The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

The 2008 IEA WEO - The World Energy Model and Energy Demand

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The purpose of the World Energy Outlook demand forecast is to show future energy market trends assuming no new government intervention takes place. This is a useful exercise because it tells governments what they need to do *now* to prevent the realization of an undesired scenario presented by IEA. Such an exercise is useful only if the underlying assumptions sufficiently resemble reality. If not, politicians can be lulled into complacency and/or issue the wrong type of policy response, resulting in disastrous consequences.

In this post I review the demand model of the World Energy Model (WEM) used in IEA's World Energy Outlook (WEO) 2008. My analysis indicates that the model has major deficiencies of a number of types. These include treating economic growth as an exogenous variable, when it is really depends on other variables, including the amount of fossil fuels available; inadequate analysis of the speed and price at which low grade fuels can be produced; and inadequate review of model outcomes compared to real-world data. Because of these and other issues, in my view, the model is not serving its intended purpose.

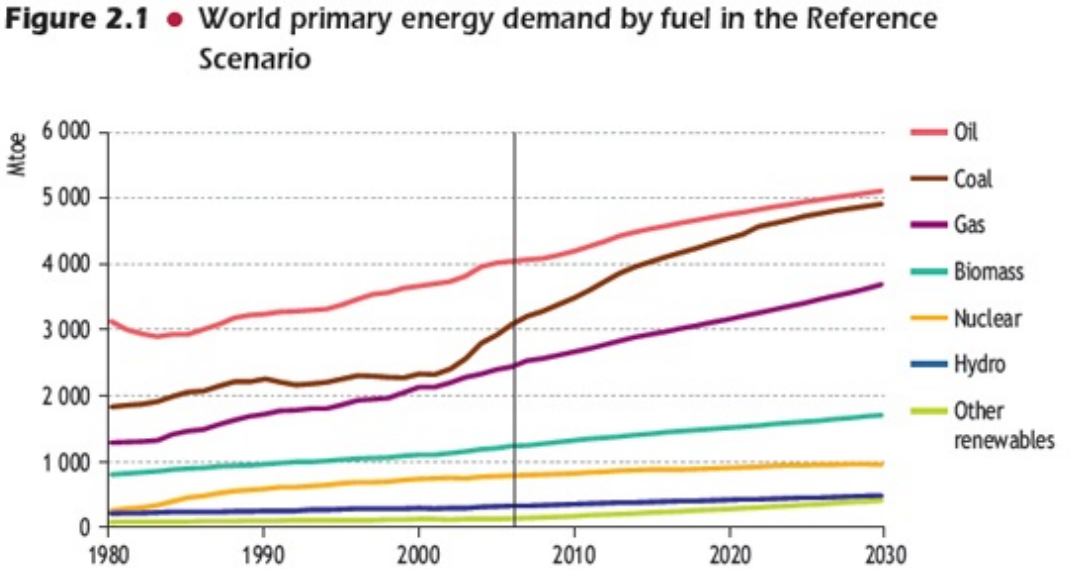

Figure 1 - World primary energy demand by fuel in the reference scenario. Figure taken from the World Energy Outlook 2008 report page 80.

Introduction

> "In our Reference Scenario, world primary energy demand grows by 1.6% per year on average in 2006-2030, from 11 730 Mtoe to just over 17 010 Mtoe — an increase of 45%." (World Energy Outlook 2008, International Energy Agency, page 38)

The outcome of the demand scenario from the International Energy Agency is an increase in energy consumption of 45% by 2030--a growth outcome that is extrapolated from present investment trends and governmental policies to the year 2030, far in the future. To state this explicitly in the IEA's own words:

> "The core projections, the Reference scenario, indicates what would happen if, among other things, there were to be no new energy-policy interventions by governments beyond those already adopted by mid-2008. This will not happen and the Reference scenario is not a forecast: it is a baseline picture of how global energy markets would evolve if the underlying trends in energy demand and supply are not changed." (World Energy Outlook 2008, International Energy Agency, page 52)

