S. HRG. 110–671

# VEHICLES POWERED BY THE ELECTRIC GRID

## HEARING

BEFORE THE

## COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

TO

RECEIVE TESTIMONY REGARDING THE CURRENT STATE OF VEHICLES POWERED BY THE ELECTRIC GRID AND THE PROSPECTS FOR WIDER DEPLOYMENT IN THE NEAR FUTURE

SEPTEMBER 16, 2008

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# C O N T E N T S

STATEMENTS



APPENDIX

# VEHICLES POWERED BY THE ELECTRIC GRID

**TUESDAY, SEPTEMBER 16, 2008**

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
*Washington, DC.*

The committee met, pursuant to notice, at 10 a.m., in room SD–366, Dirksen Senate Office Building, Hon. Jeff Bingaman, chairman, presiding.

## OPENING STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

The CHAIRMAN. OK, why don't we get started here.

This hearing is to hear testimony on the current state of the electric vehicles and their prospects for widespread use in the United States. It is hard to find an article in a newspaper lately about the automobile industry that does not mention hybrids, plug-in hybrids, or the future of the industry. So we thought it was a good time to talk about how close this electric car future actually is, and also a good time to talk about the issues, since people are understandably focused on the high price of gasoline and wondering when they are going to have real alternatives to that.

So the case for seriously reducing our reliance on foreign oil is exceptionally strong. We make that case ourselves here on a daily basis. We consume roughly a quarter of the world's oil production, and obviously this is a serious economic problem for our country in the long term.

Let me indicate that electrification of the transportation sector I think is held out as one of the great hopes for dealing with several of our problems. Obviously, there is a benefit to consumers as they would pay costs estimated to be less than a quarter of what they now pay in order to get around. You add to this the benefits to the country, both with regard to the balance of trade and national security and reducing our need to import such large amounts of expensive oil and allowing instead the use of abundant domestic electricity, I think there clearly are great benefits there.

Let me also indicate that we have examples of the technology that is going to be talked about here outside the northwest corner of the Russell Building that some of our witnesses have arranged for us, and these will be displayed for a time following the hearing. There is, as I understand it, a two-wheeled electric vehicle from Vectrix. If I misstate this, correct me. There is a four-wheeled, low-speed electric vehicle from Chrysler's GEM brand, which is also there. There is a plug-in hybrid electric Prius from Toyota, and there is a plug-in work truck from DUECO, and we appreciate you making those available for us to look at. I'm hoping if we can complete the hearing at a good hour, we will have time to go see those before the noontime.

So let me defer to Senator Domenici for any comments he wants to make, and then I will introduce our witnesses.

**STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO**

Senator DOMENICI. Thank you very much, Mr. Chairman. I apologize to the witnesses for not joining you down there to shake their hands and thank them for coming. As you know, Senator Bingaman has a few years of youth over me, and he can walk around and greet people while I sit down. That is a pretty good working relationship.

In any event, let me suggest that today the American people are more focused on energy policy than at any other point in the 36 years that I have been a United States Senator and with good reason. Over the past year, gasoline prices have reached unprecedented levels. The transportation sector is the largest user of petroleum in the United States—we all know that—totaling 70 percent of all consumption. Moreover, the transportation sector accounts for about one-third of the greenhouse gas emissions in this country.

Sometimes we do not agree on much around here, but one thing we all agree on is that we must reduce our reliance on imported oil. It seems quite obvious that what follows after that is we must find some way to use less crude oil to get around and less crude oil for the daily transportation needs of the United States people.

It is no secret that I am a strong advocate of increasing domestic production through offshore drilling, and I am also a strong supporter of more investment in advanced technologies. More conservation of our resources will be needed if we are to meet our long-term energy challenges. I have been part of enacting legislation over the past few years that helps achieve both of these goals, and I have introduced legislation this year to do even more.

Last year we took action by increasing the fuel efficiency standards by 40 percent for the first time in 32 years, establishing a 36 billion gallon renewable fuels standard and dramatically increasing funding for clean energy technologies. While Congress has made considerable progress in advancing policies that will strengthen our Nation's energy security, we must go further to address our Nation's energy challenges.

Over the past several months, I have talked a lot about a bridge of increased domestic production that is needed to sustain the country until we have developed new technologies. On the far side of that bridge lies an age when clean energy technologies like plug-in hybrid electric vehicles are available and deployable on a wide scale across the country. We must continue to take greater steps toward implementing policies that speed our path across this bridge.

The Gasoline Price Reduction Act, which I introduced along with Senator McConnell and 42 Republicans, authorized $500 million over the next 5 years to develop a better battery technology.

In response to high gas prices, Americans have curtailed their behavior by driving less. This has been rather amazing. They are also trading in their gas-guzzlers for more efficient cars. The marketplace is speaking.

Today, as we will hear from our witnesses, nearly every major manufacturer is in production or development of some kind of hybrid electric technology. According to the Electric Drive Transportation Association, increasing the number of electric and hybrid vehicles into our fleet could reduce our petroleum fuel consumption significantly. I believe you all think that is true.

Plug-in vehicles, with their potential to reduce our Nation's consumption of oil and our greenhouse gas emissions, have generated a great deal of excitement. However, technology hurdles from battery manufacturing to grid infrastructure improvements remain. I am hopeful that this new technology will benefit from the loan guarantee programs that we set up in the Energy Policy Act of 2005.

In addition, through the appropriation process, we are working with other colleagues to provide short-term assistance such as loans to help auto manufacturers retool and adjust to the new mandates and the marketplace.

I thank the witnesses, each one of you, for appearing today. This is a gloomy day not only because of the clouds, but obviously because of what is going on on Wall Street. You probably would much prefer to be elsewhere, but we will have some good testimony today.

Who knows when we will make that breakthrough that is generally needed for the United States in terms of our excessive use of petroleum products.

Thank you very much, Mr. Chairman. I am pleased to be with you this morning.

The CHAIRMAN. Thank you.

Let me introduce our witnesses and then call on them each to make their statement.

Brian Wynne is the President of the Electric Drive Transportation Association. Thank you for being here.

Edward Kjaer—is that the correct pronunciation? Kjaer is the Director of Electric Transportation with Southern California Edison. Thank you for coming.

Robert Wimmer—is that correct?

Mr. WIMMER. Wimmer.

The CHAIRMAN. Wimmer, the National Manager, Technical and Regulatory Affairs, in the Energy and Environmental Research for Toyota Motor North America. Thank you for coming.

Joseph Dalum——

Mr. DALUM. Dalum.

The CHAIRMAN. Dalum, Vice President of DUECO in Waukesha——

Mr. DALUM. Waukesha.

The CHAIRMAN. Waukesha, Wisconsin.

Thad Balkman, who is General Counsel and VP for External Relations with Phoenix Motorcars in Ontario, California. Thank you for being here.

If each of you could take about 5 or 6 minutes and give us the main points that you believe we need to understand about this issue, we would appreciate that. We will include your full statement in the record as if it were read, but we would appreciate you summarizing it if you could.

Mr. Wynne, go right ahead.

[The prepared statement of Senator Domenici follows:]

PREPARED STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

Good morning. Thank you all for being here. Thank you also to Chairman Bingaman for convening this oversight hearing on plug-in electric vehicles—technology with tremendous potential.

Today, the American people are more focused on energy policy than at any other point in my 36 years as a United States Senator. And with good reason. Over the past year, gasoline prices have reached unprecedented levels. The transportation sector is the largest user of petroleum in the United States, totaling 70% of all consumption. Moreover, the transportation sector accounts for about ⅓ of the greenhouse gas emissions in the country. Sometimes we don't agree on much around here. One thing we all agree on, however, is that we must reduce our reliance on imported oil.

It is no secret that I am a strong advocate for increasing domestic production through offshore drilling. And I am also a strong supporter of more investment in advanced technologies and more conservation of our resources will be needed if we are to meet our long term energy challenges. I have enacted legislation over the past few years that helps achieve both of these goals. And I have introduced legislation this year to do even more.

Last year, we took action by increasing the fuel efficiency standard by 40% for the first time in 32 years; establishing a 36 billion gallon renewable fuel standard; and dramatically increasing funding for clean energy technologies. While Congress has made considerable progress in advancing policies that will strengthen our nation's energy security, we must go further to address our nation's energy challenges.

Over the past several months, I've talked a lot about a bridge of increased domestic production that is needed to sustain the country until we have developed new technologies. On the far side of the bridge lies an age when clean energy technologies like plug-in hybrid electric vehicles are available and deployable on a wide scale basis across the country. We must continue to take greater steps toward implementing policies that speed our path across that bridge. The Gas Price Reduction Act, which I introduced along with Senator McConnell and 42 other Republicans, authorizes $500 million over the next five years to develop better battery technology.

In response to high gas prices, Americans have curtailed their behavior by driving less. They're also trading in their gas guzzlers for more fuel efficient cars. The marketplace has certainly spoken. Today, as we'll hear from our witnesses, nearly every major manufacturer is in production or development of some kind of hybrid electric technology. According to the Electric Drive Transportation Association, increasing the number of electric and hybrid vehicles into our fleet could reduce our petroleum fuel consumption significantly.

Plug-in electric vehicles, with their potential to reduce our nation's consumption of oil and our greenhouse gas emissions, have generated a great deal of excitement. However, technological hurdles—from battery manufacturing to grid infrastructure improvements—remain. I am hopeful that this new technology will benefit from the loan guarantee program that was set up in the Energy Policy Act of 2005. In addition, through the Appropriations process I am working with my colleagues to provide short-term assistance such as loans to help auto manufacturers re-tool and adjust to the new mandates and marketplace.

I thank the witnesses for appearing before us today. I look forward to your testimony on the state of today's technology and what we can strive for in the near-term.

## STATEMENT OF BRIAN P. WYNNE, PRESIDENT, ELECTRIC DRIVE TRANSPORTATION ASSOCIATION

Mr. WYNNE. Thank you, Mr. Chairman, Ranking Member Domenici, members of the committee. My name is Brian Wynne. I am President of the Electric Drive Transportation Association, which is located here in Washington. I am very pleased to be here today to talk with you about our industry's accomplishments, plans, and vision for electric drive transportation.

The electrification of the transportation sector brings together a range of interests and industries. At the Electric Drive Transportation Association, we represent auto manufacturers, battery and other technology developers, utilities, energy companies, and others. I am pleased to say that all of the witnesses this morning are members of my organization.

I am also pleased to report that we are on track to build new technologies and markets at a rapid pace. But building a new transportation sector will require industry and Government to work together and it will not happen overnight.

Grid-connected vehicle technology is moving forward very quickly. There are plug-in vehicle options available today, including the ones that the chairman referenced that are outside the Russell Building, and a significant number are coming, which I am going to list. They are coming to market in the next 3 years.

Major manufacturers have established ambitious vehicle time tables. Battery manufacturers are looking to scale up production, and electricity providers are making changes in order to integrate vehicles into their customer base.

I will give a brief summary of what you can expect in the next few years, but first let me explain a bit about electric drive.

In electric drive vehicles, electricity provides either all or part of the motive power for a vehicle. Electric drive vehicles are not just cars. They can be large trucks and neighborhood electric vehicles and everything in between. They get power from the grid or recharge on board. While there is enormous diversity in the technology, all the vehicles share a common benefit: they displace oil with electricity.

Vehicles that run on electricity from the grid, our focus here today, can be battery electric or plug-in hybrid vehicles. Battery electric vehicles operate entirely on their electric drive motor and have various range and speed capabilities. For instance, thousands of low-speed battery electric vehicles are in use today, like the Global Electric Motorcars neighborhood electric vehicle, and they provide a petroleum-free option for urban commuters across the country. Electric motorcycles, such as the Vectrix, are changing the two-wheeled fleet.

Also available is the Tesla Roadster, which goes 0 to 60 in just 4 seconds and travels 220 miles on a charge. Next year Phoenix, Suburu, and ZENN are planning to begin production of full-speed battery electric vehicles. The field will expand considerably in 2010. Toyota plans a Prius plug-in hybrid for the model 2010 year. Ford will put its plug-in hybrid Escape into production in the same year. Daimler has announced plans for production of a battery electric Mercedes-Benz and smart car. Tesla will begin producing their four-door family sedan. Nissan is rolling out a battery electric vehicle for fleet use with mass market introduction expected in 2012. Also in 2010, GM will begin production of the Saturn Vue plug-in hybrid and the battery electric Chevy Volt.

The Volt is different than a plug-in hybrid because the car will be propelled solely by the battery. It will have an internal combustion engine that only functions as a range extender by providing backup power to the battery. So that gives you a sense of some of the flexibility of the technology.

The 2010 production model of the Volt is being unveiled in Detroit this morning actually. It is a passenger vehicle with a range of about 40 miles on a single charge and that would cover the average commute for most Americans. GM is expecting that production will reach 60,000 units a year in 2012.

Hyundai is expecting a hybrid production over the next 4 years and is planning to commercialize plug-in hybrids sometime after 2013.

We are excited about the expanding availability of plug-in electric drive options, but how quickly they can reach commercial scale depends on a number of factors.

First, there are technology challenges that manufacturers and issue suppliers must address. The most obvious is performance and supply of new battery technologies. Some of the emerging plug-ins and the next generation of electric vehicles will use lithium-ion batteries. We need to ensure that they are as safe, durable, and affordable as the vehicle market demands. We should also work to make sure that they are manufactured here in the United States.

The shift to electric drive technology also requires significant investment in manufacturing infrastructure. Large scale production of electric drive vehicles and components in the United States will require new materials, new processes, and new production facilities.

In the utility and energy industries, grid-connected transportation will also require changes in electricity infrastructure and business models.

Changing transportation is a major undertaking. The right Federal policies can help us achieve it sooner. EDTA supports policy initiatives in three broad areas.

First, we support market initiatives to help industries and consumers invest in electric drive.

Second, we need reliable R&D support to advance the technology.

Finally, Federal policy can expand deployment in public and private fleets.

I have details on each of these three areas, which I would be more than happy to provide during the question and answer or for the record.

This is just a sampling of the work that the electric drive industry is doing to bring grid-connected vehicles to production, grow them to commercial scale, and prepare the grid for a plug-in vehicle future. Working together with policymakers we can make it happen even sooner and realize the economic, security, and environmental benefits of displacing oil with electricity.

Thank you very much for your attention this morning.

[The prepared statement of Mr. Wynne follows:]

PREPARED STATEMENT OF BRIAN P. WYNNE, PRESIDENT, ELECTRIC DRIVE TRANSPORTATION ASSOCIATION

Mr. Chairman, Ranking Member Domenici, members of the Committee. My name is Brian Wynne, I am president of the Electric Drive Transportation Association and I am very pleased to be here today to share with the Committee our industry's accomplishments, plans and vision for electric drive transportation.

The electrification of the transportation sector brings together a range of industries and interests. At the Electric Drive Transportation Association, we represent auto manufacturers, battery and other technology developers, utilities and energy companies and universities. All of these companies and organizations are committed to realizing the economic, security, and environmental benefits of displacing oil with electricity.

The reasons we need to pursue this course are painfully clear. Gas prices reached record highs this year, at one point reaching almost $140 a barrel. While they were headed down recently, we know that OPEC or Ike can change that any day.

More than the price of oil, the COST of oil to our security is enormous. Close to 60% of the petroleum we use is imported. If we switched over the U.S. light duty fleet—cars and SUVs—to electric drive vehicles—a combination of plug-in and standard hybrids, battery electric and fuel cell vehicles, we would cut liquid fuel consumption by 83%.

Environmentally, electrification of transportation makes sense as well. The transportation sector accounts for about a third of the greenhouse gas emissions in the U.S. and about 80% of urban air pollution.

A recent study conducted by the Electric Power Research Institute with the National Resources Defense Council found that plug-in electric drive vehicles running on electricity from today's power grid would produce ⅓ less greenhouse gas emissions than vehicles running on traditional combustion engines.

Understanding the potential of plug-in electric drive, we are here to discuss the current state of the industry and how to get these vehicles on the road in substantial numbers.

Grid-connected vehicle technology is moving forward at a rapid pace. There are plug-in vehicle options available today, including the ones that are outside, and a significant number coming to market in the next three years.

Major manufacturers have established ambitious vehicle timelines; battery manufacturers are looking to scale up production and electricity providers are making changes and plans for integrating vehicles into their customer base.

I am going to mention some specific vehicles (it is not a complete list) that you will be seeing on the road in the next couple of years. Along the way I would like to clarify what the differences are in these emerging technologies and why it's important to keep that diversity in mind when you are building policies to help accelerate their adoption.

As an introduction to the technology, let me explain that in "electric drive" vehicles, electricity provides either all, or part, of the motive power that propels the vehicle. Electric drive vehicles are not just cars; they can be trucks, forklifts, scooters, buses, neighborhood electric vehicles and even trains. They can get power from the grid, or recharge on board.

While there is enormous diversity in the technology, all the vehicles share a common benefit—they displace oil with electricity.

There is tremendous flexibility in electric drive and, as this panel indicates, different technology and market paths are emerging. The focus here today is on vehicles that run on electricity from the grid. These vehicles can be battery electric or plug-in hybrid vehicles.

Battery electric vehicles operate entirely on their electric drive motor and have various range and speed capabilities.

For instance, thousands of low speed battery electric vehicles in use today, like the Global Electric Motorcars neighborhood electric vehicle, provide a petroleum-free option for urban commuters across the country. Electric motorcycles, such as the Vectrix maxi-scooter, which gets between 35 and 55 miles per charge on a nickel metal hydride battery, are changing the two-wheeled fleet.

At the top end of the speed scale is the Tesla Roadster, which operates on lithium-ion battery technology. The Roadster can go to zero to 60 in just 4 seconds and can travel 220 miles on a charge. This car is available today and is the fore-runner of the company's planned line of battery electric sedans, the first of which is the Whitestar—that is being developed as—and priced more like—a family sedan.

Nissan has made a commitment in their mid-term business plan to be "the leader in zero emissions vehicles" and is rolling out a battery electric vehicle in late 2010. They plan for select fleet use at first and mass market introduction in 2012.

Phoenix, Subaru and Zenn have both announced 2009 production plans for full-speed battery electric vehicles.

Mitsubishi plans to produce a battery electric vehicle (the iMiEV) in 2010.

Daimler has announced plans for serial production of battery electric Mercedes-Benz and smart cars in 2010 and has entered into a joint agreement to provide more than 100 in Berlin in 2009.

The 2010 production model of GM's Volt is being unveiled in Detroit this morning. It is 4 door passenger vehicle with a range of about 40 miles on a single charge, which would cover the average American's daily commute.

The Volt, it is important to note, is a range-extended battery electric vehicle. Although it has an internal combustion engine, it is not a "plug-in hybrid." The engine will only be used to provide backup power to the battery. It will not provide any propulsion, as the engines in plug-in hybrids do.

Plug-in hybrid vehicles also connect to the grid, but include additional on-board power sources that can move, or assist the battery in moving, the vehicle.

Some examples of these include the planned Saturn Vue plug-in hybrid, Ford's Plug-in hybrid Escape, and Toyota's Prius Plug-in Hybrid Vehicle. These manufacturers have all announced 2010 production plans.

Hyundai is expanding its hybrid production over the next four years and is planning to commercialize plug-in hybrids sometime after 2013.

We are excited about the expanding availability of plug-in electric drive options, but how quickly they reach commercial scale depends on a number of factors.

First, there are technology challenges that manufacturers and energy suppliers must address. The most obvious is the performance and supply of new battery technologies. Some of the emerging plug-ins and the next generation of electric vehicles are likely to use lithium-ion batteries. These batteries, which are used today in laptop computers and mobile phones, hold more energy than their conventional counterparts. We need to ensure that they are also as durable, safe, and affordable as the vehicle market demands.

We should also be working to make sure they are manufactured here in the United States.

The shift to increasing electric drive technology also requires significant investment in manufacturing infrastructure by the vehicle and battery manufacturing industries. Large scale production of electric drive vehicles and components in the U.S. will require new materials, new processes and new production facilities.

In the utility and energy industries, grid-connected transportation will also require changes in electricity infrastructure and business models. Utilities need to make infrastructure investments to upgrade the transmission grid to bring new renewable sources from remote locations to urban centers where the power is needed.

They also will need to invest in smart meters to monitor the flow of electricity to the consumer household. These meters will allow consumers to recharge their vehicle batteries during off-peak times for energy savings. And, they potentially allow electricity providers to use the stored energy for load management.

Policymakers can accelerate the shift toward electrification by working with us to address these challenges. Specifically, accelerating policies include:

- Market incentives, to help industries and consumers invest in electric drive;
- Reliable R&D support to advance the technology; and
- Expanded demonstration and deployment in fleets.

Market incentives are a powerful tool in promoting manufacturing development and making new technologies more affordable for consumers.

To help buyers overcome the first-cost hurdle of new technologies and to build market acceptance, a performance-based consumer tax credit should be available for purchases of all plug-in electric drive vehicles.

As I noted earlier, there are a variety of electric drive technologies in—and coming to—the market. Tax incentives should reward performance (in reducing petroleum consumption with electricity) without picking a winning configuration. The credit should include all grid-connected transportation options—including battery electrics and hybrids and including large vehicles and small ones. The threshold for eligibility should not prejudice the development of the technology. They all will play a role in advancing the technology, building consumer acceptance and promoting infrastructure development.

Incentives also need to be provided upstream. Tax policies promoting the significant investments in electric drive technologies and facilities will accelerate the growth of the industry, for instance, by encouraging battery manufacturers to site their facilities in this country and by helping automakers to expand and establish their production facilities.

The bipartisan bill, S. 1617, of which Senator Cantwell is a coauthor, captures the key elements of effective tax incentives for consumers and manufacturers. Some of the proposals emerging in these last few weeks have included refinements to the concept that EDTA could potentially support. There are also some new provisions being offered that would actually limit plug-in technology development and vehicle options. These we would oppose.

Congress, and this Committee, included other critical support for electric drive in the 2007 energy bill, the Energy Independence and Security Act (EISA). EISA authorizes important grants, loan guarantees and direct loans to manufacturers of advanced vehicles and components.

These programs can provide a real boost to domestic capacity—but only if they are actually funded. We hope that Congress acts as quickly as possible in making these programs a reality.

In addition to market incentives, consistent and substantial federal investment in research and development will speed the development of necessary technologies.

EISA authorized approximately $300 million/year for research, development and demonstration projects for electric drive efforts, including plug-in vehicle research, advanced battery research, and medium and heavy duty vehicle R&D. The bill also authorized substantial investments in smart grid research and development programs.

These programs can make the difference in what is "near-term" technology and what is not. As I said previously, the sooner we can get these programs underway, the sooner we can address the technology and infrastructure challenges that come with rethinking transportation.

Along with R&D, Federal, state and local governments can expand efforts to deploy electric drive vehicles in private and public fleets. These "real world efforts" provide energy and environmental benefits—and they also help to identify what works well and what needs to be improved in a new technology.

Federal support for demonstration projects can help utilities and manufacturers work together to demonstrate grid-connected technologies. Today, Ford, Johnson Controls and Southern California Edison are partnering on a demonstration of the plug-in hybrid Escape. GM is working with EPRI and a group of utilities to address the infrastructure and charging issues raised by plug-in vehicles.

These kind of collaborative efforts are critical to launching a transportation shift that requires changes in vehicles, in fuel providers and even drivers.

This is just a sampling of the work that the electric drive industry is doing to bring grid-connected vehicles to production, grow them to commercial scale and prepare the grid for a plug-in vehicle future. Working together with policymakers, we can make it happen even sooner and realize the economic, security and environmental benefits of displacing oil with electricity.

I thank you for the opportunity to testify today and look forward to answering any questions you may have.

The CHAIRMAN. Thank you very much.

Mr. Kjaer, go right ahead.

## STATEMENT OF EDWARD KJAER, DIRECTOR OF ELECTRIC TRANSPORTATION, SOUTHERN CALIFORNIA EDISON COMPANY, ROSEMEAD, CA

Mr. KJAER. Good morning. Chairman Bingaman, Ranking Member Domenici, members of the committee, my name is Edward Kjaer and I am the Director of Electric Transportation at Southern California Edison. Thank you for the opportunity to speak briefly to you today.

For over 20 years, Edison has been a leading supporter of electric transportation. Today Edison operates the Nation's largest and most successful private fleet of electric vehicles, having traveled over 16 million EV miles on electric power.

Our Electric Vehicle Technical Center, unique in the utility industry, is one of only several facilities recognized by the United States Department of Energy to evaluate all forms of electro-drive technology.

Edison is working in partnership with EPRI and automakers such as Ford, General Motors, Mitsubishi, and others to evaluate and demonstrate prototype plug-in vehicles and their connection with and control by the grid.

So what are some of the challenges we face as we connect transportation to the grid?

First, helping the industry get to a sustainable business case. The stark reality is that while most major automakers are working to develop and commercialize plug-in vehicle technology, few see a sustainable business case without critical Government, State, NGO, and private sector incentives and support. Simply put, without adequate and sustained incentives, many of which Mr. Wynne has just referred to, and support, there is no guarantee that we can quickly transition from early adoption low volumes to the mass market high volumes we need in the marketplace.

The second challenge is getting multiple markets plug-in vehicle ready. Edison Electric Institute held a utility CEO Transportation Taskforce meeting several days ago, chaired jointly by our Chairman, Ted Craver, and Progress Energy CEO Bill Johnson. The goal is to generate industry-wide support for appropriate and sustained plug-in vehicle policy in partnership with EDTA, automakers, and major vehicle launch markets. In addition, the utilities will and are working with their local States to develop sustainable incentives to attract automakers to launch plug-in vehicles in their respective markets.

