S. David Freeman
Fuel Cells Conference 2002

I don't think any of you can imagine how I feel seeing this audience representing some 2,400 people attending this conference. I can remember back when there were just two or three of us, and it's ironic that the first research came out of the Office of Coal Research because that's all we were doing back then. As the Virginia Slim ad says, we've come a long way; but we've still got a long way to go.

As I look out over this audience of men—well, there are a few women here...very few—I see an enormous pool of talent, and I want to use my limited time here to try to inspire and not just simply recite our accomplishments. I think others are well qualified to do so. The inspiration I think must come from the road ahead, not what we've accomplished, which is tremendous, and where we are.

I am reminded of the fact that in 1980 when I was the chairman of the Tennessee Valley Authority, I arranged for an electric car race between Robert Redford and Paul Newman from Gatlinburg to Nashville. And I had them both committed to doing it and we were planning the race, and then it just occurred to me that we would get a lot of nationwide publicity, but what would be the result of it? There were no electric cars for sale, so we didn't do the race. Instead, I went to the automobile industry and lobbied for commitments to electric cars, and I got a letter, which I think is still in the TVA files, from the president of General Motors guaranteeing me that there would be an electric car at every GM showroom in 1984. Well, we know what happened.

I guess the reason for reciting this ancient history is that we dare not be deluded by the PR that we're getting; we dare not be deluded by the press clippings of the progress with this technology, because if everyone in this room bought a fuel cell, it would be the largest order on earth that had ever taken place. We haven't really achieved commercial viability yet, and the American people really are not, and even people who deal with sizable quantities of electricity, don't think of the fuel cell when they're talking about their next power plant. And, of course, the fuel-cell car is getting tremendous press, publicity, and discussion; and I hope and pray that it will not go the way of the electric car, that it will become a reality. But it's not a reality yet, and this nation is in serious trouble over the fuel that we need for the fuel cell, namely oil.

What I'd like to point out is that in California, we went through some tremendous tough times the last couple of years on energy. We sort of slayed [sic] the dragon, so to speak—as a matter of fact, Enron is dead—but what happened frankly was an opportunity lost. I mean, we had the most visible electricity energy crisis in the history of the industry, and it was a perfect opportunity for fuel cells to come in and just kind of occupy the space. Here was a situation where the central station power grid was visibly failing—there were blackouts—and decentralized power with the fuel cell being the leading contender just had an opportunity that it never had before. I remember talking to people in the fuel-cell business early in the crisis, but we just weren't quite ready yet for commercialization.

Now I'm an impatient man. I can remember being in Japan in '73 or '74 and talking to Tokyo Electric about the phosphoric acid cells that they had operating. We have worked hard for thirty years in developing the technology at least for power, and yet when the opportunity of a lifetime came along we just weren't quite there. I don't know if just words can inspire people to get their collective noses out of the laboratory and into the marketing and into the sales and into the commercialization, but I'm trying.

We have a situation where the transmission grid in this country is inadequate. The secretary of energy says so, everyone says so; and we're even going to the extreme of something I never thought I would see—the federal government asking for authority to use eminent domain to acquire transmission line rights of way. I don't think it will pass, but the fact that that was even suggested just points up the difficulty of building additional transmission where people already live. I hate to put it this crassly, but you can run over poor people and kind of get away with it unfortunately...sadly; but if you try to run transmission lines near homes of people that have got a lot of money, they're going to beat you every time no matter what the law is. Here we have distributed generation, which is a potentially viable alternative, and it doesn't seem to get the same kind of attention yet.

