

Gasoline: Past, present and future



Part 2 of a 3 part series

In the aftermath of the disastrous oil spill in the Gulf of Mexico, Rick Rys gives us an in-depth look at the history of energy production and then maps the alternatives being developed which will help us preserve our fragile environment.

Guest Column: by Rick Rys

In the first part of this series we have seen how the EPA came up with reformulated fuels in order to clean up air pollution in cities across the US. In this second part we will look at the powerful forces of change at work in the transportation fuel industry and get some idea what to expect. In the 3rd and final article we will explore some of the fundamentals in the competition for more efficient vehicles.

Oil refiners and car companies initially fought the EPA regulations but ultimately adapted by modifying the refineries, producing reformulated fuels, and evolving engines that run on them. There were some costs, but the overall result actually worked to reduce air pollution and give us reliable fuel injected engines that run much better than their carbureted ancestors. The changes we made in the past 50 years will look easy

compared the changes we will likely make in the next 50 years. So what is the future of transportation fuels and the engines that consume them?

The market pressures on hydrocarbon fuels are enormous and it is clear that we are right now on the threshold of unprecedented changes. The intriguing question is what technologies will fall by the wayside and just what new innovations will prevail? It will be

fascinating. We don't have a time machine, but we can look at the forces at work and make some logical predictions.

There are already regulations in place that will improve the fuels and engines for trucks, marine, locomotive, heating oil, and non-road equipment, as many of these fuels and equipment still have high sulfur, high particulates, and high NOX emissions. These changes are short term but the long term changes will be shaped by 3 powerful forces:

1. Peak Oil
2. Environmental concerns about Greenhouse Gas emissions
3. Biofuels

Peak Oil

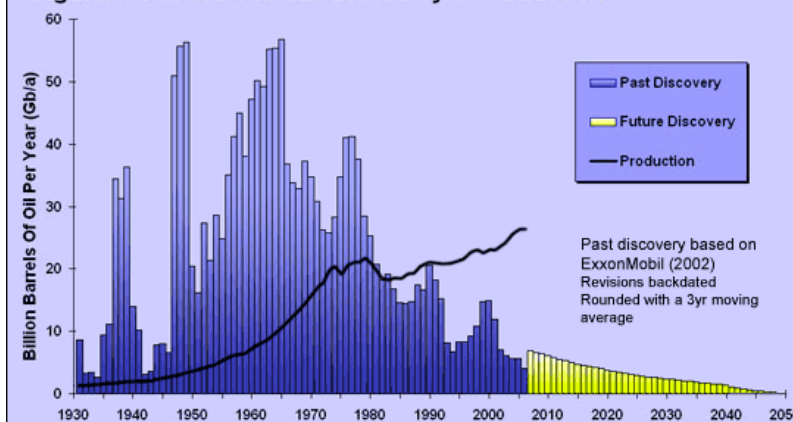
Whale Oil was once a vital resource for lanterns and lubricants but it peaked in the 1840s. It was a simple supply and demand situation; we ran out of whales. Luckily we had mineral oil to replace it. In 1956 Shell Geologist J. King Hubbert predicted 1969 as the year for peak US oil production. Initially ridiculed, Hubbert was vindicated when production actually peaked in 1970.

The US has steadily increased oil imports ever since and we currently import about 13.5 Million barrels per day at a cost of about \$400 Billion a year. We live in a world oil market, so it is important to know when world oil production will peak as the main economic disruptions will occur just after peak production.

Take a close look at the graph at the top of this page. This graph was originally prepared by Colin J. Campbell, Ph.D. Oxford, a retired British petroleum geologist who originally predicted that world oil production would peak by 2007 but revised that to 2010. What we see is that most of the oil that is being produced now (i.e. pumping it out of the known reserves) was discovered in the 60's. The rate at which we are finding new oil is well below the rate at which we are producing it and projected discovery looks bleak.

The US predictions from Hubbert assume that oil wells follow a natural life cycle without political and economic influence. Campbell's worldwide estimates make some attempt to include these, but uncertainties creep in as projections depend on government and politically influenced estimates of reserves. Such projections also need to take into account improvements in well technology, including a controversial technique called hydraulic fracturing.