The third challenge is creating industry standards for effective load control of plug-in vehicles. Today the electric grid is changing dramatically across the country. We are seeing the development of smart grid technologies designed to improve the reliability and efficiency of the electrical system while at the same time delivering more customer control of their energy use and ultimately their monthly energy bill.

Part of this effort is so-called smart meters. Edison will deploy 5 million next generation advanced meters called Edison SmartConnect by 2012. Smart meters will help control vehicle fueling load, optimizing it to generation plant utilization and infrastructure needs. This real-time control will be achieved through vehicle and grid communications, customer rates and incentives and other technologies designed to optimize the integration of transportation into the energy system. Edison, in partnership with EPRI, leading automakers and the Society of Automotive Engineers, is working to socialize industry-wide vehicle and grid communication requirements today.

The fourth challenge is products and technologies to test in the utility lab. Today we have several plug-in vehicle prototypes and more coming to Edison's unique EV Technical Center. However, we have virtually no data on the communication and load control of plug-in vehicles. It is critical that we get industry stakeholders together to fully vet the emerging technologies and communication protocols before they are implemented in vehicle design.

The fifth challenge is addressing the high cost of batteries. Edison is actively exploring whether advanced batteries developed for the auto industry have other uses outside of the vehicle for stationary applications such as emergency backup and home energy storage. The vision is to combine early market battery volumes for the automakers and potentially for the utilities to help reach economies of scale faster, helping to strengthen the business cases for plug-in vehicles in the early years.

The sixth challenge is addressing the needs of home and public refueling infrastructure. Edison, EPRI and the automakers are working to assess the infrastructure needs of plug-in vehicles. The industry is working to finalize a single connector standard and working on a single communication standard, as I have mentioned. Additionally, markets around the country are determining the need for public charging and in some areas have already committed to construction. Again, successfully deploying appropriate infrastructure will likely need both policy and financial support in the early years.

The seventh and final challenge is integration of smart grid technology and future electric transportation. Smart grid technology is required for the long-term vision of so-called vehicle-to-grid systems and energy storage systems where millions of batteries, both in the vehicles and in stationary applications, have the capacity to move stored energy backward and forwards in the grid.

But these applications are many years away. First, we must get the batteries to simply drive the wheels and last the life of the vehicle reliably. We believe that with continued engineering advances and appropriate public policy support, the widespread use of advanced batteries in plug-in vehicles and in stationary storage applications will become one of the Nation's most effective strategies in the broader effort to address energy security, reduce greenhouse gas emissions and reduce air pollution.

We congratulate the committee for the work you did last year on the energy bill. Of course, now we need to secure appropriations for the provisions authorized in 2007.

We also need Congress to pass legislation providing for consumer tax incentives and tax credits for renewables and accelerated depreciation of smart meters. The House and Senate have passed their own bills, but so far haven't reached agreement. Even before all this, though, we need manufacturing incentives to encourage a domestic supplier and production base, as Mr. Wynne mentioned.

Edison is committed, as we have been for almost 20 years now, to working with the committee, industry organizations such as EDTA, EEI, EPRI, and Federal and State agencies to realize a plug-in transportation future.

Thank you.

[The prepared statement of Mr. Kjaer follows:]

PREPARED STATEMENT OF EDWARD KJAER, DIRECTOR OF ELECTRIC TRANSPORTATION, SOUTHERN CALIFORNIA EDISON COMPANY, ROSEMEAD, CA

Chairman Bingaman, Ranking Member Domenici, Members of the Committee, my name is Edward Kjaer and I am the Director of Electric Transportation at Southern California Edison.

Thank you for the opportunity to speak to you today.

Let me begin by describing the efforts of Southern California Edison and our industry associations to address the challenges we face over the next two to three years integrating transportation in to the electric energy system.

For over 20 years Edison has been a leading supporter of electric transportation. Initially, this support was based on the need to clean up the air quality in California. Since then however it has become clear that this nation has a significant energy security challenge and a growing concern around climate change. As a recent EPRI study demonstrated, electrifying the wheels of this nation's transportation future could be the single biggest move we make to reducing our dependence on foreign oil, reducing CO2 and improving the air we all breathe.

Today, Edison operates the nation's largest and most successful private fleet of electric vehicles, having traveled more than 16 million miles on electric power.

Our Electric Vehicle Technical Center, unique in the utility industry, is one of only several facilities recognized by the U.S. Department of Energy to evaluate all forms of electro-drive technology. It is an ISO-certified facility that is widely known for its battery and prototype plug-in vehicle testing. Now the Center is focused on evaluating "smart charging" and building industry-wide consensus around vehicle/grid connection, communication and control in conjunction with next generation utility advanced meters.

To this end, last year SCE and Ford announced an industry leading collaborative to help evaluate and demonstrate plug-in hybrids (PHEVs) and their connection and control by the grid. EPRI was added to this partnership in April 2008 and they are now identifying up to seven major utilities across the country willing to participate and co-fund this first-of-a-kind program. The U.S. Department of Energy (DOE) is providing up to $10 million in co-funding support for this important effort.

In addition, SCE is part of a broad 37 utility partnership with EPRI and General Motors working to prepare the retail market for the upcoming and much anticipated Chevy Volt and Saturn Vue plug-in vehicles.

Recently Mitsubishi and SCE announced a partnership to evaluate and demonstrate Mitsubishi's new iMiEV battery EV prototypes. This vehicle will go into production in 2009 in Japan and Mitsubishi is assessing the U.S. market for EVs. I was in Japan meeting with automakers several weeks ago and I had the opportunity to test drive the iMiEV. I'm very excited about the potential of this vehicle here in the U.S.

Nissan is also intending to launch EVs to the U.S. market in the 2010-2012 timeframe. Other automakers have announced either research, prototype demonstration or production programs for plug-in vehicles including Toyota, BMW, Daimler, Chrysler, Audi, Think and Tesla Motors to name a few.

SCE will shortly announce additional automaker partnerships as we continue to collaborate with the auto industry, helping ensure that the grid is ready to connect, fuel and control mass market volumes of plug-in vehicles.

What are some of the challenges utilities face however as we connect transportation to the grid?

1. Helping industry get to a sustainable business case.—The stark reality is that while most major automakers are working to develop and commercialize plug-in vehicle technology, few see a "sustainable" business case without critical Government, State, NGO and private sector support. Brian Wynne from Electric Drive Transportation Association (EDTA) has touched on the importance of early market Federal and State incentives to encourage domestic jobs through a robust manufacturing and supplier base as well as consumer incentives to help buy down the early introduction cost of these inherently more expensive technologies. Without adequate support there is no guarantee that we can quickly transition from early adoption low volumes to the mass market high volumes we need to sustain this technology in the marketplace.

2. Getting multiple markets "plug-in vehicle ready".—Edison Electric Institute (EEI) held a utility CEO Transportation Taskforce meeting several days ago chaired jointly by our Chairman, Ted Craver and Progress Energy CEO Bill Johnson. This taskforce of major investor owned utility CEOs is now working to engage utilities across the country in the electric transportation movement. The goal is to generate industry-wide support for appropriate and sustained plug-in vehicle policy in partnership with EDTA, automakers and major vehicle launch markets.

3. Creating industry standards for effective load control of plug-in vehicles.—Today the electrical system is changing dramatically across this country. We are seeing the development of "smart grid' technologies designed to improve the reliability and efficiency of the electrical system while at the same time delivering more customer control of their energy use and ultimately their monthly energy bill. Edison will deploy 5 million next generation advanced meters called Edison SmartConnect ™ by 2012. These meters will help Edison and our customers manage the energy system. With plug-in vehicles we do not see a large system-wide challenge fueling the vehicles however we do see early adopter concentrations of vehicles that may challenge the local distribution system in some areas. To effectively and efficiently manage the system, utilities will want to "control" vehicle fueling load, optimizing it to generation plant utilization and infrastructure needs. This real time control will be achieved through vehicle and grid "communications", customer rates and incentives and other technologies designed to optimize the integration of transportation in to the energy system. Edison, in partnership with EPRI, leading automakers and the Society of Automotive Engineers (SAE) is working to socialize industry wide vehicle/grid "com-

munication" requirements" today. But there is still much work to be done and very little research and evaluation data available.

4. Products and technologies to test in the utility lab.—As mentioned, Edison has a unique EV Technical Center that is exploring the convergence of transportation and grid technologies. Today we have several plug-in vehicle prototypes and more coming. We have been bench testing advanced lithium battery modules for over three years now in the lab. However we have virtually no data on the communication and load control of plug-in vehicles. It's critical that we get industry stakeholders together to fully vet the emerging technologies and communication protocols before they are implemented in vehicle design.

5. Addressing the high cost of batteries.—Edison is actively exploring whether advanced batteries developed for the auto industry have other uses and system benefits for the electrical grid such as emergency backup and energy storage. To develop data in this area, Edison has recently constructed a "Garage of the Future" lab at our EV Technical Center. This lab will begin modeling the convergences of residential PV, home energy storage devices, vehicle energy storage and advanced meter control and communication. By combining battery volumes for the automakers and potentially the utilities, we may reach economies of scale faster, helping to strengthen the business cases for plug-in vehicles in the early years.

6. Addressing the needs of home and public refueling infrastructure.—Edison, EPRI and the auto makers are working to assess the needs of plug-in vehicles. Battery EVs, because of their 240 V charging requirements, dictate the need for more complex infrastructure development that the plug-in hybrid charging at 110 V. The industry is working to finalize a single connector and connection standard. Additionally markets around the country are determining the need for public charging and in some areas have already committed to construction. Again successfully deploying appropriate infrastructure will likely need both policy and financial support in the early years.

7. Integration of smart grid technology and future electric transportation.—Smart grid technology is required for the long-term vision of so-called "vehicle-to-grid" systems, and energy storage systems where millions of batteries both in the vehicles and in stationary applications have the capacity to move stored energy back to the grid.

In essence, these mini power plants become integrated into the future energy system as distributed energy resources. Plug-in vehicles and even stationary batteries may further enhance electrical system reliability by providing temporary power to a homeowner when outages do occur.

Plug-in vehicle technologies are not just for passenger vehicles. In fact, in the near term, we are likely to see significant growth in heavy duty trucks, buses, seaports, airports and truck stop electrification. For instance, SCE has one of about 25 prototype heavy duty hybrid utility bucket trucks built by Eaton and International that are presently being tested. A medium duty plug-in hybrid is also being built on a Ford 550 Chassis by Eaton and EPRI. SCE expects to have its prototype by the end of this year. These technologies also require public policy support.

We believe that with continued engineering advances and appropriate public policy support, the widespread use of advanced batteries in plug-in vehicles and in stationary storage applications will become one of the nation's most effective strategies in the broader effort to address energy security, reduce greenhouse gas emissions and reduce air pollutants.

We congratulate this Committee for the work you did on last year's energy bill. Let us just take a minute and recall all the good things that bill achieved last year.

i. $295 million per year for six different R&D programs on electric transportation including both vehicles and stationary energy storage applications.

ii. $95 million in grants per year for transportation electrification, such as truck stops and ports.

iii. $90 million per year for early demonstrations of PHEVs and battery EVs.

iv. Grants and loans for manufacturing PHEVs, BEVs, and EV components in the United States and grant funds for PHEV smart grid investment costs.

Of course now we need to secure appropriations for these provisions. We also need Congress to pass legislation providing for consumer PHEV tax credits, as well as tax credits for renewables and accelerated depreciation of smart meters. The House and Senate have passed their own bills, but so far haven't reached agreement. We need appropriations for fleet acquisition incentives to help buy down early costs to fleet operations of this new technology. Even before all of this, though, we need manufacturing incentives to encourage a domestic supplier and production base.

Edison is committed to working with this Committee, industry organizations such as EDTA, EEI, EPRI and Federal and State agencies to realize a plugged-in transportation future. These and other organizations help bring together automakers, utilities and industry stakeholders so we can effectively address the common energy and environmental concerns of this country.

Thank You.

The CHAIRMAN. Thank you very much.

Mr. Wimmer, go right ahead.

**STATEMENT OF ROBERT WIMMER, NATIONAL MANAGER, TOYOTA MOTOR NORTH AMERICA**

Mr. WIMMER. I would like to thank Chairman Bingaman and the Senate Energy Committee for inviting Toyota to testify at this hearing on a topic we feel passionately about, electric drive vehicles.

Though the average price of a gallon of gasoline has declined from record highs over the summer, consumers continue to demand greater fuel efficiency in their vehicles. This has led to an increased interest in vehicle electrification as a way to reduce petroleum consumption.

But as far back as the early 1990s, when a gallon of gasoline was less than $1.50 a gallon, Toyota was investing in vehicle electrification by developing both hybrid and battery electric automobiles. This type of forward thinking is summarized in the phrase, “Today for Tomorrow.” Said another way, think for the future, but act now. This is one of Toyota’s core philosophies and the basis for our environmental vision.

Since Toyota introduced our first hybrid, the Prius, in Japan in 1997, we have sold over 1.5 million hybrids around the globe. These vehicles have saved over 660 million gallons of gasoline and eliminated 13 billion pounds of $CO_2$ emissions. In the United States, fuel savings alone have saved Americans nearly $1 billion.

Once considered science experiments by some and novelties by others, hybrids are now mainstream vehicles for Toyota. We currently sell 6 fuel-saving hybrids in the United States, 3 Toyota and 3 Lexus models, and they account for over 10 percent of our United States sales. Next January in Detroit, we will introduce our third generation Prius, plus an all-new dedicated Lexus hybrid vehicle.

Future hybrid goals include global sales of a million a year in the next decade, and sometime in the 2020s, we expect hybrid drivetrains to be offered as either standard or optional equipment in all of our passenger vehicles.

Hybrid is a core technology for Toyota and will serve as the foundation for the next generation of vehicles such as plug-ins, battery electrics, and fuel cells. This evolution of mainstream technology will allow us to shorten development time and maximize use or shared components that will result in lower production costs and broader market penetration of these new technologies.

When considering the benefits of new technologies, we must understand the relationship between sales volume and fuel savings. For example, if we doubled sales of a hybrid model, the cumulative fuel savings is greater than doubling its fuel economy with no change in sales volume. Therefore, it is critical that new technologies, such as plug-ins, battery electrics, or fuel cells, are introduced at a price point and utility that allow for high volume sales.

Otherwise, their petroleum savings and environmental benefit will be negligible.

Mass market appeal is the basic philosophy behind the plug-in prototype Prius we have on display today. With minimal software changes and the addition of a second battery pack, the vehicle demonstrates the plug-in potential of Toyota's hybrid vehicle design. The vehicle operates in a manner similar to the current Prius, switching between electric mode to gas engine mode to a blended gas/electric mode. The larger battery allows the plug-in Prius to store greater amounts of electricity and to be charged by plugging into a standard electrical outlet. With more power in reserve, the vehicle is capable of operating in pure electric mode for longer periods of time and speeds up to 60 miles an hour. This means substantial gains in fuel economy and a reduction in total tailpipe emissions versus conventional hybrid systems.

Battery experts have estimated the cost of batteries for plug-in hybrids to be between $500 and $1,000 per kilowatt hour. As such, the size of the battery pack will greatly influence the retail price of the vehicle and therefore its market viability and sales potential.

The energy tax package, released by the Finance Committee, places an arbitrary 6 kilowatt hour minimum on battery pack size and redefines plug-in electric vehicles to seemingly eliminate the consumer tax credit for all but one plug-in vehicle design. Toyota believes this approach is counterproductive. It will discourage manufacturers from developing and consumers from purchasing blended plug-ins that are affordable to the greatest number of consumers. We believe consumer incentives should encourage all plug-in designs and allow the consumer market to select winners not legislation.

Before high-volume production can begin, significant challenges such as battery cost, durability, and safety must be addressed. We intend to examine these issues when we introduce our next generation plug-in hybrid with lithium-ion batteries as a 2010 model. A significant number of these vehicles will be deployed in commercial fleets around the world to help Toyota quantify real-world durability and performance and customer acceptance.

To realize the full promise of plug-in hybrids or battery electric vehicles, they must use green electricity. From an energy security standpoint, certainly any substitution of domestically produced electricity for gasoline is beneficial. Carbon reduction, on the other hand, varies greatly depending on how the electricity is generated. In France, where over 80 percent of the electricity comes from nuclear power, the plug-ins and battery electrics can significantly reduce carbon emissions. On the other extreme, if the electricity comes mostly from coal-fired plants, the reduction in carbon emissions is modest at best.

Let me conclude with a brief description of Toyota's fuel cell hybrid vehicle, another evolution of our basic hybrid drive technology. This vehicle is based on the previous generation Toyota Highlander SUV but with a fuel cell, one of Toyota's own design and manufacture in place of the Highlander's gasoline engine. The combination of an advanced fuel cell system with our hybrid drive technology more than doubles the vehicle's fuel efficiency with zero tailpipe emissions.

As with plug-ins, challenges must be resolved before fuel cell commercialization can begin. Costs must drop significantly while system power density and durability must increase. Also, a coordinated effort is required between the auto industry and energy providers and governments to assure hydrogen refueling infrastructure is in place to support fuel cell vehicle development.

So why does Toyota continue to invest millions in long-term technologies? It goes back to our "Today for Tomorrow" philosophy that drives us to develop technologies and products today that improve society for tomorrow.

I would again like to thank Senator Bingaman and the Senate Energy Committee for inviting Toyota to be part of this hearing.

[The prepared statement of Mr. Wimmer follows:]

PREPARED STATEMENT OF ROBERT WIMMER, NATIONAL MANAGER, TOYOTA MOTOR NORTH AMERICA

I am Robert Wimmer, a National Manager in Toyota's Washington DC office, working on energy and environmental research, and with over 15 years' experience in hybrid and fuel cell vehicle development. I would like to thank Chairman Bingaman and the Senate Energy Committee for inviting Toyota to testify at this hearing on a topic we feel passionately about: Electric Drive Vehicles.

Though the average price of a gallon of gasoline has declined from record highs over the summer, consumers continue to demand greater fuel efficiency in their vehicles. This has led to an increased interest in vehicle electrification as a way to reduce petroleum consumption. But, as far back as the early-1990's when a gallon of gas cost less than $1.50/gallon, Toyota was investing in vehicle electrification by developing both hybrid and battery electric automobiles.

This type of forward thinking is summarized in the phrase "TODAY for TOMORROW." Said another way—think for the future, but act now. This is one of Toyota's core philosophies and the basis for our environmental vision.

Over the last 15 years of hybrid development, we have established more than 700 hybrid patents and hybridized more than a dozen vehicle models globally. Perhaps more importantly, we believe hybrid technology will be the foundation for our emerging electric propulsion systems.

Since Toyota introduced our first hybrid, the Prius in Japan in 1997, we have sold over 1.5 million hybrids around the globe. These vehicles have saved over 660 million gallons of gasoline and eliminated 13 billon pounds of $CO_2$ emissions. In the US, fuel savings alone have saved Americans nearly a billion dollars.

Once considered science experiments by some and novelties by others, hybrids are now mainstream vehicles for Toyota. We currently sell six fuel-saving hybrids in the US—3 Toyota and 3 Lexus models, and they account for over 10% of our US sales. Next January in Detroit, we will introduce our third-generation Prius plus an all-new dedicated Lexus hybrid vehicle.

Future hybrid goals include global sales of a million a year in the next decade. And sometime in the 2020s, we expect hybrid drivetrains to be offered as either standard or optional equipment in all our passenger vehicles.

Hybrid is a core technology for Toyota and will serve as the foundation for the next generation of vehicles such as plug-ins, battery electrics and fuel cells. This evolution of mainstream technology will allow us to shorten development time and maximize use of shared components that will result in lower production costs and broader market penetration for these new technologies.

When considering the benefits of new technologies, we must understand the relationship between sales volume and fuel savings. For example, if we double sales of a hybrid model, the cumulative fuel savings is greater than doubling its fuel economy with no change in sales volume. Therefore, it is critical that new technologies, such as plug-ins, battery electrics or fuel cells, are introduced at a price point and utility that allow for high volume sales. Otherwise, their petroleum savings and environmental benefit will be negligible.

Mass market appeal is the basic philosophy behind the prototype plug-in Prius we have on display today. With minimal software changes and the addition of a second battery pack, the vehicle demonstrates the plug-in potential of Toyota's hybrid design.

The vehicle operates in a manner similar to the current Prius, switching from pure-electric mode, to gas-engine mode, to a blended gas-electric mode. The larger battery allows the plug-in Prius to store greater amounts of electricity and to be charged by plugging into a standard household electrical outlet. With more electric power in reserve, the vehicle is capable of operating in pure-electric mode for longer periods of time and at speeds up to 60 mph. That means substantial gains in fuel economy and a reduction in total tailpipe emissions versus current conventional hybrid systems.

Similar vehicles were recently given to two California universities for research and testing to evaluate real-world customer use, to help determine the optimal balance between electric mode range, charge time, battery size and cost.

Battery experts have estimated the cost of batteries for a plug-in hybrid to be $500-$1000/kW-hr. As such, the size of the battery pack will greatly influence the retail price of the vehicle and therefore, its market viability and sales potential. The Energy Tax package released late last week by the Finance Committee places an arbitrary 6kW-hr minimum on pack size before receiving a consumer tax credit. Toyota believes this is counterproductive. It will discourage manufacturers from developing smaller, lower cost plug-ins that are affordable to the greatest number of consumers. Toyota agrees the amount of tax credit should be based on battery size, but it should begin at approximately two times the size of a typical hybrid battery, 1.2-2.0 kW-hr. This way the consumer market will drive plug-in vehicle design, not legislation.

Before high-volume production can begin, significant challenges such as battery cost, durability and safety must be addressed. We intend to examine these issues when we introduce our next generation plug-in hybrid with Li-Ion batteries as a 2010 model. A significant number of these vehicles will be deployed in commercial fleets around the world to help Toyota quantify real-world durability, performance and customer acceptance.

Toyota is also re-examining battery electric vehicles. Between 1998 and 2003 Toyota delivered more than 1200 RAV4-EVs to customers in Arizona and California. Many of these were sold—not leased—to the general public, making Toyota the only Original Equipment Manufacturer at the time to sell full-performance EVs. With many of these still on the road and millions of miles of cumulative experience, Toyota understands the opportunities and challenges of producing and marketing battery EVs.

To realize the full promise of plug-in hybrids or battery electric vehicles, they must use green electricity. From an energy security standpoint, certainly any substitution of domestically produced electricity for gasoline is beneficial. Carbon reduction, on the other hand, varies greatly depending how the electricity is generated. In France, where over 80% of the electricity comes from nuclear power, plug-ins and battery electrics can significantly reduce carbon emissions. On the other extreme, if the electricity comes mostly from coal fired plants, the reduction of carbon emissions is modest at best.

Let me conclude with a brief description of Toyota's Fuel Cell Hybrid Vehicle . . . another evolution of our basic hybrid drive technology. This vehicle is based on the previous-generation Toyota Highlander Hybrid SUV but with a fuel cell, of Toyota's own design and manufacture, in place of the Highlander's gasoline engine. The combination of an advanced fuel cell system with our hybrid drive technology more than doubles the vehicle fuel efficiency with zero tailpipe emissions.

Toyota has made great progress over the last decade improving fuel cell technology. Our next generation fuel cell vehicle will be able to start from -30 degrees Centigrade and will have a driving range of over 400 miles between refuelling.

As with plug-ins, challenges must be resolved before fuel cell commercialization can begin. Cost must drop significantly, while system power density and durability must increase. Also, a coordinated effort is required between the auto industry, energy providers and governments to assure a hydrogen refuelling infrastructure is in place to support fuel cell vehicle deployment.

So, why does Toyota continue to invest millions in a technology like fuel cells, which is more than a decade away from commercial viability? It goes back to our "Today for Tomorrow" philosophy that drives us to develop technologies and products Today to improve society Tomorrow.

I would again like to thank Senator Bingaman and the Senate Energy Committee for inviting Toyota to be part of this hearing and am happy to take your questions.

The CHAIRMAN. Thank you very much.

Mr. Dalum, go ahead.

**STATEMENT OF JOSEPH T. DALUM, VICE PRESIDENT, DUECO, WAUKESHA, WI**

Mr. DALUM. Good morning, Chairman Bingaman, Ranking Member Domenici, and distinguished committee members. Thank you for inviting me here today.

My name is Joe Dalum and I am Vice President of DUECO. DUECO, headquartered in Waukesha, Wisconsin, is one of the largest final-stage manufacturers of utility trucks in the country. We produce aerial devices, digger derricks, and cranes that are sold to electric utilities for the maintenance of their power lines. DUECO also provides equipment and services for the telecommunications market, other industries, and the government.

In 2006, DUECO began to assess alternative hybrid technologies, which led to a collaborative effort between DUECO and Odyne Corporation, a developer of plug-in hybrid electric vehicle powertrains for medium- and heavy-duty trucks that weigh over 16,000 pounds. Our efforts resulted in the introduction of the utility industry's first commercial plug-in hybrid medium-duty truck in the fall of 2007.

While you have already received my more extensive written testimony, this morning I will focus on our development of plug-in hybrid medium- and heavy-duty trucks.

There are several factors that favor the introduction of plug-in hybrid trucks, including rising fuel prices, increased pressure to reduce emissions, including greenhouse gas emissions, and the national priority to improve energy security. The photo in my written testimony shows a plug-in hybrid heavy-duty bucket truck used to help maintain power lines. I invite you to see a similar plug-in truck on display outside today.