The demand trend is thus constructed from assumptions based upon current policies and extrapolating these assumptions to 2030. The assumptions are inserted into formulas used in the IEA's mathematical World Energy Model (WEM) which is comprised of the following six models: final energy demand; power generation; refinery and other transformation; fossil fuel supply; CO2 emissions, and investment. These six models have direct as well as feedback connections between each other. The simplified structure is shown in Figure 2 below, taken in adapted version from the IEA explanation paper of the WEM to make it more readable (the original version of this graph is of very poor quality). A detailed description of the WEM can be found here in PDF format.

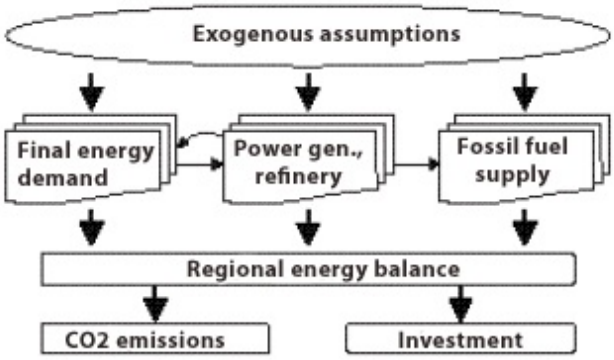

Figure 2 - International Energy Agency World Energy Model (WEM) overview adapted from the WEM model explanation graph

How are demand trends projected in the IEA's World Energy Model?

The IEA uses several main variables to project demand of which demographics, economic growth, international fossil fuel prices and technological development measured by means of energy intensity (energy usage per unit of output of the economy) are the most important. All these variables are taken as exogenous assumptions and are thus not derived from the World Energy Model (WEM) itself.

For the World Energy Outlook 2008 the following assumptions were taken for these four main variables:

• **Demographic developments**, population is projected to grow from 6.5 billion in 2006 to around 8.2 billion in 2030 in the WEO 2008. The proportion of people over 60 years old are projected to rise from 11% now to about 15% by 2030. These figures used by the IEA are drawn from the most recent United Nations projections from 2007.

• **Economic growth**, the IEA assumes that the current economic crisis is of a short lived nature. By the turn of the decade, world Gross Domestic Product (GDP) growth is expected to recover to around 4.5% per year. After around 2015 it is expected that GDP growth will progressively slow until 2030. World Gross Domestic Product (GDP) is assumed to grow by an average of 4.2% per year in 2006-2015 and 2.8% per year in 2015-2030. Combined this leads to an average of 3.3% per year over the period of 2006-2030. GDP growth is weighed by using purchasing power parity (ppp) and the input numbers are based largely on projections prepared by the OECD, IMF and World Bank for the short to medium term. In the longer term, growth in each region is assumed to converge to an annual rate dependent on demographic developments, productivity, macroeconomic conditions and the pace of technological change.

• **Energy prices**, the trajectories for international energy prices are derived from a new iterative model of supply and demand that has been introduced in the WEO 2008. An iterative model calculates the costs of energy based upon interactions between supply and demand. It means that the costs of energy increase up to the point that it makes economic sense to invest sufficiently in energy production as to meet the necessary demand growth. However, as prices rise, demand decreases since consumers can pay less and shift their consumption to other goods. A new equilibrium is thus reached in iterative steps at which demand equals supply. This year the IEA has assumed much higher costs to produce fossil fuel in general, and in particularly for oil as shown in Figure 3 below.