In California we passed a law that gives solar power the right to offset the retail rate for electricity and run the meter backwards, but that same privilege doesn't exist for the fuel cell. Frankly, I don't see the kind of organization and political action on behalf of the decentralized generating companies that renewable energy has put together, and the two are of the same class. They are the engines of the future. They are the sources of power that we have to look to. We have a situation in this country where distributed generation could play a huge role in the power game and, of course, an all-encompassing gain in the transportation sector, but yet we're at a time when the situation is just ripe for those technologies to be deployed and they're still in the pawing-the-earth, research-and-development stage. Now I'm not criticizing the fact that we now have got the huge effort going in the research area, I'm praising it; but I'm lamenting the fact that the country needs fuel cells now and the country does need to get off of oil now. I would like to say this: I think the fuel cell collaborative, the fuel cell people, ought to pay a little bit more attention to the fuel. We are on the verge, I think, of moving in the broad sense of the word, and I am joined by executives from the oil companies—Shell and BP and others—in saying this, we're moving out of the shadow of the fossil fuels into the bright era of a renewable hydrogen economy, and the fuel cell is the engine that will take intermittent energy and use it at a time that it's needed. But I don't see a lot of people talking about hydrogen in terms of a fuel-cell engine. Let me just put it bluntly: The fuel cell and hydrogen are not Siamese twins. We can start developing the hydrogen infrastructure as we perfect the fuel-cell car; and the internal combustion engine can run rather well on hydrogen, and the ICE hydrogen car is not the enemy of the fuel cell. Indeed, if we were starting to deploy hydrogen-powered ICE cars tomorrow, it would hasten the day when fuel cells were viable because it would help bring the hydrogen infrastructure into place sooner rather than later.

Let me say a word or two about why I think there is urgency. For many, many years, and you can still use the word "clean" in here too, we were catering...not catering so much, but trying to reflect the environmental ethic—the fuel cell is cleaner, the fuel cell is going to help us with the environment. But after 9/11, there is a new public interest that even overshadows the

environment—and I consider myself a very strong environmentalist—and that is this nation's security...this world's security. And if anybody in this audience doesn't think that it primarily revolves around oil, they're living on Mars. If it weren't for money that we pay Saddam for his oil, he wouldn't have the money to build weapons of mass destruction. And if it weren't for the oil money that went into Saudi Arabia, the bin Laden family wouldn't have had the money for Al Qaeda to get started. The oil money has been at the foundation of terror in this world; and there are a lot of serious people that think we are going to war in Iraq, in part, to get their oil. And what would happen if we woke up tomorrow morning and found that just as what happened in Iran, that the people in Saudi Arabia had thrown out their government and it was now in the hands of an extreme Muslim government? There would be a worldwide calamity. If we went to war, we'd alienate billions of people forever; if we didn't go to war, we might not be able to get to work. We are in a serious pickle over oil, and we do need a program of Hydrogen Now!! to at least get started toward the era of using hydrogen instead of oil; and I'm talking about not hydrogen from fossil fuels, which just puts you in a vicious circle on the environmental side, but hydrogen from the electrolysis of water using more and more solar, wind, renewable energy to make that electricity.

Whether you believe in it or not, you need to seriously examine it because I think that a program of Hydrogen Now!!—and I applaud the Bush administration for recognizing that fuel cells and hydrogen need to be part of our future—but I beg you to make it part of our present. The fact that it may take twenty years to make a transition is all the more reason why we should start today. Imagine how different this world would be if we had a program in place where two or three years from now we will have hundreds of thousands of hydrogen-powered cars being built and more and more as time goes on. The fuel cells would come on faster, not slower, because they would be needed to get the bigger cars with less efficiency having a sufficient range to be commercially viable. This is a program that really is a wartime necessity, not a peacetime luxury.

My message to the people in the fuel cell business is connect yourselves with the issues that are affecting the lives of the people. We have power shortages in many parts of this country, and the distributed generation is an answer to these shortages. We have issues of war and peace, and we need to get on with the Hydrogen Now!! program. I mean, it's not necessarily in your interest to think that the fuel for your fuel cell has got to be reformed fossil fuels. It would be far better if we created an infrastructure of service stations that were in existence where hydrogen was made with water and electricity at every service station in the world and that an infrastructure was there so that when the fuel-cell cars were commercial, the infrastructure would already be there.