The truck is unique in that a very large battery system of approximately 35 kilowatt hours, more than 15 times larger than one used in a conventional hybrid, provides power to help propel the vehicle along with a diesel engine and provides power for equipment on the truck. When the truck returns to the garage, domestically generated electricity recharges the battery system, offsetting the need for petroleum. The size of the battery system and the ability to recharge using grid power differentiates the plug-in hybrid system from a conventional hybrid. Using energy from the large battery system reduces fuel consumption and emissions during driving and provides for an all-electric stationary mode. The system completely eliminates fuel consumption and emissions at the job site for a typical day while also reducing noise.

Fuel savings and corresponding reduction in greenhouse gas emissions are dependent upon the application. The current vehicle reduces fuel consumption, resulting in an estimated savings of approximately 1,400 gallons of fuel per year per vehicle for a typical utility application, or approximately 20,000 gallons of fuel over the projected life of the vehicle.

DUECO plans to deploy 25 plug-in hybrid trucks to early adopters for evaluation, 10 of them produced to date. Our first unit was delivered earlier in the year. Several major utilities will test the units soon. We plan to ramp up production significantly in 2009 and beyond and expand the use of the technology into other applications.

Other manufacturers are also working on development of plug-in hybrid trucks. There are several challenges that affect wide-scale deployment of plug-in hybrid trucks, including battery system cost and performance challenges, infrastructure requirements for charging large numbers of high-capacity battery systems, and high costs for research, development, and investment in production systems.

DUECO encourages the Federal Government to implement programs that help the development of plug-in hybrid systems for medium- and heavy-duty trucks that are open to final stage manufacturers and other entities. The creation of tax incentives for customers, loan guarantee programs to support investment, and modification of Government purchasing policies to favor the acquisition of plug-in hybrid trucks can also accelerate deployment.

Commercial fleets consume large amounts of fuel. Developing more efficient trucks that utilize domestically sourced power from the Nation's energy grid would have several benefits. The development of this technology in the United States would provide opportunities for job creation, export opportunities, reduce the cost for businesses competing in a global market, reduce greenhouse gas emissions and emissions of other pollutants, reduce dependency on foreign oil, reduce noise within our cities, and potentially improve productivity for certain applications such as electric crews who could perform work at night in residential areas.

This is potentially an historic opportunity to develop and deploy the technology needed for the electrification of medium- and heavy-duty trucks. I ask for your support of the proposed measures outlined in my written testimony and legislation such as the Heavy-Duty Hybrid Vehicle Act that would help to accelerate research in the plug-in hybrid technology and encourage partnerships between manufacturers, utilities and the government.

Thank you.

[The prepared statement of Mr. Dalum follows:]

## Prepared Statement of Joseph T. Dalum, Vice President, DUECO, Wakuesha, WI

### INTRODUCTION

Good morning Chairman Bingaman, Ranking Member Domenici, and distinguished members of the Committee on Energy and Natural Resources. Thank you for inviting me here today. Also thank you for the opportunity to offer the views of DUECO and for soliciting the views of others on the current state of vehicles powered by the electric grid and the prospects for wider deployment in the near future.

My name is Joe Dalum, and I am Vice President of DUECO. Headquartered in Waukesha Wisconsin, DUECO is one of the largest final stage manufactures of utility trucks in the country, with facilities also located in South Dakota, Minnesota, Indiana, Ohio and Pennsylvania. We produce aerial devices, digger derricks and cranes that are sold to electric utilities for the maintenance of their transmission and distribution power lines in a 15 state region and are also used by utilities throughout the country through UELC, our rental and leasing company, with direct facilities in Florida, Texas and California. DUECO also provides equipment and services for the telecommunications, contractor, electric cooperative, municipality, gas utility and tree care markets.

In 2006, DUECO began to assess alternative hybrid vehicle technologies. Those activities lead to a collaborative development program between DUECO and Odyne Corporation. Odyne Corporation is a developer of Plug-In Hybrid Electric Vehicle (PHEV) power trains for medium and heavy duty trucks that weigh over 16,000 pounds. Our efforts resulted in the introduction of the utility industry's first commercial plug-in hybrid medium duty truck in the Fall of 2007.

Trucks consume a disproportionately large amount of fuel. Plug-in hybrid technology can substantially reduce fuel consumption, emissions and noise for many truck applications. Electricity, generated from domestic sources, partially displaces the use of petroleum. The technology is particularly beneficial for trucks that can be positioned close to the power grid when not in use to allow for recharging, are operated in stop and go driving, and/or idle for extended periods.

Plug-in hybrid technology for medium and heavy duty trucks is in the very early stages of testing and deployment. Low production volume and high cost threaten wide-scale adoption. In order to rapidly accelerate the use of plug-in hybrid trucks in the next five years, a large increase in resources directed toward research, development, engineering and production will be required.

A close partnership between manufacturers, utilities and the government can help increase wide-scale deployment of plug-in hybrid medium and heavy duty trucks. The government in particular can help accelerate the use of plug-in hybrid trucks by providing additional funding for research, by creating incentives for consumers to purchase medium and heavy duty plug-in hybrids through tax credits, by supporting private investment through loan guarantees and by encouraging federal, state and local governments to purchase medium and heavy duty plug-in hybrid trucks. The U.S. can lead the world in plug-in hybrid technology for medium and heavy duty trucks if we take strong and decisive action now.

## BACKGROUND

According to the Department of Energy, approximately 80 percent of all the goods transported in the U.S. are moved by truck. In total, the U.S. consumed approximately 140 billion gallons of gasoline and about 40 billion gallons of diesel fuel for on-road transportation in 2004. Trucks consume billions of gallons of fuel annually, and "there exists today great potential from several heavy-duty hybrid truck technologies to significantly reduce fuel consumption and emissions."[1] Plug-in hybrid technology is one of the technologies that have great potential to reduce fuel consumption for large numbers of trucks.

Truck fuel economy, power requirements and duty cycles often can differ depending upon the application. A duty cycle, the proportional time during which a truck is operated, in particular varies depending upon the application. Trucks may spend much of their time idling to power heating or cooling for the cab, or to operate truck mounted equipment. U.S. trucks idle an average of 1830 hours per year and idling of commercial vehicles is estimated to consume more than 2 billion gallons of fuel annually, while producing unwanted emissions.[2] Although the number of trucks is small compared to passenger vehicles, their fuel consumption and emissions are disproportionately large. According to figures by the Oshkosh Truck Corporation there are approximately 90,000 refuse collection trucks in the U.S. but their collective fuel consumption is roughly equivalent to 2.5 million passenger vehicles (based on 10,000 gallons/year per truck).[3]

There are more than 6,000,000 medium and heavy duty trucks in the U.S., excluding road tractors (18 wheelers). Medium and heavy duty trucks are trucks that weigh 14,001 pounds or more.

Trucks are used in a wide variety of applications and are often specialized. Trucks may perform numerous functions, resulting in a variety of types, such as parcel and postage delivery trucks, utility trucks, refuse haulers, beverage and refrigerated goods delivery trucks, road maintenance and other work or service trucks, dump trucks, concrete mixer trucks, liquid or gas transport trucks, shuttle and school buses, military vehicles and over the road trucks. Trucks also are built in many different configurations, sizes and weights.

Medium and heavy duty trucks are typically manufactured and marketed to customers much differently than cars and light duty trucks. Medium and heavy duty trucks, used by the utility industry and other vocations are typically built in multiple stages. During the first stage an original equipment manufacturer builds an incomplete vehicle, commonly known as a chassis. The vehicle is then often completed by a different company, referred to as a final stage manufacturer. Final stage

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[1] Testimony for the U.S. House Committee on Science and Technology, Energy and Environment Subcommittee, prepared Statement of Terry Penney Technology Manager, Advanced Vehicle Technologies, National Renewable Energy Laboratory, June 10, 2008

[2] Testimony for the U.S. House Committee on Science and Technology, Energy and Environment Subcommittee, prepared Statement of Terry Penney Technology Manager, Advanced Vehicle Technologies, National Renewable Energy Laboratory, June 10, 2008

[3] Committee on Science and Technology, Subcommittee on Energy and Environment, U.S. House of Representatives, Hybrid Technologies for Medium-to-Heavy Duty Commercial Trucks, Tuesday, June 10, 2008

manufacturers typically evaluate the intended application of the vehicle, perform engineering analysis, and then install an appropriate body, equipment and interface components with chassis systems in a manufacturing operation.

Medium and heavy duty trucks may also have multiple companies involved in marketing the final product. A chassis manufacturer may market directly to an end user and a final stage manufacturer may also market to the same end user. Multiple companies involved in the manufacturing and marketing of medium and heavy duty trucks tend to result in less integration of the overall process and more customization in comparison to cars and light duty trucks.

Hybrid drive systems for medium and heavy duty trucks differ in design. Some systems are primarily designed to be installed during the chassis manufacturing process by the original equipment manufacturer. Other systems are designed to facilitate either an installation during the chassis manufacturing process or in a later stage of manufacturing by another entity, such as an intermediate or final stage manufacturer. DUECO installs the plug-in hybrid drive system and interfaces the system with the chassis and installed equipment during the latter stage of manufacturing.

Hybrid drive systems for medium and heavy duty trucks can also either be installed on new vehicles or designed to be retro-fit on an existing chassis for certain applications. The plug-in hybrid system developed by DUECO and Odyne can be either installed during the manufacturing process of a new truck or it can be installed as a retro-fit on an existing chassis. Retro-fit applications must be carefully engineered, installation of a system on an existing truck requires sufficient payload, packaging space and specific chassis data communications interfaces.

Trucks used by utilities typically drive to a job site and then conduct stationary operations. In a conventional truck, the diesel or gas powered engine provides the sole source of propulsion for the vehicle and is also used to power truck mounted equipment, such as an aerial device, digger derrick, crane, compressor, winch or other equipment. While at the job-site, the vehicle may idle for many hours to provide power for the equipment and provide heat or air conditioning in the cab. A medium duty truck may average approximately 8 mpg while being driven and while at idle will typically consume approximately 1 gallon per hour or more.

A plug-in hybrid electric vehicle (PHEV) is a hybrid vehicle with batteries that can be recharged by plugging into our nations electric power grid. It shares the characteristics of both conventional hybrid electric vehicles and battery electric vehicles, having an internal combustion engine and batteries for power.

Hybrid systems used in larger trucks, greater than 16,000 pounds have typically utilized two basic design configurations—a series design or a parallel design.

Series design configurations typically use an internal combustion engine (heat engine) with a generator to produce electricity for both the battery pack and the electric motor. There is typically no direct mechanical power connection between the internal combustion engine and the wheels in an electric series design. Series design hybrids often have the benefit of having a no-idle system, include an engine-driven generator that enables optimum engine performance, typically lack a transmission (on some models), and accommodate a variety of options for mounting the engine and other components. However, series design hybrids also generally include a larger, heavier battery; have a greater demand on the engine to maintain the battery charge; and include inefficiencies due to the multiple energy conversions. Parallel design configurations have a direct mechanical connection between the internal combustion engine and the wheels in addition to an electric or hydraulic motor to drive the wheels.

Parallel design hybrids have the benefit of being capable of increased power due to simultaneous use of the engine and electric motor or hydraulic motor, having a smaller engine with improved fuel economy while avoiding compromised acceleration power, and increasing efficiency by having minimal reduction or conversion or power when the internal combustion engine is directly coupled to the driveshaft, typically through a transmission. However, parallel design hybrids typically lack a no-idle system and may have non-optimal engine operation (e.g., low rpm or high transient loads) under certain circumstances. Existing systems on trucks that have a gross vehicle weight rating (GVWR) of greater than 19,500 pounds have traditionally not had a system that combines the benefits of a series system and a parallel system.

DUECO has produced plug-in hybrid electric trucks, hybrid electric trucks and conventionally powered trucks for the utility industry.

*The need for plug-in hybrid trucks*

There are several factors that favor the development and use of plug-in hybrid trucks:

- Rising fuel prices.
- Increased pressure for environmentally friendly and green operations with lower carbon emissions.
- A national priority to reduce foreign oil dependency and increase energy security.
- Increased maintenance costs.

*Differences between plug-in hybrid electric trucks and hybrid electric trucks:*

The following compares some of the benefits of a plug-in hybrid to that of a conventional hybrid. The primary difference between the plug-in hybrid and the conventional hybrid is the size of the battery system and the ability to recharge the battery system from the domestic power grid.

While a plug-in hybrid truck offers some of the same benefits as a conventional hybrid truck, plug-in hybrids offer advantages in several areas:

- Reduced fuel consumption
  —A plug-in hybrid system has a large battery system that operates in a charge depleting mode. The energy from the battery is typically used to help propel the vehicle and operate equipment. Energy required to recharge the battery is ideally provided by the power grid or from regenerative braking, displacing the use of petroleum. A vehicle with a large enough battery system could potentially eliminate fuel consumption by operating in an all electric driving mode for a limited distance and operating in an all electric stationary mode. All electric trucks are available in Europe, while there are disadvantages such as limited range; electric trucks demonstrate that the technology is available for emission free operation.
  —A conventional hybrid typically uses power from the diesel and gas engine to recharge the battery or may be recharged from regenerative braking. Since much of the energy in the battery system results from recharging through the engine, fuel consumption may be higher.
- Reduced emissions, potentially eliminates emissions at the job site.
  —A plug-in hybrid typically reduces fuel consumption and corresponding $CO_2$ emissions during urban driving and has a large battery system that can allow the engine to stay off the entire day at the job-site. The large battery system is used to power truck mounted equipment such as an aerial device or electrically powered air conditioning system. Electricity to recharge the battery system may be generated by sources with lower emissions; some utilities generate a sizable portion of power from non-emitting sources. As an example, PG&E generates over 50% of their energy from renewable sources.
  —A conventional hybrid due to a smaller battery system often may need to restart the engine at the job-site to recharge the battery and may not have enough energy in the battery system to power large loads, such as an electrically driven air conditioner, with the engine off. When the engine is started periodically for short durations in the field to recharge the smaller battery system, emission systems may not be at optimal effectiveness, potentially resulting in greater emissions of harmful pollutants.
- Lower noise levels during stationary operations.
  —The engine typically stays off with a plug-in hybrid, resulting in lower noise levels. This increases the safety for linemen and offers quieter operation for working in residential areas. A conventional hybrid may require the engine to restart to charge the batteries.
- Uses low cost, domestically produced energy from nation's electric grid.
  —Off-sets fuel consumption by displacing petroleum with electricity. Ability to recharge at off-peak hours.
- Maintains a charge or is recharged at any time with conventional engine.
  —While a plug-in hybrid is typically designed to deplete the charge in the battery system and recharge through the grid, the system can be designed to maintain a minimum state of charge in the battery system by recharging through the engine if needed. This allows extended operations in the field during situations where it is impossible to recharge through the grid. In other words, while it is desirable to recharge a plug-in hybrid through the grid, it is not necessary to plug it in. Charging using the engine is similar to how a conventional hybrid recharges.
- Improved vehicle acceleration.
  —Electric motors provide additional power and torque to the drive train of the truck. The larger battery system of a plug-in hybrid provides more energy for extended use of the electric motor. The smaller battery system of a conven-

tional hybrid may become depleted more quickly, reducing available power when needed for climbing grades or other demanding situations.

- Standby power capability: option for 9 kW or more exportable power for applications such as job site power tools, lighting and temporary restoration of power to facilities.
  —The large battery system of a plug-in hybrid offers the ability to export power from the vehicle for external uses. In the more distant future it may be possible to export power from the vehicle to the grid (Vehicle to Grid, or V2G) to reduce peak loads on grid generation systems. The smaller battery system in a conventional hybrid typically does not have enough energy for export without turning on the engine to provide additional power.
- Reduced maintenance costs.
  —Utility vehicles often are serviced based upon hours of engine operation. A plug-in hybrid truck has reduced hours of engine operation, potentially extending maintenance intervals.

*Benefits of Electricity as a Fuel*

A plug-in hybrid electric truck uses electricity to supplement or replace the use of fossil fuels. There are several benefits to using electricity as a fuel.

- Electricity is typically produced from domestically sourced fuel or energy.
- Feed Stock diversity promotes stability
  —Hydro, Wind, Bio-Mass, Natural Gas, Coal, Nuclear
- portion of our nations existing generation fuel mix is currently $CO_2$ free.
  —Example: approximately 56% of PG&E's energy portfolio is $CO_2$ free
- Recent and ongoing legislation promotes cleaner generation mix over time
  —Renewable Portfolio Standard (RPS) legislation enacted in over 20 states
- Low fuel cost and minimal additional infrastructure required
  —Preferential rates for off-peak consumption
- Projected future renewable energy sources tend to be an off-peak energy resource
  —Wind can often produce more energy at night

A plug-in hybrid electric medium duty bucket truck* is shown above. This type of truck is typically used by utilities of maintenance and installation of power lines. The truck has many of the benefits listed previously. Specifically this vehicle has the following features:

- Hybrid launch assist and regenerative braking
- All Electric Operation at a job-site for a typical day
- 35 kWh Energy storage (note: a traditional hybrid may have 2 kWh of energy storage)
  —Electrically powered hydraulic system moves Aerial lift & outriggers, this function is also known as E-PTO
  —Electrically powered air conditioning
- 110/220VAC Electric shore power 9 kW, more optional. Also referred to as exportable power.
- Interfaces with an Allison transmission, the system may also interface with other transmissions (testing with other transmissions has not been completed).
- Modular design with standard components.
- Enhanced reliability with redundant power for critical operations.
- Advanced diagnostics & data acquisition available, ability to monitor vehicle via satellite
- Very versatile design:
  —Basic system design can be used on for a variety of truck weight classes from approximately 16,000 pounds to over 33,000 pounds, GVWR. Testing of the system on vehicles with a GVWR of 19,500 pounds and those of 33,000 pounds or greater has begun.
- Basic design can be used on a variety of chassis configurations: 2x4, 4x4, tandem. Testing has begun on the 2 wheel drive application, testing on the tandem will begin within the next year. Testing on the 4x4 has not been scheduled.
  —System should be able to interface with multiple power trains from multiple chassis manufacturers. Testing has begun on GMC and International units and on chassis with gas and diesel engines.
- Ability to tow trailer.
- No special diagnostic software.
- Enhances stability of vehicle for aerial device applications.

* All pictures and diagrams have been retained in committee files.

- Utilities can power their fleet with their own fuel: Electricity
- Charges in less than 8 hours using a 220—240 VAC 3 phase power source and charging station.

Fuel savings are dependent upon the application and unique duty cycle of the vehicle. The current vehicle reduces fuel consumption during driving in urban areas by approximately 10—15%. The vehicle will typically save 100% of fuel consumption during stationary operations at a job site, resulting in approximately 1 gallon per hour or more of reduction. There is little to no fuel savings during higher speed highway driving.

Anticipated fuel savings for a plug-in hybrid in comparison to a conventional truck depend upon many factors such as the type of system architecture, size of battery and field application. The following is an estimate for two types of plug-in systems, one with parallel system architecture and one with series system architecture. The sample application is a 20 mile drive, a 5 hour idling period, and an additional 20 mile drive.

Parallel system with plug-in battery system compared to a conventional truck:

Stated Assumptions:

Conventional chassis: approximately 8 mpg fuel efficiency during driving and approximately 1 gallon per hour fuel consumption during idle.

Parallel system with plug-in: approximately 12% decrease in fuel consumption for a plug-in hybrid during driving and 0 gallons per hour fuel consumption during idle.

Estimated fuel savings: 56% reduction in fuel consumption, or approximately 1400 gallons of fuel saved per year, based upon 250 work days per year. Over 15 years, estimated fuel savings exceed 20,000 gallons per truck.

Series system with plug-in battery system compared to a conventional truck:

Stated Assumptions:

Conventional chassis: approximately 8 mpg fuel efficiency during driving and approximately 1 gallon per hour fuel consumption during idle.

Series system with plug-in: 50% decrease in fuel consumption for a plug-in hybrid during driving and 0 gallons per hour fuel consumption during idle.

Estimated fuel savings: 75% reduction in fuel consumption, or approximately 1875 gallons of fuel saved per year, based upon 250 work days per year.

Due to the large amount of savings, medium and heavy duty trucks with plug-in hybrid technology may be able to reach an attractive return-on-investment more quickly than other vehicles.

A diagram of a plug-in hybrid electric system for a truck is shown. Electrical energy is used to increase efficiency while driving through hybrid launch assist and regenerative braking. Electrical energy also powers equipment loads at a job site, potentially eliminating the need to run the engine.

*Deployment of Plug-In Hybrid Trucks*

DUECO has started to deploy 25 plug-in hybrid medium duty trucks to early adopters. A number of major investor owned utilities across the country have agreed to use the plug-in hybrid bucket trucks in field evaluations. Ten units have been built as of September 2008; the remaining units are targeted for completion before the end of the year. DUECO completed delivery of the first unit to Adams Electric Cooperative earlier in the year. The unit has been operated by Adams in regular fleet operations to maintain power lines. Using a large 35 kWh battery system and interfacing with an Allison transmission, the plug-in hybrid system provides launch assist, regenerative braking, power for hydraulically operated equipment, electrically powered air-conditioning, and 120/220 VAC exportable power. DUECO plans to significantly ramp-up production of units in 2009 and beyond.

In June of 2008, DUECO introduced the first medium duty PHEV digger derrick. The unit is currently undergoing testing, production is planned for 2009. Digger derricks are used by utilities to drill holes, set poles and lift large loads. The demand for power from the plug-in hybrid system can be very high during certain operations, such as digging in rocky terrain.

Other manufacturers have begun to test plug-in hybrid drive systems and all electric power trains.

According to testimony provided by Mr. Eric M. Smith on June 10, 2008, Eaton was working with the Electric Power Research Institute to develop commercial PHEV trucks and was also working on the development of a PHEV for use in utility truck applications.

European truck manufacturers Modec and Smith Electric Vehicles have produced all electric commercial vehicles.

*Prospects for wider deployment in the near future*

While plug-in hybrid technology for medium and heavy duty trucks offers numerous benefits, there are several technical and commercial hurdles that must be overcome to enable the wide-scale deployment of plug-in hybrid trucks in the near term. Near term is considered to be 5 years or less.

DUECO believes that these challenges can be overcome, or largely mitigated, in the short term with a focused effort and the proper partnership between industry and government.

*Major technical and commercial hurdles for wide-scale deployment of plug-in hybrid trucks*

Although current plug-in hybrid technology has the potential to provide significant benefits for many applications, short comings in certain areas decrease the value proposition of plug-in hybrid systems for medium and heavy duty trucks. Wide scale deployment must be driven by demand. It is necessary to improve the value proposition by providing greater performance and fuel savings for less incremental cost.

*Battery system technology*

Existing battery technology either tends to offer battery systems that are relatively low cost, but heavy, large and of limited life or are relatively expensive, but much lighter, smaller and with potentially longer life. While certain applications of trucks may be able to carry lower cost, heavier battery systems, it is generally desirable to minimize battery system weight, size and cost. Development of cost effective larger advanced battery systems, potentially with energy storage in excess of 35 kWh, or even in excess of 100 kWh, would improve the performance and reduce the operating cost of plug-in hybrid trucks.

In order to accelerate deployment of plug-in hybrid trucks using existing technology, it may be desirable to design battery systems that are modular, that allow for newer technology battery systems to be placed on existing vehicles when the original battery system no longer performs to acceptable standards.

Battery systems for commercial trucks must operate in different conditions and duty cycles than those in automotive applications. Trucks must often locate the larger battery system on the exterior of the truck, exposed to the elements. Trucks may also operate for much longer duty cycles. Commercial vehicles may be driven 12—16 hours per day, or operate for multiple shifts. Cars used for commuting may only operate for a few hours per day.

*System architecture*

Existing hybrid systems for trucks tend to utilize system architectures that are similar in many ways to that of existing truck power trains. The internal combustion engine typically remains operating while the vehicle is driven to power auxiliary loads such as power steering systems, brake systems and HVAC systems. Keeping the engine running while stationary or in low speed stop and go traffic increases fuel consumption. Some vehicles also do not have a clutch in between the internal combustion engine and the transmission. While such systems utilize an automatic transmission, it may be desirable to create a method to uncouple from the transmission from the engine for improved regenerative braking or an all-electric drive mode.

In order to improve fuel economy further, different system architectures that are designed for high volume production in which the internal combustion engine can remain off during driving need to be developed. The development of electrically driven sub-systems such as braking, power steering, HVAC and others need to be brought to high volume production for medium and heavy duty trucks.

Existing parallel hybrid electric vehicle systems for trucks also tend to use relatively small electric drive components with relatively low power output, compared to the power provided by the internal combustions engine. Larger electric motors and higher capacity battery systems may allow smaller engines to be used that operate at higher efficiency without a reduction in vehicle performance, or allow the vehicle to be driven entirely by electric propulsion. Future system architectures could also combine the benefits of plug-in hybrid technology, which requires battery systems with high energy densities, with that of hydraulic hybrids that have high power densities. The combined plug-in electric hybrid system with hydraulic hybrid components could offer high horsepower during acceleration and recapture more energy during braking while providing enough energy for sustained operation with the engine off.

Alternative power train architectures, such as a combined series/parallel hybrid system with a plug-in battery system are also recommended for consideration. A combined series/parallel system would allow the vehicle to operate in an all electric mode, a series hybrid configuration or a parallel hybrid configuration, depending upon which is most advantageous given operating requirements.