Table 1.4 • Fossil-fuel price assumptions (dollars per unit)

	Unit	2000	2007	2010	2015	2020	2025	2030
Real terms (2007 prices)								
IEA crude oil imports	barrel	33.33	69.33	100.00	100.00	110.00	116.00	122.00
Natural gas								
US imports	*MBtu*	*4.61*	*6.75*	*12.78*	*13.20*	*14.57*	*15.35*	*16.13*
European imports	*MBtu*	*3.35*	*7.03*	*11.15*	*11.50*	*12.71*	*13.45*	*14.19*
Japan LNG	*MBtu*	*5.63*	*7.80*	*12.70*	*13.16*	*14.52*	*15.28*	*16.05*
OECD steam coal imports	tonne	40.06	72.84	120.00	120.00	116.67	113.33	110.00
Nominal terms								
IEA crude oil imports	barrel	28.00	69.33	107.34	120.27	148.23	175.13	206.37
Natural gas								
US imports	*MBtu*	*3.87*	*6.75*	*13.72*	*15.88*	*19.64*	*23.18*	*27.28*
European imports	*MBtu*	*2.82*	*7.03*	*11.97*	*13.83*	*17.13*	*20.31*	*24.00*
Japan LNG	*MBtu*	*4.73*	*7.80*	*13.63*	*15.83*	*19.56*	*23.08*	*27.16*
OECD steam coal imports	tonne	33.65	72.84	128.81	144.32	157.21	171.11	186.07

Note: Prices in the first two columns represent historical data. Gas prices are expressed on a gross calorific-value basis. All prices are for bulk supplies exclusive of tax. Nominal prices assume inflation of 2.3% per year from 2008.

Figure 3 - Fossil Fuel Price assumptions used in the World Energy Outlook 2008. Table taken from page 68 of the report.

• **Energy intensity** or the amount of fuel used per unit of economic output of the economy measured in terms of Gross Domestic Product (GDP). In the model energy intensity is taken per different unit of fuel (coal, oil, gas etc.) in each sub sector in the model (Industry, Residential, Services, Transport etc.). Overall, the energy intensity decline used is 1.7% per year. That means that primary energy demand per unit of real GDP is expected to decline by 1.7% a year, which is 0.6% faster than the average in the past three decades. The underlying assumption of this faster decrease in energy intensity is a continued transition to a service economy in many Non-OECD countries, as well as more rapid efficiency improvements in the power and end-use sectors in the OECD.

There are three main issues I have with the IEA demand side approach. First, it does not make sense to use the factors above as exogenous variables. Economic growth, for example, will be heavily influenced by energy supply which in turn impacts energy demand. We are currently experiencing an economic crisis for a number of reasons, among them being a lack of growth in oil production in the past three years. By taking economic growth for granted, the outcome of the model will always show growing energy demand for decades into the future. This scenario does not resemble the reality of a world in which fossil fuel supplies are limited.

The second issue lies in the lack of communication on the IEA's part to the external world (including policy makers and media) that these variables are taken for granted as exogenous variables. If one understands that growth is simply an assumption, it tremendously changes one's understanding of the IEA's World Energy Outlook 2008. If one clearly states one's assumptions, it becomes possible to challenge them. Otherwise, discussing the matter continues to be a black box of misunderstanding, and leads the media and politicians to take the IEA's scenarios for granted as likely developments, instead of scenarios that could happen under stated assumptions. I make this observation mainly from my personal experience with the media, civil servants, and

politicians in their interpretation of the IEA's message in the past four years in the Netherlands.

The third issue lies in the iterative model used to determine energy prices. The cost of increasing supply to meet increasing demand is highly dependent on the underlying assumptions. The IEA uses long term oil supply cost curves as shown in Figure 4 below as a basis for determining its estimates of supply. This involves plotting the total amount of resources available versus the estimated production costs of these resources. This shows, given the assumptions used by the IEA, that there are plenty of resources available at a relatively low costs below $100 per barrel, in a normal market environment. Normal means a market environment in which there is no OPEC cartel, there are no upcoming personnel shortages in the oil industry, and there are no external environmental issues that increase prices such as CO2 emissions. In previous editions of the World Energy Outlook, the IEA did not take into account any of such issues that change the "normal market environment". This was a limitation of the model that led to the very low price expectation of $20 to $30 per barrel in projection to 2030.

