THE BROOKINGS INSTITUTION

# BATTERY TECHNOLOGY FOR TRANSPORTATION: FROM SCIENTIFIC DISCOVERY TO MARKETPLACE

Washington, D.C.
Tuesday, February 8, 2011

**Panelists:**

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JEFFREY CHAMBERLAIN
Leader of Energy Storage Initiative
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BRIAN WYNNE
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MR. EBINGER: That's the most compliant audience I've seen in a long time. Thank you very much.

We have a very exciting panel here today comprised of scientists, technologists, entrepreneurs, and finance people, so I hope we can get very different perspectives. I'm going to do somewhat truncated biographies given the number of speakers we have. And the format is that we are trying to get each speaker to limit their formal remarks to roughly five minutes so we then have some time for me to raise some questions with the panel, but then we want once again to turn it to the floor and allow as much time as possible for interaction between you and our panelists.

Our first panelist today is Tom Baruch, who is a founder and partner emeritus of CMEA Capital where he works on energy and material investments. His primary focus is on areas of efficient lighting, solar power generation and management, bio-fuels, and surprisingly, rechargeable batteries. He serves as chairman of the board and was an integral part in the founding of each of the following companies, which gives him a very broad prospectus. Those are Codexis, Inc.; CNano Technology; Intermolecular; and Wildcat Discovery Technologies, which particularly sounds of interest. He also serves on numerous boards, and recently he accepted an invitation to serve as an inaugural member of the National Advisory Council on Innovation and Entrepreneurship, advising Secretary of Commerce Gary Locke and President Obama on key issues related to innovation and entrepreneurship. Tom?

MR. BARUCH: Thank you. We exist in Silicon Valley in California, and I've had the good fortune to be involved in the progression of Moore's Law and the application of Moore's Law to genomics. And the constant of change is actually an incredible experience. In 1970, I was at Exxon, and we were working on some of the same batteries that folks are talking about today, of lithium ion, and in hindsight, the biggest limitation in our ability to go forward was the lack of appropriate tools.

What's happened with the progression of Moore's Law is the availability of tools that we couldn't have even conceived of 30 or 40 years ago. We now have tools that allow us to

observe phenomena at the atomic level and apply that knowledge to the manufacture of products that are better, more efficient, and more productive. In the case of batteries, for example, we're involved in two companies that were mentioned. One is Wildcat Discovery and the other is Intermolecular. These companies essentially apply Moore's Law phenomena to the faster and cheaper discovery of new battery materials. These tools, which are largely based on robotics, improved hardware and software, allow in the case, for example, of Wildcat Discovery, we can do about 1,800 battery assays a week. The result is a discovery rate that's probably about three orders of magnitude faster than the conventional serial approach to materials development.

So we are sitting on the cusp of a huge revolution in material science. Our ability to leverage that knowledge, not only in products that store electrons, but also in products that create electrons, is today available at many orders of magnitude greater than anything we've seen before. And the ramifications of that in the business world are going to be huge. Both of these companies, Wildcat and Intermolecular, are companies that are applying very novel business models to the monetization of their technology. And we'll be hearing a lot more about these activities going forward, both from the perspective of doing things better, faster, and cheaper, but also from the perspective of novel business models.

MR. EBINGER: Thank you very much, particularly for staying in your allotted period of time. Our next speaker is Jeff Chamberlain. Jeff is the leader of the laboratory-wide Energy Storage Initiative at Argonne. The work involved is coordinated into four research areas: advanced battery R&D, process engineering for pilot-scale studies of battery materials, energy storage studies for power grid management, and energy storage R&D in advanced power train systems. He also plays an active role in Argonne's lithium-air battery development initiative that we heard from Dr. Isaacs, and as a senior account manager in the Office of Technology Development and Commercialization at Argonne where he is responsible for managing the intellectual property portfolios for the Laboratory's lithium-ion battery and fuel cell programs. Jeff?

MR. CHAMBERLAIN: Great. Thanks. I did want to start by saying in the lab we're not all physicists. My doctorate was from Georgia Tech in physical chemistry where we were primarily dissecting the plasma reaction that's used to etch semiconductors. So what we

were interested in was the formation of molecular orbitals, looking at the electrons as they move from atomic orbitals to molecular orbitals when new bonds are formed and broken. So I hope with that you can see the massive difference between condensed metaphysics and surface physical chemistry.

There's a lot of things I hope we talk about on the panel. I'm just going to hit kind of a high level of some of them, and one is that the timing is right for continued R&D, and we can talk about that. I'm sure we'll see -- we heard it in some of the questions earlier today. But I did want to say we certainly perform basic research in laboratories. Eric Isaacs outlined that pretty clearly in his speech this morning. And very quickly, I promise you, it is fun to look at lithium moving in and out of carbon or understanding the stoichiometry between iron and phosphate or the stoichiometry between manganese and nickel when you put a new structure together at the nanoscale. It is a lot of fun. There are people who find that incredibly enjoyable.

But -- and very quickly, you could move -- in talking to scientists and engineers, you could get caught up in a kind of bottoms-up view of what the technology means and its utility to the citizens that are paying, funding the research through their taxes. But I'd like to take a second to look at it from a tops-down, which is -- and we heard some of this this morning from both Eric Isaacs and David Sandalow -- but what is the mission we're on? If you look at it from the top down and start with what is the objective? What is the mission? And it really does boil down to -- and it's going to sound like we coordinated our talks, but we didn't -- to three things: Security, meaning if we can gain energy independence and reduce our dependence on oil particularly, that will enhance our national security; economy, there is a massively growing industry with high-value products throughout the supply chain, not just at the vehicle level, but down through the device level and the materials manufacturing; and then finally, the environment, the reduction of -- reduced fossil fuel consumption and reduce the emissions of greenhouse gases.

So that really is the mission is those three corners, and again we heard David Sandalow mention that this morning. And so I hope that after -- from our perspective, and again, our goal is to continue to do R&D that will have direct impact on the citizens in this country in

terms of those three corners of the high-level mission.

The essential question that I hear frequently at seminars or symposia like this is why now? What is -- is now the right time for commercialization? We heard some of this in the questions this morning for commercialization of electric vehicles. More specifically, is the market ready or is the technology ready? Is it too early? We hear a lot of criticism from the media that the market just isn't there; the cars are too expensive, et cetera. And I'd like to, again, at kind of a high level generalize. Either it's too late or it's too early or it's at the right time. And forgive me for over generalizing, but I do think we should think about this way.

In this country, we're either too late in moving to electric vehicles or we're too early -- and I'll say it again -- or we're right at the right time. And if you look to Asia and Europe -- and you heard some of this discussed this morning -- but we're assembling a data pack now for the Department of Energy that shows at a bare minimum, the rest of the world is investing one order of magnitude higher level of dollars and people into research for energy storage, specifically for transportation purposes, than we are in this country -- an order of magnitude. So instead of $100 million or $200 million in research in this country, we're talking about $1 billion to $2 billion in Korea and China alone for research. That's one measure. Just looking outside, are we too late or are we too early?

Another measure in terms of looking at Europe and Asia is -- or the question of is it too early? Look at the market demand versus cost, and again, we heard some questions about this this morning. Is the market demand there? And the answer, I think, is no in terms of are we ready to convert 10, 20, 30 percent of our vehicles over. But part of the reason that answer is no, and I think the main reason is the cost and performance of those vehicles. So like any technology development, the cost and performance of a new technology, whether you're looking at laptop or desktop computers or whether you're looking at plasma screen televisions, you always start at the point of the cost and performance not being there for deep penetration into the market. And that's where we are right now today.

And then the question is, are we on time? And if you look at what's happening in this country, we're looking at car companies, both Ford and GM in the U.S., as well as Mitsubishi,

Nissan, Toyota, and others that will penetrate the U.S. market. If you look at what they're doing in terms of marketing strategy, they're penetrating cautiously. I mean, they're investing huge amounts of money and banking in some sense in their companies on the success of electric vehicles, but they're looking at starting with thousands and tens of thousands of vehicles per year which although will be an economic boom regionally in the places where those plants are being built, these are a small piece of the market. And that is the right way to penetrate a market and grow that market organically from the small numbers. So I would argue that now is the right time to penetrate the market.

And the question I hope we walk away -- assuming this is a group that will help drive policy in the future -- if you look at it from a mathematical point of view, there's a complicated equation and the variables in that equation are as I mentioned cost and performance of the technology. And that's where Argonne would like to come in and say through sustained research, we can continue to improve the cost and continue to improve the performance of the technology.

But a second variable is the cost of petroleum and gasoline, and I don't think we have a lot of control over that, although we could through policy. But that is an extremely important variable and very difficult to predict other than the fact that most experts agree it's going to go up. And the higher it goes up, the more viable an electric infrastructure is.

And then finally, there's the question of policy which as a scientist, I can tell you is a very weak area for me and many of us in the lab. But policy is some combination between sustained funding for research, on connectivity to the industry that the research will enable, in other words enabling places like Argonne or some of the universities represented in the room, to work in a more substantive fashion directly with industry to expedite that R&D to commercial timeline. And then finally, rebates, subsidies, tariffs, et cetera, are all policy moves that can be made to drive the industry towards a faster adoption of the technology.

