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OPPORTUNITIES AND CHALLENGES PRESENTED IN INCREASING THE NUMBER OF ELECTRIC VEHICLES IN THE LIGHT DUTY AUTOMOTIVE SECTOR

HEARING

BEFORE A

SUBCOMMITTEE OF THE

COMMITTEE ON APPROPRIATIONS

UNITED STATES SENATE

ONE HUNDRED ELEVENTH CONGRESS

SECOND SESSION

SPECIAL HEARING

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OPPORTUNITIES AND CHALLENGES PRESENTED IN INCREASING THE NUMBER OF ELECTRIC VEHICLES IN THE LIGHT DUTY AUTOMOTIVE SECTOR

TUESDAY, FEBRUARY 23, 2010

U.S. SENATE,
SUBCOMMITTEE ON ENERGY AND WATER DEVELOPMENT,
COMMITTEE ON APPROPRIATIONS,
Washington, DC.

The subcommittee met at 10:17 a.m., in room SD–192, Dirksen Senate Office Building, Hon. Byron L. Dorgan (chairman) presiding.

Present: Senators Dorgan, Cochran, Bennett, and Alexander.

OPENING STATEMENT OF SENATOR BYRON L. DORGAN

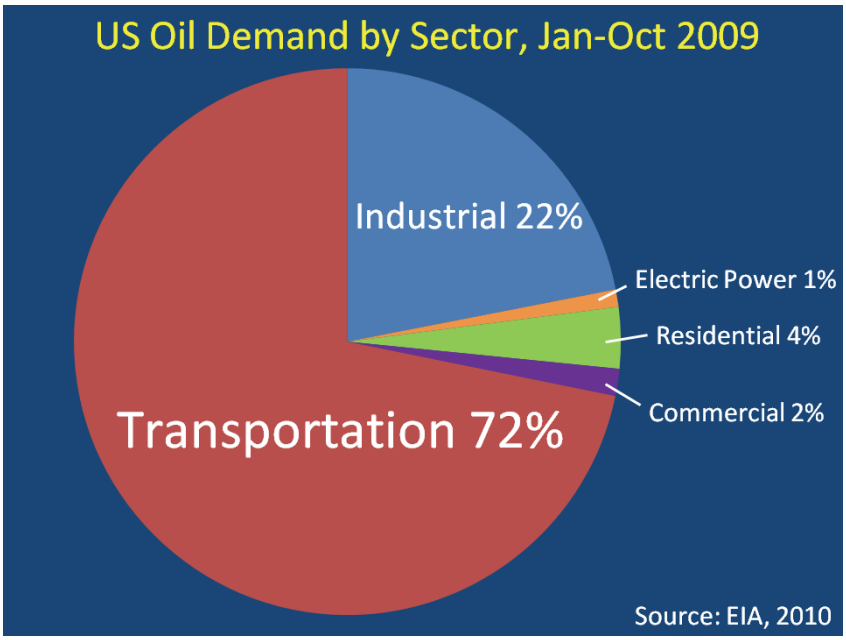
Senator DORGAN. I'm going to call the subcommittee hearing to order.

This is the Energy and Water Subcommittee on Appropriations, and we're holding a hearing today on the subject of electric vehicles and an electric drive future for America.

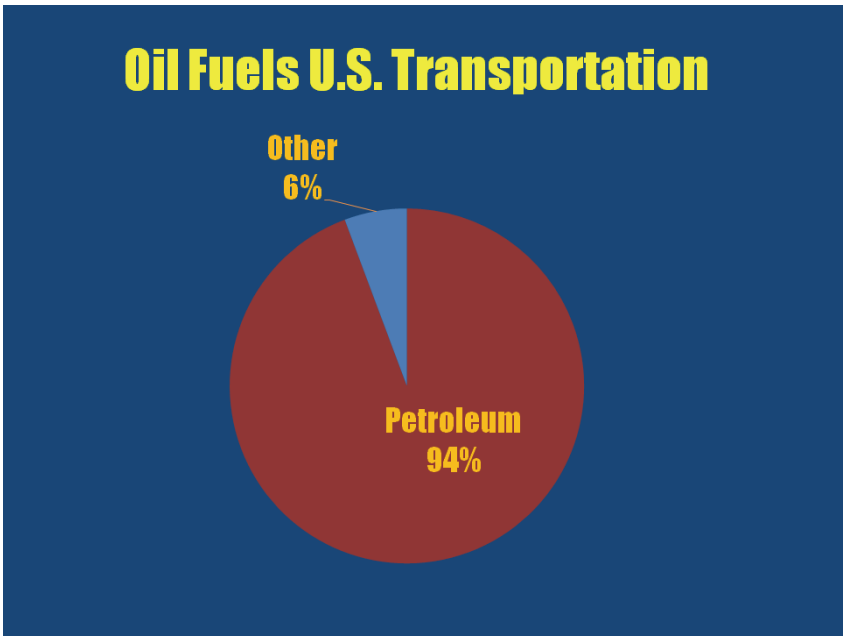
Let me talk first, in an opening statement, about some of the reasons that bring us to this judgment and to have this hearing.

I think that moving toward an electric drive future makes a great deal of sense for our country, for a number of reasons. The most compelling reason to me is national energy security. Each day, we consume about 20 million barrels of oil a day in our country. Seventy percent goes into the transportation sector. I want to go through some charts, just very briefly, that describe, graphically, the case for this.

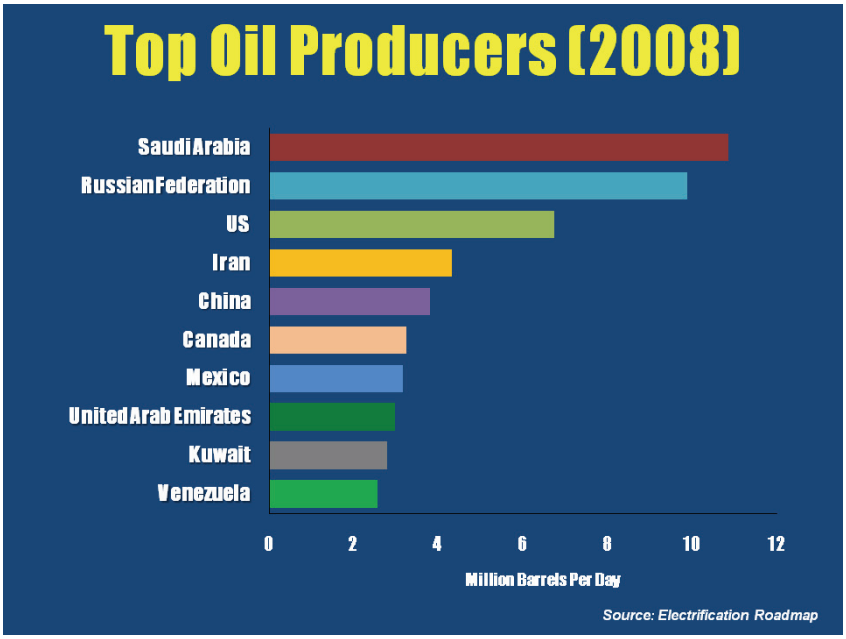
As I indicated, the first chart shows that the oil demand, by sector—72 percent of oil demand is for transportation. By far, it exceeds everything else.



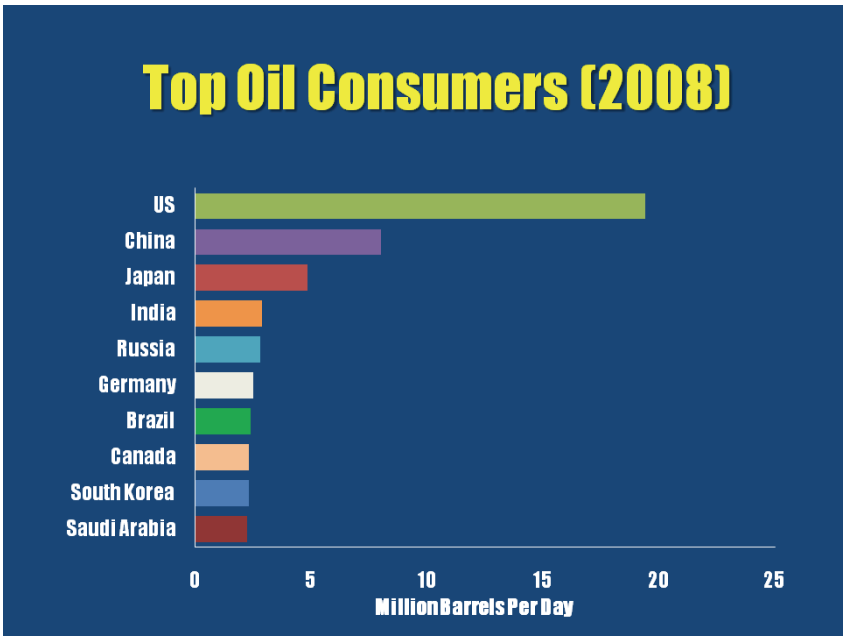
The second chart shows that, in transportation itself, petroleum accounts for 94 percent of the energy used, only 6 percent comes from other sources.



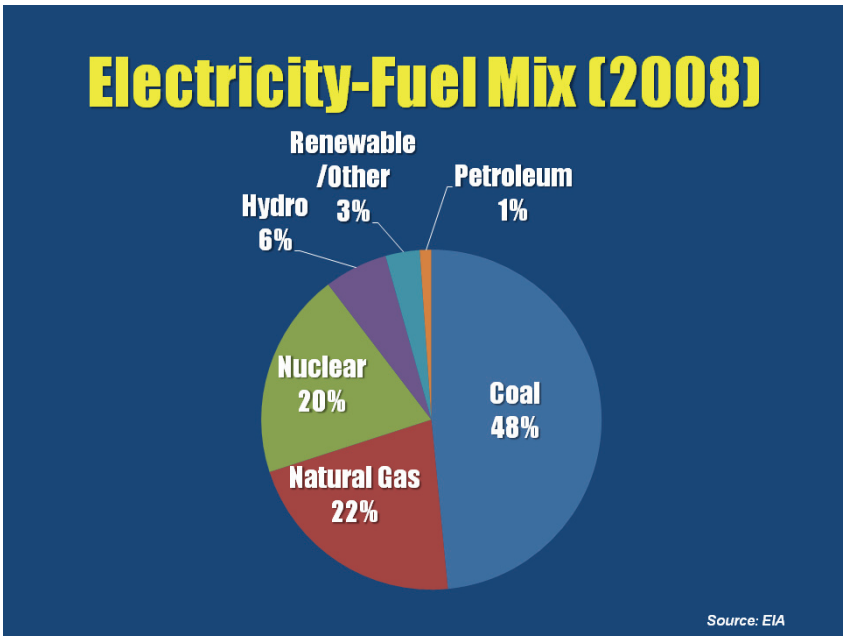
The next chart shows the top oil producers in 2008. You can't see the top line very well, unfortunately, but Saudi Arabia is at the top, and it exceeds all the other countries. And this shows where the United States is versus the Saudis, the Russians, and others. Those are the top oil producers in 2008. We are the top consumer, obviously, but not the top producer.



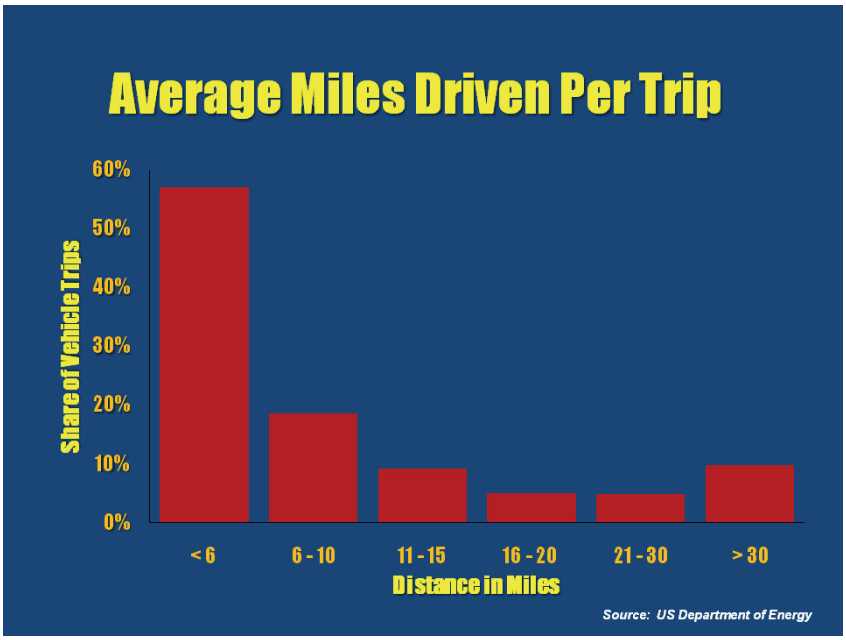
The next chart shows the top oil consumers. You see it's quite clear that the United States has a prodigious appetite for oil.



Finally, the fuel mix for electricity, which, in my judgment, is where we're headed, in terms of an electric drive future, is much different. The fuel mix for electricity is coal, natural gas, nuclear, hydro. And again, compared to the previous chart, where you have substantial oil intensity for our transportation system, this makes us much, much less dependent on foreign oil.



In terms of considering electric drive vehicles, the final chart I have is the average miles driven per trip, which I think is very interesting. Nearly 60 percent of the travel in this country, the trips in this country, travel less than 6 miles. Those are all the things that we need to understand as we talk about the need to move toward a different kind of future to power our transportation fleet. We use 24 percent, 22 percent, somewhere in that range, of the world's oil production. We produce only 10 percent, and we have less than 3 percent of the world's reserves. Well, that just doesn't add up, in terms of the use of oil and the intensity of that oil use in transportation.



So, the transportation sector, in my judgment, can be powered by electricity. It would rely much, much more, as you saw from the chart, on domestic fuels, and that would make us less dependent on foreign oil.

We can cut our dependence on foreign sources of oil, cut our smog and greenhouse gas emissions. There are a good number of things that, in my judgment, would suggest that we move toward an electric drive future.

I've worked with my colleagues on increasing funding for vehicle technologies, which include electric vehicles. Last year, the Vehicle Technologies Program was funded at about $300 million. President Obama has set a goal of getting 1 million electric vehicles on the road by 2015. The Department of Energy's budget request for 2011 includes a 14-percent increase in electric-drive-specific programs, most of which will fund research and advanced battery technology which is one of the keys to this issue of conversion to an electric drive future.

Now, like most things, this is not a new idea. One hundred years ago, 25 percent of the cars made in America were electric vehicles. The year 1900 was the heyday of electric cars. At that time, they all sold all other types of cars, and it wasn't until the Model T that electric cars began to decline. I happened to have owned a 1924 Model T that I bought as a young kid for $25 and restored lovingly. So, I understand that genesis of the internal combustion engine in the Model T.

In 1909, President Taft made an official decision to change from horses to cars. He ordered four cars, one of which was the Baker electric car. So, you know, we sit here, 101 years later, and the

more things change, the more they remain the same. We are now talking about electric cars.

I understand that there are issues here that we need to resolve and think about. A 40-mile range will be possible with the Volt, they say. That covers 90 percent of consumers' driving habits. But, they're also talking about how to extend that with the Volt. We need to be able to deploy a recharging infrastructure so that the American public is confident they can get to point A from point B without running out of power.

The cost of the battery is one of the main reasons why electric vehicles are much more expensive than their internal combustion engine counterparts at this point. But we have sunk a massive amount of money into new battery technology. We now have new companies that are opening plants in this country to produce batteries. We're making significant strides in new battery technology. And we want to lead the world in battery technology.

We see the Chevy Volt, and the Nissan Leaf, which I saw advertised on the Olympics last evening. The technology needed to produce commercial electric cars is well within our grasp. The electricity to power those cars in this country can come from many different sources, which makes us, as I said, much less dependent on foreign oil.

So, there are so many things that are moving toward an electric drive vehicle system that are advantageous for our country.

I'm a great believer in not letting things happen, but, instead, making things happen. I mean, so much of what we do in this country is, we sit around, we let things happen to us, and then we respond to it. It is much more preferable to me that we would decide, here's the kind of future we want, and here are the things that we need to do to achieve that future. That's the purpose of holding this hearing, to talk about where we are with the funding that we have committed and where we need to go if our country, indeed, wants to have a different kind of future and be less dependent on foreign oil.

I'm going to make one final point. It is not lost, it seems to me, on people who think for a living that we could wake up one morning and discover that our unbelievable dependence on oil that comes from outside of our country is interrupted. And if that is the case, our economy will be flat on its back. I mean flat on its back. We are so unbelievably dependent. That is not healthy for our country, for our future. And so, because an overwhelming amount of oil is used in our transportation sector, and because, at the same time, we are trying to see how do we reduce emissions and do all the things that will help protect our planet, it seems to me this discussion of moving toward an electric drive vehicle future is timely and critically important for our country.

Let me call on Senator Bennett for any comments you might have, Senator.

OPENING STATEMENT OF SENATOR ROBERT F. BENNETT

Senator BENNETT. Thank you very much, Mr. Chairman. I appreciate your holding the hearing, and apologize for being a bit tardy.

I've been driving a hybrid car for about 9 years now and have seen some all-electric vehicles with a booster kind of activity from

a gasoline thing that has come from a car developed in the State of Utah. And I think the direction away from a pure fossil-fuel-driven car is one that we're moving very strongly. So, I thank you for calling the hearing, and I look forward to hearing what our witnesses have to say.

Senator DORGAN. Senator Bennett, thank you very much.

Senator Alexander.

STATEMENT OF SENATOR LAMAR ALEXANDER

Senator ALEXANDER. Thanks, Mr. Chairman. I'm—I thank you for this hearing and for your approach.

You know the buzz word this week in Washington seems to be that Washington doesn't work, that's not necessarily true on electric cars or even clean energy. I mean, we have—I mean, all Republican Senators and many Democrats, you know, want to greatly increase nuclear power production. And the President, over the last month, has taken a number of significant steps in that direction. So, we agree on that. The President's been a leader on electric cars, and all 40 Republicans have endorsed the idea of doubling—of making electric cars and trucks our—you know, half of our vehicles. And if you add to that offshore exploration for natural gas and the fact that we also agree on the importance of energy research and development for the 500-mile battery and the 50-percent-efficient voltaic cell for rooftops, we have a lot of agreement. We can get into a disagreement over economy wide cap-and-trade, but there's plenty to agree about on clean energy. And this is certainly one of those subjects.

Eighteen months ago, I bought a Toyota Prius, and—that was converted with an A123 battery, so I plug it in every night, and I've driven it to work every day for the last 18 months, and I've had no problems with it, and I think I get extra mileage from it, and my electric bill hasn't gone up much. So, it seems to be working, except that the battery costs too much. But, it works fine.

And, of course, we're very excited, in Tennessee, that Nissan's going to be building not only the Leaf there, it's going to be building the batteries there for the Leaf, at the plant there. And we're very proud of Federal Express. Fred Smith stuck his neck out several years ago, and Federal Express has gone ahead with electric and plug-in vehicles, including trucks, and then his leadership nationally on helping remind us of this.

I've been fascinated, Mr. Chairman, by this from the first time I heard about it, because I simply had not realized how much unused electricity we have in the country, until a few years ago. I mean, that should be perfectly obvious to all of us, but it reminds me of Ross Perot's story, you know, in the 1960s of—in Texas, he noticed all the banks were locking up at 5 o'clock and not using their computers, so he went around and bought their unused computer time, and came around and sold it to governors at cheap rates to manage their Medicaid data, and made a billion dollars.

And I know that in the TVA region, Tennessee Valley Authority region, we have the equivalent of six or seven nuclear power plants' worth of unused electricity every night. So, if we could figure out how to take all these cars and plug them in at night, according to

many estimates, we might double—we might electrify half our cars and trucks without any new power plants.

I talked to the Austin, Texas, utility head. They've been very progressive on this subject. And he thought it was realistic that, under some circumstances, they could electrify half their cars and trucks in the Austin, Texas, area without building any new plants.

So, I'll be very interested to hear from our witnesses exactly, you know, What are the steps we ought to take? We're at a time when we don't have a lot of extra money. You know, our deficits are high, so we have to be careful with that, and here on the Appropriations Committee. And we don't want to put into the law subsidies that just go on forever and distort the marketplace's ability to make its own decisions about what works. But, it seems to me that this is a no-brainer, that probably the best way to reduce our dependence on foreign oil, to clean the air, to deal with climate change, et cetera, et cetera—

And I'm delighted the chairman has called the hearing, and I'm—I welcome it as an opportunity for us to work together to help our country move ahead.

Thank you.

Senator DORGAN. Senator Alexander, thank you very much. You're right that there is more agreement than is apparent sometimes. But, agreement is good news, and that never leads the news. There's an old saying, "Bad news travels half way around the world before good news gets its shoes on." And that certainly is the case here in Washington, DC.

We are pleased to introduce the first panel: Dr. Henry Kelly, the Principal Deputy Assistant Secretary for Energy Efficiency and Renewable Energy at the Department of Energy. Throughout his career, Dr. Kelly has been a leader in the development of new energy technology. And during the Clinton administration, he served as the Assistant Director for Technology for the Office of Science and Technology Policy, in which he helped negotiate and implement administration research partnerships in energy technology, including new automobile and truck technology.

He'll be followed by Fred Smith, president and CEO of the FedEx Corporation, if there's anybody in America who knows how to make things happen, it certainly must be Fred Smith. He is a chairman of the Energy Security Leadership Council and a member of the Electrification Coalition. Now, that Energy Security Leadership Council brings together America's most prominent business and military leaders for a major effort to support a comprehensive, long-term policy to reduce U.S. oil dependence and to improve our energy security.

Dr. Kelly, you may proceed, and then we'll call on Mr. Smith.

STATEMENT OF DR. HENRY KELLY, PRINCIPAL ASSISTANT SECRETARY FOR ENERGY EFFICIENCY AND RENEWABLE ENERGY, DEPARTMENT OF ENERGY

Dr. KELLY. Chairman Dorgan, Ranking Member Bennett, Senator Alexander, thank you for the opportunity to talk about the Department of Energy's programs in building safe, affordable transportation systems that also reduce our dependence on foreign oil and reduce greenhouse gas emissions.

Now, Senator Dorgan's introductory remarks eloquently showed how important this issue is. And we, in DOE, have designed a portfolio of research designed to try to attack this problem. We've, of course, invested in renewable fuels and advanced engines for using them. We've invested in fuel cells. But, importantly, we've also invested in electric and hybrid vehicles of various kinds.

Now, this is an interesting moment in the history of these technologies—these technologies are going to compete. It's very difficult, at this point, to find out what the market is going to be. But, consumers are likely to choose a number of these options, perhaps choosing different vehicles for different specialized purposes.

I'm going to focus, today, of course, primarily on electrics and hybrids. To begin with, the environmental benefits of these technologies depend heavily on the source of electricity. And, of course, the Department has major programs to try to invest in low carbon-emitting electricity generation—renewables, nuclear, and coal with capture and sequestration.

Now, as Senator Dorgan pointed out, electric cars have been around for a long time. They lost out to the Model T and other internal combustion engines because of cost, convenience; and that's the way the situation has really been until very recently. But, the introduction of the potential for extremely low cost and reliable safe batteries has really changed the rules of that competition. And we're certainly seeing that reflected in the market.

Hybrid electrics are now 3 percent of the market. This year, we're likely to see three or four major manufacturers have a plug-in hybrids and electric vehicles on the market. This has been driven, in no small part, by the public investment we've had through the Recovery Act and through the Department of Energy's continuing investment in research and advanced batteries, including the lithium-ion battery.

Now, there's a lot of work ahead of us. We have asked for $120 million in the fiscal year 2011 budget, plus additional money for transportation systems, to work on further battery research and the motors and controls and other devices are needed to put us on a continuous improvement path.

In the Recovery Act, we invested $2.4 billion in advanced battery and electric transportation. A lot of these battery plants are being built now. We supported the installation of over 10,000 charging sites, provided $2 billion in tax credits for manufacturing and for the purchase of electric vehicles and plug-in hybrids. We've had a $25 billion auto loan, Advanced Technology Vehicles Manufacturing Loan Program which has also covered a number of firms that are investing in advanced electric vehicles. And the 48C tax credit supported a number of firms that are investing in battery manufacturing and other technologies.

So, collectively, this work is helping put us in a position where U.S. firms will be able to produce batteries for half a million plug-in hybrids by the year 2015 and is leading rapidly to a point where the technology of electrics and hybrids of all kinds can be fully competitive with standard automobile prices and expected prices for future gasoline.

Now, clearly if electrics and hybrids become a big part of the Nation's transportation system, it's going to have an impact on utili-

ties. Hopefully, a large fraction of the resource can be met with existing generating plants, but, of course, it doesn't mean that you'll have the transmission facilities in place to move the power where you need it. It's one of the reasons for the Smart Grid. You need to have charging stations in residences, in parking spaces, and we're working very closely with electric utilities to make sure that we can do this expeditiously.

Now, the businesses that will manufacture electric vehicles, batteries, motors, controls, and the maintenance can create a lot of new business opportunities throughout America, including manufacturing. And the research that we've done over the years has put us in a position where we can, I think rightly, claim leadership in this area. But, there's absolutely no cause for complacency. A number of well-managed, well-funded projects in advanced batteries and vehicle technologies are underway around the world. Markets will move quickly. Competition will be ruthless. And new technologies will require continuous improvement.

PREPARED STATEMENT

Well-managed Federal research programs in the 20th century spurred the kind of innovation in the U.S. leadership in areas ranging from commercial aircraft to the Internet. And I'm absolutely convinced that wise management of public investment in electric vehicles can do the same thing and put us in a position where we can, in fact, lead world markets.

Thank you for the opportunity of talking here, and I'd be happy to answer questions.

[The statement follows:]

PREPARED STATEMENT OF DR. HENRY KELLY

INTRODUCTION

Chairman Dorgan, Ranking Member Bennett, and members of the subcommittee, thank you for the opportunity to appear before you today to discuss the Department of Energy's (DOE) efforts to help provide Americans with attractive, safe, affordable transportation options that sharply reduce imported fuel use and greenhouse gas (GHG) emissions. A number of new technologies—particularly rapid advances in batteries, motors, and other essential components of electric and hybrid electric vehicles—open exciting new possibilities to achieve these goals while generating many new opportunities for business growth and job creation.

Transportation is a central part of the Nation's energy and environmental challenges. It is responsible for about 30 percent of all U.S. energy use and two-thirds of total U.S. petroleum consumption.[1] The work required to build, fuel, and maintain transportation systems makes the transportation sector one of the Nation's largest employers as well.

Within that transportation system, driving, in particular, consumes a significant amount of energy while emitting GHGs; and Americans drive a lot. The vehicle miles Americans travel in just over 8 years is roughly equal to the distance to the star nearest to the sun, Proxima Centauri.[2] Automobiles and light trucks alone are responsible for nearly one-half of U.S. petroleum consumption.[3] In 2007, gasoline

[1] Transportation Energy Data Book: Edition 28, Table 2.1 and Table 1.16.

[2] Assumes an average of approximately three trillion miles driven annually (http://www.fhwa.dot.gov/policyinformation/travel/tvt/history/) and a distance from the sun to Proxima Centauri of about 24.7 trillion miles (http://heasarc.gsfc.nasa.gov/docs/cosmic/nearest_star_info.html).

[3] Transportation Energy Data Book: Edition 28, calculated from data in Table 1.13 and Table 1.16.

use in transportation contributed to 16.4 percent of total U.S. carbon dioxide emissions.[4]

DOE designed a portfolio of research projects that can help meet the challenge of producing safe, affordable, energy-efficient, and environmentally-friendly highway transportation. This portfolio includes balancing investments in basic science, highly innovative but high-risk research, and applied research focused on areas where risks and other factors have led to underinvestment by private firms. Investing the public's research money in several promising research pathways, the portfolio includes advanced engines for using new fuels from renewable resources, fuel cell vehicles, hybrid electric vehicles (including plug-in hybrid electric vehicles, or PHEVs), and all-electric vehicles, or EVs. Each of these technologies can contribute to the solution. However, it is impossible to determine which technologies will be "winners" in the future since customers will choose different cars for different missions, making vehicle markets complex and sufficiently difficult to predict in the coming decades.

The environmental benefits of PHEVs and EVs depend heavily on the fuels they use. EVs and hydrogen-powered vehicles can achieve very low net emissions if electricity and hydrogen are produced largely from low-carbon resources—renewable energy, fossil-powered generation with carbon capture and sequestration, and nuclear power. DOE is making major investments in the research needed to ensure that these energy resources are available as quickly as possible. If the Department's 2050 goals are met, the GHG emissions of PHEVs and EVs would be five times lower than those produced by today's internal combustion engine cars.[5]

My remarks today focus on the recent progress being made in hybrid electric vehicles and all-electric vehicles. DOE's Vehicle Technologies Program (VTP) manages research on improving the cost and performance of advanced batteries, efforts supported by funding from the Recovery Act, and efforts of the Advanced Technology Vehicle Manufacturing Loan Program (ATVM). Collectively, this work is helping develop the advanced battery manufacturing capacity needed to produce half a million PHEVs per year by 2015.[6]

ELECTRIC DRIVE VEHICLE CAPABILITIES

Hybrid electric vehicles, which are now familiar to most Americans, operate from fuel-powered internal combustion engines and from electric motors provided by batteries charged by the engine. Energy wasted by conventional vehicles during braking can be captured by hybrid cars to recharge batteries, and the fuel-powered engines can simply turn off when not needed—including during periods of idling. Virtually all hybrids on the road today can only operate for short distances without needing the engine to recharge the battery. Plug-in hybrids have batteries large enough to enable operation over significant distances using batteries alone. Many of the plug-in hybrids DOE supports can travel up to 40 miles on battery power alone. This means that most of the daily trips taken by Americans could avoid using any gasoline.[7] The fuel-powered engine would be available to support longer trips.

EVs eliminate the engine entirely and operate only in all-electric mode. The EVs being tested on American roads today are designed to travel 100 to 200 miles or more on a single charge.

EV BATTERY TECHNOLOGY AND ONGOING RESEARCH

Approaching 3 percent of new car sales, hybrid electric vehicles are now common on American highways[8] and electric drive vehicles are beginning to enter the market. In 2008, an American manufacturer launched a highway-capable production electric car for sale in the United States; another American manufacturer expects to release a PHEV in 2010; a Japanese company's new EV will soon be available in several West Coast cities; and a major American company will launch sales of an all-electric delivery van by the end of 2010.

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[4] Transportation Energy Data Book: Edition 28, calculated from data in Table 11.4 and Table 11.6.

[5] J. Ward, internal DOE analysis, January, 27, 2010 based on A. Elgowainy, ANL GREET analysis, January 27, 2010.

[6] Memorandum for the President from the Vice President, December 15, 2009: http://www.whitehouse.gov/sites/default/files/administration official/vice_president_memo_on_clean_energy_economy.pdf.

[7] Transportation Energy Data Book: Edition 27 (2008), p. 8–19, citing work done by Danilo Santini at Argonne National Laboratory.

[8] Green Car Congress reporting Autodata 2009 sales figures, January 7, 2010: http://www.greencarcongress.com/2010/01/hybsales-20100107.html.

Electric cars are nothing new. Henry Ford's wife, Clara, loved her EV in 1916.[9] Still, electric vehicles lost to internal combustion engines in the marketplace because of the convenience and low cost of internal combustion engines and gasoline. Storing energy in a gas tank was easier than storing it in a battery; and a gas tank could be filled in minutes while batteries took hours to charge. However, significant improvements in the performance of batteries, controls, and electric motors have changed the scope of the market.

The promise of advanced lithium-ion batteries has had the most dramatic impact. These batteries have the potential to be much lighter, smaller, safer, and less expensive than their predecessors. Working with industry partners over the past decade, DOE research has helped make steady gains in all of these characteristics. The most important remaining challenge is to cut costs. One lithium-ion battery produced today is projected to use 8 kilowatt-hours (kWh) of energy (of a total capacity of 16 kWh) and costs roughly $6,500–$8,000 ($800–$1,000/kWh of useable energy) when produced in high volume.[10] DOE and its research partners believe that the cost could likely be reduced to $2,400 ($300/kWh of useable energy) by 2014 with a combination of better materials, optimized battery designs, and improved manufacturing. At this price, the cost of driving a mile in an electric or plug-in hybrid electric vehicle would be roughly comparable to that of today's conventional cars.[11] The initial price of new vehicles would be higher, but the energy costs for driving would be much lower. Additionally, it can be expected that the battery prices will continue to fall while gasoline prices increase in the coming decades.[12]

Cost-reducing battery advances require a close partnership between government and industry. These partnerships are clearly visible in the way industry converted publicly-funded basic and applied research into commercial products and jobs. For example, DOE supported the development of the first lithium-ion battery for a production vehicle, which started manufacture in the summer of 2009. At the recent Washington Auto Show, two major American manufacturers showcased cars that utilize lithium-ion batteries. DOE supported the research and development (R&D) that provided the basis for both of these batteries.

