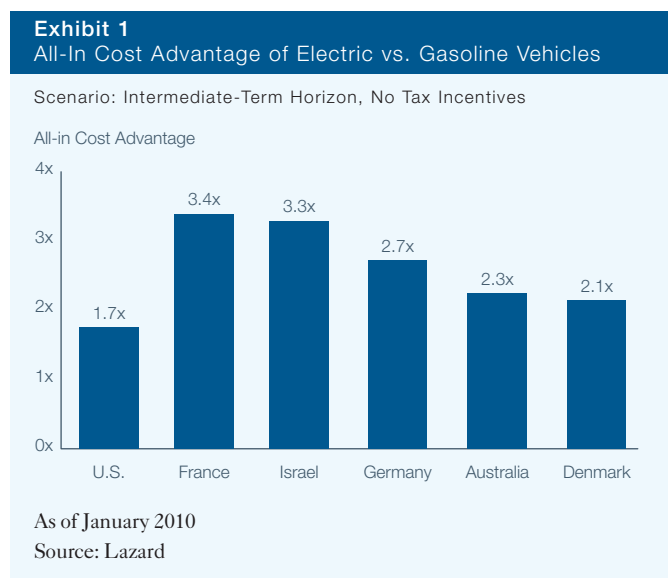
H. Peter Nesvold, CFA, CPA, Esq., Senior Vice President, Research Analyst

Electrified vehicles—or “EVs”¹—are no longer the stuff of science fiction. Electrification of the automotive industry—while clearly still nascent and still subject to many uncertainties—is a potentially significant investment theme globally for the next decade and beyond. Even more, we believe that the deployment of EVs on a commercial scale will likely begin to ramp up in selected markets over the next five years.

A confluence of economic, public policy, technological, and environmental forces are converging to power this trend forward. While we anticipate that EV adoption in the United States will lag, we believe that multiple countries, led by Israel and Denmark, will reach critical mass faster than conventional thinking reflects. The potential investment ramifications of these intriguing developments are both deep and global.

This paper outlines why we believe EVs will make investment sense. Some of our conclusions are:

- **EVs will have an increasingly material cost advantage to gasoline-powered vehicles, as battery technology shows step-change improvements.** Battery production costs are dropping sharply, while vehicle range is increasing quickly. By 2015-2016, we estimate that the fully amortized operating cost of an EV in the United States will be equivalent to approximately \$1.75 per-gallon gasoline—before tax incentives. Even more, EVs’ cost advantage will likely only widen over time, as battery costs and functionality improve while gasoline prices increase.
- **The financial case for EVs will be even more compelling to consumers in international markets, where gasoline prices are commonly twice as high as those in the United States.** Exhibit 1 illustrates the all-in cost advantage of electric versus gasoline vehicles in a half-dozen different countries.



- **Generally, electricity prices are materially more stable than oil prices,** with average annual price volatility of 2% for electricity compared to 21% for oil. With some \$395 billion spent annually in the United States alone on gasoline (assuming \$3 per gallon), such volatility in oil prices exacerbates macroeconomic shocks. In fact, every U.S. recession has been preceded by—or has occurred concurrent with—an oil price shock.
- **EVs are the key ingredient for energy independence...** Light-duty automobiles represent 40% of annual U.S. oil consumption—an apportionment that single-handedly rep-

resents 25% of the U.S. trade deficit. Electricity draws upon a diverse portfolio of largely domestic fuels, and leverages a ubiquitous infrastructure. What’s more, the existing U.S. grid has sufficient excess capacity to handle as much as 60% EV penetration. This is because charging will predominately occur at night, enhancing load balancing and potentially even improving utilities’ overall fixed cost absorption.

- **...as well as CO₂ reduction.** Transportation represents 34% of U.S. carbon dioxide (CO₂) emissions, the single largest end-use sectoral emitter. Even assuming a current U.S. fuel mix that is 50% coal, EVs could slash “well-to-wheel” CO₂ emissions by 65%. What’s more, this advantage grows as the electric grid becomes progressively cleaner. EVs could help create a more stable, and thus more profitable, market for renewable energy; substantial charging will occur at night, affording the opportunity to utilize excess wind capacity that otherwise is not monetized.
- **Swappable batteries may materially alter consumers’ perceptions of vehicle range.** As consumers come to understand the swappable battery concept, we believe “range anxiety”—or the concern about where and how long it will take to recharge—will ease considerably. We believe such concerns represent the biggest psychological hurdle to adoption in certain geographically dispersed markets, such as the United States.
- **EVs can be fun to drive.** The perception of an EV as a plastic “golf cart” are misplaced, in our view. Compared to many gasoline vehicles, EV models launching over the next several years incorporate faster and smoother acceleration, better handling, less noise, and lower servicing costs—“seeing will be believing.”
- **Government financial support is building globally.** Already-enacted tax incentives will only further improve the financial picture painted above. In Denmark, for instance, EVs are exempt from a vehicle registration fee that taxes gasoline cars at a marginal rate of as much as 180%. Similarly, in Israel, zero-emissions vehicles are taxed at 10%, while gasoline-powered cars are taxed at 92%. In the United States, the government is administering a \$25 billion program to develop EVs and improve batteries, among other advanced technologies. In addition, the new U.S. fuel economy regulations contain material incentives for original equipment manufacturers (OEMs) to produce EVs.

Still, many additional issues remain. We plan to address additional prospective questions and forward-looking scenarios in future research on this topic.

Introduction

Suppose someone offered to sell you a gallon of gasoline for \$3—would you accept? “That depends,” you might reply:

- **“Where are oil prices at this particular moment?”** Are they \$36 per barrel as in December 2008, or are they \$147 as in July 2007? (“They change minute to minute!”)
- **“What country am I in?”** That \$3 offer might potentially be attractive in the United States (depending on those minute-to-minute oil prices). But it would most certainly be compelling in Europe (regardless of oil prices), where gas prices can sometimes reach as high as \$8 per gallon.
- **“How desperately do I need it?”** If you had just climbed into your car, late for work, only to discover your son has returned it on empty (again!), you would probably respond with an emphatic, “Yes—and remind me later to take the keys away from the kids.”

Suppose, instead, someone offered to sell you gas for \$2 a gallon. The question most likely would be how much would you buy—not if you would accept. (And your answer would probably be, “As much as would fit in my tank.”)

And, finally, suppose someone offered to sell you all the gas you need at the equivalent of \$1.75 per gallon at a fixed price for the next five years—would you accept? What if the seller offered to stop by to top off your tank whenever you were at home, work, or even the movies? And what if the transaction also involved a car that was actually fun to drive? (Remember those days?) Oh, and then there are these “soft benefits” of improving the environment, slashing the trade deficit by 25%, and nearly eliminating the need for all foreign oil. After double-checking your hearing—why wouldn’t you accept?

As implausible as it might initially sound, this is precisely what electrified vehicles potentially offer—not in 2030, or 2020. Over the next five years, over 100,000 consumers in select markets around the world will likely begin to accept this offer.² EVs are no longer the stuff of science fiction. What’s more, the financial opportunity for EVs has the potential to stand on its own; the social benefits and tax incentives also supporting them are largely incremental.