*Utility infrastructure*

While studies tend to indicate that there is sufficient capacity in the nation's energy grid at off-peak periods to provide power for charging a large number of plug-in vehicles, there has been little testing on the effects of charging a large number of commercial plug-in hybrid trucks. A commercial fleet of 1000 vehicles, each with a 35 kWh battery system, could require approximately 25,000 kWh (or 25 MWh) of energy to recharge overnight. Assessment and testing on the effects of charging a large number of plug-in hybrid trucks is suggested, along with an assessment of the interface with Smart Grid technology and associated advanced metering systems.

Commercial trucks with large battery systems also typically require higher charging voltages in order to recharge overnight. The lack of higher voltage circuits in existing truck storage areas could create barriers and increase the cost to deploy such technology.

*Research into specific medium and heavy duty applications*

Plug-in hybrid technology for medium and heavy duty trucks has the potential to reduce fuel consumption and emissions in a wide variety of applications. Besides aerial utility trucks and delivery trucks, other truck applications such as those that use cranes, compressors, welding equipment, or are used in gas utility maintenance, refrigeration, rescue, refuse and construction may benefit from plug-in hybrid technology.

Specific information about the energy required for various mobile and stationary applications is typically not available. In order to optimize the design of a plug-in hybrid medium or heavy duty truck, it is recommended that data be collected on actual fleet utilization, including miles driven, time at idle, power requirements, fuel consumption and other operational factors. The development of plug-in hybrid systems for vehicles that operate at especially low efficiency should be a priority and testing should be undertaken to validate improved efficiency and reliability.

*Accelerated testing*

Plug-in hybrid technology for medium and heavy duty trucks is relatively new and still under development. Assistance is needed to accelerate testing and reduce the costs of large scale field tests.

*Investment requirements*

Development of new technology and manufacturing capability requires significant investment. The cost of capital for development has increased for a variety of reasons. Assistance such as funded loan guarantee programs backed by the government can enable companies to continue development in difficult economic times. Needed investment is estimated to be well in excess of $300 million, excluding additional investment needed for battery development.

Grants can also accelerate investment in the development of new plug-in hybrid technology. DUECO strongly encourages the Senate to adopt and support "The Heavy Duty Hybrid Vehicle Act" H.R. 6323 or similar legislation.

*Low initial production volume and high cost*

Low initial production volume, combined with high start-up costs can prohibit companies from pursuing plug-in hybrid technology. As volume increases, fixed costs are spread over more units, resulting in lower unit costs. Tax incentives can accelerate demand by lowering the initial cost to the consumer. DUECO encourages the government to consider tax incentives that result in lower costs to the market for large PHEV systems in vehicles with GVWR of 19,500 lbs. or greater and battery system sizes of up to 60 kWh or greater.

*Additional weight*

The large battery systems required for medium and heavy duty trucks add weight to the vehicle. Since newer technology battery systems with lower mass may not be ready at a commercially viable price in the near term, heavier batteries with shorter effective life may be the only cost effective alternative. The additional weight of less advanced battery systems can cause a truck to exceed 33,000 lbs., the weight limit for exemption from Federal Excise Tax. The government should consider waiving FET on vehicles that have plug-in hybrid drive systems. This will further reduce the effective cost to the consumer and accelerate deployment of PHEV technology in trucks.

*DUECO's experience with government technology development programs and how the federal role can be enhanced*

Federal technology development programs focused on plug-in hybrid systems for medium and heavy duty trucks have been very limited. DUECO has not obtained federal assistance in this area, with the exception of possible general research tax credits. Most of the funding in this area has focused on the development of plug-in technology for automobiles or has been focused on large original equipment manufacturers. The medium and heavy duty truck industry is unique in that many of its products are often manufactured in multiple stages and brought to market by companies that are not directly affiliated with the original equipment manufacturer.

DUECO encourages the federal government to develop programs that help to specifically fund research into the development of plug-in hybrid systems for medium and heavy duty trucks used in specific applications and that are open to final stage manufacturers and other entities. Assistance with testing, certification, the creation of tax incentives for customers, and modification of government purchasing policies to favor the acquisition of more fuel efficient trucks using plug-in hybrid technology can also accelerate development and deployment.

Commercial fleets consume large amounts of fuel, developing more efficient trucks that utilize domestically sourced power from the nation's energy grid would have several benefits.

The development of this technology in the United States would provide opportunities for job creation, export opportunities, reduce the costs for businesses competing in a global market, reduce greenhouse gas emissions and emissions of other pollutants, reduce dependency on foreign oil, reduce noise within our cities and potentially improve productivity for certain applications, such as electric crews who could perform work at night in residential areas.

This is potentially a historic opportunity to develop the technology needed for the electrification of medium and heavy duty trucks. I ask for your support of the proposed measures that would help to accelerate deployment of plug-in hybrid technology for medium and heavy duty trucks and encourage the development of partnerships between manufacturers, utilities and the government.

The CHAIRMAN. Thank you very much.

Mr. Balkman, go right ahead.

## STATEMENT OF THAD BALKMAN, GENERAL COUNSEL AND VICE PRESIDENT, EXTERNAL RELATIONS, PHOENIX MOTORCARS, ONTARIO, CA

Mr. BALKMAN. Thank you, Mr. Chairman. Good morning, members of the committee. I am Thad Balkman. I am Vice President of External Relations with Phoenix Motorcars. As a former State legislator, I am a little bit used to these hearings, albeit on a much smaller scale and sitting on the other side of the dais.

But I appreciate the opportunity to come this morning and give you the perspective of a small startup electrical vehicle company.

We are based in Ontario, California, and we manufacture freeway speed, full-sized battery electric vehicles. We make a sports utility truck and a sport utility vehicle. We will get a picture of the sports utility truck over here. Our vehicles sell for $47,500. We are beginning to build on a demonstration fleet and expect to begin production in early 2009.

Mr. Chairman, last week you asked about game changers. The electric vehicle is a game changer. The EPA estimates gives us a rating of 135 miles per gallon. It is 135 miles per gallon on a single charge of the battery. No gas is required. The major benefit of the electrical vehicle is that electricity costs about one-sixteenth the cost of gasoline. So I can charge the sports utility truck. It is going to cost me about $4 to charge the battery, whereas when I go back home and go to fill up my Hyundai Sonata, I am going to pay about

$64 to refill the gas tank. So electrical vehicles give consumers a great amount of choice, but also a cash back.

So I guess one of the points I want to emphasize is that—and it has been emphasized by other members of this panel—by adopting electrical vehicle transport, we are going to be no longer dependent on foreign oil. Instead, we are going to be using electricity and start using domestic resources, domestic coal, domestic natural gas, wind power, hydroelectric power, solar power, which gives us obvious benefits of national security. Best of all, it is a lot cleaner. In fact, in California, our vehicles qualify for the California zero emission vehicle gold standard and does a lot to clean up the smog that we have in Los Angeles and even here in Washington, DC.

Our sports utility truck and sport utility vehicles can be charged two ways. You can plug them in at home and let them charge overnight. It takes about 4 to 6 hours. Or you can actually use a rapid charge device, and they are recharged in as little as 10 minutes. This really helps address some of the concerns of range anxiety because with the rapid charge you can go a lot longer than the 130 miles on a single charge for a battery.

I want to also address some suggestions I have for the Senate. They are outlined in my written testimony.

But I want to encourage members of this committee and the rest of the members of the Senate to follow the House and pass the $7,500 tax credit. I know there is a number of energy measures out there, but this will do a lot because what it does is it gives people that purchase electric vehicles up to $7,500 in tax credit.

I put a little plus sign there because we would actually like to ask you to lift that cap for battery electric vehicles. Pure battery electric vehicles have twice the battery capacity, twice the energy independence, and have twice the benefits for global warming concerns. Therefore, we would hope that they would earn twice the credit. By doing that, you are actually going to be bringing down that cost I mentioned earlier. They run about $47,500. By lifting that tax credit, you are going to make the vehicle and price just about the same price range as its internal combustion gas counterpart.

Also, we would like to ask the Senate to help level the playing field with other alternative energy sources and create an alternative refueling investment tax credit.

We would also encourage the Senate to—I have heard a lot about greening the capital. We would like to see the Government fleet green and purchase electric vehicles for use in various Government departments, including here at the United States Capitol.

I would also suggest that we bring electric vehicles into the refueling fuel standard. Including renewable energy into the RFS encourages more investment in solar and wind power, which is used to recharge or in some cases used to recharge electric vehicles.

Also, I know there has been a lot of discussion about a cap and trade program. When you all figure out the details on that, I would hope that you would include electric vehicles in any future cap and trade program and allow electric vehicles a carbon allowance that would help reduce the incremental costs that we are faced with in electric vehicles these days.

Also, another suggestion would be to create a Government-backed battery guarantee program. We have heard some of the members of the panel talk about how battery technology is still in its infancy, and by creating such a guarantee program, it would help address some of those concerns because, quite frankly, the biggest cost of the electric vehicle is in the battery.

Finally, we would ask you to increase investment in advanced technology, particularly in the battery development. Today, unfortunately, the United States lags far behind other countries in the world in battery development. We would like to change that.

Like I said, I have put more detail into the written testimony and I would ask you to look at that.

I would be happy to answer your questions and also would like to invite each one of you, next time you are in southern California, to stop by. We would like to give you a drive in one of our sports utility trucks. We plan on bringing them out here in December, and you will also be invited to take a ride at that time too.

Thank you very much.

[The prepared statement of Mr. Balkman follows:]

PREPARED STATEMENT OF THAD BALKMAN, GENERAL COUNSEL AND VICE PRESIDENT, EXTERNAL RELATIONS, PHOENIX MOTORCARS, ONTARIO, CA

Mr. Chairman and members of the Committee, this document supplements and expands upon my oral testimony during today's hearing. Thank you for your invitation to share with you what Phoenix Motorcars is doing to meet the dual challenges of our nation's dependency on oil and global climate change. We join all Americans in applauding your interest in learning about the current status of vehicles powered by the electric grid and the prospects for wider deployment. Based upon our experience in developing an advanced all-electric Sport Utility Truck, we at Phoenix Motorcars are convinced that all-electric vehicles present the best near-term solution to eliminate our dependence on oil and tackle the difficult challenge of climate change. We hope that the information we share with you this morning will be of value as you consider legislation to address these important issues.

INTRODUCTION TO PHOENIX MOTORCARS

Phoenix Motorcars was founded in 2001 in Southern California. Our mission is to develop best in-class, zero emission vehicles (ZEV) for the U.S. commercial and government fleet markets initially and then later expanding into the consumer market. Phoenix is headquartered in Ontario, California. Our team of employees has over 300 years of collective experience working on vehicle and alternate fuel programs for leading automotive companies.

After six years of research and development work into full performance battery electric vehicles, Phoenix began the commercialization process of our Phoenix Sport Utility Truck model with the assistance of many strategic partners including Energy CS, Altairnano Technologies, AeroVironment and many other innovative companies. The accumulated effort of Phoenix and our partners has produced a truly best in class electric vehicle that will set the milestone for battery electric vehicles (BEV) to come. A few highlights about our BEV:

- Range of 100+ miles per charge
- Top speed of 95 mph
- High crash test safety rating
- Battery charging in as little as 10 minutes with off-board fast-charging equipment
- $3 cost per charge using the on board charger
- A projected EPA rating of 135 mpg
- 0 to 60 mph in 10 seconds

Phoenix is now set to begin production in the fourth quarter of this year with deliveries beginning in the first quarter of 2009. Our demonstration fleet is currently under build to complete testing prior to vehicle production. These demonstration vehicles use the Altairnano lithium titanate battery and demonstrate a Phoenix BEV's ability to rapid charge and perform in real world applications. The price of the Phoenix SUT and SUV are $47,500 and $54,000 respectively.

LIFE CYCLE COSTS

The retail costs of the Phoenix SUT and SUV are a bit higher than their gasoline fueled counterparts, mainly due to the cost of the battery pack. However a comparison of the life cycle cost of electric vs. gasoline shows that the owner of a Phoenix saves a considerable amount of money—with a payback in about 2 years. Per mile, electricity is 1/16th the cost of gas. The owner of a Phoenix BEV who drives 15,000 miles per year can expect to save approximately $4,000 in gasoline costs. Furthermore, BEVs have less than 10% of the moving parts when compared to gasoline powered cars. BEVs don't have pistons, transmissions, engine oil, spark plugs, valves, starters, clutches, distributors, oil filters, fuel pumps, fuel filters, air filters, water pumps, timing belts, fan belts, catalytic converters, or mufflers. No fumes, no exhaust, no smog tests, no oil changes, no radiator flushes, no loud engine, no warm-ups, and no gas lines. Maintenance savings equal about $1500 per year. Coupled with available incentives like California's $5000 tax rebate and the federal $7500 rebate under consideration, and the purchaser of an BEV realizes a payback in less than 2 years.

RAPID CHARGE INFRASTRUCTURE

Phoenix Motorcars is currently the only electric vehicle manufacturer that has safely demonstrated the ability to rapid charge a vehicle in 10 minutes, using fast-charging technology developed by AeroVironment, Inc., which like Phoenix Motorcars is a home grown American BEV technology leader. This unique ability requires industrial 480V 3 Phase power and a 250kW off-board charger that is controlled by the vehicle's battery management system. Because our advanced Li-Ion batteries can be fully recharged in 10 minutes with no impact on battery calendar or cycle life, so-called "range anxiety" is eliminated. Our vehicles can be recharged in the same time it takes to fill the tank of a gasoline vehicle. Even with this ability, some utilities have expressed concern about the potential impact on the grid of many Phoenix vehicles "rapid charging" during peak power use. However, duty-cycle studies show that most of our vehicles will be recharged overnight when electricity demand is low. According to the U.S. Department of Energy's National Renewable Energy Laboratory, the large-scale deployment of plug-in hybrid electric vehicles will have negligible impact on the electric power system which has sufficient available capacity to electrify up to 84% of our nation's cars, pickup trucks, and SUVs for the daily 33 mile driving distance of the average American. For the small percentage of electric vehicles that will be "rapid-charged" at central charging stations, Phoenix has developed a technical solution that will enhance penetration of renewable energy such as solar and wind power, and is based on an electrical storage variation of the traditional gas station model.

Today, gasoline stations rely upon underground liquid petroleum storage tanks. When the driver realizes she's low on fuel, she simply pulls into a conveniently located gas station and purchases a desired amount of fuel for her vehicle. The capital cost of storage and dispensing equipment at these gas stations typically exceeds a million dollars. But, if one also considers the external costs associated with groundwater contamination, smog and its associated disease and property damage, the total cost of each service station is millions of dollars.

The electric vehicle "rapid charge" station concept developed by Phoenix follows a similar model but with a fraction of the capital cost and none of the external human health and environmental cost. Instead of petroleum storage tanks to hold gasoline and diesel, multi-megawatt battery banks will be installed below or above ground to fill the need for daily electric vehicle charges. These batteries can be recharged from the utility grid during off-peak distribution times (such as in the middle of the night), from solar panels, wind power or other electricity power generation methods. An electric vehicle driver finding her vehicle in need of a quick charge will pull into a charging station, connect the charging cable to the vehicle, and begin transferring energy from the stationary battery bank to the electric vehicle battery. The same credit card system we use today in gasoline stations will be used to purchase the charge and return the driver back on the road in a matter of minutes.

This charging station model will provide real benefits to electric vehicle owners as well as to federal and state governments. Batteries will present no lingering environmental concerns for the sites they are located on. Rapid charging stations will hasten and assist mass adoption of electric vehicles and will create synergy for the adoption of renewable electricity from wind and solar technology. Battery banks at recharging stations also will provide a second life for older vehicle batteries no longer suited for transportation but which are still viable for stationary applications. Battery banks will feed energy back onto the energy grid under certain conditions. Cost of the energy can be regulated and controlled domestically, on US soil. In this way, batteries will provide power sources distributed across the nation that can be deployed as temporary power sources during emergencies.

FORECAST FOR FUTURE

Phoenix has received over 600 orders from fleet customers and more than 20,000 individual reservations. These orders represent billions of dollars in domestic production. Among those placing orders are: City of Fresno, City of Santa Monica, Waste Management, and Clark Pest Control. We are also on the GSA list and have begun discussions with numerous federal agencies interested in greening their fleets.

Our current business plan sets the following sales targets for both the fleet and consumer markets:

| | |
|---|---|
| 2009: | 2,500 vehicles |
| 2010: | 10,000 vehicles |
| 2011: | 51,000 vehicles |

CHALLENGES WE FACE

Phoenix BEVs incorporate the following core technologies: BEV integration, vehicle drivetrain, accessory components, battery systems, battery tray, vehicle integration module, battery management system, drive-by-wire, climate control operations, and vehicle certification. While some of these components are common to traditional ICE vehicles, the market and supply chain for batteries and electric motors is still in its infancy and is limited. This is especially true here in the United States. And the cost for these essential components is still not competitive. The Center for Automotive Research estimates battery costs alone add $7,000 to $10,000 per vehicle.

PAST ATTEMPTS TO ADDRESS EVS

In order to overcome these barriers to market and to promote energy independence for our nation, Government must take bold steps to adopt an alternative fuel policy agenda that places BEVs front and center and elevates them to at least the same level if not higher as other alternative fuels supported in the past.

Nearly 32 years ago, in the face of our last energy crisis, Congress passed the Electric and Hybrid Vehicle Act of 1976, which declared that the era of the electric vehicle had arrived and that it was the policy of Congress to:

> (1) encourage and support accelerated research into, and development of, electric and hybrid vehicle technologies;
> (2) demonstrate the economic and technological practicability of electric and hybrid vehicles for personal and commercial use in urban areas and for agricultural and personal use in rural areas;
> (3) facilitate, and remove barriers to, the use of electric and hybrid vehicles in lieu of gasoline and diesel powered motor vehicles, where practicable; and
> (4) promote the substitution of electric and hybrid vehicles for many gasoline- and diesel-powered vehicles currently used in routine short-haul, low-load applications, where such substitution would be beneficial.

The Act created a new loan guarantee program to encourage the commercial production of electric and hybrid vehicles. The new program authorized DOE to guarantee principal and interest on loans for the purposes of:

> (1) research and development related to electric and hybrid vehicle technology;
> (2) prototype development for such vehicles and parts thereof;
> (3) construction of capital equipment related to research on, and development and production of, electric and hybrid vehicles and components; or
> (4) initial operating expenses associated with the development and production of electric and hybrid vehicles and components. See 15 U.S.C. §2509.

Unfortunately, the loan guarantee program utterly failed. Since the passage of the Act in 1976 (following an over-ride of President Ford's veto), precious little has been done to help create the market for BEVs. This is not to say that the Congress has not tried. In fact, since 1976, various Congressional committees have convened more than 40 hearings and received tens of thousands of pages of testimony from the automobile industry, academia, government laboratories, government agencies and other experts seeking an answer to the same question we face today: how can our

Nation break our addiction to petroleum? A sampling of these various Congressional hearings follow:

November 24, 1979: Hearings on Storage Batteries for Electric Vehicle Applications;
March 7, 18, 1980: Hearings on World Auto Trade: Current Trends and Structural Problems;
April 15, 1980: Hearing on Automotive Average Fuel Economy Standards;
May 2, 1980, Hearings on Automotive Technology and Fuel Economy Standards;
May 28, 1980: Hearings on National Automotive Research Act;
July 17, 1985: Hearings on Rollback of CAFE Standards and Methanol Vehicle Incentives Act of 1985;
September 14-16, 1988: Hearings on the Global Environmental Protection Act of 1988;
May 2, 1989: Hearings on Global Warming and CAFE Standards;
September 7, 1989: Hearings on Motor Vehicle Efficiency Act of 1989;
January 11, 1990: Hearings on Alternative Fuels
September 23, 1990: Hearings on Electric Vehicle Technology and Commercialization;
October 24, 1990: Hearings on Energy Policy Implications of the Middle East Oil Crisis;
February 21, 1991: Hearing on Motor Vehicle Efficiency Act;
April 26, 1991: Hearings on Global Warming and Other Environmental Consequences of Energy Strategies;
May 16, 1991: Hearings on HR 1538, National Electric Vehicle Act of 1991;
June 11, 1991: Hearings on Electric and Hybrid Vehicle Technologies;
May 11, 1993: Hearings on Status of Domestic Electric Vehicle Development;
September 29, 1993: Hearings on Alternative Transportation Fuel Additives;
June 30, 1994: Hearings on Electric Vehicles and Advanced Battery R&D;
June 14, 2000: Hearings on the Clean Air Act: Environmental Benefits and Impacts of Ethanol
January 2, 2001: Hearings on National Energy Policy: Conservation and Energy Efficiency;
March 21, 2001: Hearings on the Clean Air Act Oversight Issues;
May 30, 2001: Hearings on Innovative Environmental Technologies;
June 22, 2001: Hearings on National Energy Policy: Conservation and Energy Efficiency;
June 12, 2001: Hearings on Effect of Federal Tax laws on the Production, Supply and Conservation of Energy;
July 18, 2001: Hearings on National Energy Issues;
December 6, 2001: Hearings on Corporate Average Fuel Economy (CAFE) Reform;
January 24, 2002: Hearings on National Security, Safety, Technology, and Employment Implications of Increasing the CAFE Standards;
June 2, 2002: Hearings on Department of Energy's Freedom Car: Hurdles, Benchmarks for Progress and Role in Energy Policy;
March 5, 2003: Hearings on The Path to a Hydrogen Economy;
March 6, 2003: Hearings on Energy Use in the Transportation Sector;
March 3, 2004: Hearings on Reviewing the Hydrogen Fuel and Freedom Car Initiatives;
February 9, 2005: Hearings on Improving the Nation's Energy Security: Can Cars and Trucks Be Made More Fuel Efficient?;
May 15, 2005: Hearings Public Policy Options for Encouraging Alternative Automotive Fuel Technologies;
July 28, 2005: Hearings on Automotive Technologies and Energy Efficiency
October 20, 2005: Hearings on U.S. Foreign Policy, Petroleum and the Middle East
May 17, 2006: Hearings on The Plug-In Hybrid Electric Vehicle Act of 2006
March 7, 2006: Hearings Energy Independence
October 3, 2007, Hearings on Energy Storage Technologies: State of Development for Stationary and Vehicular Applications;
January 3, 2007: Hearings on Transportation Sector Fuel Efficiency;

After 32 years of hearings and debate it is time for action. Today, our Nation is perilously dependent upon foreign oil to fuel our cars and trucks. In June of 2008 the Energy Information Administration reported that in 2007 we imported 12 million barrels of foreign oil each day. With crude hovering at $100 per barrel Americans sent $120 million per day of their hard-earned wages to foreign countries. This dependency poses both a security risk and an economic crisis never before experienced by our Nation. The urgent nature of the problem compels Congressional intervention to finally catalyze the market for electric vehicles. No other near term automotive technology offers the ability to immediately end dependence on foreign oil, drastically cut smog and global warming emissions, and avoid a massive decades-long investment in new fuel distribution infrastructure.

Phoenix Motorcars understands that Congress is appropriately reluctant to legislate winners and losers among competing technologies. However, battery electric vehicles should be the one exception to this rule. It is the only technology that can solve our problem of petroleum dependency and global warming emissions within 10 years. The battery technology enabling high density energy storage has finally arrived and is steadily improving. The supply infrastructure to refuel the vehicles exists in every home and business across the Nation. At the very least, Congress must give electric vehicles equal treatment with the other alternative fuel options. With the right mix of market incentives, an historic opportunity exists to change fundamentally our transportation paradigm away from petroleum and toward electricity supplied from renewable sources.

It is only with decisive action by the Congress will our Nation finally begin to solve its twin Achilles Heels of dependence on foreign oil and runaway carbon emissions. The time for more hearings, more debate, and more study has passed. Meaningful legislative action is needed.

## HOW GOVERNMENT CAN ASSIST

Cost is the principal barrier to rapid adoption of BEVs. Our vehicles cost about $15,000 more than their gasoline counterparts largely because economies of production in battery manufacturing and vehicle integration have not yet been achieved. This incremental cost is a big barrier to commercialization of the technology because data show that consumers will not pay extra for more fuel efficient vehicles unless the pay-back is 2.5 years or less. The pay-back must be relatively immediate or consumers will not pay the higher price. This means that BEVs with incremental costs upwards of $15,000 may not sell and manufacturers, facing an uncertain market, will not produce them.

Phoenix Motorcars is pleased that the House passed a tax credit for plug in vehicles in the energy extenders bill earlier this year. But this tax credit does not go far enough. Phoenix Motorcars believes that a key to accelerating the adoption of BEVs is to foster fairer competition among the various alternative fuels within the Federal Government's existing fuel diversification policy framework. Electric vehicles currently receive less incentives than other alternative fuel vehicles even though they release no pollution, require no massive investment in new fuel infrastructure, and cause no price disruptions in our food supply.

Following are a number of additional tools that Congress should provide to help expedite the commercialization and wider deployment of battery electric vehicles in the near future.