And then what I'll leave you with is -- and this is, again, as a scientist who spent the first 14 years of my career in industry reporting up through people who were driven by the profit motive, and now for 4.5 years I've worked at Argonne where I report up through essentially

politicians here in D.C. -- a key component is sustained political will, and we don't know what to do about that. We do hear on the Hill in this particular technology area that it's an issue that does bridge across the aisle. And we hope that proves to be true in the near future with the recent election of the fall.

But as fun as this is to work on and as exciting as it is for the scientists, I will tell you for the scientists and engineers that work for me, one thing that's really exciting is that we're working on a problem that's bigger than ourselves. It's not just our career that we're concerned about. And this is what most scientists and engineers from the time we were children hoped we would end up doing, is working on a problem that can have impact on humanity, that's bigger than ourselves as individuals, and that's very exciting for us to be working on.

But this question of political will, sustained political will, hangs over our heads like a guillotine because we don't know, we have no way of predicting. Will the funding be sustained? And we see it around the world, and we're hopeful that that will be the case in the U.S. And we've been encouraged that it will be, but hopefully we can hear some comments from the other panelists on that issue as well as the day progresses.

All right, thank you.

MR. EBINGER: Thank you, Jeff. We now move into the policy arena, hearing from Dr. Kathryn Clay, who is the director of research for the Alliance of Automobile Manufacturers. In this role, Dr. Clay works to develop policy options and recommendations, promoting advanced vehicle technologies and a vision of sustainable mobility. She has a great deal of policy experience, having worked on the professional staff of the Senate Energy and Natural Resources Committee where she played a major role in drafting the provisions related to vehicle and fuels, climate change, and clean energy technologies both in the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007.

Dr. Clay has served in positions with the staff of the Energy Subcommittee of the United States House of Representatives Committee on Science at the Massachusetts Division of Energy Resources, and as a research fellow in the Alternative Fuels Vehicle Division of the Ford Motor Company. Dr. Clay?

DR. CLAY: Great. Thank you very much. It's really wonderful to follow on after Jeff because I had the opportunity to build on so much of his comments. I really agree very wholeheartedly with his characterization of the need for political will in particular and also on the drivers that we're facing.

I want to address a particular question that Jeff raised. When is the right time? And I would submit that automakers believe that the time is now, and that we are acting as an industry and as policymakers in government. Many of us recognize that and are trying to seize that moment. It is not theoretical, but in fact is part of the ongoing discussion that policymakers are having with the industry at this moment in developing the new standards that will come into effect in the 2017 through 2025 period.

The assumptions about penetration, for market penetration, for electric vehicles, electric drive, and hybrid vehicles, including but not limited to grid-enabled vehicles, these are essential assumptions that we're seeing enter into the models that the agencies -- the Environmental Protection Agency and NISA -- are entering into to make their characterizations of what is achievable for fuel economy going forward. So it's not a theoretical question. This is something that is an active part of our policy dialogue that will go into regulations being decided for the MPRM later this year, and that will extend on their impact for the industry going out for the next almost 15 years.

So in light of that current conversation that we're having, automakers are deeply committed to electric-drive vehicles, and I should say that our members, representing twelve major global automakers, are looking at very different vets along that spectrum. For some of our members, they believe that the real sweet spot is the full hybrid, the kind of hybrid that you think of when you think about the Prius. Some of the members think that the pure electric vehicle is ultimately the game changer; others think an extended-range hybrid. And so it's not a question of picking one technology, but really having a portfolio approach and not making a decision at a policy level of which of these should be the winner.

Now the good news is that for many of these different choices, a lot of the enabling technologies and a lot of the research questions we need to address are the same. So

we have that commonality of purpose, and a great deal of it comes down to the batteries. The truth is that in today's market with the battery technology that we have at this moment, we cannot make vehicles that are cost competitive with internal combustion engine vehicles. We need to have the support of incentives to promote early adoption of these vehicles, and that sustained political commitment to maintain those incentives is critical. That's why we were so heartened by the recent remarks from the Administration, indicating that they are planning on supporting the $7,500 tax credit going forward and, in fact, making it easier for that to be a motivator for buyers.

We also were heartened by the continued commitment the Administration signaled for R&D. We recognize that tax incentives are a useful bridge to get into the phase beyond the early adopters to start making inroads into the mass market. But they can only be a bridge toward a sustainable market and to do that, to reach that sustainable market, the key for us is having the batteries that can deliver the cost and a lifetime in performance that we need to make these vehicles attractive to consumers.

Finally, I'd just like to say that automakers believe that we have an important role to play in the development of these vehicles, but we really need to adopt an integrated approach. And what I mean by that is we need to bring in all of the players that have to play a role to make this happen. That includes automakers, of course. It also includes energy providers such as the utility industry and the third parties that will probably emerge to help fill the gap between the production of electricity and making it available for charging, so the producers of charging equipment.

And then finally, we need to engage consumers. That means we have to think about exactly the things that Jeff ended on when he was talking about what it takes for any high-technology product to really achieve market acceptance. It has to perform, and it has to do so at cost. We would like to see a price on gasoline that would make that competitive. We think the other part of the equation is, of course, making the batteries more cost effective, but we have to have a multi-pronged approach, bringing in all stakeholders and automakers are at the table looking forward to helping make this a reality. Thanks.

MR. EBINGER: Thank you, Dr. Clay. As a longstanding supporter of a big

gasoline tax, I like your thinking along those lines.

Reading Atul Kapadia's biography, I must say I think I'm ready to call my stockbroker and fire him and hire a man who obviously has an outstanding track record as an investor and entrepreneur. Mr. Kapadia was the founding investor and is currently the chairman and CEO of Envia Systems, a lithium-ion battery materials company founded on basic Argonne National Laboratory patents related to layered lithium-rich composite structures. In addition, he has been an investor in promising companies, dealing with cancer stem research, and he has a rich history of investments and a host of technologies that have been acquired by some of the biggest information technologies and other technologies in our nation. It's a great pleasure to introduce Mr. Kapadia.

MR. KAPADIA: Thanks very much, Charles. I'm going to hire your stockbroker and give him my portfolio to manage.

Well, it's a real pleasure to be here, and I was a happy venture capitalist until last year when during last summer -- I have a nine-year-old who was looking into the vehicle brochure that came with my BMW. And she looked at it and she said, oh, boy, daddy, did you know that this one gives only 14 miles per gallon? And that was a high moment for me.

I had already invested in a company called Envia Systems three years ago in 2007, founded by Dr. Sujeet Kumar and Mike Sinkula, which worked on cathode material as Dr. Isaacs described earlier. The battery is made up of four key components: Anode, cathode, electrolyte, and separator, and cathode seems to be the one in terms of performance and cost, and I already made the investment in 2007.

That last summer when I had that conversation with my daughter, it was a longer conversation. And she said, well, you're talking about clean tech, and you're driving a BMW. Well, the BMW went last fall, and I became the chairman and CEO of Envia.

Migrating from a venture capital job to an entrepreneurial job is a mighty difficult challenge. First of all, with due respect to Tom, the work hours are different. The compensation is much lesser, but I think this is the right time for us to do this. And the reason I think this is the right time -- I want to put my money where my mouth is: 37 years ago to this date, Henry

Kissinger announced project independence for the U.S. when he said that by 1980 we're going to have energy independence. It didn't happen. We made some progress. We built the Trans-Alaskan Highway pipeline. We changed the speed limits to 55, which are back up to 65 now. But we made some progress, but it really didn't happen. It changed the mindset of a few people. We wanted to make sure that it's never a '73-type crisis again, but we never went all the way. There was the EV1 program at GM that I think someone referred to earlier, which was also cancelled. In one of final speeches that Rick Wagoner, CEO of GM, gave he said that was his biggest regret, which was canceling the EV1 program.

Well, I think that -- to use Secretary Clinton's words from a few days ago -- I think we have reached the perfect storm here, and I think the time is now. And the reason I think we have reached the perfect storm is because if you look at the U.S. Department of Energy, what they say as far as life expectancy of fossil fuel where it's concerned. Whether it's 50 years or 100 years, it's going to end eventually. And we don't wait -- most of us don't wait until the oil -- the gas indicator in our car changes to an orange light, goes down to zero, and shuts off before we go and refuel. We start refueling much in advance to make sure that there's a continual uninterrupted supply. So the fossil fuel supply, whether it changes 50 years from now or 100 years from now or 20 years from now, it will end. And that will create an enormous economic crisis, chaos around the world. And so we want to avoid that.

There is one reason, macro reason, why we want to do this. There are skeptics on both sides of the aisle -- well, at least on one side of the aisle as far as carbon footprints and global warming is concerned. But most of us know the basic facts that there's about 20 billion tons of carbon dioxide emitted by our cars every single year, and only 10 billion of that carbon dioxide is absorbed naturally by natural processes. So that's the second point. And the third point is we all know what's going on in the Middle East as far as oil is concerned. There is 4,500 U.S. lives lost over the last 8 years. And I think the confluence of all these coupled with the fact that today we are spending about 20 million barrels of oil a day; 45 percent of that 20 million barrels of oil goes into cars, and 70 percent of that 20 million barrels of oil goes into the transportation sector. These are huge numbers, lots of lives lost, and there's a lot of confluencing

trends that are coming together and I think this is the right, perfect storm.

