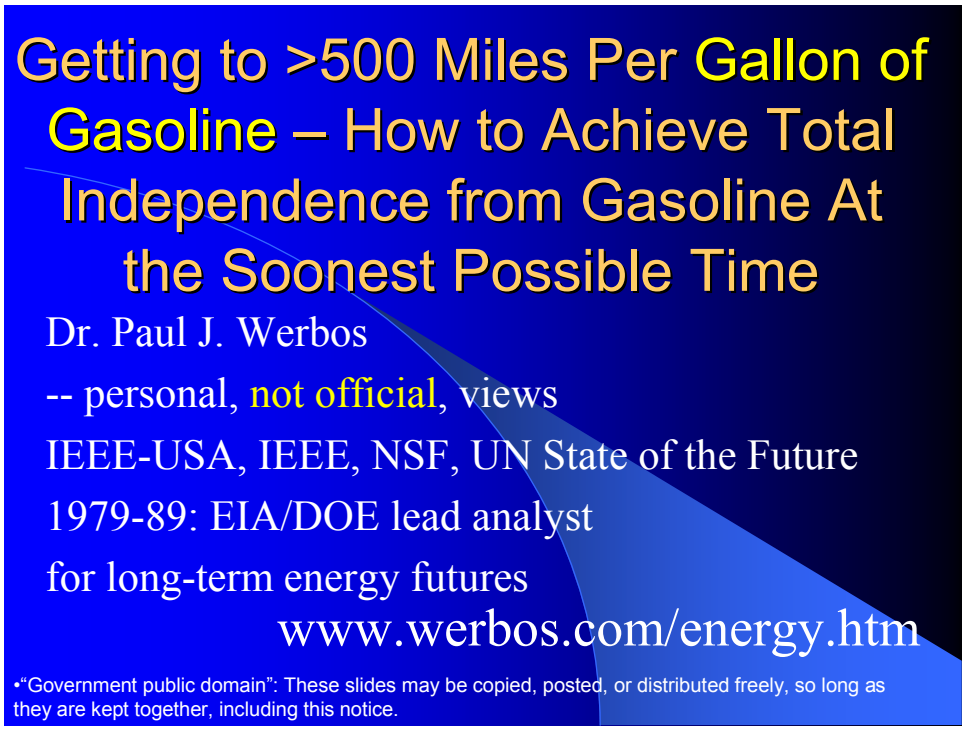
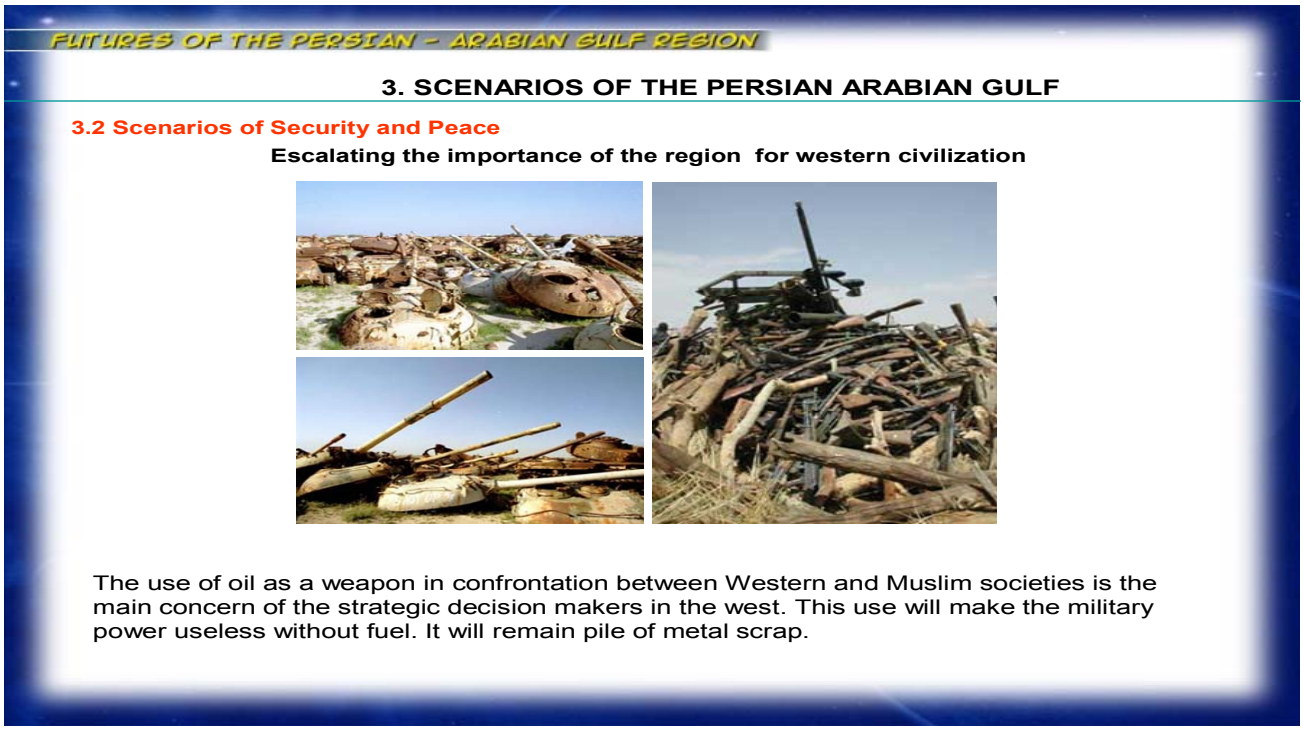