- Congress should not cap the tax credit for BEVs at $7,500. The existing proposed tax credit of up to $7,500 for qualified plug-in hybrid electric drive vehicles consists of a base credit of $2,500 for each qualified plug-in hybrid electric drive vehicle plus $400 for each kilowatt hour of battery capacity above 4 kilowatt hours. As structured, the credit treats BEVs the same as hybridelectric vehicles even though BEVs eliminate the use of gasoline entirely, have zero emissions, and are more costly, all due to their larger battery packs which eliminate the need for internal combustion engines. By lifting the $7,500 cap for BEVs only, Congress would provide greater incentives for the production of all-electric vehicles because the cost premium would be substantially reduced. Thus, the Phoenix Motorcars SUT, which uses as 35kWh battery, would qualify for a $15,000 credit. The Tesla sports car, which uses a 53kWh battery, would qualify for a $22,000 credit. Due to their higher cost, BEVs will have a much smaller market penetration in the next few years when compared with PHEVs unless they receive tax credits proportional to their larger battery size and energy-independence benefit. Raising the tax credit limit for BEVs would require additional funding for the legislation, but not by a substantial increment given the low-volume production which is projected over the next five years.
- Congress should bring electric vehicles charged with solar, wind, or other renewable electricity, into the Renewable Fuels Standard program under Section 211 of the Clean Air Act. The Energy Independence and Security Act of 2007 amended the RFS created by the 2005 Energy Policy Act by requiring refiners to ramp-up production of ethanol to 36 billion gallons by 2022. The RFS program provides for credit trading between refiners subject to the RFS standard. Certain other fuels that are not even blended into gasoline also qualify for credits, including biodiesel and biogas. However, renewable electricity used to fuel

BEVs currently is not included in the RFS. By making renewable electricity eligible under the RFS, the Congress would encourage more investment in solar, wind, and other renewable energy sources to recharge electric vehicles. In turn, petroleum refiners subject to the RFS mandate would have more options available to satisfy the RFS mandate by purchasing credits generated by solar and wind electricity. This, in turn, would help alleviate some of the economic pressure to divert corn crops to the production of ethanol. The diversion of 25-35% of the domestic corn crop to ethanol production is a prime factor in the recent increase in global food prices.

- Congress should mandate government fleet purchases of BEVs, with particular emphasis on Air Quality Control Districts with severe ozone non-attainment issues to leverage the co-polluton reduction benefits of BEVs. This could be accomplished by revising the alternative fuel vehicle (AFV) fleet program created by the Energy Policy Act of 1992. The AFV fleet program was intended to reduce our dependence on foreign oil by forcing government agencies, oil refiners and energy utilities to buy alternative fuel vehicles. By legislating market demand, the AFV fleet program was expected to induce the automobile industry to manufacture AFVs at scale, thereby leading to a gradual conversion of our Nation's vehicle fleet to AFVs. Unfortunately, as with the loan guarantee program of the Electric and Hybrid Vehicle Act of 1976, the AFV program has failed. The only mass-produced alternative fuel vehicle technology inspired by the program is a $100 change to the fuel system of gasoline vehicles to enable so-called E85 "flex-fuel" capable vehicles. Ninety-eight percent of the Federal Government's AFV purchases in 2006 were E85 flex-fuel vehicles that run on ethanol only a tiny fraction of the time due to limited ethanol delivery infrastructure. By mandating that a specified percentage of government AFV purchases be all-electric vehicles, the Congress would create the kind of market demand first envisioned by the 1992 Energy Policy Act.
- Congress should include BEVs in any future $CO_2$ cap & trade program thereby monetizing their lifetime $CO_2$ benefits and creating additional value that would reduce their high incremental cost. $CO_2$ allowances could be awarded to BEVs at the point of initial sale under a "lifetime bonus allowance set-aside." We suggest an initial bonus allowance set-aside ratio of 4:1. Under the bonus concept, certain valuable technologies are allocated allowances at a ratio greater than one allowance to one ton of $CO_2$ reduced or sequestered. The bonus concept is consistent with the Carbon Capture & Storage provisions of the Lieberman-Warner bill. Using EPA data, we estimate that a single Phoenix Motorcars SUT or SUV eliminates roughly 35 tons of $CO_2$ over 150,000 miles as compared to an average light-duty gasoline powered vehicle at 20 miles per gallon, a $CO_2$ emissions rate of 19.4 pounds/gallon, and the national average $CO_2$ content of the electric grid. At a projected allowance price ranging between $22 and $61 per ton in the year 2020 under various future cap and trade scenarios, monetizing the lifetime $CO_2$ reductions of BEVs under a bonus allocation of 4:1 would reduce incremental cost by roughly $3,000 to $8,500. Making BEVs eligible for lifetime $CO_2$ bonus allowance set-asides within the $CO_2$ cap and trade system—at least until economies of production scale are achieved—would create a direct incentive for OEMs to produce BEVs and would reduce incremental cost by monetizing their $CO_2$ reduction benefits. By capturing the discounted value of the total amount of avoided $CO_2$ emissions over the lifetime of a BEV, the incremental cost of BEVs could be reduced and the technology could enter the market more quickly. The lifetime $CO_2$ reduction benefits could be monetized through a prepaid forward contract approach, under which the buyer of a commodity stream over time prepays the seller for the entire stream up front. This prepaid forward contract approach is often used in energy markets, such as natural gas volumetric production payment contracts, which enable energy traders to hedge price risk. As applied to BEVs the prepaid forward contract approach would enable the estimated income stream from the $CO_2$ allowances generated each year over a specified period to be monetized, discounted to present value, and transferred at the vehicle point-of-sale. The associated "income" from the sale of the lifetime pollution reduction benefits would be revenue neutral.
- Congress should consider creating a government-backed battery-guarantee program, which was suggested by David Sandalow of the Brookings Institute in his book "Freedom from Oil."
- Congress should increase investment in advanced technologies, namely advanced battery development.

FINAL OBSERVATIONS

Loan guarantees, basically direct subsidies to large OEMs, will not create the necessary competitive market conditions to foster innovation to create truly advanced vehicles, like the Phoenix Motorcars SUT and SUV. This kind of subsidy program did not work with the 1976 Electric and Hybrid Vehicle Act, nor did it work more recently with the 2005 Energy Policy Act, Title 17 of which had a similar $2B loan guarantee program for "production facilities for fuel efficient vehicles, including hybrid and advanced diesel vehicles." Tellingly, none of the Big 3 applied for loan subsidies under either of these programs.

It is also doubtful that massive retooling really is necessary to produce electric vehicles at scale. The basic components of both the Phoenix Motorcars SUT and SUV, for example, the body, electric motor, and battery pack are produced and supplied by third-party vendors. The same is largely true for the Chevrolet Volt, the motive power for which will be supplied by an electric motor and a battery pack produced and supplied by third parties who have the expertise and manufacturing know-how in electric motors, power electronics, and battery chemistry. Therefore, Phoenix Motorcars does not perceive a true need to retool drive train manufacturing facilities to produce electric vehicles like the Volt, because the engines and mechanical transmissions are entirely eliminated with electric vehicles. Instead, Phoenix Motorcars believes it would be far more effective if Congress would implement market-based measures such as those advocated previously in this testimony.

One-hundred years ago, there were dozens of American automobile manufacturers who were primarily vehicle integrators not unlike Phoenix Motorcars, Tesla, Miles Electric, Zap Electric, and the handful of other entrepreneurial companies today who are working on the commercialization of electric vehicles. Much like the start-up companies of today, these early pioneers assembled bodies and engines produced by independent third-party suppliers. This fostered innovation and enabled start-up firms to enter the market with minimal barriers. If you had a better idea you could find the capital and run with it. Steam-powered, electric, and gasoline-powered automobiles all competed for predominance. While petroleum-based transportation ultimately won the day, and dozens of competing American firms were consolidated into three, many believe that this was only because petroleum was cheaper than electricity and was more capable of being stored.

Today, we are witnessing a total reversal of the underlying fundamentals that drove transportation toward petroleum. No longer is gasoline cheaper than electricity. In fact, depending literally on the day, it is four to five times more expensive than electricity. And, as we have come to learn, its true external cost in the form of national security costs, human health costs, and climate costs, make petroleum far more costly than electricity. Finally, as our electricity is supplied by ever-more diverse forms of generation, from solar, wind, biomass, natural gas, nuclear, and coal, electricity-based transportation is the ultimate fuel diversifier.

The CHAIRMAN. Thank you very much. Thank you all for your excellent testimony.

Why don't we do a 5-minute round of questions here?

Let me start with you Mr. Kjaer. You say in your testimony that the industry is working to finalize a single connector and connection standard. Could you indicate when that is going to be done?

Mr. KJAER. The connection standard is basically done now, Mr. Chairman. What we are starting to focus on now is the communications standard. That is what is going to be so critical. So J1772 I think it is—J1772 I think is the connection standard. That is basically done. But what we need work on now, between the utility industry and the auto industry, is how these vehicles are going to communicate with the grid and the grid communicate with the vehicle. That is a combination of work under the Society of Automotive Engineers, utilities like Edison which is leading the progress toward the communication standard, and then two core global alliances, Home Plug and ZigBee. ZigBee is a wireless communication protocol. Home Plug is a power line carrier. So what we have done is we have worked to bring these two global alliances together, and now work with the auto industry on a communication protocol for the vehicles.

The CHAIRMAN. Mr. Dalum, you talked about other applications for your technology, as you see it, that you are going to be exploring. What are some of those other applications that——

Mr. DALUM. There is a diversity of trucks that are operating in the United States obviously. So our company is going to be looking at what is called a gas crew truck, which is another nice application for this technology. Those are trucks are used by gas utilities to service the infrastructure of the gas lines themselves. Those trucks typically operate at a job site stationary. The engine idles all day to operate large pieces of equipment. Our technology will have enough power to operate that type of on-board truck-mounted equipment.

There are other applications like refuse trucks and obviously shuttle buses and things like that that are applicable for plug-in hybrid technology in my opinion.

The CHAIRMAN. Mr. Wimmer, as I understand your testimony, the vehicle you have out there for folks to see today is a nickel metal hydride battery and that is not what you would intend to bring to market as a plug-in electric vehicle. Is that right?

Mr. WIMMER. Correct. Our next vehicle generation vehicle, which we will introduce late next year, will use lithium-ion batteries that are being produced by our joint venture company with Panasonic EV.

The CHAIRMAN. That would be available for purchase by consumers when?

Mr. WIMMER. The plan is to introduce a fair number of these vehicles, in the hundreds, to commercial fleets both in Japan, United States, and Europe in the 2010 timeframe. Based on how those vehicles perform, we would then look very carefully at introducing a consumer version. But we need to confirm the battery durability and how the operators are using the vehicle before we move forward.

The CHAIRMAN. What distance range do you expect to have without use of the engine?

Mr. WIMMER. We have not said specifically on that vehicle the range of that vehicle. That information has not been released yet. But we have said publicly that a 15- to 20-mile range for a plug-in—electric range is a good target.

The CHAIRMAN. Mr. Balkman, let me ask you. Do you have any purchases by Federal agencies for your sport utility truck, any contracts to purchase?

Mr. BALKMAN. We are on the GSA list and we have actually had a lot of Federal agencies come and talk to us. I do not know that we are able to disclose those, but it is safe to say that there are quite a few Federal agencies that have expressed an interest and cannot wait to get their new Phoenix when we start production.

The CHAIRMAN. You are starting production early this next year.

Mr. BALKMAN. Yes.

The CHAIRMAN. How many do you expect to produce, say, in 2009/2010?

Mr. BALKMAN. We expect to produce 2,500 vehicles in 2009 and then ramp up to about 10,000 in 2010.

The CHAIRMAN. Are the components of that—are you doing assembly if they are in Wisconsin, or are you doing actually manufacture of most of——

Mr. BALKMAN. We have an assembly production facility in Ontario, California. The auto body actually comes over overseas as a body part. Then we assemble the electric motor and the battery pack in the vehicle. That is all done in Ontario, California.

The CHAIRMAN. The battery pack comes from where?

Mr. BALKMAN. Altairnano. That is a Reno, Nevada company.

The CHAIRMAN. Very good. Thank you again for the testimony, all of you.

Senator Domenici.

Senator DOMENICI. Thank you, Mr. Chairman. Thanks to all of you. A very interesting panel, and I think we will have enough time, Mr. Chairman, to go take a look, if that is what you would like to do.

Let me just ask any of you or all of you—how is the United States positioned in advanced battery technology? Do you want to start at your end, anybody that thinks they can contribute to the——

Mr. WYNNE. Good news and bad news, Senator. I think we have some excellent technologies coming available particularly in the lithium-ion area and some that actually leverage old lead-acid technology but with new nanomaterials, et cetera. There are a variety of technologies that are coming to market, I think as many as 23 or 24 different chemistries that leverage lithium-ion, which is not as energy-dense as gasoline, but it is a lot better than the batteries than we have been working with.

The challenge that we are going to have is the manufacturing because there is very limited manufacturing today with lithium-ion batteries, partly because it is relatively new. It has been proven technology in cell phones and laptops, but we need to get to automotive grade and we need to get the volumes in order to bring those battery prices down to levels where it is reducing the premium associated with these vehicles. That is going to be the big challenges: infrastructure, developing the infrastructure. A new battery plant could cost as much as $300 million of investment and that is what we are asking for Government support with, along with industry investment.

Senator DOMENICI. I do not want to use the whole time. I do not want to take a lot of time, but just give me your own views real quick, going on to you, Edward.

Mr. KJAER. Senator Domenici, I think one of the things that we need to be concerned about is are we swapping reliance on imported petroleum for reliance on imported batteries.

Senator DOMENICI. Yes, sir.

Mr. KJAER. So we definitely need to be focused on how to encourage domestic supplier and manufacturing base in the United States to, Mr. Wynne's point, automotive grade. That is five nines production quality. Every single cell in every single module in every single pack has to be of consistent quality. Otherwise, that pack will not perform in the harshest of environments imaginable being the automobile. So this is not a cell phone battery. It is not a laptop battery. It is a considerably different proposition. We do not have domestic capacity today.

Senator DOMENICI. Are you the right people? I will get right to you, Mr.—how do you say your name?

Mr. WIMMER. Wimmer.

Senator DOMENICI. Wimmer. You are at Toyota. Right?

Mr. WIMMER. Yes.

Senator DOMENICI. I could call you Mr. Toyota.

Mr. WIMMER. No, no.

Senator DOMENICI. If you know, tell me; if not, pass to the next person. I am very concerned about the very point you have made. This is happening in a couple of areas. We are moving to a new technology, but it looks like maybe somebody else will take over that technology and we move away from the use of crude oil to a new one. But we do not own the new technology.

Now, with appropriate partnership funding by the United States, can we make a good, competitive case for advanced technology and advanced batteries in the United States? Where would we get the estimate for how much that might cost?

We have been talking about putting up a lot of money, and we talk about advanced battery R&D and technology. We have to know how to do that. Are you the ones to tell us, or are there other experts to tell us how?

Mr. KJAER. Nobody here is a battery manufacturer. I mean, I would strongly recommend——

Senator DOMENICI. Is that where we should go?

Mr. KJAER. Absolutely. Johnson Controls-Saft, A123.

But I was just in China 2 weeks ago—China and Japan. The governments of China and Japan and Korea, for that matter, are very, very focused on this issue of energy storage technology, maturing energy storage technology, creating industry around energy storage. Sadly, we are not there yet, and so that is a big concern to us, that we are losing this race before we even launch the cars in the United States market.

Senator DOMENICI. Does anybody want to comment on my question? I am going to go ahead and yield back in a minute. I will just make an observation myself.

Mr. BALKMAN. I will just add as a domestic producer, we would like to buy domestic batteries. In fact, we are using Altairnano. They are a great R&D company. They do lack a manufacturing capacity. That is one of the concerns we have. But we want to buy American. Unfortunately, there are just not a lot of choices.

Mr. DALUM. I would just add that one of our primary concerns is the current cost of the technology. For us I would consider it prohibitive for many of our customers.

Senator DOMENICI. Might I ask, Senator Bingaman, do you remember where we are right now with reference to money for advanced batteries? Do we have it in an appropriation bill now? Does anybody know?

The CHAIRMAN. My impression is we have a significant amount in the defense appropriation bill, both current year and the upcoming year. We also have a smaller amount in the energy and water appropriation that you are responsible for. We have various proposals legislatively to try to integrate those two and have a national program that coordinates those because we are not spending near the amounts we should in this area. Of course, as we all know, we wind up authorizing a lot of stuff we do not appropriate.

Senator DOMENICI. That is right.

Mr. WYNNE. Senator, if I might. My testimony does get into this in some detail. I would like to thank the committee for your leadership, particularly in the EISA bill. There was a very significant authorization for battery technology R&D which we supported. All of the companies that have been mentioned here, A123, Johnson Controls-Saft, Electrovaya, et cetera are members of EDTA, and we have been pushing very hard for this. But we do need those authorizations appropriated. That is what we are working on today.

Senator DOMENICI. I do not think there is any Senator Bingaman is correct in his summary. We have a lot of authorization, but we have to put up the dollars and it has to be more than 1 year. We cannot put the dollars up for more, but we could have a program that indicates we are committed for 2 or 3 years at least with the battery companies.

I thank you, Mr. Chairman. I yield.

The CHAIRMAN. Senator Craig.

Senator CRAIG. Thank you very much, Mr. Chairman.

Gentlemen, your testimony is fascinating. I sense when you hear questions coming from Senator Domenici or Senator Bingaman, there really is an obligation on the part of your industries collectively to awaken us to the needs and to stay at it and stay at in a very focused way, whether it is through your associations collectively or individually.

I say that because we are making a variety of assumptions here that may or may not develop but could develop and develop much more rapidly if we were to not only incentivize, Thad, like you are suggesting and do more of it more aggressively, but also focus resource or create the incentives that allows resource to focus.

I am not sure you should rely as heavily on us for the dollars and cents as you should for allowing us to help you direct the traffic. We spin our tires here a great deal and it is not through electric power that we spin them. We tried to put a loan guarantee program together in the Department of Energy, and finally some of the industry just left. They did not need it anymore because they had to wait too long. Please do not wait on us.

But more importantly, I become very excited. I tell my children and grandchildren that there will be the day when they drive and they will only own an electric car. I suspect that will happen based on what you are telling us and what is going on in the industry, and the marketplace is adjusting for that.

Have there been any studies done—because we make these assumptions that there is this abundance of electricity sitting out there at night. We can all go plug into it. Have there been any studies done that would say there is an abundance, but it peaks out at about a certain volume of plug-in? Because we have an obligation also to create policy that keeps the grid growing, that keeps the supply of electricity going.

Mr. Wimmer, I know you ought to be proud of the Prius. It is a fine vehicle. At the same time—and yes, you did displace a lot of carbon, but the point has been made when you plug these cars into the grid, if you really want a green car, then the power has to be green. Sixty percent of it is not today, or somewhere in that vicinity, or more or less.

So would any of you respond to how many million cars can plug into the current electrical infrastructure we have before we max it without focus on the grid and the production and generation of electrical power in that respect? Has any of that kind of work been going on?

Mr. KJAER. Yes, it has, Senator Craig. The Department of Energy did a study about 12 months ago, I believe, and they looked at the United States grid and suggested there is enough excess capacity off peak in the United States grid to fuel about 73 percent of all of the light-duty cars and trucks on the road today.

Senator CRAIG. So we have got substantial capacity there.

Mr. KJAER. Somewhere in the neighborhood of about 160 million/170 million vehicles could connect to the grid tomorrow, and we would not have to build one new powerplant. This is a really important point.

The electrical grid is a national energy security asset. Of all of the alternative fuels that we are excited about in this country, ethanol, methanol, biodiesel, natural gas, hydrogen, electricity, there is only one that has a ubiquitous infrastructure today, and that is electricity. That infrastructure has a lot of excess capacity because we have a very peaking system.

The operative phrase, though, is going to be we have the capacity with control. So it is going to be important that we create the communication standards, the technology that, as these vehicles connect to the grid, the market design, the right incentives to encourage the right customer behavior so that they do soak up that excess capacity first before we start putting charging on peak.

Senator CRAIG. You also mentioned the ability of the automobile to communicate to the grid. Put some more to that for my own interests and knowledge. What are you talking about?

Mr. KJAER. This is kind of really an interesting notion. Today we consume electricity, and 30 days later we get a bill. We look at it, and we really do not understand what we did to cause the bill to be what it is. We have no concept of what electricity costs, and we have little concept of how to control those costs.

With advanced meters, we are going to have the ability for two-way communication. So now for the first time, we are going to send information and incentive programs and education through to the customer, and they are going to be able to look at this on their laptop or their PDA or their cell phone, and they are going to be able to understand cause and effect in much more real-time terms, not 30 days after they have consumed, but hour by hour.

Senator CRAIG. I assume that they will be able to go sit in their car, push a button on the screen. It will also show it? Cars are going to do that?

Mr. KJAER. What is amazing—it is called human interface technology. What is amazing is the computing power on board the vehicle and the ability with this communication standard and protocol that I am talking about to send data bursts to the car. So, for instance, with your key, you could go in, turn your electric car on or your plug-in hybrid car, and it could say, good morning, Mr. Craig.

Yesterday you consumed X kilowatt hours and it cost you $1. Your wife could go and do the same thing and she could get some different information. So this is all kind of added features and benefits and communication and education that the auto industry is working on in conjunction with the utility industry.

Senator CRAIG. So I am also making the assumption—and I think several of you talked about it. Thad, you had mentioned it—the ability to fast charge because out West, when you guys talk 20 and 40 miles and even 100 miles, I begin to say maybe at 100 you are beginning to talk interest. I want something that does 400 miles or I want something that does 300 miles. That is just a trip across a quarter of my State. So I need some capacity, folks, before you are really going to excite me. Commuting? Different story.

I want to fast charge but not at my meter. I want to fast charge down at the office, but I am not going to bill the office for my transportation or they are not going to bill me. Does my car send a message that it is charging somewhere else and that I should be billed because me, the car, is charging somewhere else other than at my own home meter? Are we doing that kind of capability?

Mr. KJAER. That is the kind of capability that is being engineered into this communication protocol. That is called roaming. Think of it as your cell phone. It is kind of a cell phone model. So as long as that car is connecting to a "smart grid," there will be the ability for that car to identify itself relative to you as the owner wherever that car travels. That is the goal.

Senator CRAIG. Yes, because if you can recharge me in a few minutes, I could stop and have a cup of coffee along the way and wait for a new power source to build up so I could go a little further.

Mr. KJAER. Those are other issues. That is kind of fast charging. I mean, I was talking about the communication and the billing. But fast charging is a whole other issue.

Senator CRAIG. I can see the routine pattern here of home to work to home, but when you want to get beyond that pattern, the concept of a smart—or roaming, that begins to make a lot of sense. You have got to do it.

Mr. KJAER. Yes. You have the battery electric car for urban commuting and then you have the plug-in hybrid for both urban commuting and highway travel.

Senator CRAIG. Thank you, gentlemen. Please, go ahead.

Mr. DALUM. Yes. I would just like to add that one of the considerations that you have when you have a very large battery system—we have a 35 kilowatt hour battery system—in order to charge that, you do need higher voltages. Not every customer has that type of capability where they are going to be charging these vehicles. So I just want to bring that to your attention. Especially for trucks, that is a factor that as you put larger batteries in there, you need higher voltages.

Senator CRAIG. So truck stops take on a whole new character.

Mr. DALUM. Potentially, or truck depots, you know, where they store their trucks that they require 220, 240, or even higher voltage.

Senator CRAIG. Thank you.

Mr. BALKMAN. If I could chime in, that is one of the reasons why one of our suggestions was that we expand the investment tax credit into these refueling stations so that we can help develop an infrastructure.

Senator CRAIG. Thank you.

The CHAIRMAN. Senator Murkowski.

Senator MURKOWSKI. Thank you, Mr. Chairman.

If you come up north to Alaska, at our public parking lots, at the school parking lots, you have got the plug-ins. Every car has a head bolt heater. You have got to keep warm. A little bit different but kind of the same in the sense of you are not charging from your home, but if you did not have it, you would be losing employee time by going outside and heating your car anyway. That is up north.

But I do want to ask a question about the technology and where we are right now. I think in your testimony, Mr. Wimmer, you indicated that Toyota is looking to the technology and where we are with those batteries that can withstand the colder temperatures. I think I had seen that you are looking at perfecting the fuel cell vehicle that can start and run in cold climates down to 30 below. Where are you with that technology? What is the situation right now with the plug-ins that we have now? Do we see a loss in storage capacity and performance at colder temperatures, and where are we in understanding the performance?

Mr. WIMMER. I think the industry is beginning to understand the performance degradation that particularly lithium-ion batteries have at cold temperatures. Now, based on the chemistry, some perform better than others at very low temperatures, but there is—at least our experience, most lithium-ion chemistries will have a reduction in performance at sub-zero temperatures. But because these are plug-in hybrids, if they are charging, you could program the vehicle to preheat or precool so the cabin temperature is comfortable when you choose to leave. That will also help prewarm the battery to allow you to have greater all-electric range in very cold temperatures.

Senator MURKOWSKI. Is it going to affect your range then? I mean, if you've got a vehicle that can theoretically go 100 miles in colder temperatures, would you only be able to do 75? I am trying to understand——

Mr. WIMMER. For a pure electric vehicle, for a pure battery vehicle, yes, that would affect your range, but with the plug-in concept, the engine starts and the vehicle operates normally as a standard hybrid vehicle.

Senator MURKOWSKI. So you are working on developing that.

Mr. WIMMER. Yes. That is the plug-in technology that we are developing. We are also reexamining battery electric technology.

Senator MURKOWSKI. Let me ask a question—I don't know—maybe to you, Mr. Balkman, or any of you can join in. You have suggested or you have encouraged us as policymakers to move forward with the tax credit for individuals so that they can purchase the vehicles, whether it is a $7,500 offset toward the purchase. Is that where we should be putting the Federal dollars, to help the consumer there, or should we perhaps be putting those incentives to help with the technology to develop the battery so that we can get the cost down? I suppose you are going to throw that back at me and say, well, that is for the policymakers to decide.