Now, some skeptics will say, well, lead acid batteries have a certain energy density and lithium-ion batteries have a certain energy density. We haven't really made a lot of progress in the last 50 years or 70 years as far as battery capacity is concerned. That's absolutely true. We didn't make a lot of progress until the 1960s when Intel Corporation was started as far as silicon was concerned. There was sustained focus, sustainability and a complete domination as far as research and equipment section of that company was concerned. Twenty percent of Intel's revenues went back into R&D every single year, and over the last -- and you guys all have heard of Moore's Law -- 18 months, double the number of transistors. Well, that's exactly what happened in the last 40 years since the late '60s till now. We have mastered the art of silicon and microprocessors, and that exactly I think is where we are, the threshold of where we were in the '60s as far as battery technology is concerned. This is the beginning of the commercialization and massive option of lithium-ion batteries.

Dr. Isaacs is right. There's a thermodynamic limit to how much we can extract out of lithium-ion batteries. There will be follow-on innovations, and we are hoping that Argonne can deliver some of those lithium-air batteries. And there are many other innovations that are coming in the pipeline. But I believe that this is indeed the right time for us to get started on this part of innovation. There will be sustained political will, sustained funding, and sustained focus required by companies, the private sector, and national labs.

As far as Envia is concerned, we are really excited that we just announced a $17 million financing, which is a true indication of a public-private partnership, how it works. Envia started with a $250,000 check from my pocket 3 years ago. There were two guys who were working out of the public library. They used to give that post office box as an office address. We went to Jeff, I think, and tried to license the patents. Jeff said, set up shop and then come back to me. Well, we gave them $250,000.

That was followed by an enormous amount of development thanks to Argonne as far as the cathode idea is concerned, cathode intellectual properties is concerned. Two years into their development cycle, the Envia scientists realized that now they need to make the anode.

Well, there was no money to make the anode. Venture capitalists like me and Tom refused to give them money because we wanted them to have singular focus, and the focus should be on cathode, cathode, cathode. You live and die by the first product in a stock. That's when ARPA-E came back and gave them about $4 million or $5 million with some cost-sharing arrangement. This was a grant to go and develop the anode. That was invaluable, the right amount of help at the right time, so we are very thankful for ARPA-E for that.

And all this work over the last three and a half years, mastering the chemistry and manufacturing around 70 kilograms a day power, eventually reached to General Motors saying, yes, this looks good. We're going to use it in GM's new Chevy Volt. There's still validation left to be done, but early promise is very good.

We also have two other investors, Asahi Kasei and Asahi Glass from Japan, investing with us. Asahi Kasei is the largest manufacturer of battery separators, and Asahi Glass is an existing cathode manufacturing giant in Japan. With that, I'll reiterate that the puck is already here, and we need to get there as soon as possible.

MR. EBINGER: Thank you, Atul. Our next speaker is Dr. Bart Riley who is the co-founder and chief technology officer of A123 Systems. Dr. Riley has more than 20 years of experience in technology development and commercialization in advanced materials and energy industries. He is currently responsible for R&D at A123 Systems and sits on its Board of Directors. Prior to co-founding the company in 2001, Dr. Riley held a number of key technical and management positions at American Superconductor. Dr. Riley?

DR. RILEY: Thank you. It's good to be here. A123 is a player in this emerging electrification of vehicles revolution. We're an MIT spin-off. We were founded in 2001. The VCs at the time gave us a lot of money to work on our first idea, which didn't turn out to work. And we actually had a DOE SBIR that funded a separate side project, and that's the one that ended up working. We'll be receiving an award next week at the White House, being inducted into the SBIR Hall of Fame as it were for essentially this technology, which has helped the company establish a leadership position in this phase.

The technology itself is based on a new cathode material. So yes, it can be

done, framed around a cathode. But A123 chose a different path. We decided to make batteries and systems themselves. We had a big break early on, working with Black & Decker and developing a new product for Black & Decker. They launched a 36-volt line of power tools that allowed more power to come from a cordless power tool than from the corded equivalent, which was a revolution in that space. With that success we launched products into the automotive area with great help from USABC. They gave us some very significant programs, all told about $20 million to take our power tool technology and modify and evolve it into products for both hybrid electric and plug-in hybrid electric vehicles.

At this point in time we're a public company. We went public in 2009. We had about $100 million in sales last year. We have factories in China, and we're a very grateful recipient to some of the federal government's programs to bring jobs to the U.S. And we're opening up a series of factories in Michigan where I'll be flying later today to make sure we're all on track over there. And that's a basic summary.

MR. EBINGER: Very well. It's very exciting. Thank you. Our next speaker is Steve Rosenstock who is manager of Energy Solutions at the Edison Electric Institute. He works with member companies and government agencies on technical applications and studies of en-use equipment such as smart appliances, electric transportation, building and appliance codes and standards, and Internet data centers. He works with managers from national accounts on technical and energy efficiency issues and is responsible for cataloging and benchmarking the efficiency of demand response programs.

MR. ROSENSTOCK: Thank you very much. As we all heard this morning, President Obama has set a goal of having one million electric vehicles on U.S. roads by 2015. I'm happy to say I've been driving one since 2008, a converted Prius with a A123 system. It's working very well, thank you very much, and I think we're all very excited. In fact, the dealer told me that he's done well over a hundred of the conversions in the D.C. area, and I know that -- I think there have been some announcements out, several hundred plug-in hybrids or electric vehicles were sold in December 2010 if you look on the Internet.

So we're very excited about the increase in the usage of electricity for vehicles.

And we'd also like to say electric utilities are ready for electric vehicles. There's a CEO Electric Transportation Task Force that set up workrooms of company experts to work on issues in key areas such as codes and standards, communications, policy, rates, and infrastructure. Just going back, if you -- we actually have a little collection of Thomas Edison materials in our library and there's a picture of Thomas Edison driving one of the first electric vehicles back in the early 1900s. And utilities have been involved for many decades, especially in the 1990s with the resurgence of electric vehicles with EV1 and other manufacturers.

As I like to say, you know, there are -- in terms of policy, we would like to say that we do support the current policies on vehicles infrastructure that have been passed over the last several years. In fact, Senator Stabenow is going to introduce a new bill this week, which will probably increase some of the incentives and policies to further increase the adoption of electric vehicles in the United States.

EEI as an industry has made a pledge that was agreed to in October of 2009 that's on our Web site with five areas of focus to support electric vehicles in terms of infrastructure, customer support, customer and stakeholder education, vehicle infrastructure incentives, and utility fleets. Several utilities have made pledges to convert their fleets, both their light duty as well as their medium- and heavy-duty vehicles -- also known as bucket trucks -- up to alternative fuels as soon as possible.

We've also done -- we also do polling, and we've done something called the "power poll" of consumers. Our last power poll was done in the fourth quarter of 2010, and we got some very interesting results. According to our survey of a thousand consumers in the U.S. in December of 2010, 32 percent said they were somewhat or very likely to purchase an electric vehicle in the next 5 years. You do that timeframe up to 10 years, 53 percent said they were somewhat or very likely to purchase an electric vehicle.

In terms of charging time, it was very interesting. We asked questions about public charging versus private charging, and over 53 percent said that they were okay with charging in their home, taking 1 to 8 hours. So again, they don't mind. People do not mind charging their vehicles overnight as there are issues with quick-charging systems.

In terms of some of the market demand as was discussed, it is interesting. Sometimes I do like to consider myself kind of a history buff. And going back, there are some articles on Yahoo and some others about how the first VCR in the 1960s cost $10,000. A DVD player in 2001 cost you $1,000. If you wanted a plasma TV about 7 years ago, that cost about $10,000. That was at Best Buy. That was on sale at Best Buy. An LCD TV started out about $5,000. And look where we've come in less than 10 years for all those technologies. So as things ramp up and there's more competition, the prices will come down and there will be more market acceptance in my view. It's happened with other advanced technologies. I believe it will happen with plug-in hybrid and all-electric vehicles.

In terms of R&D issues, we're excited about the advances in batteries, not only for vehicles, but also for utility applications. Because as we know, there were over 9,900 megawatts of wind turbines installed in the United States in 2009, and there were 5,100 megawatts of wind installed in 2010. With good energy storage systems located at substations or even further up the grid, those variable energy resources will be more useful for everybody, including for recharging plug-in hybrids and all-electric vehicles.

And, of course, with batteries everyone wants the Holy Grail of lighter weights, longer life cycles, quicker charging, and energy density. And we see -- we're very encouraged by all the advances. And like I said, I think there's not one technology fits all, but with a portfolio of electric batteries and different types of vehicles, we are very encouraged by what we are seeing.

And I'll stop right there. Thank you very much.

MR. EBINGER: Thank you, Steve. Listening to your talk and I think that's great to remind ourselves what's happened, bringing technological prices down. I look forward when I'm in retirement to seeing my electricity bill drop by a factor of 10. But I'm sure Edison Electric Institute can make it happen.