THE GROWING GAP
Regular Conventional Oil: Discovery & Production



Peak Oil projections

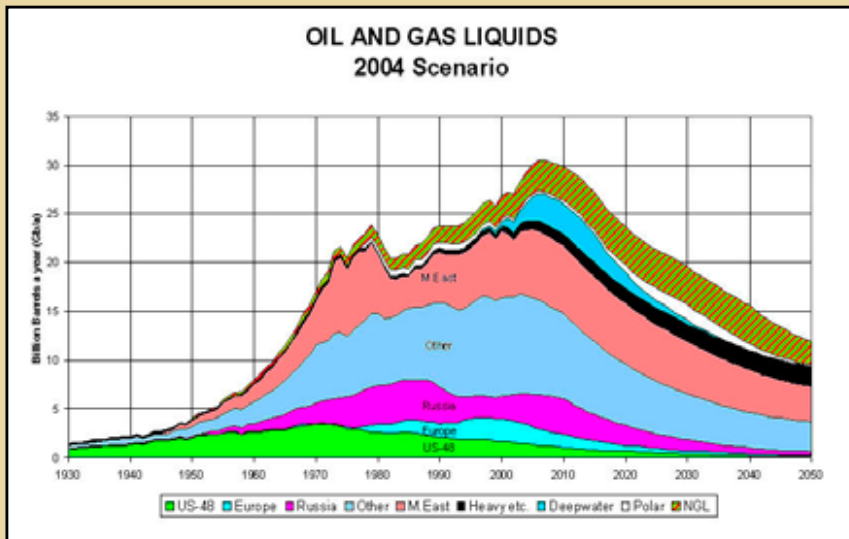
Projected Date	Source of Projection	Background & Reference
2006-2007	Bakhitari A.M.S.	Oil Executive (Iran)
2007-2009	Simmons M.R.	Investment banker (U.S.)
After 2007	Skrebowski C.	Petroleum journal editor (U.K.)
Before 2009	Deffeyes K.S.	Oil company geologist (ret., U.S.)
Before 2010	Goodstein D.	Vice Provost, Cal Tech (U.S.)
Around 2010	Campbell, C.J.	Oil geologist (ret., Ireland)
After 2010	World Energy Council	World Non-Government Org
2012	Pang Xiongqi	Petroleum Executive (China)
2010-2020	Laherrere, J.	Oil geologist (ret., France)
2016	EIA nominal case	DOE analysis/ information (U.S.)
After 2020	CERA	Energy consultants (U.S.)
2025 or later	Shell	Major oil company (U.K.)
Never	OPEC	

Sources: top, Colin J. Campbell, Ph.D., Oxford, UK; bottom, Department of Energy Hirsh Report 2005

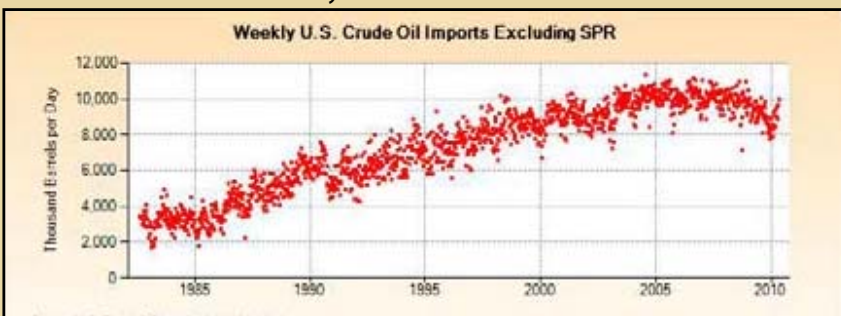
We can't drill our way out of this problem

Long time oil man, T. Boone Pickens said: "We cannot drill our way out of this problem." This is confirmed by drilling results. The state-of-the-art in seismology allows for finding a needle in a haystack, but has failed to find any new major oil fields. Most new fields fizzle. Putting one or two exploration wells into a formation and projecting a zillion barrels of oil does not make them actually exist. The largest oil field ever discovered ... gets discovered about every six months. The truth is none of these new recent fields including the hyped Bakken field in South Dakota is likely to live up to its publicity. The projected size of a field is hypothetical. Getting widely dispersed oil out of the ground cheaply is a very difficult problem.

