IEA Oil Projections Revisited

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On the basis of scenarios computed by means of the OILPROSPECTS program, this paper disputes the IEA WEO2004 oil demand and production projections. The scenarios are comparable to the WEO 2004 scenarios. The computational method is described in the report *Oil-based Technology and Economy - Prospects for the Future*, published by the Danish Board of Technology and the Society of Danish Engineers in April 2004 (www.tekno.dk ; www.odac-info.org Assessments).

This paper is an elaboration of the paper *IEA Oil Projections Disputed* (Illum, December 2004) including a number of amendments. The discussion of the assumptions made by the IEA has been elaborated in more detail. The amendments concern the quantification and the graphical display of the non-conventional production needed to fill the gap between demand and supply when conventional production can no longer meet demand. Moreover, the scenarios shown have been modified.

The scenarios shown serve only to illustrate the implications of assumptions made by the IEA and, thereby, to raise questions as to the consequences of continued growth in oil consumption. They should not be interpreted as forecasts.

Contents:

1. Introduction

> *In the short era of abundant oil the all-embracing cheap-oil technological complex has extended worldwide, driven by motive forces at land, at sea, and in the air which by orders of magnitude exceed what was ever before available to man. As it is a cheap-oil complex, it depletes the oil resources much faster than long-term economic considerations would justify.*

Shortly after the report *Oil-based Technology and Economy - Prospects for the Future* was published, steeply rising crude oil prices signalled that the oil market has reached a capacity peak: there is presently little upstream swing capacity left in the Middle East or elsewhere; in the US in particular, the demand for light crude is high because of limited refinery capacity for heavier crude with a higher sulphur content; the oil tankers are busy; the supply from Iraqi oil fields has not grown as expected; and global oil demand is growing at a faster rate than hitherto foreseen by the International Energy Agency (IEA). However, the IEA expects that the upstream and downstream bottlenecks will soon be widened and that, therefore, the price of crude will soon drop well below $30/barrel.

The IEA states in its *World Energy Outlook 2004* (WEO2004) that

"The primary objective is to identify and quantify the key factors that are likely to affect energy supply and demand. The central projections are derived from a Reference Scenario. ....."

"These projections should not be interpreted as a forecast of how energy markets are likely to develop. The Reference Scenario projections should rather be considered a baseline vision of how the global energy system will evolve if governments take no further action to affect its evolution beyond that which they have already committed themselves to." (op. cit. p. 40)

This is a questionable statement because *"the global energy system will evolve"* as described in the Reference Scenario only if it *can* in practice evolve as described. No matter whether the time-series of figures shown in the many tables and graphs are interpreted as projections, scenarios or visions, they are relevant only if they display trajectories which are in accordance with assumptions as to future demand growth and production capacities which are not entirely hypothetical but within the ranges of at least physically and technologically, if not economically, plausible values. Moreover, it should be made clear what the actualization of the development trajectories implies in the longer run and how the trajectories change when the assumptions made are modified.

Regarding oil, the Reference Scenario is based on the assumption that

> *"Global oil production will not peak over the projection period [2003 - 2030] so long as necessary investments in supply infrastructure are made. New capacity will be needed to offset production declines and to meet demand growth. About $3 trillion will need to be invested in the oil sector from 2003 to 2030. Financing that effort will be a major challenge."* (op.cit. p. 81)

This statement presupposes that the global oil consumption will grow at an average rate of 1.6% p.a. until 2030. Thus it is a paraphrasing of the statement:

> If demand grows at 1.6% p.a. until 2030 and the investments needed are made, then global oil production will not peak before 2030.

The statement is true only if the hypothesis behind it holds, the hypothesis being that the world's accessible oil endowments are sufficient to render a 1.6% p.a. production growth over the next 25 years technologically possible. In accordance with this hypothesis, world oil production by source in the Reference Scenario is shown (p. 102-103) in a table and a graph (the graph *World Oil Production by Source* is shown below). The graph shows continued growth in production until 2030 and shows no indication of a decline after 2030. The questions to be asked are:

- What are the prospects beyond 2030 if the investments needed (be they $ 3 trillion or more) are actually made so that global production capacity can meet global demand (at a growth rate of 1.6%) until 2030 ?
- What are the prospects if the growth in global demand exceeds 1.6% p.a. ?
- What are the prospects if the assumptions as to future reserve additions (including new conventional oil findings amounting to some 470 Gb, according to IEA's *World Energy Investment Outlook 2003,* p. 107) and growth in production capacity are not fulfilled ?

The analysis presented in this paper addresses these questions, showing the implications of the assumptions upon which the WEO2004 Reference Scenario is based and the consequences of changes in these assumptions. The scenario S1, described below, corresponds to the Reference Scenario. The graphs shown below illustrate the magnitudes of the new reserves and the new production capacities to be added in the coming years in order to meet a demand growth of 1.6% until 2027. They also show that meeting a demand growing at 1.6% p.a after 2027 requires a dramatic growth rate in non-conventional production. The two other scenarios shown, S2 and S3, serve to illustrate the consequences of changes in the assumptions made in the S1 scenario.

2. Reserve and production data

Table 1 below shows the reserve and production data recorded for 2002. Naturally, the recording of reserve quantities to an accuracy of three significant digits does not imply that the quantities can be measured to any such accuracy. Proven reserves are estimates based on experience and seismic surveys. The undiscovered reserves figure is guesswork based on geological and probabilistic or statistical assessments. Nevertheless, these figures are assumed in the following analysis so as to make the results comparable to the WEO2004 Reference Scenario.