These commercial successes do not mean that the role DOE's R&D role in battery technologies is complete, but rather that the Department will need to address additional challenges in the sector. DOE's fiscal year 2011 budget request includes $120 million to continue work focusing on a wide range of research barriers facing developers of hybrid and electric vehicles, including specific materials problems that limit battery lifetimes, safety, charging rates, and production costs.[13]

DOE has already begun to address these barriers through investments in the next generation of battery technologies. Lithium-ion batteries include a family of chemistries, each of which has advantages and disadvantages based on the cost of materials and safety. Other chemical systems, such as lithium metal polymer batteries and lithium-sulfur batteries, remain in the research stage and have shown promise in the laboratory. However, these will require significant additional work before they can become viable products.

The Department's Vehicle Technologies Program currently funds 17 industrial lithium-ion battery and materials development contracts. VTP also sponsors two major coordinated efforts spanning 10 National Laboratories and 12 universities. These efforts include those at the Lawrence Berkeley National Laboratory (LBNL) and Argonne National Laboratory. LBNL leads the Batteries for Advanced Transportation Technologies effort which focuses on relatively long-term R&D associated with advanced materials, modeling, and diagnostics. Argonne National Laboratory leads the Advanced Battery Research initiative which focuses on more immediate, or short-term evaluation and demonstration of new materials and technologies in advanced batteries. The 57 projects in these 2 efforts received approximately $30 million in fiscal year 2010.

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[9] http://www.henryfordestate.org/claracar.htm.

[10] TIAX, PHEV Battery Cost Assessment, page 32, LiMn2O4 high case, with 50 percent useable energy.

[11] A. Brooker, M. Thornton, and J. Rugh, Technology Improvement Pathways to Cost-Effective Vehicle Electrification (preprint of a conference paper—NREL/CP–540–47454), February 2010.

[12] From the VTP's published program goals in Department of Energy fiscal year 2011 Congressional Budget Request, http://www.mbe.doe.gov/budget/11budget/Content/Volume%203.pdf, and from the Early Release Annual Energy Outlook 2010, U.S. Energy Information Administration (EIA).

[13] U.S. Department of Energy fiscal year 2011 Congressional Budget Request, http://www.mbe.doe.gov/budget/11budget/Content/Volume%203.pdf.

RECOVERY ACT IMPACT

In addition to the ongoing R&D concentrated on overcoming technical barriers to widespread adoption, the Department is supporting the development of advanced battery technology for EVs and PHEVs. In August 2009, President Obama announced award selections for up to $2.4 billion in Recovery Act funds to accelerate the manufacturing and deployment of the next generation of U.S. batteries and EVs. Vice President Biden, Secretary Chu and three other Cabinet members participated in events across the country to mark this historic announcement—the single largest investment in advanced battery technology ever made.

The Recovery Act supports 48 new projects for advanced battery and electric drive components manufacturing and electric drive vehicle deployment in more than 20 States. Funding for those projects includes up to $1.5 billion dedicated to building battery manufacturing facilities that provide an opportunity for the United States to lead the world in lithium-ion battery technology. Today, most lithium-ion batteries are made for consumer electronics applications such as mobile phones and notebook computers. More than 95 percent of these batteries are made in Japan, China, and South Korea, as East Asia is the epicenter of consumer electronics manufacturing. However, when the Recovery Act funded manufacturing plants are completed, the United States will have the capacity to make batteries for half a million PHEVs per year.

The revenue generated by the lithium-ion battery market for vehicles could be as much as 10 times larger than that for consumer electronics batteries since the size and energy storage capacity for a PHEV or EV battery pack is several thousand times that of a mobile phone battery.[14] Battery manufacturing is also a highly automated system. With low production costs that do not depend on low-wage labor, U.S. battery manufacturing can compete with producers anywhere in the world. Furthermore, the jobs that are created by domestic manufacturing will be well-paid. New domestic battery facilities will be able to supply advanced batteries for defense applications, consumer electronics, power tools, utility voltage regulation, and truck idling mitigation.

In addition to building U.S. manufacturing capacity, Recovery Act funds support the installation of over 10,000 charging sites for PHEVs and EVs that will serve more than 5,000 PHEVs being tested in on-road use. This is the largest number of PHEVs ever on U.S. roads, and the in-use, operational, and charging data gathered in this effort will help inform how additional PHEVs and EVs can be introduced in the future. The Recovery Act is also funding the first programs to educate first responders and emergency personnel in how to deal with accidents involving EVs and PHEVs.

Moreover, the Recovery Act includes $2 billion in tax credits ranging between $2,500 and $7,500 for the purchase of PHEVs and EVs. Credits also cover 10 percent of the cost of converting hybrids or internal combustion engine vehicles to PHEVs and EVs.

ADVANCED TECHNOLOGY VEHICLE MANUFACTURING LOAN PROGRAM

Separate from the Recovery Act programs above, the Department's ATVM Program strives to support the growth of domestic advanced vehicle technology manufacturing. The ATVM Program is authorized to make up to $25 billion in loans available to auto manufacturers and their suppliers for the cost of re-equipping, expanding, or establishing U.S. manufacturing facilities to produce qualified advanced technology vehicles or components. To be eligible to receive these loans, companies must be engaged in manufacturing "advanced technology vehicles" (ATVs) or components for these vehicles. ATVs must be light-duty, meet 125 percent of the miles per gallon achieved by "substantially similar vehicles" in 2005, and they must meet existing and any new emissions standards for fine particulates. Qualifying components must be specifically designed for installation in qualifying ATVs and must contribute to the qualifying ATV's performance requirements.

So far, the program has awarded loans to five companies, amounting to almost $9 billion. Four auto manufacturers—Ford Motor, Nissan Motor, Tesla Motors, and Fisker Automotive—received loans to produce more fuel-efficient vehicles, including EVs and PHEVs. A fifth company, Tenneco Inc., will design, engineer, and produce emission control components for gas, hybrid, and diesel-powered vehicle engines.

[14] Ralph Broddarp, Broddarp of Nevada, Inc., speaking at the 2nd International Conference on Advanced Lithium Batteries for Automobile Applications, Tokyo, Japan, November 26, 2009.

EVS AND THE ELECTRIC GRID

If PHEVs and EVs become a major part of the Nation's transportation system, investments in the Nation's electrical grid need to be made to support the new demand for electricity. Charging facilities will need to be installed in residences, parking facilities, and other sites. DOE is working with utilities and other partners to explore how this can best be accomplished. It is expected that PHEV owners will typically charge their vehicles at night, which will limit the impact on the electric grid and allow consumers to take advantage of off-peak electricity rates. A study by the Pacific Northwest National Laboratory shows that up to 70 percent of the U.S. vehicle fleet could be comprised of PHEVs without a significant impact on the electric power grid.[15]

Given the sophisticated controls possible with electric meters and other smart grid technologies, the electricity storage capacity of EVs and PHEVs could be a valuable asset to utility grids by helping utilities manage loads more efficiently without compromising service quality or reliability. These controls could ensure that vehicles are charged at times when generation costs are low (in many cases this may be when most of the electricity comes from more efficient, environmentally attractive plants), and thus, could lead to lower utility costs for all customers. It could also be possible to design systems that provide homes connected to electric vehicles with backup electric power during power outages. All of these functions have been demonstrated in limited experiments, such as in A123Systems' two megawatt grid stabilization batteries for AES Energy.[16]

CONCLUSION

PHEVs and EVs show enormous promise to help the United States cut dependence on imported petroleum and meet national environmental goals with cars that are safe, reliable, and fun to drive. The businesses that will manufacture these vehicles—and the batteries, motors, controls, and other components they contain—can create new business opportunities and many new manufacturing jobs in America. The research DOE has funded over the years has put the United States in a position to lead in many key areas of battery, EV and PHEV development. Recovery Act investments provide America with the opportunity to lead the world in this critical new technology. However, there is no room for complacency. A number of well-managed, well-funded projects in advanced battery and vehicle technologies are underway around the world. Markets will move quickly, competition will be ruthless, and new technologies will require continuous improvement.

Well-managed Federal research programs in the 20th century spurred tremendous innovation and U.S. economic leadership in areas ranging from commercial aircraft to the Internet. I am optimistic that similar sustained U.S. research investment in 21st century technologies like electric vehicles will provide renewed U.S. scientific leadership, economic growth, and job creation. It will enable the United States to meet its national energy and environmental goals while providing export opportunities that support global sustainability efforts.

I would be pleased to answer your questions.

Senator DORGAN. Dr. Kelly, thank you very much.

And, Mr. Smith, I've already properly introduced you, I think, and we're really pleased that you're here. You may proceed.

STATEMENT OF FREDERICK W. SMITH, MEMBER, ELECTRIFICATION COALITION; CHAIRMAN, PRESIDENT, AND CEO, FEDEX

Mr. SMITH. Thank you very much, Senator Dorgan, Senator Bennett, Senator Alexander, always good to be with you, in Washington or Tennessee. We appreciate the opportunity to put the views of the Energy Security Leadership Council and the Electrification Coalition present.

Mr. Chairman, I think you set the issue up very clearly. After nuclear proliferation and weapons of mass destruction, this is the

[15] Kintner-Meyer M, Schneider K and Pratt R (2007) Impact Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids, Online Journal of EUEC 1:Papers #4 and #5.

[16] A123Systems press release, 2008: http://ir.a123systems.com/releasedetail.cfm?ReleaseID=403097.

Nation's biggest economic and national security issue. In 2008, we had a very visible example of the effects of precipitous run-ups in fuel prices. There's just no question that the $147-a-barrel oil prices that we saw in July 2008 were the match that lit off the financial crisis. People literally had to choose between making their mortgage payments or driving to and from work. And as we've looked at this problem over the last several years, with the reports that the Energy Security Leadership Council put out and the Electrification Coalition report that was released in 2009, this really is the only solution to significantly reducing our dependence on petroleum, and particularly on petroleum imported from places around the world which are hostile to the interests of the American people.

As was pointed out, the infrastructure already exists. That's very different than any other potential solution. The sources of supply are highly diversified. The sources of supply, relative to the types of automotive and transportation power that we are currently consuming, are very clean. We have substantial spare capacity, as Senator Alexander pointed out.

And, to me, probably the most important element here is that, after the transitional period, it's quite obvious that the electrification of a large segment of our short-haul transportation is highly cost efficient. Our estimate, in the report that we produced, is that an electric plug-in vehicle or a grid-enabled vehicle, with gasoline at about $3 a gallon, costs about 2.5 cents per mile to produce a mile of transportation in a personal vehicle. That contrasts to about 10 cents a mile in a gasoline-powered vehicle. Now, the reason for that, quite simply, is that electricity has a higher efficiency of conversion into power than an internal combustion engine. The energy conversion ratio is about 90 percent for electrical power. It's about 25 to 27 percent for an internal combustion engine.

So, the relative issues of converting to a modern grid, putting the recharging stations in place from a national productivity standpoint are highly effective. Our recommendations, in the electrification roadmap, are about $120 billion, spread over 8 years, about $15 billion a year. But, contrast that into the U.S. Department of Energy estimate that U.S. oil dependence costs were $577 billion in 2008 alone. And, of course, we're spending enormous amounts of our national wealth protecting the oil trades, and are involved in two shooting wars, in large measure because of this issue.

PREPARED STATEMENT

So, we think that the expenditure of $15 billion a year to make this transition in order to eventually end an addiction, that you laid out there that costs us upwards of $600 billion a year in perpetuity, is a very good expenditure, and we would recommend that the Nation move along this electrification path.

Thank you.

I have a complete statement I've submitted for the record.

[The statement follows:]

PREPARED STATEMENT OF FREDERICK W. SMITH

Good morning, Chairman Dorgan, Senator Bennett, and members of the subcommittee. I would like to thank you for giving me this opportunity to speak to you regarding one of the great challenges facing our country today: ending the very real and pressing threats posed to our Nation by our dependence on petroleum.

These are threats, Chairman Dorgan, that I know you are very familiar with. You have been one of the Senate's most stalwart champions in finding real solutions to our energy security challenges, and I thank you for your dedication and leadership.

I am proud to serve both as co-chairman of the Energy Security Leadership Council and as a member of the Electrification Coalition, two organizations dedicated to facing these threats head on.

The Energy Security Leadership Council, formed in 2006, is a coalition of business executives and retired national security leaders who believe that our dependence on oil, much of it imported from unstable and hostile regimes, poses an unacceptable economic and national security threat.

The Electrification Coalition, formed in 2009, is a group of business leaders who represent the entire value chain of an electrified transportation sector and who are committed to promoting policies and actions that facilitate the deployment of electric vehicles on a mass scale.

I became involved in these organizations for a single reason: it is my belief that after terrorism and the proliferation of weapons of mass destruction, our increased dependence on petroleum represents the biggest single threat to our Nation's economy and national security.

I can speak to this issue personally. FedEx delivers more than 7 million packages and shipments per day to more than 220 countries and territories. In a 24 hour period, our fleet of aircraft flies the equivalent of 500,000 miles, and our couriers travel 2.5 million miles. We accomplish this with more than 275,000 dedicated team members, 670 aircraft, and some 70,000 motorized vehicles worldwide.

FedEx's reliance on oil reflects the reliance of the wider transportation sector, and indeed the entire U.S. economy. Oil is the lifeblood of a mobile, global economy. We are all dependent upon it, and that dependence brings with it inherent and serious risks.

In 2008, Americans consumed nearly 20 million barrels of oil a day—one-fourth of the world's total. We imported 58 percent of the oil we consumed, leading to a U.S. trade deficit in crude oil and petroleum products that reached $388 billion—56 percent of the total trade deficit.

At the crux of America's oil dependence is the energy demand of the transportation sector. Transportation accounted for almost 70 percent of American oil consumption in 2008. Cars and trucks were 94 percent reliant on oil-based fuel for their energy, with no substitutes immediately available in anything approaching sufficient quantities.

The volatility of oil prices affects every American. At the beginning of 2001, oil prices were steady at $30 per barrel. Over the subsequent 5 years, prices steadily rose, reaching $75 per barrel in June of 2006. After retreating slightly, benchmark crude prices jumped 50 percent in 2007, from $60 per barrel in January to more than $90 in December. In 2008, oil prices soared rapidly, eventually reaching their all-time high of more than $147 per barrel on July 3.

We are all aware of the sharp financial burden on U.S. households that faced—and still face—resets in their adjustable rate mortgages. But it is important to understand that increases in energy costs have been on the same, or even a greater, order of magnitude for the entire American economy. A typical subprime borrower with a poor credit history who bought a $200,000 house in 2006 with a 2 year/28 year ARM with a 4 percent teaser interest rate for the first 2 years would have seen monthly mortgage payments increase from about $950 a month before the reset to about $1,330 after the reset—an increase of about $4,500 a year. In the meantime, between 2001 and 2008, the average retail price of gasoline increased from $1.46 to $3.27, costing typical households $1,990 a year in increased fuel expenses. And that increase in energy costs affected all U.S. households—not just the one household in 20 that held a subprime mortgage.

This burden, multiplied across millions of households, was a major contributor to the ensuing economic slowdown. We saw an explosion in home ownership, with many purchases being made by people who had heretofore not qualified for mortgages. When the price of oil and the price of gasoline began to rise, and inflation on commodities began to take hold, and interest rates began to increase, you had a tremendous diminution in purchasing power and cash flow, which contributed to people having to walk away from their mortgages. The rise in oil prices was the match that lit the fuse of the mortgage mess and the subsequent recession.

The U.S. economy lost more than 700,000 jobs between December 2007 and the beginning of September 2008, and the unemployment rate increased from 4.5 percent to 6.1 percent—all before the financial crisis truly hit later in September. In fact, as early as August 2008, many economists believed the U.S. economy was already on the verge of recession, largely driven by sharply rising and volatile oil prices.

And the steps we usually would take to help strengthen the economy and create jobs in times of weakness are just as easily overcome by oil price volatility. The total effect of changes to the Federal tax code from 2001 to 2008 code was a decrease in annual Federal income and estate taxes by about $1,900 for the median household. But a typical household's energy costs rose more than that. In other words, every penny that the most Americans saved due to Federal income and estate tax cuts over the past 8 years was spent on higher gasoline bills.

All told, U.S. families and businesses spent more than $900 billion on refined oil products in 2008, representing 6.4 percent of GDP. Today, prices have receded. But for how long? Many of the underlying fundamentals that pushed oil prices up are still present today, and once demand—temporarily reduced due to the recession—begins to pick up again, prices are likely to follow. Our oil dependence could strangle an economic recovery just as it is beginning to take hold.

The threat to American national security is equally as urgent. The vulnerability of global oil supply lines and infrastructure has driven the United States to accept the burden of securing the world's oil supply. Much of the infrastructure that delivers oil to the world market each day is exposed and vulnerable to attack in unstable regions of the world. According to the U.S. Department of Energy, each day more than 50 percent of the world's oil supplies must transit one of six maritime chokepoints, narrow shipping channels like the Strait of Hormuz between Iran and Qatar. Even a failed attempt to close one of these strategic passages could cause global oil prices to skyrocket. A successful closure of even one of these chokepoints could bring economic catastrophe.

To mitigate this risk, U.S. armed forces expend enormous resources patrolling oil transit routes and protecting chronically vulnerable infrastructure in hostile corners of the globe. This engagement benefits all nations, but comes primarily at the expense of the American military and ultimately the American taxpayer. A 2009 study by the RAND Corporation placed the cost of this defense burden at between $67.5 billion and $83 billion annually.

Oil dependence also constrains U.S. foreign policy. Whether dealing with uranium enrichment in Iran or a hostile regime in Venezuela, American diplomacy is distorted by the need to minimize disruptions to the flow of oil. Too often, oil dependence requires us to accommodate hostile governments that share neither our values nor our goals, putting both the United States and its allies at risk.

Finally, petroleum consumption poses a long-term threat to global environmental sustainability. Curbing emissions is a global issue, and there is not yet an international consensus on a long-term stabilization objective or on the changes in emissions trajectory needed to meet such a goal. International discussions are increasingly centered on a stabilization level that ranges between 450 and 550 parts per million (ppm) CO_2 equivalent (CO_2-eq). Regardless of the exact nature of a final emissions stabilization target, what is clear is that the transportation sector is going to have to play a major role in virtually any carbon abatement scenario.

We cannot continue down this path. We cannot continue to send untold billions of dollars and jobs overseas to pay for our addiction. We cannot continue to send men and women into harm's way to protect an increasingly vulnerable supply line. We cannot continue to put our future in the hands of hostile nations or fanatical terrorists who can turn off our crucial oil lifeline at the drop of a hat.

There is a solution. The lynchpin of any plan that is serious about confronting oil dependence must be a transportation system that today is almost entirely dependent on petroleum. The solution can be found in something that nearly every single one of you has either on your belt or on the table in front of you. The lithium ion batteries that power our cell phones and laptop computers can one day form the nucleus of an electrified transportation sector that is powered by a wide variety of domestic sources: natural gas, nuclear, coal, hydroelectric, wind, solar, and geothermal. No one fuel source—or producer—would be able to hold our transportation system and our economy hostage the way a single nation can disrupt the flow of petroleum today.

Electricity represents a diverse, domestic, stable, fundamentally scalable energy supply whose fuel inputs are almost completely free of oil. It would have clear and widespread advantages over the current petroleum-based system:

—*Electricity is Diverse and Domestic*.—Electricity is generated from a diverse set of largely domestic fuels. Among those fuels, the role of petroleum is negligible. In fact, just 1 percent of power generated in the United States in 2008 was derived from petroleum. An electricity-powered transportation system, therefore, is one in which an interruption of the supply of one fuel can be made up for by others. This ability to use different fuels as a source of power would increase the flexibility of an electrified light-duty vehicle fleet. As our national goals and resources change over time, we can shift transportation fuels without having to

overhaul our transportation fleet again. In short, an electrified transport system would give us back the reins, offering much greater control over the fuels we use to support the transportation sector of our economy. Moreover, while oil supplies are subject to a wide range of geopolitical risks, the fuels that we use to generate electricity are generally sourced domestically. All renewable energy is generated using domestic resources. We are a net exporter of coal, which fuels about one-half of our electricity. Although we currently import approximately 16 percent of the natural gas we consume, more than 90 percent of those imports were from North American sources (Canada and Mexico) in 2008. And in fact, recent advancements in the recovery of natural gas resources from unconventional reservoirs like shale gas, coal bed methane, and tight gas sands have led to wide consensus that our domestic undiscovered technically recoverable reserves are well in excess of 1,000 trillion cubic feet. We do import a substantial portion of the uranium we use for civilian nuclear power reactors. Forty-two percent of those imports, however, are from Canada and Australia.

—*Electricity Prices are Stable*.—Electricity prices are significantly less volatile than oil or gasoline prices. Over the past 25 years, electricity prices have risen steadily but slowly. Since 1983, the average retail price of electricity delivered in the United States has risen by an average of less than 2 percent per year in nominal terms, and has actually fallen in real terms. Moreover, prices have risen by more than 5 percent per year only three times in that time period. This price stability, which is in sharp contrast to the price volatility of oil or gasoline, exists for at least two reasons. First, the retail price of electricity reflects a wide range of costs, only a small portion of which arise from the underlying cost of the fuel. The remaining costs are largely fixed. In most instances, the cost of fuel represents a smaller percentage of the overall cost of delivered electricity than the cost of crude oil represents as a percentage of the cost of retail gasoline. Second, although real-time electricity prices are volatile (sometimes highly volatile on an hour-to-hour or day-to-day basis), they are nevertheless relatively stable over the medium and long term. Therefore, in setting retail rates, utilities or power marketers use formulas that will allow them to recover their costs, including the occasionally high real-time prices for electricity, but which effectively isolate the retail consumer from the hour-to-hour and day-to-day volatility of the real-time power markets. By isolating the consumer from the price volatility of the underlying fuel costs, electric utilities would be providing to drivers of GEVs the very stability that oil companies cannot provide to consumers of gasoline.

—*The Power Sector has Substantial Spare Capacity*.—Because large-scale storage of electricity has historically been impractical, the U.S. electric power sector is effectively designed as an "on-demand system." In practical terms, this has meant that the system is constructed to be able to meet peak demand from existing generation sources at any time. However, throughout most of a 24-hour day—particularly at night—consumers require significantly less electricity than the system is capable of delivering. Therefore, the U.S. electric power sector has substantial spare capacity that could be used to power electric vehicles without constructing additional power generation facilities, assuming charging patterns were appropriately managed.

—*The Network of Infrastructure Already Exists*.—Unlike many proposed alternatives to petroleum-based fuels, the Nation already has a ubiquitous network of electricity infrastructure. No doubt, electrification will require the deployment of charging infrastructure, additional functionality, and increased investment in grid reliability, but the power sector's infrastructural backbone—generation, transmission, and distribution—is already in place.

—*Electric Miles are Cheaper Than Gasoline Miles*.—Operating a vehicle on electricity in the United States is considerably less expensive than operating a vehicle on gasoline. In large part, this is due to the high efficiency of electric motors, which can turn more than 90 percent of the energy content of electricity into mechanical energy. In contrast, today's best internal combustion engines have efficiency ratings of just 25 to 27 percent. With gasoline at $3.00 per gallon, the operating cost of a highly-efficient internal combustion engine vehicle (30 miles per gallon) is 10 cents per mile. For current pure electric vehicles, assuming an average electricity price of 10 cents per kilowatt hour, operating costs are only 2.5 cents per mile. Recent research confirms the potential savings of electric propulsion. The Electric Power Research Institute (EPRI) has determined that a compact size plug-in electric hybrid vehicle will use only 160 gallons of gasoline a year, compared to 300 in a gasoline electric hybrid and 400 in a conventional internal combustion engine compact car. With gasoline at $3 a gallon, a

plug-in hybrid would save its owner $10,000 over the course of the vehicle's lifetime compared to a conventional vehicle.

—*Electric Miles are Cleaner Than Gasoline Miles*.—Vehicle miles fueled by electricity emit less CO_2 than those fueled by gasoline. Several well-to-wheels analyses conclude that vehicles powered by the full and proportionate mix of fuel sources in the United States today would result in reduced carbon emissions. As renewable power increases its share of the electricity portfolio, and to the extent that new nuclear power comes on line, which I believe is important, the emissions profile of the U.S. power sector and the GEVs powered by it will continue to improve over time. Moreover, to the extent that GEVs are charged overnight using power from baseload nuclear or off-peak renewable power, their emissions footprint can be nearly eliminated. In 2007, the Natural Resources Defense Council and the Electric Power Research Institute published a well-to-wheels analysis of several different automotive technologies fueled by a range of sources commonly used to generate power. Their analysis concluded that using a PHEV would reduce carbon emissions as compared to a petroleum-fueled vehicle even if all of the exogenous electricity used to charge the PHEV was generated at an old (relatively dirty) coal power plant. Whereas a conventional gasoline vehicle would be responsible for emissions, on average, of 450 grams of CO_2 per mile, a PHEV that was charged with power generated at an old coal plant would be responsible for emissions of about 325 grams of CO_2 per mile, a reduction of about 25 percent. Emissions attributable to the vehicle could be reduced to as low as 150 grams of CO_2 per mile if the exogenous power was generated at a plant without carbon emissions and ranged between 200 and 300 grams of CO_2 per mile if the power used was generated using other fossil fuel generation technologies. In other words, no matter where the power consumed by a PHEV is generated, the overall level of emissions attributable to its operation are lower than those of a conventional gasoline vehicle.

In short, high penetration rates of grid-enabled vehicles—vehicles propelled in whole or in part by electricity drawn from the grid and stored onboard in a battery—could radically minimize the importance of oil to the United States, strengthening our economy, improving national security, and providing much-needed flexibility to our foreign policy while clearing a path toward dramatically reduced economy-wide emissions of greenhouse gases.

No other alternative to petroleum can claim these widespread advantages. This is not to say that other alternatives have no role to play in a post-petroleum transportation sector. On the contrary. Natural gas, for example, may be used successfully in fleet vehicles, particularly those that can be centrally refueled, such as taxis, buses, specialized harbor and airport vehicles, and refuse-collection trucks. Even more importantly, natural gas will play a crucial role in providing electricity, a role in which it can be far more efficiently deployed than in actual vehicles. Other alternatives may also offer advantages in niche uses. But none offers the array of advantages that electricity does.

We also recognize that there may be unforeseen challenges to an entirely new transportation system. For example, some have raised concerns about the supply of lithium, which is crucial for the batteries that will drive the cars and trucks of the future. We have examined this issue and found that, because the vast majority of material in lithium ion batteries is recyclable, the increased use of grid-enabled vehicles does not present the United States with additional resource dependency. Particularly when recycling is assumed, global lithium reserves are adequate to support even the most bullish GEV deployment scenarios. Moreover, at a structural level, dependence on lithium is unlike dependence on oil. Vehicles do not deplete batteries as we drive; they deplete the energy stored within them. In other words, batteries are like the engines in conventional vehicles of today; though their life span is finite, they last for many years. Coupled with the fuel diversity of the electric power sector, grid-enabled vehicles generally insulate consumers from volatile commodity markets.

The logical next question is how we can successfully devise and deploy an electrified transportation system.

Make No Mistake.—Electrification at a mass scale is a complex undertaking. We are not only talking about cars here. We are talking a highly-integrated system of batteries, vehicles, generation, transmission and charging, in which every part depends on the other. We would see few results if we improved transmission in the northeast, created a smart grid in the northwest, and introduced more electric cars in the deep south.

In November 2009, the Electrification Coalition released its Electrification Roadmap, a sweeping report outlining a vision for the deployment of a fully integrated electric drive network. The report details the dangers of oil dependence, explains the

benefits of electrification, describes the challenges facing electric cars—including battery technology and cost, infrastructure financing, regulatory requirements, electric power sector interface, and consumer acceptance issues—and provides specific and detailed policy proposals to overcome those challenges.

Perhaps most importantly, the Roadmap proposes the selection and creation of specific geographic areas in which all of the elements of an electrified transportation system are deployed simultaneously and beyond early adopters, thus providing a crucial first step toward moving electrification beyond a niche product into a dominant, compelling, and ubiquitous concept. These geographic concentrations of electrification would:

—*Drive Economies of Scale*.—Concentrating resources in a limited number of geographic areas will allow participants in the GEV value chain to take advantage of economies of scale, particularly with respect to the deployment of charging infrastructure. Utilities will incur fixed costs to support the operation of GEVs; those costs will be more affordable if spread over a greater number of vehicles. Power providers also can reduce the cost of charging infrastructure through economies of scale. While it is unclear how many public vehicle chargers will be necessary for a GEV transportation system to operate smoothly in a given community, it is clear that some public charging facilities will be needed. Previous pilot studies demonstrate that the cost of installing charging facilities can be reduced significantly when groups of facilities are installed at once. Furthermore, these geographic concentrations will stimulate demand for grid-enabled vehicles at a rate that is likely to be far greater than if the vehicles are simply purchased by early adopters scattered around the United States. Early on in the process, this higher level of demand will simply be the result of magnified consumer incentives. Subsequently, as individual metropolitan areas gain exposure to GEVs and confidence increases, adoption rates should be measurably expedited.

—*Demonstrate Proof of Concept Beyond Early Adopters.*—By demonstrating the benefits of grid-enabled vehicles in a real world environment, this deployment plan will make consumers, policymakers and industry aware of the tremendous potential of electrification of transportation. Most Americans are familiar with traditional hybrids, having seen them on the road for most of the past decade; far fewer drivers are familiar with electric vehicles. In general, consumers are probably unaware that GEVs have evolved to the point where they can meet most individuals' daily driving needs. In addition, electric drive vehicles generally have faster acceleration and operate more quietly than internal combustion engine vehicles. They hold out the promise of offering drivers a wide range of features, based on the electronic package in the vehicle, that are beyond our imagination today in the same way that iPhone applications would have been beyond our imagination a decade ago. The problem is that consumers are not aware of the opportunities presented by GEVs and are not yet convinced that they can operate reliably and affordably at scale. Concentrating investments and other efforts in a limited number of communities will accelerate the opportunity to demonstrate that grid-enabled vehicles can meet drivers' needs. In addition, these projects will demonstrate that a community is capable of putting the infrastructure in place, operating the vehicles over their lifetimes, and disposing of them after their useful life has ended, all in a manner that profits the participants in the value chain.

—*Facilitate Learning by Doing*.—While GEVs present a great opportunity, their deployment also raises a number of questions. Deploying large numbers of GEVs in concentrated areas will allow for the collection of information and experience that is needed to successfully deploy GEVs nationwide. It will help automakers learn how much consumers are willing to pay up front for a car that costs less to operate and has a lower total cost of ownership over its lifetime. It will allow utilities and charging station providers to learn when and where drivers want to charge their vehicles. It will allow utilities and other aggregators to learn who can best sell power to drivers and what types of rate structures meet both drivers' and utilities and aggregators' needs. It will help determine whether there is a viable business model for public charging infrastructure. It is clear that for GEVs to succeed there must be a model in which each party in the value chain is able to operate profitably, or in which the Government determines that, as a matter of public policy, certain aspects of the system should be publicly supported in a manner that facilitates further competition. Deploying GEVs in a series of geographic regions around the country where resources can be concentrated and data can be collected and studied will ultimately accelerate wide-scale GEV deployment. Therefore, rather than allowing the market to develop scattershot across the country, it is critical that the

market be encouraged to develop at a deliberate pace in clearly identified geographic regions in which a large number of vehicles can be deployed in a relatively short period of time.

The success of this path will require focused and sustained public support. Ideally, the technology and deployment of electric vehicles would emerge through regular market mechanisms. Unfortunately, events conclusively demonstrate that this path to wide-spread electrification is unlikely.

We understand that this is a challenging time for suggesting increased Government expenditures for any project, no matter how worthwhile. We also, however, believe that certain aspects of the threat of oil dependence and the solutions we recommend make this a unique issue.

First is the urgent national security threat posed by our dependence on oil. While we cannot and should not ignore costs, threats to national security have always occupied a unique place of priority in our budget considerations. And make no mistake: the dangers posed by our oil dependence are not theoretical. Our safety and security are threatened by oil dependence, and every single day that we do not act is another day that we remain vulnerable.

Second is the economic cost of inaction. The total cost of provisions that we recommend in the Electrification Roadmap is approximately $120 billion spread over 8 years. But Department of Energy researchers have estimated that U.S. oil dependence costs were $577 billion in 2008 alone, including $333 billion from transfer of wealth, $168 billion from economic dislocation, and $76 billion in foregone GDP.