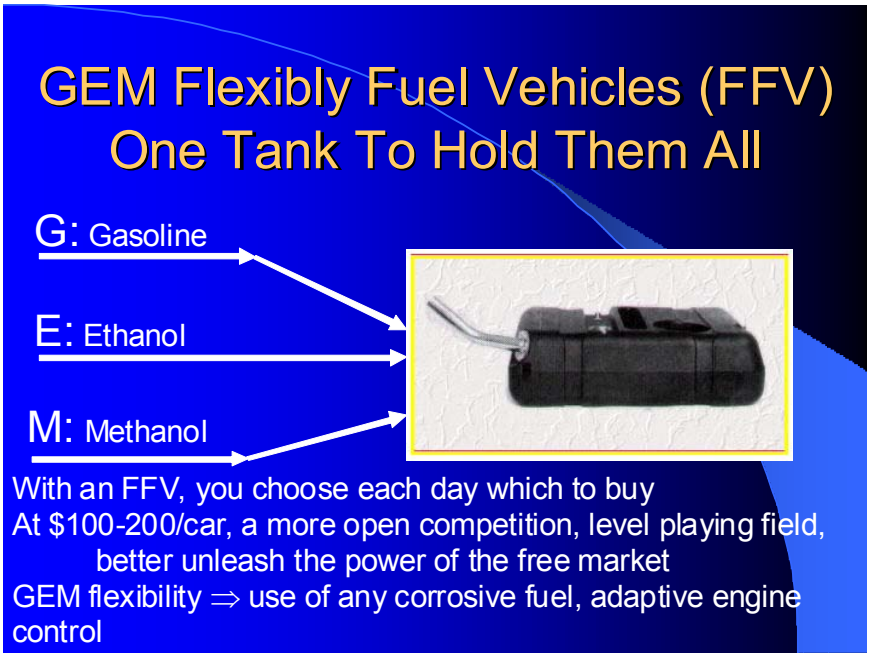
Good afternoon! To begin with, I would like to thank Anne **Korin** and you all for bringing us here to start taking action on a matter of life and death for the entire world. Anne has asked me to talk about how to get cars which can get 500 miles per gallon *of gasoline* -but the truth is that we can do better than that. China has already begun to mass market new types of cars, available *this year*, which make it possible to drive long distances without sacrificing anything, and without using any gasoline at all. The US can do the same.

Since time is limited, and we are dealing with a matter of life and death, I will skip over most of the history **and the larger context**, and go directly to the question of the day. But there are two preliminary points I do need to stress. First, these are my personal views, and not the official views of the US government. Second, if you are skeptical – as you should be – you can find the details and the history at my web site, www.werbos.com/energy.htm.