Conventional oil 2002:

	Produced (1) Gb	Proven reserves (2) Gb	Additional reserves (3) Gb	Production Mb/day
Middle.East	240	686	269	21
FSU	142	77	140	9.3
Latin.America	99	111	102	10.2
Africa	75	77	62	7.9
North.America	187	37	83	10.6
Europe	46	21	30	6.9
Asia	64	39	27	8.0
Other	20	1	220	1
Total:	873	1048	933	74.0

Ultimately recoverable reserves (1 + 2 + 3): **2852 Gb**
Including Natural Gas Liquids

Additional reserves = Undiscovered reserves and reserve growth

Non-conventional oil (Heavy; oilshale; tarsand; gas-to-liquids)

	Mb/day
2002	1.1
2005	2
2010	3.8
2020	6.5
2030	10.1

Sources:
Proven reserves and production: BP Global energy statistics 2002
Undiscovered reserves and non-conventional production: IEA WEO2002

Table 1

4. Conventional-production constraints

In this analysis a distinction is made between:

- Conventional production from existing proven reserves
- Conventional production from additional reserves (undiscovered reserves and reserve growth)

Conventional production from existing proven reserves

For each of the seven regions listed in Table 1, the area covered by the curve 'Production from existing conventional reserves' (from 2002 to infinity) equals the proven reserves (2002). The production is assumed to peak when a certain percentage of the ultimately recoverable reserves has been produced. According to the Hubbert theory the peak occurs when about 50% of the reserves have been produced. To allow for possible postponement due to enhanced recovery techniques, 60% is assumed in this analysis.

After the production in a particular region has peaked, the decline is assumed to be a logistic function. Depending on the parameters of this function, the decline curve may assume different forms: if it is less steep at the beginning, it will be steeper further on, and vice versa. In some cases the shape may thus be determined by enhanced recovery techniques by means of which production is kept at a plateau before it eventually declines.

Additional conventional reserves

Where, when and at which rate new reserves will be added to existing reserves is unknown. Therefore future reserve additions are pooled into one curve. At this stage of the history of oil exploration it is reasonable to assume that future additions in the next few years will occur at a rate similar to the average rate experienced in the last decade and that the rate will then decline following a logistic function. Thus, the reserve additions will begin at an estimated initial rate and then follow a declining curve which covers an area equal to total additional reserves.

Conventional production from additional reserves

Like reserve additions, the future production from additional reserves is pooled into one production curve. The area covered by this curve is the same as the area covered by the reserve additions curve, namely equal to total additional reserves. Its shape is determined by the rate of reserve additions, the time lag before production from new additional reserves begins, and the general shape of the production curves.

4. Non-conventional production

Non-conventional production, i.e. the mining of tar sand and oil shale and the conversion of natural gas or coal into oil, is not subject to resource constraints such as those limiting conventional crude oil production but rather to environmental and economic constraints. Therefore, the future non-conventional production is assumed to grow as projected by the IEA, see Table 1.

In the graphs below, the non-conventional production projected by the IEA, extrapolated to 2050, is shown as 'Non-conventional production. Forecast'. When 'Total production' (= Conventional production + this forecasted non-conventional production) can no longer meet the demand, the IEA assumes that the deficit will be covered by increased non-conventional production. In the graphs below, the non-conventional production required to cover the deficit is shown as 'Non-conventional production. Required'.

5. Oil production scenarios

Using the reserve and production data given in Table 1, different production scenarios can be derived from different assumptions regarding

- Future demand growth rates
- The initial rate of conventional reserve additions
- Modifications of the assumed conventional reserve quantities.

Three scenarios S1, S2 and S3 are summarized in Table 2. Graphic displays are shown below.

Scenario: *Assuming non-conventional production growth as shown in Table 1 (forecast)*	**S1**	**S2**	**S3**
(1) Demand growth 2004-2030	1.6% p.a.	1.9% p.a.	2.2% p.a.
Initial rate of conventional reserve additions	20 Gb/year	16 Gb/year	14 Gb/year
Total conventional reserve additions 2002 - 2030	500 Gb	400 Gb	360 Gb
Modifications of assumed remaining ultimate reserve quantities (*)	None	Reduced by 10%	Reduced by 18%
Ultimate conventional reserves	2855 Gb	2660 Gb	2510 Gb
Demand exceeds production in at	2027 41 Gb/year 112 Mb/day	2017 37 Gb/year 101 Mb/day	2016 36 Gb/year 98 Mb/day
Production peaks in at	2030 41 Gb/year	2020 38 Gb/year	2017 37 Gb/year
(2) Production decline rate after the peak	1.5% p.a.	1.2% p.a.	1.3% p.a.
(1) + (2)	3.1% p.a.	3.1% p.a.	3.5% p.a.
R/P ratio, 2002 conventional production 2017 (**) 2030	38 years 27 - 16 -	34 years 20 - -	34 years 19 - -

(*) In relation to Table 1
(**) R= reserves in year (not including reserves added later)
P= production in year

Table 2

Scenario S1 corresponds to the WEO2004 Reference Scenario. In this scenario production can meet demand until the peak occurs a few years before 2030. Then a gap between demand and production occurs, growing at a rate of 3.1% p.a. In the Reference Scenario the IEA assumes that the gap will be filled by non-conventional production (see the graph below). However, as shown by the S1 graphs this requires a growth rate in non-conventional production capacity ('Non-conventional capacity. Required') which, like the assumed growth in production from reserves added after 2002 ('New conv. capacity. All regions') is questionable.

In the scenarios S2 and S3 (which may be compared to the WEO2004 Low Resource Case scenario, Table 3.4, p. 102) the gap opens ten years earlier than in S1 and the growth rate in non-conventional production required to fill the gap is even higher than in S1.

The S1 scenario is as unlikely as it is unfortunate. It is unlikely that the industry within the next 20 years will obtain new conventional production capacity amounting to 70% of the present global capacity. And it is unfortunate that the world economy will become more and more dependent on oil while at the same time eroding the oil resource base. The growth in oil consumption implies that at the time when supply can no longer meet demand, no alternatives to oil-based technologies will have penetrated the market. Because - as assumed by the IEA - oil will remain cheap until the decline in production sets in. Truly a prescription for economic disarray.

It is not that the transition to an economy less addicted to oil is not be desired. But it is unfortunate that the transition in this scenario will take place under such unfortunate conditions.