Our next speaker is Brian Wynne, who is the president of the Electric Drive Transportation Association. Mr. Wynne was appointed president of the Electric Drive Transportation Association in April 2004, where he acts as chief staff executive of the member-based international organization, promoting battery, hybrid, plug-in, and fuel-celled vehicles and infrastructure. He

previously served as senior vice president for Business and Trade at the Intelligent Transportation Society of America, and prior to that role, he headed a global technology association as CEO of AIM International, Inc. Currently, Brian serves on the U.S. Department of Energy's Electricity Advisory Committee as a key representative for the electric drive industry. He also serves as president of the World Electric Vehicle Association, an international organization launched in 1990 with the objective of promoting the research, development, and dissemination of electric vehicles on a global scale.

Brian?

MR. WYNNE: Thank you, Charlie.

In 1984, during the presidential nomination run, John Glenn was asked during one of the debates, there was a whole panoply of candidates on the stage, and they were doing the beauty contest question. If you were president, what problem would you fix? And they all went down the line and some people said energy issues, some people talked about Middle East peace, et cetera. It got to John Glenn, who was on the end. He said, batteries, we need better batteries. I think we should have paid attention to John Glenn. This was a guy that floated around outer space in a tin can. Without batteries, he would have been in a lot of trouble getting home.

But I was reminded of that not too long ago by a good friend of mine, and I thought of it when I was looking at this. Energy storage is really, really critical for what we're trying to get done right now, and it's really a privilege to be here with folks from Argonne and entrepreneurs who are working on these technologies, and I really do think there's an amazing convergence that's going on right now.

EDTA is a collaboration that started between the automobile industry and the utility industry 22 years ago. That relationship has kind of waxed and waned over the years, but since 2004, it's gotten very robust and add to that the component manufacturers, including battery manufacturers such as A123. The smart grid people, the charger companies, et cetera, really the entire value chain. Very recently, we've had others joining our happy band that include groups like Hertz Rental Car and Best Buy, which is looking to use its Geek Squad to provide

charging solutions for folks. So, it's a very, very diverse group of folks that are working to electrify transportation and, to my mind, that's a very exciting thought.

Secretary Sandalow talked about the electric drive or the electric vehicle industry. It's more like a community of interest that are coming together to work on these things. We do focus primarily on policy here in Washington, and we recently came out with our new action plan, sort of the next steps that need to be done for moving this forward from where we are, which is a very, very exciting moment in time into the mainstream. We're going to be at that for some time, as we all know, from the forecast or the range of forecast I should say. But I'll just start sort of in declining order from our group or basically from the ground up from the standpoint of the way we've been discussing it today.

We need to continue to work on research and development, and we're very supportive of what's going on in the national labs, particularly in the energy storage arena, but also in terms of power electronics, where you can increase quite a bit of the technology and the lightweighting. We need to lead manufacturing in this country. That's extremely important both from the standpoint of competitiveness which has been touched on, as well as the price points that we're trying to get down into.

We need to reduce market barriers. We've talked about tax credits and making them more flexible so that they can be realized at the point of sale. We need to coordinate regulations and standards. That's no mean feat given the way our utilities are regulated in this country. And, finally, we need to educate consumers, as Kathryn pointed out. Consumers get a vote, too. We're all consumers here. How many people think in terms of cost per mile? Well, I do because I've been driving an electric vehicle for the last two months. By the way, these are really fun cars to drive. I sell cars now. (Laughter)

Seriously, it's amazing, and people follow me in the parking lots asking me questions about the car, and I'm privileged. I've done spur of the moment ride drives in every place from church to the grocery store. The consumer is trained to think in miles per gallon. That doesn't work terribly well with electricity, but so we've got some work to do. So, about two years ago, we started the National Plug-In Vehicle Initiative to put together neutral information to make

it available to consumers so that people would be able to make more informed choices about this.

I just want to close with sort of an aperture, let's step back for just a second and think about this in terms of the economics because I'm a recovering economist. The challenge really is getting over the barriers. Several have spoken to it. My phone app is telling me I'm done now. It's the first time I tried doing this. I won't do it again.

We're talking about batteries because that's the focus of today, that basically we're going to have 80 percent capacity in these batteries at the end of their useful life. That's the target for automobile companies. That means that there's an inherent value to these batteries. So, we're asking people, we're loading the cost of these batteries, but at the end of that battery life, there's 80 percent value. We've talked about energy storage for the grid that's required to leverage intermittent renewables. Okay, you've got utility companies now talking to automobile companies. It's just a matter of time before we start figuring out ways of amortizing that cost over a much longer lifecycle, and the economics of this change very, very rapidly. That's why I'm very convinced that we're making sound investments on the policy side in this country, and in a tight environment just so that I can get out ahead of the justification question, in a tight environment, you really focus on your priorities.

I think several people have pointed out at it. We really can't afford to be this dependent upon on global, fungible commodity any longer. And if you go back, there's a wonderful slide that shows every president back to Eisenhower saying we have to take control of our energy future and reduce our dependence on foreign oil. I think it was at 32 percent when President Eisenhower was in office. Every single president, you see that percentage grow. We have an opportunity to change that now. It's not going to happen immediately, but we've really go to stay the course.

Sorry I went over, Charlie.

MR. EBINGER: Thank you very much. And I might just add because I think it's very relevant here, we've heard a lot of talk about security supply, energy, security, and the role that electric vehicles and other alternative vehicle can do in helping us meet that goal, but having just been at a major international oil and gas conference, it might interest some of you that don't

follow these factors to realize that the oil producers are as concerned about the security of demand, as they call it, they're well aware of what is embarking upon in the west with electric vehicles and other alternatives, and are deeply concerned about the long run how that affects their interests. So, perhaps, there's somewhere along here a meeting of the minds that would benefit everyone.

The format here will be since we have such a wide array of distinguished panelists, I think the best way to do this; I'm going to open with a couple questions that any of the panelists that want to address. I don't think anyone should feel they have to say something if it's not their particular area of expertise, and then when we get to the audience, I think it would be useful if you have a particular question for a particular panelist to address it to that panelist, but if not, throw out your question and we'll see who on the panel feels that they have the most to contribute to your particular question.

We've heard a lot today about how in the State of the Union address last month, President Obama stated that, "With more research and incentives, we can break our dependence on oil and become the first country to have a million electric vehicles on the road by 2015." And in a similar vein in July of last year, the president when he visited the Smith Electric Vehicles Plant in Kansas City, pledged that by 2015, the U.S. would be making 40 percent of the world's advanced batteries from 2 percent in 2009. In response to these two statements, one very famous critic I'll leave unidentified has said that this is not an energy policy, but is a public relations policy. Others have noted that using energy security as a guise for this new industry is really not very useful when you consider that we have roughly 246 million vehicles on the road today. So that even when 1, 2, 3 million down the road, while important certainly in moving us towards the new direction over time, it doesn't do much for energy security say over the next 10 to 15 years.

I was wondering from the perspective of the panelists, whoever would like to address this, what do you see as the principle challenges in effecting the broad goals the president has outlined in these two speeches?

Anybody have a point?

DR. CLAY: All right.

MR. EBINGER: All right.

DR. CLAY: I'll start us off.

So, before I address what the challenges are in meeting that, I want to take a moment and define that challenge. I think it's important for us to realize that electrification of vehicles is an important pillar of our approach going forward, but it is not the only pillar. We're looking at creating a vehicle fleet in the coming decades that is going to be much more technologically diverse than we've seen in the past century. So, in the previous turn of the century, there was really a competition between different kinds of vehicle technologies, and as I think it was Brian who noted that that was, or forgive me, another panelist noted that -- it had a picture of Thomas Edison driving an electric vehicle.

SPEAKER: That was Steve.

DR. CLAY: That was Steve. Great. So, we had a real competition between technologies and we had a clear winner. We saw the internal combustion engine really take the day, and I would submit that we are not going to see a simple replay of that kind of race. We're not going to see one single winner. We're instead going to see a much more diverse field where we have flex-fuel vehicles, we have clean diesel vehicles, that we have electric vehicles, but that will include not just battery electric, but also hydrogen fuel cell vehicles, and we'll probably have several decades of that kind of diversity. So, we have to bear that in mind that when we talk about electric vehicles and electrification, that we don't over-promise because if we over-promise what one technology can deliver, we will end up disenfranchising consumers.

So, having said that though, electric vehicles do have a very important contribution that they will play going forward, and I think we've hit some of the important challenges. I'll recap two of them and then add a third.

The first challenge is continuing to do the R&Ds so we can get the battery cost down without sacrificing performance or lifetime. The second is maintaining a commitment to the financial incentives that will bridge us past the early adopters.

And the third one, and this is an important one that some of the panelists and I

were speaking about before we began, and that is the appropriate attribution of upstream emissions. Dealing in a rational way with the emissions associated with the generation of the electricity so that we don't disadvantage electric vehicles out of the box by making automakers responsible for emissions that occur beyond their control before they even get to the vehicle. If you don't do that, what you end up doing is making electric vehicles and their greenhouse gas ratings only marginally better than the technologies we're trying to displace, and it simply isn't cost effective for automakers to try to embrace a really game-changing expensive technology without a very strong policy incentive to do so and a real delta in greenhouse gas emissions can do that.

MR. EBINGER: Anybody else care to make a comment? Yes, go ahead.