The question we are facing here is very simple: how can we Americans become totally independent of gasoline *as soon as possible?* How can we reach a state of *energy security,* where we could keep driving our cars to work and to stores even if our access to gasoline were totally cut off or if we simply could not afford to pay for gasoline any more? **We need to remember to keep coming back to these basic questions, whenever people distract us with glowing and persuasive stories about the wonders of their own vested interest; the energy field is full of such stories.**



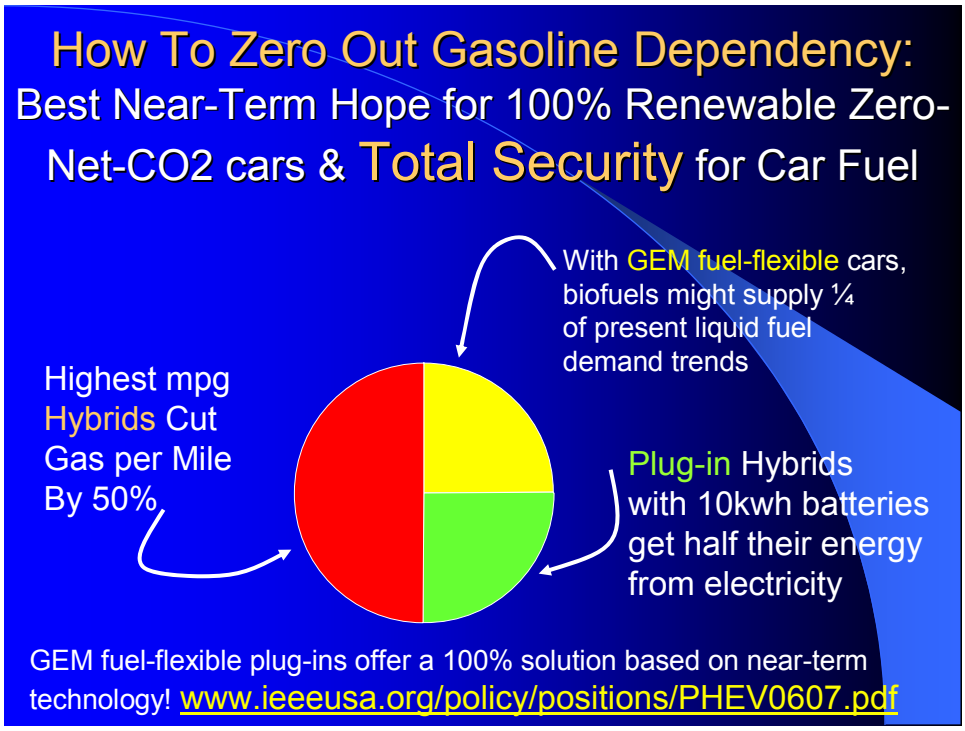
Many people will tell you that we should not ask such bold questions. They tell us we should just keep making minor tweaks to the automobile here and there, small improvements, so that they can keep bleeding us to death forever. But in the world today, that has become a very, very risky strategy – risky for national security, and risky for the very survival of our economy**, especially if you look ahead 10 to 20 years, like the guy who put this slide together. (Ismail Al-Shatti; see my web site for more details.)** The only way that we can become truly independent of gasoline is to buy cars, as soon as possible, which let us get to work and to stores without needing any gasoline. The good news is that we really can do this, in just a few years, using two types of new technology. We don't have wait, and we can't afford to wait.



The first of these technologies is something I call "GEM fuel flexibility." You have all heard about cars which let you shift back and forth between gasoline fuel and ethanol fuel. But there is *third* very important fuel called *methanol*, which I will talk more about. In the 1980's, Ford sold thousands of cars capable of switching between ethanol, methanol and gasoline, without damaging the engine or anything else. The technology has become cheaper and more available, and we can use it today.

The second of these technologies is called the "plug in hybrid car" or "PHEV." The plug-in hybrid is simply a state-of-the-art hybrid car with a bigger battery and a plug added. This is a picture of an actual plug-in Toyota Prius, operating several years ago. The car can still drive hundreds of miles using gasoline, but this Prius has a battery so big that it can go for twenty miles just on the battery. The plug lets you recharge it in your garage or in recharge sockets in other places, if you can find them.