Electrification of the automotive industry—while clearly still nascent and still subject to many uncertainties—is a potentially significant investment theme globally for the next decade and beyond. A confluence of economic, public policy, technological, and environmental forces are converging to power this trend forward. While we anticipate EV adoption in the United States will lag, we believe that multiple coun-

tries—particularly those countries, such as Israel and Denmark, with commercial launches expected to start in the next 12-24 months—will reach critical mass faster than conventional thinking reflects. These launches are being managed by Better Place, a company with roots in both Silicon Valley and Israel that is rapidly emerging with critical first-mover advantage as the global network operator linking battery makers, auto OEMs, energy companies, consumers, and leasing companies. We believe the emergence of such a network operator has the potential to materially accelerate the adoption cycle for EVs in many markets.

This paper outlines eight reasons why we believe EVs will make investment sense. Future research will address a number of additional prospective questions and forward-looking scenarios. These include:

- What are some of the most common arguments against the potential success of EVs? (Far and away, we believe the greatest concerns converge around driving range, the electrical charging infrastructure, time needed to refuel, and the historical disincentive to be an early adopter ahead of an industry’s declining cost curve.)
- Where do we believe some of the most common arguments may prove wrong?
- Why do we think so-called swappable batteries—a key differentiator in the Better Place model—materially accelerate the prospective adoption cycle compared to fixed batteries?

One final introductory note: By its very nature, we believe that the path to EV adoption will be fluid—developments on the regulatory, technological, and financial fronts can impact the analysis at any given time. As a result, we suggest that readers look at our present and future research as “points in time” perspective.

Why Do EVs Make Sense?

In 2003, the National Academy of Engineering, a division of the National Academy of Sciences, convened to rank the greatest engineering achievements of the 20th century. Petroleum and petroleum technologies finished in the 17th position. The telephone placed 9th. Airplanes? Number 3.

Yes, the nation’s premier group of engineers considered “electrification”—the development of the system of generation, transmission, and distribution of electric power to virtually every corner of the United States—and the automobile to be the number-1 and number-2 greatest engineering achievements of the 20th century, respectively.³

Even still, the technologies behind both of these engineering feats have remained fundamentally unchanged over the past 100 years. Consider a scenario, similar to one recently proffered by the Department of Energy,⁴ in which Alexander Graham Bell, Thomas Edison, and Henry Ford were all somehow transported to the 21st century. Bell would not begin to recognize the components of modern telephony—cell phones, texting, cell towers, PDAs, and so forth—while Edison and Ford, both of whom were early architects of their respective industries, would be completely familiar with today’s electrical grid and internal combustion engine (ICE), respectively. That may begin to change, particularly with respect to the ICE.

The discussion that follows outlines why we believe EVs are nearing a critical inflection point—effectively combining the number-1 and number-2 greatest modern-day engineering achievements—with mass adoption increasingly a viable option due to technological, financial, and public policy developments.

Reason 1 Electric Miles Cost Substantially Less Than Gasoline Miles

Even in markets with relatively low fuel costs, such as the United States, EVs can be as much as 40% to 50% less expensive to drive than gasoline vehicles. This is partly due to the fact that electric motors are highly efficient, converting as much as 90% of the electrical energy content into mechanical energy. Gasoline engines, by contrast, have an efficiency rating in the 25% to 27% range.⁵ (The rest is lost to waste heat.) Of less focus in this paper, but also worth mentioning as further lowering vehicle lifecycle costs, is that an EV drivetrain is likely to require little maintenance due to its simplicity of design (effectively only a single-speed transmission and highly reliable electric motors).

The precise cost-per-mile arbitrage between electric miles and gasoline miles differs based on country. In the United States, as one example, the variable operating cost of the typical light-duty ICE vehicle (with an average fuel economy of 25.3 miles per gallon)⁶ is \$0.12 per mile, assuming gasoline costs \$3 per gallon. (See Exhibit 3 later in this paper.)

In contrast, we estimate intermediate-term (c. 2015-2016) operating costs for an EV of \$0.07 per mile before tax incentives. This cost is comprised of two components:

- First, a battery amortization cost of roughly \$0.04 per mile. Our intermediate-term scenario assumes a battery purchase price of \$12,500 (versus roughly \$23,500 today for a battery with 30 kilowatt-hours (kWh) of capacity), a residual value

Exhibit 2
Estimated Automotive Lithium-Ion Costs Over Time

	2010	2011-12E	2015-16E
kWh/mi	0.312	0.312	0.312
Range (mi/charge)	100	100	100
kWh needed	31.2	31.2	31.2
\$/kWh	\$750	\$500	\$400
Battery cost, gross	\$23,400	\$15,600	\$12,480
Less: Residual value (15%)	-3,510	-2,340	-1,872
Battery cost, net amortizable	\$19,890	\$13,260	\$10,608
Charge cycles	2,000	2,500	3,000
Range (mi/charge)	100	100	100
Amortization cost	\$0.10	\$0.05	\$0.04

As of January 2010

Source: Lazard

Estimated results do not represent a guarantee of future results and are subject to change.

of 15% (unknown currently, but potentially conservative),⁷ 3,000 charge cycles (versus 2,000 assumed today), and 100 miles per charge (at the high end of current technology). Exhibit 2 outlines the assumptions underpinning our \$12,500 battery forecast over the intermediate term.

- Second, a variable operating cost for fueling an EV of about \$0.03 per mile. This assumes electricity costs \$0.10 per kilowatt hour (kWh) and that each mile consumes approximately 0.312 kWh.⁸

As the analysis in Exhibit 3 illustrates, this \$0.07 per electric mile is the equivalent of approximately \$1.75 per gallon of gasoline—even before we factor in tax incentives. Moreover, the EV cost advantage is only likely to improve over time—oil prices seem likely to increase with emerging-market growth, while lithium-ion battery prices are expected to continue to fall and vehicle range is expected to continue to increase.⁹ As a result, the ICE-EV arbitrage spread will likely widen as time progresses.

In international markets, which we expect to lead in terms of EV adoption, this arbitrage is even greater due to a larger spread between gasoline/diesel prices and electricity. As of December 2009, gasoline cost \$7.34 per gallon in Denmark, \$7.19 in Germany, \$6.89 in France, \$6.13 in Israel, and \$3.79 in Australia.¹⁰ Even assuming higher retail electricity prices in selected markets, this implies an operating cost arbitrage of as much as 3.5x in some international markets (again, before tax incentives). In a nutshell, we think economics such as these can stand on their own—before we even consider the social, environmental, and other benefits.