Campbell's projections are in line with several others according to the February 2005 U.S. DOE study commonly called the Hirsh report shown in the table above. Notice OPEC's optimistic prediction of "Never." Saudi Aramco routinely avoids any discussion about peak oil, but their largest field Ghawar, by far the largest in the



Source: Association for the Study of Peak Oil and Gas



Source: U.S. Energy Information Administration

world, is estimated to have reached its peak in 2005. Many oil producers keep production figures secret and inflate their oil reserves, as this can affect stock prices and banking loans. The mere statement of oil reserves appears to be a political issue today, as it has economic repercussions. Economists tend toward optimism and geologists tend to have more pessimistic projections.

The ASPO (Association for the Study of Peak Oil and gas) chart at the top of this page was created before the 2008 recession and gives some idea of how peak oil will play out.

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According to The International Energy Agency (IEA) data (March 12, 2010), China's demand for oil in January 2010 increased an astonishing 28% from the prior year. Oil demand in the so called developed countries declined by 0.3% in the same period. The bottom graph on this page shows the feed rate to US refineries as reported by the IEA. Have we peaked in 2005?

Refineries run efficiently at 90-95% of capacity. Refining capacity in January 2010 was at 78.4% or 17.6 million barrels per day. When Valero closed its Delaware plant in November 2009 (I was a contractor at that refinery), the facility was losing \$1 million a day, according to the company. The problem in just a few years is that we will not be able to produce enough oil to meet demand, and continued refinery closings are inevitable.

Environmental Concerns about CO₂

On April 1, 2007 the Supreme Court ruled that CO₂ is a pollutant and the EPA must act to regulate it. This issue is the obvious "elephant in the room" since unlike all

the other pollution problems that have been solved by reformulated fuels, catalytic converters and sophisticated engine management systems, CO₂ is a fundamental component in the exhaust and there is no easy way to eliminate CO₂ emissions short of phasing out carbon based fuels altogether. This certainly is an enormously difficult problem for all of us and puts the EPA as well as all of our law makers in the position of making tough choices.

Two basic regulatory approaches are emerging to deal with CO₂ emissions. They are the Cap and Trade system and the Carbon Tax. The general consensus is that both systems can be effective, but both are painful. The Cap and Trade system is market-based. It is subject to speculation and also subversion as various schemes have not actually worked the way they were intended. In one example, carbon credits were accumulated by paying Rain forest loggers not to cut trees in a specified area. The loggers used the money to buy newer equipment and moved the operation to a new area.

The carbon tax is more direct and less subject to loopholes but has not been favored by businesses. Although not designed as a carbon tax, Europeans have long taxed fuels and over time their industries have

adapted. Americans use 24.8 barrels of oil per year per person, but Germans use only 12.0. The Germans have not given up their fascination with cars, but they have made many adaptations. The Indians use only 0.8 barrels per year, and their Tata Motors car company is focused on low cost small cars. Transportation fuels are very much related to the electric power industry, as hydrocarbons and Biofuels are potential sources of fuel for making electric power. In principal, wood and coal could be used as transportation fuel, but there is a good argument that it is more efficient to use such fuels to generate power for the grid and then use electric vehicles.