It turns out that these two new technologies *fit together easily*. When we build a plug-in hybrid car, it's easy enough to give it full GEM fuel flexibility. That leads directly to the full strategy:

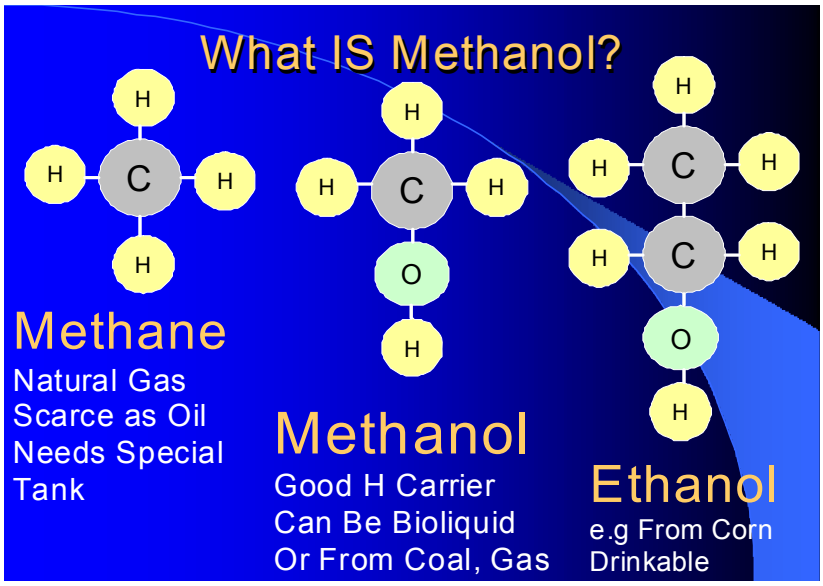


What we need to do, very simply, is to get GEM-flexible plug-in hybrid cars on the road in the largest possible numbers as soon as we can, as efficiently as we can. That's our nearest term option for *total* independence from gasoline, as you can see on this pie chart. This pie chart is basically just a picture version of a longer technical white paper approved this past year by IEEE, the world's largest engineering society. It went through very extensive technical review, at many levels of the society. The basic idea here is that we can already get rid of half of our gasoline use by using efficient hybrid cars like the Prius. We can get rid of half of our remaining gasoline use, even without changing our driving habits, by adding the battery and the plug. At that point, our need for liquid fuels is so low that we can meet it by using *existing technology* to convert *nonfood biomass* – like wood chips or grasses – into wood alcohol or other liquid fuels – *not limiting it to ethanol*. That's enough. You can see the IEEE white paper by going to this web site, or, if you can't remember it, by going to my web site and following the link.

Notice that no one is asking you to give up *using* gasoline yet, so long as you can afford it and it's available. But if you have a car like this, you would be able to give up gasoline in a week if you suddenly had to. The extra electricity would cost you less than $1 per gallon of gasoline equivalent, and there is no problem in supplying it, even with today's electric power grid – but that's another talk. It may take a few years for people to build up the supply of wood alcohol in our gas stations, even after we create this new market for wood alcohol, but in a crisis, we could still all get to work and to the stores we need by using electricity alone, if the batteries are big enough and we build enough public recharge sockets to plug into.

So that's basically it. Now I'd like to show you just a few of the details, quickly…

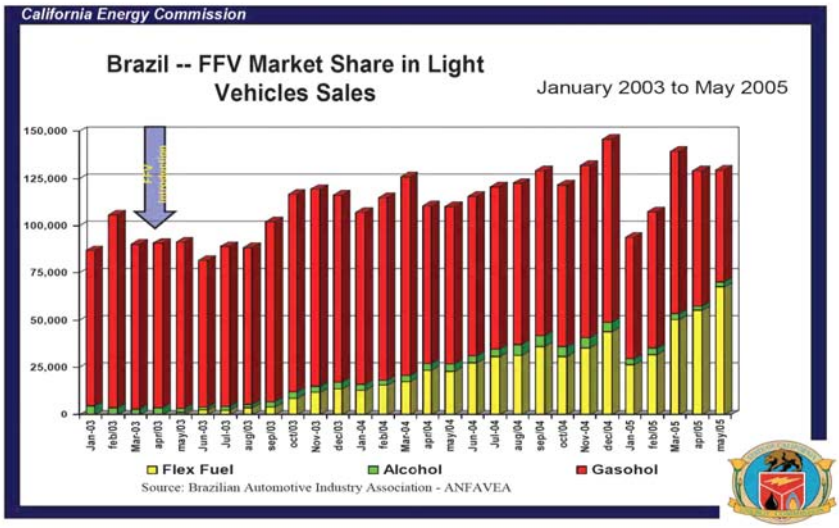
This is the IEEE Task Force which I lead which has been doing a lot of the technical work here…



This slide shows you what methanol is, and why it is important. Unlike methane or natural gas, it is a *liquid*, which you can carry in an ordinary gas tank. Once we have cars which can *use* methanol or mixed alcohols, there are lots of ways that people can provide us with methanol. Methanol made from natural gas is *already* cheaper than gasoline, and there is already a large global supply that can move very quickly into gas stations when cars and gas stations are ready to use it. But it's also the easiest kind of liquid fuel that we can make from coal or from biomass, as I mentioned.