In the 2008 WEO edition, such issues are taken into account to a limited degree, leading to higher price expectations of around $100 per barrel in the next decades. It is doubtful whether the assumptions go far enough, however. There are several reasons why I think this is the case: First, the speed at which lower grade fuels can be produced is much slower than the speed at which conventional oil can be produced. In fact, the speed is so slow that it will be impossible to meet a large increase in demand through unconventional sources of fossil fuels in the next two decades. Second, it is doubtful whether conventional oil exists in the quantities shown in the oil supply cost curves chart. Third, this calculation does not take into account quality differences between these resources in a useful manner. One of the most important variables in determining costs is the increasing energy inputs required to produce progressively lower grades of oil.

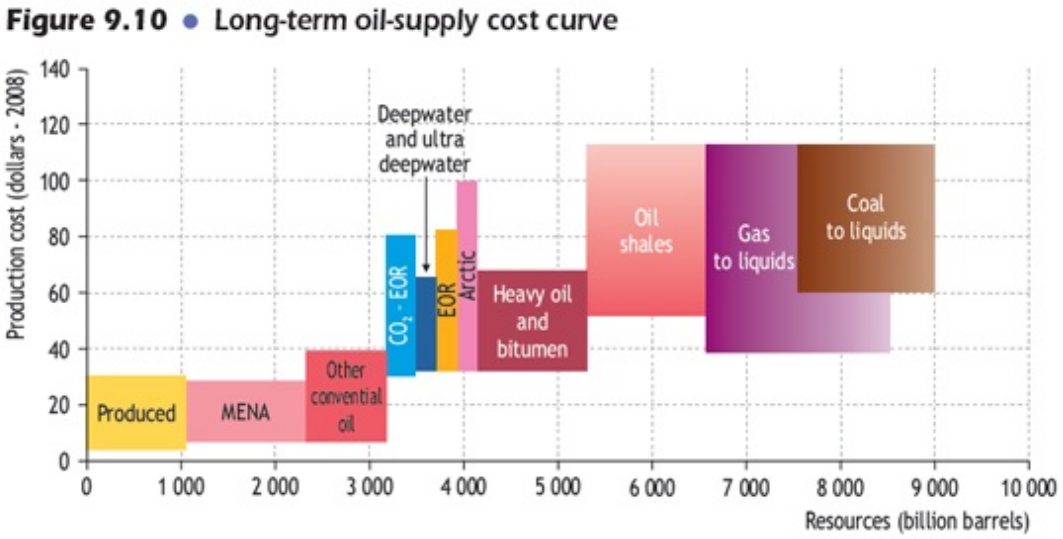

Figure 4 - Long term oil supply cost curve used in the World Energy Outlook 2008. Figure taken from page 218 of the report.

The energy demand outcomes of the WEM model

With an exogenous economic growth assumption of 3.3% per year to 2030, and an energy intensity decline of 1.7% per year, it is not surprising that the WEM calculations lead to an energy demand increase of 45% by 2030, as shown in Figure 5 for different types of fuels. Most growth comes from coal, which will almost overtake oil as the biggest energy source by 2030. The reason for this shift is because energy consumption is expected to increase in China and India, as a result

of demand growth in the next two decades, and these countries are expected to meet most of their incremental demand through coal. Although it is not explicitly stated in the WEO 2008, the gradual change to greater coal consumption is likely an effect of a combination of the WEM's relative price assumption of coal to that of oil and gas, plus the expected coal availability in China and India.