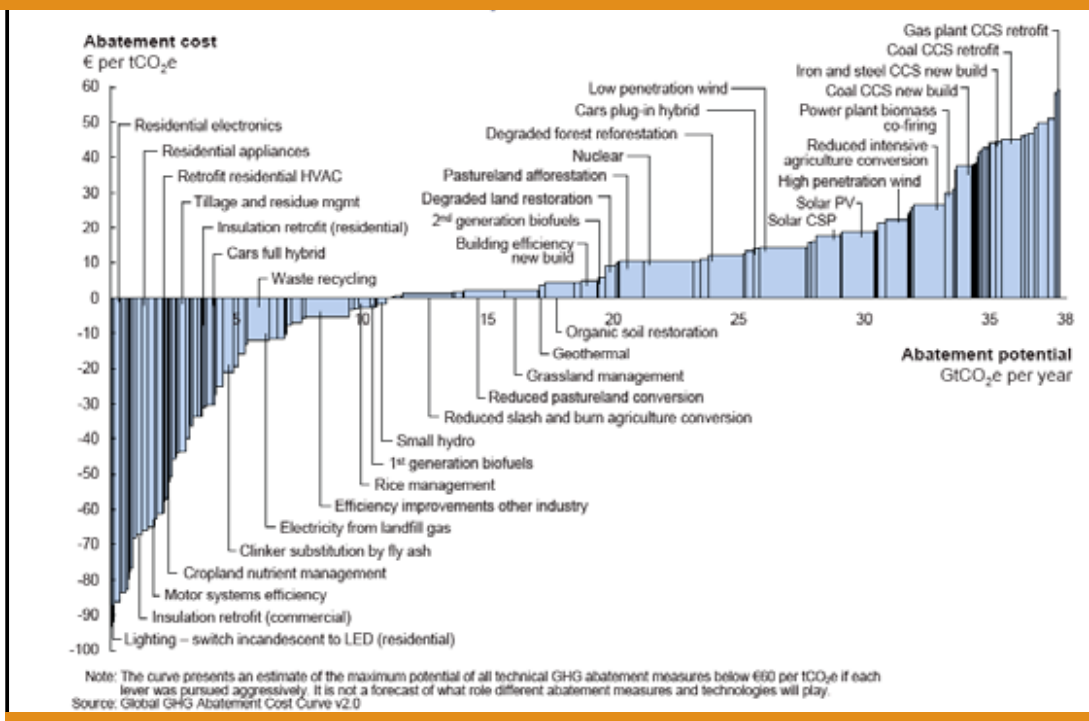
Typically the operational costs of “plug in” electric cars are about 50% lower than gasoline cars in terms of dollars per mile. However, switching to electric cars by itself barely helps the CO₂ problem, as the US electric grid is 40% powered by coal. Coal has the highest CO₂ emissions per Megawatt of any generating source.

Capturing CO₂ from car exhaust would be much more expensive compared to the modest costs for making reformulated fuels and upgrading engines and catalytic converters. I found it surprising that 1 gallon of gasoline weighs about 6.3 lbs. but makes 19 lbs. of CO₂. Gasoline is mostly carbon and gets it’s weight from oxygen in the air. Imagine we refrigerated our exhaust and captured our CO₂ as dry ice. After burning 10 gallons (63 lbs.) of gasoline, we have 190 lbs. of dry ice in the trunk that we need to pump down a deep well or somehow keep from evaporating (sublimating) into the air. CO₂ emissions are a hard problem to solve.

Renewable energy for power and fuels would cut oil imports and CO₂. Renewable energy investments in 2009 were:

European Union (27 nations)	\$41.1 Billion
China	\$34.6 Billion
United States	\$18.6 Billion

It is clear the US is trailing the rest of the world in the movement toward energy independence.



So what should we do and how fast do we need to do it? The number of investment options is mindboggling. The chart above is from the McKinsey report which made a cost benefit analysis of many options. The McKinsey report objective was to detail abatement options that might hold the rise in the mean global temperature 2 Degrees Centigrade (2 DegC) below pre-industrial levels. 2 DegC is a widely accepted target that is believed to be the threshold for the most damaging consequences of global warming. We have already experienced a temperature rise of 0.74 +/- 0.18 DegC. Notice in the chart above that McKinsey rates carbon capture from power plants as one of the most expensive, which is consistent with the difficulties we discussed for cars.