My message to you this morning is to suggest that even though the work that has been done on fuel cells is excellent, it's insufficient to be on the one-inch line when the world needs you now. It is insufficient to just be focusing on the fuel cell without really letting the public know that the fuel to make the fuel cell is just as important and the most plentiful element on earth is hydrogen. If we tie the fuel cell to the era of fossil fuels, you're tying yourselves to the past. The fuel cell needs to be connected to the renewable sources of energy—the wind, the sun, the biomass. We can certainly use natural gas as an interim step to get us started, but we need to have a vision that will capture the imagination of the country. When John F. Kennedy said that

we were going to go to the moon in nine years, people didn't ask detailed questions of how and what are the obstacles; it was something that the country decided to do. I don't think that the federal government has to do this. I think what we need is enough voices out there pointing out what is possible and a million American people walking into the showrooms of the automobile industry and saying that we want a hydrogen car. Now today it may be an IC engine, tomorrow it will be a fuel cell; but Hydrogen Now!! is the message that I think we should preach; and I think if you do, you will find that the fuel cells will become commercial that much faster.

Thank you.

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Hydrogen and Fuel Cell Vehicles in Perspective

David Friedman

March 3, 2003

Union of Concerned Scientists

Presentation Overview

- Energy and Environmental Challenges
- Technology Options
- Addressing Oil Dependence

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Energy and Environmental Challenges

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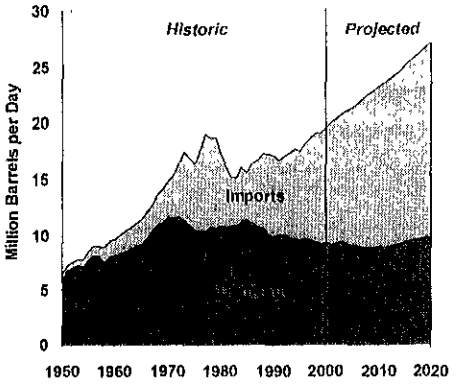
Oil Use: *Unprecedented Increases*

US Petroleum Product Supply



Source: EIA Annual Energy Review 2000. EIA Annual Energy Outlook 2001 (adjusted for no mpg increases)

- **Imports currently over 50%, rising to 65% by 2020.**
- **500,000 barrels per day from Iraq, 1.5 million barrels per day from Saudi Arabia.**
- **$200,000 sent overseas every minute.**
- **Consumers spending $170 billion on gasoline each year.**

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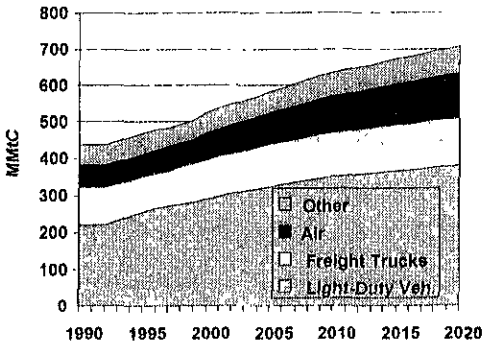
Climate Change Emissions:
Continued Growth

Projected US Transportation Carbon Emissions



Source. EIA Annual Energy Outlook 1999.

