2007: Peak Oil
The Electric Vehicle Imperative

Market Analysis

Technology Assessment

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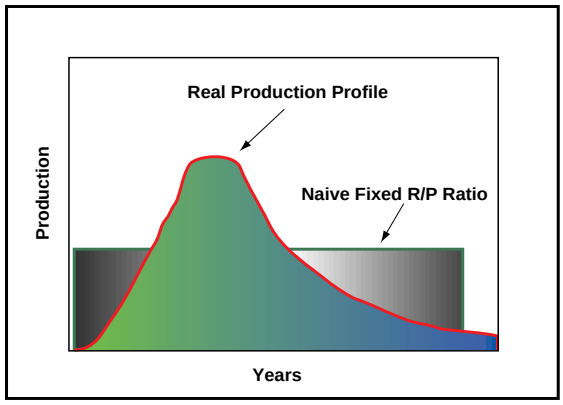
Reserves to Production Myth

The forthcoming Peak of Global Oil Production has been widely ignored due to the fallacious belief in the ratio of “Reserves to Production”. It is naively assumed that if there are say 1 billion barrels of oil in a reservoir and it is extracted at 1M barrels a day, the reservoir will last for 1000 days. This gives a flat production profile for the life of the reservoir.

In reality, oil production from a typical field increases to a maximum where it may plateau for a few years and then once about half of the oil has been extracted, production starts to fall and then tails off over many years. It does not stay constant at a high level.

FIGURE 2 **REAL OIL PRODUCTION PROFILE vs R/P RATIO**



Therefore, while there will still be oil in the ground in 50 or 100 years time, production will continually decline as less and less can be extracted each year.

2007: The Peak of Global Oil Production

In the 1950s, oil geologist M. King Hubbard forecast that oil production in the USA would reach a maximum in or about 1970 and then start to decline. This prediction was fulfilled.

In 1980, the "Global 2000" report, commissioned by the US President, predicted that the Peak of Oil Production would be near the end of the 20th century. The biggest uncertainty lay in forecasting oil demand, not how much oil could still be discovered. Since 1980, it is demand that has not risen as quickly as forecast, pushing out the peak by a few years into the first decade of the 21st century.

Applying the same methods to global oil production indicates that Global Peak Oil will occur around 2007 - 08 at the latest. The signs are now very clear that we have entered final approach to Peak Oil. By 2008, the ever increasing demand for oil will exceed supply and oil production will enter permanent decline.

We are facing the Peak Oil Emergency.

2.5 The Real Production Outlook

The ASPO predict that by 2010, global oil production will in fact have fallen to about 82 M b/d.

By 2020, it will have fallen further to 65 M b/d and only 33 M b/d in 2050.

Demand in 2010 is predicted to be over 95 M b/d - a gap of 15M b/d with projected ASPO production or a shortfall of 9M b/d according to CIBC World Markets' more optimistic supply forecast.

The CIBC World Markets production forecast of 86.8 M b/d in 2010 is probably too high but may be achievable as pressure bites to maintain production.

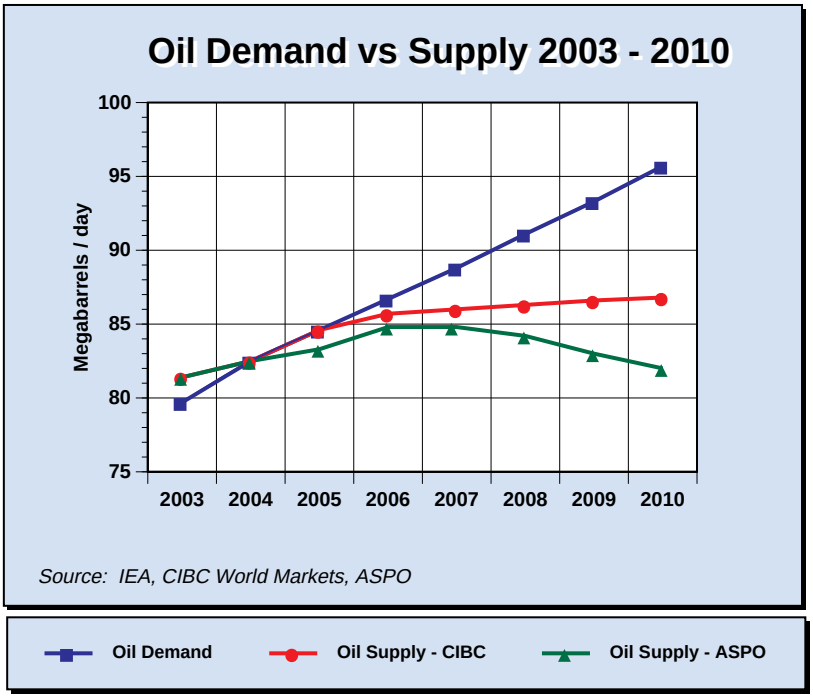
Either way, production will fail to meet demand by at least 10% in 2010.