The scenarios S2 and S3 may be somewhat less unfortunate because the world economy's oil addiction has not been allowed to rise to the same level as in scenario S1.

6. Demand growth

As against IEA's assumption that the oil consumption in China until 2030 will grow by 3.0% p.a. on the average, China's consumption of crude oil is expected to grow by 12% in 2005, from 288 million tons (about 2.19 Gb) in 2004 to 320 million tons (about 2.44 Gb) in 2005 (www.oilnews.com.cn and China Economic Net http://en.ce.cn/Industries/Energy&Mining/200501) in spite of the steep increase in crude prices in 2004. Although the growth in China in 2005 is expected to be somewhat less than the growth experienced in 2004, the continued high growth at high oil prices indicate that oil is such a basic element in the present economic growth in China, India and other countries in Asia and South America that a crude price well above $30/barrel need not strongly curb demand. Meaning that sustained economic growth does not imply that alternatives to oil-based technologies will penetrate the market to a significant extent

Thus, there are strong indications that world consumption will grow at a rate substantially higher than the 1.6% p.a. assumed in the WEO2004 Reference Scenario.

After the point where production can no longer meet demand, the demand curves in the scenarios displayed below show what the demand presumably would have been had production continued to meet demand. Hence, the gap between the demand curve and the production curve indicates the rate at which oil-based technologies must be replaced by other technologies in order to sustain the economic growth implied in the demand growth. In other words, the rate at which the investments made to consume oil at a still faster rate - i.e. investments in cars, roads and bridges, aeroplanes, airports, etc. - must be written off.

In reality, demand can, of course, only be measured as consumption. In a free market economy the oil price will ensure that demand = consumption equals supply in the short run. The price will rise until those of lesser means reduce their oil consumption and their consumption of goods produced and transported by means of oil to the amounts which can be supplied. If the economy plunges into a deep recession with high unemployment, the oil price need not remain very high to keep demand low. In an economy in spasms it might fluctuate in an unstable feed-back loop. Probably, not even the oil exporting countries and the oil industry will be blessed with windfall profits in a sellers' market where 1 billion motorcars are left in parking lots and carports for more and more hours and thousands of aeroplanes fly less frequently - which is what decline in oil consumption means in an economy which has become increasingly oil-addicted.

Surprisingly, economists have not analysed and drawn political attention to the economic and social consequences of such a development.

7. The demand-production equation

Apart from fluctuations in inventories and strategic oil reserves, which are relatively small as compared to annual consumption, annual oil consumption equals annual production. Hence, in the present cheap-oil technology complex, in which the purchasing of oil from refineries worldwide amounts to only about 2% of the global GNP, the oil producers and the manufacturers of oil consuming machinery (cars, airplanes, boilers, etc.) and infrastructures (roads, motorways, parking lots, airports, etc.) together with the consumers manage to keep annual production equal to annual demand because the equation

Demand = Production

can hold as long as

(#) $$\sum_c demand_c(P_c;\bar{x}_c) \leq prodcap(\overline{y})$$

where

$demand_c(P_c)$ is demand in country c at the present consumer price P_c under the conditions $\bar{x}_c$ and

$prodcap(\overline{y})$ is the global production capacity (Mb/day) as determined by the conditions $\overline{y}$.

The determinants $\bar{x}$ and $\overline{y}$ comprise arrays of interrelated factors which are correlated to the price P_c , see the cross-reference table Table 3.

Quantities, factors, infrastructures and regulations:	Directly influenced by or functions of:									
		P_c		$\overline{x_c}$				$\overline{y}$		
	GD	CoP	Opr	GDP	SUB	TE	CoPre	INV	Geo (¤¤)	Reg/ Pol
$demand_c(P_c; x_c)$		*		*	*	*	*			
GD: Global demand	$\sum demand_c$									
Pr.cap: $prodcap(\overline{y})$								*	*	*
CoP: Consumer price			*							*
Opr: Oil price ab refineries	*							*		*
GDP		*			*	*	*	*		*
SUB: (¤) Substitutions for oil-based technologies and infrastructures		*					*			*
TE: Technological efficiency within the COTC		*					*			*
CoPre: Consumer Preferences		*			*					*
INV: Investments in exploration, development, refineries, etc,	*		*							*
Reg: Market regulations: Environmental Technological Economic (taxes etc).			*						*	
Pol: Political regulations: Production quotas Embargoes etc.	*									
AR: Accessible Resources								*	*	

(¤) COTC: Cheap-oil Technology Complex. (¤¤) Geology and Geography

Table 3. As long as accessible resources can be acquired at non-prohibitive costs and soon enough to meet demand, the oil market can function relatively smoothly through the complicated lattice of interrelated determinants shown in this table. When production can no longer meet demand, the function changes as some relations become much stronger and others much weaker. Therefore, past experience does not apply to the modelling of the future market development.

As long as the inequality (#) holds, consumption is driven by demand at moderate oil prices. At the time - which may be before production peaks - when (#) does no longer hold, i.e.:

$$(\#\#) \qquad \sum_c demand_c(P_c^o; \bar{x}_c) > \sum_c consumption_c(P_c; \bar{x}_c) = prodcap(\bar{y})$$

the oil prices P_c^o must increase to P_c so as to reduce demand to production capacity because demand reductions by changes in the technological and structural determinants $\bar{x}_c$ take time, in particular if economic recession sets in because of high oil prices. In an economy ever more addicted to oil, substitutions for the oil-based technologies and infrastructures upon which the economy is based will take a long time to implement.