SPEAKER: This is kind of outside my area, but I would just say based on some of the things I've seen for electric generation technologies, I think trade policy is really kind of going to play a huge role in what happens in this. I mean, it would be so wonderful to have 40 or at least 50 or 80 percent of the batteries manufactured and produced in the United States, but as we've seen with free trade and world trade the way it is, there are huge battles going on.

For example, there are lawsuits. I think it was steel workers brought a lawsuit against Chinese manufacturers wind turbines. That's before either the International Trade Commission or the WTO about possibly "dumping wind turbines into the United States' market." There were other stories about solar panels, about how the Chinese manufacturers are producing -- it was 10 percent, and now they're up to about 50 percent of the world's solar panels, and there are similar trade issues. There are probably going to be some lawsuits coming on about that.

We have this conundrum. We want to see the battery prices come down, but on the other hand, if it's all happening overseas, then is that good or bad? Again, that's a political and it's a trade issue. So, I think for this particular question, that could be the biggest challenge in terms of is trade policy really going to dictate what's going to happen in this area?

SPEAKER: Yes, I think everything we've heard today about batteries can also be applied to other aspects of the energy infrastructure. This is not really about batteries; this is about clean energy, and what exists today that didn't exist in the past is our understanding of the

impact of the energy infrastructure on climate, and 20, 30 years ago, not a concern. The good news is that we have made advances in technology along the lines of Moore's laws several people here have mentioned, and that those advances can be applied broadly, they can be applied to creation of energy, the storage of energy to automotive engines to reducing pollution from automotive engines to increasing mileage to biofuels.

So, this is a very, very broad energy infrastructure problem. It's not just about batteries. And the same from the government perspective, the question is: Do we have the will today when we didn't have it before? And that's going to be a function of programs, of policies, all of which have been mentioned so far in one sense or another, but most importantly is the question of leadership, and will our national leadership have the ability to sustain the current emphasis on energy?

For example, will we be able to sustain ARPA-E program is not altogether certain, and this is a fantastic program. It absolutely has filled a void in early stage venture investing for innovative ideas like yours, and it's not altogether certain that ARPA-E is going to be able to continue to exist, and it would be an absolute shame for that to happen. So, my hope is that now that the president has taken the bully pulpit to this issue and to the issue of innovation and entrepreneurialism generally, that that will in fact be sustained into the energy infrastructure.

MR. WYNNE: Yes, I wanted to agree with what Kathryn said, that this is not about electrifying everything. In the initial phases, the objective is sort of anything but oil, and it's going to be extremely important. This is one of the reasons why we changed the name of our organization and our focus away from electric vehicles, this was before me, but in 2002, 2003 to electric drive as a technology. Electric fuel-cell vehicles, of course, or electric drive vehicles, they just create their electricity onboard using hydrogen as the energy carrier. So, my point being that it's a very flexible technology.

To the point about why do we bother with this? Just to focus on the battery EVs or those that plug into the grid because, needless to say, not every single platform, and there are many vehicles in the fleet, battery technology can't be applied to every single one of them at this point, nor will it be appropriate for many applications for a long time.

But to the extent that we can switch, every gallon of gasoline that we move from oil over to electricity, that also is diversifying our fuel structure because we have a very diverse energy mix that we're using for grid, but important to recognize is that that is to an extremely high degree domestic feedstock. So, every time that we shift over, 65 percent of our oil and transportation comes from abroad. Frankly, I don't care if it's Canada, Mexico, or someplace else, it's still not staying here; it's going elsewhere, and it's a global, fungible commodity. We do not control that price. The more we can mitigate that, the more we can shift over to electricity that's coming from a diverse feedstock that is a domestic feedstock, the more we can invest money in our energy future.

MR. EBINGER: Yes?

MR. KAPADIA: I'll try to address the million car question by 2015.

So, there are three main reasons in our focus groups that we find why consumers are not buying electric cars and why automakers are not making sufficient cars today. There's obviously capacity, but capacity problem has been relieved by companies like A123 that have built some plants here, and there is battery production elsewhere in the world, but there are three reasons. One is mileage anxiety, which means hey, I'm going to run out of miles, I'm going to run out of charge, and I'll have to recharge it, and there is not enough recharging stations here. Number two is cost, cost, and cost, which is we have a Chevy Cruze and a Chevy Volt equivalence and there's still a 15-, $20,000 difference as far as value is concerned between the two cars. And the third is safety. It's great to drive a Tesla. Somebody this morning said they drove a Tesla, but you're sitting on a bunch of cobalt, and cobalt is very greatly packed material and it's not exactly very safe.

So, those are the three reasons why consumers are aversion to buy. Why are the automakers not making these cars? Why are they not making a million cars? If there was capacity, if there was capital, why would they not make those cars? Forty percent of electric vehicles/cars' cost today, everybody has their own version of numbers, but I'll give you mine, it comes from batteries. So, if it's a $40,000 car, $16,000 is going to the battery. Forty percent of that goes into the cathode, which is about $7,000. So, cathode is made with lithium, cobalt, and

oxide. Not all the cathode, but, today, the largest shipping cathode in the world is lithium, cobalt, and oxide. Cobalt is very expensive metal. And that's why the costs are so high. Argonne's technology that they developed, that we licensed, and now we call HCMR, high capacity manganese rich. "High capacity" meaning we can drive many more miles than your existing battery, and "manganese rich" implies it's much more cheaper, and that's why GM is really interested in working with Envia.

So, I think that we will probably be one part of the puzzle, the big puzzle that the other panelists are talking about, which is to relieve mileage anxiety by having higher energy density and capacity in the battery and the cathode. Second is cost, by using manganese, which is cheaper, and substituting it for more expensive things like nickel, aluminum, and cobalt. And third is safety. We don't use cobalt as much, and, thus, the batteries are intrinsically more safer.

MR. EBINGER: Thank you, all, very much.

I'm going to hold the other questions that I had prepared because I think it'd be more interesting to hear from the audience, and if time allows, we'll come back to some of the additional questions that we've prepared.

Can we get any questions from the audience? Yes, sir? Again, please identify yourselves. Wait for the mike, please.

MR. GALOS: Again, my name is Alexander Galos. I'm a student at the National Defense University.

I'm writing my thesis on energy security, and I've got a little background in international business at GW, but I've heard all of you. I mean, your experts in the field, and I've heard you talking about producing electric battery-run vehicles for domestic market. But what about producing it for export? When you've got a market in Europe, for example, that's increasingly dependent on Russian gas and it offers a lot more opportunities for electric vehicles or not to have a competition for other choice of vehicles that would be running from other sources of energy. Why do we only focus on production for domestic purposes and not for export?

Thank you.

MR. RILEY: Well, I can start with that. So, at A123, we have a global footprint.

We have manufacturing facilities in China and engineering offices in Europe, as well as the United States and Asia. So, actually, we have customers with some major OEMs in Europe. We have Daimler, we have Volvo, we have BMW, and there's been some great leadership by the European OEMs in terms of green technology both with electric and conventional drives. So, it is. It's a global situation.

I think the point that may come up in other questions later on is China is very aggressive in this space and a very large and rapidly-growing market, and, so, we are spending quite a bit of time in the China area, as well, and formed a joint venture with SAIC to penetrate that market. The Chinese are being very strategic about their national interests there, and are setting up regulatory environments and policy that favor Chinese-based companies and looking to import technology to make the Chinese companies competitive. So, it's something that we feel a very strong force for and something that the U.S.-based efforts should take into account.

MR. CHAMBERLAIN: And I'll take a second just to Echo Bart's comments, particularly in China, that they're incredibly aggressive in their goals, and we've started to recently have a series of discussions, as encouraged from David Sandalow's office from the laboratory perspective. So, not only are they aggressive in trying to adopt technology and create a market for electric vehicles in China, but they're aggressive in trying to capture some of the R&D work going on in the United States to importing to China.

But I'd add to the comments by saying recognize that in Japan, it's a very different situation. A lot of Japanese cars are driven around the world -- and I'd appreciate comment from other folks on the panel here on this, but the automakers are all essentially married to specific battery makers. So, penetrating that supply chain in Japan will be exceedingly difficult as compared to China and in Europe, as well. I agree with Bart on that.

MR. KAPADIA: Well, I think what we are facing right now is a very (inaudible) balance. What you're talking about is exporting batteries from here to abroad. Ninety-five percent of the batteries today are being supplied by Korea, Japan, and China. Even most of the battery materials, as Dr. Isaacs said this morning, cathode was invented by Dr. Goodenough, the lithium battery cathode, and the anode was invented simultaneously at Bell Labs in Grenoble,

Paris, in France. But 95 percent of the batteries today come from abroad, so it's really hard for us to just sort of change it around, flip-flop, and start exporting right away.

I think that at the end of the day, the only thing that's going to win is innovation, innovation, innovation. We have to be ahead of the game. It's going to be exactly like semiconductors, which is the one who innovates, i.e., has the most for the cheapest cost is going to have luxury of some time to set up production plants, manufacturing plants, and start exporting this technology, start exporting these products abroad.

I don't think that this is going to be easy, but I think with generation to generation shift, we'll have to continue to innovate this technology over the next 25, 30 years, and that's the only way we can sort of turn the balance around.