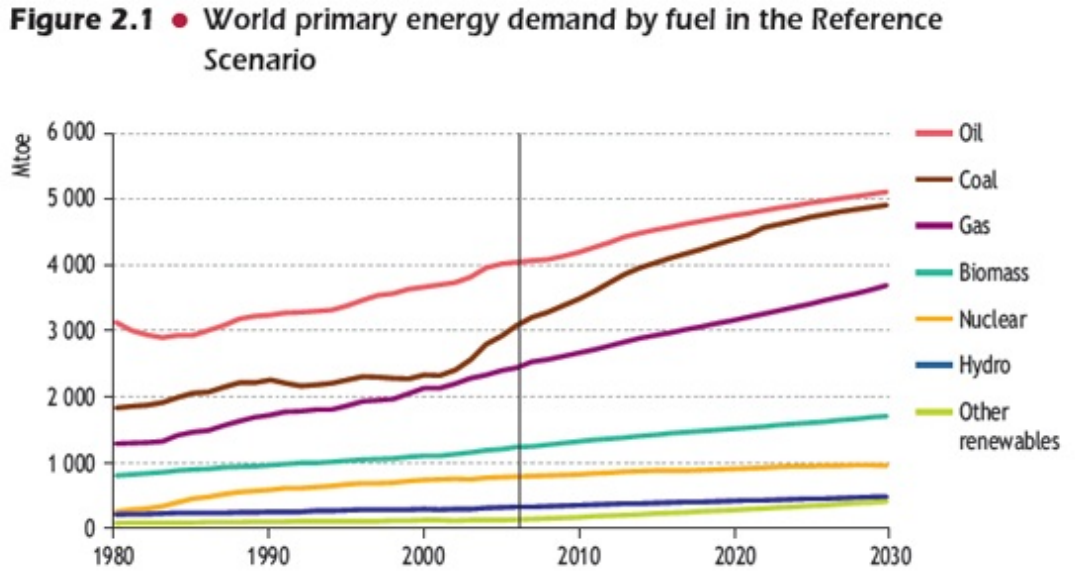

Figure 5 - World primary energy demand by fuel in the reference scenario. Figure taken from the World Energy Outlook 2008 report page 80.

Nearly all of the energy consumption growth of the world (87%) is expected to come from non-OECD countries in the future. Energy consumption in the OECD hardly grows, even as GDP increases at 2% per annum, due to an assumed continuous efficiency improvement in the power and end-use sectors. The biggest contributor to non-OECD growth is China. The country is expected to nearly double its energy consumption between 2006 and 2030 to a level of 3.8 million tonnes of oil equivalent, as shown in Figure 6 below.