Shortly after completing the Electrification Roadmap, the Electrification Coalition commissioned the Interindustry Forecasting Project at the University of Maryland and Keybridge Research to study the long-term economic effects of our policy proposals. This expert modeling team collectively has decades of experience building and performing simulation studies with large-scale econometric models and conducting public policy research on energy and macroeconomic issues. Our goal was to produce a detailed, sober analysis based on conservative, realistic assumptions stretching out over the next 20 years.

We have not yet released the resulting report, but I wanted to share with the subcommittee some of the key findings in advance.

If the policies we recommend were passed today, the resulting effect on the annual Federal deficit would turn positive by 2020. Even more importantly, on a cumulative basis, the budget effect would turn positive by 2025. By 2030, the total positive impact on the Federal budget would be $336 billion (in between $135 and $156 billion in current dollars).

It is important to remember that one of the results of our oil dependence is the direct transfer of enormous amounts of wealth and capital overseas. Our economy benefits when we reduce oil dependence because we are using more of our own wealth productively here at home instead of sending it to others.

Job creation would also benefit. Enacting these proposals would result in a total of 1.9 million new jobs by 2030, mostly in the manufacturing sector and in direct or indirect support of the motor vehicle industry. Job creation would start immediately with 227,000 in 2010 alone, growing to 700,000 in 2015 and almost 900,000 in 2020. Most importantly, these would not be jobs that we stimulate once and go away once the stimulus is gone. These are jobs that would be a permanent part of a new, ongoing industry.

The U.S. trade balance, which remains one of our Nation's greatest fiscal challenges, would improve by $127 billion—0.35 percent of GDP—by 2030 under the policies we recommend.

The final report, when we release it shortly, will detail additional economic and fiscal benefits, including to household income and GDP.

In short, this economic modeling makes explicit what common sense perhaps already should make clear: if we can spend approximately $15 billion a year for 8 years in order to eventually end an addiction that would otherwise cost us upwards of $600 billion a year in perpetuity, does it not make wise budgetary sense to do so?

The dangers we face are not going to go away on their own. We have before us a responsibility, a necessity to act to put our Nation on a pathway toward once and for all ending our dangerous dependence on petroleum and leaving a stronger, safer America in its place.

It is also an opportunity to strengthen our economy, create jobs, reduce our carbon footprint, and help to balance our budget in the long term.

This is not a question of technology. The technology is there. If anyone on this subcommittee has been watching the Olympics, you've seen the commercials for the Nissan Leaf. You know the Chevy Volt is just around the corner. You're about to hear from business leaders what they can already produce. But the technology is

not enough without the support needed to build infrastructure, encourage manufacturing and consumer acceptance—in short, to create in a few short years an entirely new transportation system. This is not pie-in-the-sky. It's simply a matter of organization, and—more importantly—a matter of will and a matter of execution.

Here is what I know, as the leader of a company that both depends on and helps to strengthen the mobility upon which our global economy is built: If the Government supports this new path, if it helps to build these concentrations of electrification that are so crucial to jumpstarting a new, national transportation system, then that is a game changer. It is a game changer for businesses like mine, for employees, for consumers, for the economy, and for the country. A new future is ours for the taking, but only if we choose it and support it.

Thank you for your attention.

Senator DORGAN. Without objection, we'll include the complete statement of all the witnesses today in the record.

Let me begin. Dr. Kelly, fast-forward 5, 7, or 10 years. You know the amount of money that we have put into battery technology. We are seeing new plants being built in the United States. We're pumping a massive amount of money into new battery technology. Is it your assessment that, in 5, 7, or 10 years, that we are going to make substantial strides in the new batteries that will make the electric cars much, much more attractive to consumers?

The reason I ask the question is there are some consumers that are just very worried about getting in an electric car and running out of power and not having a gas station to pull into. So, give me your assessment, going forward, on battery technology.

Dr. KELLY. Well, of course, for one thing the hybrids run the gamut from the Prius, which, of course, is largely electric with a comparatively small battery, and go all the way up to all-electric batteries. So, if you're concerned about running out on a long trip, you can always get a vehicle that has an onboard engine. And the plug-ins are categorized by how many miles they'll operate without any backup of fuel power. And 40 miles seems to be one of the sweet spots, and that's been where a number of the major companies are going.

In terms of the batteries themselves, we're very optimistic. We've been, of course, in very close conversations with battery producers, in the process of reviewing bids for the Recovery Act, and right now the goal we've set is reducing the price of the lithium-ion battery from what we think is now around $800 a kilowatt hour down to about $300 a kilowatt hour. That seems very feasible in the fairly near term, 2014 or something like that.

In the future, we have our bets on a number of even more advanced technologies that may drive the price down even further. So, I think that the consumers should be optimistic that this problem of battery costs, performance, safety, and lifetime is under control.

Senator DORGAN. Mr. Smith, while there may be a national urge to reduce dependence on foreign oil, and a lot of reasons to move toward a different type of vehicle—electric drive vehicle, in this case—the fact is, if you build a product and consumers don't buy it, you know, it's not going to succeed. We've seen that. A great example is the Edsel car, which a number of us in this room remember. You're a consumer. You, at FedEx, run a lot of vehicles. I don't know how many. But, you're a consumer. Evaluate this from the perspective of a consumer.

Mr. SMITH. Well, Senator, we operate over 70,000 vehicles, so we have a keen appreciation for the exact point that you're making. That's why, in my summary of my testimony, I tried to focus on the productivity improvements inherent in electrification. Your chart, that showed the significant percentage of U.S. automotive trips being less than 40 miles, mean that this concern about running out of electrical power should not be the case for the vast majority of people in the vast majority of instances.

And I don't think that you'll see the country convert completely to electric vehicles, any more than aviation has done away with turbo props in the era of the Jet Age. But, when you start talking about productivity numbers of per-mile cost with a grid-enabled vehicles of 2½ cents a mile versus 10 cents a mile for an internal combustion powerplant over the course of the lifetime of that vehicle, that's about a $10,000 savings.

So, really the issue, I think, is getting the charging stations out. And people, I don't think, should be intimidated by that. Fifteen years ago, I don't think many of us were equipped with one of these devices, which has, obviously, electrical power. We monitor it with a little gauge up here. We clearly know when we have to plug it in to stay in communication, and so forth. And I think this whole psychology of electrical power has been not only held by the lithium-ion battery development because of telecommunications and information technology, it's also been a psychological thing where people feel pretty comfortable with electrical power because it powers so much of our life.

So, I think if you can get these things into scale production where the costs come down, I believe consumers will adopt them, you know, for a lot of their utilization, contrary to a lot of the naysayers. I don't think that today that's a problem.

I'd also point out that one of the things that the Electrification Coalition looked at was whether we would go from a dependence on imported petroleum from hostile regimes to being held hostage to the importation of lithium from hostile areas of the world. And our research indicates, for many reasons, not the least of which that lithium is recyclable, that there is plenty of lithium available from a diverse number of suppliers to allow the electrification of an enormous part of our transportation system and a significant reduction in our dependence on petroleum.

Senator DORGAN. Well, a couple of things. No. 1, I think consumers will beat a path to the door behind which they believe are advantages. So, the cell phone you held up, you know, 15 years ago I think there were some cell phones, but they were the size of a small shoe box, and heavier. And I think the point you made earlier about ramping up from $38 to $147 in day trading, with the price of oil run by speculators who have made money on the way up and money on the way down, leaves consumers very uneasy. I think once we have a circumstance with the product, the infrastructure, and understanding that there's an inherent advantage for consumers and for the country, my guess is that this country is going to move very quickly to it.

The new technologies have persuaded consumers to move very quickly when they think it's in their advantage or when they think it offers something to them that is new and better.

Senator Bennett.

Senator BENNETT. Thank you, Mr. Chairman.

Ms. Smith, I think you hit on a very important point when you were talking about the existing infrastructure. And I'm a little concerned about having charging stations. Let me again use my own example, which I don't think is that atypical. I've been driving a hybrid car, as I say, for about 8, 9 years now. I started out with the Honda Insight. Senator McConnell called it the car you put on like a pair of pants and everybody was wondering how I was able to get in and out of one.

But, I was, and, after a while, decided I wanted a little more car around me for safety purposes, and so, I am now driving a Ford Escape.

And clearly the vast majority of my trips are under 40 miles a day. I commute back and forth. It's about 4½ miles from my house in Arlington to the Capitol. And there's plenty of room to do that and take a few trips downtown and so on. And then the end of the week comes and I have to go to Dulles Airport. And there's no way I can drive that car to Dulles Airport and back with a 40-mile range limit. And may—there's probably, if I've been using it for the running around town, the time I have to go to Dulles Airport, I can't even get there, let alone get back, with the 40-mile circumstance. So, it becomes very limiting, and the cost of building a charging station at the kind of convenience that we have for gasoline stations becomes an infrastructure expense.

So, let me take you to the car that we have going in Utah that I have seen. And this is not a commercial for the company, but the simplicity of the idea struck me as being so obvious, I wondered why the company in Utah was the only one that had come up with it.

They put me in a Hummer. Now, I don't much like a Hummer, but they put me in a Hummer because it's the symbol of the American consumption of gasoline. And the Hummer runs 100 percent on electric power. But, they do have a small gasoline engine on the back of the Hummer. It has nothing to do with driving the Hummer. It is tuned to its most efficient capacity to get the highest quality—or, pardon me, the highest productivity out of the gasoline. It doesn't start up and have all of the inefficiencies connected with a gasoline engine that has to power your jackrabbit start when the gas—when the light changes or any of the rest of it. It only operates at one very narrow band, the most efficient, to run a charger. So, this very small gasoline engine is running a charger on the back of the Hummer so that there's enough range that I could drive 400 miles in that Hummer without ever having to stop to a charging station, therefore duplicate the kind of range that I have in a regular car. And the efficiency of the gasoline motor is substantially better than the efficiency of a gasoline motor tied to a truck or a—take a FedEx truck going around neighborhoods, going to deliveries—relatively short number of miles traveled, but you fill the gasoline tank and the entire power comes from electricity.

It seems to me it would be easier for us to build those kinds of vehicles, and concentrate on that as our first goal, than to say let's make the national investment of trying to have a charging station

everyplace where you have a gasoline station, and then people have to wait while it's charging, and so on and so forth. I'd like your reaction to that technology and that thought.

Mr. SMITH. Well, Senator, I completely agree with you. I mean, if you think about the evolution of a lot of technology, its turning things on its head. In aviation, of course, propellers were the first power plant.

Senator BENNETT. Right.

Mr. SMITH. And then, Sir Frank Whittle and Ohain, in Germany, figured out how to take a propeller, put a shroud on it, and a compressor, where you then vastly increase the efficiency and the power that you could produce. But, the concept was essentially the same. So, today every one of our automobiles has a big internal combustion engine and a very small battery. The battery starts the car and does this and that, and then it is just regenerated.

Well, what you just described is just turning everything on its head, where the powerplant that does the work with the efficiency that I mentioned, of 90 percent, where the electrical power is, you know, turning the wheels at a much, much higher efficiency of the internal combustion engine, and a small internal combustion engine that serves as a generator that keeps the vehicle charged. And I believe that will be the way this technology goes out, rather than pure electrics, for the reasons that you just say. That way, you have the ability to operate all electric on the majority of your short-haul trips. But, when you go to Dulles or wherever you might be driving this, several hundred miles, you've got the capability to do that.

I—just as there are turbo props left in aviation, I don't think that the technology you described will preclude all-electrics. But, I certainly think that a mix will be the same. And when you do have that kind of technology that you just mentioned, you can put your charger at your home garage.

Senator BENNETT. Right.

Mr. SMITH. And, in fact, putting 220-volt capabilities in most homes and apartment buildings is not that big a deal. And, in fact, many of the more modern apartment buildings and electrical installations have 220-volt things. So, your charging stations will become much less of an issue.

But, I agree with you, that technology makes a lot more sense to me.

Senator BENNETT. Dr. Kelly, have you ever heard of anything of that kind or had done any research in that area?

Dr. KELLY. Well, agreeing with Mr. Smith, that technology probably will be the dominant technology for most vehicles. When you say "hybrid vehicle," what you mean is a device that is both powered by electricity and by some kind——

Senator BENNETT. That's correct.

Dr. KELLY [continuing]. Of engine.

Senator BENNETT. The ones I drive now, you're driving sometimes with the gas, you're driving sometimes strictly with the electric motor, and sometimes with both.

Dr. KELLY. Right. The virtue of the plug-in is that when you have utility power available, it's probably cheaper and more efficient to buy it from a utility——

Senator BENNETT. Yes——

Dr. KELLY [continuing]. Than to generate the electricity on board. But, plainly, if you've got the engine on board, then you have unlimited range. You can drive across Utah with it with no problem. It's actually one of the dilemmas of trying to figure out how to calculate miles per gallon for——

Senator BENNETT. Yes.

Dr. KELLY [continuing]. These hybrids, because the ratio of charging to gasoline consumption is going to vary.

Senator BENNETT. Well, they—this company said if you're just making the short trips and you never have the gasoline engine go on, because you can charge it at home, you—it's the equivalent of 800 miles to the gallon, or something like that. And then, they said, if you drove across the country and never charged it, so that it was entirely charged by the little gasoline engine, its 60 miles to the gallon. So, in any event, it's substantially better than anything we're getting now. Yes.

Thank you, Mr. Chairman.

Senator DORGAN. Right.

Senator Alexander.

Senator ALEXANDER. I think we will find—it's always interesting to watch how this technology develops—I think we'll find, if you drove across the country, that might be true if you drove at 35 miles an hour and never accelerated very rapidly and never turned on the air conditioner, because soon as you do, the gasoline engine goes on and——

But, the plug-in—I mean, as I mentioned—we're all talking about our own experiences—every night—I just have a regular plug outside my house. I just plug it in every night. And that's the way the one I have works.

Mr. Smith, the—there've been some widely varying estimates of how rapidly we might be able to make our cars and trucks electric. The National Research Council had a very limited view of what might happen, recently. What's your view? I mean, is it unrealistic to think that, in 20 or 30 years, we might electrify half our cars and trucks? Is that just way out of the ball park? Or is the National Research Council too conservative in its estimates?

Mr. SMITH. We think that they're far too conservative in their estimates. The electrification roadmap would indicate that a much higher percentage of the U.S. automotive fleet can be converted to grid-enabled vehicles, either pure electrics or electric hybrids, by 2025, 2030. And the reduction—I don't recall them right off the top of my head that are in the report—but, the reduction in U.S. oil consumption as a result of this is—it's really dramatic. As I recall, it's something like 5 or 6 million gallons of—is that right—a day?

Senator ALEXANDER. By 2030, it will be 3.2 million barrels a day.

Mr. SMITH. Yes, 3.2-million-barrels-a-day reduction by 2030, with the electrification laid out in that road.

Senator ALEXANDER. Government subsidies are a problem, in the sense that, once they get started, they're hard to stop. You know, we—I've been a critic of the subsidy for wind, because it may have been fine in 1992, but suddenly wind gets subsidized, per megawatt-hour, 25 times all of the forms of producing electricity, which was not what was originally intended. My question is, about re-

search and development—Dr. Chu, I believe, has talked about a 500-mile battery as a grand goal someday. And I have thought, and proposed actually, that we have a mini Manhattan Project on advanced batteries, and just do whatever it took to try to get the battery up to 300, 400, 500 miles per hour. What's the likelihood of that? And why would that not be where we ought to put our greatest effort? Because if we were to get the battery cost down from $7,000, $8,000, $10,000 to a lot less, wouldn't that just create all the other consequences that make electric vehicles marketable?

Dr. KELLY. Well, I think that if you're going to make a short list of grand challenges in all energy that would be one of them. And we are, in fact, trying to put together a very aggressive program in this area. You may know that we have a proposal in our budget for a hub built specifically around advanced battery technology. The Office of Science has been aggressively looking at new materials. And we, of course, are continuing to work with our industrial partners to try to look, not just at the current generation of lithium-ion batteries, but look at lithium-air batteries and a whole range of really interesting, more advanced concepts. So, it's a project certainly worth investment. We think we've got an aggressive program in the works and we'd be anxious to talk to the subcommittee about any other ideas.

One of the dilemmas we have with the National Academy study was I think that they were very pessimistic about driving down the cost of batteries. And I think that their estimates are going to be proven untrue by what's going to actually be in the market in the next few years. So, we're looking forward to sitting down with them and finding out whether we can work through the differences, because I think that we have a very compelling case that dramatic reductions in battery prices and increases in performance are very plausible.

Senator ALEXANDER. Dr. Kelly, I—just as one Senator, but I think there are a lot of Senators on the Republican side, as well as the Democrat, who would say the same thing—I strongly endorse the ideas that Dr. Chu has talked about, about these innovation hubs or mini Manhattan Projects, in a limited number of areas. I mean, you know, the highly efficient photovoltaic cell, whatever else we could figure out about recapturing carbon, that's sort of a—in a way, that's the next Nobel Prize, if you figure that out of—coming out of coal plants. Advanced biofuels would be another. But, the advanced battery would be one. And though—that also seems to me to be a more—the most appropriate use of Federal dollars. I mean, Federal R&D is something we're comfortable with, and is easy to justify. It doesn't interfere with the market too much. It doesn't duplicate as much what is naturally done in the private sector. So, I want to congratulate you for those objectives and encourage you, especially, just to—if you're doing three acts, to try to do four acts or five acts or six acts, in terms of advanced batteries.

Thank you.

Senator DORGAN. Senator Alexander, thank you.

I just would observe, if you take a look at previous supplementals, the omnibus and the Economic Recovery Act, we almost have—both in terms of grants, direct appropriations, and loan

guarantees, a kind of a mini Manhattan Project on batteries. There is a massive amount of money moving in that direction from several different sources. So, I certainly support the thought of the Senator from Tennessee. I think this investment can yield very significant results.

Senator Cochran.

Senator COCHRAN. Mr. Chairman, first, let me thank you for calling the witnesses to this subcommittee to discuss these interesting issues.

I'm particularly glad to be here and welcome my friend Fred Smith. We appreciate Dr. Kelly's participation, as well.

I was looking through the electrification roadmap recommendation that has been developed—I guess, by the Coalition, which you're chairing—and I wonder, specifically what can Congress do now that will help encourage or give direction to those who will be involved in moving us into this new era of electrification of our transportation system? Is there a roadmap for us in Congress, as well as a road map for policymakers and business and industry that you are recommending that we consider?

Mr. SMITH. Okay. Well, Senator, yes, sir. In that roadmap, there were several recommendations for the Government.

Before I get into that, let me just mention a couple of numbers, because they'll relate to the recommendation. The Electric Power Research Institute estimated that a plug-in hybrid vehicle, like Senator Bennett mentioned, will consume about 160 gallons of gasoline a year. That compares with a—the current gasoline electric hybrid, which has, essentially, two power systems in there, one electric and one gasoline, of about 300 gallons per year, and a conventional internal combustion engine, of about 400. So, I mean, it is order-of-magnitude savings. And over the lifetime of that car, that's about $10,000 less expense to the driver, based on electrical power at today's grid rate.

So, the issue is not that these vehicles can't be cost effective; it's not like wind power, where we just don't know how to make wind power that is competitive with coal power, nuclear power, natural gas power, hydroelectric power. This technology is cheaper than the technology it replaces on an operating basis. So, it's the upfront capital costs.

And so, the number-one thing is to drive the economies of scale. And our recommendations in that report is to concentrate the efforts in a few areas so that you have the vehicle technology and the grid technology coming to fruition at the same time—that's one thing—and to continue to demonstrate the benefits of the technology by deploying a lot of these vehicles in a few locations, where it becomes obvious to people that these economics are correct.

And I believe, based on my experience in—and again—I hate to keep going back to aviation, because—but it's very similar, in many ways. There were so many things that, when they first came out, the production cost of them, relative to the technology that they replaced, was very, very high. But, after they began to be adopted, they became quite cheap. And in aviation, as you know, the Government subsidized aviation for many years through airmail contracts, because there simply was no airplane that could earn its own way. And then Donald Douglas built the DC–3, and the DC–

3 was the first airplane that could make money carrying passengers and a little bit of air express. And World War II came along, and they produced thousands of them, and we were literally off to the races, in terms of modern aviation standing on its own.

So, this technology has a return on investment right now. It's simply that people—unlike a business, if the car costs more to buy, they don't look at the net present value of that $10,000 of savings. So, you've got to drive the production costs down so they can have their cake and eat it, too. They can have comparable acquisition costs and less operating costs, both.

Senator COCHRAN. Well, thank you very much.

And thank you both for the contributions you're making to this national debate—improving our information base, leading us in the direction of better decisions.

Thank you.

Senator DORGAN. Senator Cochran, thank you very much.

Let me thank both Dr. Kelly and Frederick Smith. Thank you for being here today, and thank you for your testimony. And we'd like to have you available to respond to written questions if we submit written questions to you.

The second panel today will be Richard Lowenthal, founder and CEO of Coulomb Technologies. They've been a leader in the development of technology for electric vehicles. They currently offer a wide range of products and services that provide charging infrastructure for plug-in vehicles.

Mr. Alan Taub, who is the vice president for research and development at General Motors, he's responsible for GM's advanced technical work activity which manages major innovation programs within the company. He has also worked at Ford Motor Company for 8 years, where he was manager of the material science department and manager of vehicle engineering for the Lincoln brand.

Mr. Kraig Higginson, chairman and founder of Raser Technologies, is chairman and founder of a clean energy company focused on comprehensive low carbon strategies through the development of new geothermal and electric vehicle technologies, and Mary Ann Wright, vice president and managing director of Johnson Controls. Ms. Wright is leading a dedicated global project team to oversee the Department of Energy ARRA Grant Program for advanced energy storage, including the launch of Johnson Control's first U.S. manufacturing facility in Holland, Michigan. She also previously worked at Ford Motor as a director of sustainable mobile technologies and the hybrid vehicle programs. And while at Ford, she served as the chief engineer of the 2005 Ford Escape Hybrid, the industry's first full-hybrid SUV.

Senator BENNETT. Mr. Chairman, if I may, Mr. Higginson is the CEO of the company that put me in the hybrid, and the—put me in the Hummer, rather—and the technology that I described is his company's technology. I wanted, while the experts were here, to keep it plain vanilla, but now that the constituent is here I want to say, very directly, that Raser is—Raser Technologies is the company that has developed that. They actually have a car, it does work. And they did not charge it off the grid. They do geothermal, and they charged the Hummer that I drove entirely out of heat coming out of the ground. So, I'm happy to acknowledge you're the

constituent here, and do a little bit of hometown home cooking now that he's here at the table.

Senator DORGAN. Well, thank you, Senator Bennett. By the way, how heavy is that Hummer?

Senator BENNETT. It's as heavy as any other.

Well, ask Mr. Higginson, he can tell you that.

Senator DORGAN. One other question. I got a call from the Governor of California, Governor Schwarzenegger, one day, thanking me for my work on hydrogen and so on, and he talked about his Hummer. Were you involved with his Hummer?

Mr. HIGGINSON. We actually took the Governor to lunch in the Hummer, so he's driven it.

Senator DORGAN. Aha, okay.

Well, thank you, Senator Bennett, for the additional information and the hometown commercial.

Let me thank all of you for being here. Your entire statements will be part of the permanent record. You may proceed.

Mr. Lowenthal, you first.

STATEMENT OF RICHARD LOWENTHAL, FOUNDER AND CEO, COULOMB TECHNOLOGIES

Mr. LOWENTHAL. Thank you very much, Chairman Dorgan and the members of the subcommittee. We appreciate the opportunity to be here today to talk about this tremendous opportunity for our country.

I'm the founder and CEO of Coulomb Technologies, a company that is deploying charging stations and business software systems for electric vehicle charging, a necessary ingredient for the successful adoption of electric vehicles.

Recently, Coulomb Technologies was selected by the Department of Energy to participate in an Electrification of Transportation Program that was recommended for funding by this subcommittee. Thank you very much. This public/private partnership, entitled "Charge America," will deploy a charging infrastructure in 12 American cities. We'll begin to deploy technology almost immediately, creating American jobs in engineering, manufacturing, and installation.

Electric vehicles will begin to appear on American roads and highways this year. But, for electric drive technology to be truly transformative, the market will need assistance in overcoming a number of challenges. Beyond financial issues, there are a set of regulatory issues that will need to be addressed at the Federal level.

Electric vehicle charging stations, known formally as Electric Vehicle Supply Equipment or EVSE, are available in three levels. Level I EVSEs are based on 110-volt household electricity. Level I charging is slow. A 30 kilowatt-hour battery, like the one in my BMW MINI–E, takes 23 hours to charge on Level I. Smaller PHEV batteries, like the plug-in Prius, will take less time. And the Chevrolet Volt, which you'll hear more about, I'm sure, is specified to take approximately 10 hours to charge completely at Level I.

The Level I charger times will likely convince most EV owners to opt for higher voltages and faster Level II charging.

Level II charging is specified at 220 volts, similar to an electric clothes dryer. With a Level II charger, vehicles will take about 4 hours to charge.

Level III, or DC chargers, can charge vehicles in under an hour. DC fast-charging equipment will be significantly more expensive than Level I and Level II chargers, and it's expected to be available only at commercial charging establishments.

Setting aside technical specifications, charging infrastructure can generally be divided into two categories: private charging infrastructure, for in the home, and shared charging infrastructure, for places like condominiums, apartments, retail centers, public parking facilities in the workplace, and along transportation arteries.

As important as access to home charging will be for achieving high rates of electric vehicle deployment, shared charging is arguably even more important during the early stages of EV adoption. Drivers are accustomed to being able to fill up using the ubiquitous gasoline infrastructure developed over the last 100 years. Insufficient public charging opportunities will generate hesitancy and could hinder the adoption of electric vehicles. Studies show that 80 percent of EV owners will want to charge the cars more than once a day.

Range anxiety on the part of consumers remains a substantial challenge for EV adoption. People are afraid that their vehicle will be incapable of traveling the long distances required or that they will be unable to get the necessary recharge along the way. Despite the fact that data on consumer habits shows that drivers rarely travel long distances, when asked their opinions, they express unease over range. Early research supports the conclusion that reliable access to public charging infrastructure diminishes this anxiety.

The first mass-produced, fully-electric vehicles in the U.S. markets will have an all-electric range of approximately 100 miles. With these vehicles, when the battery is depleted, it must be recharged before the vehicle can be driven again. Consumers are unlikely to purchase a vehicle unless they have confidence that it can be conveniently refueled.

So, I have some policy recommendations. Permitting electrical work is a local issue, typically the responsibility of a city or a county government, and rules vary widely between jurisdictions. The process of requiring an electrician to obtain a permit and schedule an inspection can stretch an otherwise short and simple electrical upgrade into a burdensome, several-weeklong process, a concern that was confirmed by several participants in the recent project conducted by BMW in Los Angeles, New York, and New Jersey.

So, first, policy, we need streamlined permitting processes nationwide for the installation of EVSE in order to get those times to reasonable levels.

Second, today there are roughly 54 million private garages for the 247 million light-duty vehicles that we have in the United States. For consumers who park in parking lots or curbside at night, overnight charging requires shared stations. By treating electricity as a transportation fuel, regulators can foster competition in the nascent EV infrastructure marketplace and help to facilitate a rapid deployment of public charging infrastructure.

The California Public Utilities Commission recently indicated that it is not inclined to regulate electricity for sale for EVs. Nonetheless, the decision is not yet finalized and represents the opinion of only a single PUC.

In many cases, current regulations require a seller of electricity to be treated as a regulated utility. In other words, if an apartment building, shopping center, or fast food restaurant has been—has charging stations, it could be subject to the full range of regulatory compliance mechanisms that affect utilities. This level of regulation would likely present—prevent even minimal deployment of charging infrastructure in the public, in private garages, in condominiums, apartments, and the workplace.

Rather than depending on the Nation's public utilities commissions to rule on this, we would ask that the Federal Energy Regulatory Commission ensure that electric vehicle charging is a competitive marketplace with market-based pricing.

I'll leave some of these issues, because I'm running out of time, for you to read it at your leisure. Let me skip a couple, hit on one that was mentioned earlier.

The electric power sector has substantial untapped generating capacity offpeak, which can already allow millions of EV batteries to be charged without adding power generation or transmission. However, consumers will likely require incentives to charge offpeak, and disincentives to charge during peak demand, high-cost hours. Utilities and equipment providers should provide Smart Grid integration technology for demand response and time-of-use charging.

Let's see, I'm going to skip the next one.

EV charging stations are designed and manufactured in the United States, and distribution is available nationwide. Our products are "shovel-ready" and require the skills of local electricians and contractors to install, providing jobs nationwide. Each station we install employs three people for a day.

Our company has faced the classic chicken-and-egg problem. Consumers will not adopt electric drive technology if they're not confident in their ability to refuel. At the same time, there is little incentive for companies to install charging infrastructure before cars arrive.

The Federal Government can, and is, playing an important role as it considers stimulus spending and other financial incentives to assist this nascent market for electric vehicle charging infrastructure. And so, I recommend that—public investment in EV infrastructure that creates jobs and addresses this chicken-and-egg problem.

Next, currently there's a 50-percent tax credit available for charging-infrastructure installations, which expires at the end of this year. We would like to see that extended. The time—the vehicles have not rolled out yet, and it would be very helpful for that to be extended, and, in addition, for it to be improved.

PREPARED STATEMENT

Finally, let me add one other comment in support of the Electrification Coalition. We would like to see targeted spending, as the DOE has recommended and deployed in other cases, where par-

ticular areas of the country are focused on for deployment of electric vehicles in order—and infrastructure—in order to ensure these programs have the scale necessary for success.

Thank you very much.

[The statement follows:]

PREPARED STATEMENT OF RICHARD LOWENTHAL

Good morning Chairman Dorgan, Senator Bennett, and members of the subcommittee. Thank you for the opportunity to speak with you regarding a tremendous opportunity for our country—the transition to electric-drive transportation. I'm the founder and CEO of Coulomb Technologies, a company that is deploying charging stations and business software systems for electric vehicle charging, a necessary ingredient for the successful adoption of electric vehicles.

Recently, Coulomb Technologies was selected by the Department of Energy to participate in the Electrification of Transportation program that was recommended for funding by this subcommittee. This public/private partnership entitled "Charge America" will deploy charging infrastructure in up to 12 American cities. We will begin to deploy technology almost immediately, creating American jobs in engineering, manufacturing, and installation.

An electric drive future is one that leverages the diversity, flexibility, and stability of the electric power sector to sustainably power our transportation sector. Today, our cars and trucks rely on a single energy source—petroleum—for more than 95 percent of their delivered energy. This heavy reliance has generated profound economic, national security, and environmental risks for the United States. In contrast, vehicles that draw power from the grid—grid-enabled vehicles (GEVs)—derive their energy from the full range of fuel sources that produce electricity in the United States today. These fuel sources are stable, domestic, and diverse.

Grid-enabled electric drive systems can be either pure electric vehicles (EVs) or plug-in hybrid electric vehicles (PHEVs). Both EVs and PHEVs store energy from the grid in on-board batteries. Energy from the battery powers a highly efficient electric motor that propels the vehicle. EVs substitute an electric drivetrain for all conventional drivetrain components. PHEVs retain the use of a down-sized internal combustion engine that supplements a smaller battery.

Both EVs and PHEVs provide consumers and the broader economy with two distinct advantages compared to conventional vehicles. First, electric miles are cheaper than gasoline miles. Operating a vehicle on electricity in the United States is considerably less expensive than operating a vehicle on gasoline. In large part, this is due to the high efficiency of electric motors, which can turn 90 percent of the energy content of electricity into mechanical energy. In contrast, today's best internal combustion (IC) engines have efficiency ratings of just 25 to 27 percent. With gasoline at $3.00 per gallon, the operating cost of a highly efficient IC engine vehicle (30 miles per gallon) is 10 cents per mile. For current pure electric vehicles, assuming an average electricity price of 10 cents per kilowatt hour, operating costs are only 2.5 cents per mile.

Second, electric miles are cleaner than gasoline miles. Vehicle miles fueled by electricity emit less CO_2 than those fueled by gasoline—even with today's mix of generating resources. As renewable power increases its share of the electricity portfolio, and to the extent that new nuclear power comes on line, the emissions profile of the U.S. power sector will continue to improve over time; this improvement will directly enhance the emissions benefits of grid-enabled vehicles.

By adopting these technologies at scale, the United States would dramatically reduce its dependence on petroleum, achieve significant reductions in energy-related greenhouse gas emissions, and catalyze the next generation of industry and manufacturing jobs that could be the backbone of our country's economic competitiveness in the decades to come. Ultimately, moving to an electric-drive transportation sector would also substantially increase disposable income for American households, because overall spending on energy would decrease.

This transition is not only technologically possible, it is fundamentally necessary if we are to improve our economic and national security while preserving our natural environment. However, the wide-scale transformation of our petroleum-based transport system to one powered by electricity is far from certain today. There are a number of challenges facing electrification that, if not addressed in the near-term, could postpone or prevent progress toward a more secure, efficient transportation sector.