The cornucopians referred to by Peter J. McCabe of the US Geological Survey[1] argue that the *demand = production* equation will hold in future because reserves are not fixed but, as illustrated in Table 3, determined by

> *"the mix of knowledge, technology and investment that sustains the process of exploration and production sufficiently to meet short- and medium-term demand expectations. Reserves depend on the interaction of this process, government policies and, finally, the price people are willing to pay for oil products. Since we cannot know future technology or prices, we cannot quantify future reserves. This should not be a concern, since it is these processes that are important. Ultimately, as [Morris A.] Adelman commented, 'oil resources are unknown, unknowable and unimportant'* " [2]

This statement contrasts with the following statements by M.King Hubbert:

> *"My analyses are based upon the simple fundamental geologic fact that initially there was only a fixed and finite amount of oil in the ground, and that, as exploitation proceeds, the amount of oil remaining diminishes monotonically. We do not know how much oil was present originally or what fraction of this will ultimately be recovered. These are among the quantities that we are trying to estimate."*

> *"If oil had the price of pharmaceuticals and could be sold in unlimited quantity, we probably would get all out except the smell. However, there is a different and more fundamental price that is independent of the monetary price. That is the energy cost of exploration and production."*

Quotations from M. King Hubbert's response to remarks by David Nissen, Exxon, 1982.
www.hubbertpeak.com/hubbert/to_nissen.htm

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[1] Peter J. McCabe: *Energy Resources - Cornucopia or Empty Barrel ?* AAPG Bulletin V.82, No.11 (November 1998)

[2] John Mitchell et al.: *The New Economy of Oil. Impacts on Business, Geopolitics and Society.* Earthscan Publications Ltd, London (2001). Op.cit. p. 46-47.

Thus the conflicting views are, on the one hand, the theoretical view of the cornucopians and, on the other, the pragmatic view expressed in Hubbert's statements. As shown in the graph *World Oil Production by Source* shown below, the IEA projections reflect the cornucopians' view. They are based on the assumption that investments which are lucrative for the oil industry can soon enough bring about production capacity sufficient to cover a growing demand, if need be by accelerated exploitation of non-conventional resources, see the S1, S2 and S3 scenario graphs below. However, as Hubbert says, the costs of covering a growing demand will eventually become prohibitive - one may add: even in a peaceful world.

Today there can be little doubt that if demand keeps growing at a rate of 1.6% p.a. or more, oil production capacity (conventional plus the non-conventional capacity foreseen by the IEA in its WEO2004 Reference Scenario) will not meet demand beyond 2030. It is as likely that the shift from (#) to (##) will occur well before 2020, as in the S2 and S3 scenarios shown below. The shift may take place because the investments needed to keep production capacity above demand are not deemed lucrative by the private oil industry or not advantageous for the national oil companies - or because wars and sabotage prohibit production, transportation, exploration and development in many countries. Or because accessible resources have been depleted to the extent that production from many fields - in particular the old giant fields in the Middle East - begins to decline no matter which extraction technologies are applied.

8. IEA's Alternative Scenario

In the WEO2004 Alternative Scenario it is assumed that governments implement stricter technological standards, primarily as regards energy efficiency of cars, and renewable energy programmes in addition to standards and programmes already implemented or planned. It is envisaged that thereby the growth in oil consumption will be reduced to 1.2% p.a. and that the crude oil price in 2030 will be 15% less than in the Reference Scenario.

This would be steps in the right direction but far from the deconstruction of the oil-based technological complex at the rate required to ensure that demand peaks before production capacity peaks. If the demand growth rate in scenario S1 is reduced from 1.6% p.a. to 1.2% p.a., the gap between demand and total production opens in 2035 instead of 2027, at the same consumption level as in the Reference Scenario, namely 121 Mb/day (44 Gb/year). Thereupon the decline in production will be somewhat steeper than in the S1 scenario. This is because consumption from 2002 to 2035 at a growth rate of 1.2% p.a. is bigger than consumption from 2002 to 2027 at a growth rate of 1.6% p.a. Therefore the area covered by the production curve after a peak in 2035 becomes less than the area covered after a peak in 2027.

If the "business-as-usual" demand growth is rather 2% p.a. and hence reduced to 1.6% p.a. in the Alternative Scenario and/or reserve additions in the next decade turn out to be less than 20 Gb/year, the gap between demand and production capacity will occur well before 2030.

Thus the Alternative Scenario does not represent a safeguarded solution to the *demand = production* equation in the next decades. It does, however, show that the efficiency measures and renewable energy programmes assumed to be implemented in that scenario to achieve a reduction in demand growth of 0.4% p.a. are far from sufficient to fend off the unfortunate economic consequences of a 1.5% p.a. decline in production after the peak in production capacity.

It should also be noted that in the Alternative Scenario it is assumed that the future crude oil price will be lower than in the Reference Scenario (15% less in 2030). This means that the economic incentives to pursue higher technological efficiency standards and renewable energy programmes will be even less than in the Reference Scenario. Hence, the Alternative Scenario is based on the assumption that peoples and their governments will become alerted to the serious consequences of continued growth in oil consumption so that a worldwide general consensus on the need for strict political consumption regulations will develop in the coming years. But then the Alternative Scenario should be much more far-reaching so as to inform about the undertakings needed to ensure that demand peaks before production capacity peaks.

It is not enough that *"The World Alternative Policy Scenario depicts a more efficient and more environment-friendly energy future than does the Reference Scenario"* (op.cit. WEO2004 p. 367). What is needed is a scenario which informs peoples and their governments about what it really takes to deconstruct the oil-based technological complex so as to build sustainable energy systems.

In the market economy the taxation of energy consumption is the most obvious way to ensure that alternative technologies will become competitive and to influence consumer behaviour. Nevertheless, a partial shift from the taxation of labour to the taxation of fossil fuel consumption, oil consumption in particular, is not among the policies considered in the Alternative Scenario. However, if consumer oil prices are not regulated upwards by taxation, the lower oil price assumed will induce a growth in annual car, truck and air transport mileage which will at least partially offset the reductions achieved by increased energy efficiency.

