*FORECASTING WORLDWIDE PETROLEUM CONSUMPTION BY CORRELATING GDP AND ENERGY EFFICIENCY*

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## Overview

This study forecasts the global demand for petroleum will increase from the current 82 million barrels of oil per day (MMBPD) to 113 MMBPD by the year 2030. The increasing GDP in developing countries will account for most of the increase in demand. Using world GDP and energy efficiency allow for an accurate forecast of future demand since the two parameters account for world population, economic, and technological growth. Most of the world's petroleum is refined into transportation fuels so meeting the demand for oil may require development of alternative fuels and changes in how transportation vehicles are powered. Even though it is likely that conventional petroleum will meet most of the world's transportation fuel needs, alternative promising means of meeting the predicted demand should be pursued. Since alternative fuels have only slightly positive energy returns, the most promising path to world's future transportation needs are electric cars ('plug-in' hybrid or battery). Additional electrical generation capacity can be developed economically using hydropower or natural gas. Nuclear power, while promising, is still too expensive on a kilowatt hour basis. Although hybrid vehicles are currently popular, the economic breakeven point for some models is 10 to 20 years. The fuel mileage of gasoline powered light duty vehicles is inversely proportional to the vehicle's weight, neither engine horsepower nor body style are primary factors. This relationship points the way to vehicles with good gas mileage and also limits the improvements to fuel efficiency that can be expected.

## Methods

We gathered data from various sources including, the BP Statistical Review, IEA World Energy Overview, ExxonMobil, and journals and modeled the data using regression analysis. We also analyzed alternative fuel processes and non-conventional oil from an economic, engineering, thermodynamic, and physics perspective to determine the technical feasibility of proposals to meet world energy demand.

## Results

World GDP can be modeled by the equation World GDP (trillion 1996 US$) = 19.742 $e^{(0.0306 * X)}$, where X is the (year - 1980). The $R^2$ correlation coefficient of this equation is 0.996. The world's energy efficiency is the ratio of how many million barrels of oil are required to generate a trillion dollars of GDP. World energy efficiency can be modeled by the equation, Efficiency = 2.8948 $e^{(-0.0168*X)}$, where X is the (year - 1980). The $R^2$ value of this equation is 0.970. The implementation of technology and innovations is a slow and steady process resulting in steadily improving efficiency. Combining these two equations results in a prediction that the world will consume oil at a rate of 113 MMBPD in the year 2030, up from 82 MMBPD in 2006. This forecast is similar to ones made by EIA, IEA, and ExxonMobil.

Since the majority of the petroleum consumed by the world goes to the transportation sector, we looked at economics of producing more oil, alternative fuels, and the efficiency of light duty vehicles to understand how the world can meet the increasing energy needs. The consumption (and production) of oil is a function of GDP and efficiency, and not strongly correlated to the price of crude oil. To supply the future needs for transportation fuel, alternative fuels, e.g., non-conventional oil, bio-fuels and hydrogen, might be viable options. An examination of the thermodynamics and energy balances of these fuels reveals that bio-fuels can only supply a tiny (< 5%) of the US's gasoline needs and to do this will require converting 40% of the world's corn crop to ethanol. Hydrogen has an extremely unfavorable energy balance, requiring at least twice as much energy to manufacture as is released upon burning. Hydrogen is required to "upgrade" non-conventional oils but since hydrogen must be made from conventional fossil fuels developing non-conventional oil will increase the demand for natural gas and conventional oil.

A more promising way of meeting future transportation energy needs is by moving to lighter vehicles, especially if they could use stored electricity as their energy source. An examination of fuel efficiency of light duty vehicles revealed that their fuel mileage (miles per gallon) can be modeled by the equation: MPG = 74660 Weight $^{-1.0025}$ for vehicles weighing between 2000 and 6000 lb. In order to achieve gasoline mileage above 35 mpg, the vehicle would have to weigh less than 2100 lb. An alternative that would allow the transportation sector to use less oil would be to further develop economical rechargeable battery electric cars, i.e., 'plug-in' hybrids. If the electricity were provided from hydroelectric or natural gas fueled power plants, the forecast oil needs of the world would be reduced.

## Conclusions

1. World oil consumption is related to GDP and energy efficiency and the rate is forecast to rise from 84 million barrels of oil per day (MMBPD) to 113 MMBPD.
2. There are no signs that "peak oil" has occurred and it is possible that production rates of oil may continue to rise. There has been a shrinkage of the global surplus refining capacity in the past three years and the removal of slack from the system renders it susceptible to production or refinery disruptions.
3. Biofuels such as corn based ethanol convert food into fuel with a marginal energy return. The cost of converting corn to ethanol is increasing world hunger.
4. There are several sources of non-conventional oil such as oil sands, coal, and oil shale. Converting these materials into transportation fuels will require large amounts of energy, natural gas and water. Since disassociating hydrogen from water or methane is inefficient, the process of making syn-fuels is also inefficient.
5. One way to lower the cost of future fuel efficient vehicles would be to develop an electrical infrastructure that could support 'plug-in hybrid' or electric vehicles. Currently, hydropower and natural gas fired power plants produce the least expensive electricity. Wind energy and solar energy are the most expensive, although technological improvements may rapidly improve their economic viability. Electricity from nuclear plants is currently more expensive than coal fired electricity.
6. Currently the price of gasoline is too low to economically justify alternatives to petroleum but if gasoline becomes expensive, electric vehicles may become justifiable. A six thousand dollar price premium for a hybrid engine car requires more than twenty years to breakeven when gasoline is $3/gallon. If gasoline becomes much more expensive or if the price differential of fuel efficient vehicles were less, then alternatives would become viable.
7. The fuel efficiency of a light-duty vehicle is inversely proportional to the vehicle weight. Manufacturing vehicles that get good gas mileage is simply a matter of making light weight vehicles.

## References


Bennet, D. J.; The Elements of Nuclear Power, Longman 1972 p59 - 64

DiPardo, Joseph; "Outlook for Biomass Ethanol Production and Demand"

EIA Annual Energy Outlook 2007, available at: http://www.eia.doe.gov/

ExxonMobil "The Outlook for Energy: A View to 2030" http://exxonmobil.com/Corporate/Citizenship/Imports/EnergyOutlook06/index.html

Graboski, M.S. and McClelland, J.; "A Rebuttal to "Ethanol Fuels; Energy, Economics and Environmental Impacts" www.ncga.com/ethanol/pdfs/EthanolfFuelsRebuttal.pdf

IEA World Energy Outlook 2006; available at: http://www.worldenergyoutlook.org/2006.asp

Lomborg, Bjorn; The Skeptical Environmentalist Cambridge University Press, 1998 p 131

Lovins, Amory; "More Profit with Less Carbon" Scientific American Vol 293, No 3 2007 P74-83

Maddison, Angus; The World Economy: Historical Statistics, OECD Development Centre, Paris 2003

NRCAN Natural Resources Canada; CO2 Technology Roadmap. Available at: www.nrcan.gc.ca/es/etb/cetc/combustion/co2trm/pdfs/co2trm3_bpearson.pdf

Pimentel, David and Patzek, Tad W.; "Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower" Natural Resources Research, Vol 14, No. 1 2005 p 65-75

Skov, A. M.; "World Energy Beyond 2050" SPE 77506 Society of Professional Engineers 2002

Vaclav Smil; Energy at the Crossroads MIT Press 2005