Unless effective measures are taken to start reducing oil consumption as soon as possible, the world economy will start to experience global recession progressively leading towards depression over the next five years.

Short Term Outlook to 2010

The graph below shows projected unconstrained oil demand out to 2010 and the two supply scenarios by CIBC World Markets and the ASPO.

FIGURE 8



5.2 The Future of Hybrids - The PHEV

It is clear that the Plug In Hybrid car is overwhelmingly the best existing solution to declining oil supplies. A PHEV60 - a plug in hybrid that can travel 60 miles on battery power alone before requiring the petrol or diesel engine - would meet the daily mileage requirements of the vast majority of drivers in the USA and Europe without any need for petrol or diesel at all. The concept is not new - Volvo and Mitsubishi both proposed PHEVs to the California Air Resources Board in 1995.

It is likely that the first Plug In Hybrid cars will be limited to 20 - 30 miles electric range. The main reason is to reduce the cost of the battery and therefore reduce the price premium of the PHEV20/30 over a conventional hybrid. As production volumes increase, battery prices will fall and the all-electric range can be increased.

In addition, 50% of US drivers travel less than 20-30 miles per day. Therefore even a PHEV20/30 would reduce overall petroleum consumption by over 50%.

The data on which this is based is shown below in Figure 14, taken from the 1990 National Personal Transportation Survey.

FIGURE 14

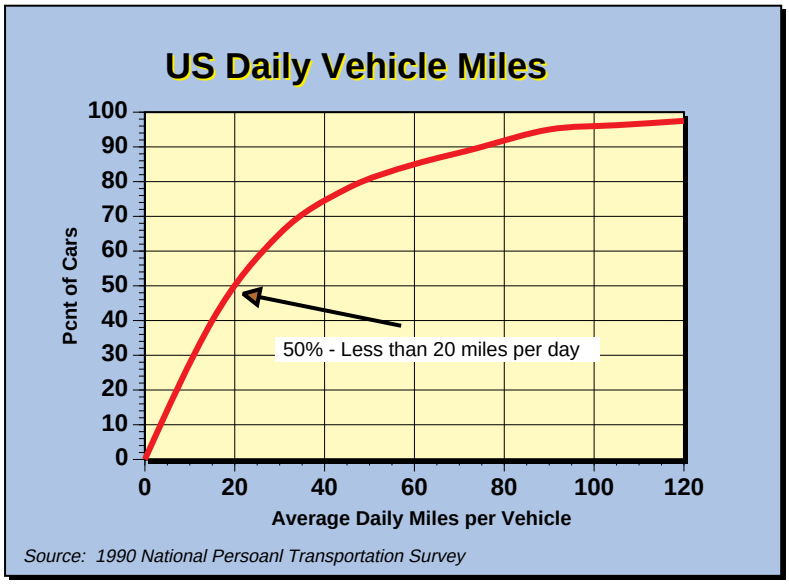


Figure 14 shows that on any given day, 50% of the Light Vehicles on the road in the USA will drive less than 20 miles.

90% of the cars will drive less than 80 miles per day.

Therefore a PHEV80 could theoretically reduce US petrol or gasoline consumption to 10% of existing levels.

FIGURE 31 **R1e**

Subaru claim that the battery can be 90% recharged in five minutes. This is a 10C charging rate. The $LiMn_2O_4$ cathode material can support high discharge rates but a 10C charge rate might indicate that the anode is not graphite but a high rate material such as Lithium Titanate Spinel. The main US proponent of Li Titanate Spinel anodes (Altair) views Li Manganate Spinel as the ideal cathode to complement the anode. If this is indeed the combination used in the R1e, it will have lower energy density than standard LiIon but much greater safety.

Mitsubishi MIEV

In September 2005 Mitsubishi announced that they would market an EV within 3 years, i.e. by 2008. Mitsubishi have therefore brought forward their original plans by 2 years and earlier in 2005, Mitsubishi abandoned fuel cells in favour of Battery EV development.

The vehicle will be based on the existing Colt platform. It will have a range of 250km (155 miles) between recharges and will be capable of being recharged within 4 hours with the on-board charger. (This would be from a 220V supply, not a US 110V supply). The price planned for the vehicle is said to be $18,000.

The prototype was developed with the Tokyo Electric Power Company and has a range of 150km. The battery will be LiIon (type unknown).