But right now, people are kind of looking at what is going on out here. They get excited when they see nice flyers like this and think about the technology, but then they hear that, well, it is going to cost me $47,000. Maybe I wait. Maybe I hold off and do not make this purchase. So we are kind of a little bit of a limbo.

Where should we be putting the incentives? Do we want to incent people to buy now and that encourages you to do more, or should we be putting more into that R&D, more into the credits for the manufacturers so we can get the prices down to the consumers? What end do we——

Mr. BALKMAN. I will take a stab at that. You know, I think the tax credits are a big help because there is clearly a market for these. We have done very little by way of sales and marketing. We have a waiting list of some 6,000 people who said, hey, I want one.

You kind of have to look at the electric vehicles and the battery technology as the same place where laptops were 10 years ago. Laptops were a lot more expensive. The batteries did not last as long. They had issues with overheating. We have come a long way in addressing those. There is still a long way to go in perfecting the art of the batteries for vehicles. But I think the best way you are going to get people to be early adopters and to broaden the deployment of these vehicles is put the cost down.

We are not talking large scales. I told you our numbers. Next year—or 2010, we expect to have 10,000 vehicles. That will be great for us. That is not a lot of cars in the grand scheme of things. Primarily those cars will be on the west coast in California. So that is still a small scale. Let that experiment work, and I think as more people start driving and increase demand, things will follow.

But the best answer is we want both. We would like to have tax credits and more research and development in the battery because it is all part of the same picture.

Senator MURKOWSKI. Mr. Dalum.

Mr. DALUM. Yes. I would like to comment on the heavy truck side. In my opinion, I agree we need both. Research assistance would be very helpful and also tax credits.

On the research side, there is in the House the Heavy-Duty Hybrid Vehicle Act. Much work has been already done. That provides competitively awarded grants. The proposal would be for competitively awarded grants for the development of medium-and heavy-duty hybrids. It would be open to also plug-in hybrids. So that is one that is underway that I think has a lot of promise.

Then on the tax credit side, some of the legislation that I have seen has not specifically addressed medium-and heavy-duty trucks, and I would encourage to look at larger battery systems and the overall gross vehicle weight of the vehicle and offer incentives that address some of these unique characteristics of a medium-duty truck, a larger battery system and heavier weight.

Mr. WYNNE. Senator, if I might, I would just put a broader context around it, that we are competing with a very mature technology, the internal combustion engine, a very well entrenched fuel system. It is difficult to pick and choose. We really have barriers here to market entry that tax credits will help us address. We have

R&D challenges that will help us move that technology down the road and get it more competitive. Ultimately deployment helps us with greater scale that helps with all of these things. So it is difficult for us to pick and choose.

I think to Senator Craig's point before, the industry, as you can see, is moving down the road. The question is how many of these things can we work with Government on to accelerate that progress.

Senator MURKOWSKI. Thank you.

Mr. WIMMER. Senator, Toyota generally supports consumer-based tax incentives as a way to increase volumes and to maximize the affordability of the technology to the largest number of consumers. Our hybrid program, for example. We have been selling hybrids for over a decade now, and due to the high volumes, we are still improving the technology, bringing costs down. So from our standpoint, it is really high-volume production that helps bring the cost down to be competitive with gasoline.

The CHAIRMAN. Senator Sessions.

Senator SESSIONS. Thank you.

Senator DOMENICI. Senator Sessions.

Senator SESSIONS. Yes.

Senator DOMENICI. Would you yield for 1 second?

Senator SESSIONS. I would be glad to.

Senator DOMENICI. I have to leave now, and I was just telling the Senator I would be leaving. But I did want to make a statement for the record.

On funding for battery research, what we can find out so far is that there is $100 million in the energy and water appropriation bill that is a $50 million increase over what was in the executive branch bill. That is to go for battery research. That might not be enough, but I just want to report that that is what is in there. That bill is waiting consideration and match-up with the House and see what they have done.

As I leave, I am going to try to go see your vehicles and meet some of you out there. I want to thank you again.

Thank you, Senator Bingaman. You are probably in the most exciting part of trying to help with the oil problem. We have rocked along for so many years, but it looks to me like you are on the threshold here. This is going to be something for real. How quickly you can go I do not know, but I wish you wonderful luck next year.

Thank you.

The CHAIRMAN. Senator Sessions.

Senator SESSIONS. Thank you.

This is, indeed, exciting. As I have had my town hall meetings and heard the pain really of consumers in Alabama with high energy prices, we think about the negative impact it has had on our economy, our balance of trade deficit. Half of that is fuel. We need to do better.

I have been saying that I consider the thing that is most close to success to become practical that could virtually eliminate a huge portion of our demand for fuel would be plug-in hybrids.

But the question is this. Maybe, Mr. Dalum, I will just ask you. We could pass a law that says we are going to incentivize hydrogen or incentivize eliminating the law of gravity, and we might not be able to get there yet. I was at the University of Alabama Transportation Center, and one professor told me that on conventional battery technology, there was not—his best judgment was—a lot of increase possible. It was going to take a breakthrough technology.

How would you as a consumer—I guess you are a little bit of a skeptic here. Give us your view of how much—are the lithium-ion batteries today—you use them in your vehicles, which are utility vehicles, I guess, mostly. What is your best judgment about whether we are ready for prime time with the lithium-ion and how much improvement is necessary?

Mr. Wimmer, maybe I will ask you to comment also.

Mr. DALUM. Let me first state that there is a variety of different battery technologies available. Lithium-ion is one of the most promising. From our company's standpoint, as I previously stated, lithium-ion is an extremely expensive technology, and that is probably one of the primary limitations that we have right now.

Our company has chosen, in order to accelerate production, to go with a different, more conventional technology. Because of the large truck you can carry much larger payloads, so we have gone with the more conventional advanced lead-acid battery, an AGM lead-acid battery, that is modular, that can be exchanged because it does have a limited life. So we have chosen to go a different direction until, in our view, lithium-ion is ready.

So I think there is a variety of different approaches. It just depends on, quite frankly, what kind of constraints you put on your design.

Senator SESSIONS. Mr. Wimmer, in your view, is the battery technology available today that would make a plug-in hybrid practical and feasible, and if not, what kind of improvements in the battery would be necessary and how much, what kind of percentage increase?

Mr. WIMMER. I think the lithium-ion battery technologies that are out there today, although they are expensive and durability has yet to be proven, they have the potential to satisfy the requirement of a light-duty plug-in electric vehicle. But longer term, if we are looking at true battery EVs that can compete with gasoline vehicles for range and durability, that is really going to take a battery breakthrough, new technology.

Toyota feels strongly about that and has actually created a research division now to study these next generation batteries just to try and find the breakthrough that will get us to a battery that is low cost and durable enough to compete with a conventional gasoline vehicle.

Senator SESSIONS. So you were saying it is not quite there yet?

Mr. WIMMER. We are working hard on it, and hopefully will determine in, as I mentioned, our commercial fleet test program whether our battery will be durable enough.

Senator SESSIONS. Now, the plug-in hybrid, as I understand it—if your commute is, say, less than 20 miles and the goal would be to be able to go 40 miles, about there, without any utilization of a liquid fuel and after that, there would be an engine that would carry you an indefinite distance. Is that what we are talking about?

Mr. WIMMER. It depends on the system design. Our approach, which is a blended design, will provide vehicle speeds up to approximately 60 miles an hour just off the battery. If you wanted to go faster than that, the engine would start and supplement the battery. If you are running in, let us say, a lower speed, urban type of mode, that range could be in—we feel it should be in the 15 to 20 mile range before the engine would start and the vehicle would operate as a conventional hybrid vehicle.

Senator SESSIONS. So you would have an unlimited range ultimately——

Mr. WIMMER. Correct.

Senator SESSIONS [continuing]. With the plug-in hybrids.

But what about cost? Would we have a shortage of the components that would go into a battery if we made large numbers of them?

Mr. WIMMER. There have been some studies that have questioned the supply of lithium if we were to double the quantities of lithium that is currently being used today for the consumer electronic market, if we were to double it with battery vehicles. I have not looked at a number of studies to draw a conclusion myself. But lithium is currently only produced in a number of Latin American countries, only a couple of sites in the entire world. So there are some limitations there on lithium.

Senator SESSIONS. Mr. Kjaer or Mr. Wynne, one question. Would you agree? Both of you, I think, would see the advantage to move forward with electric or hybrid vehicles. Should we be looking at things other than the lithium-ion battery? Do we have enough funding and research going on in other kinds of battery technology that could be this breakthrough technology that would be a leap ahead of traditional battery systems?

Mr. WYNNE. I think there are other types of battery technologies that are being explored. There is no question that—again, lithium is not as energy dense as gasoline. So at the end of the day, if you are going to compare them one on one, that is the benchmark.

My perspective on this is we must not let the best be the enemy of the good, and the beauty of electric drive—forgive for being one of its greatest fans—is it is so flexible, and it can be configured many, many different ways. There are lots of different vehicles and drive cycles in the fleet today.

So I think what you are seeing here is as many different approaches as I have mentioned manufacturers to electric drive aiming perhaps even at different areas of the market and different demographics. So the plug-in hybrid or even the battery EV with a range extender is sort of an effort to leverage the technology that exists today, including improving lithium-ion battery energy storage technologies, but certainly there is room for improvement going forward and that is being explored.

Senator SESSIONS. Mr. Kjaer.

The CHAIRMAN. Senator Sessions, let me just indicate I am going to have to leave. Why don't you go ahead and ask any remaining questions and then conclude the hearing?

Senator SESSIONS. I would be pleased to.

The CHAIRMAN. Great. Thank you all very much for being here. We appreciate it very much.

Mr. KJAER. Senator Sessions, we have lithium-ion batteries from a number of major battery companies in our labs now bench testing. The longest test we have had running is over 3 years for plug-in hybrid modules, battery modules. We are seeing good cycle life that would be commensurate with the life of the vehicle. We do not know yet about calendar life. But I think the technology is maturing quite rapidly.

The automakers that are the most aggressive about plug-in technology feel that the vehicles will definitely be ready somewhere between that 2010–2012 time period. Some of them are saying that they feel that the batteries will absolutely be ready as well.

The Japanese Government and I think the Chinese Government are very focused on not just maturing lithium technology, but to your point, what is the next whiz-bang technology after lithium technology. The Japanese Government is very, very focused on that area and have set targets to get to over the next, I think, 10 or 15 years. We should be also concerned about that and be thinking about what are we doing here in the United States We absolutely have the capability of doing it. This is not a question of can we do it. It is a question of will we do it.

I think it comes back again to that fundamental point that I made earlier on, and that is that we need a much more robust focus domestically on energy storage technology because it will be a fundamental game changer not just to the transportation industry, but also to the utility industry.

Senator SESSIONS [presiding]. So you would say that it is possible to make a quantum leap, a major step forward, but it would take a new technology probably and we should be investing in that?

Mr. KJAER. I think we absolutely should be investing in the lithium technology today because that will help to get these cars out on the road that will start to create new applications in the energy system around energy storage. But we should not take our eye off the ball about what is the next step 10, 15, 20 years from now.

Senator SESSIONS. The implication is in your testimony we are not doing enough of that in the United States. Is that a function of governmental incentives, and should we have more? Briefly. I do not want to take too long.

Mr. KJAER. I do not think it is just incentives. I do not think we can lay all of the blame just on incentives or lack of incentives. I think we need to get focused as a Nation around the issue of energy storage and what that can mean to us from an energy security perspective and from an energy efficiency perspective.

Senator SESSIONS. Mr. Wimmer, I saw something that Toyota's Camry had the quickest payback of any battery car. I do not know if you want to comment on that.

But how do you feel about this question of should the United States be doing more? Surely we should pursue the lithium-ion or any traditional type batteries, but should we be looking for more of a breakthrough technology?

Mr. WIMMER. I think when we are talking about battery breakthrough technology, it is a global challenge. Scientists have been working on batteries for centuries. I mean, it is hundreds of years of development. So with that type of challenge, it is going to take all the nations and all the scientists to jump beyond where we are today with the next generation of batteries.

So I think DOE's basic energy sciences activities is working on battery materials. A number of the national labs are working on these advanced materials. I think all of that is going to be very useful in finding the material breakthroughs, as well as the basic electrochemistry breakthroughs that are going to be necessary.

Senator SESSIONS. But just throwing money at that does not mean we are going to solve the problem next year.

Any other comments on that particular question? Mr. Balkman?

Mr. BALKMAN. Yes, Senator Sessions. I just want to point out that I testified earlier that we will begin production in 2009. Another pure electric company out in California, Tesla, is actually delivering electric cars that are on the roads today. We are beginning this now. It is not perfected, but it is here.

I would add—and I do not know the specifics of all the battery technology, but I can tell you this, that if the Congress and if our Federal Government will put as much effort behind this technology, specifically battery technology, to drive electric transport, as we have in other alternative energy sources, just level the playing field and pay as much attention to this as we have other things, I think we will see a lot more progress a lot quicker, and we will be a lot closer to electrifying our fleet not just in years from now, but maybe as soon as next year and a lot closer, a quicker.

Senator SESSIONS. I offered legislation that would require the Department of Energy to evaluate all our incentives and make some recommendations as to which ones they think have the best prospect. I have not heard from them. But I really think it is difficult for us as nontechnicians, nonscientists, to be sure exactly where we should put the research dollars.

Mr. Wimmer, one thing I would ask you is I believe you made reference to nuclear power. It seems to me, without any doubt, that nuclear power emits no greenhouse gases or other pollutants into the atmosphere and has virtually unlimited capacity to expand and comes out cost effective. I am convinced that it is at least as cheap as coal will be. So would that not be a wonderful future in which we have a nonpolluting nuclear electric generation with battery automobiles that could run on that clean power?

Mr. WIMMER. I think clean power is key, or cleaner power. Whether that is from nuclear or renewables, it really depends on the flexibility of the power grid and what makes the most sense from an economic standpoint, as well as potentially from a regulatory standpoint. But clearly, as the grid becomes greener, the amount of $CO_2$ produced generating electricity and therefore driving these advanced electric vehicles will come down and they will become more environmentally friendly.

Another concern is, with this pending climate change legislation, how the credits for electric vehicles would be handled. Would that be given to the utilities, or would that be given to the auto manufacturers? I think that is something that we need to work out here as we move forward. Or to the customer?

Senator SESSIONS. That is an honest—you are correct.

Any more brief comments on the nuclear question?

[No response.]

Senator SESSIONS. Thank you very much.

Chairman Bingaman does such a good job of having hearings on important issues. I really compliment him on that. He is seeking the truth, and that is what we have been trying to do today.

I am so excited about the possibility of plug-in hybrid technology and would hope that we can see that develop and become a big part of what we do. But I know it is maybe not perfectly ready today to do everything we would like, but maybe we can make those breakthroughs and continue to do so. That will be a very feasible future for us.

Thank you so much and I appreciate your excellent testimony.

[Whereupon, at 11:28 a.m., the hearing was adjourned.]

# APPENDIX

## Responses to Additional Questions

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Responses of Edward Kjaer to Questions From Senator Bingaman

*Question 1.* It's notable that many of the nearer term entrants we are likely to see are "city cars" or other shorter range vehicles. One might imagine that cities where these would be the most useful would also likely be places where housing is dense a substantially smaller part of the population have garages to plug in vehicles at night. Is this true, and if so are there programs to address this?

Answer. Various studies suggest between 30—60% of the U.S. households have access to a plug for "home refueling."

The issue of providing metered charging facilities in high-density housing (apartments, condos, etc) situations is one of the important actions required of plug-in vehicle (PEV) infrastructure development. A few startup companies, several cities (San Jose and San Francisco, CA), and some utilities are beginning to address how to deal with this aspect of vehicle charging infrastructure. In general, much more work needs to be done in this area to understand planning, placement, and costs to install and operate this kind of charging infrastructure. Adoption rates for PEVs will likely be modest in the early years as a result of technology cost and product availability/choice. It is anticipated that early adopters will have access to home refueling plugs.

In the mid-to-long term, understanding how to support all types of charging infrastructure (residential, workplace, fleet and public charging) is critical to effectively supporting mass market adoption of electric vehicles (EVs) and plug-in hybrids (PHEVs). Planning, combined with a strategically timed rollout of infrastructure to support developing populations of plug-in vehicles is likely to result in the most effective use of available public and private capital resulting in higher vehicle owner satisfaction.

There is substantial risk in broad pre-deployment of public charging facilities without the vehicle population to adequately use these facilities. This will tie up near-term capital that could be better applied to support home-based charging infrastructure (this will better serve most early adopters) and creates a strong possibility of poor station location or negative public perceptions of plug-in technology (unused, reserved parking locations resulted in poor public perceptions of electric vehicles in the 1990s in CA).

*Question 2.* In your testimony you discuss your efforts in developing 'smart charging' where vehicle charging is controlled remotely in order to best match generation availability. Where are you in respect to developing Vehicle-to-Grid (V2G) technology where a plug-in can take energy from the grid AND put it back on the grid?

Answer. While the potential of V2G is intriguing, we are many years away from realizing a scalable model across the U.S. Most challenging is how to control a complex and diverse system of vehicles sending energy back to the grid.

However SCE is exploring with several automakers the potential of Vehicle-to-Home (V2H). In this scenario small amounts of energy may be drawn occasionally from the vehicle's battery (without impacting battery life) for residential "peak shaving" or "emergency backup". However, the energy would not be sent back to the grid, but only back to the home.

We believe it is a matter of prioritization. We believe that there is much work to be done on "grid-to-vehicle." In others, we need to focus on getting the vehicle to be successful, before focusing on long-term value propositions.

*Question 3.* What are the main challenges, both for technology and policy that you see in developing V2G?

Answer. Like any other RD&D project, V2G will have to go through all the phases of development from proof-of-concept to large-scale demonstrations. The complexity of managing energy from millions of vehicles will have to be addressed. Automakers will need to be brought into the process, as the V2G capable vehicles will need large kW discharge capability, battery warranties, and other issues to be addressed. If this technology is proven, then policies at FERC and other agencies will need to be revamped.

RESPONSES OF EDWARD KJAER TO QUESTIONS FROM SENATOR DOMENICI

*Question 4.* In your testimony you said that you do not see a large system-wide challenge fueling plug-in electric vehicles. Can you explain that in more detail? For example, if we saw a significant increase in the number of electric vehicles, say 50% of the light duty vehicle fleet, what would that represent in terms of increased energy demand with all other things being equal and how does that translate into the number of new power plants required?

Answer. A joint study by Electric Power Research Institute (EPRI) and the Natural Resources Defense Council (NRDC) studied the environmental and energy impacts of large fleet penetrations of PHEVs. The range of electrical energy demand possible by converting the light-duty transportation fleet to PHEVs or EVs is relatively modest in the context of the full electric sector—if 10 million plug-in vehicles with 40 miles of electric range (similar to the Chevy Volt) materialized on today's grid they would represent less that 0.5% of total U.S. electrical demand.

EPRI and NRDC also found that large market penetrations of plug-in hybrids (as much as 80%) would create at most a small need for additional capacity, between 1.2% and 4.6%. This equates to 19-72 GW in total new capacity added over a forty-year period (an average nationwide annual increase of 475 to 1800 MW from 2010 to 2050).

The above number is based on a very conservative scenario where 25% of the charging occurs on-peak. However, defective implementation of smart charging technologies and customer programs to incentivize off-peak charging will have the potential to minimize the need for new power plants while improving generation plant utilization. Off-peak charging is defined primarily as minimizing charging load during the weekday peak hours in the summer months or winter for cold-weather utilities. This is synergistic with providing vehicle owners with the lowest possible cost of electricity while maintaining convenience of charging. Other studies by the Department of Energy's Oak Ridge National Lab and Pacific Northwest National Lab found that the on-peak demand for new power plants could almost entirely be mitigated with utility involvement.

*Question 5.* With regard to the efforts now underway to standardize technology needed for the vehicle to grid interface and for "smart grid" technologies, do you believe these efforts are sufficient to establish robust industry standards by the time we see significant market penetration by plug-in vehicles? In other words, what is the risk of consumers being stranded with obsolete technology like the Betamax tape systems of the late 1970s?

Answer. Representatives of the electric utilities have been working closely with the automotive industry on creating the necessary "recommended practices" that would guide all automakers in designing PHEVs and EVs that are compatible with smart charging infrastructure. There are two important recommended practices, one defining the physical connection between vehicles and the grid (SAE J1772) and one defining the way vehicles communicate with smart metering and other smart grid systems (SAE J2836). Both of these standards efforts are scheduled to be completed in over the next several years. Once completed and approved by standards committees representatives (comprised of automaker, supplier, utility, and government reps), automakers would follow these practices in the design of their production plug-in vehicles.

Electric utilities and EPRI are also conducting intensive technology development efforts with automotive partners (Ford, GM, and others) to ensure a rapid maturation of the technology and verification of the sufficiency of these standards to ensure that the many different smart grid approaches are easily compatible with the single automotive standard for smart charging.

From a policy perspective, we support open-source standards, and are concerned that a proprietary charging system may occur for 120 or 240 V charging. We believe policy is needed to discourage development of proprietary charger connection or communication standards, or proprietary technology that limits free access.

*Question 6.* Please describe your company's history of using electric drive vehicles.

Answer. Southern California Edison (SCE) has a long history of using electric drive vehicles. Since the 1970s, SCE has actively researched and implemented electric vehicles in its operations. It began with early prototypes from auto manufacturers, to pre-production prototype evaluation in partnership with major OEMs, to refined fully-functional electric vehicles in fleet revenue service. Since 1998, SCE has maintained a fleet of EVs of greater than 200 in number, which reached a peak of 320 in 1999, and currently numbers 293. Today, SCE operates the largest private fleet of EVs in the country that has traveled over 16.7 million EV miles in real world day-to-day fleet operations with company meter readers and field service personnel, and saved over 830,000 gallons of gasoline.

*Question 7.* How many PHEVs do you currently have in your fleet?

Answer. SCE currently has 4 PHEV prototypes in its evaluation and testing fleet. This includes: 2 Ford Escape PHEVs, 1 Sprinter PHEV van, and 1 International heavy-duty PHEV utility truck. Today there are no commercially available PHEV vehicles from Tier 1 manufacturers.

*Question 8.* What has been the feedback from employees who are driving the vehicles?

Answer. SCE's EVs in our meter reader services division perform flawlessly and are well liked by employees. Their feedback includes favorable reactions from customers and the general public; access to carpool lanes greatly reducing "windshield time" and quite, clean reliable operation without having to go to a gas station.

The Ford PHEV prototypes have consistently returned favorable reviews. SCE staff report that the vehicles are just as comfortable and smooth riding as conventional versions, with the smooth power transitions between electric and hybrid drive. Charge time is easily accommodated overnight with 120 volt power.

The Daimler Sprinter prototype van has been useful for fixed route delivery type applications, such as hauling medium loads in an efficient package. The electric drive function of the Sprinter PHEV has been reported to be very powerful and capable of full driving functionality in excess of 50 mph.

The International PHEV truck prototype was the first of its kind, built by SCE in 2001, and demonstrated in the SCE fleet in 2004. It was able to do all the work of a "troubleman" truck with the added benefit of reduced exposure to harmful noise and emissions.

*Question 9.* Are you tracking the PHEV miles per gallon? If so, what kind of values are you seeing?

Answer. Several Ford PHEVs have been tested in multiple configurations at SCE's EV Technical Center located in Pomona, CA. They have also been baselined against the stock Ford Escape HEV version. Currently two PHEVs are in reliability test and mileage accumulation.

With regard to fuel efficiency, we are evaluating the vehicles under accepted procedures based on industry and government developed standards. So we are indeed tracking miles per gallon, but it is probably more appropriate with this technology to use different terms to describe fuel economy. With the broadening of technology which we are currently experiencing in the transportation field, comes a need for new metrics to understand energy use. With these vehicles we are actually replacing one fuel for another—electrical energy in place of gasoline—and that can lead to confusion. PHEVs also do not have constant fuel economy; rather, the fuel economy is related to the distance driven. As the electrical energy is used first to maximize the benefit, the fuel economy is much higher for shorter drives than longer drives. Vehicle usage data for the U.S. showed that 68% of all residents drive 30 miles or less per day to go to work and back.

If we were to use the traditional metric of miles per gallon for fuel efficiency with a PHEV like the Chevrolet Volt, and apply that to the 68% of commuters with a round-trip drive of 30 miles or less, the Volt, with a stated 40 mile range on its battery, would in fact have infinite "mpg." Pure electric vehicles have previously been rated with window stickers showing miles per unit AC kWh. Groups like the Society of Automotive Engineers have required conversion of electrical energy to liquid fuel equivalence, which is then added to the volume of liquid fuel used.

SCE's results for a 30-mile drive of the 1st Ford Escape prototype PHEV on the urban test course show a 57% reduction in gasoline used over a stock hybrid Escape without PHEV capability. The amount of gasoline used by the prototype PHEV Ford Escape for the 30-mile test loop was less than one-third of one gallon, with the balance of the drive energy coming in the form of electrical energy from the grid. The gasoline savings on a national basis if such vehicles were in use for those 68% of commuters can thus be easily estimated, given the total number of commuters.