9. The endgame

The longer the oil industry defers the point of time when production can no longer meet an ever-growing demand, the more unfortunate the situation at that point becomes: the world economy will have become even more addicted to oil when production eventually can no longer meet demand and subsequently begins to decline. Moreover, the decline will be steeper the longer the peak is deferred. This is because although each curve in the scenario displays may assume a somewhat different form, the area covered by the total production curve (2002 - infinity) must be equal to the proved 2002-reserves + additional reserves (in the cases here considered these reserves are given in Table 1). Likewise, the areas covered by the production curves for existing proven reserves must equal the proven reserves region by region. And the area covered by the production curve for additional reserves must equal the total additional reserves.

However, the industry may not in all circumstances seek to exhaust their existing reserves and find new reserves as fast as they can in order to meet growing demand at a low price. Private as well as national oil companies are not in business to ensure low oil prices but to make profits. And they may find it more profitable to produce from existing reserves at a slower pace and a higher price rather than at a faster pace at a lower price and thereby also make exploration and development of new fields more profitable. At $30-40/barrel crude oil is still cheap as compared to its real commodity value, meaning that at prices within that interval demand growth need not be significantly reduced. Therefore, as long as Saudi Arabia has any swing capacity left, OPEC may seek to keep prices within that interval, a policy option which has been voiced by some OPEC officials.

In any case it is uncertain whether an increase in the oil price as experienced in 2004 signals an intermediate or a permanent lack of swing capacity - a permanent lack of swing capacity meaning that the production peak is imminent. There may be no unambiguous economic signals that a crisis is impending.

Under these circumstances economists can dispute and discard warnings from oil geologists and engineers as "crying wolf" because no one can be sure that the wolf is there before the consequences of the attack are indisputably recognisable.

Many oil geologists and engineers reckon that the IEA assumptions are unrealistic on the optimistic side, and that should IEA's estimates of undiscovered reserves be realistic, it is highly questionable whether undiscovered reserves and reserve growth will add 20 Gb/year to the resource base in the coming years. Moreover, IEA's assumption that demand will grow by only 1.6% p.a. on the average until 2030 is disputable. However, even if the IEA assumptions should hold, production can hardly meet demand for another 30 years - unless non-conventional production is drastically increased. Should IEA's assumptions not be entirely fulfilled, the day of reckoning will not be so far away.

10. Conclusion

The energy intensity of oil and its ease of transportation and storage makes it a unique, most precious energy source. In the short era of abundant oil the all-embracing cheap-oil technological complex has extended worldwide, driven by motive forces at land, at sea, and in the air which by orders of magnitude exceed what was ever before available to man. As it is a cheap-oil complex, it depletes the oil resources much faster than long-term economic considerations would justify.

There is no energy source in sight which can replace oil at the present rate of consumption. Therefore, as the era of abundance is coming to an end, energy policies should be directed towards the replacement of the cheap-oil technological complex - not the further expansion of its infrastructures. Yet, ever more motorways and airports are being built all over the world and the car, lorry and aeroplane factories send out more oil-consuming vehicles than ever before.

The conclusion is that huge investments in oil production lines and oil-based machinery and infrastructures resulting in the rapid erosion of the resource base and increasing CO_2 emission are misplaced. There are better investment opportunities. Some of these alternative investment opportunities are described in the WEO2004 Alternative Scenario. However, the results of these investments only amount to moderate changes in the oil-based technological complex. They do not ensure that oil demand peaks before oil production peaks.