Exhibit 3 All-In Cost Advantage of Electric vs. Gasoline Vehicles

Scenario: Intermediate-Term Horizon, No Tax Incentives

	U.S.	International Markets				
		France	Israel	Germany	Australia	Denmark
ICE Economics						
Gas/gallon (\$) ⁽¹⁾	\$3.00	\$6.89	\$6.13	\$7.19	\$3.79	\$7.34
Assumed MPG	25.3	25.3	25.3	25.3	25.3	25.3
ICE cost per mile	\$0.12	\$0.27	\$0.24	\$0.28	\$0.15	\$0.29
EV Economics						
<i>Variable costs</i>						
Retail electricity cost (\$/kWh) ^(2,3)	\$0.10	\$0.14	\$0.12	\$0.22	\$0.10	\$0.32
Electricity consumption (kWh/mi)	0.312	0.312	0.312	0.312	0.312	0.312
EV electricity cost per mile	\$0.03	\$0.04	\$0.04	\$0.07	\$0.03	\$0.10
Variable cost differential	3.7x	6.1x	6.3x	4.1x	4.8x	2.9x
<i>Battery amortization (intermediate-term)</i>						
Purchase price (no tax incentives)	\$12,480	\$12,480	\$12,480	\$12,480	\$12,480	\$12,480
Less: Residual value (15%)	(1,872)	(1,872)	(1,872)	(1,872)	(1,872)	(1,872)
Charge cycles	3,000	3,000	3,000	3,000	3,000	3,000
Miles per charge	100	100	100	100	100	100
Battery amortization cost per mile	\$0.04	\$0.04	\$0.04	\$0.04	\$0.04	\$0.04
All-in EV cost per mile	\$0.07	\$0.08	\$0.07	\$0.10	\$0.07	\$0.14
All-in cost differential	1.7x	3.4x	3.3x	2.7x	2.3x	2.1x
<i>Per-gallon gasoline equivalency</i>						
All-in EV cost per mile	\$0.07	\$0.08	\$0.07	\$0.10	\$0.07	\$0.14
(x) Assumed MPG	25.3	25.3	25.3	25.3	25.3	25.3
Per-gallon gasoline equivalency	\$1.72	\$2.03	\$1.86	\$2.65	\$1.68	\$3.44
Gas/gallon (\$)	\$3.00	\$6.89	\$6.13	\$7.19	\$3.79	\$7.34
EV cost advantage (no tax incentives)	-43%	-71%	-70%	-63%	-56%	-53%

(1) Source: http://en.wikipedia.org/wiki/Gasoline_and_diesel_usage_and_pricing (last accessed Jan. 21, 2010).

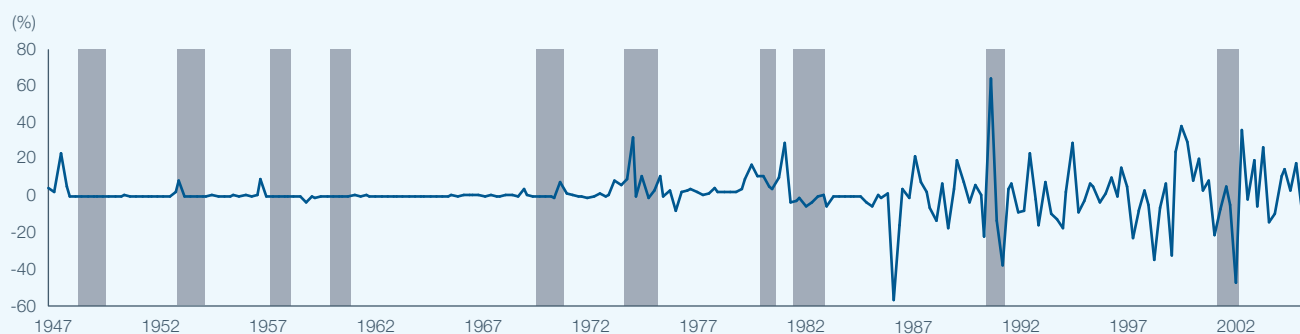
(2) Source: U.S. Department of Energy, <http://www.eia.doe.gov/emeu/international/elecprh.html> (last accessed Jan. 21, 2010).

(3) Data reflects retail electricity prices, which are typically higher than industrial prices. Lower industrial rate could be applicable instead.

As of January 2010

Source: Lazard, except as otherwise noted

Exhibit 4 Percentage Change in Quarterly Crude Oil Prices



As of 31 December 2005

Source: Federal Reserve Bank of St. Louis Review

Note: Shaded bars indicate National Bureau of Economic Research-dated recessions.

Exhibit 3 summarizes the all-in cost comparison for an ICE vehicle versus an EV for both the United States and international markets.

Reason 2 Electricity Prices Are Stable

Generally, electricity prices are significantly less volatile than oil or gasoline prices. Since 1983, the average retail price of electricity delivered in the United States has risen by an average of less than 2% per year in nominal terms and has actually fallen in real terms. Moreover, prices have risen by more than 5% per year only three times during that time period.¹¹

Oil prices, by contrast, have risen by an average of 7% per year in nominal terms. More significantly, however, is the average year-to-year volatility in oil prices over that time—a dramatic 21%. (Moreover, oil price increases and volatility have both heightened over the past decade relative to this 25-year average.) Economists at the Federal Reserve Bank of St. Louis have argued that such oil price volatility exacerbates macroeconomic shocks.¹² In fact, every recession over the past 35 years has been preceded by—or has been concurrent with—an oil price spike, as shown in Exhibit 4. Building on the example in point 1 above (“Electric miles cost substantially less than gasoline miles”), we have concluded that EVs are the equivalent of stable and declining \$1.75 per-gallon of gasoline.

Reason 3 Battery Technology and Prices Have Started to Show Step-change Improvements

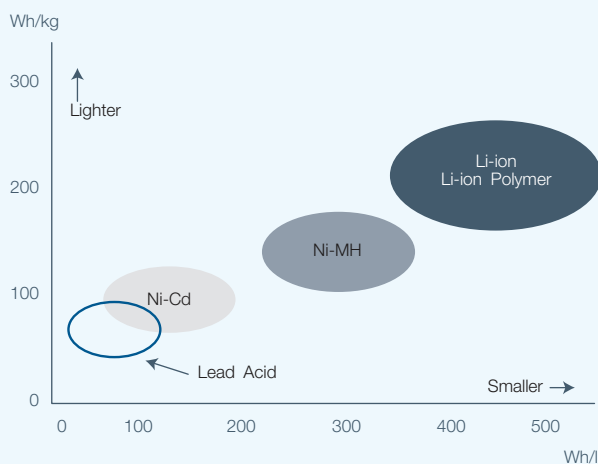
Historically, there have been two key technical challenges holding back increased adoption of EVs:

Historical challenge #1

Limited driving range. Historically, batteries have been unable to compete with the energy density of oil, keeping the practical limit on range for EVs very low. Twenty years ago, the only commercially practical rechargeable battery technology was lead-acid. These batteries were very heavy and had limited energy density, with only about 25 watt-hours per kilogram (Wh/kg).¹³ Since then, however, automotive rechargeable battery technology has transitioned from lead-acid, to nickel-metal hydride (NiMH), to lithium-ion (Li-ion)—each time benefiting from increased specific energy¹⁴ and lower weight. Today’s Li-ion batteries, for instance, have an energy density of roughly 150 Wh/kg—a six-fold improvement versus earlier technologies.¹⁵

This increased energy density has led to an ever-increasing range for EVs—in some cases as high as 200 miles per charge.¹⁶

Exhibit 5
Comparison of Energy Density among Various Small, Sealed Battery Systems



As of December 2005

Source: National Institute of Standards

Exhibit 5 illustrates the energy storage capacity of these various technologies. Energy storage is expressed as watt-hours per volume (Wh/l) and watt-hours per unit weight (Wh/kg). The larger values of Wh/l translate into a smaller cell, while larger values for Wh/kg translate into lighter weight for a given cell voltage and ampere-hour capacity.¹⁷

Even within the category of Li-ion batteries, there has been significant progress over the past 20 years. Sony first introduced Li-ion batteries into the consumer electronics market in 1991; over the subsequent ten years, the specific energy of such batteries increased at roughly a 7% compound annual rate.¹⁸ A key reason for this steady improvement is the fact that, unlike NiMH batteries, Li-ion batteries can support a wide range of chemistries and metal-oxide cathodes. Such metals range from relatively expensive cobalt (the most common choice in recent years) to less-expensive nickel, manganese, or aluminum. Each of these competing chemistries favors a different weighting of three competing dynamics—cost, safety,¹⁹ and durability—making it generally possible to select a particular chemistry based on a specific application.