I want to be clear in stressing that these challenges are not technological problems with batteries, vehicles, or chagrining infrastructure. While ongoing research

and development will be critical, battery technology has advanced to the point at which grid-enabled vehicles will provide consumers with the performance, safety, and durability that they require. To be sure, cost continues to be a factor. However, it is important to note that based on existing Federal tax credits, and at today's gasoline prices, a plug-in hybrid electric vehicle will already provide consumers with a net economic benefit over the life of the vehicle.

Electric vehicles will begin to appear on American roads and highways within a year. But for electric drive technology to be truly transformative, the market will need assistance in overcoming a number of challenges. Beyond financial issues, there is a set of regulatory issues that will need to be addressed at the Federal level.

SOME DEFINITIONS

Electric Vehicle charging stations, known formally as electric vehicle supply equipment (EVSE), are available in three "Levels". Level I EVSEs are based on 110-volt household electricity. Level I charging is slow. A 30 kWh battery in a pure EV could take as long as 23 hours to fully charge. Smaller PHEV batteries will take less time, with the Chevrolet Volt specified to take approximately 10 hours to completely charge at Level I.

These Level I charge times will likely convince most EV owners to opt for higher voltage and faster Level II charging. Level II charging is specified at 220 volts, similar to an electric clothes dryer. With a Level II charger, vehicles will take about 4 hours to charge.

Level III, or DC chargers, can charge vehicles in under an hour. DC fast-charge equipment will be significantly more expensive than Level I or II chargers and is expected to be available only at commercial charging establishments.

Setting aside technical specifications, charging infrastructure can generally be divided into two categories: shared and private. Private charging infrastructure would include a charging station installed in a private home for dedicated use by a single customer. Shared charging infrastructure would include units installed in condominiums, apartments, retail centers, public parking facilities, the workplace, or along major transportation arteries.

For drivers with access to a dedicated outlet, the most convenient time to charge their GEV will be overnight at home. Most passenger vehicles sit parked during the hours between roughly 8 p.m. and 6 a.m., which could provide ample opportunity to supply consumers with the charge levels required for typical daily usage of GEVs. Moreover, by concentrating charging during off-peak hours, the electric power sector could today charge more than 100 million GEVs (if the vehicles were entirely PHEVs, the number could be as high as 160 million) without the need to install significant additional generating capacity. While Level I charging will be an option for some PHEV owners, most consumers will prefer Level II charging in their homes.

As important as access to home charging will be for achieving high rates of electric vehicle deployment, shared charging is arguably even more important during the early stages of EV adoption. Drivers are accustomed to being able to fill up using the ubiquitous gasoline infrastructure developed over the last 100 years. Insufficient public charging opportunities will generate hesitancy and could hinder the adoption of electric vehicles. Studies show that 80 percent of EV owners will want to charge more than once a day.

Range anxiety on the part of consumers remains a substantial challenge for EV adoption. People are afraid that their vehicle will be incapable of travelling the long distances required, or that they will be unable to get the necessary recharge along the way. Despite the fact that data on consumer habits shows that drivers rarely travel long distances, when asked their opinions, they express unease over range. Early research supports the conclusion that reliable access to public charging infrastructure diminishes this anxiety.

The first mass-produced fully-electric vehicles (BEVs) to reach U.S. markets will have an all-electric driving range of approximately 100 miles. With these vehicles, when the battery is depleted, it must be recharged before the vehicle can be driven again. Consumers are unlikely to purchase a vehicle unless they have confidence that it can be conveniently refueled.

Regardless of which technology—PHEV or EV—captures the dominant share of the market at any time, consumers will demand access to public charging infrastructure. Whether one is concerned about operating efficiency or basic necessity, grid-enabled vehicles will need to charge their batteries conveniently. If the market fails to meet this standard upfront, high operating costs and consumer anxiety about range will simply prevent grid-enabled vehicles from reaching mass market penetration. In this sense, we are faced with a classic problem of coordination. Con-

sumers will not adopt electric drive technology at scale if they are not confident in their ability to refuel. At the same time, there is little incentive for the private sector to install public charging infrastructure if that equipment is expected to sit idle.

POLICY RECOMMENDATIONS

Permitting electrical work is a local issue—typically the responsibility of city or county governments—and rules vary widely between jurisdictions. The process of requiring an electrician to obtain a permit and schedule an inspection can stretch an otherwise short and simple electrical upgrade into a burdensome, several week-long process, a concern that was confirmed by several participants in a recent pilot project conducted by BMW in Los Angeles, New York, and New Jersey. Market participants have suggested allowing third parties to inspect newly installed equipment and even to allow installers to self-certify the installation.

Policy 1.—We Need Streamlined Permitting Processes Nationwide for Installation of EVSE

Today, there are roughly 54 million private garages for 247 million light-duty vehicles (cars and SUVs). For consumers who park in parking lots or curbside at night, overnight charging requires shared stations.

By treating electricity as a transportation fuel, regulators can foster competition in the nascent EV infrastructure marketplace and help to facilitate rapid deployment of public charging infrastructure. The California Public Utilities Commission recently indicated that it is not inclined to regulate electricity sales for EVs. Nonetheless, the decision is not yet finalized and represents the opinion of only a single PUC.

One critical issue is that electricity for GEVs is not yet viewed as a transportation fuel. For public charging infrastructure, this precedent could present particularly burdensome regulatory issues. In many cases, current regulations require a seller of electricity to be treated as a regulated utility. In other words, if an apartment building, shopping center, or fast food restaurant has charging stations, it could be subject to the full range of regulatory compliance mechanisms that affect utilities. This level of regulation would likely prevent even minimal deployment of shared charging infrastructure in the public, in private garages, in condominiums, apartments, and the workplace.

Rather than depending on all of the Nation's public utility commissions to come to the conclusion that we need a competitive commercial market for vehicle charging, we need a national policy of allowing free-market vehicle charging, potentially through Federal Energy Regulatory Commission policy and authority.

Policy 2.—FERC Should Ensure That Electric Vehicle Charging is a Competitive Market With Market-Based Pricing for Charging Vehicles

The United States has over 3,000 electric utilities. Drivers will charge in several different utilities' service areas. Because no third-party provider is likely to be ubiquitous, some type of "roaming" capability will likely be necessary. On longer trips, this is sure to be the case.

It is important that the responsibility not be placed on drivers to establish billing relationships with all utilities within whose service area they may charge.

Policy 3.—Payment Systems That Allow for Consumer Roaming Should Be Encouraged

Today, the electric power sector has substantial untapped generating capacity off peak, which can already allow millions of EV batteries to charge without adding power generation or transmission capacity. However, consumers will likely require incentives to charge off-peak and disincentives to charge during peak demand, high-cost hours. Utilities and equipment providers should include smart-grid integration technology for demand response and time-of-use charging plans.

Policy 4.—Smart Grid Integration, Demand Response, and Time of Use Pricing Should Be Required

Coulomb has developed electric vehicle charging stations and business software systems that ensure EV charging is a sustainable, scalable business. Our stations include a business software suite that includes a billing system that provides money to pay for all recurring costs, and asset management tools to allow infrastructure to be well-managed. We have the capability to build charging infrastructure that will enable rapid growth of the electric vehicle market, and we have been shipping these products since 2008.

Policy 5.—Charging Infrastructure Selection Must Consider Life Cycle Costs

EV charging stations are designed and manufactured in the United States and distribution is available nationwide. Our products are "shovel-ready" and require the skills of local electricians and contractors to install, providing jobs nationwide. Each station we install employs three people for a day.

Our company has faced a classic chicken and egg problem. Consumers will not adopt electric drive technology if they are not confident in their ability to refuel. At the same time, there is little incentive for companies to install charging infrastructure before the cars arrive.

The Federal Government can play an important role as it considers stimulus spending and other financial incentives to assist the nascent market for electric vehicle charging infrastructure. Public sector investment in shared charging infrastructure during the early phases of EV deployment can help overcome consumer range anxiety and enable those who don't have home charging stations to buy these cars.

Policy 6.—Public Investment in EV Infrastructure Creates Jobs and Addresses the Chicken and Egg Problem

Currently, there is a 50 percent tax credit available for infrastructure installations, which expires at the end of this year.

Congress should extend the tax credit for alternative fueling facilities and make it useful by making it convertible to a rebate or to a payroll tax credit.

There are far too many restrictions in the current tax credit. For example, it cannot be used for station owners who pay the alternative minimum tax or for companies with tax loss carry forward.

Policy 7.—Extend and Improve the Infrastructure Tax Credit That is About to Expire

In order to benefit from Level II charging in their homes, a large percentage of EV consumers will require the installation of a dedicated 220 volt circuit in their garages or car ports. These installation costs can be dramatically reduced if garages are pre-wired for electric vehicle charging.

While building codes are generally a local/municipal issues, I cannot stress their importance enough. All new garages and parking lots should be required to include wiring for future electric vehicles. This will significantly lower the cost of adding EVSE later.

Policy 8.—The Federal Government Should Use its Clout To Ensure That Building Codes Nationally Require all New Parking Places Include Wiring for Future EVs

Finally, like Mr. Smith, who spoke on your first panel, I am a member of the Electrification Coalition, a group of CEOs from companies that represent the entire value chain of electrification. The Coalition and its members are committed to promoting policies and actions that facilitate the deployment of electric vehicles on a mass scale in order to combat the economic, environmental, and national security dangers caused by our Nation's dependence on petroleum.

As a final policy recommendation, I would like to stress the importance of the concept of targeted investment in a limited number of electrification ecosystems. Such a program will accomplish a number of important objectives: it will prove that electric vehicles work as a concept; it will help drive economies of scale for a number of businesses; and it will facilitate critical research on technology and driver behavior. Most critically, it will create the local networks in which electric vehicles can thrive.

This technology is here today. We have the capability right now to deploy an electrified transportation sector that will dramatically improve our Nation's trade balance, national security, and environment, and reduce consumers cost of transportation. What is required is coordination and support to push past initial regulatory and financial hurdles. This is the right thing to do for our Nation, and I urge you to move forward.

Thank you for your time and your attention.

Senator DORGAN. Mr. Lowenthal, thank you very much, next, Alan Taub, vice president for research and development at General Motors.

Mr. Taub, thank you for being here.

STATEMENT OF ALAN I. TAUB, Ph.D., VICE PRESIDENT, GLOBAL RESEARCH AND DEVELOPMENT, GENERAL MOTORS

Mr. TAUB. Pleasure to be here today and, in particular, to talk about General Motors plans for vehicle electrification, and specifically the Chevrolet Volt. I couldn't have done a better job than Mr. Bennett just did to describe the philosophy of the consumer that was behind the Chevy Volt theory.

What we do on the Volt is have it plug into the grid; put the electricity into the battery, and that will enable 40 miles of driving range. When, in the course of the drive, that battery is depleted, we have a motor—an engine generator on board to allow the consumer to go the additional 300 miles they're used to today. It's the way to get the best of today's vehicle technology and introduce this breakthrough of electric drive systems. We're hoping that's actually the car you'll be choosing next.

We're going to be launching the vehicle this——

Senator BENNETT. Can I ask you, does the gasoline engine drive the wheels or the——

Mr. TAUB. No. In our full hybrids, our two-mode hybrids, say, we have on the Escalade, that's what's called a parallel hybrid and goes——

Senator BENNETT. Right.

Mr. TAUB [continuing]. Straight to the wheels. This is called a series hybrid, which is what you're describing——

Senator BENNETT. It does the same thing that Mr. Higginson——

Mr. TAUB. It's the same concept, with different embodiments.

Senator BENNETT. Okay. Thank you.

Mr. TAUB. And so, ours will be launching, this November. In its first year, we'll be selling thousands of these, and, as we ramp up in subsequent years, tens of thousands a year is in our production plans.

Clearly, the success of any vehicle electrification requires not just the vehicle solution, but the infrastructure. And it's important that we design that infrastructure to meet the consumer needs. So, we've been studying this problem with EPRI, with electric utilities, with other interested parties and battery makers.

Our conclusion is that the research shows that consumers refuel close to home and close to work. And so, we believe the first priority for the infrastructure should make easy charging for the consumer at home. And Mr. Lowenthal spoke about some of those options. Then move the infrastructure to the workplace. And because our Volt technology eliminates the range anxiety, we really think the public charging infrastructure should happen, but later on in the development of the infrastructure.

You asked us to talk about how we get this to high volume. Clearly, we need the refueling infrastructure to keep up with the vehicle, infrastructure in the vehicle production. But, I also want to emphasize, we need to get through making this technology affordable in the right value equation for the consumer. Traditionally in the automotive industry, that means three cycles of learning, three cycles of technology development, and three cycles of commercialization. It's in that third cycle, where the technology has become robust, cost effective, and is able to go into the tens of millions of units, that we feed into the car park.

In order to get to the first generation of technology, the efforts of this subcommittee, the Department of Energy, and the other agencies, have really allowed us to accelerate up to that first cycle. So, whether it's the Freedom Car funding, the fuel partnership, or the stimulus funding, which allowed us to go forward for domestic production by GM of motors and battery packs, that's the first step.

Our view is to keep up the momentum on this key technology. We need to find a way to take our private/public partnership through generation two. It's at generation three, we've met the consumer value equation and it's self-sustaining. It's the partnership through generation one and two, both technology development and commercialization, that's key.

So, to summarize, in terms of the priorities as we see them, first, again, focus the initial infrastructure for charging on the home.

Second and I want to remind the subcommittee that the batteries, right now, are the most expensive element of electric vehicles, but similar efforts are needed on electric motors and power electronics. The breakthroughs in technology are required on all three components, and we need to ensure that production of those three is also done domestically.

Third key is, as we develop automotive batteries, at the end of vehicle life they are still good batteries for other applications. And as the Electric Coalition pointed out, there are ways we can put in place to incentivize the use of these batteries after vehicle use, such as putting a floor on the value of the automotive batteries if they make their way into the stationary grid.

The last point I want to make is a reminder that—for General Motors and, I think, for the industry, electrification means the vehicle is powered by—moved by motors that are powered by electrons. There are two ways to do that on a vehicle. One is the battery electric vehicle we've been talking about. The other is a fuel cell vehicle, which still has the same motors, power electronics, and other drive elements. Fuel cells have the advantage of being applicable to larger vehicles and also having larger vehicle range. What that means is, as we see the future of vehicle electrification, it's not an either/or, it's an "and" solution. A plug-in grid, battery vehicles, augmented by the auxiliary power units that we described, our Voltec technology, and for larger vehicles, the hydrogen fuel-cell economy.

PREPARED STATEMENT

And so, relative to that, in addition to continuing to support the battery work, we really would like to see the United States remain the leader in fuel cell technology, as well. And specifically, what we'd like to recommend is extending the present Fuel Cell Test and Validation Program into fiscal year 2011, and also to think about incentivizing the marketplace by a pre-commitment of Government fleets for fuel cell vehicles, in order to enable that technology to move. And just like you're having this hearing, the question is, how do we ensure the United States puts in the infrastructure for not just electrification, but for hydrogen, so we keep pace with Japan and Germany in that regard?

I'll look forward to your questions. Thank you.

[The statement follows:]

PREPARED STATEMENT OF ALAN I. TAUB, PH.D.

Mr. Chairman and subcommittee members, thank you for the opportunity to testify today on behalf of General Motors. I am Alan Taub, Vice President of Global Research and Development. I lead GM's worldwide R&D efforts on advanced technology.

I am pleased to be able to speak to you today regarding our plans for the Chevrolet Volt and our other electrically driven vehicles. I also look forward to discussing the infrastructure that will be needed to ensure that recharging and refueling options are available to American consumers.

This is an important time in the history of the automobile industry. The world we live and do business in is changing. Automotive technology is clearly changing and the challenges and opportunities faced by our industry continue to evolve.

For these reasons, GM has placed very high priority on vehicle electrification. We believe electric vehicle technology is one of the best long-term solutions to simultaneously increase energy independence and security, remove the automobile as a source of emissions, and enable more sustainable energy pathways.

The electrification of the vehicle will also allow automakers to create exciting new vehicles that customers will want to drive and own. This is critical. Achieving high-volume sales of advanced technology vehicles is the only way to realize the large-scale energy and environmental benefits we are seeking.

To support our focus on bringing the right products to market, at the right time, for the right cost, GM has an advanced propulsion technology strategy that addresses both energy efficiency and energy diversity.

As part of this strategy, we are working to dramatically improve the efficiency of our conventional engines and transmissions, as we've been doing for decades. We have also been working hard to improve overall vehicle efficiency by reducing vehicle weight and improving aerodynamics and rolling resistance.

At the same time, we have intensified our efforts to displace petroleum-based fuels by building more vehicles that run on alternative fuels. This includes biofuels such as ethanol and biodiesel. In fact, of the 7.5 million E85 flex-fuel vehicles currently on U.S. roads, more than 4 million are GM cars and trucks. GM, along with Ford and Chrysler, has committed to make one-half of our vehicle production flex-fuel-capable by 2012, provided there is steady growth in the fueling station infrastructure.

Our commitment to alternatives also includes expanding and accelerating our development of electrically driven vehicles.

Today, I want to highlight our progress on GM's broad-based plans for vehicle electrification, which includes the Chevrolet Volt extended-range electric vehicle, plug-in hybrids, and fuel cell-electric vehicles. GM is working on all of these vehicle solutions because they are all electrically driven, yet each offers unique attributes that align with different driving needs.

Electrification simply means the vehicle is powered by electrons that energize the motor. There are two ways to accomplish this. One is to use a battery that draws electricity when it is plugged into the grid. The other way is to store electrical energy in the form of hydrogen on board the vehicle and convert it into electricity in real time.

Developing a variety of electric vehicles is also the best way to meet the driving needs of our customers. Those needs can involve a short commute to work, longer-range driving, or the requirement to carry more passengers or haul cargo. In other words, we think consumers will love the compact Chevrolet Volt extended-range electric vehicle for city and suburban driving. Meanwhile, our Chevrolet Equinox fuel cell EV—which has logged more than 1.2 million miles of driving through our Project Driveway market test—would appeal to drivers who need a larger vehicle.

Since electrically driven vehicles use many common components and subsystems, technology developments can be applied across the range of EV options.

GM believes there are many benefits available with electrically driven vehicles. They have the potential to:

—Reduce petroleum consumption.

—Create the pathway to new energy sources.

—Reduce CO_2, especially as utilities add renewable energy sources to their portfolio.

—Create new technology jobs in areas such as cell chemistry, batteries, motors, power electronics and controls, and vehicle systems. Today, the Volt supply base already includes 196 suppliers in 24 States. And that's just beginning to scratch the surface of the potential for advanced vehicles to be a real driver for economic and jobs growth.

Beyond these societal benefits, the electrification of the vehicle also enables auto manufacturers to design a better vehicle. The instant torque at the wheels available with electric drive makes the vehicle more fun to drive. Electrification frees vehicle designers and engineers to develop exciting new architectures. It also enables faster, more capable, more responsive vehicle subsystems, features, and accessories.

The Volt combines the best aspects of battery electric propulsion with the technology on today's vehicles to deliver a superior consumer experience. It will deliver up to 40 miles of electric-only, gas-free, emissions-free driving. And when the battery is depleted, its extended-range capability provides up to an additional 300 miles of range, supplying electricity to the drive unit while also sustaining the charge of the battery.

GM is targeting the launch of the Volt in November. We have announced our initial markets, which include the greater Los Angeles area, Detroit, and Washington, DC and we will be expanding beyond these three markets. We are working on a managed start and we will build thousands the first year and tens of thousands after that.

GM is working with the Electric Power Research Institute, electric utilities, and other interested parties on launch market plans that include home, work, and public charging. We are grateful to the Department of Energy for the grant provided under the American Recovery and Reinvestment Act (ARRA) that will allow us and our utility partners to demonstrate how the Volt interacts with the electric grid. Our research shows that consumers refuel close to home and work. For this reason, we believe efforts to support initial infrastructure investment should focus on home and work location opportunities, then public charging.

You have asked us to address the issue of how to get electric vehicles to high volume. In addition to creating the refueling infrastructure for electric vehicles, this will require vehicle solutions that are robust and affordable for consumers. This is a question not only of technological maturity, but of getting through the 2–3 cycles of learning needed to reach high-volume production.

With respect to the technology, we still need to achieve cost breakthroughs, faster recharge, and good low-temperature performance with lithium-ion batteries. We also need to address technical challenges related to electric motors and power electronics. Along with batteries, these are the other key components of electric vehicle systems. In both these areas, we need to realize materials, cost, design, and efficiency breakthroughs.

DOE has been supporting vital research on batteries, motors, and other electric vehicle technologies through the FreedomCAR and Fuel Partnership. The Department is also helping build U.S. manufacturing capability through ARRA funding. GM is grateful for the grants we received to help us open our new battery manufacturing plant in Brownstown Township, Michigan and our electric drive production center in White Marsh, Maryland. These two facilities are among the first advanced battery and electric motor manufacturing plants in the United States to be operated by a major auto company. They will enable us to gain valuable learning as we move down the cost curve on these technologies.

Reducing cost is crucial because today's first-generation technology remains out of reach for many buyers. In our industry, driving to the right value equation for consumers generally takes three cycles of learning before a technology can become cost-competitive. For the automotive industry, this period from first commercialization to the third cycle of learning is a critical time when a new technology can either take off, become a niche play, or even fade away entirely. If we cannot get beyond this period, a new technology will never get to large volumes—and will not significantly impact our national petroleum consumption or greenhouse gas emissions.

Transitioning to the point where the technology can be used in enough cars to achieve the necessary economies of scale to make it affordable is a large challenge. Historically, Government technology development programs have ended before this point. In many of these programs, the goal is to meet a series of technical milestones. These may get you to first-generation technology, but if our metric is how much a technology decreases petroleum consumption or greenhouse gases, we really need to move the focus to that third generation of the technology, when high-volume manufacture and sales are possible. This will require more than just consumer tax credits for new technologies. It really means deeper re-thinking of our efforts to accelerate the deployment of advanced automotive technologies.

The challenge of getting through the first few cycles of learning is compounded by the need to create a new infrastructure. At GM, we are making a very large commitment in dollars and manpower to bring our extended-range electric vehicle technology to market this year. In order to reach our national goals, we need a similar commitment to infrastructure development.

What does all this mean for the subcommittee? In preparing this year's Energy and Water Appropriations bill, we urge the subcommittee to consider the following:

—First, focus any funding for EV infrastructure on making home recharging easy for the consumer. This should be followed by workplace charging. Public charging facilities will become more important over time, but if we do not make home chargers work for the consumer, we are not going to get EVs to a scale where public charging makes sense.

—Second, increase the level of DOE's efforts on reducing the cost of electric motors and power electronics. To make EVs affordable, we need to reduce these costs, not just the cost of the batteries.

—Third, there are a number of options for repurposing automotive energy storage batteries after their initial use in electric vehicles. Congress has a role in incentivizing the creation of these options. It should consider adopting either the concept of a battery warranty fund or the proposal of the Electrification Coalition to establish a floor on the value of advanced automotive batteries that are repurposed for use in stationary energy storage.

—Fourth, remember that electric vehicles powered by batteries are not the only type of electric vehicles—and, in fact, are not the best vehicle solution in some market segments. I urge the subcommittee to extend the Fuel Cell Test and Validation Program in fiscal year 2011 with technology insertion to ensure that we have the latest in fuel cell technology on U.S. roads. Congress should also begin to fund section 782 of the Energy Policy Act of 2005, which will pay for the cost differential for Federal and State fleet purchases of fuel cell vehicles. This funding should also be available until expended, so that auto companies can plan on early fuel cell purchases in the 2012–2015 timeframe, when early Federal purchase of even a few thousand vehicles will have a huge impact on accelerating the technology.

—Fifth, ensure that the United States keeps pace with Germany and Japan on hydrogen infrastructure, but focus these efforts in 2–3 regions of the country where commercialization can start. For example, 40 hydrogen stations in the Los Angeles metro area would be a game-changer.

—Finally, reframe multi-agency goals and priorities for advanced technology vehicles, from the point where technology metrics are met to the point where high-volume production is possible—basically, at the third cycle of learning.

GM needs support for all advanced technologies, including the Volt. We welcome Government and cross-industry partnerships to accelerate both technology development and early commercialization.

Thank you for the opportunity to testify today. I look forward to your questions.

Senator DORGAN. Mr. Taub, thank you very much.

Next we'll hear from Kraig Higginson, the chairman and founder of Raser Technologies.

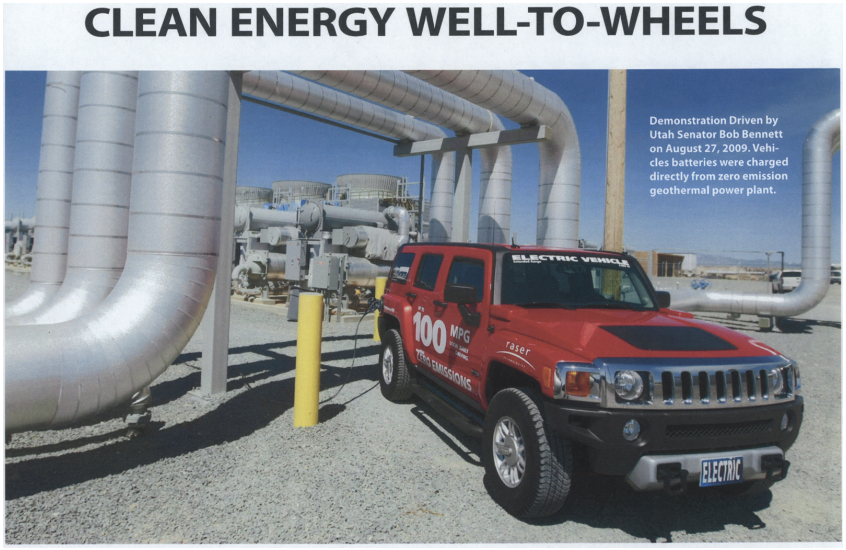
Mr. HIGGINSON.

STATEMENT OF KRAIG T. HIGGINSON, EXECUTIVE CHAIRMAN OF THE BOARD, RASER TECHNOLOGIES

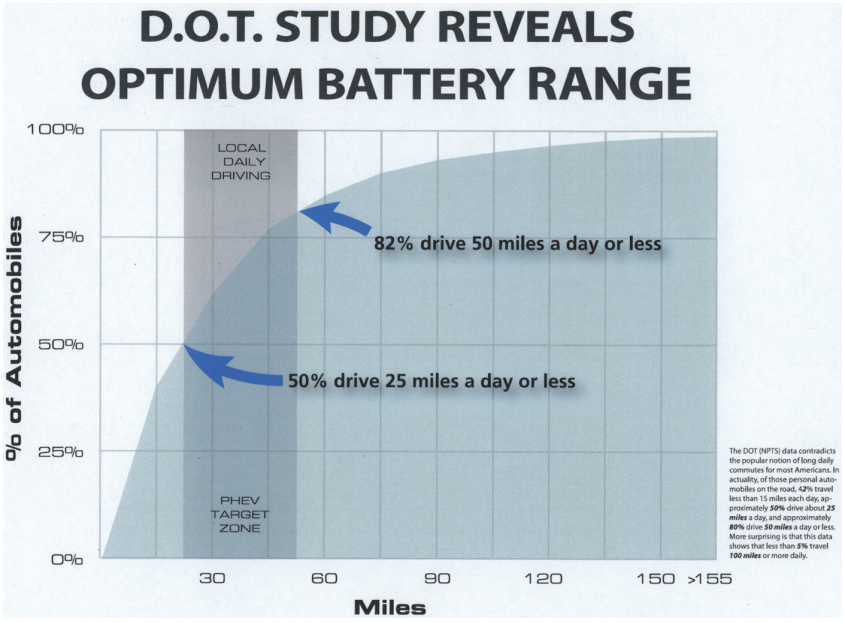
Mr. HIGGINSON. Thank you, Chairman Dorgan and Senator Bennett and Senator Cochran. It's my pleasure to be here today to testify.

I'm the chairman of Raser Technologies. And 8 years ago, it was our mission to develop advanced geothermal power plants and electric power plant—powertrain technologies to build what we called a "wells-to-wheels" solution to the energy problem in this country. We did that on private financing, and got to a significant point in that development. In fact, our new 10 megawatt geothermal power plant, that just came online this year in southern Utah, is now powering Anaheim, California, and our favorite, Disneyland. So, we've been successful on the geothermal power plant side, worked closely with United Technologies in developing a technology that's doing some things pretty incredible in that front.

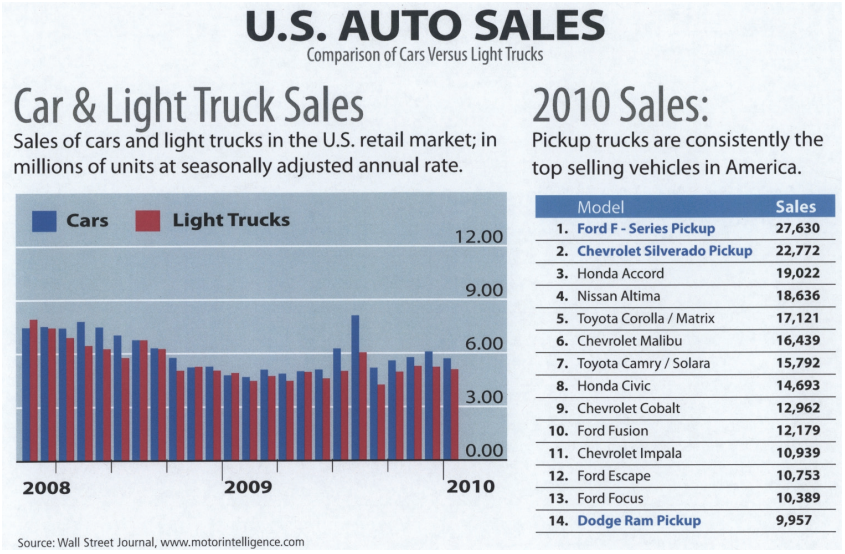
At the same time, we teamed with General Motors on a project to develop the vehicle that you see in that picture over there. It's an electric Hummer.



We began our quest for this solution back in 2002. We were drawn to a chart—to this chart, if you'll look at the chart that identifies what Senator Dorgan had talked about earlier, and that was—there's an interesting dynamic—that most of the vehicles out there drive less than 25 miles a day. In fact, many of them drive far less than that. But, at that range, you can solve this problem. And this—we started looking at this back in 2001, 2002, probably one of the earlier people to look at this idea of saying, "Okay, if we can solve the problem at the short range of these electric vehicles, we will have the solution."

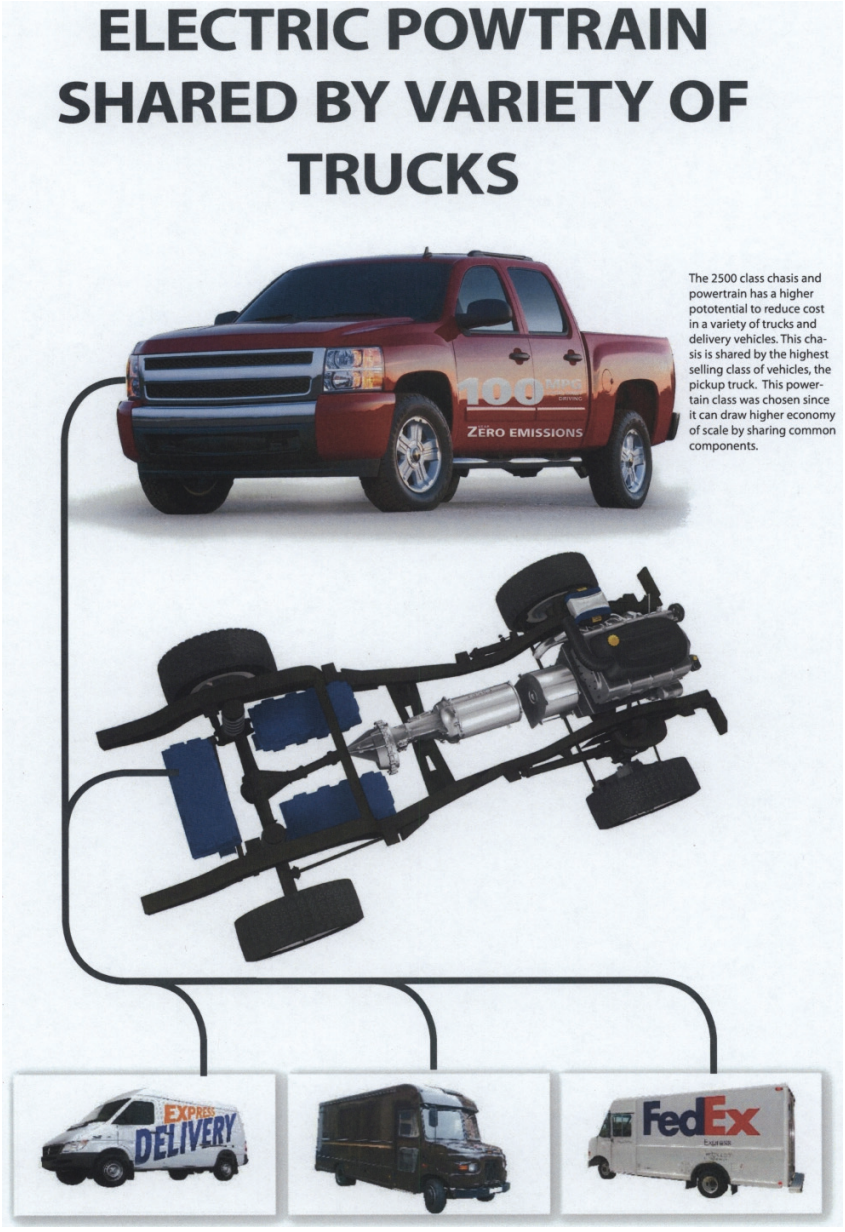


What we did was, we went on to deal with the average daily driving cycle, and then extend the range for the occasional longer trips by using a small onboard generator, as the good Senator described that for us.