These are the actual results from both test vehicles for the 30-mile urban test loop (30.6 miles actual distance):

HEV: 0.68 gallons gasoline
PHEV: 0.29 gallons gasoline and 6.0 AC kWh 10.

*Question 10.* What kind of charging system are you using to recharge the PHEVs?

Answer. Due to the size of their batteries, most PHEVs utilize an on-board charger. Using appropriate safety equipment (e.g. GFCI), the on-board charger is connected to the power grid. Depending on the vehicle requirements and design features, power is then transferred from the utility grid at either 120 volts or 240 volts.

*Question 11.* What kinds of corporate applications are you using the PHEVs for? Meter reading? Distribution work? Company outreach efforts?

Answer. SCE's PHEV prototypes are in vehicle testing applications only and are not integrated in to our working fleet. As PHEV products become commercially available SCE will integrate them in to our fleet operations where appropriate.

*Question 12.* What is the current status of Lithium Ion batteries for hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEVs), and electric vehicles (EVs)?

Answer. Lithium Ion batteries include more than a dozen different electro-chemistries. The performance, safety and cost vary widely. Small form factor (cylindrical cell vs prismatic cell) Lithium-Ion batteries are commonly used in consumer products. Large battery packs require massive paralleling of small form factor battery cells or the use of larger form factor batteries. Several battery manufacturers are currently producing large lithium cells suitable for automotive applications, and use various electrochemistries and form factors. Laboratory testing of those cells have shown encouraging results. In general, Lithium Ion "power" batteries (gasoline hybrids) are just coming to market now in limited volumes/applications. Next year we will start to see Lithium Ion "energy" batteries in low volume launches of BEVs and possibly PHEV demonstrations. In both cases however, the technology is still in very early stages of maturity.

*Question 13.* What are the major technical/market barriers for commercialization of lithiumion batteries?

Answer. Recently, lithium Ion batteries have made significant progress, although manufacturers are still working on improving overall battery safety, cycle life (the ability of the battery to maintain performance after multiple charge and discharge cycles) and calendar life (the ability of the battery to sustain performance over the life of the vehicle).

One of the main barriers remaining is cost. At current low production volumes, the cost remains high. At higher production levels (several hundred-thousand battery packs a year), the cost is expected to drop significantly. From a policy perspective, establishing large-scale volume to get to mass production (secure lower costs due to economies of scale) is the key issue for policymakers to help address. While the costs are higher today, the historical introduction of new technology into the auto industry (e.g. automatic transmissions) has been overcome as the value has been understood by the consumer.

*Question 14.* Plug-in vehicles hold great promise in our ongoing efforts to lessen our dependence on foreign sources of oil. However, U.S. transmission infrastructure has increased by only 6.8% since 1996. In last year's energy bill, Congress encouraged the modernization of the electricity grid in "Smart Grid" provisions that include the deployment and integration of plug-in electric and hybrid electric vehicles. What kind of infrastructure improvements must we undertake to accommodate the eventual use of plug-in vehicles?

Answer. SCE strongly believes that research is needed covering the intersections of vehicle connection and communication, load management and smart charging, bi-directional energy flow, smart meters and smart grid. A smart grid will greatly enhance the deployment of PEVs, but is not a prerequisite for the large-scale deployment of PEVs.

Given the anticipated slow adoption rates, we do not anticipate any near term transmission system challenges meeting the load from transportation grid connecting. However we do anticipate some local distribution system challenges with early adopter concentrations of PEVs. These challenges will be addressed at the local utility level, and are similar to other challenges that utilities have been addressing for years. The impact of full function pure battery EVs on the distribution system is greater than the impact of PHEVs. This is because full size, full function battery EVs use 6.6 kW charging systems (or larger) which is much larger than the typical 1.4 kW charging system used by PHEVs.

Also see answers to questions 4 and 5 for answers on the impact on utility generation systems and other infrastructure.

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RESPONSES OF BRIAN P. WYNNE TO QUESTIONS FROM SENATOR BINGAMAN

*Question 1.* You mentioned that tax incentives should reward performance rather than picking winners and losers. Others might argue that basing the incentive on the size of the battery is biasing policy towards a particular technology. Is there a more neutral approach such as one linked to fuel consumption that would be equally effective for electric vehicles and competing technologies?

Answer. If the goal is to reward only efficiency, than a completely neutral incentive with an efficiency-only metric could be developed. However, if a credit were to have multiple goals, such as rewarding efficiency and advancing technology development, or promoting fuel diversity, then additional metrics are useful.

In the current tax code, consumer credits are available for alternative fuel vehicles, hybrids, advanced diesel and fuel cell vehicles. Each has specific metrics to ensure that diverse technologies meet emissions and efficiency goals of the credits.

Based on the current tax policies for advanced vehicles, a battery metric measures emissions and oil displacement performance and targets the highest cost element in emerging plug-in vehicle technology.

*Question 2.* It's notable that many of the nearer term entrants we are likely to see are "city cars" or other short range vehicles. One might imagine that cities where these would be the most useful would also be likely to be places where housing is dense [and] a substantially smaller part of the population have garages to plug in vehicles at night. Is this true and if so are there programs to address this?

Answer. First to clarify, "city car" sometimes is used as a technical term for a mid-speed vehicle (as opposed to a low or full speed battery electric vehicle.) In this instance, assuming that the term is used here meaning "for urban use," the answer is that a large segment of the early adopters of plug-in vehicle technology, be it battery electrics or plug-in hybrids is likely to be urban consumers using the vehicle for commuting and other shorter range travel.

Plug-in hybrids and extended range battery electrics offer additional fuel, or recharging power, on board. Pure battery electrics do not. All will need their batteries recharged at some point. The difference is how often.

Whether plug-in vehicles have a short or long range on a charge, new charging models need to be identified to serve consumers that do not have a private garage charging option.

Options being privately demonstrated include daytime public recharging; with a fast charge option; multi-tenant garage recharging. Other models, such as the Better Place demonstrations are promoting a recharging model that would allow customers to swap out batteries at ubiquitous stations rather than recharging them.

Different users, such consumers and commercial fleets, are likely to require different recharging approaches. Efforts to promote non-private charging should allow for this diversity while moving toward equipment and recharging standards to maximize interoperability and safety.

The Department of Energy, through programs like the Clean Cities program, can help to fund cooperative vehicle and fueling demonstrations, but is constrained by limited funding. Additional demonstrations authorized in Section 131 of the Energy Independence and Security Act (EISA) of 2007 offer validation paths for recharging models as well, but they have not yet been funded.

RESPONSES OF BRIAN P. WYNNE TO QUESTIONS FROM SENATOR DOMENICI

*Question 3.* In your written testimony, you note that there some tax provision being offered that would actually limit plug-in technology development and vehicle options. Please elaborate.

Answer. During the extended debate on energy tax legislation, several versions of a tax credit for plug-in vehicles were at some point considered. There were several bills that would have established a credit only for "plug-in hybrid vehicles," excluding battery electric vehicles that plug-in, but are not hybrids.

Later in the debate, a proposal to lift the threshold eligibility requirement from a 4 kWh battery to 8kWh. The latter threshold would have excluded many of the smaller-battery plug-in hybrid models that have been proposed, such as the including the proposed Prius plug-in.

In addition, the higher threshold would also have penalized plug-in vehicles vehicles that operate in a blended fashion, i.e., the battery and conventional engine can work simultaneously, rather than serially. These can be extremely efficient using a smaller battery.

With this emerging technology, we support the inclusive incentive that was adopted, which allows the market to determine a preference in plug-in options, including blended operation plug-in hybrids, pure battery electric vehicles, extended range battery electrics like the Volt or plug-in hybrids that would operate serially, like the proposed Saturn Vue.

*Question 4.* Please describe the differences between EVs, HEVs, and PHEVs. Which technology is most widely used in the U.S.?

Answer. Each of these, as well as fuel cell electric vehicles (FCEVs) are electric drive vehicles, meaning electricity provides some, or all, of a vehicle's motive power—i.e., electricity moves the wheels.

Battery Electric Vehicles (BEVs) are plug-in electric drive vehicles. (Not all plug-in's are hybrids.) They use batteries to power an electric motor to propel the vehicle. BEVs produce no tailpipe emissions. The batteries are recharged from the grid and from regenerative braking. Full function EVs are being produced by Tesla and are planned by other manufacturers, including Nissan, Mitsubishi, Chrysler and BMW. Battery electric vehicles in widespread use today include low-speed, neighborhood electric vehicles, airport ground support equipment, and off-road industrial equipment such as fork lifts.

An extended-range battery electric vehicle (BEV-ER) is variation on the BEV configuration. It includes an internal combustion engine or fuel cell, but that power source is only used to recharge the battery; it does not move the wheels.

Hybrid Electric Vehicles (HEVs) use both an electric motor and another energy source such as internal combustion engine (or compression—diesels can be hybridized as well) to propel the vehicle. A hybrid is designed to capture energy that is normally lost through braking and coasting to recharge the batteries (regenerative braking), which in turn powers the electric motor—without the need for plugging in.

A 'parallel' hybrid electric vehicle uses the electric motor or the internal combustion engine to propel the vehicle. A 'series' hybrid electric vehicle uses the electric motor to provide added power to the internal combustion engine when it needs it most, for example, in stop-and-go driving and acceleration. Hybrid electric vehicles have the potential to use electricity to power onboard accessories or to provide outlets to plug in appliances or tools. All have the potential to achieve greater fuel economy than conventional gasoline-engine vehicles.

Plug-in Hybrid Electric Vehicles (PHEVs) are hybrid vehicles with plug-in capability. That is, they use a combination of grid electricity, regenerative energy from braking, and power from another onboard source, such as an internal combustion engine or fuel cell. The last of these is what distinguishes them from the other plug-in vehicle, the BEV.

In addition, plug-in hybrids can be configured to operate serially, or in a blended fashion. In a serial configuration, the vehicle runs on electricity alone at some points, like starting, and uses its other power source alone at others, for example, when accelerating. Alternatively, a plug-in hybrid may be configured for blended operation, i.e., the battery and the conventional engine operate together.

While forms of battery electric vehicles have been around the longest, HEV's have achieved the greatest commercial penetration in the 10 years since their introduction. Since the introduction of the Honda Insight in late 2008, the number of hybrids offered for dale in the US has risen to 20 models. Toyota has sold over a million hybrids worldwide. In the U.S. this year, sales figures to date for hybrid vehicles are approximately 270,000 vehicles. Due to variations in sales reporting, the numbers are not exact. However, a breakdown of sales by manufacturer and vehicles by year is available at: http://www.electricdrive.org/index.php?tg=articles&topics=7

*Question 5.* How widespread is the use of electric drive in public transportation?

Answer. Hybrid and fuel cell buses, school buses are being added into city and school transit in small numbers, but with significant benefits in fuel and operating cost as well as emissions. According to the American Public Transportation Association's (APTA) "2008 Public Transportation Fact Book," electricity powered .1% of buses in 1996 to 2.3% in 2007.

The Park Service also uses electric drive for public transportation. For instance, in Alaska's Denali National Park, the Park Service is trying out a hybrid bus to reduce fuel costs and air pollution in this pristine area. The bus has a hybrid system developed by Enova Systems and will provide over 30% reductions in particulate matter, 20% reduction in $NO_X$ emissions, over 40 percent reduction in $CO_2$ and in excess of 70% percent improvement in fuel economy.

*Question 6.* What is the role of PHEV in fleet applications?

Answer. PHEVs can potentially play a significant role in private and in regulated fleets, which have significant economic and regulatory requirements to reduce petroleum use. The managed travel and central recharging characteristic of fleets are optimizing features for plug-in vehicles.

For fleets regulated under EPAct 92, the 2007 EISA explicitly recognized the use of plug-in hybrids (and, finally, hybrids) in meeting petroleum reduction requirements through alternative fuel vehicle acquisition. This recognition will substantially expand the acquisition of electric drive, specifically PHEVs, in covered fleets.

In private and municipal fleets, economic concerns and environmental requirements have led to many fleets to incorporate HEVs and plan to incorporate PHEVs into their fleets as they become available.

At the local government level, at least 10 U.S. cities have or are considering enacting requirements for taxicabs traversing their roads. Other cities are trying an incentive approach. For instance, after the New York City edict for hybridizing the cab fleet by 2012 was blocked in court, city officials recently announced new financial incentives for trading traditional taxis in for hybrids. The Medium and Heavy Duty HEVs are currently being used in fleets of major enterprises such Wal Mart, UPS, FedEx and others. Environmental Defense has a useful survey of available vehicles in this category: http://www.edf.org/page.cfm?tagID=13394

*Question 7.* You said that we could cut our fuel consumption by 83% by switching the light duty fleet to electric drive and hybrid technologies. Can you explain the assumptions you used to arrive at this number?

Answer. We used an internal modeling exercise with aspirational timing benchmarks to highlight the oil-saving potential of electric drive. We posited a light duty fleet (cars & trucks) with a mixture of electric drive technologies, including hybrids, plug-in hybrids, fuel cells and battery electric vehicles.

We used the 2006 EIA projections of light-duty vehicle stock and liquid fuel consumption. (The modeling was done last year.)We posited market entry in 2010 with 100% new car sales being electric drive by 2020 (15 million per year) and 100% of the vehicles being electric drive with an average equivalent electric of 40 miles by 2030.

The timeline we used is short, to highlight the oil savings potential of electric drive, rather than project real-word market penetration rates.

*Question 8.* As you noted in your testimony, we import the majority of the oil we use for our transportation fleet. Not only does this put as at a strategic disadvantage, it also causes us to send a huge fraction of our nation's wealth overseas. Given the new technology and materials involved in electric and hybrid vehicles, are there crucial areas we should monitor to may give rise to strategic vulnerabilities for our country?

Answer. In addition to the importance a domestic automobile manufacturing industry, domestic capacity for advanced battery manufacturing is a critical need for the emerging electric drive industry. Currently there is very little domestic manufacturing of lithium ion batteries and hurdles to commercial scale industry include not only the materials but the manufacturing processes and equipment for automotive scale battery manufacturing must be developed. Congress can play an important role in building a domestic industry by funding the battery and manufacturing programs authorized in EISA 2007.

Questions have also been raised about the availability of lithium. It has been noted that lithium is currently known to be concentrated in geographically remote and geopolitically inhospitable areas of the world, including the Andes in South America.

Answer. While Congress should be monitoring the availability of lithium, it is worth noting that reliance on lithium ion batteries for the global personal computing and cell phone applications has not been limiting to date. Nevertheless, the search for the next iteration of the lithium ion chemistry, and of advanced battery technology, is ongoing.

*Question 9.* You noted the importance of developing and maintaining a domestic battery manufacturing capacity. Recently there have been advances in the performance of traditional lead acid batteries for which there is a mature manufacturing and recycling industry in this country. What do you think the prospects are for traditional lead acid batteries playing a role in the electrification of the transportation sector?

Answer. Traditional lead acid batteries are already playing a role in the electrification of transportation, as they power low speed electric vehicles (or neighborhood electric vehicles). These vehicles provide battery electric options in communities, campuses and increasingly urban options. They are road legal in 40 states and help to build market, infrastructure and acceptance of electric transportation.

Advanced lead acid options are also options for certain configurations of hybrid vehicles. For example, advanced lead-acid batteries of the Absorbant Glass Mat type, are an excellent technology for micro-hybrid vehicles, which operate with conventional powertrain and use battery power at idle and stop (and in some cases mild regenerative braking) to enhance fuel economy.

*Question 10.* What is the current status of the lithium ion batteries for hybrid electric vehicles, plug-in hybrid electric vehicles and electric vehicles?

Answer. First generation lithium ion batteries are market ready, for instance lithium ion batteries power the Tesla EV, A123 plug-in hybrid conversions and Johnson Controls' lithium ion battery will be in the 2009 Mercedes hybrid. However, continuing advances are needed for vehicle applications of this relatively young technology. Reductions in cost, advances in battery life, durability and abuse tolerance are needed to achieve the scale and performance certainty required for global commercial scale vehicle applications.

*Question 11.* What are the major technical/market barriers for commercialization of lithium ion batteries?

Answer. Technical barriers for widespread commercialization include durability, length of life and safety. Department of Energy research and development programs are a critical part of the industry effort to address the technical challenges. The Department Energy Storage program is working on some salient technical challenges, including performance over time; abuse tolerance (including overcharge and overdischarging, and high temperature environments); and life—the battery needs to last and perform for the 15-year life target of the vehicle.

Cost is a technical and a market hurdle. The incremental cost of lithium ion batteries for plug-in vehicles is estimated at $500 to $1000 per kilowatt hour. To put this in perspective, the Chevy Volt is designed to operate on a 16 kWh battery. Even at the lowest end of the cost projections, the battery would add $8000 to the cost of the vehicle. Federal and private research and development partnerships can help to address the technical aspects of the cost. The market hurdle can be mitigated by consumer tax incentives that address the retail cost and manufacturing incentives that mitigate production costs.

Section 641 of EISA, the Energy Storage Competitiveness provisions developed by the Senate Energy and Natural Resources Committee, provide a critical template for advancing battery technology; funding for these programs going forward can accelerate the development of energy storage technology and electric drive transportation overall.

*Question 12.* Plug-in electric vehicles hold great promise in our ongoing efforts to lessen our dependence on foreign sources of oil. However, U.S. transmission infrastructure has increased by only 6.8% since 1996. In the last year's energy bill. Congress encouraged the modernization of the electricity grid in Smart Grid provisions that include the deployment and integration of plug-in electric and hybrid electric vehicles. What kind of infrastructure improvements must we undertake to accommodate the eventual use of plug-in vehicles?

Answer. A 2007 study conducted by the Electric Power Research Institute and the National Resources Defense Council concluded that 84% of the energy needed for a plug-in light duty vehicle fleet could be met with existing electricity capacity. Grid connected transportation won't require more electricity generation for a very long time. It will require better management of existing electricity resources.

The national scale adoption of grid-powered transportation requires updating the the "hardware" and the "software" of electricity infrastructure. Better technology and better communication will optimize the energy and environmental benefits of plug-in vehicles.

Smart meters that allow two way communications between energy users and suppliers are needed so that consumers can maximize savings and benefit from price signals and electricity providers can manage load, maximize off-peak charging and ultimately use the energy stored in batteries to improve grid reliability.

Public charging and fast—charge infrastructure will be needed to meet the needs of diverse drivers who want or need an alternative to home charging. This will also require new payment protocols that allow billing to be as mobile as the plug-in vehicle user.

Grid-powered transportation will become more sustainable as the grid becomes greener. Transmission lines should be upgraded to increase the efficiency of the grid, minimize line loss and enable distributed, renewable generation to be used in the grid.

In addition, interconnection standardization will be needed to enable the energy stored in batteries to be delivered to homes for backup power and one day to the grid.

This committee identified key elements of the necessary modernization effort in Title XIII of EISA and provided key threshold incentives in the HR 1424 tax incentives for smart meters and alternative fuel vehicle recharging infrastructure. Funding for the former and expansion/extension of the latter can help to speed the changes needed for large scale integration of grid-powered vehicles.

TOYOTA,
WASHINGTON OFFICE,
*Washington, DC, December 5, 2008.*

Hon. JEFF BINGAMAN,
*Unites States Senate, Committee on Energy and Natural Resources, Washington, DC.*

DEAR CHAIRMAN BINGAMAN: Thank you for your letter of November 20, 2008 containing additional follow-up questions from your September 16 hearing on the Electrification of the Automobile. I appreciate the opportunity to respond to these questions (attached).

If you have any further questions or if I can be of further assistance as you move forward in consideration of legislation, please do not hesitate to contact me.

Sincerely,

ROBERT WIMMER.

RESPONSES TO QUESTIONS FROM SENATOR BINGAMAN

*Question 1.* As I understand your testimony, the main factor in determining the all-electric range of the next generation Prius is the cost of the batteries and your desire to make a mass-marketable price point. If the US market had incentives on the scale that Mr. Balkman advocates that would significantly reduce the cost to consumers of larger battery packs, would that alter the calculations for what is feasible for the market?

Answer. Toyota supports broad-based consumer tax incentives to promote the purchase or lease of advanced technology vehicles, like those included in the Energy and Tax Extenders Act of 2008. Any incentives that support all manufacturers' PHV designs are beneficial to the industry and will speed deployment.

It is often a decade or more between the start of vehicle design and the end of a model's production run. With such a long time frame, it is risky to develop global designs optimized for one market's incentives. Toyota designs our vehicles to provide attractive affordable transportation to greatest number of potential customers in multiple markets. Incentives in the early stages of marketing a new technology are certainly beneficial in lowering a vehicle's price point and making it more affordable to a greater number of possible customers. But ultimately, such incentives are temporary and technologies must compete on overall value to the consumer.

Regarding all-electric range of a PHV, the larger the battery the more dead weight must be carried after the battery is discharged. This of course negatively affects overall vehicle mileage, especially on long trips. Also, the larger the battery the less room for passengers and cargo, negatively affecting functionality, a key selling point of the Prius (small battery) concept.

*Question 2.* We've heard previous testimony that prices for lithium ion batteries are only likely to drop significantly when high production volume is achieved. Of course, this high volume will only follow from high sales volume of vehicles using lithium ion batteries. In your estimation, what kind of volume in battery production might represent a "tipping point" where the batteries would be inexpensive enough to be used in a substantial portion of vehicles?

Answer. As Li-Ion battery production increases, manufacturers can apply lessons learned and develop advanced manufacturing technologies to,lower production costs. But even in high volumes, battery experts do not expect pack prices to drop below—$500/kW-hr.

As Toyota designs new hybrid and PHV models we will evaluate all battery options and select the chemistry that best meets vehicle performance goals, customer expectations and price targets. Battery cost is a key factor, but only one of many that go into the vehicle design process.

Another consideration must be the long-term commodity price of lithium metal. Current low-cost sources, like dry lakes in Latin America, cannot support massive increases in the global demand for lithium. New, more costly sources will need to be developed as demand increases. As a result, much of the cost savings from manufacturing improvements may be negated by higher material costs.

RESPONSES OF ROBERT WIMMER TO QUESTIONS FROM SENATOR DOMENICI

*Question 3.* Are you performing any sort of vehicle-to-grid research with these vehicles?

Answer. We have a joint research project with the French electric utility EDF (ElectriciteWe France) to explore public recharging and some vehicle-to-grid communication issues. We also participate in a number of national and international standards organizations, Society of Automotive Engineers for example, that are developing codes and standards for plug-in vehicles.

*Question 4.* How many miles will your vehicle or vehicles travel in its "all electric" mode?

Answer. The current prototype travels about seven miles all-electrically. Next year's PHV, to be leased to commercial fleet users, will have significantly greater range. Once EPA certification testing is completed and we near product launch, Toyota will announce the all-electric range of the next-generation vehicle.

It is important to note that battery cost is closely related all-electric range. As mentioned in our testimony, Toyota is seeking to find the appropriate balance between electric range, vehicle cost, consumer desires and other factors when determining electric range.

*Question 5.* What are the challenges presented to your vehicles by extreme environments? What will buyers in Arizona and Wisconsin have to face?

Answer. Toyota designs vehicles to operate reliably and efficiently in all climatic conditions. The PHV will be no exception.

As with conventional vehicles, cold weather operation will reduce a PHV's fuel efficiency. There should be no noticeable loss of performance, but all-electric range will be less.

In extremely hot conditions, the vehicle's control system may limit battery charge and discharge rates to assure battery longevity. This will result in a slight increase in fuel consumption as the engine operates more frequently, but should not affect performance.

*Question 6.* As sales of Toyota hybrid and electrical vehicles in the U.S. increase what investments are Toyota prepared to make in manufacturing infrastructure development in the U.S.? For example, will a domestic lithium ion manufacturing capability be important to Toyota's business model.

Answer. Toyota is a global company that strives to manufacture where we sell. Since initial PHV volumes are expected to be modest, production will likely take place at a single manufacturing facility to minimize cost. As we near start of production, Toyota will announce which facility is slated to produce PHVs.

*Question 7.* What is the current status of Lithium Ion batteries for hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEVs), and electric vehicles (EVs)?

Answer. We have announced we will be using Li-Ion batteries in our next-generation PHY that begins production next year. This battery will be built on a new, dedicated assembly line by Panasonic EV, a joint venture between Panasonic and Toyota.

As Toyota develops new hybrid systems, we evaluate all battery options and select the chemistry with the best cost/performance tradeoff that meets our customers' expectations and provides required battery durability and life.

Though Toyota is committed to mass production of Li-Ion batteries, challenges of the chemistry have us looking "beyond lithium. To this end, we established a separate advanced battery group with facilities in both Japan and the US (Ann Arbor) to examine innovative battery chemistries that may lead to a breakthrough in energy storage.

*Question 8.* What the major technical/market barriers for commercialization of lithium-ion batteries?

Answer. Key issues we see with Li-Ion batteries are cost, life-of-the-vehicle durability and cold weather performance. Another issue is sustainability of the lithium metal supply as demand grows for automotive batteries. Lithium commodity prices are expected to increase as demand grows and traditional lower-cost sources of lithium are exhausted.

*Question 9.* Plug-in vehicles hold great promise in our ongoing efforts to lessen our dependence on foreign sources of oil. However, U.S. transmission infrastructure has increased by only 6.8% since 1996. In last year's energy bill, Congress encouraged the modernization of the electricity grid in "Smart Grid" provisions that include the deployment and integration of plug-in electric and hybrid electric vehicles. What kind of infrastructure improvements must we undertake to accommodate the eventual use of plug-in vehicles?