- **Today, 1 gallon of gasoline = 24 pounds CO_2.**
- **CO_2 emitted today stays in the atmosphere for 100+ years.**
- **US cars and trucks emit more CO_2 than each individual country other than US, China, Russia, and Japan.**

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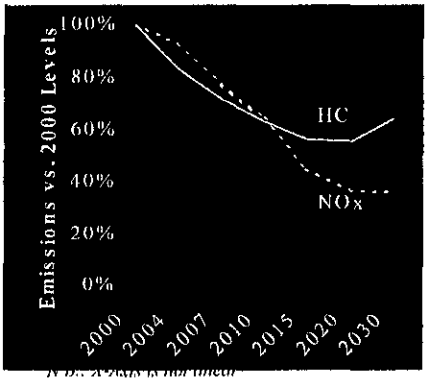
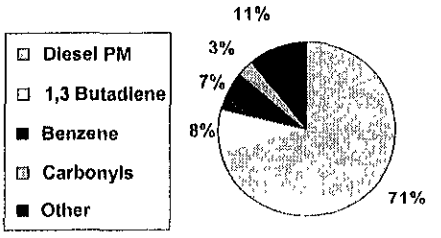
Air Pollution:
Continued Challenges and New Issues

Total US Light-Duty Vehicle Emissions



Source: M. Walsh based on EPA Tier 2 Model.

Average Los Angeles-area Cancer Risk from Air Toxics = 1400 in 1,000,000



Source. South Coast Air Management District, *MATES II*, November 1999. Data collected from April 1998 to June 1999.

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Technology Options

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Technology Menu

Broad array of technology available for near, mid and long-term fuel economy improvement.

- On-the-Road Technology
  - 30+ mpg
- Evolutionary Conventional Technology
  - 40 mpg
- Hybrid Electric Vehicles
  - 50-60 mpg
- Fuel Cell Vehicles
  - 100% oil displacement, 50-90%+ GHG reduction, potential for 15% of the fleet by 2020

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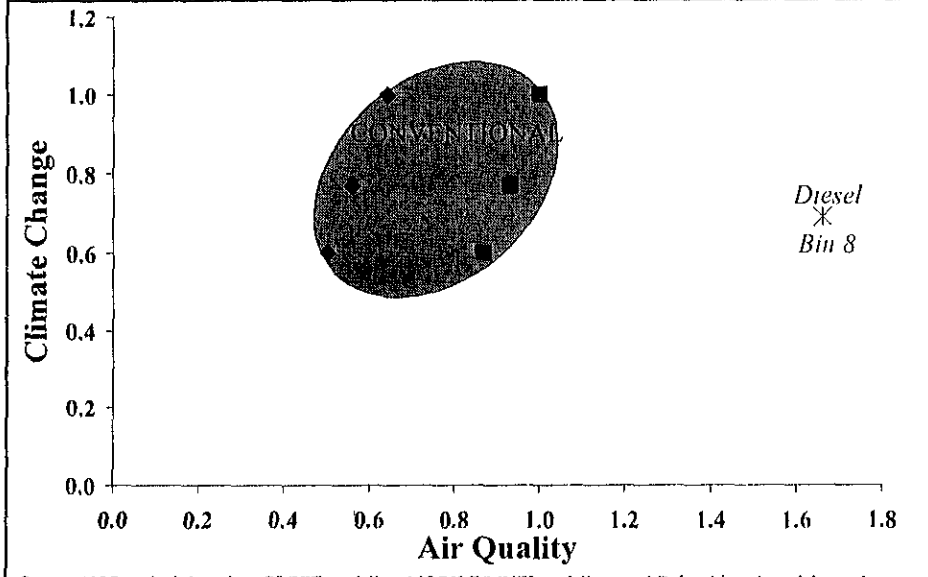
Environmental Performance



Source: UCS analysis based on GREET modeling, MOBILE/MVEI modeling, and Delucchi et al. social cost data