In automotive applications, balancing these three competing dynamics has historically been an unusually difficult challenge—as cost, safety, and durability are all critical elements contributing to the likelihood of mass adoption of EVs. This challenge underscores why the automotive industry has been substantially slower to adopt Li-ion batteries than the consumer electronics industry.

Probably the most significant recent development supporting automotive applications has been the emergence of lithium

iron phosphate (LiFePO₄). Researchers at the University of Texas discovered the chemistry less than 15 years ago, and A123 announced its use in batteries as recently as 2005. Compared to cobalt-based chemistries, LiFePO₄ batteries are less likely to experience thermal runaway (which can lead to fires), and have better peak power, longer cycle lives, and an improved environmental impact.

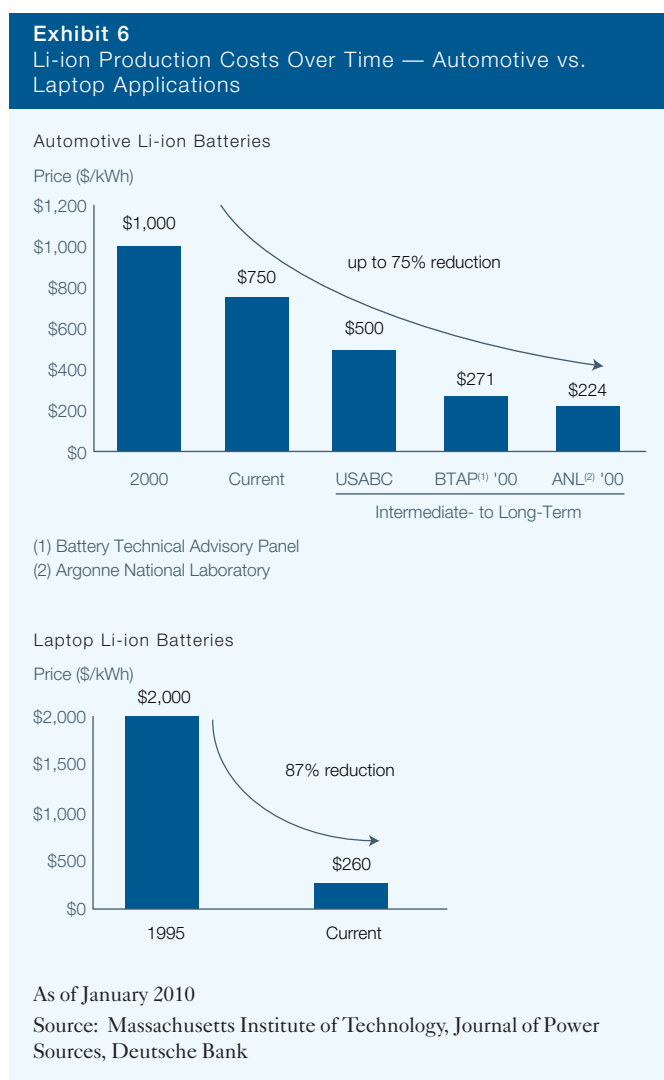
Accordingly, current Li-ion automotive technologies are expected to yield a commercially practical vehicle with a range of up to 100 miles. In addition, while most industry participants are currently assuming 2,000 “charge cycles” (the number of times a battery can be charged) in their business plans, many such participants also tell us that they believe current batteries can already support more—possibly 3,000 charges or more. This would materially bring down the amortization costs of Li-ion batteries.

Historical challenge #2

High production costs. The second key technical challenge holding back adoption of EVs to date is that battery costs have been prohibitively high. Around the edges, this is starting to improve—and at an accelerating rate. Manufacturing costs have generally improved from roughly \$1,000/kWh in 2000, to as low as \$750/kWh today (heavily dependent upon volumes). (Our research suggests that some manufacturers are quoting \$500/kWh today for the 2012 timeframe. This price, which implies a 50% decline from the 2000 baseline, is already in line with the longer-term goal of the U.S. Advanced Battery Consortium, or USABC.) Other forecasts have the longer-term production cost declining to approximately the \$225 to \$270/kWh range.²⁰ This range, which we currently believe would push the outer limits of possible scenarios, would represent a decline in production costs of roughly 75% from the 2000 baseline level.

The biggest contributor to the cost decline to date has been the increased substitution of cheaper materials for use as metal-oxide cathodes. (See preceding discussion on improved range.) In one instance, this improved process reduced cathode costs from 50% to 10% of the total material cost.²¹ Going forward, and putting aside further potential improvements in materials costs, the cost of Li-ion batteries is expected to continue to decline as production volumes increase over the next several years.

Exhibit 6 illustrates the magnitude of the expected price declines compared to our 2000 baseline estimate. For point of reference, Exhibit 6 also highlights that production costs for laptop Li-ion batteries have dropped approximately 87% over the past 15 years. In fact, the most aggressive projected auto-



otive Li-ion battery production costs shown in the exhibit (\$224-\$271/kWh) are roughly in line with current laptop battery costs (\$260/kWh) — although automotive batteries are more complex than laptop batteries. Nevertheless, these data points suggest to us that production costs can decline significantly from current levels.

Reason 4 EVs Can Be Fun to Drive

Ask a typical consumer to describe an EV, and you might hear the words “golf cart”—small, plastic, and hardly suitable for longer-distance driving. Similarly, ask the owner of a Toyota Prius—perhaps the second-closest mental model many have of an EV—why he or she bought the car, and you are unlikely to hear, “I think it’s sporty.”

We believe both of these perceptions will be refuted as EVs come to market. For a vehicle to be widely adopted, generally it must appeal to the consumer on an emotional level. That means it should be fun to drive.