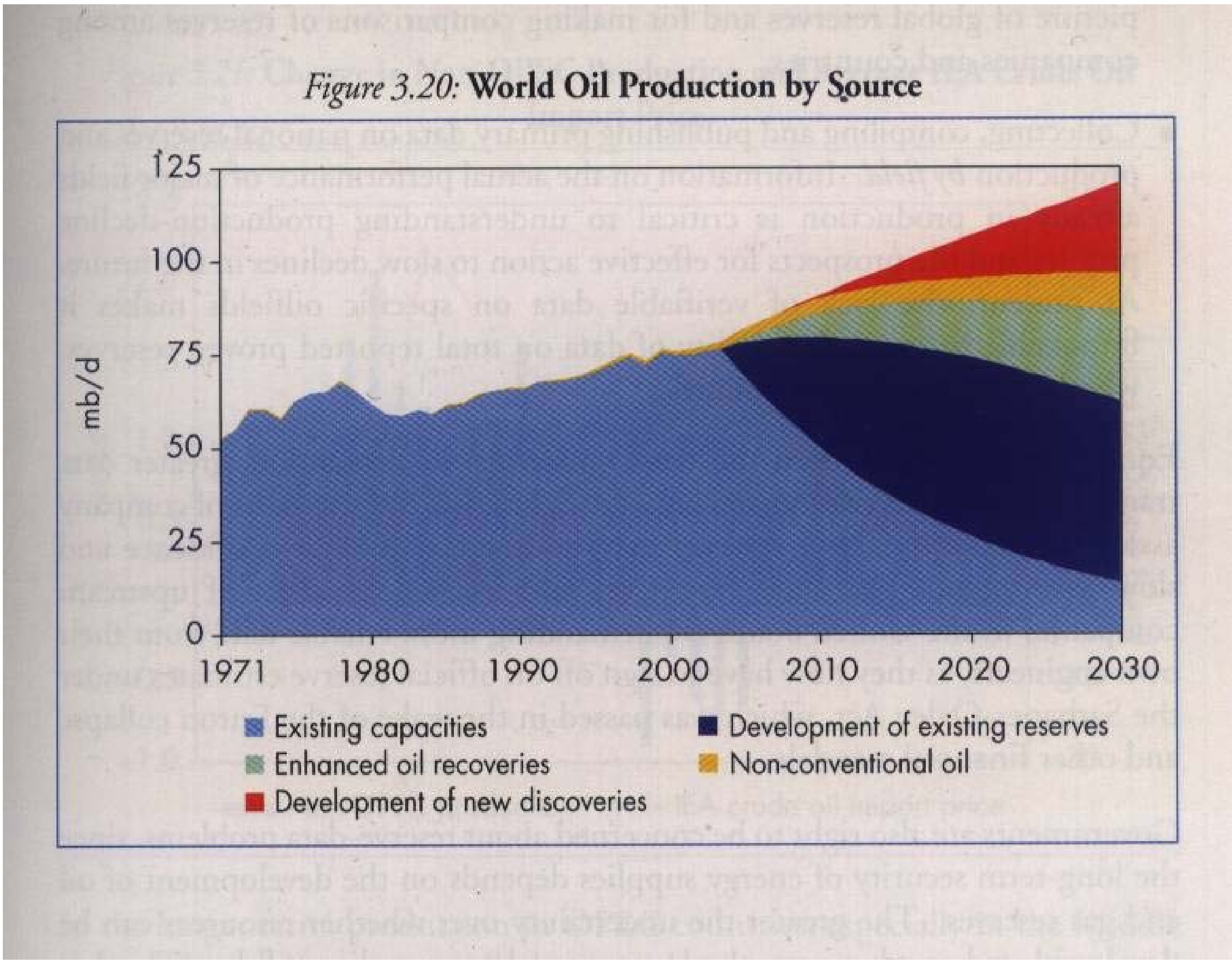
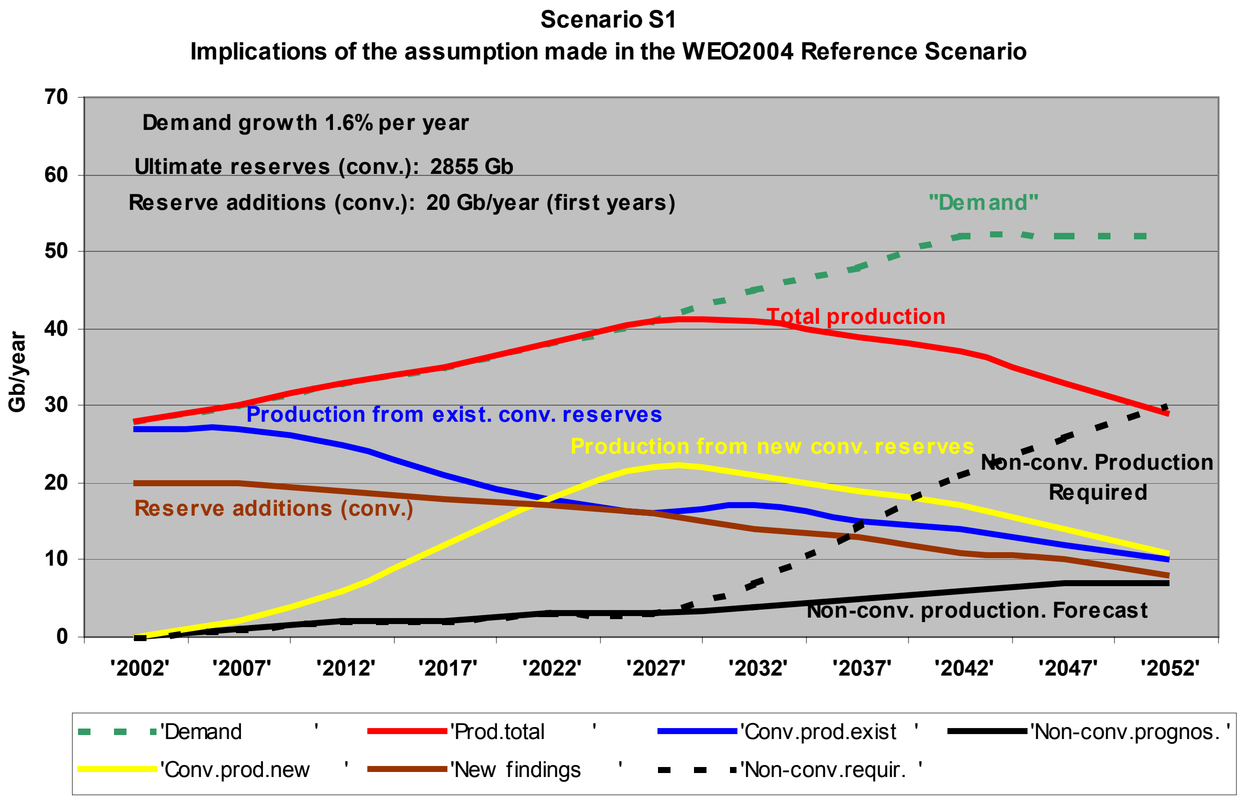
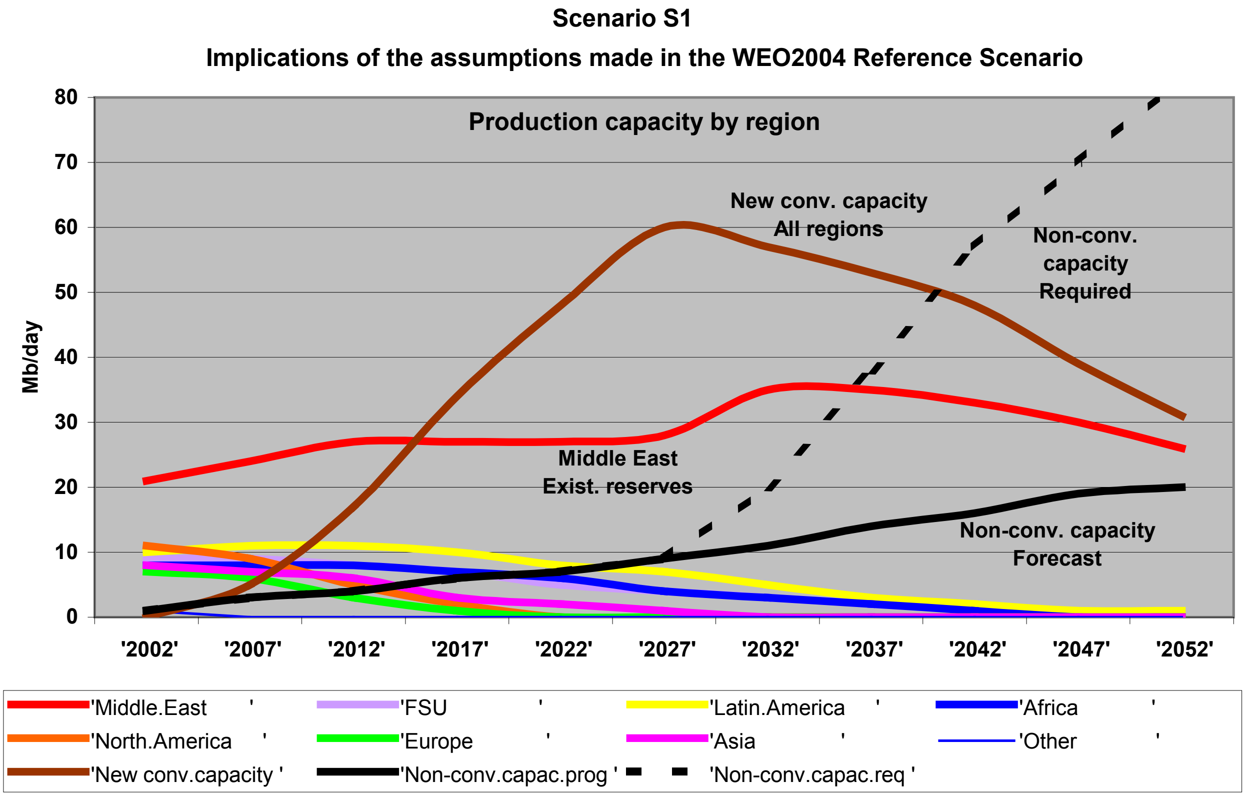