MR. EBINGER: The gentleman with the red tie?

MR. FRIBERG: Lars Friberg, Swedish Office of Science and Innovation, Embassy of Sweden.

Secretary Sandalow mentioned that one of the roles for government beyond supporting research and innovation is standards. I would be interested in hearing Atul's and Bart's comments on would you see a role for -- clearly, governments should not pick which technology, but similar to the role of freight containers in trade, whether or not one could try to move towards having standardized container for the battery across different car technologies because probably your battery in your Nissan is going to be outdated before the car is outdated so that people don't buy into dead-end cars so they can go in for an upgrade. Maybe not going all the way like better place, but at least so that you're able to continuously change your battery as the technology for the batteries evolve.

What do you think about this idea?

MR. KAPADIA: I think it's really premature right now as far as standards are concerned because, as Jeff was alluding to, each car manufacturer finds the battery to be mission critical component of that car as far as EVs and PHEDs are concerned. So, what they want is they want a complete control in the supply chain in the way the battery is made. The battery is an integral part of the system. It's not a commodity right now like the lead acid battery

has been for the last many years. Once the technology stabilizes, and, right now, when we talk about lithium ion, we're still talking about a thermodynamic limit in some multiple hundred watt hour per kilogram. Once the technology stabilizes a little bit, I think the standards will start to emerge automatically for cost reduction and mass production, but I think right now, we are very embryonic stages of innovation and productization. I'd love to hear Bart's comments.

MR. RILEY: So, I have a couple of observations based on meeting with the customers who were the various OEMs, and, so far, it's been a little bit of a group grope. Everybody's kind of trying to find the particular solution that works for them with the constraints of the technology that's available. So, in that sense, I'm in agreement that the technology is not quite mature.

But there are some standards, efforts that are emerging. For EVs, people are looking at putting batteries under the car, which might be amendable to a certain cell size because you want to have a certain thickness under the car. There's an effort in Europe through VDA, which is like the European version of SAE, to standardize cell terminals, locations so that it'll drive down cost at the engineering and integration level.

And then, finally, there's actually an interesting opportunity that is actually pretty uniquely aligned with our chemistry as opposed to cobalt or some others with respect to drop in replacements for starter batteries. It turns out that lead acid is a mature technology and some standard characteristics to it, and there's a nice drop in opportunity for advanced lithium ion to give improved performance over life. So, I think it's probably a little bit of a spectrum. In some cases, it's premature, in some cases, there's some efforts starting now, and in some cases, there's looking like a drop in.

DR. CLAY: And maybe I can add quickly. So, just to underscore the point that we are too early for that part of the conversation about standardizing the battery pack, if you look within one of OEM's offerings of different kinds of hybrids, it's not even standardized within one OEM, so, trying to get standardization across the industry is a whole function beyond where we can think about today, and I think we're much more likely to see a progression in standardization, as Bart was alluding to, of the cells, and then move on to standardization of modules before we

can start thinking about the pack configuration.

MR. KAPADIA: I'll actually take that even a step further. Even within the Nissan Leaf there are two different types of cells. So, I have some pictures on my iPhone if you want to look at them. (Laughter)

MR. EBINGER: Yes, sir?

MR. SANG: James Sang. Take Riley's comment about dropping batteries and his history of A123's involvement with Black & Decker and Sandalow's comment about Chinese motorcycles reminds one of Clayton Christiansen's comment that new technologies really need to find niches because they're usually not as good. And, so, obviously, there are niches in vehicles, but what other kinds of niches are there that could allow you guys to make some money and develop the technology rather than wait for the 200-mile car to show up, battery to show up.

MR. RILEY: I think that's for me. So, where can we make some money? So, it's fun being at a battery company because everybody wants a better battery. I think that was said earlier. John Glenn, I guess, said it. But it's true that everybody wants a better portable storage capability.

We had one meeting with Mattel, the toy company, and they had some advanced remote-controlled toys, and I had formed the CTO-to-CTO connection, and my son was quite pleased by that because in the mail to us came the next generation toys for us to play around with. So, you can kind of go anywhere with it.

This is very niche-y, but we delivered the highest powered density lithium ion cells, yet produce, we delivered to the McLaren F1 Team had a power density of 20,000 watts per kilogram. For those of you who know numbers, know that that's a whopping power density. So, that's small and niche-y. It was very useful from a business perspective because it got us into the door with Daimler, where we now have actually a pretty broad base of business across some of their truck areas and car areas. So, it does. It can start with the small, niche-y thing.

I guess the last is the grid area, where we have essentially a semi tractor-trailer that's a hybrid electric battery at the grid level. It has 2 megawatts of power capability, and we have a number of units down in Chile at the end of a long transmission run to assure power quality for a

lithium mining operation, believe it or not. So, we're out there prospecting and seeing what interesting opportunities pop up, but basically consistent with this basic strategy we have of going after industrial transportation and grid in terms of the main market areas.

SPEAKER: And, Bart, if I could add to that, and correct me if I'm wrong, but at A123 and at Enterdill, and I think to a lesser extent Johnson Controls, your capitalizing on your existing cell and module manufacturing skills or style, is that correct, in terms of --

MR. RILEY: Right.

SPEAKER: -- moving from transportation to the grid?

MR. RILEY: Right. So, what you have is you're developing the next thing and, so, that 2 megawatt semi tractor-trailer HEV battery for the grid has 80,000 power tool cells in it. So, it's not the optimal cell design for that application, but it's what we had, and it was a good way to enter the market quickly.

SPEAKER: (inaudible) market are there any niche vehicles? Any kind of niche vehicles that (inaudible)?

SPEAKER: Well, I think in --

MR. RILEY: Well, F1 is pretty niche. Does anybody here have an F1 car? (Laughter)

SPEAKER: Well, I think in China, there's the big application now is in buses. And there's a lot of investment in that infrastructure. Of course, from what I've heard, they have 200 lithium ion battery companies to support it. So, the niches are going to be there, and they're not very good, but they're good enough, and they'll get a lot better.

MR. RILEY: I do have an additional comment, and that is the importance of heavy-duty truck and bus to jumpstarting electrification in vehicles cannot be understated. Our largest revenue customer last year was BAE, and they make hybrid electric propulsion systems for buses. So, we have about 3,000 buses now worldwide with lithium ion batteries in them, and if you're in New York City, the buses that hang out at 106 and Broadway all have A123 batteries on their roof. So, it's happening, but more through the heavy-duty than it is through niche cars, I'd say.

MR. EBINGER: Bart, could you make a comment on what would be the advantages of an electrified bus as opposed to a bus running on CNG, which we have a lot here in the Washington area.

MR. RILEY: Well, I guess just take a step back and look at the value of electrification. There's really two kind of applications. One is really I guess efficiency. So, regenerative braking, start, stop, things like that is one element, and the other basic benefit of electrification is it doesn't matter what the power source is if you can convert it into electricity, you can store it as electricity.

So, it can be coal, whatever, nuclear whatever, so, it gives you a lot of flexibility from that perspective. But from an applications point of view, it's really the hybrid truck and bus that's emerging as an important one because if you want to think about it, the perfect application for hybrid vehicles is a garbage truck because it's stopping so frequently or a bus for that matter. It's stopping, it's starting so frequently that it's a huge efficiency boom, and there's actually a lot of government regulation to support that in terms of subsidizing the excess cost of the hybrid systems with the net over ownership costs that spills out to the communities that use them.

MR. EBINGER: Before moving on, I just want to note hearing Bart talk about his children and getting all these advanced toys, that those of you old enough to remember the toy cap pistols when we were all little kids playing westerns, my father was the chief lawyer for the manufacturers of all the cowboy guns, so, I always got the newest ones on the shelf, too. (Laughter) I guess we've just gone a couple (inaudible).

I have a lady in the back.

MS. LLOYD-GEORGE: Hi, my name is Alice Lloyd-George, and I'm a junior guest researcher at Brookings, looking into the clean energy markets in China. You've all touched on what's going on with the dynamic there, but I was wondering if you could just talk a little bit more about the changes in the sort of value chain shifting to China. There's a lot of clean energy companies shifting their R&D bases to China now. Is that going to be happening in the battery field? And can you talk a bit about the financing models of the U.S. versus China? How can the U.S. compete with a state-owned enterprise as you're getting more and more involved in

these new technologies?

MR. KAPADIA: I'll just give you from personal experience, we have most of our cathode manufacturing happening in Newark, California, but we also wanted to set up a prototype cell development facility. So, we had two options: One was to set it up in China, and one was to set it up in the U.S. The bill was $18 million to set it up in the U.S., $650,000 to set it up in China, number one.

Number two is at the end of last year, like every company goes through; we went through our annual merit raises, right? And I got a budget from my finance guy saying, hey, this is the budget for the U.S. It was around $150,000. And then I got another spreadsheet from my China guy, GM in China, and it looked like 77,833, something like that. I said that's pretty steep. Same head count, but I thought the pays were less, $77,000 versus $150,000. Well, that was not dollars, that was Yuan, so, it was divided by eight.

So, the cost of setting up things in China is so much cheaper, at least for prototypes. It's very hard for a private enterprise to justify setting it up here except for the fact that most of these prototypes have to be close to R&D so that the R&D and prototyping guys can work very closely together to optimize the product. I'm sure Bart can talk a bit more about manufacturing costs.