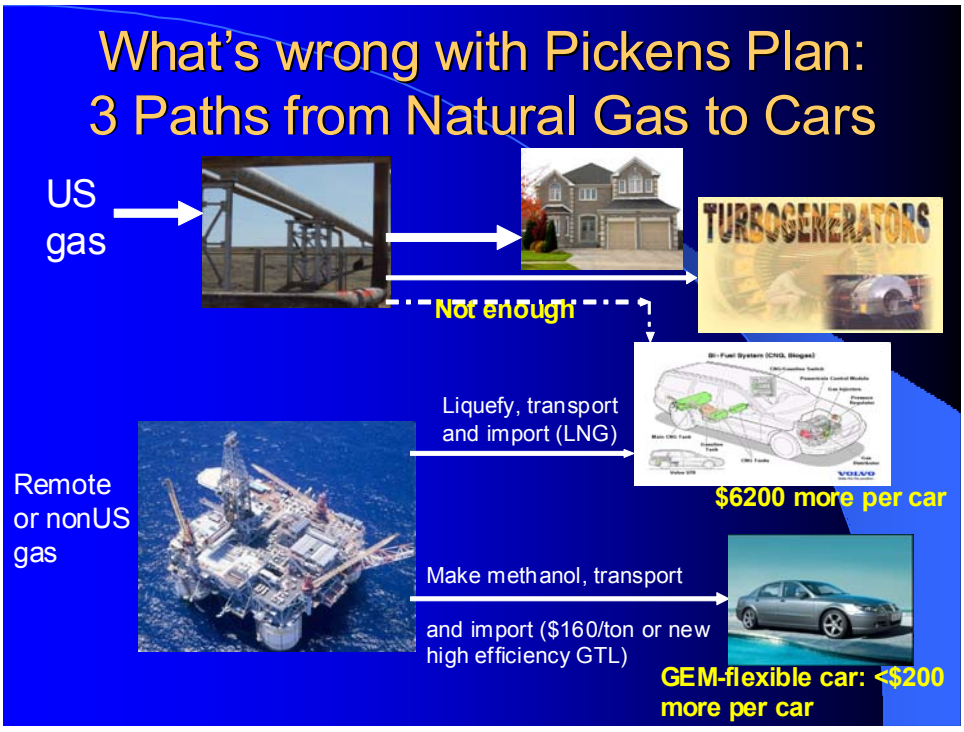
Making ethanol from cellulose may be a research project – but people have known for centuries how to make *impure* alcohols from wood at a lower cost. We should still be doing research to improve the efficiency of this technology, but it is here today, and ready to use – as soon as we create the market for it.

Fuel flexibility can be brought online very quickly, much faster than hybrids merely doubling every year!



All major manufacturers which sell in US have sold such cars in Brazil!!