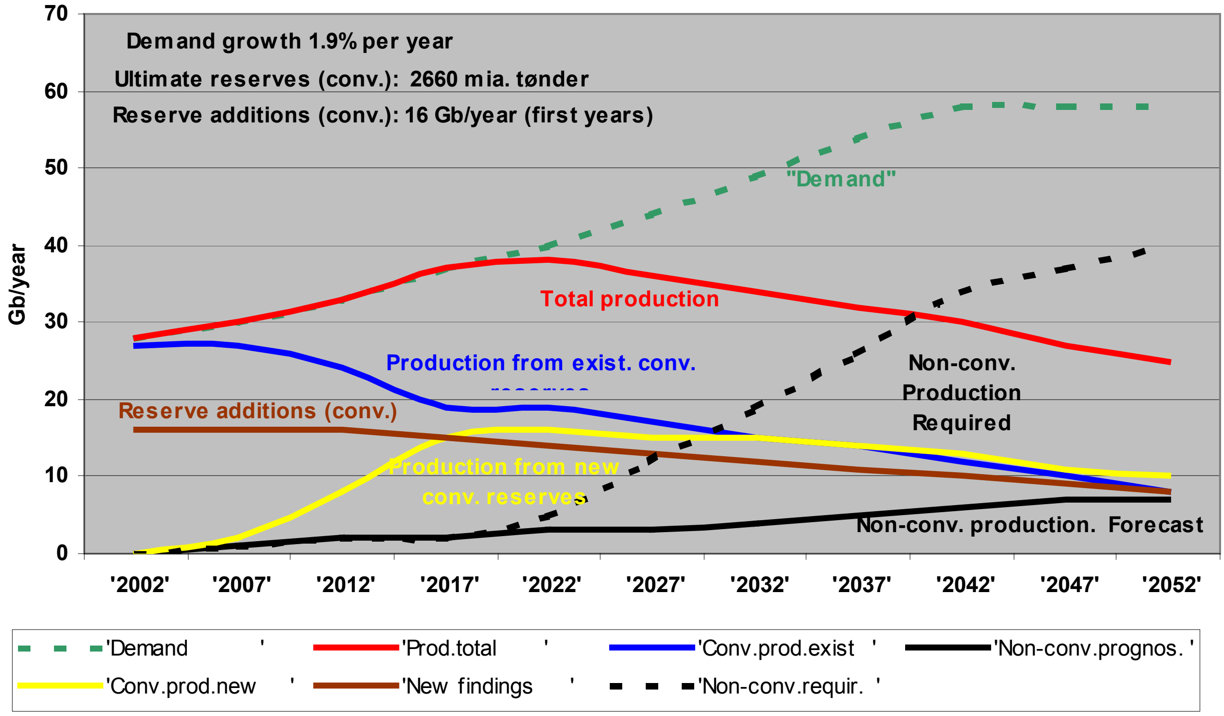
Figure 3.20: **World Oil Production by Source**

IEA projections. World Energy Outlook 2004, p. 103


Scenario S1
Implications of the assumption made in the WEO2004 Reference Scenario
Demand growth 1.6% per year
Ultimate reserves (conv.): 2855 Gb
Reserve additions (conv.): 20 Gb/year (first years)
"Demand"
Total production
Production from exist. conv. reserves
Production from new conv. reserves
Non-conv. Production Required
Reserve additions (conv.)
Non-conv. production. Forecast
Gb/year
70
60
50
40
30
20
10
0
'2002' '2007' '2012' '2017' '2022' '2027' '2032' '2037' '2042' '2047' '2052'
'Demand '
'Prod.total '
'Conv.prod.exist '
'Non-conv.prognos. '
'Conv.prod.new '
'New findings '
'Non-conv.requir. '