Biofuels

Fossil fuels took 300 million years to create a 200 year fuel supply. We need to improve on this a little if Biofuels are to be viable. Mistakes have been made and the



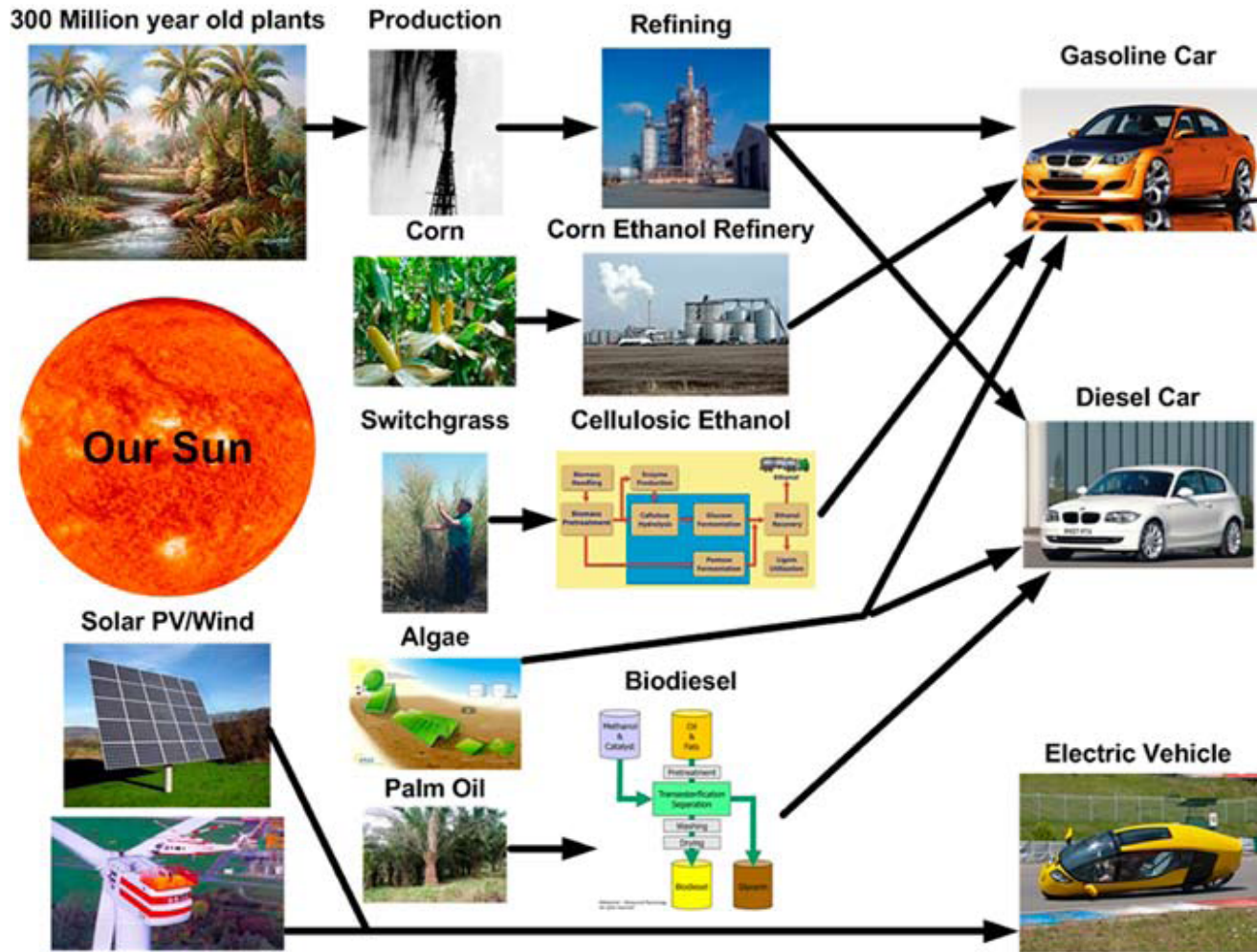
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The Solar Fuel competition



This flow chart shows the production and refining chain for traditional oil vs. Biofuels.

evolutionary path to create a Biofuels industry will be enormously complex and hard to predict. The illustration of the competition for pathways for the sun to push our cars shows only a few of the myriad options. Nuclear, Coal, Tidal, and Geothermal energy are options too. We subsidize some of these options with various tax credits. The government is basically picking the winners by providing tax incentives, environmental penalties, and other funding mechanisms to selected options. Not an easy task to get right when technology is changing so quickly and we learn about the full impacts on our fragile planet.