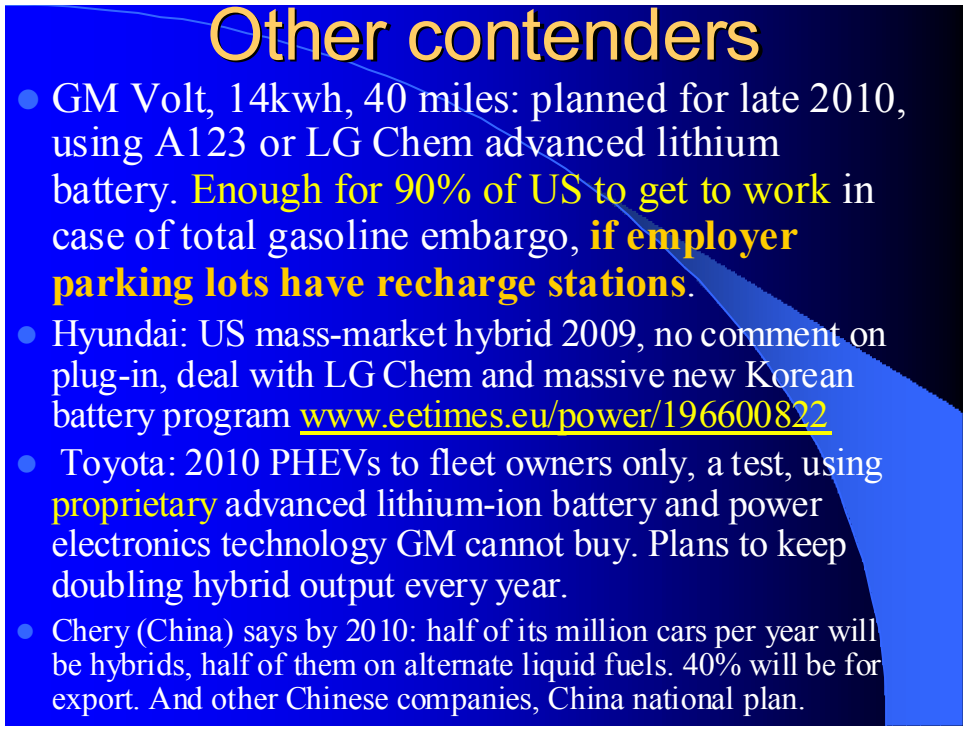
This slide shows just how quickly we could shift the entire US over to GEM fuel flexibility, if we made up our minds to do so and backed it up with legislation. In early 2004, I gave a major speech in Brazil calling for GEM-flexible cars **and a fuel flexibility mandate.** The idea was picked up by their mass media people and some key decision-makers. **In little more than one year, they ramped up from about 10% to** having more than half their cars gasoline-ethanol flexible. It's a shame they were focused so much on ethanol – but it's not much harder to do full GEM-flexibility. Notice that these folks making cars for Brazil are the same folks who make cars for the US; they already know this technology.



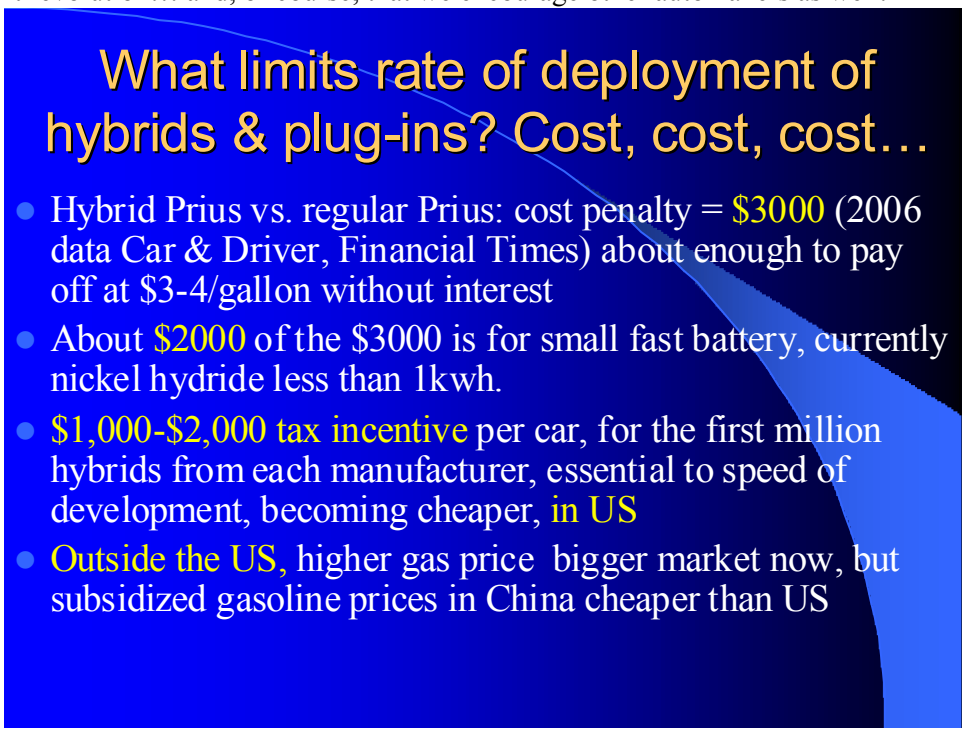
This slide shows what is wrong with the Pickens plan for energy security **in the US**. Pickens has suggested that we start using cars which can use natural gas directly, instead of methanol or electricity. Fuel-flexible cars using natural gas *do exist* today. You see here a cut-away of one that Volvo sells. But the problem is that it costs $6200 more per car. GEM flexibility costs less than $200 per car. Furthermore, since we already are using all the natural gas we can produce here in the US, we could only power those cars by buying more liquefied gas carried here from other parts of the world. If we want to use natural gas from remote parts of the world to power our cars, it's actually more efficient for them to convert that gas to methanol at the remote site, and sell it to us in the form of methanol.