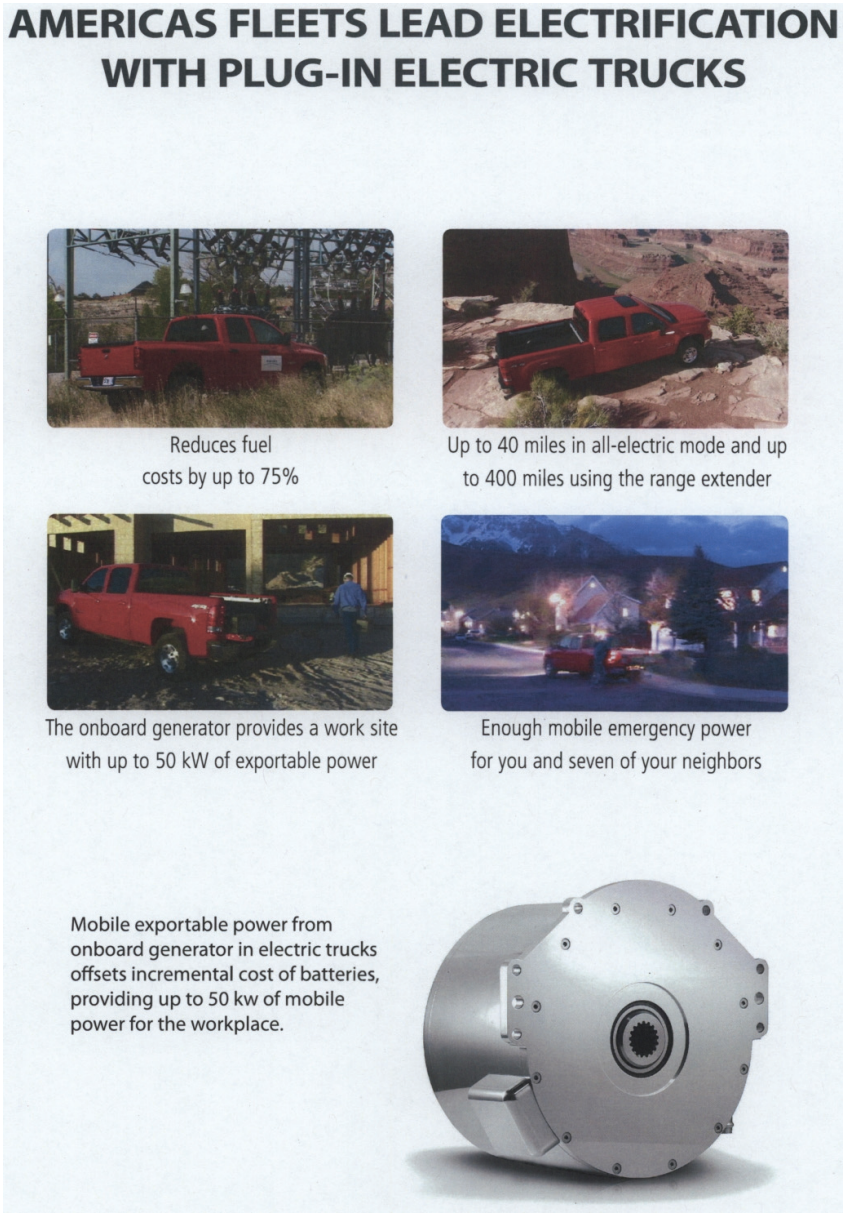


In 2004, we founded the Plug-in Hybrid Development Consortium with Pacific Gas and Electric, Southern California Edison, and other leading utilities, along with technology companies such as A123 Systems and other companies. Recently we completed a 2-

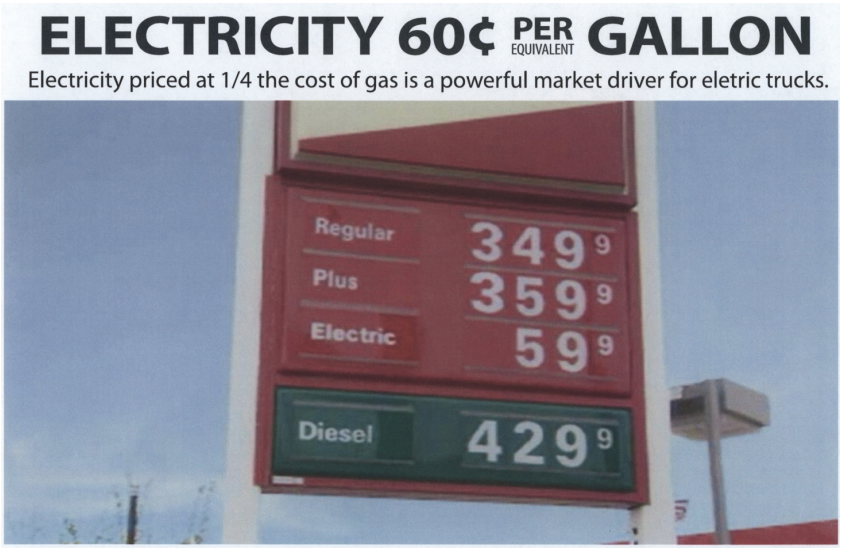
year program with General Motors to develop an extended-range electric powertrain, similar to the Chevy Volt, but designed for larger vehicles, including trucks, SUVs. Working with GM, we introduced this technology at the SAE Conference in a midsized sport utility vehicle, that beautiful red Hummer that we see again.



Since most people drive less than 40 miles a day, on most days this vehicle will not burn a drop of gasoline. Applying this powertrain to light-duty trucks, gas consumption could reasonable be cut more than in half in America's top-selling vehicles.



The key to achieving the maximum benefits of electrification was designing an electric powertrain for heavier vehicles that optimized the vehicle battery for the average miles driven.



The fact is the United States has led the world in the development of electric motors, drives, and battery technologies needed for electrification of vehicles. Yet, today the U.S. is in a high-risk position of losing its leadership in both automotive manufacturing and electric vehicle technology to foreign competitors, who have significant government backing at this time. At one time, the United States had more than a 10-year lead in the world on electric vehicle development. With GM's foresight in launching the EV1 program, we were the clear leaders.

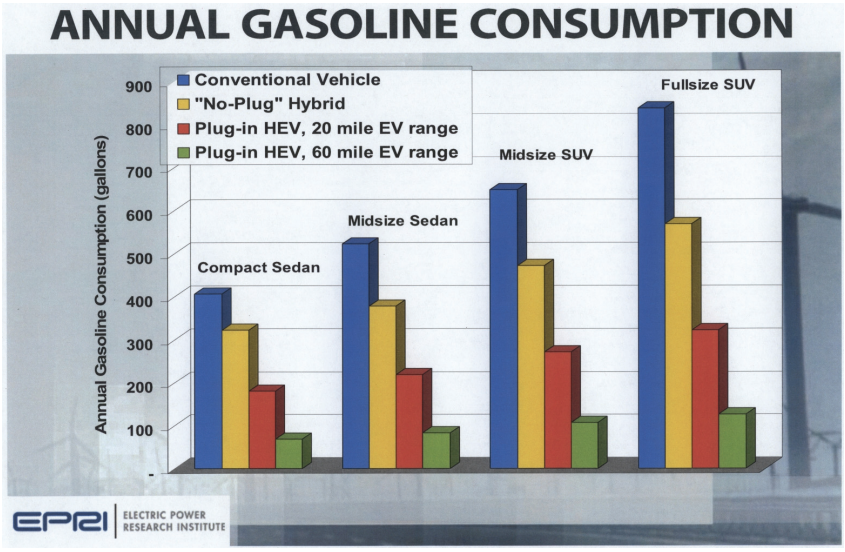
People ask me the question, and I've heard it asked here today, "Why trucks, why SUVs?" and even more specifically, "Why the Hummer?" The Hummer is clearly the vehicle of choice when it comes to the car that everyone hates to love; it's the vehicle that's got the reputation of having the worst fuel economy on the planet. By the way I don't necessarily agree with that reputation, but that is its reputation. And that's exactly why, back 4 or 5 years ago, I said, "Let's do it in the Hummer." Nothing could be more dramatic than demonstrating a vehicle as egregious as a Hummer getting more and better fuel economy than a Toyota Prius. And that's what we did.

Working with the PHEV Consortium, Raser has initiated a Green Fleet Program to introduce extended-range fleet vehicles and fleet trucks, beginning with the Nation's largest utility, Pacific Gas and Electric.

It is clear that electrification of transportation is the most practical and immediate way to reduce dependence on oil and dramatically reduce greenhouse gas emissions. In your efforts to encourage automakers to improve fuel economy, Federal fleets can provide tremendous support to the market by simply leading the way to purchase plug-in electric fleet vehicles. It's the smart thing, and it's the right thing to do. We can now build clean electric working

trucks and SUVs, and in doing so, we can cut gas consumption in half in this country.

If you look at this chart—our prior panelist, Fred Smith, referred to this earlier—and this is a chart that shows that—if you look on the far right-hand side, this is identifying trucks and SUVs as the largest consumer. This is a—the purple is the current utilization of fuel in these vehicles. And if you go over to the right, to the orange column, which is about one-third of the consumption of fuel, that would be the Hummer that we've designed and built and are driving today. So, there is significant savings to come from using this in these larger vehicles.



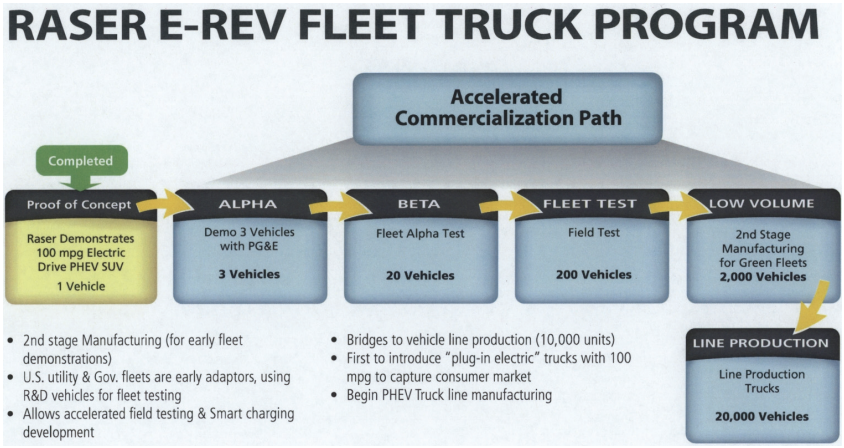
FUEL ECONOMY BY RANGE

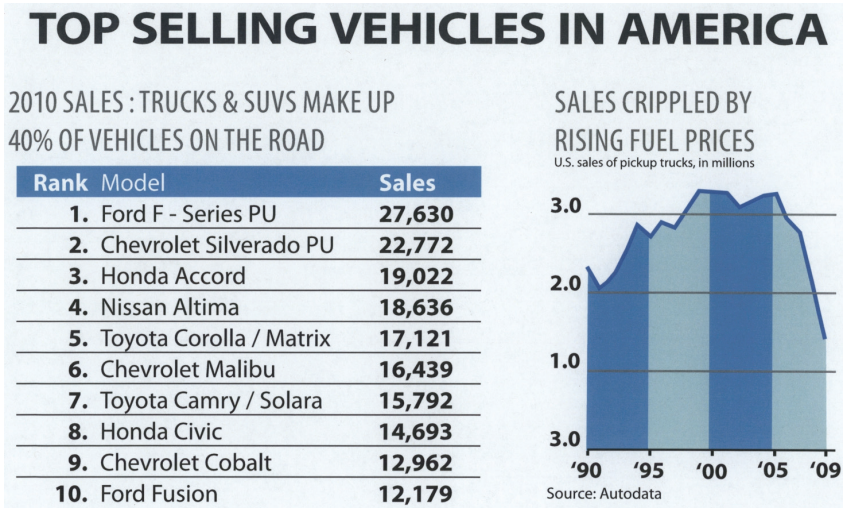
Raser's electric powertrain cuts fuel consumption in half or more for a variety of trucks.

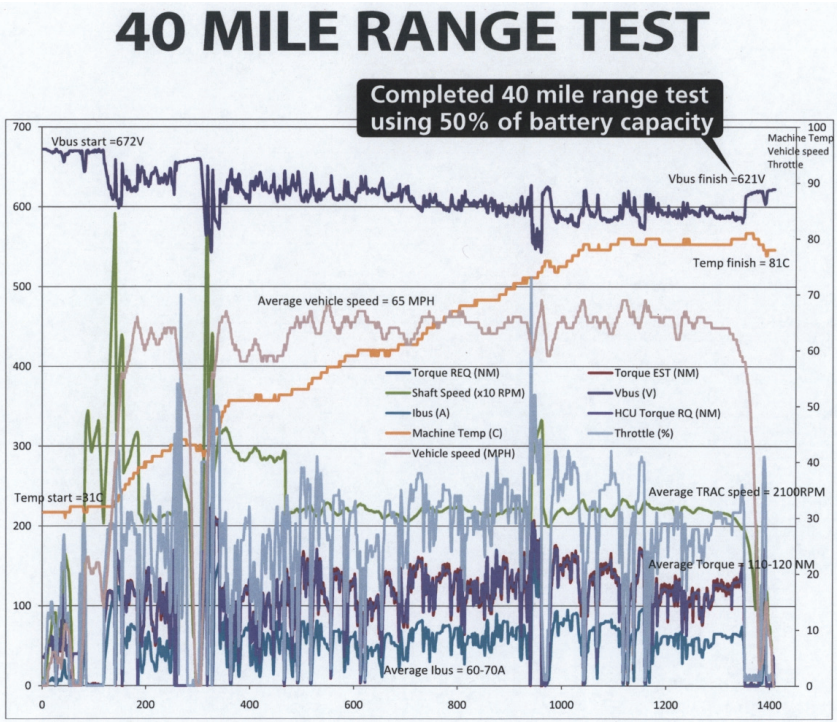
	Electric Range	40 Mile Fuel Economy			50 Mile Fuel Economy			60 Mile Fuel Economy			100 Mile Fuel Economy		
	miles	mpg			mpg			mpg			mpg		
	EREV	Stock	EREV	Improvement	Stock	EREV	Improvement	Stock	EREV	Improvement	Stock	EREV	Improvement
H3T													
City	33	14	65	364%	14	36	157%	14	27	93%	14	18	29%
Highway	40	18	electric only	--	18	90	400%	18	53	194%	18	30	67%
Silverado 1500													
City	29	15	44	193%	15	28	87%	15	23	53%	15	16	7%
Highway	38	21	309	1371%	21	69	229%	21	46	119%	21	27	29%
Silverado 2500													
City	28	12	36	200%	12	25	108%	12	21	75%	12	15	25%
Highway	35	17	140	724%	17	55	224%	17	39	129%	17	25	47%

Estimated gas fuel economy based on computer modeling and road testing. Assumes daily charge from electric grid.

I want to just add one point, as I close, that it is the larger vehicles, the working vehicles in America, that do, in fact, create the biggest problem of pollution. It's not the Toyota Prius, or it's not even the Chevy Volt, that we're going to be worried about. It's the trucks. The working trucks of American working people. If we can solve the problem at that level, we solve the majority of the problem.







Senator DORGAN. Are you talking about fleet trucks, or are you talking about individually-owned trucks?

Mr. HIGGINSON. I'm talking about everything from light-duty pickup trucks to a Federal Express truck. Our system was designed for that market. So, we've designed, from the ground up, for the larger, heavier vehicle market for a plug-in series hybrid.

PREPARED STATEMENT

I want to thank you for the opportunity to share, today, our vision of the electrification of the transportation industry. We, as a country, find ourselves in a position of tremendous opportunity. We can once again lead the world if industry and government join in this most important mission. That is our generation's mission. Our parents' and grandparents' mission was to put a man on the moon, and they did it. It's now our turn. We have the technology, we certainly have the need. Let us work together so that future generations will able look back at us with pride and say that, "We did it. We led the world out of dependence on oil and air pollution."

Thank you.

[The statement follows:]

PREPARED STATEMENT OF KRAIG T. HIGGINSON

Thank you for the opportunity to participate in this hearing today. My name is Kraig Higginson. I am the chairman of Raser Technologies, a public company on the New York Stock exchange. We develop advance geothermal energy and electric powertrain technology, a "Well-to-Wheels" approach to reducing our Nation's de-

pendency on oil and green house gas emissions. In our automotive division, we work with Tier 1 suppliers and OEMs. Alan Perriton, a former senior executive at GM is on our board.

In 2004, we co-founded the Plug-in Hybrid Development Consortium with Pacific Gas & Electric, Southern California Edison and other leading utilities along with technology companies such as A123 Systems & others. Recently we completed a 2 year program with GM to develop an extended range electric powertrain, similar to the Chevy Volt, but for larger vehicles including trucks & SUVs. Working with GM, we introduced this technology in a GM mid-size SUV, demonstrating between 30 and 100 mpg in gas fuel economy for the average driver using electricity as the primary fuel. Because most people drive less than 40 miles a day, on most days it won't burn a drop of gas, driving its first 40 miles on electricity using advanced lithium ion batteries. Applying this powertrain to the light duty truck, America's top selling vehicle, gas consumption could reasonably be cut in half or more. And we can begin doing this beginning today and begin commercialization with America's fleets.

TABLE 8.12.—HOUSEHOLD VEHICLE TRIPS, 2001 NHTS

	Number of daily vehicle trips	Average vehicle trip length (miles)	Daily vehicle miles of travel
1990	3.3	8.9	28.5
1995	3.6	9.1	32.1
2001	3.4	9.9	32.7

Source.—U.S. Department of Transportation, Summary of Travel Trends, 2001 Household Travel Survey, December 2004, p. 12.

Trucks and SUVs account for about one-half of the vehicles sold in this country with light duty trucks constantly the No. 1 selling vehicle in America. We can improve their fuel economy through electrification by as much as 100 percent or more depending on the route. This significant reduction in petroleum consumption will lead directly to greater national energy security, economic growth and reduce our trade deficit resulting from exporting cash for oil , cleaner air and most importantly new American jobs with a sustainable future.

The key to achieving the maximum benefits of electrification is designing an electric powertrain that optimizes the vehicle's battery range for the average miles driven. According to the Department of Transportation (figure 1) most Americans today drive less than 40 miles a day. An electric vehicle with 20 to 40 miles of battery electric range and a small gas/electric generator or range extender, could provide most of the benefits of an electric vehicle while removing critical barriers to mass market penetration such as range limitation and charging infrastructure.

It is becoming clear that Electrification of Transportation is emerging as the most practical and immediate way to reduce dependency on oil and to reduce green house gas emissions.

Why Extended Range Electric?—This is due to the many advantages of electric transportation. We have a well-established electric infrastructure in place, capable today of accommodating millions of additional electric vehicles. Electric motors are much more efficient, about 90 percent efficient compared to about 15 percent for gas engines. According to a study by the Electric Power Research Institute, charging electric vehicles from today's grid would cut GHG emissions in half, even with today's coal fired power plants. As States meet their renewable portfolio standards, the grid continues to become cleaner. The two key steps to meeting the Nation's energy goals are (1) plugging in electric vehicles to the grid, and then improving the grid with renewable energy. The United States has the advantage of massive reserves of alternative fuels and renewable energy including the world's largest reserves of geothermal energy.

In fact, the United States has led the world in the development of electric motor drive and battery technologies needed for vehicle electrification including, the invention of the Nickel Metal Hydride and Lithium Ion batteries and advanced AC induction and hybrid motor designs.

Yet at the same time, the United States is at high risk of losing its leaderships in both automotive manufacturing and electric vehicle technology to foreign competitors with government backing.

At one time, the United States had a 10–20 year lead on electric vehicle development. But sadly we have a history of being excellent at innovation, but poor at commercialization, failing to capitalize on our own intellectual property in emerging new industries.

As a case in point, although the LCD display technology was invented here in United States, foreign competitors now manufacture over 90 percent of world's LCD screens, which have nearly completely replaced traditional cathode ray tube or CRT displays. This was due to closer cooperation between private industries and government in countries like Korea.

AMERICAN AUTOMOTIVE RENAISSANCE

My company has struggled with these very issues. Today we stand together at the crossroads. We can look back and remember the days when America led the global automotive industry, or look ahead to an American Automotive Renaissance inspired by clean electric vehicle technology: the RIGHT STUFF in the RIGHT PLACE at the RIGHT TIME. My message to you today is that we have the technology in hand to solve these very significant challenges. Of course we will grow through generations of improvements, just as we have in the computer and networking industries.

Now, I'd like to share with you my thoughts on where we get the most "bang-for-the-buck" so to speak.

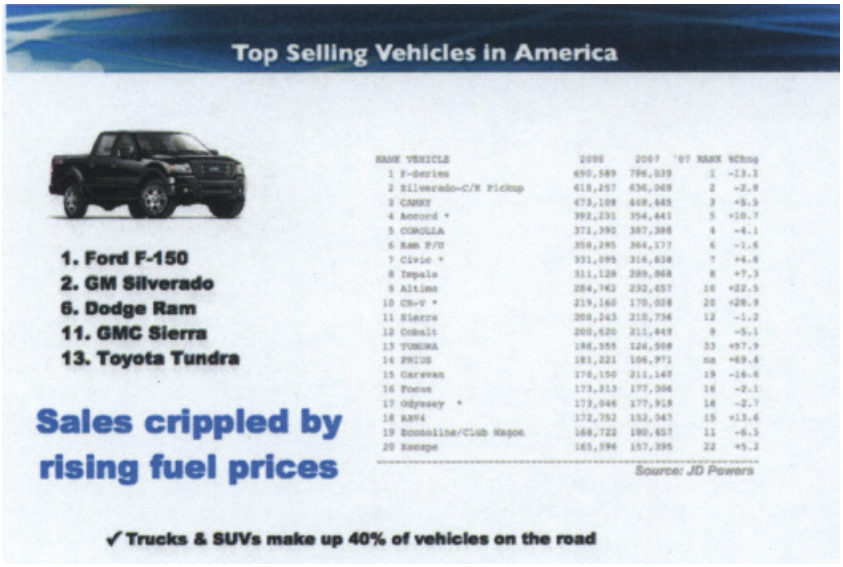
I confess, that when I imagined the "car to save the planet," I had something more like the sexy Tesla Roadster in mind, or the elegant Fisker "Karma." (Don't tell my friends at GM but I have already placed an order for the Fisker Karma.) However there is another less flashy vehicle that I believe we will also need on the road to electrification. It is a vehicle very unique to America's working class. A vehicle that is so important to our economy that it has been the number one selling vehicle in this country for the past several decades. It is the humble but hard working pick up truck. This is an important vehicle both for the rebuilding of the economy and the automotive industry.

HIGH VOLUME & HIGH MARGIN

For a significant reduction in nationwide gas consumption and green house gas emissions, high volume market penetration is imperative. Therefore, the ideal vehicle for early commercialization would have both high volume and high margin. It is very difficult for automakers to add $25,000 of advance technology and batteries to an economy car with very low margin and stay profitable. Light duty trucks have both high volume, and high profit margin and can better accommodate the additional cost of new technology.

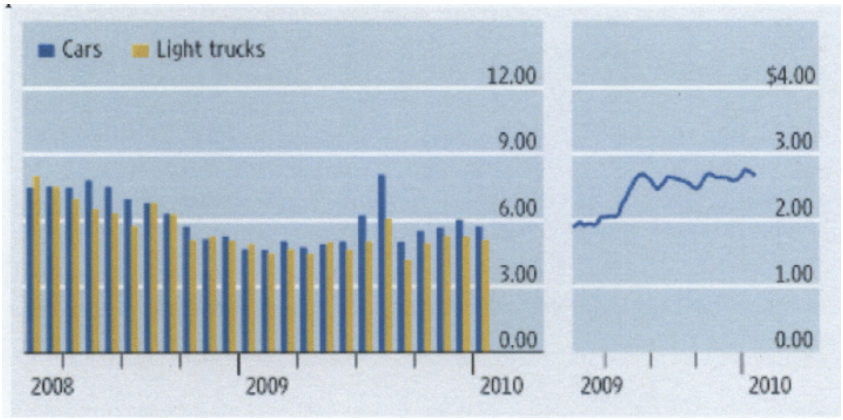
WHY TRUCKS? THE GREATEST GOOD

Light duty trucks are the number one top selling vehicles in America (figure 2). When combined with SUVs and vans, they make up about one-half the vehicles sold. Trucks & SUVs are also responsible for a majority of vehicle emissions and fuel consumption. Trucks are the vehicle of choice of America's small businesses. Trucks are not driven on Wall Street, but they do drive hard working families in America's heartland back to work. I've heard it said that behind every Prius owner is a friend with a truck, to move-in, to build or repair their home or take their family camping. Trucks are also the number one vehicle in America's working fleets It will be hard to rebuild the housing industry without the trucks we use to build our houses. It's hard to put a 4 by 8 sheet of plywood in the back of a Prius. America's government and utility fleets are among the highest truck users. If we're going to clean up the air, we need to clean up our trucks.



On the other hand, the greatest reduction in GHG and fuel consumption can result through electrification of America's working trucks. But can it be done? Is it practical? Is it even possible?

America leads the world in electric vehicle powertrain development for this class of vehicles. Another case in point: I refer again to Raser and GM the first to build and demonstrate a full performance four wheel drive extended range electric vehicle powertrain for SUVs and trucks.



Auto sales are nearly matched by the sale of light trucks, but suffer more as gas prices increase.

WHY FLEETS? FLEETS WILL LEAD THE WAY

Working with the PHEV Consortium, Raser has begun a "Green Fleet Program," to introduce electric fleet trucks in the Nation's largest utility fleet, Pacific Gas & Electric. David Meisel, Director of Fleet Services for PG&E comments:

"In a continuing battle to reduce operating costs, fleets prefer the stable low cost alternative to gas. In most States as in California, utilities Fleets have strong inherent drivers for early adoption of plug-in electric vehicles led by concerns over rising gas prices and a desire to reduce emissions. Working fleet trucks typically need both fuel economy and occasional light payload. The ideal fleet vehicle has the gas fuel

economy of a Prius, with the payload of a pick up. In the past, trucks have been largely excluded from significant increases in emissions standards. Utility fleets are strong supporters of plug-in electric vehicles. Additional funding and incentives to the Nation's public and private fleets who are willing early adopters of electric work vehicles majority of duty is 'hauling people' with occasional moderate payloads."

GREEN FLEET PROGRAM

Raser is leading a good example of the role that fleets can play. In addition to being one of the Nation's largest and cleanest utilities, PG&E is also a leader in the development, demonstration and deployment of clean alternative fuel fleet vehicles with over 1,500 alternative fueled vehicles operating in its fleet today.

PG&E is co-founder of the Plug-In Hybrid Development Consortium and has been working with Raser Technologies to demonstrate six new plug-in electric fleet pick-up trucks. PG&E operates more pick-up trucks than any other vehicle in their fleet, and with the extended range electric trucks developed by Raser, PG&E can confidently deploy these trucks throughout their service territory as a solution to many of their business goals, including reducing emissions while lowering fuel costs, and helping to address the Nation's dependence on imported oil.

MINIMAL CHANGES

The pick up truck has a very high volume to weight ratio giving it the room and payload needed to accommodate the additional weight of a large lithium ion battery pack safely between the frame rails without reducing cargo or cabin area.

OFFSETTING BATTERY COSTS WITH MOBILE EXPORTABLE POWER AND ADDITIONAL VALUE

In addition, the incremental cost of batteries, particularly in early stages of low volume production, can be largely offset by the additional value of mobile exportable power in extended range electric trucks equipped with a 100 kW generator used to provide additional power to the motor and to recharge the vehicles batteries and when driving beyond battery range. That's enough to power construction tools or the entire construction site or enough to provide power to run your home and six of your neighbors in an emergency. Municipal and maintenance crews use Utility fleets and highly value the mobile emergency power built into the truck. Unlike consumer vehicles, working fleets find enough value in the mobile power generation to nearly offset the incremental cost of batteries.

KEY TO OEM PROFITABILITY

In a recent article, the Wall Street Journal sites trucks as key to GM's profitability due to higher margins and high volume. To offset reduces sales due to higher gas prices, GM plans to improve truck fuel economy to meet the 24.1 mpg CAFE standard set for 2011. High vehicle profit margins are needed to absorb additional cost of new technology. The Ford F–150 is the top selling vehicle model in America followed by the Chevy Silverado. However, if combining both the Silverado™ and the GMC Sierra brand which is essentially the same truck, then GM would hold top honors.

Trucks offer U.S. automakers a position of strength upon which to rebuild profitability if they can overcome sagging sales due to rising gas prices. Shifting from the more volatile gasoline to electricity will allow U.S. automakers to maintain truck sales volumes while dramatically improving CAFE fuel economy in trucks. This in turn puts Americans back to work building a clean truck with a sustainable future powered primarily by electricity.

Fleets sales constitute a significant portion of truck sales volumes and are strategically important to GM and other OEMs. Utility Fleets seek lowest volume pricing for gas vehicles, while tolerating a higher price for very clean vehicles that meet their customers expectations for environmental responsibility. Pick up trucks are the most popular vehicle with both Fleets and with consumers. The vehicle of choice by America's Heartland and working families.

BRIDGE TO HIGH VOLUME

Rapid acceleration to high volume is one of the best ways to amortize the tremendous costs of new technology. Fleets are key to early adoption, rapid market penetration and can provide a crucial bridge to volume. Pacific Gas & Electric's fleet alone contains over 12,000 vehicles with over 8,000 trucks. Government fleets are required to meet EPAct with 75 percent of all new fleet purchases being alternative fueled vehicles. Government fleets including municipal, State and Federal, are some of the largest users of light trucks & SUVs. In their efforts to encourage automakers

to improve fuel economy, Federal fleets can provide tremendous stimulus to the market by "walking-their-talk" and purchasing plug-in electric fleet vehicles and trucks given the right incentives.

MARKET DRIVERS

The most powerful market driver for electric vehicles is the comparatively low cost of grid electricity when charging at night during off peak hours. With a national average of about 6 cents per kilowatt hour, a fleet truck can drive on electricity for about 60 cents per equivalent gallon. This could translate into a 75 percent reduction in fleet fuel costs. For large fleet operators, such as FedEx, UPS, Comcast, AT&T and others, the fuel savings can increase dramatically over a mild hybrid or even a plug-in HEV that remains gas-engine dependent representing often a 75–100 percent improvement over mild hybrids. This savings is particularly augmented when vehicle route & duty cycle can be matched to the battery range.

For most working fleets, fuel is the highest operational expense. On average, electricity costs about one-fourth as much as petroleum nationwide. Because of the benefits of "load leveling" by charging in "off peak" hours, most utilities now offer or plan to offer a nighttime "off peak" electric vehicle charging program. Pacific Gas & Electric offers a night-time EV rate of just 6 cents per kWh. This translates into less than 60 cents per equivalent gallon. SMUD, the Sacramento Utility District offers a 50 percent discount for nighttime charging of electric vehicles. The Los Angeles Department of Water and Power (LADWP) offers a discounted rate of just 2.5 cents/kWh for electricity used to charge EVs during off-peak times. Southern California Edison offers a discount program of about 8 cents per kWh and San Diego Gas & Electric offers about 9 cents per kWh. This translates into about a 75 percent reduction in fuel costs, a powerful market driver. (source DOE Department of Energy Efficiency & Renewable Energy http://www.afdc.energy.gov/afdc/progs/view__ind__mtx.php/in/DICS/CA/0)

GOOD FOR THE GRID

Plugging in at night is good for the consumer and good for the utility. Night time off peak vehicle charging offers load leveling benefits to the utility improving grid efficiency.