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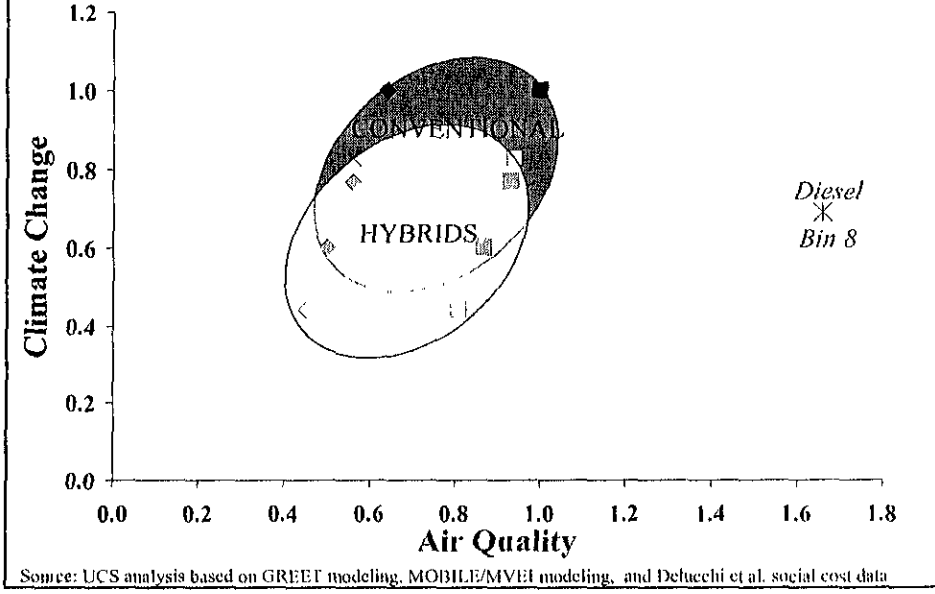
Environmental Performance



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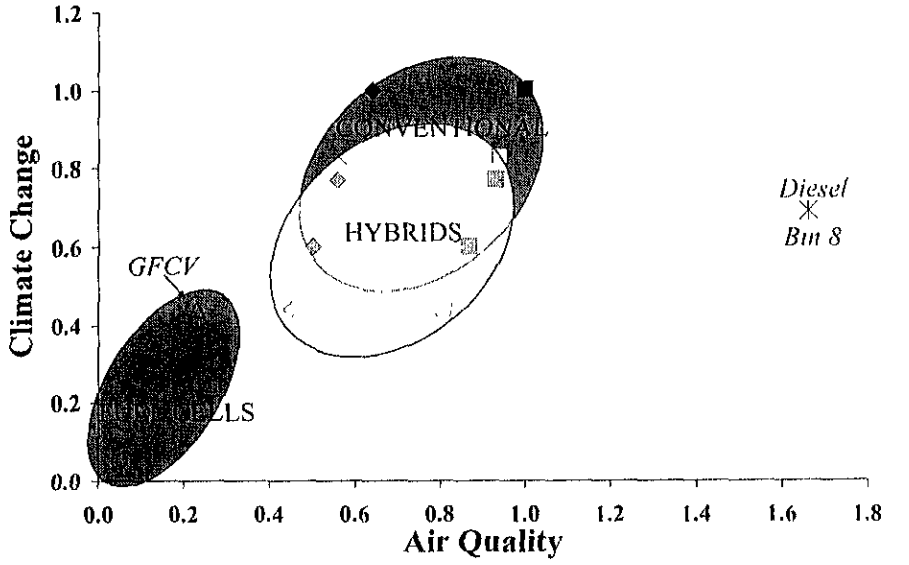
Environmental Performance



Source: UCS analysis based on GREET modeling, MOBILE/MVEI modeling, and Delucchi et al. social cost data

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Fuel Cell Vehicles (FCVs)

Fuel Cells Vehicles offer great promise to address the full set of energy and environmental problems.

- Ultimate vision
  - 100% oil displacement
  - Zero tailpipe emissions
  - Near zero greenhouse gasses, criteria and toxic emissions
- Realistic timeline
  - At today's pace: 10-15 years before significant commercialization
  - +15 years for vehicle turnover = 20-30 years before dramatic improvements from FCVs

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Fuel Cell Vehicles (FCVs)

Many hurdles must be addressed to make the promise of hydrogen and fuel cell vehicles a reality.