As for plug-in hybrids, the world can expect to see them on the mass market *this year*, probably for less than $20,000, because of China's very aggressive plan for energy independence and because of its advanced battery technology – way ahead of any US manufacturers.

You can learn more about that plan on my web page…



The most exciting event in the US this year has been the announcement by GM of its plans for the Volt car – and the passage by Congress of tax incentives good enough to make it possible for GM to move ahead at a decent speed on that effort. The future of the US and the future of humanity demand that we do all we can to make sure that GM succeeds, and succeeds well, in this important revolution… and, of course, that we encourage other automakers as well.



The biggest problem in getting hybrid cars and plug-in cars to everyone is the cost of the batteries…

The view from Morgan-Stanley

March 11, 2008

- "We see lithium-ion PHEVs today as akin to MP3 players in 1998. They are likely to revolutionize the automobile as we know it, but it is still unclear who will develop the equivalent of the iPOD"
- Projected battery costs: $4,025 for 7kwh (20 miles all-electric) , $5,585 for 14kwh (GM Volt)
- www.vvcars.com/pdf/PHEV_MorganStanley.pdf

The biggest barrier to GM succeeding is the cost of bigger batteries, plus the cost of developing battery management systems and battery testing, even to let it use batteries as good as the best that China has to sell today. Some people object to buying batteries from China… but if I had to choose between spending $45 billion per year buying batteries from China, versus $700 billion to buy oil from the world market we have today, I'd go for the batteries as fast as I could.

Lithium Iron Phosphate Batteries: The One Proven Key to Breaking the Cost Barrier

- Invented in 1997 by NSF grantee Prof. John Goodenough, U. Texas
- Winner of the Japan Prize www.japanprize.jp/e_2001(17th).htm
- Recent huge surge in production at:
  - A123, to manufacture in China
  - LG Chem
  - BYD (Shenzhen), claims to be world's #2 producer of rechargeable batteries
  - Thunder Sky (Shenzhen), safety add-on

But even as we try to help GM with its near-term problems, we should remember that the best batteries made today were invented in the US, by a university professor…

Workshop on "Drug Discovery Approach to Breakthroughs in Batteries" Sept 8-9 at MIT

- Focus: How could new crossdisciplinary research maximize the probability of breakthrough battery designs, suitable for new plug-in hybrid cars but costing only half as much or less as what is coming already?
- Motivation: IEEE white paper argues that fuel-flexible plug-in cars offer our best near-term hope for independence from oil imports, but the high cost of batteries for new cars like the GM Volt is the main obstacle.
- Sponsors: ECCS. Participation from DOE, DARPA, GM. Strong encouragement from OSTP. http://web.mit.edu/dsadoway/www/nsfworkshopMain.htm
- Key findings:
  - The "design space" is huge, and poorly explored due to cutbacks in US electrochemical engineering (other than fuel cells), and the slow speed of traditional Edisonian "shake and bake" methods.
  - Systematic exploration, using computational approaches (quantum modeling, learning from data, stochastic search) as now used in the pharmaceutical industry show great promise. Sang-Tae Kim, former OCI Director, helped build new partnerships here.
  - The uncertainties are great, but somewhere between 2X and 10X improvements are likely to be possible, **if** we follow up on this opportunity. No one else is doing it yet in the US.
  - A new EFRI topic in this area would have huge workforce benefits for the US in this key area even in the worst case where GM imports batteries from China, whose industry is now well ahead of the US industry in this area.
  - In addition to battery design, new lifetime analysis, catastrophic safety analysis and open-source models for battery management systems are all badly needed.

http://web.mit.edu/dsadoway/www/nsfworkshopMain.htm

If we start new, more aggressive battery research, based *firmly in the university community and small business*, there is good reason to hope that we could develop new batteries here in the US twice as good as the best that Asia has for sale today. Just last month, we held a workshop at MIT that confirms this, and charts a way forward. If NSF, DOE and the auto industry could join together as partners on this, the US could not only keep up but could lead the world to energy security much faster than anyone expects today.