FIGURE 32 **MITSUBISHI MIEV COLT MIEV**

Mitsubishi favour the use of individual wheel motors rather than a central electric motor and driveshaft. The Colt EV is equipped with two

TABLE 21 **ACPROPULSION - FOCUS FCV vs PRIUS BEV**

	Focus FCV	Prius LiIon EV Concept
Range	200 miles	200 miles
Energy Storage	4kg H_2	34kWh LiIon
Kerb Weight	3528 lb	2800 lb
Electrical Energy to Refuel	240kWh	40kWh

8.5 Conclusion

The FCV approach is impractical, uneconomic, unsafe and uncompetitive with either BEV or Hybrid technology.

While a Ford Focus or Honda FCX Fuel Cell vehicle has a range of only 200 miles and costs 3 to 5 times the cost of today's cars, a LiIon pure BEV version of the Toyota Prius with only enough batteries to give it the same 200 mile range would cost about the same as today's Toyota Prius Hybrid. With the Zebra battery in volume it would cost even less. The latest (2005) Mercedes Benz B Class FCV vehicle (equipped with the "F Cell") has a maximum range of only 250 miles.

FCVs use three times as much energy as a BEV, the propulsion system weighs 43% more, takes up 3 times as much volume for the same power output as a BEV and costs 46% more (conservative optimistic assumption) than a BEV propulsion system. Refuelling cost is 3 times as great without including the cost of hundreds of billions of dollars to build a hydrogen infrastructure: the refuelling infrastructure has already been built for EVs[1].

There are certain technologies which claim that on-board resonant pulse electrolysis of water can produce hydrogen much more efficiently than conventional electrolysis. Even if this is the case, this will be a later technology requiring R&D; it will not be suitable for near-term implementation.

1. "Fuel Cell Vehicles: Solution or Shell Game?", S. Eaves and J. Eaves, University of California at Davis, 7th April 2003.

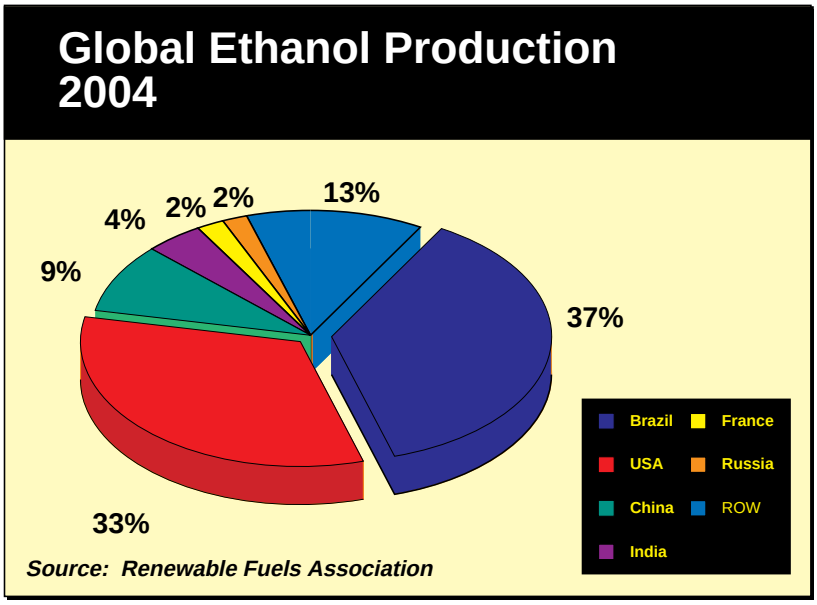
9.4 Ethanol

Global Production

Ethanol is the leading biofuel in production today. Some 10 billion USG of ethanol are now produced each year, compared to about 500M USG of biodiesel. Ethanol is now receiving political support in the USA as a means to reduce dependence on oil imports. The USA is the second largest ethanol producer in the world after Brazil, producing 3,535 million USG in 2004.

Production of ethanol across the globe has increased dramatically since the late 1990s - it has more than doubled from 5,000M USG in 1999 to over 10,000M USG last year.

FIGURE 42



- Global Ethanol production in 2004 was 10,770 million USG.
- Brazil is the largest producer with nearly 4,000 million USG followed by the USA with 3,535 million USG.
- Ethanol capacity in the USA now stands at 4,000 million USG with another 1,100 million USG of capacity under construction.
- 5,000M USG per annum of ethanol is equivalent to 220,000 b/d of gasoline - 2.4% of US Light Vehicle gasoline consumption.

Although ethanol only has two thirds of the energy content of petrol or gasoline, it can be blended directly with petrol and used in unmodified car engines. All new cars in the USA will operate on E85 - a blend of 85% ethanol and 15% petrol. Ethanol production is continuing to expand rapidly across the world. Numerous countries in South America are following Brazil's lead and intend to make 10% ethanol blended fuel mandatory from 2006 - 2010.