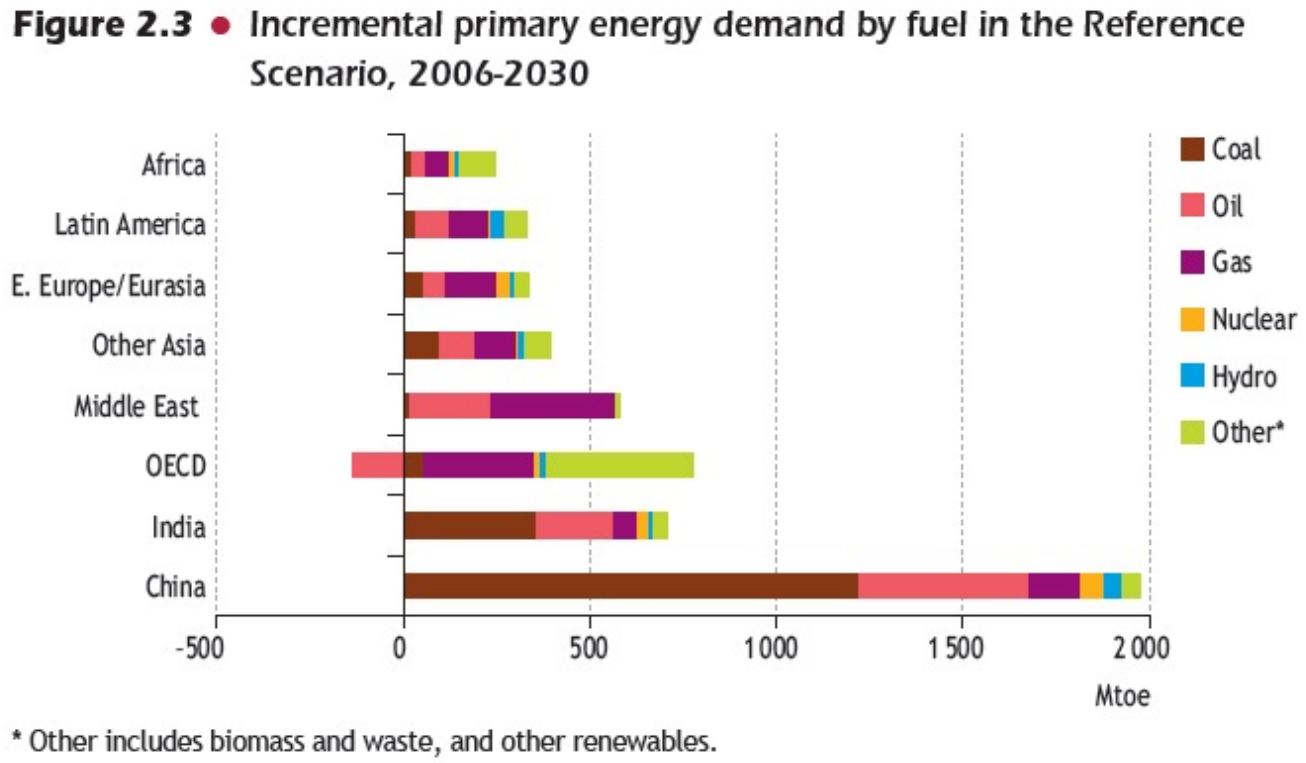

Figure 6 - Incremental primary energy demand by fuel per region/country from the World Energy Outlook 2008. Figure taken from page 82 of the report

If we take the assumed model structure with exogenous variables for granted, what can it tell us? Does the scenario provide a plausible enough outcome to show that the current energy path will lead to an energy consumption growth of 45% in the time period of 2006-2030? Even in the case that we do not take significant supply constraints into account?

Unfortunately, time has been too short between the publication of the World Energy Outlook and publishing this post in the next day to analyze the internal validity of the model's outcome myself. Fortunately, a recent article written by Nel and Cooper (2008) gives great insights in this issue. The article is called *"A critical review of IEA's oil demand forecast for China"* and was published in the January edition of the Energy Policy journal (PDF is downloadable here for those with access to Energy Policy). Although the article is based upon the oil demand projections from the IEA's WEO 2006 for China, its conclusions are still valid as the oil demand projection from the WEO 2006 hardly differs from that of the WEO 2008. China's oil consumption is expected to grow to 15 million barrels per day in 2030 in the WEO 2006 compared to 16.6 million barrels per day in 2030 in the WEO 2008.

In the article, Nel and Cooper look at the historical relationship between economic growth and oil consumption for several hundred countries in the world. The report concludes that in the most efficient historical cases, oil consumptions grows to 11 barrels per capita as GDP per capita grows to $20,000 (measured in purchase power parity terms). When comparing this value with the IEA's projections for Chinese GDP and oil consumption, they surprisingly find that China can do something which no nation on earth has done in history, growing to a level of wealth of $20,000 of GDP per capita as oil consumption per capita only increases to 3 barrels per capita, as shown in Figure 7 below. The authors conclude their paper by stating that:

> "The application of logistic curves to the lower-bound global historical data of GDP per capita in comparison to oil consumption per capita emphasizes the fact that the IEA forecasts for China diverge significantly from historical trends. Although potential contributing factors associated with the unique attributes of China could contribute to such divergence, the IEA projections are unprecedented in history." (Nel and Cooper, Energy Policy 36, page 1104)