In our view, EVs offer a driving experience superior to many ICE vehicles. (Some automotive enthusiasts may be surprised to learn that BMW, an OEM that prides itself on driving experience, will release an EV as early as 2011. This would complement the 100-mile-per-charge Mini-E that the automaker has already supported under the Cooper brand.) Although this is one area where “seeing will be believing,” we would summarize these benefits as including:

- Faster acceleration (depending on application), in the form of instant thrust due to the electric motor output at low rpm;
- Smoother acceleration, as an electric motor does not need multiple gears;
- Better handling, considering that under-floor batteries lower the vehicle’s center of gravity;
- Reduced NVH (noise, vibration, and harshness), thereby lowering cabin noise—a common issue with some high-performance vehicles;
- Lower servicing, repair and ownership costs, a benefit of the simpler powertrain; and
- A highly sophisticated user interface (more traditionally referred to as a dashboard), which in some models incorporates GPS (including where to find charge spots), vehicle diagnostics (such as battery monitoring), and multimedia functionality that we consider as much as two product cycles (a product cycle is typically thought of as five years) ahead of what is found in most ICE cars.

Reason 5 Electric Miles Are Cleaner Than Gasoline Miles

The Department of Energy reports that transportation is the single largest end-use sectoral emitter of CO₂ in the United States, alone accounting for 34% of 2007 U.S. emissions.²² Moreover, the capital stock within transportation turns over much more frequently than other large sectoral emitters of CO₂. As a result, the transition to EVs will also further public policy objectives reducing CO₂ emissions.

Exhibit 7 summarizes the findings out of MIT regarding both the tank-to-wheel and the well-to-wheel CO₂ emissions from various powertrain technologies. These powertrains include current ICEs, diesels, HEVs, and PHEV-30s (i.e., with a 30-mile range). As this exhibit illustrates, PHEV-30s offer as much as an 84% reduction in carbon emissions on a tank-to-wheel basis, and a 65% improvement on a well-to-wheel basis. What’s more, the advantages of the plug-in hybrid vehicle grow as the electric grid becomes progressively cleaner. (Note

Exhibit 7 CO₂ Emissions (grams of CO₂ per mile) of Various Powertrains

Scenario: Current U.S. Fuel Mix⁽¹⁾

	ICE	Diesel	HEV	PHEV-30
Well-to-Tank	91.7	27.7	31.8	83.8
Tank-to-Wheel	311.0	175.7	107.8	54.1
Well-to-Wheel	402.7	203.4	139.7	137.9
% Reduction from ICE	N/A	-49.5	-65.3	-65.8

(1) Current U.S. fuel mix is 49% coal, 21% natural gas, 20% nuclear, 6% hydro, 3% non-hydro renewable, and 1% oil.

As of May 2007

Source: Massachusetts Institute of Technology

that this does not necessarily mean exclusively renewable fuels, but also a coal-to-natural gas conversion.)

International discussions surrounding CO₂ emissions, led by the United Nations Intergovernmental Panel on Climate Change, are increasingly centering on a CO₂ stabilization level of 450 parts per million (ppm) CO₂ equivalent (CO₂-eq).²³ This would require slashing annual per-capita CO₂-eq emissions to two metric tons globally by 2050 from seven metric tons today. (The United States today emits 26 metric tons per capita.) Should the United States choose to adopt this standard, the International Energy Agency (IEA) has concluded that more than 60% of new U.S. vehicle sales would need to be based on some form of electrification (ranging from traditional hybrids to pure electric vehicles) by 2030.²⁴

Reason 6 New Fuel Economy and CO₂ Requirements in Both the United States and Europe Are Important Drivers for OEM Development

The newly tightened fuel economy—corporate average fuel economy or CAFE—regulations in the United States contain strong incentives for auto OEMs to “push” more EVs into the market. In the United States, the Energy Independence and Security Act of 2007 (EISA) directed the Department of Transportation (DOT) and the Environmental Protection Agency (EPA) to tighten existing fuel economy standards.²⁵

EISA raised the U.S. CAFE standard to 35 MPG by 2020 from 25 MPG in 2010—a 40% hike. President Obama subsequently announced plans to pull forward this standard even further, moving toward a 39 MPG standard for passenger cars by 2016 (versus 27.5 MPG today) and a 30 MPG requirement for light-duty trucks (versus 23.1 MPG currently).²⁶ President Obama also set a target of 250g/mile of CO₂ emissions by 2016

(roughly a 37.5% decline from current levels). In so doing, the federal government effectively adopted California’s pre-existing, tighter regulations (which 16 other states had also adopted).

Historically, the auto OEMs would have considered it a near-impossibility to achieve a 35% to 40% type ratcheting of fuel economy requirements in little more than one product cycle. In administering EISA’s requirements, the DOT (via the National Highway Traffic Safety Administration, or NHTSA) and the EPA have proposed rules with two important factors that we believe will prove to be meaningful catalysts for the OEMs to favor EVs in order to achieve these standards:

- **The U.S. CO₂ calculation only considers “tank to wheel” emissions.** As illustrated in the discussion around Exhibit 7, an EV’s assumed CO₂ emissions depend on two dynamics: whether one considers just “tank to wheel” or the full “well to wheel” production equivalent, and what fuel mix one assumes for electricity production. (The study summarized in Exhibit 7 actually does not consider a pure-electric vehicle, but rather a PHEV-30 vehicle—or a series hybrid with a 30-mile all-electric range. A pure-electric EV theoretically would have zero CO₂ emissions.) For the purpose of calculating CAFE compliance, the EPA and NHTSA assume an EV produces no CO₂ emissions.

- **The U.S. CO₂ formula also uses a multiplier on EVs.** In addition to assuming that an EV produces no CO₂ emissions, the formula also weights each EV somewhere in between 1.2x and 2.0x, depending on the specific vehicle produced.

Exhibit 8 illustrates how this might work in application. The EPA-NHTSA joint proposal uses the Chrysler 300 as an example of a full-sized passenger car. Under the joint proposal, the vehicle would have a target CO₂ emissions level of 261g/mile and fuel economy of 32.8 MPG.²⁷ According to the U.S. Department of Energy (DOE), this vehicle currently has CO₂ emissions of 617g/mile and fuel economy of 18 MPG for model-year 2010.²⁸ All else being equal, this implies a necessary CO₂ reduction of 58% for this vehicle in a little more than one product cycle.²⁹ An OEM could partly achieve this reduction by downsizing the engine to four cylinders, adding a turbocharger, incorporating gasoline direct injection, etc. However, we believe a 58%-type reduction in one product cycle is unlikely without the OEM’s also using the EV mechanism built into the proposed regulations.

Exhibit 8 assumes three different scenarios: EV penetration of 10%, 20%, and 30%, respectively, of assumed Chrysler 300 annual unit sales of 100,000 in 2016. This analysis also assumes that the EV multiplier will be 1.8x for purposes of calculating compliance with the regulations.

Exhibit 8
Hypothetical Application of Proposed DOT/NHTSA CO₂ Emissions Regulations

	Current	2016		
		10% EV Penetration	20% EV Penetration	30% EV Penetration
CO ₂ target (g/mi)	617	261	261	261
Fuel economy target (mpg)	18	32.8	32.8	32.8
ICE				
Annual production	100,000	90,000	80,000	70,000
CO ₂ emissions (g/mi)	617	313	378	462
Implied CO ₂ reduction in baseline ICE	N/A	-49%	-39%	-25%
EV				
Assumed EV penetration (%)	0	10	20	30
Annual production	—	10,000	20,000	30,000
Assumed multiplier	—	1.8	1.8	1.8
Effective production	0	18,000	36,000	54,000
CO ₂ emissions (g/km)	—	—	—	—
Average CO ₂ (g/mi)	617	261	261	261
Implied average CO ₂ reduction		-58%	-58%	-58%

As of January 2010

Source: U.S. Department of Energy, EPA, Lazard

Estimated results do not represent a guarantee of future results and are subject to change.