MASS MARKET PENETRATION RANGE & INFRASTRUCTURE

Two of the most significant barriers to high volume market penetration of electric vehicles has historically been (1) range limitations and (2) infrastructure. Extended range electric vehicles can bring benefits of immediate electrification without the requirement of huge investment in infrastructure. Mass penetration of alternative fueled vehicles has historically been limited by range and infrastructure issues.

In addition to the benefits to the environment, a national fleet of thousands of extended range electric vehicles offers National security of mobile emergency power generation for municipal, military and other critical operations.

FLEXIBILITY

To adapt to best available alternative fuels, the extended range electric vehicle can accommodate a variety of fuels including diesel, bio diesel, CNG, and others providing a high degree of flexibility

FUEL CELL READY

The United States has invested billions of dollars into hydrogen fuel cell research. The extended range electric powertrain is by nature "fuel cell" ready. The combustion generator in an EREV can be replaced with a fuel cell generator for zero emission operation in the future. Hydrogenics, a leading fuel cell company sees this as a more practical pathway to commercialization for fuel cell technology, significantly reducing the size and cost of the fuel cell stack.

WELL TO WHEEL EMISSIONS, IMPROVING

Driving on grid electricity will provide over a 60 percent reduction in total well-to-wheels emissions in California according to an EPRI study. More importantly, as the State's grid improves to meet new RPS (renewable portfolio standard) in the next few years, the total well-to-wheels emissions will continue to decrease as the percentage of renewable energy increases. PG&E in California offers one of the greenest energy mixes in the country with over 50 percent of its power coming from low emission sources such as hydroelectric, nuclear, geothermal, wind and solar. As

the United States moves to meet a national RPS, the well-to-wheels emissions will continue to go down. This is part of the long-term advantage of the plug-in electric vehicle that aligns well with the Nations overall energy plan.

CURRENT STATUS OF ELECTRIC VEHICLE DEVELOPMENT

Raser Technologies recently completed a program with General Motors to develop an extended range electric demonstration vehicle. The Demonstration vehicle selected was a midsized SUV. The gas powertrain was replaced with an extended range electric powertrain designed for larger vehicles. In testing the 6,000 lb vehicle achieved over 40 miles in electric range on a mixed city/highway drive cycle using about 50 percent of the available battery pack. We are now applying the powertrain to popular pick up trucks to demonstrate in the Nation's leading fleets beginning with the largest utility fleet, Pacific Gas & Electric.

David Meisel, Director Fleet Services for PG&E comments:

"In addition to being one of the Nation's largest and cleanest utilities, PG&E is also a leader in the development, demonstration and deployment of clean alternative fuel fleet vehicles with over 1,500 alternative fueled vehicles operating in its fleet today. PG&E is co-founder of the Plug-In Hybrid Development Consortium and has been working with Raser Technologies to demonstrate six new plug-in electric fleet pick-up trucks. PG&E operates more pick-up trucks than any other vehicle in our fleet, and with the extended range electric trucks developed by Raser, PG&E can confidently deploy these trucks throughout our service territory as a solution to many of our business goals, including reducing emissions while lowering fuel costs, and helping to address the Nation's dependence on imported oil."

In southern California Raser is working with the city of Anaheim to begin implementation of ultra low emission extended range electric fleet trucks. Fleet Superintendant Karl Hopfer writes:

"Anaheim City is proud to offer its customers clean electric power from Raser's geothermal power plant. In addition, we have teamed with Raser to demonstrate how much cleaner plug-in electric fleet trucks can be, especially when charged with electricity from a zero emission geothermal power plant. Extended range electric trucks offer us the electric range we need for typical daily routes, with the flexibility for longer trips. For us the E–REV truck is like a pick up truck and is just what fleets like ours are looking for. Fleets can play a key role in bringing this new cleaner technology to the market. We are in favor of any additional incentives that may be available to help early adapting fleets."

—Karl Hopfer, Director Fleet Superintendent, Anaheim Public Utility.

The city of Anaheim also provides power to help Mickey Mouse's home town "go green as well".

Working with consortium partners, over 11,000 soft orders for plug-in electric fleet vehicles have been acquired from over 76 cities, 166 public utilities and 17 State and Federal agencies. The green fleet program could soon be ready to convert those soft orders to purchase orders as it completes its beta and field testing. For example, we were recently invited to meet with the city of Seattle who is scheduled to receive $20 million in stimulus funding in association with Clean Cities, to purchase clean fleet vehicles. Matching fleet demand with fleet incentives to can provide tremendous velocity to commercialization. There are hundreds of cities across the country like Seattle, Anaheim and others who are seeking to use stimulus funds to buy new clean vehicles.

Due to current low volumes, battery pricing still remains high. However, we are now receiving bids from battery companies with high volume capacity that now approach $500 per kilowatt hour, with lower prices closer to the DOE targets on the horizon given adequate volumes. The key seems to be getting batteries to a high volume capacity. We believe that working with fleets will provide an essential bridge to volume early to accelerate commercialization.

Many fleets are willing to pay more for clean vehicles if the value is there including a more significant improvement fuel economy over previous models. Our market research shows that an improvement of over 50 percent in gas fuel economy can drive a higher vehicle price particularly as gas prices are predicted to continue rising as global demand outpaces supply due to emerging economies such as China and India with a large energy appetite. However additional value is needed to overcome the anticipated incremental vehicle costs during low volume. For working fleets, such as utilities, maintenance crews, contractors, farmers and others, the additional value of mobile power generation may offset a significant portion of battery costs.

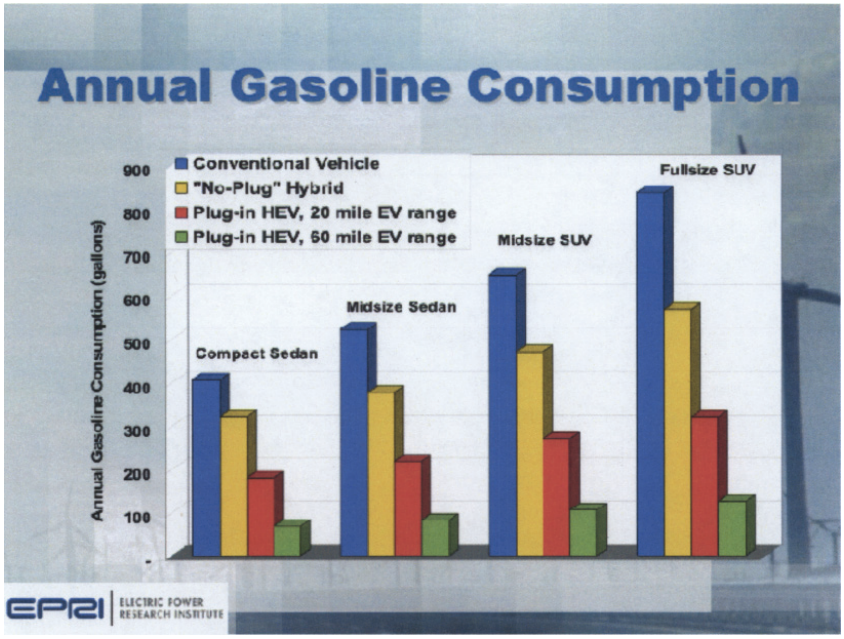
HOW MUCH WILL IT COST?

In volume we are targeting a 30 percent incremental cost for the Advanced Technology package for consumers. Statistics from the Commerce Department show that the average truck price is about $30,000, or 20 percent over base vehicle. In addition, nearly 25 percent of all trucks are sold with options adding over 25 percent to vehicle price. We anticipate that an Advanced Technology Package, with Ultra High Fuel Economy of 50 mpg or higher in a truck, will capture significant market share from 15 mpg competitors and may command a 25 percent premium package option price. This price point has already been established by consumers who regularly spend 25 percent more for other high-end options such as a comfort package including leather, wheels, navigation, additional horse power and an entertainment system. Selling value for price is an appropriate strategy.

Incentives such as the current $7,500 tax credit (applicable to EREV–40 trucks) and other incentives are key to bridging to high volume.

ECONOMIES OF SCALE—SHARING COMMON COMPONENTS

Greater economies of scale are needed to reduce rapidly the cost of new technology. Similar to the way we build on the economies of scale applying a number of different vehicles to a common chassis, we need to find the same economies of scale by leveraging a common electric powertrain class that can be applied in tandem to a chassis class to power a broader number of vehicles. For example, the cost of a specialty delivery vehicle for FedEx, USPS or the military can be greatly reduced if it shares a common powertrain with light trucks already in high volume production. The computing industry has successfully leveraged this strategy in the popular "WinTel" model providing flexibility and economies of scale. For example, we have carefully selected the 2500 class chassis due to its high potential for commonality among a number of high value vehicle platforms shared in common with high volume light duty trucks.



A 20 mile plug-in has the potential to cut gas consumption in half, and a 60 mile EV range vehicle can cut gas consumption by over four times according to this analysis by EPRI.

WHAT IS NEEDED

Four areas of policy support are needed to aid in the commercialization of vital advanced electric vehicle technologies, manufacturing and consumer incentives, and

incentives for early adopting fleets and streamlining of emissions and vehicle certifications.

MANUFACTURING INCENTIVES

For smaller innovative technology companies, capital-intensive operations such extended R&D and new tooling for manufacturing of new technology can be prohibitive. Technology suppliers and tier one suppliers play an important role in supporting the Nation's larger automakers with the innovations needed to leap ahead. Loan guarantees for suppliers working with OEMs can be tremendously helpful. Once manufacturing can be achieved, then tax credits can take affect.

EARLY ADOPTING FLEET INCENTIVES

The most near-term and effective incentives that are needed should be provided to early adopting fleets who replace low fuel economy trucks & SUVs for electric trucks & SUVs. Many fleets especially government fleets are unable to take advantage of tax credits. Due to the key role that early adopting fleets play in the acceleration of commercialization of electric vehicles, additional incentives need to be offered to fleets to help bridge to volume and reduce the incremental cost of clean electric vehicles. This would allow government fleets to lead the way without exceeding current replace purchasing budgets for a limited time, say 3 years.

CONSUMER INCENTIVES

Several consumer incentives for electric vehicles can help accelerate commercialization and increase total volume. The vehicle's all electric range correlates directly with the amount of petroleum displaced. Therefore purchase incentives tied directly to the vehicles all electric range can be in the public's interest and justified to bridge to volume production. This can be called Petroleum displacement credits valued by the electric vehicles incremental improvement or reduction of emissions over the gas version. This would provide a one-time incentive for owners of so-called "gas guzzler" vehicles to upgrade to an electric version which would provide a greater overall reduction in emissions and fuel consumption.

ELECTRIC FUEL CHARGING INCENTIVES

Incentives to charge vehicles at night would benefit the utility and the national grid. Incentives should increase for households who select night time and renewable energy charging options. Overall utility rates can also be discounted with temporary Federal and State subsidies.

LOW CARBON FUEL INCENTIVES.

Provide additional incentives for clean fuel graduating by lowest carbon content.

SALES TAX THE HIGHEST POLLUTERS

An environmental recovery tax on vehicles that do not meet C.A.F.E would encourage automakers and consumers to reduce the number of high emissions vehicles and provide funding needed for electric vehicle incentive programs.

DISCOUNTS IN STATE REGISTRATION FEES FOR ELECTRIC VEHICLES

—Streamline Safety & emissions testing for pre-certified vehicles with new clean powertrains
—Mandate Government Fleets to order first
—Fund study quantifying TOTAL cost of ownership of cleaner vehicles including total ownership costs including fuel, hidden costs to government and society
—Loss of life
—Damage to environment from emissions
—"cost of carbon"

CONCLUSION

I feel it a privilege to be alive today, to be apart of this great change for the better. It has been my passion and my pleasure to be a small apart of what I consider to be the greatest challenge of our time. I believe that our success in going to the moon four decades ago, served to teach us that we can meet any challenge if we work together and set a clear objective. How much more important is our challenge today . . . to make a giant leap for mankind. Until now, we have lacked only the will to do it. We have built this vehicle. It's not perfect, but its more than good

enough to begin the journey. In Neal Armstrong's words, "It's time to take the first small step!"

ADDITIONAL RESOURCES

Extended Range Electric Fleet Trucks http://www.rasertech.com/media/videos/rasers-extended-range-electric-fleet-truck.

Forty mile range test of Extended Range Electric SUV—100 mpg http://www.rasertech.com/media/videos/test-drive.

EREV Powertrain 3D Animation http://www.rasertech.com/media/videos/series-phev-drive-system-video.

Governor Schwarzenegger Introduces EREV Hummer http://www.rasertech.com/category/media/videos.

Senator DORGAN. Mr. Higginson, thank you very much for being here and for your testimony.

Next, we'll hear from Mary Ann Wright, vice president and managing director of Johnson Controls.

You may proceed.

STATEMENT OF MARY ANN WRIGHT, VICE PRESIDENT AND MANAGING DIRECTOR, POWER SOLUTIONS DIVISION, JOHNSON CONTROLS

Ms. WRIGHT. Thank you, Chairman Dorgan and Senator Bennett and Senator Cochran. And I'm glad to see you like your Escape hybrid, because that was probably the best project I ever worked on at Ford Motor Company. I'm very proud of it.

Well, we left the batteries for last, so let's talk about the state of play of what's going on in the batteries, and the challenges and the opportunities that are facing us so that we can drive to mass commercialization.

As a way of background, Johnson Controls and our partner, Saft, opened our first mass production facility in France in 2008, where we support Daimler and BMW for their first generation of lithium-ion batteries. We also are supporting, on a preproduction basis, Ford Motor Company/Azure Dynamics for commercial applications, VW, and other global OEMs. So, we're already in production. And, thanks to the vision and the foresight of the legislators, we also were recipient of an ARRA grant. And the importance of that grant is that it allowed us to make our next investment—our expansion of our capacity—in the United States versus and going and expanding in Europe or Asia. And that's really important, because that wasn't in our plan originally. So, we were very appreciative of that.

Now, our grant was based on our commitment that we wouldn't just build a manufacturing facility, but that we would lead in standing up an industry all the way from the raw material suppliers to the end-of-life recycling infrastructure. I'm very proud to say that, as of today, we've already recruited two Asian raw-material suppliers to the State of Michigan and—who will be supporting, not only Johnson Controls and Johnson Controls staff, but other manufacturers in the United States. We've developed strategic relationships with battery recycling partners so that we can drive for the end-of-life and the responsible disposition of these batteries.

I certainly want to tell you that the plant that we're putting up in the United States is going to be located in Holland, Michigan, which is—if you're not from Michigan—is over here. And we're on track to launch it in September of this year, where we'll be sup-

porting our first U.S. customer, Azure Dynamics, and then, next year we go into production with Ford Motor Company for their first plug-in hybrid mass production. And we are their exclusive supplier.

What's also really important is, by 2012 we will move all of our production, that's currently in Europe, to the United States, to this Holland facility. And you probably don't hear that very often, where U.S. guys are bringing stuff back and we'll be exporting it again. So, we're very proud of that.

So, lots of good news. We have good customers. We're very fortunate to have our feet underneath us. But, here's the challenge: We simply do not have enough demand to efficiently and economically operate our facilities. The capacity that's being installed is on a mass scale, and this industry requires scale to drive down the cost. And the biggest factor for our cost is, really, volume—about driving our raw material prices down, our processing costs, our manufacturing technology.

And so, what we—what we're going to talk about today, and where we're going to need help, is in demand creation. Just a couple of facts that will—should be rather startling to you, if you think about between now and 2015, there is estimated 2-million-vehicle demand globally for any level of hybridization, from hybrids all the way to electric vehicles. There will be 4 million units of installed capacity for batteries. Two million of that capacity will be here in the United States. So, we have a very significant gap in our demand.

But, we have some solutions. And, Craig, you talked about them. And that is, we have a great opportunity in the transition of our government fleets. Starting with the Federal fleets, if you look at the GSA, the Postal Service, the DOD, they operate over a million vehicles. All of them are ideally suited for some level of electrification, whether they are mild hybrids all the way to full EVs. And if you look at a particular fleet, the Postal fleet that is an ideal—when you look at—most of the miles driven are only less than 18 miles per day.

Given that we're running a bit short on time, I think the key point that I would leave with you is that these fleet programs are a great way to stimulate demand. We really need to leverage the ARRA investments that the U.S. taxpayers have made, to put these assets on the ground and to help us establish a domestic battery industry.

You know, I'd have to ask the question; shouldn't we give preference to vehicles with batteries made by companies which receive taxpayer stimulus dollars? The risk is—if we don't utilize these investments, is that our tax could go to purchase vehicles with components made in foreign countries, and strand these assets that we put in place.

PREPARED STATEMENT

Finally, as we look to the future—and Dr. Kelly talked about it, and so did you, as well—the need for ongoing research and development. The technology is very complex. And if we want this 500-mile battery, we're going to have to collaborate very closely, as a private sector and the national labs, so that we can take these

great technology ideas and get them out on the street for commercial success. And so, we're going to look for continued support from the government, in terms of funding, as well as, enabling us to collaborate on a closer basis.

So, I thank you very much for the opportunity to testify. We look forward to answering questions.

And thank you.

[The statement follows:]

PREPARED STATEMENT OF MARY ANN WRIGHT

Mr. Chairman and members of the subcommittee, my name is Mary Ann Wright. I am the Vice President and Managing Director, Business Accelerator Project, Power Solutions Division of Johnson Controls, Inc. We are the leading independent supplier of battery systems for hybrid vehicles, plug-in hybrid vehicles, and electric vehicles. Johnson Controls is a founding member of the Electrification Coalition. In addition, I serve on the Board of Directors of the Electric Drive Transportation Association (EDTA).

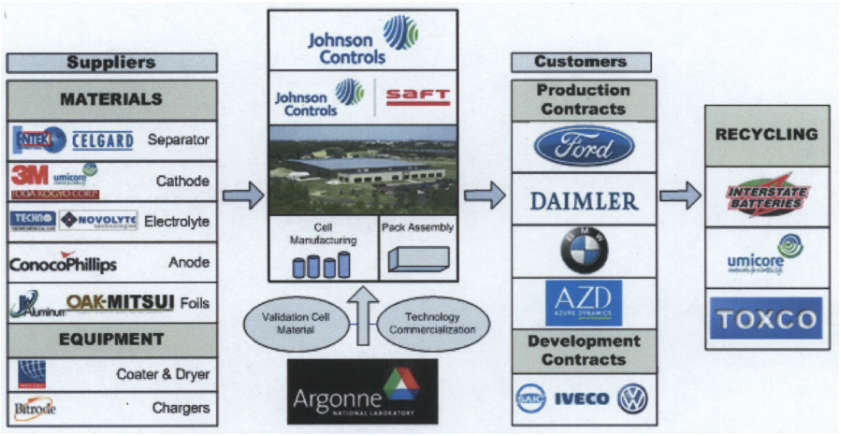
I greatly appreciate the opportunity to discuss with you today the current status of batteries for electric vehicles and the opportunities and challenges we face. I am honored that you have asked me to speak before you today on a topic so critical to the security, economic vitality, and environmental stability of our country and planet.

OUR NEW LI-ION BATTERY PRODUCTION FACILITY

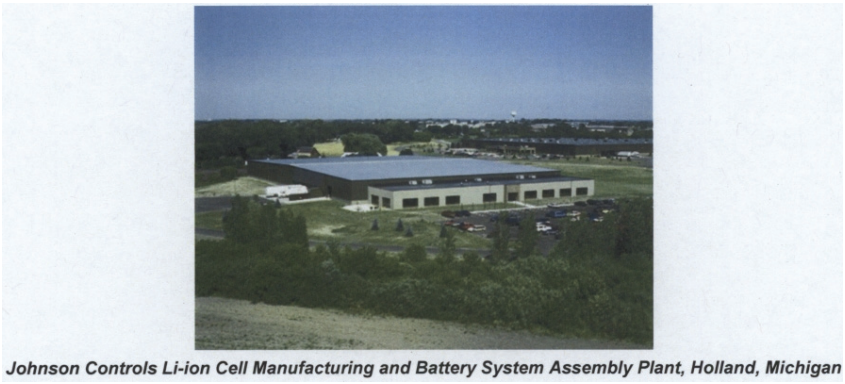
Let me start with an important status update on our first lithium-ion automotive battery manufacturing plant in the United States. As background, Johnson Controls, in a joint venture with Saft America, named Johnson Controls—Saft Advanced Power Solutions, launched the world's first automotive lithium-ion cell manufacturing and battery assembly facility in Nersac, France in 2008. That facility is currently mass producing lithium-ion cells and packs for Mercedes and BMW hybrid vehicles.

In August 2009 we were awarded an ARRA matching grant to create an advanced battery manufacturing industry in the United States. This grant, along with significant incentives from the State of Michigan, played a key role in our decision to build a manufacturing plant for advanced batteries in this country. Without this support from the DOE, we would have likely built our second lithium-ion battery plant in Europe or Asia.

We are not just building a domestic advanced battery manufacturing plant. We are also building a domestic supply chain and recycling infrastructure for the manufacture of lithium-ion batteries for electric drive vehicles. This initiative includes suppliers of critical materials and components in addition to U.S. equipment suppliers for the specialized machinery the industry will need. To date, we have helped recruit two Asian materials suppliers to the U.S. (Michigan). We have formed strategic partnerships with global battery recyclers to implement battery collection, transportation, recycling and material recovery and reuse processes. The Recovery Act funding for advanced battery manufacturing is stimulating economic activity in many industry sectors including one of critical strategic importance—the development of a lithium mine in northern Nevada. Our technology partners include the Department of Energy's Argonne National Laboratory, who will help us accelerate commercialization and validation of cell materials. We also have partnered with the DOE's Oak Ridge National Laboratory under a separate contract to validate and implement manufacturing process enhancements for lithium-ion cells. We have established commercial viability through customers who have awarded us long-term production contracts. We have production contracts with Ford, Daimler, BMW and Azure Dynamics. Notably, we have pre-production development contracts with several global customers, including Jaguar Land Rover and Volkswagen, in support of their production program plans. Below is a diagram of our advanced battery initiative funded in part by the ARRA grant.



We have chosen an existing manufacturing location on our technical campus in Holland, Michigan to site the plant. We are drawing on a workforce from an area rich with skilled automotive workers. Through the reemployment of local talent, we will help reverse the recent trend of job loss in the automotive industry generally and the Midwest specifically.



Johnson Controls Li-ion Cell Manufacturing and Battery System Assembly Plant, Holland, Michigan

This investment is an important step toward creating and building an industry in the United States that addresses market requirements and long-term opportunities for growth and new jobs in this country. Construction of our plant in Holland, Michigan is progressing as planned with battery pack assembly set to begin in August of this year and cell production starting in 2011.

We will support several important customers from this facility. Johnson Controls is the exclusive supplier for the complete battery system for Ford Motor Company's first series production plug-in hybrid electric vehicle (PHEV), which will be introduced in 2012. In October it was announced that we will supply batteries for the Ford Transit Connect commercial van in 2010 in collaboration with Azure Dynamics. We are working with Azure to supply batteries for other commercial delivery trucks that will start in production in 2010. In addition, we will supply batteries for the Mercedes S-Class and BMW 7-Series mild hybrids, presently produced in France.

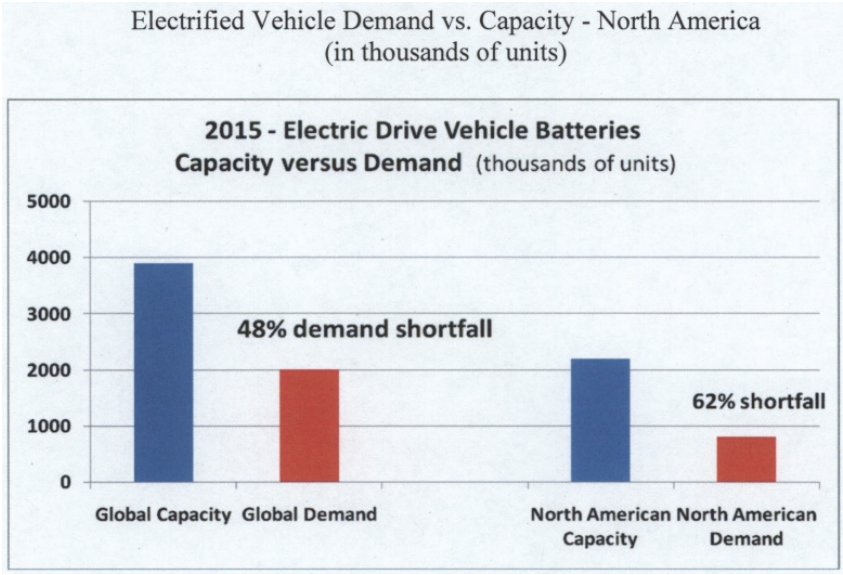
Ford Transit Connect Electric

Designed for fleet customers – On Sale in late 2010

Battery: Johnson Controls 28 kw-hr Lithium-Ion, expected to last the life of the vehicle
Top Speed: 75 mph
Range: 80 miles on a single charge
Charging: Both 120V and 240V

THE CHALLENGE—DEMAND FOR ELECTRIC VEHICLES

Congress has shown vision and determination in appropriating $2 billion in ARRA funding to support the development of a U.S. manufacturing industry for advanced batteries and for electric drive components. However, the sustained success of this investment will depend ultimately upon creating demand for electric drive vehicles. We run the risk of creating more capacity to build batteries and critical components for new electric drive vehicles than what the market will demand, particularly during the early stage of commercialization. Of concern is the near-term, i.e., 2010 through 2015 when market demand, if left uncatalyzed will lag manufacturing capacity. The bar chart shown below underscores the challenge—we estimate that by 2015 domestic capacity in vehicle units will exceed demand by approximately 1.35 million units, a gap of 62 percent.



Early in the life cycle of any new product or technology, scale is one of the critical factors enabling manufacturing success, as well as cost reductions. Electrification of vehicle fleets, including government fleets, can be a major contributor toward rapidly achieving scale.

Combined, the U.S. General Services Administration, Postal Service, and Department of Defense operate approximately 1 million non-tactical vehicles. Many of these vehicles, particularly Postal Delivery LLV vans, are excellent candidates from an economic standpoint for some level of power train electrification. The average Postal Delivery vehicle travels 18 miles a day at very low speeds in stop-start mode and averages only 10 mpg. The Postal Service's Inspector General Office estimates that a full electric version of a delivery vehicle will save $1,500 per year in fuel cost if gasoline is priced between $3–$4 per gallon. Many other Federal fleet vehicles are also good candidates for electrification and would help create demand.

Beyond the Federal Government, the 50 states collectively operate another 1 million vehicles. Electrification of State and local government fleets would have a significant impact on creating demand. Johnson Controls Building Efficiency business operates a service vehicle fleet of 5,548 vehicles. Seventy-seven percent of these vehicles travel less than 60 miles daily and 25 percent travel less than 40 miles per day. This represents a tremendous opportunity for us to electrify our own vehicles and gain invaluable field experience and help to build demand. We have implemented a pilot program in Milwaukee and will be taking delivery of our first fully electric service van within the next month.

LEVERAGING THE ARRA MANUFACTURING INVESTMENT

In order to stimulate demand through government agency purchases of electrified vehicles for their fleets, we will need to leverage our existing ARRA investments. This could be done by establishing a preference to purchase electric drive vehicles for government fleets that contain batteries and components manufactured in facilities supported by ARRA grants. The risk if we do not leverage our investment is that our tax dollars could go to purchase electrified vehicles assembled in the United States but with batteries and components made in foreign countries. This could have the unintended consequence of stunting the utilization of domestic capacity, ultimately resulting in shuttered facilities and lost jobs.

ELECTRIFICATION COALITION ECOSYSTEM CITIES

Another approach to stimulating market demand is advocated in the Electrification Coalition's Roadmap—the creation of Electrification Ecosystems. Investing in a series of large-scale demonstration projects will encourage the adoption of electric vehicles and prove their market readiness. The establishment of Electrification Ecosystems has three important goals:

—Prove that wide scale deployment of grid-enabled vehicles is not only possible, but desirable;
—Take advantage of economies of scale; and
—Support research to answer critical questions about usage and recycling patterns.

By concentrating investments in a limited number of communities, we can maximize leverage from the opportunity to demonstrate that grid-enabled vehicles can meet drivers' needs. As the Roadmap stated:

"Electrification ecosystems will demonstrate that a community is capable of putting the infrastructure in place, operating the vehicles over their lifetimes, and disposing of them after their useful life has ended, all in a manner that profits the participants in the value chain. In short, electrification ecosystems provide the best opportunity to give consumers confidence in the safety, performance, and benefits of the vehicles themselves and the reliability of the surrounding infrastructure." (Electrification Roadmap, November 2009, Electrification Coalition, page 141.)

A third and critical element to help spur demand is the continuation of tax incentives for the purchase of electrified vehicles. These incentives are proven demand boosters that must be maintained. Failure to continue these important tax policies at this time would send exactly the wrong signal to the marketplace and individual customers.

RESEARCH AND DEVELOPMENT—THE FUTURE

As we execute our plan to create an advanced battery manufacturing industry we cannot ignore the future. The nature of technology is that there is always something better on the horizon. For the United States to achieve global product and manufacturing leadership in this technology is just the first step; we must sustain it with continuing and robust Federal R&D funding. In the same manner that lithium-ion is now supplanting nickel metal-hydride as the technology of choice for electric drive vehicles, the next game-changing chemistry is already being pursued by our global competitors in partnership with their governments. Japan has set a national technology goal for a seven times improvement in specific energy coupled with a 94 percent cost reduction for electric drive vehicle batteries by 2030. Commercialization of these technologies will depend on not only fundamental chemistry and materials breakthroughs, but also substantial innovations in manufacturing processes and equipment.

Technology R&D on this scale is risky and costly, requiring more resources, both capital and intellectual, than what is available in the private sector alone. Continuing Federal support through the DOE and its national laboratory network is critical to ensuring that the technology of the future is made here at home. The near

collapse of U.S. financial markets over the last 2 years has made it painfully clear that our eroded manufacturing base must be rebuilt and returned to its time-tested position as the cornerstone of a healthy economy.

We need to develop next generation lithium-ion batteries by improving electrochemistries, as well as the battery systems which support and extend cell life. We must discover and develop the successor electrochemistry to lithium-ion. There are several technologies under consideration as the next transformation in battery technology. Equally important is the rest of the battery system, which includes sensors and thermal management components. Federal R&D support must be maintained in these areas in order for our domestic industry to remain competitive. We need to foster a collaborative relationship with the national labs and private industry to enable technology ideas to go from the labs to commercial success in the market place.

ADDITIONAL CONSIDERATION—TAX TREATMENT OF ARRA GRANTS

Currently, recipients of ARRA grants for advanced battery and critical components manufacturing, as well as the recipients of Smart Grid technology grants, need clarification on the tax treatment of these funds. Nothing in ARRA indicates that these grants are taxable. Legislation gave a clear intent of a 50:50 cost-share grant structure. Should the IRS interpret these grants as being taxable income, we may find that at a 30 percent taxation rate, many millions of dollars from the grants merely will go back to the Government and not be spent on actual manufacturing and jobs. We understand that the IRS may be able to interpret their current authority and the intent of the legislation to not tax the ARRA grants. If not, the IRS may need a statutory ability to grant an exclusion and not consider these ARRA grants as taxable income.

ARRA was designed to help create jobs and innovation in the United States in a tough economy and a hard competitive environment. Every dollar of the grant should be spent on hiring workers and developing new technologies that will propel American companies forward and enable them to compete with foreign manufacturers. Facilities such as ours can be great successes for the ARRA. We hope that the intent of the legislation will be clarified and the entire sum of the grant will go toward our facilities.

In conclusion, let me thank the subcommittee for this opportunity to testify. We are making important investments needed to develop a domestic and sustainable manufacturing base for the commercialization of electric drive vehicles. However, our progress must be maintained by creating demand for these vehicles by electrifying our fleets, establishing valuable demonstration projects, maintaining tax incentives, and investing in research and development. The success of these initiatives is critical to the security, economic vitality, and environmental stability of our country and planet.

Senator DORGAN. Ms. Wright, thank you very much. I don't think you used the term "Buy American" but your final comments will raise the hackles of some in Congress, though it sounds like the right kind of music to me. I offered the Buy American provisions in the Economic Recovery Act, and, you know, some of my colleagues had an apoplectic seizure about it. But, I noticed, yesterday, that Mr. Pascal, in Europe, indicated that there was nothing violative of our WTO obligations with respect to the Buy America provisions in the Economic Recovery Act. I also happen to share your view, that, If we're trying to promote economic recovery here, why would we not make the investment here?

You're on the way to opening a plant in Michigan. We hear a chorus of music these days that the Economic Recovery Act was a complete, total failure, creates no jobs, and so on. I fully disagree with that. But, I assume you're opening a plant here, in part, because you've gotten some funding from the Economic Recovery Act. Is that correct?