With our massive farming industry in the Midwest, Biofuels looked like the answer. When the government offered massive subsidies, Ethanol plants popped up all over the Midwest. Outside of the heavy subsidizes that guaranteed Ethanol to be the Biofuel of choice, and the taxes on cheaper Brazilian Ethanol that guaranteed that it would be US made, there are three other criticisms.

1. First, Ethanol is currently made from kernel corn and this competes with food production. News reports abound about how US companies like ADM and Cargill have bought up corn from Mexico causing the prices of tortillas to triple, leading to protests on the street and a crisis for President Felipe Calderón's administration.
2. The second criticism of the current Ethanol production scheme is that it has little if any benefit for overall greenhouse gas reductions. This is due to the energy intensive methods of farming and processing.
3. Finally, although 10% of the gasoline is Ethanol, the overall reduction of conventional oil imports is debatable and some have claimed the current Ethanol scheme has actually increased oil imports.

The Federal Energy Independence and Security Act of 2007, signed into law in December 2007, boosts the 2005 requirements for renewable fuel use to 36 billion gallons by 2022. The act requires "advanced Biofuels"

which are defined as fuels that cut greenhouse gas emissions by at least 50%, to provide about 60% of the total requirement. Such advanced Biofuels could include ethanol derived from cellulosic biomass, such as wood waste, grasses, and agricultural wastes; as well as biodiesel, butanol, and other fuels.

California has established the Low-Carbon Fuel Standard (LCFS). This first-in-the-world greenhouse gas (GHG) standard for transportation fuels will spark research in alternatives to oil and reduce GHG emissions. This law will require measuring the "life-cycle carbon intensity" of transportation fuels and will likely shift ethanol development from kernel corn to biomasses like trees or grasses.

On July 28, 2008, Governor Deval Patrick signed the Clean Energy Biofuels Act. This act waives the Massachusetts gasoline taxes for cellulosic ethanol, but so far there have been no takers. That is because there is no cellulosic fuel industry. Today there is a mad scramble by companies and scientists to make Biofuels a reality.

Recent funding at universities has begun to look at the complex chemistry of converting sunlight to liquid fuels. Not surprisingly research is aimed to literally design plants and micro-organisms for the job using modern Genetic Engineering methods often called Synthetic Biology. We know how to ferment sugars to make ethanol, but the hard problem is figuring out how to convert cellulose and lignin into sugars.

There are many other Biofuel options that can avoid this problem altogether. For example, a company called Joule Biotechnologies has designed a proprietary single cell micro-organism that consumes CO₂ from industrial sources and secretes diesel fuel. The system looks much like solar panels for hot water, except that it circulates cells in clear tubes. Another option is to heat a biomass without air, using catalysts. This process can produce a range of gasoline-like components directly. This process could also produce other valuable chemicals that may have a higher value than fuels.

Biofuels use sunlight to push our cars. The difficulty of converting CO₂ into Biofuels, and the poor thermal efficiency of the gasoline engine means there will be competition for other solutions. The fuel industry will compete with the power industry for Biomass. Simply burning the cellulose to make steam and generate electric power is a well known technology that combined with electric vehicles is another option.

Conclusions

Powerful forces are at work that will change the cars we drive, the fuels we use, and the way electric power is generated and distributed. Most peak oil predictions

have peak oil happening as we speak, while few predictions are in the range of 2020.

Biofuels on a massive scale have not yet been proven practical and are likely to have unforeseen impacts. It is complicated and we need to be very careful what we ask for, because we just might get it. Although Americans have been slow to act so far, we have yet to see the full impacts of American Ingenuity. In the next and final article in this series, we will discuss the competition for efficient transportation vehicles. ♦



Editor's Note: Rick Rys is a BM-WCCA and BMWMOA member. He is a registered chemical engineer (MA). He worked for Foxboro Company for 20 years, but has run his own consulting engineering company for the past 13 years. He developed equipment, software, and control systems to manufacture and blend gasoline and diesel fuel at many oil refineries worldwide to meet the EPA and CARB requirements for reformulated gasoline.



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