- Key hurdles:
  - Hydrogen fuel source.
  - Hydrogen infrastructure.
  - Renewable fuel sources.
  - Hydrogen storage.

  } Least Developed by Industry

  - Vehicle near-term cost.
  - Education.

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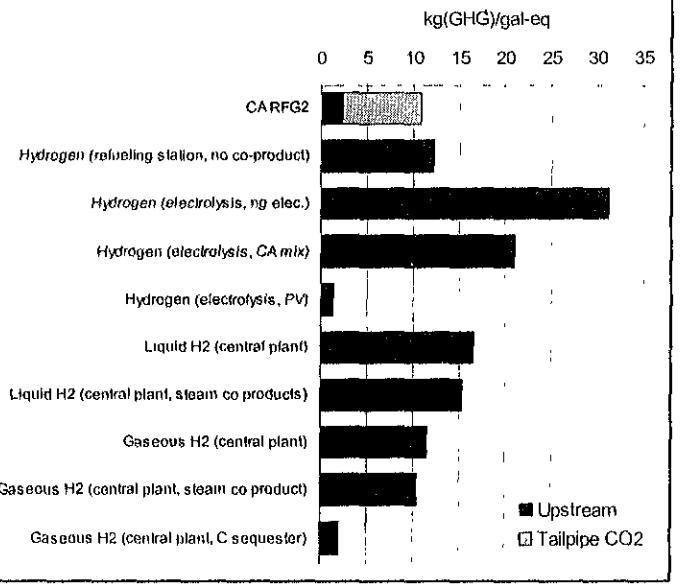
Hydrogen Fuel Supply

- Hydrogen is NOT necessarily clean by definition
- Local reforming of natural gas: best near term option.
- Solar, wind, biomass best long term options.
- Coal, Nuclear?



Union of Concerned Scientists Hydrogen Infrastructure

- Total infrastructure costs are large
  - $150–300 billion for national hydrogen system
- Investment rates are reasonable
  - $1–10 billion per year
  - current gasoline-related investments: $11 billion per year
- Ironically, near term supply technology is further developed than vehicles

Union of Concerned Scientists Hydrogen Storage

- Compressed hydrogen
  - 5,000 psi certified (200-250 miles range)
  - 10,000 psi recently certified (300-400 miles range?)
- Metal hydrides
- Carbon nanotubes
- Chemical storage
- Gasoline or Methanol

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Addressing Oil Dependence

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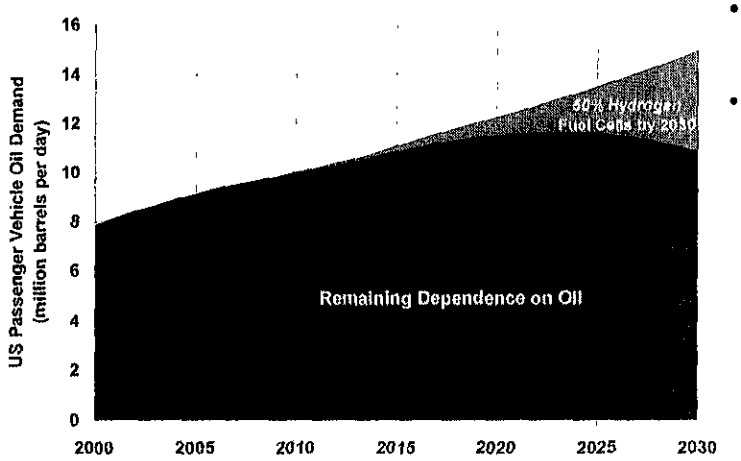
Passenger Vehicle Oil Use: *Technology Potential*



- Base Case
  - 24 mpg
- Fuel Cells
  - 15% by 2020
  - 50% by 2030
  - 65 mpg (2030)
  - Hydrogen from natural gas

Source. UCS. *A New Road* January 2003.