In the first scenario, if Chrysler were able to cut the CO₂ emissions of its baseline ICE by roughly 50%—from 617g/mile to 313g/mile—it could still achieve the necessary 58% reduction by selling 10,000 EVs (which would count as 18,000 units, or 1.8x 10,000 units). If Chrysler could only cut its baseline ICE emissions by 40% (to 378g/mile), it would need a 20% penetration of EVs in order to comply with the regulations. And finally, if Chrysler could only cut its baseline ICE emissions by 25% (to 462g/mile), the OEM would need 30% penetration of EVs. Accordingly, our sense is that the less prepared an OEM is to make an immediate improvement in its CO₂ emissions, the more aggressively it will need to market EVs in order to comply with the proposed U.S. regulations.

Europe also has key CO₂ regulations in place that will likely incentivize auto OEMs to produce more EVs. In that region, automakers will have to phase in a 130g/mile standard on average (depending on vehicle mix) by 2015.³⁰ Although diesel (with roughly 200g/mile of emissions) is already well-penetrated in that continent, it appears likely that increased sales of HEVs and EVs will be necessary to bring the industry average down to the 130g/mile level. More important, the EU is targeting a 95g/mile standard by 2020—which would undoubtedly require meaningful electrification.

Of additional interest from the OEM side is the increasing support of EVs from key decision makers at several auto companies, as summarized in the following quotes:

- “[T]he electrification of the automobile is inevitable.” Bob Lutz, Vice Chairman, General Motors, January 2008³¹
- “At the present time the automobile is unthinkable without a highly efficient diesel or gasoline engine. The future however, and that is certain, will belong to the electric motors.” Martin Winterkorn, CEO of Volkswagen AG, June 2008³²
- “The conditions for electric cars to exist have finally been met.” Carlos Ghosn, CEO of Renault, February 2009³³
- “[I]n 10 years, 12 years, you are going to see a major portion of our portfolio move to EVs.” Alan Mulally, CEO of Ford, March 2009³⁴
- “In 12 years we see 30 per cent of all cars being electric.” Frank Stronach, CEO of Magna, June 2009³⁵

U.S. oil consumption averaged 20.4 million barrels per day (mdb) during the five-year period from 2004 to 2008 (roughly one-fourth of total global demand). Of this amount, light-duty vehicles (cars, SUVs, and motorcycles) represented 8.6 mdb, or 40%.³⁶ This translates into an astounding \$395 billion of annual expenditures (assuming \$3 gasoline) for passenger cars in the United States alone.³⁷ The majority of these expenditures are attributable to foreign oil, as the United States imports roughly 58% of the petroleum it consumes.³⁸ In fact, the imported oil attributable solely to U.S. light-duty vehicles represented approximately 25.6% of the total U.S. trade deficit in 2008.³⁹ In addition, one study estimated that approximately 12% to 15% of the current defense budget is devoted to guaranteeing the free flow of oil.⁴⁰

Reason 7 Other Government Support Is Growing Globally

We believe that the economics of EVs can work in many geographic regions without tax and other government incentives. However, we are encouraged that various countries are supporting the transition to EVs on policy grounds as well.

Governments around the world are looking for solutions to help control climate change, promote renewable energy sources, and (particularly in oil-importing nations) improve their national energy security. The promotion of zero-emission EVs is at the forefront of many governments’ response to these challenges.

The Boston Consulting Group estimates that governments around the world have pledged to spend \$15 billion over the next five years to support EVs, batteries, and infrastructure.⁴¹ The following are some examples of already-enacted tax

incentives and other government programs that would be in addition to the variable cost advantage described above:

- **In Israel**, zero-emission vehicles such as EVs will be taxed at 10% (increasing to 30% in 2015), while gasoline-powered vehicles are taxed at 92%. (Hybrids and other lower-emission vehicles will be subject to a 30% to 92% tax rate, depending on engine size and emission levels.) On top of this, Israel has recently announced a “feebate” system whereby each car model will be graded for its environmental footprint and emissions profile, and will receive a “green grade” that will determine the respective tax rate for that model.
- **In Denmark**, there is an existing gap of 105% to 180% between the tax on ICE vehicles and the tax on EVs. That is, EVs are generally exempt from taxation while ICEs are subject to a 105% tax on the first 76,400 Danish krone (U.S. \$14,000), and 180% for each additional krone.
- **In France**, consumers are offered a €5,000 (\$7,100) purchase “bonus” for buying EVs through 2012, explicitly designed to reduce the upfront cost of EVs. The French government has also announced a €1.5 billion (\$2.1 billion) program to install a ubiquitous EV charging infrastructure across France, with a target of around four million public charging spots servicing two million EVs by 2020.
- **In China**, EVs were recently identified as a significant opportunity to offset the impact of the global financial crisis and air pollution. China has stated that it aims to be one of the leading producers of HEVs and EVs within the next three years, with a target of 500,000 vehicles per annum in production by 2011. In support of this effort, the central government announced a rebate of up to approximately renminbi 60,000 (\$8,800) for each EV put into public use.
- **In the United States**, President Obama has set a goal of one million EVs and PHEVs on the road by 2015. To this end, the Department of Energy is administering a \$25 billion program to develop EVs and improve batteries (among other advanced technologies). Recently, U.S. Energy Secretary Steven Chu announced an additional \$2 billion of funding for EVs and batteries as part of the economic stimulus program, one of the few areas within the budget to receive a significant boost. The federal government also announced tax credits of \$2,500 to \$7,500 depending on battery size, with \$7,500 starting from 16kWh battery size.
- **In Japan**, the government has projected 40% penetration for HEVs and EVs by 2020. This penetration could exceed 50% following additional, recent targets.⁴²

Exhibit 9 Estimated Incremental Electricity Demand from 60% EV Penetration

Miles per day	25.5
Electrical efficiency (kWh/mi)	0.312
Daily kWh per vehicle	8
Total U.S. car parc (in 000s)	254,403
Assumed conversion to EVs (including PHEV)	60%
Number of EVs (in 000s)	152,642
Incremental electricity used, daily (bill. kWh)	1.2
Days per year	365
Incremental electricity used, annual (bill. kWh)	443.3
Annual U.S. electricity production, annual (bill. kWh)	4,110
Percentage increase from EVs	10.80%
As of January 2010 Source: Lazard, Bureau of Transportation Statistics, CIA Estimated results do not represent a guarantee of future results and are subject to change.	