MR. RILEY: Yes, so, I guess I don't have time to tell the whole A123 story, but the simple summary is that we built our first manufacturing capability in China in part because of its low cost and the VCs don't like owning factories. So, they didn't want to give us a lot of money for U.S.-based operations to begin with. But really as importantly or more importantly, the speed to market, it's dramatic in China. You can go from a green field to a qualified production capability in less than a year, whereas it's two or three years in the United States.

So, there are great business benefits that are obvious on cost and timing. The problem is the high leakage rate of intellectual property. There's very high turnover in head count over there. The culture of secrets is very different. There is no culture of secrets in the private sector. (Laughter) And, so, you really want to be strategic about how you properly surf China, and I think that's really the challenge for any U.S.-based organization. It's such a big entity in

terms of its market size and its ability to get things done that you have to find a way to work in China, but you need to do it so you don't give away your business.

MR. EBINGER: If I may comment?

SPEAKER: Just a quick comment. And somebody said it earlier. I don't know if was you, Dr. Isaacs, but the point about manufacturing, advanced manufacturing part, you might want to respond to this, but a lot of what's happening in China is not necessarily advanced manufacturing. The advantage in China is the labor cost. So, one of the reasons that I think it's so important for us to stay focused here and keep our political will high on this is innovation is going to follow the market. That's not my line. But take it on for a second. If we continue to build our market here, the Chinese are very aggressive about electric transportation, and I think that's great. I commend them for that. We want them to be successful with electric transportation. We want them to electrify as much of their transportation as they can for reasons that have to do with shared environmental storage shift. But we need to continue to build our market here, and I made the point earlier, we really want to lead in manufacturing.

A lot of this manufacturing for large format lithium ion batteries, whether it's China or here, is Greenfield because it's advanced manufacturing techniques that are required. The automotive industry requires a high degree of quality and the word's failing me. The batteries have to be the same. You're going to package up a bunch of big, large-format batteries; they need to operate the same so that you can regulate them properly. So, the quality of those batteries is extremely important.

MR. EBINGER: Let me, if I may, just throw in a question here, and I think Dr. Clay and others may react to. Recently at Deloitte Consulting Company, that canvas industry experts and potential buyers of electric vehicles, found that from now until 2020 only, and I quote, "Young, very high-income individuals," those from households making more than $200,000 a year, would be interested in plug-in hybrids or all electric cars. This small number of people, according to Deloitte, will provide nowhere near the volume needed for mass adoption. One critic has even gone further, asking where does the federal government get off spending the average person's tax dollars to help better off than average Americans buy expensive new cars?

I guess the question that emerges here, in spurring innovation and commercialization of vehicle electrification, what is the right role for government, particularly vis-à-vis industry, academia, the financial community and other stakeholders to disseminate this new technology?

DR. CLAY: Well, it's a good question. There are a lot of threads to that question. I'll try to take on at least a couple of them.

So, first, I think the equity question. So, the question about why we should be subsidizing what are today very expensive vehicles for high-income buyers, and I think that we have to recognize that we are trying to initiate a transition, and if we take the long view, we know where we want to go. We want to get to a world where we have electric vehicles that are accessible to the mass market, to a wide range of consumers, but as we've heard alluded to earlier, that is not the way that new technologies commonly enter the market where they're ready to come to the masses immediately. We also should recognize that these tax incentives that we have today do not bear the full cost of the increment between a comparable internal combustion engine vehicle and the electric vehicle. So, those high-income buyers are already bearing part of that load. We're not completely transferring head on to the government, onto taxpayers.

It's really I think, again, coming back to the long view, if we keep in mind where we want to go and we recognize that we are trying to capture a public good and fit it into the private industry, so, automakers, in the absence of greenhouse gas regulations and the absence of market signals to incentive us to address energy security, we cannot do so. We need to have the government help us bring those public goods into the cost and pricing of energy and if we can't do it directly thorough a gas tax, which is the cleanest, most elegant way to do it, then we have to do it through incentive programs and the like, and it's not a perfect system, but it reminds me of what they say about democracy, right? It's not the perfect system, but it's better than all the alternatives. So, I think that's where we are.

MR. EBINGER: Anybody else have a comment? Yes?

SPEAKER: Yes, I think the point is that the clean energy market is the next great market, and for the U.S. to compete in that market, we have to leverage what we do well, and

what we do well is we know how to innovate and we have a cadre of very experienced, competent, technology entrepreneurs, and we have to leverage that capability to enable us to participate in the clean energy market, and that includes not only research programs such as RPE, but it includes all the concomitant policies, it includes things like improved pre-K through 12 education, it involves immigration policy, it involves support of research at universities. The university system in the U.S. is absolutely the premiere system in the world, but it isn't always going to be, and we have to continue to support that university system because, as somebody mentioned earlier, the industrial research activity is pretty well gone. Bell Labs, HP Labs, Sun Labs, there's no more, and, so, the universities are a primary source of science.

I look at our industry and venture capitalists, we're the midwives of innovation in that we bring together research with entrepreneurial people who can create companies that are competitive on a global basis, and that's the story. I think the market, as we see more and more renewable energy standards being in place, legislated by the states, 20, 30 percent, as much as 50 percent in Alaska, surprisingly, we're going to see changes in the energy infrastructure to accommodate these renewable energy standards which I think will involve investment opportunities of up to $1 trillion a year in the near-term future. That's the impact on infrastructure, of what's happening with RES, and RES is not going to go away, not withstanding the fact that there's nothing happening on the federal landscape. It is happening in the states and it is happening in Europe, and surprisingly, it's even happening in China.

MR. EBINGER: Thank you. Yes?

SPEAKER: With all due respect to the Deloitte quote, a study that we just did doesn't show that at all. If only that niche market of people making over $200,000 a year were interested, our numbers would say. Our numbers show like anywhere from 30 to 50 percent of people interested in electric vehicles. Now, that's interest, not the actual purchase, obviously. But, still, I'm not sure how they did their study. I have some issues. I'd like to see how they did some of their research there.

And in terms of some of the roles. I think there are a lot of parties aligned, and I think we just have to look back the hybrid vehicle tax credit that started as a result of EPAct of

2005. It was 60,000 vehicles per manufacturer with a phase out period, and that tax credit didn't run out actually until last December 31, 2010. So, it ran out, but the market is self-sustaining, and, yes, there is a proper role, and, again, some people might want to think there can't be a certain catalyst time for some of these incentives, but, again, once you know the market is self-sustaining, then you know it was a success.

MR. EBINGER: Okay. Okay, that's fine. Go ahead.

MS. LLOYD-GEORGE: I've already asked a question.

MR. EBINGER: Yes, could you ask the gentleman in the white shirt there?

MR. GECAN: Hi, I'm Ron Gecan of the Congressional Budget Office.

I'd like to ask a question you've probably heard before, and it is the National Academy study of about a year ago, that honestly was very pessimistic on the prospect for vehicle uptake because the battery costs were very high, and they did not believe that such costs would decline significantly enough for decades.

I'm just wondering what comments you would have on that. How do you respond to those questions and that observation?

MR. RILEY: Well, certainly, the Academy made those statements, but I think you'd recognize very controversial. Many of the scientists and engineers got up and including some of the key and best modelers in the country at Argonne put forth different cost figures for projected costs when full volume is achieved in terms of manufacturing batteries. But I would defer to Kathryn to respond to that in terms of what the automobile manufacturers have in their own estimates for costs that are projected from what we hear privately from the automakers, and I think they even made some public statements during that debate after the Academy report came out, and I don't know if you can comment on that, Kathryn.

DR. CLAY: Well, actually, I think I probably shouldn't comment on prices too much. Maybe what I can say is that the automakers broadly agree on the kind of goal of about $300 per kilowatt hour, and maybe Bart can comment a little more on what your customers are asking you to produce in the long-term. We're not there yet. We have a long way to go.

The other thing will follow on Jeff's comment to say that we have to all be very

careful when we're talking about battery costs because it's very easy to accidentally compare apples and oranges. So, when you talk about costs, do you mean the costs to manufacture, do you mean the retail costs, do you mean the cost of the cells, or of the aggregate, integrated battery pack? And, so, the devil is really in the details. So, the discussion of battery cost can get very muddy very quickly.

MR. RILEY: I'll make some general statements. First of all, the rate at which costs are dropping right now, the lithium ion area is dramatic. It's sparked a bit by a sense of the technology works, it's real, every OEM is launching multiple programs into this space. There's a lot of competition between the cell and system providers to capture that share. The Koreans are particularly aggressive, we're aggressive, Japanese, Chinese, other players. And the costs have come down and they're now lower than what was indicated as future pricing in that report.

So, it is a very pessimistic report, it's not at all what we see in the real business that's going on right now, and although the automotive have communicated a cost for energy-based systems of $300 per kilowatt hour at the systems level, we're not there yet. But we have a pathway there. We have a technology roadmap. There are things, new technologies, some of which are represented here, that we're looking at to incorporate into our next generation batteries, and I'm quite confident that, over time, the question is how fast that we'll get to where we need to to broadly enable the electrification.