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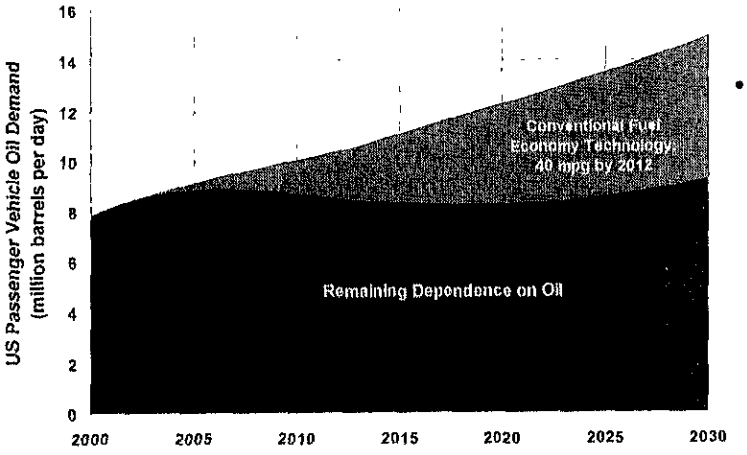
Passenger Vehicle Oil Use: *Technology Potential*



- Base Case
  - 24 mpg
- Conventional Technology
  - 40 mpg by 2012
  - Existing technology

Source: UCS. *A New Road*. January 2003.

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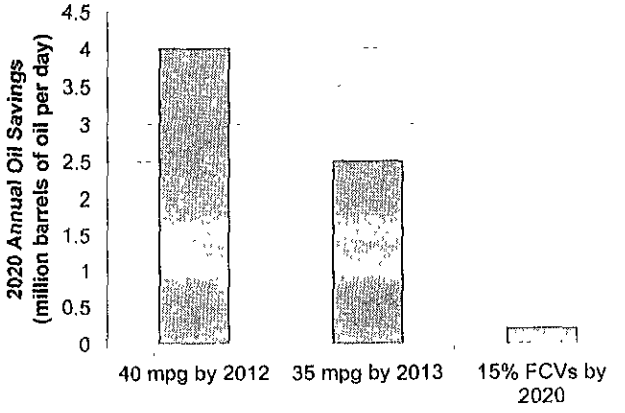
Passenger Vehicle Oil Savings: *Technology Potential*

Conventional technology out-performs fuel cells on oil savings through 2020.



Source: UCS

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Questions?

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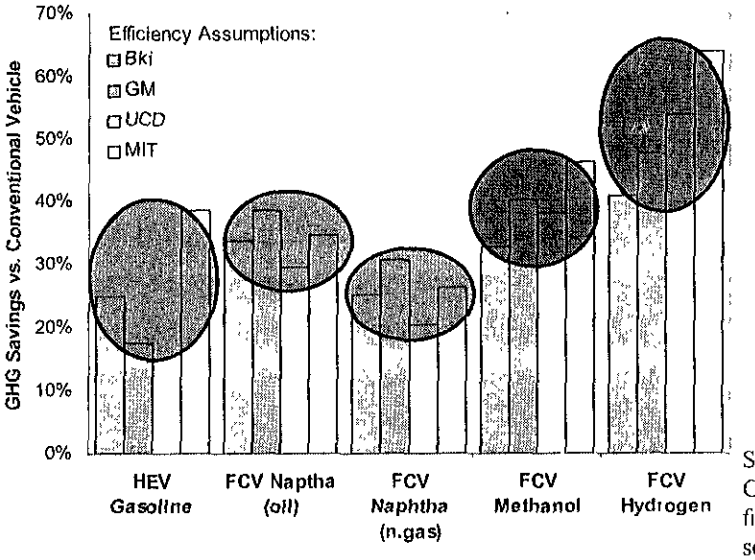
Greenhouse Gas Savings:
Impact of full fuel cycle



Source: UCS Calculations from listed sources.