Reason 8 Electricity Has Structural Advantages over Oil in Many Markets

We see five primary structural advantages. Two of these were discussed previously—e.g., that electricity prices are generally less volatile than oil prices, and that electricity is more efficient and has a better emissions profile than oil. Three additional structural advantages are as follows:

- **Using electricity promotes fuel diversity.** Electricity is generated from a diverse set of fuels, including coal, uranium, natural gas, flowing water, wind, geothermal heat, the sun, landfill gas, and so forth.⁴³ This helps mitigate the impact of unusual price volatility in any single fuel source. (In addition, EVs can potentially stimulate investment in renewable energy by creating a more stable market for it. For example, in Denmark, Better Place will buy wind energy generated at night—which is now essentially given away—thereby increasing demand, which in turn allows for additional investment in renewables.)
- **In the United States, electricity is generated from a domestic portfolio of fuels.** In many countries, the role of petroleum is negligible in the production of electricity. In fact, petroleum represents only 1% of total U.S. electricity production.⁴⁴
- **Even in the United States, the power sector has sufficient existing capacity.** The United States currently consumes about 4.1 trillion kWh of electric power each

year.⁴⁵ If 60% of the 254.4 million total U.S. car *parc* were to convert to EVs of some form,⁴⁶ and each vehicle were to consume 8kWh of power a day (implying 25 to 26 electric miles driven per day),⁴⁷ the grid would need to produce an additional 440 billion kWh of power each year (an increase of roughly 10.8%). These calculations are summarized in Exhibit 9.

Much of this charging could likely be done during off-peak hours, which would flatten the load curve and enhance the efficiency of power plants. In fact, based on one analysis, there already exists sufficient off-peak generating capacity to cover this incremental demand.⁴⁸ Also worth noting is the fact that, unlike many other alternative fuels, electricity already has a ubiquitous infrastructure network that it can leverage.

Conclusion

We believe that EVs are nearing a critical inflection point, with mass adoption increasingly a viable option in selected international markets due to technological, financial, and public policy developments. Specifically, we believe EVs make sense for at least eight reasons:

- 1 Electric miles cost substantially less than gasoline miles.
- 2 Electricity prices are stable.
- 3 Battery technology and prices have started to show step-change improvements.
- 4 EVs can be fun to drive.
- 5 Electric miles are cleaner than gasoline miles.
- 6 New fuel and emissions regulations are important drivers for OEM development.
- 7 Other government support is growing globally.
- 8 Electricity has structural advantages over oil in many markets.

In future research, we plan to tackle the following two issues:

- What are some of the most common arguments against the potential success of EVs?
- Where do we believe some of these arguments may prove wrong?

NOTES

- 1 For the purposes of this paper, EVs are comprised of both pure electric vehicles (which are powered entirely by batteries and have no on-board internal combustion engine) and series hybrid vehicles (which are powered by batteries or some other capacitor, but also have a small internal combustion power generator used to recharge the energy storage device). Generally, when we refer to HEVs, we are referring to parallel hybrid vehicles or PHEV (which are powered primarily by an internal combustion engine, but use a battery at very slow speeds). A key example is the Toyota Prius. In our view, HEVs are not a long-term solution because the vehicle still derives the overwhelming majority of its propulsion from petroleum.
- 2 Privately held EV network operator Better Place, which has raised more than \$700 million (including from Lazard Asset Management), is expected to launch commercial operations during late 2011 in Israel, with Denmark to follow soon thereafter. The company has an alliance with Renault-Nissan to initially deploy 100,000 vehicles into these markets. Potential pipeline markets for Better Place include Australia, Hawaii, Northern California, and Canada, among other regions.
- 3 “The Smart Grid: An Introduction,” U.S. Department of Energy, Office of Electricity Delivery & Energy Reliability, at 9 (2008), available at [http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages\(1\).pdf](http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf) (last accessed Jan 20, 2010) (hereinafter “DOE Smart Grid Introduction”).
- 4 *Id.* at 8.
- 5 “Electrification Roadmap: Revolutionizing Transportation and Achieving Energy Security,” Electrification Coalition, at 13 (2009), available at <http://www.electrificationcoalition.org/electrification-roadmap.php> (last accessed Jan 19, 2010) (hereinafter “Electrification Roadmap”); see also Rod Lache et al, “Electric Cars 2: A Mega-Theme Gains Momentum,” Deutsche Bank, at 6 (2009) (hereinafter “Deutsche Bank (2009)”).
- 6 This 25.3 mile per gallon (MPG) average assumes a 50/50 sales mix between passenger cars and light-duty trucks, and applies the model-year 2009 corporate average fuel economy (CAFE) standard of 27.5 MPG for passenger cars and 23.1 MPG for light-duty trucks.
- 7 We believe that lithium-ion batteries that are no longer roadworthy can be resold in the secondary market for alternative applications, such as stationary power storage. This is because the battery at the end-of-life for an automotive application should still have roughly 80% of its storage capacity compared to when the battery was new. (Lithium-ion batteries lose both battery capacity and power as a function of time and use.) Accordingly, even at lower efficiency levels, lithium-ion batteries previously used in EVs can be valuable for such applications as load balancing for solar and wind power generation. Alternatively, lithium-ion batteries, unlike nickel-metal hydride batteries, are easy to recycle and thus offer at least some pure scrap value.
- 8 “Environmental Assessment of Plug-In Hybrid Electric Vehicles,” Electric Power Research Institute, Natural Resources Defense Council, Table 5-1 at 5-1 (2007), available at <http://mydocs.epri.com/docs/public/000000000001015325.pdf> (last accessed Jan 19, 2009) (hereinafter “EPRI (2009)”) (summarizing DC electricity consumption in terms of Wh/mile for various vehicle types).