Added Later (10/30): What I left Out in the Talk

No one can say everything in 12-15 minutes. To get the policy right, we need to get into many of the details with the same level of intensity, focus, public discussion and questioning that we start out with, for the big picture. This talk was part of the larger Energy Summit conference organized by www.setamericafree.org, which began to get into some of the further details. Here I will simply list the most important things I left out.

First – energy security is not the only issue of urgent importance to the US and the world. In my view, greenhouse gasses, nuclear proliferation, and world population growth are all just as important and just as urgent. The day of reckoning may come further in the future for those issues, but they will take longer to solve; thus we need to act now on all of them. Still, freeing ourselves from the addiction to oil is *necessary* to ensure our survival, and we do need to push this strategy as hard as we can. Everything suggested here is part of what we need to do in the larger context as well. I discuss the larger context more on my web site.

Second – a lot of people at the conference asked: how can we make peace with the oil producers? Can we achieve more partnership and dialogue with oil-producing companies and

nations? I for one argued for dialogue here. Progress in these technologies is good and important for all of humanity. Lyndon Johnson used to say – if you make a bigger pie, you can give a bigger slice to everyone. Economists talk about "Pareto optimality." In other, longer talks and other conferences I have discussed what kind of grand bargain we might try to go for here.

Third, I didn't say anything about the actual *cost* of transporting methanol or other corrosive fuels. In an earlier talk, I calculated that the US consumer could already be saving more than $200 billion per year in 2004, if cars were GEM-flexible at that time and gasoline prices were at the $2.50 per gallon level at that time; in my quick calculation, I assumed that distribution costs *per physical gallon* of methanol are the same as costs per gallon of gasoline. At the conference, Methanex said that the cost per gallon of transporting methanol is actually less than that of gasoline, and promised to send details. It is certainly a known, established technology. They certainly stand ready to respond quickly if we open up a bigger market for them.

Fourth, we really need to think about how to minimize the time it takes for biofuels to fill in the last quarter of the pie. One approach is to accelerate and improve research into biofuels, and make sure that the research takes advantage of GEM flexibility to maximize what we get per ton of biomass of all kinds. Those are big topics themselves. Just yesterday, I heard an exciting talk from Prof. Agarwal of Purdue University, opening up new possibilities in that arena. **Equally important**, we should be doing much more to explore new technologies which cut that quarter of the pie down to an eighth, by doubling the efficiency of hybrid cars when using liquid fuels. The small gasoline engine used in the Prius is only 30% efficient; we could try to replace it by *GEM-flexible* new alternatives, like a fourth generation Stirling engine, a "JTEC" system or JTEC-enhanced engine, or a solid oxide fuel cell. The fourth-generation Stirling and the JTEC also have the potential to cut the cost of solar energy from "solar farms" in half. There are detailed papers on these technologies on my web site. Also see http://www.spectrum.ieee.org/mar08/6079.

Fifth – in the talk I only hinted at some of the major actions we need to break our addiction to oil, above and beyond maximizing the number of GEM-flexible PHEVs on the road. We need more recharge stations near where people work, and at major shopping sites. At the conference, Sven Thorsen described some of the low-cost simple recharge stations his company is deploying in Denmark, Israel and Australia. We need more and better open source, company-independent research in battery modeling, lifetime evaluation and battery management systems, hopefully using the best we have learned about new optimizing control systems like adaptive dynamic programming and neural networks. We need information flows which are capable of responding more quickly to new ideas and connections in these complex, fast-changing areas of technology.

Sixth, I did not discuss the new Open Fuel Standard in my talk, but the folks from the Set America Free Coalition certainly followed up on that important issue. It certainly is the most obvious, direct way to get more GEM-flexible cars on the road.

Seventh, I did not mention all the advantages of GEM-flexible cars. As a consumer, I would be very happy to own a GEM-flexible car, even if I were stuck with gasoline in my neighborhood forever. Why? Because I remember what happened to my ex-wife one time when the old hoses in her car blew up. I remember what happened to a friend years ago when she got a little bit of water in her gas tank. The better, more durable hoses, gaskets and engine materials in a GEM-flexible car are good things all by themselves. So is adaptive engine control, which can improve mileage and reduce pollution even for gasoline itself. The mathematics which underlie the most powerful forms of adaptive engine control are also discussed on my web site.