Ms. WRIGHT. That's absolutely correct. After we opened our facility in France and started looking at our global footprint strategy—I will be perfectly honest with you, coming to the United States wasn't on the list. We were looking at expansion in Eastern Europe

and in Asia. And we are in the United States, and we are building our entire business model in the United States, as a result of the ARRA matching grant. So, yes, that's correct.

Senator DORGAN. Nobody knows what ARRA is, in terms of the acronym, but it's the stimulus funds or the economic stimulus funds.

Ms. WRIGHT. Yes.

Senator DORGAN. How many employees will you have at the plant in Michigan?

Ms. WRIGHT. That's a great question. And I'll give you a number, but first let me—the number of employees is going to depend upon the demand that we can create, because we have to—we'll have employees that will support the production. At full capacity, each one of our plants will employ, directly, 550 people.

Senator DORGAN. Now, let me ask about international issues. What's happening in China, what's happening in France, and Japan, and so on with respect to converting to electric drive? Who has some information about that, anybody?

Mr. LOWENTHAL. I can speak up, because half of our business is in Europe now. And it's just a bit ahead of the United States, I'd say, in demand for electric vehicle infrastructure—in part, I have to say, driven by the Kyoto Protocol adoption, of some countries. Our biggest single customer is the city of Amsterdam, who has already deployed 100 stations and wants 2,500 more, and the city of London, who's talking about ordering 25,000 charging stations. So, Europe is moving pretty well.

I'm proud to say that all of our products are manufactured in the United States, so it's a good balance-of-trade issue for us. We're happy to sell in the international realm.

We are also anxious about exporting our products to Asia. Asia has moved ahead pretty quickly, in part, because they have low regulatory standards.

So, the international field is moving well. I think it can be to the benefit of us.

Senator DORGAN. I thought your anxiety was, because if you send it to China, they'll reengineer it and you'll lose your intellectual property.

Mr. LOWENTHAL. We have to manage that anxiety.

Senator DORGAN. Mr. Higginson?

Mr. HIGGINSON. Yes, just to add a little bit to that. One of the few known secrets of the world might have been that, back when General Motors made the decision to sell the Hummer brand to a Chinese firm, a lot of technology was going to China with that. It's no mystery that we were contacted fairly immediately by the Chinese, who had great interest in our technology. They flew to Utah and spent a fair amount of time talking with us and talking about that technology that we had built for the Hummer going with it to China. And the jury's out on that, at this point. We're hopeful that the technology, including Hummer, will stay in the United States, and we'll see what happens over the coming weeks.

But, that is one of the things that we witnessed happen. We were not only involved, but anxious to be a bidder in that process, and we came up short, due to the tremendous strength of the Chinese

Government supporting their buyers over there. So, there is some pressure on the technologies right now.

Senator DORGAN. Now, we're talking about automobiles, electric drive vehicles and trucks. I've been reading now, for 1½, 2 years, that the Chinese are gearing up a very significant automobile export effort, and we expect low-cost Chinese automobiles to be sold in our market, at some point, soon. Does General Motors understand that that is going to happen, from all that we know and read?

Mr. TAUB. Well, first recognize that the automotive industry is becoming consolidated among multinational players. In fact, China has recently set a policy in place recognizing that their domestic companies need to get economy of scale through consolidation. General Motors has been No. 1 in sales in China, with our JVs there. To date, the Chinese market is expanding so quickly, the domestic production is ramping up to meet their consumption there.

At the same time, there's no question that the Chinese Government has set automobile industry as a priority. Their university infrastructures, their national lab infrastructures—remember their domestic companies are state-owned. We've been in a joint venture that's been very successful for over 10 years as part of that.

Senator DORGAN. What percent of the joint venture do you own?

Mr. TAUB. Up until very recently, it's been a 50–50 joint venture. And, by the way, there are Chinese regulations requiring that level of ownership, maximum. We just did a renegotiation, because we're working with our partner to enter India, so it's now 51 percent SAIC, a very successful partnership. We're both doing technology advance, we're both making money in the fastest-growing market in the world right now.

Senator DORGAN. Let me just ask—and I'm taking more time than I should—what is SAIC?

Mr. TAUB. SAIC is the name of our joint-venture partner in China, Shanghai Automotive.

Senator DORGAN. So, General Motors is 49 percent now.

Mr. TAUB. We just changed to a 51–49; it was part of our financing to expand the operation into other parts of Asia.

Senator DORGAN. What part of that is General Motors, 49 or 51?

Mr. TAUB. Forty-nine. By regulation, these joint ventures had to be no more than 50 percent U.S.-owned.

Senator DORGAN. My understanding is, the Chinese would prohibit majority ownership by an American company building cars in China.

Mr. TAUB. Correct.

Senator DORGAN. But, let me ask you the more important question. Are you aware that, in the Bilateral Trade Agreement that we did with China, with whom we have a $260 billion merchandise trade deficit, after a phase-in, the Chinese automobiles, when exported to the United States—and they are coming—will have a 2½ percent tariff attached to them, and any U.S. automobiles that would be sold in China, would have a 25-percent tariff attached to them? So, our own negotiation with China, in a bilateral agreement, gave the Chinese a 10-to-1 advantage, even if the Chinese would allow our cars in. They don't want our cars; they want you to manufacture cars in China, with minority ownership. That's

what China wants. But, my point is, as we gear up in this country to think through: how do we have a vibrant automotive sector? How do we build new cars? How do we move toward electric drive? We are confronting very serious trade problems that suggest you, in General Motors, may not be able to compete, on American streets, with the Chinese automobile that comes in here with a 2½ percent tariff—I'm just telling you.

Mr. TAUB. Well, you know, clearly, we're subject to those regulations. We try to influence how they go. And I think we could go offline on policy discussions around that. I think the real focus of this hearing, and the way I've approached putting our testimony in is this breakthrough technology. We are reinventing the automobile, as we've known it for the second century.

Take batteries, in the 1990s, the United States, which, prior to that, had led in battery technology, basically abandoned that charter. It was maintained by Meady in Japan, and the breakthroughs came there. I think it's time for a public/private partnership so that the United States will be not only the place to develop the technology, but the place to implement it and commercialize it. We have the will, I think we have the team, and it's going to take a partnership to get there, coupled with the right trade policies, so we make sure we're not taken advantage of.

Mr. LOWENTHAL. If I may, Senator, chime in——

Senator DORGAN. My time has long since expired.

Mr. LOWENTHAL. Oh, sorry.

Senator DORGAN. That's all right. Yes, sir, go ahead, Mr. Lowenthal.

Mr. LOWENTHAL. Oh, thank you. Well, I just want to say, we're not intimidated by foreign competition. We need a level playing field, but then we can win. And in Europe now, we get a 70-percent market share. Seventy-percent market share. So, we can build great products.

Senator DORGAN. Yes. Mr. Taub, I understand, you can't come to Congress—in fact, you can't say anywhere publicly, "We're really concerned about this imbalance with the Chinese. Fix it, Congress. You owe it to us, as an automobile manufacturer, to fix it." Because if you did that, the Chinese would say to you, "You know what? We don't really want you in joint ventures over here." So, that's why we never hear a word from the major automobile manufacturers in our country about this unbelievable imbalance and the avalanche that is coming, that is, in my judgment, going to be very hard to compete with, because we don't have fair trade rules. You're not in a situation to be able to be a chorus of noise here on it. But, somebody needs to be, because otherwise we can do all these things, and we can have all the innovations, and we can electrify our fleet, and ultimately, the fleet is going to be made elsewhere.

Mr. TAUB. That's not our objective.

Senator DORGAN. I understand that, and I appreciate your being here to talk about what you did talk about. Senator Bennett, thanks for indulging me, and the same to you, Senator Cochran.

Senator BENNETT. Thank you, Mr. Chairman. I enjoyed the exchange and enjoyed the information that you got.

Looking at the chart you have there, U.S. auto sales, you have cars and you have light trucks. And the sales—sometimes light

trucks are higher than cars, and sometimes the cars are higher than light trucks. I don't know, but my impression is that that's not true in other countries, that the sales in other countries are more cars than they are light trucks. Is that true?

Mr. TAUB. Yes.

Senator BENNETT. Okay.

Mr. TAUB. But, also, if you look around the world, you'll find the personal use of what would be defined as a car and a truck, versus the work use, tends to scale with how fuel is priced.

Senator BENNETT. Yes.

Mr. TAUB. And what we saw in the United States was that markets shifted from 60–40, truck to car, to 40–60, truck to car, when gasoline crossed $3.75. So——

Senator BENNETT. Shifted the other way.

Mr. TAUB. It shift—it was 60-percent truck——

Senator BENNETT. Right.

Mr. TAUB [continuing]. And it went to 40-percent truck. So, clearly the consumers look at the price of energy, the price to fuel the——

Senator BENNETT. Sure.

Mr. TAUB [continuing]. Vehicle, in making that decision.

Senator BENNETT. Well, since the truck seems to be more of an American love affair than it is European, and certainly, from my experience, not Japanese, because the roads in Japan—of course, maybe since the Lost Decade, when they keep repaving the roads in an attempt to get their economy kick-started, they're wider and so on, but—I've driven the roads in Japan. I used to own a business in Japan, and go there fairly regularly. They can't accommodate the American car, let alone the American truck. You see an American car on the streets in Tokyo, and it looks huge compared to the other vehicles that are running around.

So, talking the strategy here, it would seem to me that focusing on getting this technology into trucks as fast as possible—that being an American vehicle of choice—when fuel is a problem, is a way to kick-start this whole circumstance.

Mr. TAUB. And, just so you know, when we introduced our two-mode technology, which is not our plug-in, but our base-strong hybrid, we concentrated it on our SUVs and large vehicles, for exactly that problem, that the—that's the largest source of fuel consumption, and where we could make the biggest impact. So, your conclusion is correct for hybridization.

Senator BENNETT. Yes.

Ms. WRIGHT. So, as you look at the markets and how we're trying to create demand, there is this natural sweet spot in our Federal fleets, State and local fleets. The commercial market is, for sure, a very good candidate, given short-haul stop-starts. And I used the Postal Service as an example. We're so—we believe that so profoundly that Johnson Controls, which operates about 6,000 vehicles internally, we're going to have to walk the talk and we're going to transition our own fleet, as well. And—but, we're going to do it because, not only do we have the technology and we know it's the right thing to do, but, when you look at the operating costs, the greenhouse gas emission reduction, it's the right thing to do for us, as a business, as well.

Senator BENNETT. Mr. Higginson, you——

Mr. HIGGINSON. Yes, I think, just to put an emphasis on what both Alan and Mary Ann have said, that the driver of getting these vehicles to the marketplace right now is clearly going to be getting quantities up, and the best place to do that is going to be through fleet operations. We have approximately 11,000 soft orders that we're looking at right now, from fleets that come from municipalities, county governments, utility fleets, et cetera, who are ready, willing, anxious to participate in this process.

So, I think we're going to see it happen, and that's where it will happen. We think the Federal Government really should lead the way. It should be—Federal fleets should be moving that way faster than anyone.

And just to draw a little bit of a distinction, I think it was Chairman Dorgan who had the chart up earlier that talked about the difference between what a plug-in hybrid—a series hybrid does versus what a dual-mode hybrid does, for example, and literally more than doubled the fuel economy out of a plug-in series——

Senator BENNETT. Right.

Mr. HIGGINSON [continuing]. Versus a dual-mode hybrid. And I think—not—that's not to criticize General Motors' product, because I think it's a great one. In fact, one of the top engineers that designed the dual-mode worked, works for me now at Raser. So, we're proponents and fans of that technology.

But, I think that the key right now is, if we can get the critical mass that Mary Ann talked about, relative to the battery manufacturing, fill the facilities up that we have now invested in here in the United States, doing that through fleet purchases is going to be a real kick-start. Then we're going to see happen what happened in the LCD world and, hopefully, without the end result of that world. That technology was developed here in the United States. Great technology displaced the picture tube itself. And, in fact, that technology developed here is now, 90 percent of it, being manufactured in Korea.

And I think, in the world of the vehicle and plug-in series hybrid vehicles and the electrification of transportation, our country sits in the leadership position today, and it really is ours to lose. It's not something we've got to chase; it's in our hands, and it's ours to lose.

Senator BENNETT. Well, it occurs to me that, if we go in the direction you're talking about, one of the advantages of putting the Federal fleet into this technology, or large corporate fleets, they all overnight at a corporate headquarters. They don't drive them home. And consequently, the whole charging question becomes very easy to deal with, because you simply—you're now dealing with a scale that can give you the kind of circumstance that you wanted. So that you put in a charging system at the local Post Office, and all those trucks get charged overnight, just—that's the way it's done, and there's no big hassle.

Whereas, if you're going to the individual market, homes maybe have to be retrofitted, you've got to get the 240 in some places where they don't have it, so somebody will avoid it for this, that, and the other.

But, moving in the fleet direction strikes me as making a whole lot of sense, and it's a product that the rest of the world doesn't necessarily want.

Mr. HIGGINSON. And, Senator, it's——

Senator BENNETT. So, there—you're not going to get competition from the Chinese building those kinds of trucks.

Mr. HIGGINSON. And it's precisely that scale that you talk about that allows the cost to come down on the battery systems quickly. We heard, from Fred Smith earlier, that the real challenge, one of the real hurdles here, is the cost of the battery system in these vehicles right now. It's strictly a scale question. To the extent we can utilize fleets to launch this project and get the battery plants operating at or near capacity, and growing from capacity, we'll see the price of this stuff tumble quickly. It's just a—it's a pure fact of economic life. And——

Senator BENNETT. Yes.

Mr. HIGGINSON [continuing]. That's what we need to do. To the extent we don't do that, someone else out there will be doing it.

Senator BENNETT. Okay.

Thank you, Mr. Chairman.

Senator DORGAN. Thank you.

Senator Cochran.

Senator COCHRAN. I couldn't help but think about the fact that if you use the tax code as an incentive, you're bound to make progress, if it's targeted in the right way and priced so that the public will accept it, as a political matter. But, that's outside the jurisdiction of this subcommittee, so you hadn't had a lot of questions about the investment tax credit or other benefits that might flow through the utilization of our tax code as an incentive.

Are there tax provisions in place now that encourage investment or reward the investments that you're making in bringing this to reality?

Mr. HIGGINSON. Senator, we do have one piece of legislation that we were involved in fairly heavily early on with a—it's called the Clear Act, and we've heard mention of that here today. It allows for up-to-$7,500 tax credit for battery systems that go into hybrid electric vehicles. Interestingly, that was sponsored by a couple of people that were well known is—one, Senator Orrin Hatch from Utah; and secondly, a junior Senator at the time, Barack Obama.

And so, I think you see something happening, as we heard talked about here earlier today. This isn't an issue of one side or the other of the aisle. This is an American issue that I believe we see good consensus on both sides to solve these problems. It is the problem of the day, and I think we're seeing good consensus, and we'll, hopefully, stand by for some more things that can come in the tax code that will help support this effort.

Mr. TAUB. And the—that present offset of a tax credit for individuals that will be buying the Volt is the right example of incentivizing the Gen1 commercialization that I talked about.

I think the key element, as you think through this, is we do need incentives to get through the first two learning curves. We should only do that on technologies and solutions that are then sustainable, where we have the confidence we can do the cost walk, we have the confidence we can do robust, durable products, and the

confidence that the consumer is going to value it. And I think this technology falls in that realm.

Mr. LOWENTHAL. I wanted to weigh in a bit on tax credits. There is a tax credit on infrastructure, as well. There's a 50-percent tax credit. It's part of the energy bill. It expires at the end of this year, which is not great timing, given that the vehicles just start coming out then. So, we would like to see that extended.

It has a flaw in it, in that it's an income tax credit, and many of the fleets now are county fleets and city fleets, none of whom pay any taxes. So, it actually isn't working very well. Most cases where we try to use that income tax credit, it isn't working. It's a wonderful idea, and so there's the idea. In fact, Senator Hatch has an idea of converting that to a payroll tax, which will work a lot better, as opposed to an income tax credit.

We do see, for example, sort of a mixture of these ideas. The county of Sonoma, in California, wants to create one of these ecosystems, where the county of Sonoma's known for EVs and attract EV players; they've attracted Nissan, they're attracting others to the county, as an EV Center of Excellence. In their case, they have an innovative idea, which is that the city and county fleets have charging stations and are being electrified, and then the—and they use those at night; in the daytime, they open them up to the public. So, they've—this is a way of getting two-for-one on this investment. But, still, the tax credit doesn't work, because it's the county of Sonoma.

Senator COCHRAN. Thank you very much. I think your presentations have added to our understanding of the challenges we face and the direction that we ought to consider, in terms of legislation from the Congress and the use of the tax code as incentives.

Thank you very much for being here today.

Senator DORGAN. Senator Cochran, thank you very much.

I think it's clear from this discussion, that we all know we are unbelievably dependent on foreign sources of oil, and that we have challenges with respect to the planet and wanting to have a lower-carbon future. We understand that there are ways to begin to light a fuse and start a change. With respect to the automobile, I think, from the early 1900s, when it was decided that we wouldn't use alcohol and we really would discard electricity, we'd just do an internal combustion engine and use gasoline, from that moment on, we have just been unbelievably addicted to that source of energy.

So, 70 percent of that which we need to run our economy is used in the vehicle fleet, and much of it comes from outside of our country. The question is whether we let things happen and perhaps do nothing to address these questions, or whether we decide, as a matter of public policy, to make things happen. The one thing that's important to understand, is that we can't make consumers buy something. Consumers are an unbelievable source of power here. But, as Senator Bennett just mentioned to me, if you can get 60-cent-a-gallon fuel for a Hummer, the consumers will very quickly beat a path to that source of energy for their vehicle.

I think that based on the discussion we've had today, if the Federal Government could decide it is going to move toward an electric drive fleet it would have a profound impact.

If we can find a way to use tax credits that bring the cost down for conversion, we will incentivize those that are hauling our garbage, FedEx, and all of those kinds of trucks running around this country, to convert very quickly. That mass moving, from the Federal Government to its fleet to the other truck fleets and so on, would have a profound impact on moving this country in a completely different direction, toward an electric drive future.

I also think the consumers would very, very quickly follow, because all of the advances that will come from that—and there'll be a lot of advances in technology and capability—will, I think, show up in the marketplace very quickly for the kinds of vehicles that consumers want to drive.

ADDITIONAL COMMITTEE QUESTIONS

So, I really appreciate your willingness to come and talk about this. At this time I would ask that the subcommittee members submit any questions they have for the record.

[The following questions were not asked at the hearing, but were submitted to the witnesses for response subsequent to the hearing:]

QUESTIONS SUBMITTED TO DR. HENRY KELLY

QUESTIONS SUBMITTED BY SENATOR ROBERT F. BENNETT

Question. How do you rate the potential for a "true breakthrough(s)" in battery technology and any thoughts on when and where that might occur?

Answer. The Department of Energy (DOE) views the potential for a breakthrough in battery technology for advanced electric drive vehicles as being high. Multiple universities, national laboratories, and commercial companies are investigating and developing breakthrough technologies. A small sample include advanced anodes (Silicon and other alloys), cathodes (high voltage, high capacity cathodes a), and electrolytes (such as composite electrolytes for use with lithium metal anodes). It is believed timescale for some of these technologies is 3–5 years in PHEVs, and perhaps 10 years before commercial application in BEVs. In addition, the Advanced Research Projects Agency—Energy's (ARPA–E) work on transformational energy storage concepts is accelerating the development of these and other technologies such as lithium/sulfur and lithium/air which promise to triple or quadruple the energy density of today's lithium ion batteries. The timescale for these technologies is highly speculative, although some have estimated an additional 15–20 years of development will be needed.

Question. Where should DOE and industry focus their efforts in R&D to get the biggest return on their investments?

Answer. The Department of Energy (DOE) works closely with industry, academic leaders, and our national laboratories to design a research portfolio that balances long-term investments in basic science and engineering, investments in using this science to develop transformational energy storage concepts, and work to help industry convert breakthrough ideas into practical products. EERE battery programs work closely with the Office of Science and their Energy Frontier Research Centers, and worked with ARPA–E to help craft their recent solicitation for new energy storage concepts. Together we are exploring the widest possible landscape looking for promising new ideas as we move the current generation of concepts into the market. For example, early DOE support led directly to a generation of new lithium ion batters that is now entering the marketplace with high-leveraged DOE support—with considerable new funding from the American Recovery and Reinvestment Act of 2009. At the same time, we're supporting higher risk research on lithium/air and lithium/sulfur batteries. And we worked with ARPA–E to help craft their new call for breakthrough energy storage technologies and hope this will attract some spectacular new concepts. R&D is a top priority for the Department, and we will continue to work closely with our partners to harness science and ideas to address energy challenges.

Question. Do you expect to meet the DOE goals for battery cost and performance? If not by DOE's dates, when would you expect to?

Answer. With sustained future R&D investment, there is a very high likelihood of meeting the Department of Energy (DOE) performance goals. The battery life goals, both the 15-year calendar life and the charge/discharge cycle life, are also likely to be met. The cost goals may be the most challenging, but battery development efforts are on track to meet the 2015 cost targets. The path to achieving the necessary cost reduction is through a combination of technology advancements, learning-curve improvements, and manufacturing economies-of-scale. The path to achieving the necessary cost reduction is through a combination of technology advancements, learning-curve improvements, and manufacturing economies-of-scale.

Question. How do you see the applicability of electric vehicles to different geographic regions (different climatic conditions) of the country, such as Minnesota vs. California?

Answer. The initial introduction of electric-drive vehicles to different geographic regions of the country will be driven by the manufacturers producing the vehicles. Work at the Department of Energy and elsewhere indicates that electric drive vehicles face performance problems in extreme climates. Extreme climates also add to the heating or air conditioning loads that can limit the range that can be provided by the batteries. The Department is working with industry and academic experts to further quantify these problems and address them. We expect that manufacturers are likely to introduce electric-drive vehicles first in locations which do not have extreme hot or cold temperatures. We are confident that improved designs will encourage manufacturers to offer these vehicles in all geographic regions. Over the long term, we believe that electric vehicles will be deployed across the country.

Question. How important is it that PHEVs are charged at night?

Answer. Charging at night enables greater cost savings and system benefits of grid-connected vehicles to be realized. Vehicle charging during off-peak night-time hours will allow electric utilities to plan for more stable load profiles, while enabling intermittent generation resources such as wind—which is typically most prevalent at night—to be more fully utilized. Consumers will realize economic benefits from lower electricity rates during off-peak hours. We anticipate the majority of electric-drive vehicles will be charged during off-peak, overnight hours.

Initially, there will be few PHEV vehicles in use, minimizing the importance of when they are charged. However, the importance of night-time, off-peak charging will rise with increased market penetration of grid-connected vehicles. Through the Transportation Electrification projects awarded under the American Recovery and Reinvestment Act, the Department of Energy is working with electric utilities and vehicle charging infrastructure providers to prepare for properly managed smart-charging systems so off-peak electricity capacity is utilized, maximizing the benefits of widespread utilization of electric-drive vehicles while minimizing their impacts on the U.S. electric grid.

Question. Will public or other charging stations that are used during peak hours be a problem?

Answer. Unmanaged charging of large numbers of electric-drive vehicles during peak grid operation, especially charging at higher rates such as those utilized in faster charging Level II and Level III public stations could result in load management problems for electric utilities. The Department of Energy is working with utility and industry partners to ensure Level II and Level III chargers will be equipped with communications and control capabilities that will allow utilities to track utilization of each charger and be able to coordinate charging as needed to reduce load during peak demand conditions, while still meeting customer needs.

It is anticipated the vast majority of electric-drive vehicles will likely be charged at home during off-peak hours. Publicly available charging sites will predominantly be utilized for opportunity charging (partially charging a battery whenever power is available instead of when battery is completely discharged) to provide incremental increases in range of electric-drive vehicles. These public stations will help overcome consumers' range anxiety with electric vehicles. The Department will study various use scenarios as part of eight American Recovery and Reinvestment Act Transportation Electrification Electric-Drive Vehicle Demonstrations, including how best to encourage off-peak charging. These scenarios, which will include the use of several different time-of-use utility rates, will be evaluated to determine how best to minimize the impact of electric-drive vehicles on the electric grid.

Question. At what point will additional capacity (generation, transmission, or distribution) be required because of the extra demand from PHEVs?

Answer. Based on the results of a Pacific Northwest National Laboratory study conducted for the Department of Energy, we estimate currently available off-peak electric generation and transmission capacity is sufficient to support the conversion of over 70 percent of the existing U.S. light-duty vehicle fleet to PHEVs. Additionally, a 2007 joint-study by the Electric Power Research Institute (EPRI) and the

Natural Resources Defense Council (NRDC) concluded there is an abundant supply of electricity for transportation—a 60 percent U.S. market share for PHEVs would use 7 percent to 8 percent of grid-supplied electricity in 2050. This study can be found at http://energytech.pnl.gov/publications/pdf/PHEV__Economic__Analysis__Part2__Final.pdf.

It is possible local distribution networks may experience some adverse effects in a scenario involving a sudden increase in unmanaged vehicle charging. However, we anticipate these effects will be minor due to the gradual adoption of electric-drive vehicles by consumers, and they will be mitigated by planned infrastructure upgrades by local utilities.

To evaluate and anticipate the potential impacts of electric-drive vehicles on the U.S. electric grid, DOE is partnering with electric utilities through demonstration projects as part of the Transportation Electrification projects awarded as part of the American Recovery and Reinvestment Act. These demonstration activities will allow the Department and the utility industry to assess the true impact on the electric grid of large numbers of electric-drive vehicles in concentrated locations. This will in turn facilitate the development of plans to incorporate intelligently managed vehicle charging systems into the U.S. electric grid with minimal impact.

Question. How will the proposed Batteries and Energy Storage hub contribute to advancing electric vehicles? Are we just continually throwing money at this problem?

Answer. Today's electrical energy storage technologies suffer from limited energy and power capacities, lower-than-desired rates of charge and discharge, calendar and cycle life limitations, low abuse tolerance, high cost, and poor performance at high or low temperatures. The current state of technology for electric energy storage has significant limitations not only for electric vehicles, but also for storing electricity from broad classes of power generation technologies ranging from nuclear power to intermittent sources like solar and wind.

Many of the fundamental performance limitations for energy storage are rooted in the constituent materials making up the storage system and in the fundamental physics and chemistry that govern the transport and storage of energy in the material. The potential for scientific advances are great and the needs for technology applications are many. The Department of Energy believes that establishing a focused energy storage research and development effort the size, scope, and duration of an Energy Innovation Hub will garner long-term commitment from many of our most innovative researchers, and the Hub will act as a beacon for attracting our Nation's most enthusiastic science and engineering students.

The Batteries and Energy Storage Hub will target science knowledge gaps that are preventing breakthroughs for both mobile and grid applications. Specifically, the Hub will address key research areas identified in the Basic Energy Sciences workshop report Basic Research Needs for Electrical Energy Storage: expanding our scientific base for synthesis of novel nanoscale materials with architectures tailored for specific electrochemical performance, developing new methodologies to characterize materials and dynamic chemical processes at the atomic and molecular level, and expanding our competencies in simulation and prediction of structural and functional relationships using leading computational tools. These research challenges are inherently multi-disciplinary. The Hub would bring together multi-disciplinary, collaborative teams of scientists and engineers, in a way that hasn't been done before, to focus on specific milestones or research opportunities for energy storage where highly integrated basic and applied research can accelerate the innovation process.

The Hub's ultimate technological goals include the development of radically new concepts for producing storage devices from materials that are abundant and have low manufacturing cost, high energy densities, long cycle lifetimes, and high safety and abuse tolerance for a broad range of energy storage applications. Each of these issues is important to further the commercialization of all electric or plug-in hybrid vehicles.

Question. Could you detail some of the specific milestones or research that the Hub could accomplish that were not possible through the significant amounts of Federal investment in prior year appropriations or the stimulus package?

Answer. The Batteries and Energy Storage Hub's purpose is to accelerate the feedback loop between fundamental science and engineering to scalable, cost-effective energy storage solutions. The Hub would draw upon the scientific and technical knowledge being generated across the Department's existing energy storage research efforts, which span fundamental research, development of specific technologies, and demonstration projects. The investments made in prior years have been especially critical to targeting specific areas of fundamental research, as well as to incremental improvements to existing technologies, including funding for bat-

tery and component manufacturing supported via the American Recovery and Reinvestment Act of 2009, which feed directly into the marketplace. The Hub is different than prior technology development activities in that the selection of the specific milestones for applied research and development opportunities in energy storage will be based on down selecting the most promising scientific discoveries, which will be done within the Hub's highly integrated basic and applied research teams; accelerating the innovation process.

By addressing both the scientific and engineering challenges to cost-effective manufacturing and deployment, the Hub would go beyond existing technologies to develop radically different energy storage designs, concepts, and architecture. The scale of the Hub effort is important to ensure that the technology and manufacturing/production needs will be linked to the fundamental science. The longer-term Hub investment provides motivation to top scientists and engineers to redirect their careers toward the sole focus of the Hub mission. Collectively, these aspects define the Hub and delineate it from other funding models in the Department.

Key scientific questions that could be addressed by the Hub include:

How Can We Approach Theoretical Energy Densities?—To answer this question the Hub could explore the efficacy of structure in energy storage by pursuing new approaches combining theory and synthesis for the design and optimization of materials architectures including self-healing, self-regulation, failure-tolerance, and impurity-sequestration; seek a molecular-level understanding of the full range of interfaces in order to design tailored interfaces/interphases; and extensively study the chemistry occurring at solid/electrolyte interfaces and within the cathode, anode, and electrolyte.

How Do We Increase Safe Storage Capacity, Power Density and Optimize the Charge and Discharge Rate?—To answer this question the Hub could investigate the science of charge transfer and transport, seeking a molecular scale understanding of interfacial electron transfer, and electrolyte-electrolyte interfaces with strong ionic solvation, weak ion-ion interactions, high fluidity, and controlled reactivity; which could increase rates of energy utilization. The Hub could pursue materials discovery focused on systems with more than two electrons per redox center, such as bimetallic, amorphous nanoporous or porous nanostructures.

Can We Approach Full Reversibility to Achieve Maximum Cycle Life?—To achieve this goal, the Hub could develop new probes and of energy storage chemistry and physics at all time and length scales, including analytical tools capable of monitoring changes in structure and composition at interfaces and in bulk phases with spatial resolution from atomic to mesoscopic levels and temporal resolution down to femtoseconds. The Hub could pursue advances in multi-scale modeling; developing computational tools with improved integration of length and time scales to understand the complex physical and chemical processes that occur in electrical energy storage from the molecular to system scales.

Examples of potential outcomes include the discovery of novel nanoscale materials that offer possibilities for the development of revolutionary three-dimensional architectures that simultaneously optimize ion and electron transport and capacity; new in situ photon- and particle-based microscopic, spectroscopic, and scattering capabilities and techniques that allow observation of the dynamic composition and structure at an electrode surface in real time during charge transport and transfer processes; and new integration of experiments with novel multi-scale theory with different time and length scales appropriate to energy storage to enable the identification of new mechanisms and predictive trends, as well as the discovery of new materials for advanced energy storage solutions. Once awarded, the Hub will be assessed against the goals and benchmarks outlined in the approved research and management plan.

QUESTIONS SUBMITTED TO RICHARD LOWENTHAL

QUESTIONS SUBMITTED BY SENATOR ROBERT F. BENNETT

INTEGRATION INTO THE ELECTRIC GRID

Question. There is general agreement that the existing power grid could accommodate a large number of electric vehicles. Utilities would only need to proceed with planned updates to the grid, which are not specific to the vehicles. Additional demand by electric vehicles could help to stabilize the peak-and-valley cycles that utilities face. This assumes, however, that electric vehicles are charged at night and not when demand for electricity peaks.

How important is it that PHEVs are charged at night?

Answer. First, I want to stress the general importance of plugging in grid-enabled vehicles, both EVs and PHEVs. The first plug-in hybrid electric vehicles to reach U.S. markets will have an all-electric driving range of approximately 40 miles. When the battery's energy is depleted, these vehicles will essentially function as traditional hybrid vehicles, relying on an internal combustion engine to charge the battery. The first mass-produced fully-electric vehicles (EVs) to reach U.S. markets will have an all-electric driving range of approximately 100 miles. When the battery is depleted, it must be recharged before the vehicle can be operated.

In the case of the fully electric vehicle, the need for reliable access to both public and private charging equipment should be obvious. The vast majority of consumers simply will not purchase a vehicle unless they have complete confidence that it can be conveniently refueled, day or night. For PHEVs, the equation is somewhat different, because the vehicle can continue to operate even after the battery has reached its minimum state of charge. There are, however, two important caveats to this. First, the operating costs for PHEVs are significantly higher when they are relying on gasoline as opposed to electricity. (The same is true for the emissions profile.) To the extent that a PHEV driver charges the battery infrequently, the fuel savings—and thus the cost savings—of owning a PHEV are significantly diminished.