- 9 Deutsche Bank forecasts a 50% decline in battery production costs over the next 10 years, combined with a doubling of battery performance over the next seven years. See Deutsche Bank (2009), *supra* note 5, at 7. All else being equal, the fact that per-mile amortization costs are likely to continue falling would arguably create a disincentive for early adopters. However, the Better Place model removes this risk from the consumer, as we will discuss in future research.
- 10 Source: http://en.wikipedia.org/wiki/Gasoline_and_diesel_usage_and_pricing (last accessed on Jan 14, 2010).
- 11 Department of Energy, Energy Information Administration, Annual Energy Review 2008, at 261 (Table 8.10) (2009) (hereinafter AER 2008); Electrification Roadmap, *supra* note 5, at 38.
- 12 Hui Guo & Kevin Kliesen, "Oil Price Volatility and U.S. Macroeconomic Activity," Federal Reserve Bank of St. Louis Review (Nov/Dec 2005), pg. 669.
- 13 Electrification Roadmap, *supra* note 5, at 56.
- 14 A battery's "specific energy" refers to its energy per unit of mass. (In many ways, specific energy is analogous to, and even may have the same physical units as, pressure.) In the above comment that Li-ion batteries have higher specific energy than NiMH batteries, it is worth mentioning as an aside that NiMH generally has the higher charge storage capacity of the two technologies. However, this is more than accounted for by Li-ion batteries' higher voltage—whereas the standard NiMH cell voltage is about 1.2V, the standard Li-ion cell voltage is closer to 3.3V to 4.3V. Matthew A. Kromer and John B. Heywood, "Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet," Massachusetts Institute of Technology, available at http://web.mit.edu/sloan-auto-lab/research/beforeh2/files/kromer_electric_powertrains.pdf (last accessed Jan 15, 2010).
- 15 Electrification Roadmap, *supra* note 5, at 56.
- 16 Kromer & Heywood, *supra* note 14, at 31.
- 17 *Id.*
- 18 Ralph Brodd, "Factors Affecting U.S. Production Decisions: Why Are there No Lithium-Ion Battery Manufacturers in the United States?" Prepared for National Institute of Standards, Contract SB 1341-02-W-1445, June 2005 at 62, available at <http://www.atp.nist.gov/eao/wp05-01/wp05-01.pdf> (last accessed Jan 15, 2010).
- 19 Like many other forms of energy storage, Li-ion batteries can pose safety risks. In October 2006, major computer makers (including Dell and Apple) had to recall up to 9.6 million Li-ion notebook batteries manufactured by Sony due to concerns that such batteries may overheat and cause a fire. This can occur when the battery becomes overcharged or overheated, and the metal-oxide cathode becomes unstable and releases oxygen due to the excess heat. This, in turn, can ignite the flammable electrolyte or the lithium that is deposited on the anode—generating more heat and possibly igniting neighboring cells (known as thermal runaway). While we will not delve further into this topic, different chemistries address this risk in different ways. (Kromer & Heywood, *supra* note 14, at 38.) More important for the purposes of this and future papers, the increasingly dominant chemistry for automotive Li-ion batteries, lithium iron phosphate, appears superior to cobalt-based chemistries for managing thermal runaway.
- 20 See, e.g., Linda Gaines & Roy Cuenca, "Costs of Lithium-Ion Batteries for Vehicles," Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, available at <http://www.transportation.anl.gov/pdfs/TA/149.pdf> (last accessed Jan 15, 2010).
- 21 Kromer & Heywood, *supra* note 14, at 44 (citing Andrew Ritchie & Wilmont Howard, "Recent Developments and Likely Advances in Lithium-Ion Batteries," *Journal of Power Sources* 162 (2006), ppg. 809-12).
- 22 Electrification Roadmap, *supra* note 5, at 34.
- 23 *Id.* at 34-35. According to the United Nations Intergovernmental Panel on Climate Change, the CO₂ stabilization range is between 450ppm and 550ppm. The low end of this range corresponds to a 50% chance of restricting the increase in global average temperature to around 2°C, while the high end of this range corresponds to a rise of around 3°C (compared with 1,000ppm and up to 6°C in the base case).
- 24 Electrification Roadmap, *supra* note 5, at 34; IEA, "How the Energy Sector Can Deliver on a Climate Agreement in Copenhagen," Special early excerpt of the World Energy Outlook 2009 for the Bangkok UNFCCC meeting (October 2009).
- 25 A 2007 U.S. Supreme Court decision—which clarified that the EPA has a responsibility to evaluate whether CO₂ is a potential pollutant and, if found to be so, that the agency must regulate it—was likely a key driver behind EISA.
- 26 Electrification Roadmap, *supra* note 5, at 62; Deutsche Bank (2009), *supra* note 5, at 11. These standards are based on CO₂ emissions-footprint curves, where each vehicle has a different CO₂ emissions compliance target depending on its footprint value (related to the size of the vehicle). Generally, the larger the vehicle footprint, the higher the corresponding vehicle CO₂ emissions target.
- 27 "Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Proposed Rule," 74 Federal Register 186 (Sep 28, 2009), at 49476, available at <http://edocket.access.gpo.gov/2009/pdf/E9-22516.pdf> (last accessed Jan 20, 2010).
- 28 United States Department of Energy, Energy Efficiency and Renewable Energy, Model Year 2010 Fuel Economy Guide, available at <http://www.fueleconomy.gov/FEG/noframes/28663.shtml> (last accessed Jan 19, 2010) (providing estimates for MY 2010 Chrysler 300 V6 AWD).
- 29 We acknowledge three imperfections in this analysis: (1) it is unclear currently whether the DOE and EPA-NHTSA use the same process to measure CO₂; (2) there are other means, in addition to EVs, for auto OEMs to influence their respective CO₂ calculations, including alternative fuels; and (3) the EPA-NHTSA joint requirements technically apply on a fleet-wide average basis, and not specifically to any single model. Accordingly, the analysis above is intended only to illustrate the mechanics of the proposed EV-related CO₂ credits.
- 30 Deutsche Bank (2009), *supra* note 5, at 16.
- 31 Keith Naughton, "Bob Lutz: The Man Who Revived the Electric Car," *Newsweek*, Jan. 7, 2008, available at <http://www.newsweek.com/id/81580> (last accessed Jan 22, 2010).
- 32 Green Car Congress, June 26, 2008, available at <http://www.greencarcongress.com/2008/06/volkswagen-unve/comments/page/2> (last accessed Jan 22, 2010).
- 33 Sidney Goodman, "The Opposition's Rebuttal Remarks" (part of an economist debate on future automotive technologies), *The Economist*, May 23, 2009, available at <http://www.economist.com/debate/days/view/323> (last accessed Jan 22, 2010).
- 34 Nichola Groom, "Electric Vehicles to Dominate Ford's Future Lineup: CEO," *Reuters*, March 5, 2009, available at <http://www.reuters.com/article/ousivMolt/idUSTRE5240ZZ20090305?pageNumber=1&virtualBrandChannel=0> (last accessed Jan 22, 2010).
- 35 John Morrissy, "Magna Seeks Ottawa Help for Electric Car," *Financial Post*, June 2, 2009, available at <http://www.financialpost.com/news-sectors/story.html?id=1655279> (last accessed Jan 22, 2010).

NOTES (CONTINUED)

- 36 Electrification Roadmap, supra note 5, at 12.
- 37 8.6 mdb x 365 days x 42 gallons/bbl x \$3.00 gallon.
- 38 Electrification Roadmap, supra note 5, at 31.
- 39 (8.6 mdb for LDV x 365 days x 58% imported x \$95.23 avg. price of imported crude in 2008)/\$677.1bn net deficit
- 40 Electrification Roadmap, supra note 5, at 30.
- 41 Deutsche Bank (2009), supra note 5, at 3.
- 42 Id. at 3.
- 43 Electrification Roadmap, supra note 5, at 37.
- 44 Id.; Department of Energy, Energy Information Administration, Electric Power Annual 2007 at 2 (2009).
- 45 Central Intelligence Agency, The World Factbook, available at <https://www.cia.gov/library/publications/the-world-factbook/rankorder/2038rank.html> (last accessed Jan 19, 2010).
- 46 Bureau of Transportation Statistics, available at http://www.bts.gov/publications/national_transportation_statistics/html/table_01_11.html (last accessed Jan 22, 2010) (providing car parc data). Assumed penetration of 60% is intended to reconcile to IEA's annual sales penetration target of 60% by 2030.
- 47 Based on an assumed electric efficiency of 0.312 kWh/mile. See EPRI, supra note 8, at 5-1. Roughly 90% of U.S. vehicle trips are less than 30 miles. Electrification Roadmap, supra note 5, at 43.
- 48 Electrification Roadmap, supra note 5, at 41 (citing Michael Kintner-Meyer et al, "Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids Part 1: Technical Analysis," Pacific Northwest National Laboratory, January 2007; Michael Scott et al, "Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids Part 2: Economic Assessment," Pacific Northwest National Laboratory, November 2007.)

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