Answer. Studies show that the US electrical grid has the nighttime capacity to support tens of millions of PHVs. However, experience from our electric vehicle program in California has shown that consumers are "opportunity chargers" and will charge whenever convenient.

We expect similar behavior from PHV owners as they will want to maximize fuel and cost savings by "plugging-in" as often as possible. Remote, public recharging stations will be needed to accommodate this cell-phone mentality. Charging during lower-cost off-peak-hours will initially dominate vehicle recharging, but significant growth in daytime charging could ultimately stress the electric grid.

Notwithstanding the issue of daytime versus nighttime charging, the greater near-term infrastructure need is at the residential level.

Currently, less than half of US households have the ability to charge a PHV. Those that can not, include multi-unit residences with parking lots and homes that have no off-street parking. Charging infrastructure must be built for these residences before their occupants can benefit from PHV ownership.

Another issue is the electrical capacity of sub-divisions. As more and more households begin recharging their vehicles at night, the electrical capacity of entire subdivisions could be exceeded. Smart meters may reduce this possibility, but ultimately upgrading many subdivisions' electrical systems could be required.

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RESPONSES OF THAD BALKMAN TO QUESTIONS FROM SENATOR BINGAMAN

*Question 1.* As you know, the automotive industry is both highly competitive and capital intensive. Has something changed that has made it more likely that a company such as yours, or Tesla is likely to succeed in breaking in where other efforts have failed in the past?

Answer. The established model of vertically integrated automobile manufacturing is giving way to a systems integration manufacturing model much as occurred in the computer industry. This has profoundly reduced barriers-to-entry for manufacturers of battery electric vehicles (BEVs). Under the systems integration manufacturing model employed by Phoenix, Tesla, and others, the manufacturer undertakes the R&D and integrates the vehicle elements while suppliers contribute virtually all components and materials and much of the innovation at the sub-system level. See Nutek (Swedish Agency for Economic and Regional Growth), Globalization and Regional Economies, Case Studies in the Automotive Sector (2007) at http://fm.nutek.se/forlaget/pdf/r__2007__11.pdf. The greater efficiency and cost reduction opportunity presented by the systems integration model has enabled the emergence of an entirely new collection of American automobile manufacturers within the past five years, the first new entrants in the automotive sector in decades. Nearly all of these new manufacturers are relying on electric propulsion systems consisting of electric motors and advanced lithium batteries designed and supplied by third parties. In contrast, traditional automobile manufacturers depend on their own vertically integrated manufacturing plants dedicated to the production of IC engines and transmissions, which require the engineering, design and manufacture of thousands of moving parts. Thus, the low-cost design and manufacture of combustion technology and transmissions are the primary "value added" by traditional automobile manufacturers which have accumulated substantial expertise over the past 100 years. The sheer complexity of vertically integrated manufacturing for decades has effectively barred the entry of new actors. See Green Mountain Chrysler v. Crombie, No. 2:05-CV302 (D. Vt. Sept. 12, 2007), available at http://www.vtd.uscourts.gov/Supporting%20Files/Cases/05cv302.pdf. The major OEM's have become so large and complex that each new vehicle launched costs hundreds of millions of dollars and requires hundreds of thousands of unit production to break even. In contrast, BEVs replace IC engines and transmissions, two of the primary business units of the automobile industry. See U.S. EPA, Staff Technical Report: Cost and Effectiveness Estimates of Technologies Used to Reduce Light-duty Vehicle Carbon Dioxide Emissions , available at http://epa.gov/otaq/climate/420r08008.pdf ; EVWorld.com, Inc., Interview with General Motor's Vice President of Research and Development, Dr Larry Burns (March 12, 2007), available at http://www.evworld.com/article.cfm?archive=1&storyid=1208&first=3630&end=3629.

*Question 2.* Assuming we were to put in place some of the incentives you advocated in your testimony to bring down the initial costs of battery electric vehicles, how long would you anticipate such incentives would be needed? In other words, at what point do you anticipate that enough scale is achieved in battery manufacturing to bring costs in line with standard vehicles available today?

Answer. Clearly investments in bringing down the initial costs of battery electric vehicles must be a sustained multi-year effort to be successful. Generally speaking, economics of scale in manufacturing are not fully achieved until hundreds of thousand units are produced. See Bandivadekar, Evaluating the Impact of Advanced Vehicle and Fuel Technologies in Light Duty U.S. Vehicle Fleet (2008) http://esd.mit.edu/people/dissertations/anup__bandivadekar.pdf. Internal combustion technology has dominated for 100 years and benefits from several billion units of production. New technology comes with a price of development. If advanced electric vehicles are to be successful market incentives are critical for a sustained period of time to help early adopters offset the initial investment. As volume from Phoenix Motorcars and others increase, component prices will come down and allow for future cost reduction in our existing and future models.

RESPONSES OF THAD BALKMAN TO QUESTIONS FROM SENATOR DOMENICI

*Question 3.* You testified that consumers will not pay extra for more fuel efficient vehicles unless the pay-back is 2.5 years or less. What is the pay-back period for the two electric vehicle models Phoenix Motorcars will introduce next year?

Answer. Without incentives our vehicle shows a payback period of 3.5 years at a gasoline price of $4.00 per gallon. The higher the gas prices the shorter the payback period and the lower the gas price the higher the payback period. With the incentives available to today in California and thru the Federal Government the payback period can be met in the first year of operation making Electric Vehicles truly a zero compromise alternative to the fleet or consumer in these economic times.

*Question 4.* How do you arrive at the payback period for your vehicles?

Answer. Payback period is determined by the annual cost of ownership for an internal combustion vehicle (ICE) compared with the annual cost of ownership of a Phoenix EV. While the initial cost of a Phoenix SUT is higher ($47,500) than the initial cost of a comparable ICE ($28,000) the operational costs is substantially lower with electric vehicles.

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|---|---|---|---|
| **Phoenix Price** | **$47,500.00** | **Comparison Vehicle Price** | **$28,000.00** |
| Federal Incentive | $ 7,500.00 | Federal Incentive | |
| State Incentive | $ 5,000.00 | State Incentive | |
| Other Incentive | $ - | Other Incentive | |
| **Adjusted Price** | **$35,000.00** | **Adjusted Price** | **$28,000.00** |
| Annual Miles | 15000 | Annual Miles | 15000 |
| Miles per kWhr | 31.5 | Miles per Gallon | 14 |
| Cost per KwHr | 0.8 | Cost per Gallon | $ 4.00 |
| Annual Maintenance | $ 500.00 | Annual Maintenance | $ 2,000.00 |
| **Annual Running Cost** | **$ 880.95** | **Annual Running Cost** | **$ 6,285.71** |

*Question 5.* You note that there are a number of advantages that electric vehicles have over traditional gasoline powered vehicles including simpler mechanics and environmental emissions as well as lower infrastructure emissions. Are there potential disadvantages that are unique to electric vehicles, for example battery chemistry and manufacturing infrastructure, that we must also consider?

Answer. There are three concerns that early adopters will have to face. First—charging infrastructure will take time to build out to provide the opportunity to quickly recharge your vehicle and continue driving. Second—users will need to become familiar with the idea of plugging in their vehicles at home leaving each morning with a full charge. Statistics show that most Americans do not drive more than 40 miles per day. Third—battery technology production is just coming on line in many instances and will take some time to allow large production of hundreds of thousands of units. In most cases these large format batteries will require cold and hot weather validation for use in different climates within the US.

All of these challenges can and are being addressed and will be proven out with time and marketing. The market is pulling for these alternatives which greater assists in the reformation of the idea of transportation in the US. Investments into furthering technologies for alternative fueled vehicles will assist in closing the hundred year head start that the internal combustion engine has had.

*Question 6.* What is the current status of Lithium Ion batteries for hybrid electric vehicles (HEV) plut-in hybrid electric vehicles (PHEVs), and electric vehicles (EVs)?

Answer. The market as a whole now views lithium ion based batteries as the best alternative for transportation. With any transportation application size, weight, safety and durability are all important considerations. Lithium ion batteries allow for the highest energy density batteries providing a smaller less weight solution. With advancement in Lithium Titanate and Lithium Polymer batteries you now have a durable safe chemistry. Phoenix Motorcars view that large prismatic lithium cells are best suited for electric transportation.

*Question 7.* What the major technical/market barriers for commercialization of lithium-ion batteries?

Answer. The largest barrier is the domestic manufacturing capacity of large format lithium-ion based batteries.

*Question 8.* Plug-in vehicles hold great promise in our ongoing efforts to lessen our dependence on foreign sources of oil. However, U.S. transmission infrastructure has increased by only 6.8% since 1996. In last year's energy bill, Congress encouraged the modernization of the electricity grid in "Smart Grid" provisions that include the deployment and integration of plug-in electric any hybrid electric vehicles. What kind of infrastructure improvements must be undertake to accommodate the eventual use of plug-in vehicles?

Answer. One advantage of electric transportation is the ability to use the existing electricity grid infrastructure to refuel your vehicle. Unlike our vehicles at present time that refuel most often during the daytime hours, electric vehicles can recharge at night when the existing utility grid capabilities are "idling" burning electricity off the grid until the need arises the following day as we wake up. In addressing the rapid recharge station we promote the model that gas stations use today. Instead of large tanks that hold gasoline, we envision using a large battery that recharges off the grid at night or thru renewable sources. As a vehicle pulls ind uring the day it transfers the required energy from this large battery instead of from the grid. Not only would this proposed model assist the utilities thru use of this elecgtricity during the day, but national security would be greater assisted by having power distributed throughout the grid.

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RESPONSES OF JOSEPH T. DALUM TO QUESTIONS FROM SENATOR BINGAMAN

*Question 1.* Your technology seems to be an exceptionally good fit for several heavy duty applications where idling is a significant part of the fuel consumption. With fuel prices where they are, why isn't this sector, which is historically so sensitive to fuel prices, adopting this technology quicker? It would seem it would pay for itself fairly quickly.

Answer. In my opinion there are several reasons that explain why the heavy duty truck segment has not adopted plug-in hybrid technology more quickly:

1) High acquisition price

Low initial production volume, combined with high start-up costs contribute to a relatively high acquisition price for current plug-in hybrid systems. The high price deters wide-scale adoption of this technology by commercial customers.

The start-up costs include costs for research and development, testing and validation, production floor-space and tooling, low volume manufacturing activities, service and operator training, marketing and other costs associated with launching a new product. Those costs are spread over an initially low production volume, resulting in higher per unit sell prices. Critical components that are used in the system are also not typically available in high volume, resulting in higher material cost. Although per vehicle fuel consumption is high, making the heavy truck segment a good target for plug-in hybrid technology, heavy duty commercial truck unit volume is low in comparison to light duty car and truck volume. The relative low volume for this sector makes it less attractive to some automotive component suppliers to develop products for this market.

DUECO strongly recommends that the Federal government pass and fund legislation similar to H.R. 6323 Heavy Duty Hybrid Vehicle Research, Development, and Demonstration Act of 2008. The legislation would provide for competitively awarded grants to accelerate development of hybrid and plug-in hybrid technology. In my opinion, additional research and development is likely to result in plug-in hybrid systems for heavy duty trucks with lower costs and better performance.

2) Weak economy and low fuel prices

Commercial truck customers are currently reducing purchases and may have difficulty accessing credit. When purchasing trucks with a limited budget, customers tend to favor low priced products that provide the best short-term return. Low fuel prices and a difficult economy tend to make it more difficult to sell a higher priced product, even if it has substantial benefits over existing products.

The expected return on investment of current plug-in hybrid systems for medium and heavy duty trucks may extend beyond the period that some customers use to determine whether they will pay more money up front for a product with the expectation of lower operating costs later. The recent collapse in fuel prices to less than $2 per gallon essentially doubles the time before fuel savings alone will offset the higher initial cost of the system, compared to when the cost was $4 per gallon.

DUECO strongly encourages the Federal government to enhance the plug-in hybrid tax credits by doubling the credit through 2011 for vehicles that weigh 14,001 pounds or more. The initial tax credit was developed during a period of high fuel costs, but fuel prices are now less than half of the peak price. The increase in the tax credit would help to stimulate demand for this green technology, create jobs and the increased production volume would ultimately result in lower costs.

In addition, DUECO recommends that a credit be developed for plug-in hybrid trucks that weigh more than 33,000 pounds, by modifying the Tax Extenders Bill (H.R. 1424) to create a tax credit of up to $40,000 for a plug-in vehicle weighing more than 33,000 pounds.

The plug-in hybrid tax credit should also be made available for the upgrade of existing heavy trucks that are modified by adding a plug-in hybrid drive system. Unlike light duty cars and trucks, heavy trucks are typically built in multiple stages for custom applications and are more easily modified. Due to the large number of existing Class 4-8 trucks on the road today (~6.5M, excluding road tractors), addressing the retrofit market can have an immediate and sizable impact on job creation, improved emissions, and reduced fuel consumption within the medium and heavy duty truck market.

Many of the trucks in this fleet of millions of trucks can be converted to plug-in hybrids, potentially creating tens of thousands of jobs in the retrofit sector.

3) Hesitancy to adopt new technology

Commercial truck buyers are typically quite conservative, and are currently more likely to buy trucks that are very similar to others in their fleet. Trucks that are purchased may remain in the field for 20 years or more, so unless there are substantial incentives, the transition to plug-in hybrid trucks will likely occur incrementally. Our experience has been that some customers have adopted a wait and see attitude.

4) Weight

Plug-in hybrid systems typically require much larger battery systems. The additional weight can create a problem for certain applications.

DUECO strongly encourages the government to support advanced battery programs to develop advanced batteries for commercial truck applications that have high power and high energy densities at low costs. The lower weight of an affordable advanced battery system would increase the number of applications in which plug-in hybrid system technology could be used.

5) Stability of supply chain

Current economic challenges and reduced access to credit has negatively affected some suppliers of critical hybrid components. The overall weakness of the automotive supply chain could jeopardize the availability of key components and cause consumers to wait before purchasing new technology.

In order to reduce the cost of development and improve access to capital, DUECO strongly encourages the government to modify Section 136 of the Energy Investment and Security Act (EISA—H.R. 6—P.L. 110-140) which established the Advanced Technology Vehicle Manufacturing (ATVM) program. The current law does not provide for any loans or grants to manufacturers of heavy duty trucks for the development of advanced technology vehicles. The law only assists light duty vehicle manufactures. DUECO believes this law should be expanded to include final stage manufacturers of trucks that weigh 14,001 pounds or greater, and include other entities involved in manufacturing or modifying heavy trucks, such as chassis manufacturers, intermediate manufacturers and alterers.

*Question 2.* As I understand it, a big part of the fuel savings in your vehicles is realized through idling reduction rather than depleting the charge driving. The CAFE provisions in the energy bill we passed last year contemplate future regulation of the medium and heavy duty sectors. Do you know if the duty cycle fuel savings you achieve would be given credit under such a CAFE regime?

Answer. DUECO does not know if the duty cycle fuel savings achieved would be given credit under a CAFE regime that would be developed for trucks that weigh 14,001 pounds or more. Our current experience in the evaluation of various existing truck duty cycles indicates that many of the duty cycles do not closely match the use of the vehicles we have observed in the field. Work truck duty cycles may have a significant component of stationary idle time in which the primary engine is used to power truck mounted equipment at a job site. Most existing truck duty cycles do not incorporate the same proportion of idle time and stationary engine loads.

DUECO encourages the government, perhaps through the Department of Energy (DOE) Laboratories, to measure and study actual truck duty cycles and to assess other factors before determining if a standard should be adopted. Unlike higher volume light-duty cars and trucks, heavy trucks tend to be built in greater variation with different profiles, weight distributions and uses. Additional regulation could cause commercial truck prices to rise further if test costs and associated administrative costs are spread over low sales volume. If standards were adopted, DUECO recommends that test duty cycles closely match actual use, be made optional, and that tax credits or other incentives be used to encourage consumers to purchase higher efficiency vehicles.

DUECO believes that the best performance standard for plug-in hybrid heavy duty trucks is to measure the reduction in fossil fuel consumption from diesel heavy duty trucks, provided that the heavy duty hybrid truck utilizes a certified engine without modification. The DOE is already using this standard through its Clean Cities program. DUECO is confident that this metric will demonstrate substantial reductions in fossil fuel consumption between comparable vehicles performing comparable tasks over a period of time, whether this is one day, one month or one year. Our initial testing indicates that fuel consumption may be reduced by as much as 50 percent over the course of a day, depending upon the duty cycle. We believe these savings will be even higher once battery weight and costs are reduced.

DUECO initially recommends a performance metric that demonstrates a reduction of 10 percent in fossil fuel use for the purposes of developing various incentives, such as the use of an expanded Advanced Technology Vehicle Manufacturing Program for plug-in hybrid heavy duty trucks. This metric will allow oversight over the expansion of the plug-in heavy duty truck sector, without harming efforts to expand this sector. We recommend 10 percent initially because we are concerned that fleet managers will not measure comparable vehicles, or that they won't properly maintain the plug-in vehicles by failing to charge them through an external grid, making them less efficient during the period when they are learning to use these trucks.

DUECO recommends increased government funding for the DOE's Clean Cities Program.

RESPONSES OF JOSEPH T. DALUM TO QUESTIONS FROM SENATOR DOMENICI

*Question 3.* How many miles will your vehicle or vehicles travel in its "all electric" mode?

Answer. Our vehicle has the capability to provide "All Electric Operation at a jobsite for a typical day," as stated in my written testimony. The all electric mode is used while the vehicle is stationary to provide power for truck mounted equipment, lights, air conditioning and exportable power (e.g. power for tools). Those loads are normally powered by an idling engine in a traditional truck. Our plug-in hybrid heavy duty vehicle utilizes a parallel hybrid power train configuration in which the engine operates, along with the electric motor. The electric motor is used to provide "launch assist" when the vehicle accelerates, and regenerative braking when the vehicle decelerates which also recharges the batteries. Since the engine operates along with the electric motor, there is no all electric range using this configuration. Like conventional hybrid trucks of similar size, the internal combustion engine must remain on when the vehicle travels in order to power vehicle sub-systems such as brake systems, steering and HVAC. Further changes to those sub-systems, such as the possible electrification of associated components, and modifications to the drive train could make it possible to create a truck with all electric range. A series/parallel design could allow a truck to have a limited all electric range as described in the System architecture section of my written testimony shown below:

> System architecture:
>
> Existing hybrid systems for trucks tend to utilize system architectures that are similar in many ways to that of existing truck power trains. The internal combustion engine typically remains operating while the vehicle is driven to power auxiliary loads such as power steering systems, brake systems and HVAC systems. Keeping the engine running while stationary or in low speed stop and go traffic increases fuel consumption. Some vehicles also do not have a clutch in between the internal combustion engine and the transmission. While such systems utilize an automatic transmission, it may be desirable to create a method to uncouple from the transmission

from the engine for improved regenerative braking or an all-electric drive mode.

In order to improve fuel economy further, different system architectures that are designed for high volume production in which the internal combustion engine can remain off during driving need to be developed. The development of electrically driven sub-systems such as braking, power steering, HVAC and others need to be brought to high volume production for medium and heavy duty trucks.

Existing parallel hybrid electric vehicle systems for trucks also tend to use relatively small electric drive components with relatively low power output, compared to the power provided by the internal combustions engine. Larger electric motors and higher capacity battery systems may allow smaller engines to be used that operate at higher efficiency without a reduction in vehicle performance, or allow the vehicle to be driven entirely by electric propulsion. Future system architectures could also combine the benefits of plug-in hybrid technology, which requires battery systems with high energy densities, with that of hydraulic hybrids that have high power densities. The combined plug-in electric hybrid system with hydraulic hybrid components could offer high horsepower during acceleration and recapture more energy during braking while providing enough energy for sustained operation with the engine off.

Alternative power train architectures, such as a combined series/parallel hybrid system with a plug-in battery system are also recommended for consideration. A combined series/parallel system would allow the vehicle to operate in an all electric mode, a series hybrid configuration or a parallel hybrid configuration, depending upon which is most advantageous given operating requirements.

DUECO strongly recommends that the Federal government pass and fund legislation similar to H.R. 6323 Heavy Duty Hybrid Vehicle Research, Development, and Demonstration Act of 2008. The legislation would provide for competitively awarded grants to accelerate development of new power train designs.

In addition, to reduce the cost of development and improve access to capital, DUECO strongly encourages the government to modify Section 136 of the Energy Investment and Security Act (EISA—H.R. 6—P.L. 110-140) which established the Advanced Technology Vehicle Manufacturing (ATVM) program. The current law does not provide for any loans or grants to manufacturers of heavy duty trucks for the development of advanced technology vehicles. The law only assists light duty vehicle manufactures.

*Question 4.* Given the different duty cycles required for medium and heavy duty trucks and light-duty passenger cars and trucks, how well do you think technology development in either of these market segments will benefit the other?

Answer. While medium and heavy duty truck cycles and power requirements differ significantly from those of light-duty passenger cars and trucks, there are some technologies that can be shared between each segment. Areas of technology development that could be shared are listed below:

- Advanced battery systems
- Charging technology (i.e. “Smart Chargers”)
- Inverters and electric motors
- Control systems

While individual components may be different due to the larger power and greater energy requirements of heavy duty trucks, the underlying technology is very similar and could be shared in these areas. In order to reduce the cost for heavy duty plug-in hybrids, it would be beneficial to utilize higher volume, lower cost light-duty vehicle technology wherever possible.

*Question 5.* Do you think any fuel economy differences seen between parallel and series drive systems for medium and heavy duty trucks will also apply to light duty vehicles?

Answer. In my opinion, the fuel economy differences seen between parallel and series drive systems for medium and heavy duty trucks will not be as readily apparent in light duty vehicles due to the fact that technology for light duty vehicles is more mature and fuel consumption per vehicle in the light duty segment is much less. Light duty power train systems have in many cases already become highly efficient. Light-duty hybrid power trains have been in production for years (although present in only approximately 2% of light-duty vehicles) and power trains that offer extended range or 100% electric operation are under development and are targeted for deployment in 2010 (such as the GM Chevy Volt). So, in other words, the relative difference as technology improves for light duty power trains will not be as great as that for heavy duty trucks.

In the near term it will be difficult to achieve further improvements in advanced light-duty power trains while maintaining a competitive value proposition relative to lower cost conventional hybrids. As an example, a light duty vehicle that achieves 50 mpg using conventional hybrid technology and 100 mpg using plug-in hybrid technology saves approximately 100 gallons of fuel when driven 10,000 miles per year using the more advanced plug-in power train. At $2 per gallon, a driver will only save $2000 over a ten year period (or less if the cost of charging the vehicle is included). $2000 does not currently cover the increased incremental cost required to obtain 100 mpg.

However, medium and heavy duty trucks, due to their lower overall current efficiency, offer a more compelling value proposition for the use of advanced power train technology. Overall, medium and heavy duty trucks consume a disproportionately large amount of fuel as compared to light duty vehicles. A large truck that can use advanced technology may save over 1000 gallons of fuel per year. At $2 per gallon, the operator can save $2000 per year in fuel costs, or $20,000 over a 10 year period. It is more likely in my opinion that the increased cost of power train advancements in heavy duty trucks can be offset by reduced fuel expenditures. Unfortunately, as discussed previously, the current cost of heavy duty plug-in hybrid technology is still relatively high, which causes demand to be relatively low.

*Question 6.* What is the current status of Lithium Ion batteries for hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEVs), and electric vehicles (EVs)?

Answer. I have deferred this question to two manufacturers of Lithium Ion battery systems: Valence Technology Inc. and Johnson Controls—Saft.

*Question 7.* What the major technical/market barriers for commercialization of lithium-ion batteries?

Answer. DUECO believes that the primary barrier for commercialization of lithium-ion batteries is high cost. The price per kWh of energy storage is prohibitively high for large plug-in advanced battery systems. Other concerns including safety, ease of recycling and limited performance history in the field can also deter wide-scale commercialization.

DUECO recommends that a portion of government funding for advanced battery research, development and demonstration programs should be directed to heavy duty truck applications (trucks that weigh 14,001 pounds or greater). Any federal funding for advanced battery manufacturing should also include funds for the manufacturing of battery systems for heavy duty truck applications.

*Question 8.* Plug-in vehicles hold great promise in our ongoing efforts to lessen our dependence on foreign sources of oil. However, U.S. transmission infrastructure has increased by only 6.8% since 1996. In last year's energy bill, Congress encouraged the modernization of the electricity grid in "Smart Grid" provisions that include the deployment and integration of plug-in electric and hybrid electric vehicles. What kind of infrastructure improvements must we undertake to accommodate the eventual use of plug-in vehicles?

Answer. There are two types of potential infrastructure improvements in my view that are needed in order to accommodate the eventual use of plug-in vehicles.

One is the immediate interface between the vehicle and the surrounding infrastructure. A charge station is required to connect the battery system of a plug-in vehicle to an electrical power source. Charge stations must be installed near the parking places of plug-in hybrid vehicles, which in the case of a commercial vehicles, may be a garage or storage area (e.g. parking lot for commercial vehicles). It may be necessary to modify or add electrical connections between the charge station and the existing source of power for the location.

DUECO recommends that assistance be provided to users of plug-in hybrid vehicles to help offset the cost of charge station installations.

The second type of infrastructure improvement may be to the electrical distribution or transmission system, depending upon the number and type of vehicles connecting to the grid and the ability of the utility to control the size of the loads added to the grid and the timing of the addition of the loads to the grid. For further information, DUECO recommends that the Senator contact PG&E for further information. PG&E is one of the largest utilities in California.

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