In any area where the grid is limited by generation or distribution, it is important that grid-enabled vehicles be charged off-peak. (Roughly speaking, peak load is from noon until 7:00 p.m.) In California, where we do approach the capacity of the grid in summer afternoons, it is more than desirable to charge off peak—in fact, it is an issue of reliability for the grid. The good news is that the average American drives less than 30 miles a day. In that context, it will take about 7 kWh of electricity to recharge the average drivers' vehicle battery. At 110 Volts, such a charge would take about 7 hours. At 220 Volts, 16 Amps, it would take about 3.5 hours. Either way, with 17 off-peak hours each day, grid-enabled vehicles can be charged at night or in the morning. Typically, then, the average Chevy Volt driver will charge their vehicle at home for 3.5 hours after peak times, and then at work in the morning before noon.

Question. Will public or other charging stations that are used during peak hours be a problem?

Answer. The answer is no, and the reason is simply that it won't happen enough to matter. First, the vast majority of shared and other charging stations will be Level II (charging at 220 Volts). The power draw from these stations will be manageable for the generation and distribution assets in most of the Nation. More importantly, however, most people will charge their vehicles at night and when they first get to work.

From a systems standpoint, it is also important to note that smart charging stations will have mechanisms that limit charging to off-peak hours. If utilities are able to offer pricing incentives to charge off-peak, very little charging will take place on-peak form shared or private Level II chargers.

DC Charging (formerly called Level III charging) is another matter. DC charging will be used to refuel electric vehicles during longer trips when vehicle batteries are fully discharged. DC charging will allow a driver to fully charge the battery in a Nissan Leaf in 30 minutes. With DC charging, there are three issues. One is that the power rates are high, up to 50 kW. To put that in perspective, homes use an average of 1.2 kW. So DC charging is like providing power for 40 homes. The second issue is that typical drivers will only use DC charging when they have a fully discharged battery, so they need a lot of energy. Finally, and somewhat related, is the fact that DC charging will typically take place when drivers are in a hurry, so they will not wait for off-peak times.

It's my view that to compensate for these challenges, DC chargers should come with storage batteries that can be charged off-peak at modest rates. The batteries could then assist in charging vehicles during peak hours to minimize the grid impact.

Question. At what point will additional capacity (generation, transmission, or distribution) be required because of the extra demand from PHEVs?

Answer. The only problem in the short term will be localized loads. The power available to the average home is about 30 kW. A Tesla roadster can charge at up to 15 kW. So adding a Tesla Roadster to a home will frequently require additional distribution to the home. Adding a few of these vehicles on a block can require more transformers and more local distribution lines.

From a broader perspective, the need to add generation and transmission will be so slow that we will never notice. Automotive technology adoption is very slow. After having hybrid technology for about 10 years, it still amounts to less than 4 percent of the automotive inventory of the United States. People keep their cars for about 7 years and even then most don't pick new technology vehicles. In general, the util-

ity industry will have adequate time to plan to stay ahead of the demand for electricity from grid-enabled vehicles.

Another way of looking at this is that the average home uses about 1 MWh of energy a month. A vehicle will use about 250 kWh of energy a month. So when every home in America has an electric vehicle, home energy use will go up by 25 percent—a manageable increase at an aggregate level. This transition will take decades.

QUESTIONS SUBMITTED TO ALAN TAUB

QUESTIONS SUBMITTED BY SENATOR ROBERT F. BENNETT

Question. How much investment have you committed to producing electric vehicles?

Answer. To date, we have invested more than $1 billion on electric vehicle development, including $700 million to develop and manufacture the Chevrolet Volt extended-range EV.

Question. What will be the resulting rate of production?

Answer. The start of production for the Volt is scheduled for late 2010. Production rates will be managed to ensure a quality launch experience. We expect to be able to produce tens of thousands of vehicles as we ramp up production. These products will be produced at our Detroit-Hamtramck, MI high-volume production facility, with battery packs being manufactured in Brownstown Township, MI. In addition, our Volt supply base includes 196 suppliers in 24 States.

Question. How fast do you expect the costs of the battery cells and packs to drop?

Answer. It normally takes three generations of development to meaningfully reduce the cost of a new technology. The speed with which we transition from one generation to the next is largely dependent on parallel advances in R&D and engineering development, associated advances in manufacturing processes, and, finally, the commercial incentives that are in place to accelerate these efforts. GM has analyzed the potential cost reductions through the three generations; these internal analyses show potential cost reductions at least as good as those set forth by the U.S. Advanced Battery Consortium (USABC). Policies and initiatives that support the production of cells, packs, and vehicles in the United States will facilitate further reductions.

Question. How will your plans change if they don't drop that fast?

Answer. The future of sustainable personal mobility involves many technology alternatives, including batteries, motors, power electronics, hydrogen fuel cells, ethanol, and other biofuels. GM is committed to accelerating all alternative technologies and we will work to ensure that durability, cost, and timing stays the course.

Question. How do you expect to measure and guarantee battery performance, since battery capacity will deteriorate over time?

Answer. Our long-term goal is to design the system to minimize battery life deterioration. It is important to note that, because of known battery usage and calendar life degration, GM designed the Volt to meet specifications based on projected battery performance of 10 years/150,000 miles. We continue testing of batteries at our state-of-the-art battery lab and on the road in support of our current highly competitive warranty program. We are also looking to secondary markets for battery re-use after initial vehicle life. Programs that support battery residual value and help mitigate the risk of aggressive development are important to the expansion of the vehicle electrification market.

Question. Based on your understanding of customer preferences, how big is the market for electric vehicles given the higher cost and changes in driver behavior they will require?

Answer. We believe the Volt, with its extended-range capability, provides the functionality needed to allow an electric vehicle to appeal to the broadest possible market. The size of this market will depend largely on vehicle cost and consumer preferences; therefore, incentives are important to attract consumers and accelerate the expansion of this new market.

QUESTIONS SUBMITTED TO MARY ANN WRIGHT

QUESTIONS SUBMITTED BY SENATOR ROBERT F. BENNETT

MEETING DOE GOALS FOR COST AND PERFORMANCE OF BATTERIES

Question. The Department of Energy (through the EERE office) has established cost and performance goals for both 10-mile and 40-mile batteries to be achieved in 2012 and 2014, respectively. The current technology is behind the curve in meeting these goals. The goals for the 10-mile battery are as follows:

	2012 Goal	Current Status
Cost	$1,700	$3,400
Cycle Life	5,000	1,700–2,000
Life	10+ years	3+ years
Weight	60 kg	80–120 kg

Do you expect to meet the DOE goals for battery cost and performance? If not by DOE's dates, when would you expect to?

Answer. By the year 2015 we expect the cost of our PHEV battery systems to be at $500/kWh. The EERE goal is based on a battery system with 3.4 kWh of available energy. Battery systems are designed with an energy content buffer to provide satisfactory vehicle performance and ensure reliability and warranted life. This means that a battery with 3.4 kWh of useable energy will be designed to have a total energy content of 5.2 kWh. The corresponding battery system cost at $500/kWh is $2,600. By 2015 we expect to meet or exceed the following goals:

—Calendar life of 10 years (our 8+ years of real-time testing provides a high confidence factor).

—Cycle life of 4,500 cycles.

—Battery system mass of 60 kg.

By the year 2020 we expect to be at a system cost level of $1,250 or less, have a cycle life of 5,200 cycles and a battery system mass of less than 60 kg.

WARRANTING BATTERIES

Question. According to the National Research Council's report on electric vehicles, replacing the battery pack when it is depleted could cost more than $3,300 for PHEV–10s and $14,000 for PHEV–40s. Although there is some uncertainty about the exact cost, without doubt it will be significant. Given this cost, the warranty that a company decides to offer on the battery will be a key factor in the marketability of these vehicles.

Although DOE has set a goal of 10+ years for the calendar life of PHEV batteries, I understand that current technology is only capable of approximately 3–5 years.

What warranty do you expect to provide on your batteries sold for 2015 installation?

Answer. Ten years for HEV batteries. The duty cycle for PHEV batteries places much greater stress on the battery than the HEV application. This combined with the emergent nature of PHEV battery technology will require us to offer a range of warranty terms based on the vehicle application requirements and specific battery chemistry. A full 5 year/50,000 mile with a 6–10 year pro-rata warranty is a possibility.

Question. Are you confident that the great majority of these batteries will meet the warranty?

Answer. This will be very much dependent on the manufacturer. We are confident that Johnson Controls battery products will satisfy our warranty specifications, but we cannot speak for our competitors. Also, the small start-up vehicle OEMs that will produce relatively small volumes annually may not feel compelled to offer the same vehicle system warranties as the larger established OEMs.

UNCERTAINTIES AND TRADE-OFFS WITH DURABILITY, SAFETY, AND COST

Question. The batteries envisioned for electric cars have not been deployed on this scale before, and are therefore untested in the commercial field. Accordingly, battery manufacturers will have to rely on assumptions and demonstration-scale information about the durability, safety, and cost of these batteries. Although most observers believe that the durability and safety questions can be resolved in the short-term (<5 years), this is a big assumption that is often simply overlooked.

To offset the significant cost of the battery, it may be tempting to provide less durability or safety. We saw a similar problem in 2008 when certain lithium laptop batteries overheated (with some actually causing fires and property damage) because of the tradeoffs associated with reducing cost and size.

How do you expect to handle issues of durability for the first few years before the manufacturers gain actual in-field commercial experience?

Answer. First, lithium batteries for consumer electronic devices and lithium batteries for electric drive vehicles are two very different products and should not be compared on the basis of name similarity alone. Li-ion cells and batteries for vehicle motive power are designed to the exacting and rigorous standards of global automobile original equipment manufacturers which include very rigorous requirements for performance, cost, and safety.

Durability, defined as long life without deterioration in performance, is a non-issue for batteries for electrified powertrain vehicles. Specifically, in the case of PHEV batteries, the key performance metric is electric equivalent range which corresponds to battery energy capacity. All electrochemical systems will demonstrate a predictable reduction in capacity and/or power as the battery accumulates cycles. The battery performance requirements formulated by the United States Advanced Battery Consortium (USABC) and/or other vehicle manufacturers are end-of-life requirements that allow for a performance buffer to be designed into the battery pack. The performance buffer is simply additional energy capacity that compensates for the energy gradually lost during the accumulation of driving cycles and calendar time. The other vehicle systems dependent upon battery energy, most notably the powertrain, are managed based on the battery end-of-life characteristics. This ensures that even as the battery ages, the vehicle owner/operator will experience no discernable changes in vehicle performance, fuel economy, or emissions.

Reliability, or dependability, is related to manufacturing consistency of the raw materials as well as the finished cells and assembled battery systems. The reliability of new technologies can be ascertained in the laboratory with a high degree of confidence. Follow-on field testing is performed to validate these findings. A common example is the use of internal combustion engine test stands by the automotive OEMs. Credible battery manufacturers routinely put cells and complete battery systems on accelerated testing not only to maximize the data available, but to accelerate the battery cycling process (discharging and charging) so that 10 year life capability can be established in a much shorter timeframe, e.g., 15 months.

Product reliability is a function of the entire supply chain, materials and equipment included. The critical importance of a dependable supply chain is the reason why Johnson Controls successful proposal for Recovery Act funding emphasized not only building advanced battery manufacturing facilities, but standing up an advanced battery industry including the domestic supply chain for materials, equipment, and recycling.

Ultimately, battery system ratings for life, cycle life, power, energy, and safety are data driven; nothing is assumed.

Question. Batteries face issues related to durability, safety, and cost; how do you see the relation among these three and the trade-offs that exist? For example if you aggressively reduce cost, is it likely that you will give up durability or reduce safety?

Answer. The safety of our products is non-negotiable. We will not introduce any product into the marketplace that does not satisfy our Johnson Controls internal criteria for safety as well as our customer's safety and abuse tolerance requirements. We will continue to aggressively reduce costs while ensuring compliance with all automotive standards.

However, there are legitimate opportunities to optimize cost versus design life. From a design and manufacturing perspective we are pursuing dual paths to cost reduction:

—Improved utilization of key materials; enhancing the energy and power output of existing materials without adding mass or volume. This will be accomplished via improved process capability in both our manufacturing plant and our suppliers' facilities. Domestic supply chain development and maturation is a key facet of this approach.

—Lowering the unit cost of key materials. This is a function of scale, but also requires a mature and capable domestic supply chain to ensure that we have access to materials and components which represent the most current product and manufacturing technologies.

It would be possible to take cost out of a battery system if it did not have to be warranted for 10 years/150,000 miles as part of advanced technology vehicle warranties dictated by California laws for emissions control devices or for the 8 year/80,000 miles Federal standard. Having said that, it is important to emphasize that

cost versus life optimization is not the same as cost versus reliability. Poor reliability means poor quality.

STANDARDIZATION OF TECHNOLOGY

Question. To successfully integrate a significant number of electric vehicles into the fleet, there must be a certain amount of standardization of the technology. Standards in some of these areas are being developed, such as the type and size of the plug to charge the car.

Which components of PHEVs and electric vehicles will need to be standardized, such as the type of plug needed to charge the car?

Answer. For purposes of cost, reliability, serviceability, and safety, standards would be appropriately applied to the interfaces between the battery system and the vehicle and the operator and the vehicle. For example:

—High power connector from the vehicle to the battery
—Battery to powertrain controller communications bus
—Charging plug from external alternating current power source to vehicle
—Terminology and nomenclature relating to vehicle owner/operator understanding of battery state-of-charge and charging procedure(s)

An area equal to and perhaps more critical to the sustainability of our fledgling industry is transportation standards for domestic and international shipments of cells and batteries. We responded to the DOT's recent rulemaking proposal for shipments of lithium-ion cells and batteries. In summary, we felt that these proposed regulations, if approved, would place unnecessary burdens on battery companies doing business in the United States, thus thwarting the goal of both the Congress and the administration for America to become a leader in green transportation technologies. Although their rulemaking proposal contains numerous detailed discussion points, we identified two high level areas where the DOT language represents missed opportunities to help enable the development of a sustainable transportation industry in the United States:

—In many instances the DOT proposed rules differ from those recently promulgated by the U.N. concerning international shipping of batteries. This lack of harmonization is frustrating from two critical perspectives:
  —It runs contrary to DOT's stated position that harmonization of international shipping regulations is a desired goal; and
  —It will impose cost penalties on commerce done in the United States, thus putting American producers at a competitive disadvantage.
—The proposed regulations for air shipments are particularly onerous and would result not only in increased costs, but the likelihood of a shortage of qualified battery cargo space on aircraft.

Question. Who is involved in the standardization discussions? What is the status?

Answer. From the product side, the key standards organizations are:

ANSI: American National Standards Institute
BCI: Battery Council International
CENELEC: European Committee for Electrotechnical standards
DOE: U.S. Department of Energy
EN: European Norm
IEEE: Institute of Electrical and Electronics Engineers
JIS: Japanese Industrial Standards
PRBA: Rechargeable Battery Association
SAE: Society of Automotive Engineers
UL: Underwriters Laboratories

In the United States SAE, ANSI, UL, and IEEE are already engaged in the standards process and many SAE standards already exist or have been proposed. However, much work remains to be done, particularly in terms of international harmonization of standards.

We appreciate the opportunity to discuss the broad issue of standards. In fact, there is specific language for Electric Drive Transportation standards in S. 1462—American Clean Energy leadership Act in section 153. The legislation states:

"IN GENERAL.—Not later than 180 days after the date of enactment of this act, the Secretary, in consultation with the National Institute of Standards and Technology, the National Laboratories, utilities, vehicle manufacturers, battery manufacturers, industry trade associations, and such entities as the Secretary determines to be appropriate, shall submit to Congress a report containing recommendations for establishing and adopting consensus on industry standards for electric drive transportation."

We support the Senate directive that DOE assumes a strong role in this process, but we believe it is in the best interest of the vehicle manufacturers, battery manufacturers and consumers for the ultimate decisionmaking authority on final consensus standards language to be maintained by the traditional governing bodies, in particular SAE, IEEE, and the battery industry trade associations BCI, and PRBA.

The legislation lists a number of areas in which standards should be developed. Specifically, we would recommend strengthening section 9(a)(2)(vi) on battery safety, by changing the line to read:

"(vi) battery safety including test methods and metrics; and"

In conclusion, the broader answer to your question of reliability and feasibility of this technology is that for the first time in the United States serious investment has been made by a great variety of companies including large manufacturers and suppliers. This is the moment to drive the industry forward. Warranty, cost and standards are key elements to be worked out. However, the issue of cost for warranty and batteries is primarily based on demand; thoughtful Government investment into spurring demand via fleet electrification, purchase incentives, and standardization policies will make a great difference in the future of this technology and our collective success.

Senator DORGAN. Ms. Wright, you talked about building a plant and at this point, you only see the capacity for 50 percent of your potential production. So, you're betting on a future. I guess all of you are betting on a future that many of us hope will exist, and it probably will only exist if we understand the need to change public policy to try to lead in that direction, as opposed to sitting around and waiting for something good to happen.

CONCLUSION OF HEARING

So, let me thank all of you for your being here today and your testimony and your contribution to this hearing.

This hearing's recessed.

[Whereupon, at 12:10 p.m., Tuesday, February 23, the hearing was concluded, and the subcommittee was recessed, to reconvene subject to the call of the Chair.]

MATERIAL SUBMITTED SUBSEQUENT TO THE HEARING

[CLERK'S NOTE.—The following testimonies were received by the Subcommittee on Energy and Water Development subsequent to the hearing for inclusion in the record.]

PREPARED STATEMENT OF PG&E CORPORATION

PG&E Corporation is an energy holding company headquartered in San Francisco, California and the parent company of Pacific Gas and Electric Company (PG&E). Pacific Gas and Electric Company is California's largest utility, providing electricity and natural gas to more than 15 million people throughout northern and central California. PG&E is a recognized leader in energy efficiency and has among the cleanest mixes of electric power of any utility in the country.

PG&E is committed to improving California's air quality and addressing the challenges associated with climate change, and reducing greenhouse gas emissions from the transportation sector is a key step in meeting both of these objectives. For nearly two decades, PG&E has actively worked to advance cleaner, more efficient transportation technologies for our customers and our own operations. This is a key pillar of PG&E's overall emissions reduction and environmental stewardship strategy —no less important than procuring clean sources of energy or protecting wildlife habitats.

No one fuel or technology is the answer to our fuel dependency and climate challenges, however, PG&E views electric vehicles (EV), including battery electric (BEV) and plug-in hybrid electric vehicles (PHEV) and trucks as practical and dynamic solutions. Parts of PG&E's territory are expected to be early adoption hubs for electric vehicles, therefore our readiness to safely and reliably integrate these vehicles into our electric grid will be a critical success factor in the California electric vehicle market.

In addition to extensively modeling electric vehicle adoption scenarios and the potential impacts to the electric grid down to the local neighborhood level, PG&E is actively involved in real-world testing and research aimed at providing a clear roadmap for our electric transportation readiness.

Currently, PG&E is using its fleet to test the usefulness, effectiveness, cost, durability, reliability, infrastructure support requirements, and safety of newly commercialized electric drive vehicle and truck technologies. For example, in 2008, we added four passenger electric drive vehicles to our fleet—a Ford Escape PHEV, Scion e-box BEV, Mitsubishi i-Miev BEV and our second Toyota Prius PHEV. PG&E has also partnered with General Motors and will take delivery of 10 Chevy Volts later this year.

PG&E is one of 14 fleets in the Nation to assess a hybrid diesel-electric bucket truck developed by International Truck and Eaton Companies, which eliminates the need to idle and burn diesel while operating the bucket used to hoist servicemen to perform repairs. Field test results show the hybrid diesel-electric bucket truck reduces fuel consumption between 30–60 percent, reduces emissions 50–90 percent, improves operational and scheduling flexibility, and reduces maintenance costs.

PG&E has also partnered with Smith Electric Vehicles for 12 medium duty battery electric trucks in 3 configurations to support our field work, including boom, flat bed, and service trucks. In addition, with pick-up trucks being the most common vehicle in PG&E's fleet, PG&E has partnered with General Motors to take delivery of more than 100 of their hybrid units. PG&E has also partnered with Raser Technologies for six plug-in hybrid pick-up trucks.

Through field tests of these vehicles, we are helping to demonstrate the increased efficiency of electric vehicles. We are also helping to understand the impact on the grid of charging electric vehicles—and the need for a robust "smart charging" infrastructure to enable vehicles to recharge batteries automatically when ample electric supply is available. PG&E's current deployment of nearly 10 million smart meters, the largest roll-out in the country, provides a critical foundational technology that

will help ensure as more electric vehicles are commercially introduced, PG&E can ensure they are safely and reliably integrated with the grid.

To support the development of a smart charging infrastructure, PG&E is actively engaged with the Electric Power Research Institute (EPRI) and the Society of Automotive Engineers to develop and revise the important codes and standards related to charging of EVs and the protocols needed to allow EVs to communicate with the grid.

Beginning in Q2 of 2010, PG&E will embark on a large pilot project with EPRI to test various electrical chargers and load management systems to minimize the effects of EVs on the electrical grid while maximizing customer convenience at various EV rates. This project will enable PG&E to develop critical knowledge and expertise to safely and reliably begin supporting electric vehicle customers as the broad rollout of EVs begins in late 2010.

In addition to the important testing and deployment work that PG&E is conducting in CA, the company actively supports Federal policy aimed at expediting the successful market development of electric vehicles. PG&E has long been an active member with board representation at the Electric Drive Transportation Association.

In 2009, PG&E joined the Electrification Coalition which is committed to promoting policies that expedite the deployment of grid-enabled vehicles and infrastructure on a mass scale, moving electrification beyond a niche concept into a compelling and widely available alternative to the current transportation system. In November 2009, the Electrification Coalition released its Electrification Roadmap, a sweeping report outlining a vision for the deployment of a fully integrated electric drive network. The Electrification Roadmap outlines critical policy recommendations, such as promoting the inclusion of electric vehicle related investments in utility rate base and adjusting utility rate structures to facilitate EV deployment, both necessary to successfully establish Electrification Ecosystems around the country and drive the economies of scale needed to sustain and grow the electric vehicle market.

As global demand for oil increases from the emergence of economies such as China and India, along with our Nation's increased dependence on foreign supplies of oil, we face an uncertain energy future. The time is now to establish bold policy commitments that will chart a different future for our Nation's energy supply and transportation infrastructure. PG&E recognizes the strong commitment of the Congress to adopt Federal policies aimed at creating a market for electric transportation, such as those in the American Recovery and Reinvestment Act and the House passed Advanced Vehicle Technology Act of 2009. Our hope is that Congress will recognize and act to implement the bold and necessary policies outlined in the Electrification Roadmap.

PREPARED STATEMENT OF LINDSAY LEVEEN, TIBURON, CA

AN ESSAY ON THE THERMODYNAMICS AND ECONOMICS OF LITHIUM BATTERIES

My name is Lindsay Leveen. I am a chemical engineer and my interest is to apply my scientific knowledge to alternate energy sources. My graduate work involved the study of thermodynamics. Over the last 35 years my work has been in cryogenics, microelectronic device fabrication, nanotechnology development, fuel cell fabrication, and most recently biotechnology.

Purpose.—The purpose of this essay is to provide the subcommittee with reasoning based on thermodynamics why lithium batteries will likely not lower in cost and therefore why plug in passenger vehicles (cars and trucks) will probably not make any significant dent in the consumption of gasoline and diesel. I wish to prevent the waste of precious resources on a technology that I believe is headed toward a dead end.

I have no commercial interest in any energy or battery technology and am writing this essay as a concerned citizen to inform the Senate Subcommittee on Energy and Water Development of the severe thermodynamic limitations of Lithium Secondary Batteries and of the probable long term unaffordable economics associated with plug-in passenger vehicles that will rely on them. Much of this report is taken from my presentations, reports, publications and blogs www.greenexplored.com I have produced in recent years.

Thermodynamics—Definition.—The science concerned with the relations between heat and mechanical energy or work, and the conversion of one into the other: modern thermodynamics deals with the properties of systems for the description of which temperature is a necessary coordinate. (dictionary.com).

Moore's Law and Learning Rates for Technologies.—Gordon Moore one of the founders of Intel Corporation, postulated that semiconductor integrated circuits

would enjoy a doubling in performance in a period of every 18 months. This rate of learning allows performance to be improved exponentially with time for the same original cost.

Many technologies that engineers and scientists develop need a "Moore's Law" in order to improve their performance and correspondingly their economics to capture vast markets. Most efforts around the improvement of alternate energy technologies vis a vis competing with fossil fuels have not yielded these "Moore's Law" rates of learning. In particular for the past decade as much as $6 billion has been spent without any real success toward the "learning curve" of PEM fuel cells. Much of these $6 billion was appropriated by the Federal Government. The learning curve for PEM fuel cells over the past decade yielded a yearly learning rate of less than 2 percent. By comparison the Moore's Law yearly learning rate for integrated circuits has averaged over 40 percent for more than three decades.

My Experience With Moore's Law.—For almost 20 years I directed teams of engineers that designed state of the art Integrated Circuit (IC) fabrication facilities that helped drive this rapid rate of learning and therefore cost improvement in computers and other electronic devices. A simple explanation for the high learning rates in IC fabrication is that the technology was neither constrained by thermodynamics nor reaction kinetics but simply by the line width of the circuits within the ICs. To drive Moore's law in IC fabrication improvements in lithography, higher purity gases for deposition, implantation, and etch, as well as the occasional increase in the size of wafer being fabricated were needed.

Moore's Law, Thermodynamics and Lithium Batteries.—To drive the learning rate in PEM fuel cells and similarly lithium secondary batteries both thermodynamic and reaction kinetic constraints have to be overcome. The reason why thermodynamics places such constraints is that the functioning of these systems depends on chemical reactions. Thermodynamics determines how much useful energy can be derived from a chemical reaction. But we know that the thermodynamic constraints cannot be overcome as the laws of thermodynamics are inviolable. ICs do not undergo chemical reactions to function, but all batteries and fuel cells do involve chemical reactions to deliver energy. It is these chemical reactions that are limiting the possible learning rate.

The Resulting Economic Problem.—Significant effort and much money is now being spent on advanced batteries for plug-in full electric or plug-in hybrid vehicles. Such vehicles will require between 10 kilowatt hours and 50 kilowatt hours of stored electricity if the range of the vehicle purely propelled on stored electricity is to be between 40 and 200 miles. Lithium chemistry based secondary (chargeable) batteries presently offer the best performance on a weight and volume basis and therefore represent the best "hope" for a "Moore's law" to solve the world's addiction to fossil oil. Sadly "hope" is not a winning strategy. Present costs of such battery packs at the retail level range from $800 per kilowatt hour of storage to over $2,000 per kilowatt hour of storage. One can purchase a 48 volt 20 amp hour Ping Battery for an electric bicycle directly from this Chinese "manufacturer" for less than $800 delivered by UPS to any address in the USA. A123 offers a battery system that will modify a standard Prius to a 5 kilowatt hour plug-in Prius for $11,000 or around $2,200 per kilowatt hour fully installed by a service station in San Francisco. The Ping battery delivers much less instantaneous power (watts) and that is the reason their batteries are less expensive on a stored energy basis (watt hours) than are the A123 batteries. Both the Ping and the A123 batteries claim safety and claim to be manufactured with phosphate technology that will neither short circuit nor burn.

Economic Case Study the Example the Standard Prius vs Plug-in Prius.—The following is an economic analysis of a standard Prius versus a plug-in Prius using A123's lithium battery pack: The standard Prius will get 50 MPG and let's assume that the driver drives 12,000 miles a year. The standard Prius driver will need to purchase 240 gallons a year of gasoline at an estimated cost of $720 per year with gasoline at selling for $3 per gallon. If the driver purchased the A123 plug-in system and can recharge the system at home and at work such that half the mileage driven in a year is on batteries and half is on gasoline the driver will save $360 a year on gasoline. The driver will need to buy some 2,000 kilowatt hours a year of electricity from the grid in order to save this gasoline. At 10 cents per kilowatt hour the driver will spend $200 a year for electric power and will therefore only enjoy $160 a year in net operating savings. The $11,000 set of batteries have a maximum expected life of 8 years and the owner must set aside $1,375 a year for battery replacement without accounting for the time value of money. The battery replacement cost is simply too expensive to justify the savings in gasoline. How high do gasoline costs have to rise and how little do batteries have to cost to make the plug in viable? Let's assume gas prices reach $6 per gallon and electricity remains at 10 cents a

kilowatt hours we have a yearly operating savings of $520. These savings will still be far short of the money needed for battery replacement.

The A123 batteries will need to drop to 15 percent of their present cost to make the proposition of converting a Prius to a plug-n "worthwhile". To reach this cost target in a decade one needs a yearly learning rate of approximately 26 percent. With 35 years of work experience, I have concluded that in the best case of battery costs (no inflation in raw materials) a 4 or 5 percent yearly learning rate could be achieved over the next decade. But if we believe that gasoline will double then we also have to assume that plastics, copper, cobalt, nickel, graphite, etc. will also double in unit cost. As raw materials account for three-quarters of the manufacturing cost of lithium batteries the inflation adjusted cost will increase at a higher yearly rate than the learning rate will lower costs. My prediction is therefore that lithium secondary batteries will likely cost more per unit of energy stored in 2020 than they do today.

Toyota is a company well known for its cars with improved fuel economy and therefore is a master of thermodynamics and must have "optimized" the cost and performance of its batteries in the standard Prius deploying a relatively small battery pack and with the choice of Nickel Metal Hydride chemistry rather than lithium chemistry. While Toyota may be experiencing safety problems no one can fault this company on fuel efficiency. Other car companies such as Ford have also chosen Nickel Metal Hydride as their hybrid car battery platform. Fisker and GM are touting plug in hybrids with lithium batteries and are much more aggressive in their claims of cost improvement and their ability to drive "Moore's Law" in their battery systems. My educated guess on all of this is that Toyota, Ford and the car manufacturers that stick with smaller nickel metal hydride battery systems and the traditional non plug-in hybrid will sell tens of millions of such vehicles over the next decade. Renault, GM, Fisker, Tesla, and others who go for plug-in hybrids or full electric vehicles will only sell a few tens of thousands of vehicles in the next decade. I simply believe we will not have "Moore's Law" at play here but have a very fractional Moore's Law that holds.

Argonne National Labs published an exhaustive review of the materials and associated costs of lithium batteries back in May 2000, http://www.transportation.anl.gov/pdfs/TA/149.pdf. The total material cost for the cell was estimated at $1.28 and the total manufacturing cost of the cell including overhead and labor was estimated at $1.70. This Argonne report is perhaps the best report written on the economics associated with lithium battery fabrication. Actually had folks read this report back in 2000 they would have realized that the learning curve for lithium batteries would be painfully slow. Materials just make up far too much of the battery cost and the quantity of materials is fixed by the chemistry. Therefore economies of scale could not drive a Moore's Law type rate of learning and a very fractional Moore's Law resulted. In the early years of lithium cell development from approximately 1990 to 2000, the improvements in chemistry and in economies of scale did allow the technology to enjoy a Moore's Law type learning rate and it has been reported that costs of an 18650 cell reduced from $18 to $2 per cell in that decade. Unfortunately the technology has now hit an asymptote in their cost reduction curve.

By doing a Google search on an 18650 lithium ion battery I came across this link http://www.batteryjunction.com/li18322mahre.html. This site lists a selling price of $5.29 each for 200 or more cells. The cells are 3.7 volts with 2.2 amp hours so they are capable of holding 8.1 watt hours of energy from full charge to discharge. Expressed in cost per kilowatt hour of nominal capacity these loose cells cost around $650. My guess is that if you applied today's costs of cobalt, nickel, lithium, lithium salts, plastics, copper, graphite, and other constituent materials that make up a cell, the material cost in November 2009 compared with May 2000 have increased by more than 150 percent and a current estimate of the materials used in the Argonne labs report will show cost of about $3 per cell versus $1.28 back in May 2000. Hence this company sells the cells for $5.29 each. From my previous analysis of the probable learning rate I would not be surprised if in 2020 the selling price per 18650 lithium cell is as high as $6 rather than as low as $3.

Conclusion.—Lithium batteries are and will remain best suited for items as small as a cell phone and as large as a bicycle. The cost relative to performance or these batteries will likely not improve by much in the coming decade. Although some standard hybrid vehicles may use lithium batteries with low capacity, their cost will remain high. Also plug-in vehicles that have a range longer than 10 miles using battery power will likely not penetrate the market significantly. Given the likely scenario that plug-in passenger cars and trucks based on lithium battery technology will not reduce U.S. consumption of gasoline and diesel fuel in large measure, I am

asking the subcommittee to limit the funds that the U.S. Government will appropriate for research and development of this technology.

Thank you

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