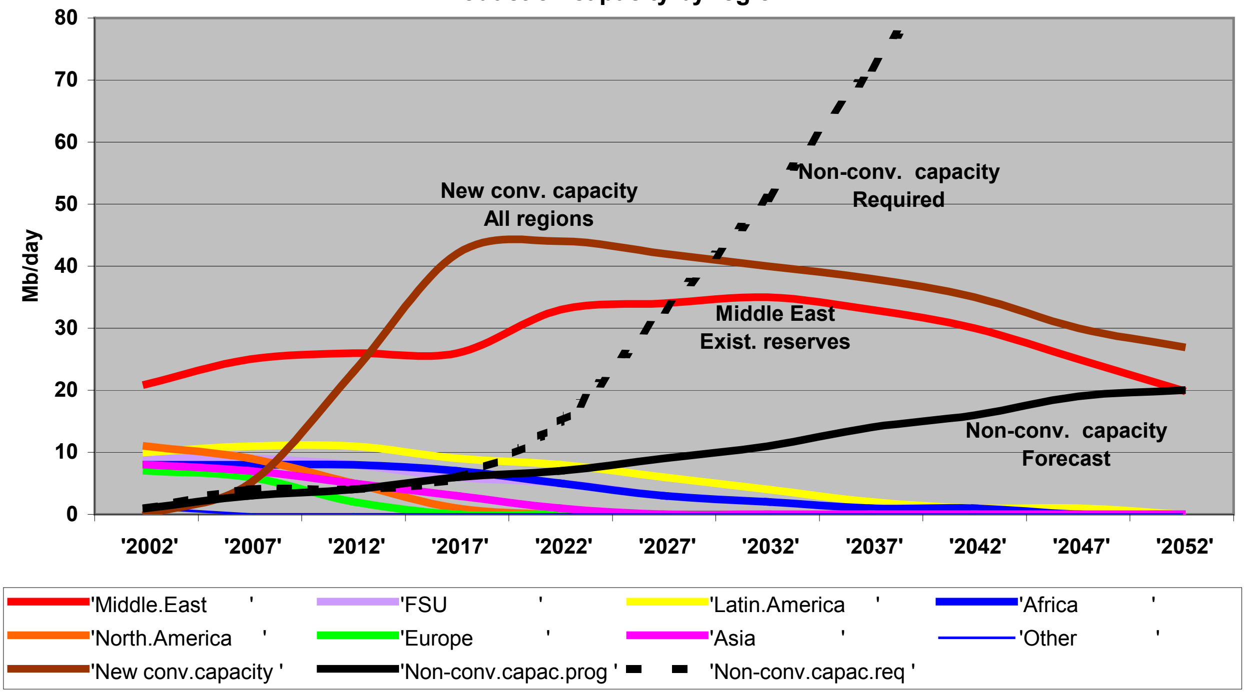

Scenario S1
Implications of the assumptions made in the WEO2004 Reference Scenario
Production capacity by region
New conv. capacity All regions
Non-conv. capacity Required
Middle East Exist. reserves
Non-conv. capacity Forecast
Mb/day
80
70
60
50
40
30
20
10
0
'2002' '2007' '2012' '2017' '2022' '2027' '2032' '2037' '2042' '2047' '2052'
'Middle.East '
'FSU '
'Latin.America '
'Africa '
'North.America '
'Europe '
'Asia '
'Other '
'New conv.capacity '
'Non-conv.capac.prog '
'Non-conv.capac.req '

Scenario S2

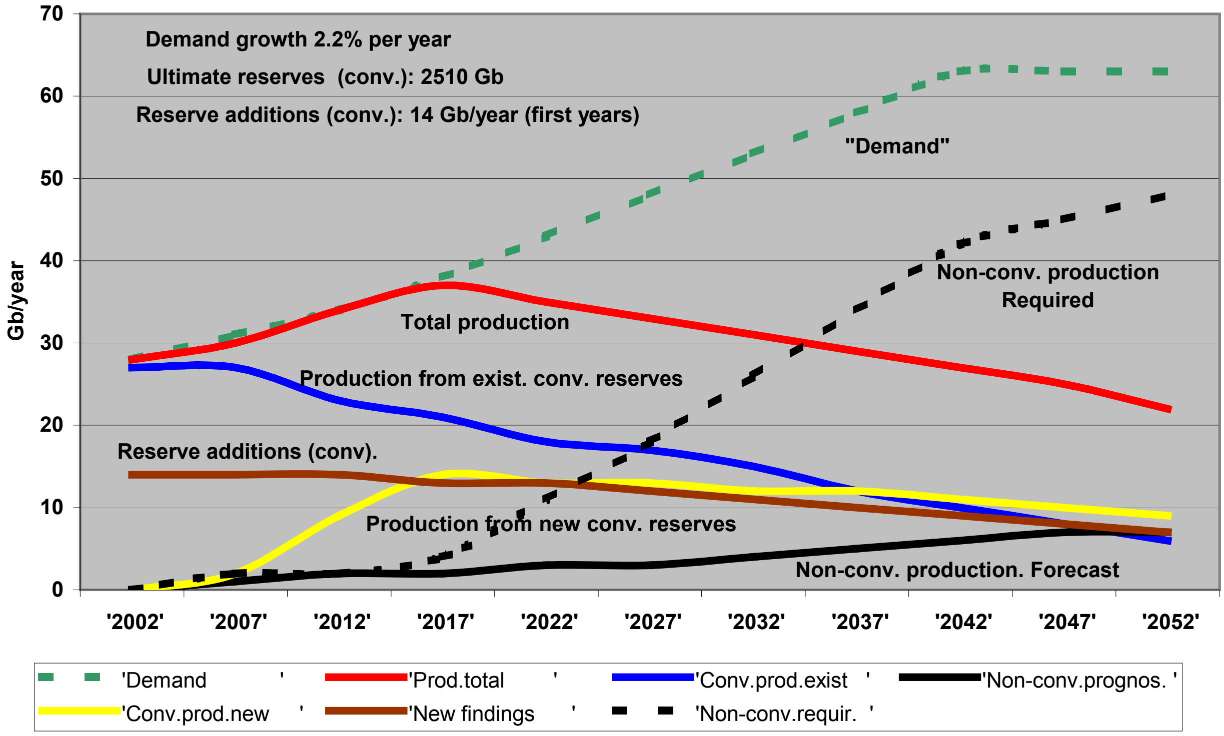


Scenario S2

Production capacity by region



Scenario S3



Scenario S3

Production capacity by region