11 Petroleum Consumption Reduction Strategies

11.1 Introduction

How much oil could particular Oil Consumption Reduction measures save? Will they be sufficient to respond to declining supply? How many vehicles of what type must be introduced and how quickly to keep oil demand within falling oil supply?

We will examine a number of scenarios and their potential impact.

11.2 US Oil Consumption

We will first examine the impact certain oil efficiency measures would have on the largest consumer of oil, the USA.

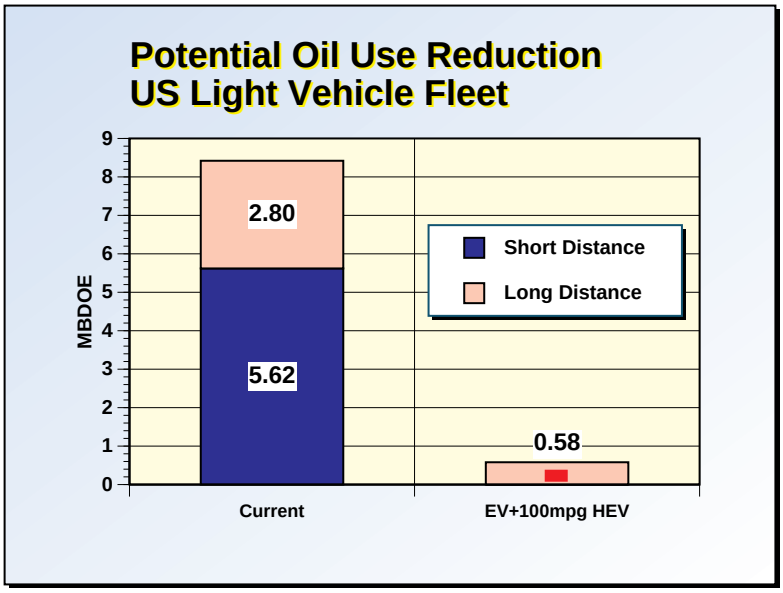
Table 31 shows the size, oil consumption, productivity and fuel efficiency of the different US transportation modes in 2004.

TABLE 31 US TRANSPORTATION OIL USE 2004[a]

	Units (million)	MBDOE	Fleet Miles Travelled p.a. ($x10^9$)	mpg (miles per USG)	Miles per Vehicle
Cars and Light Trucks	222.7	8.4	2627	20.68	11,833
Medium Trucks	5.67	.32	67	13.85	11,823
Freight Trucks	2.25	2.23	225	6.7	100,219
Buses	.78	.12	-	-	-
Air, Shipping, Rail, Other Transport	-	2.94	-	-	-
		14.01			

a. Source: EIA

FIGURE 53



Total US Oil Consumption would therefore fall to 13.2 M b/d.

This scenario would be achievable in a single vehicle type: a Plug In Hybrid with a 100 mile range on battery power. The IC engine “genset” would act as an onboard range extender.

11.7 Scenario 5 - 50:50 Split Between Battery EV and 100mpg HEV

If the 17 million Light Vehicles sold in the USA each year were split 50% between 100mpg Plug In Hybrids (which could drive 50 miles or more on battery power alone) and 50% BEVs (with a range of 100 - 200 miles), this would provide the US automobile driver the possibility of completely replacing petrol for short journeys with electric power while retaining the range of the petrol hybrid for longer journeys over 100 miles.

If we assume the same 17 million units per year replacement pattern as before, this time with 50% BEV and 50% Hybrid operating at 100 mpg (which is very conservative and gives no credit for the pure battery mode on short trips), the following oil consumption reduction scenario would result.

12.5 Airframe Design Solutions

If measures are taken without delay to start introducing significant fuel saving technologies for entry into service in 2010, some of the effects of declining fuel availability could be mitigated.

The next generation of aircraft planned for the next decade must prioritise Fuel Efficiency or propulsion technologies that minimise the use of oil.

Blended Wing Body

The McDonnell Douglas Blended Wing Body programme, which was under active development in 1997, was projected to be 27% more fuel efficient than the equivalent sized conventional design.

FIGURE 63 **BWB**

The project was cancelled when Boeing took over McDonnell Douglas.

The Boeing 754

The Boeing 754 Lifting Fuselage design (based on the original Vincent Burnelli Lifting Fuselage designs) was intended to be Boeing's first medium widebody twin engined aircraft. After orders were placed by Cargolux for the cargo version the project was cancelled in favour of the 767.

On payload-range basis, the Boeing 754 would have been twice as fuel efficient as the 767.

The following illustration appeared on the front cover of the 1975 Cargolux Annual Report after the airline became a launch customer for the B754.