SPEAKER: I've seen projections of cost in technology products in the last 30 to 40 years that are pessimistic like that, and who would have predicted that the cost of processing power and semiconductor integrated circuits would be as low as it is now? Who would have predicted that this flat panel display screens could be as cheap as they are now? Who could have predicted that computer semiconductor memories and other memory products would be as cheap as they are now?

And most importantly, for example, in 2000, we sequence the first genome that cost $3 billion. Today, you can sequence a genome for $50,000, and within a very short period, it's going to be $1,000, and maybe even less than that. This is the power of exponential technologies.

MR. RILEY: And before you ask your follow-on question, I'll give you one more level of detail. Kathryn mentioned the $300 per kilowatt hour goal, and if I remember correctly, the Academy was saying that there's no way we could get below $1,000 roughly per kilowatt hour. But the report I would encourage you to read I believe has been published by Nelson Santini and Gallagher at Argonne who are well-respected in the field of modeling in terms of ultimate costs. They predict that with known technology today, materials that are already being produced at full scale manufacturing, batteries will be down to about $500 per kilowatt hour, and that is aligned with what we hear from the vehicle industry, and that does not include innovations, some of which these companies here today are commercializing now. So, the prediction is that report is, at best, controversial.

SPEAKER: I think the thing to bear in mind about that report, too, was that what got play was the low end, which was, I think, $15 million. What was the year? 2030? Somebody who's got a better memory than me. The high end was $40 million. So, it goes to the question of the range of how many vehicles could be on the market when you adjust that assumption.

The other assumption that's a really big assumption here and affects the modeling, of course, is the price of gasoline, which we have agreed that we're not going to try and control.

MR. EBINGER: The gentleman in the corner.

MR. DRAKE: My name is Alex Drake. I'm with Wellford Energy Advisors.

And this is primarily for Dr. Clay, but I'd love to get anyone else's thoughts. You said it's important that we don't pick winners, and, yet, I would argue that the ATVM program does just that with their loan guarantees, and isn't that a big reason why the Volt was able to get to market today?

MR. RILEY: Is that for me?

MR. EBINGER: Whoever cares to take it on.

SPEAKER: He said Dr. Clay.

DR. CLAY: Okay.

SPEAKER: Sorry.

DR. CLAY: Well, so, thank you for the question. I think yes, I mean, loan guarantees, they're an important tool. We are glad that the Department of Energy had -- it's a relatively new tool for the Department of Energy. It was given in one of the energy policy acts. And it's helped GM with the Volt, it's helped several of the other automakers that received loans under the Advanced Vehicle Technology Program that was in 2007 bill. So, several automakers have received generous loans or loan guarantees from the department, and it's an important tool for the government to help us make the transition to these advanced technologies and get them into the marketplace.

MR. EBINGER: I think we had a question in the back.

MR. CHAMBERLAIN: There's one other thing --

MR. EBINGER: Go ahead.

MR. CHAMBERLAIN: -- I would add on to that before we move on if you have a second, and I don't speak for the government. I work for a government-owned contractor operated facility, but it's a very good question. I can tell you from our perspective even when we invent something and go license it, we still have to answer that fundamental question because we are picking winners by even licensing the technology. And I guess my short answer is there's almost no way to avoid that and still enable the industry to thrive.

MR. KAPADIA: I agree with Jeff on that, specifically if you look at ARPA-E and the grants that were awarded to Envia Systems. We have a quarterly meeting of the ARPA-E scientists and team comes and visits Envia Systems for a brief rundown on what the annual development is, and the kind of questions these guys ask from ARPA-E, they are so intense, and they go head to head against my scientists, and that is really refreshing to see. The reason it's refreshing to see is because of Jeff said, which is you have to pick a winner, and I'm glad that ARPA-E is picking winners on that side of the aisle because they are so qualified in my opinion to pick those winners. Self-serving, of course, because we were picked.

DR. CLAY: And, also, just to clarify, just to add one more comment about the picking winners and losers, I think that we have to bear in mind that it's a portfolio approach, right? So, if you look at one particular incentive or one particular loan guarantee, it always looks

like in that instance you picked a winner, but the important thing is that the government policy overall is investing broadly in different technologies, and I think that this administration and in the previous administration really have done that. They've invested in biofuels, we've got very exciting work in biofuels going on in some of the Department of Energy laboratories and continuing to work on the traditional internal combustion engine. So, if it's a portfolio approach, I think that's how we get away from the winner and loser predicament.

MR. CHAMBERLAIN: In fact, I'll add one more level of granularity to that in that even if you dig down into the battery space and look at the $2.4 billion in grants that were awarded to establish battery manufacturing plants in the U.S. A123, you've got a good one, second largest, I think. It's Dalcocum, A123, Enterdill, Johnson Controls Insurance, and LG Chem. And if you look down into the details of the materials that are going in those batteries, I don't know whether this was intentional or not, but DOE spread its bet across a variety of technologies, I think in part to avoid picking winners before the merge which would the winning technologies.

MR. EBINGER: Yes, ma'am?

MS. CRESPO: Jackie Crespo, Cassidy and Associates.

In talking about getting to that $300 per kilowatt goal, what do we think in terms of the future and financing gaps for commercialization of these advanced battery technologies? I understand we have ARPA-E, we talked about increasing R&D monies, but there is a gap between that and the new loan guarantee program that wants shovel-ready projects. There is this commercialization gap, and for folks like Atul and Thomas who are very much in the venture weeds, so to speak, what do you see as your plan for commercialization and is there a way maybe to facilitate strategic investments from automobile manufacturers?

MR. KAPADIA: That's an absolutely great question. This is exactly what we are dealing with nowadays, which is we have technology that has been proven as far as pilot vehicles are concerned. GM has tried it out, they have come back to us and said we are willing to take the next step with you if you build a pilot plant of sufficient capacity. DOE is not going to give us money to build a pilot plant.

So, what are the different avenues we can do, right? One is we can go and raise venture money. Tom here knows very well and I know, too, that when you raise venture money, you have to return 10X the amount of money that you just raised, and venture capitalists, as Mark pointed out, don't like to give money for manufacturing.

Second is we can take debt. There are now banks who are willing to give us debt because of the enormity of the market size. Again, you have to return that money, and that debt is layered on top of all the equities. So, it's very difficult for us to justify that.

Third is somewhat of what we did, which is we took money from (inaudible) as I mentioned before, who could be potential manufacturing partners, who could be potential business development partners. We did not sign any exclusive contracts with them for the longer-term, but what we did is we took their money and we gave them a seat on the table and we said keep observing us, and if at some point of time it's interesting enough, let us know if you'd like to manufacture it. Well, also, let me tell you this. If you'd like to manufacture it, you won't be the exclusive party on the table. I'm going to line up all the rest of the manufacturing parties and they're going to make a bidding war, and rather than do a joint venture, I'd rather do a contract service as manufacturing relationship with these guys.

So, there's a variety of structures we can look at.

There's another one, which is this is not a proposal, but companies like Bart's, who are much more mature as far as their lifecycle is concerned than companies like us, with less than 30 people, we could marry and work together on providing these novel solutions.

So, these are all the different -- none of this is an ideal solution, but maybe they'll be a hybrid of one or two solutions. And I think by the end of the year, I think the writing will be on the wall.

Also, just one more point on the cost. The 300 kilowatt, I think that's very achievable goal, and I think it's achievable in the next 24 months. That's my only comment right now.

SPEAKER: Yes, the fact is we won't invest in a company unless we believe that the platform is robust enough to enable a company to form industrial collaborations.

So, for example, there's a company called Intermolecular, which is in our portfolio. Intermolecular has relationships with three of the major semiconductor memory companies which account for more than 50 percent of the semiconductor solid-state memory market. And to us, that's an indicator that there's a customer out there who believes, and without that kind of customer intimacy, we don't believe that a platform is big enough to be monetized. And so, generally, those kind of collaborations have to come before any substantial government money. The early government money or the ARPA-E money, is really more research and development money, it's very high-risk money, and ARPA-E recognizes that, and I absolutely agree with everything my colleague here said. And they are an extraordinary group of people.

MR. EBINGER: Yes?

MR. RILEY: Just a couple of comments. One is, Atul, I'll have to talk with you afterwards about that non-proposal. (Laughter) But there is actually through U.S. Department of Energy and the U.S. ABC, there is actually a pot of money that's for so-called product development. So, it's lower risk horizon. A significant cost share, 50 percent cost share is required from the participant. Twenty percent. Anyway, it's a significant cost share requirement from the company that's meant as both an incentive to somebody not in the automotive game to get into the automotive game, which is how we used it in the beginning and also an accelerant in terms of pulling technology into products that are specific to the transportation industry. So, it's been quite a successful program for us.

MR. EBINGER: Well, I'm sorry. We're at the witching hour. So, I'm sorry any questions that didn't get answered, but I think the intensity of the audience's questions and the excellent responses from our panel indicate that we all had a very good session here today.

I want to thank Dr. Isaacs, all our panelists, your staff at Argonne, and the staff from Brookings for making this event very successful. This is part of an ongoing series Brookings has on, for lack of a better term, we call game-changing energy technologies, so, we'll make sure that everyone attending today will be notified of future events.

Thank you, all, very much. (Applause)

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