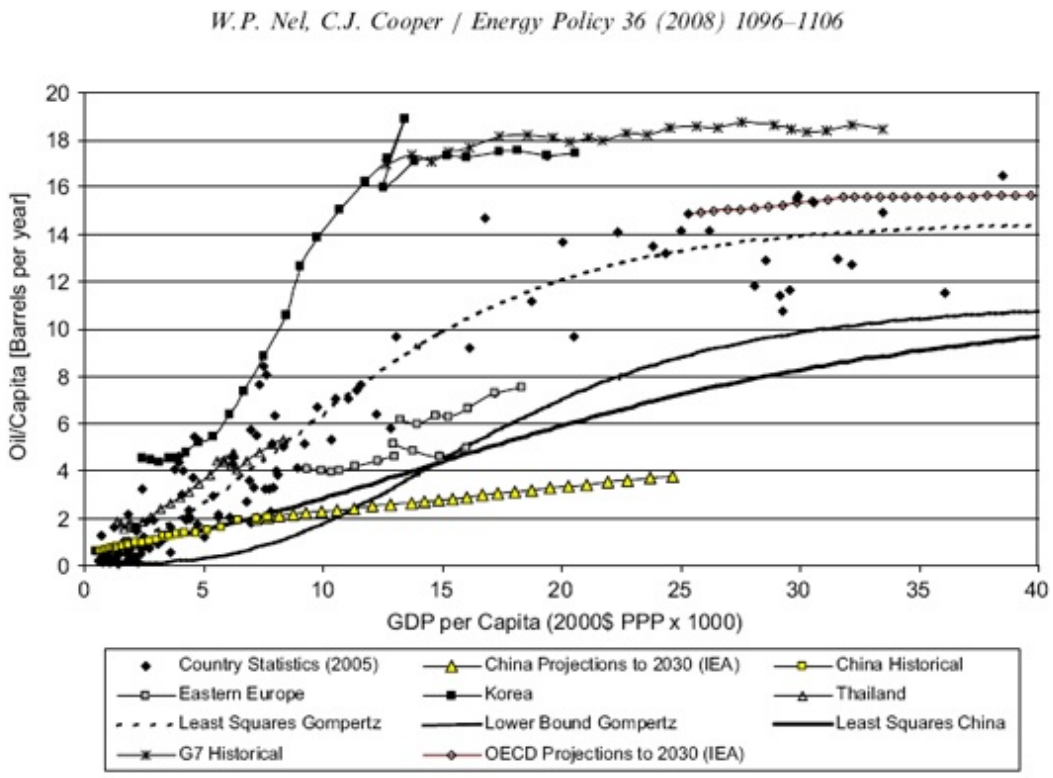

Figure 7 – Graphical presentation of projected demand growth for China in the WEO 2006 compared with historical data for other countries and candidate logistics curves, taken from Nel and Cooper (2008).

While this is hardly a comprehensive analysis of the entire energy demand model of the IEA, it raises significant doubts on the validity of the assumptions used in the demand part of the IEA's WEM used for the World Energy Outlook 2008.

Conclusions

I began this post by indicating that it is the IEA's intent to show how global energy markets will evolve if underlying trends in energy demand and supply are not changed by political intervention. I think that this goal has not been reached, as the assumptions in the energy demand part of the model do not sufficiently resemble the dynamics of reality. More directly stated: the world energy model in my opinion does not sufficiently resemble reality to answer any question or provide insight into the evolution of global energy markets without new political intervention.

In order to improve future versions of the WEM and World Energy Outlook, I suggest that it would be worthwhile for the IEA to examine the following key variables/issues more closely:

• Feedbacks between supply, demand, economic growth and energy prices

• Identification of the increase in the energy cost of fossil fuel production in the future that is expected to occur because of a decrease in the quality of the remaining fossil fuels over time

• Review of the empirical relationship between economic growth and energy consumption

• Explicit identification of assumptions and limitations regarding the WEM in the management summary of the World Energy Outlook

References

Nel and Cooper 2008, A critical review of IEA's oil demand forecast for China, Energy Policy, number 36, pages 1096-1106