Primary supply & fuel prices

Management summary

*This report describes the main trends in primary energy sources between **2002 and 2030**. It is mainly based on the "World Energy Outlook 2004" published by the International Energy Agency, the most complete published source for energy demand projections. The World Energy "Outlook 2005", published on the 7th November 2005, concentrates on Middle East and North African markets (MENA). When possible this report also refers to forecasts updated in the most recent Outlook.*

***Economic growth is the main driver for energy demand growth**, especially in developing countries. Primary **energy intensity** (i.e. primary energy use per unit of world GDP) is **assumed to fall by 1.5%** per year over the projection period. Combining these assumptions World primary energy demand is expected to grow from 10 723 Mtoe in 2003 to 16 272 Mtoe in 2030, i.e. an average annual growth of 1.6%. At the end of the period, oil demand will represent 34% of primary energy demand, gas represents 25%.*

*On the other hand, as time elapses, oil and gas **reserves will deplete**. Oil and gas supply will become more concentrated in a limited number of zones. Almost all the net increases in energy production will occur in non-OECD countries. Developing countries will thus emerge as the leading energy producers. Moreover the distance between supplying and consuming countries will increase. Concentration increases potential for market power while longer distances increase transport costs.*

As a consequence, supporting demand growth will require timely and massive investments, just as well in capacity expansion and new technologies as in demand reduction. Inadequate investments could lead to capacity shortage and to higher prices. These in turn might compromise economic growth.

*The main driver for **oil** demand growth is the transport sector, particularly in developing countries. In this sector there are few alternatives for oil. Promising alternatives are starting to develop (Gas-to-Liquids, Coal-to-liquids) but they are costly and their production is characterized by high CO2 emissions. Hydrogen might be an alternative in the longer run.*

There is a lot of uncertainty on the size of oil reserves, and as a consequence on future oil production as well as on prices.

Transport sector's increasing demand for fuel, as well as the characteristics of remaining crude oil reserves will necessitate important expansions of the existing refinery capacities throughout the projection period.

***Gas** demand will be driven by developments in the power generation sector. The gas reserves are assumed to be sufficient to cover at least the projection period. However as the cheapest and closest reserves are depleted first it can be expected that production and transport costs will rise.*

As reserves deplete an increased demand competition for more concentrated resources will emerge, potentially giving rise to monopoly or oligopoly rents and to higher prices.

***Coal** will continue to play an important role, especially in power generation in developing countries. Their primary concern is growth, not environmental constraints. Moreover some of these countries, like China and India, have important reserves themselves.*

Reserves are abundant, as such prices should remain stable in the long run.

*The International Agency for Atomic Energy (IAAE) assumes that **nuclear** reserves are sufficiently large for at least the projection period, even in a scenario of a high increase of nuclear energy production. Due to the high fixed costs of nuclear power plants, Uranium prices contribute only moderately to power production costs. As a consequence changes in Uranium prices have a relatively small impact on nuclear energy prices.*

Due to often contradicting evolutions (energy demand, CO_2 emissions, remaining energy reserves, geostrategic risks, physical limitations, ...) an energy policy for the next 25 years should not exclude any possible options in order to guarantee a maximal energy supply continuity for the country's economy.

1 Overview: primary energy demand by fuel type

1.1 World primary energy demand

In its World Energy Outlook 2004 the International Energy Agency considers two scenario's;

- a reference scenario: it "*takes account of those government policies and measures that were enacted or adopted by mid-2004, though many of them have not yet been fully implemented*"[1] [2]
- an alternative scenario: it *"depicts a more efficient and more environment-friendly energy future than does the Reference scenario"*[3] [4] [5]

In the IEA reference scenario World Primary Energy demand is expected to rise by 1.7%/year between 2002 and 2030 as can be seen from table 1.

Table 1: World Primary Energy Demand (Mtoe) - IEA Reference scenario

	WEO2004				WEO2005	
	1971	**2002**	**2030**	**2002 -2030***	**2030**	**2002-2030**
Coal	1407	2389	3601	1.5%	3724	1.6%
Oil	2413	3676	5766	1.6%	5546	1.5%
Gas	892	2190	4130	2.3%	3942	2.1%
Nuclear	29	692	764	0.4%	767	0.4%
Hydro	104	224	365	1.8%	368	1.8%
Biomass and waste	687	1119	1605	1.3%	1653	1.4%
Other renewables	4	55	256	5.7%	272	5.9%
Total	**5536**	**10345**	**16487**	**1.7%**	**16272**	**1.6%**

Source: IEA, World Energy Outlook 2004, p. 59, World Energy Outlook 2005, p. 82, own calculations

Oil will remain the main primary energy source in 2030 (almost 35% of total primary energy in 2030, in 2002 oil's share was 36%), followed by Gas (25% in 2030 against 21% in 2003) and then by Coal (22% in 2030, 23% in 2002). Nuclear energy's share will go down from 7% in 2002 to 5% in 2030. Renewables' share remains stable at 14%. WEO2005's figures differ only marginally from the ones in WEO2004.

Energy intensity will continue to decline as energy efficiency improves and the global economy relies less on heavy industry.

OPEC's estimates of future energy demand on a world level yield higher growth rates than IEA's reference scenario. Their projection period only goes to 2025 (see table 2):

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[1] IEA, World Energy Outlook 2004, p 41.

[2] The European emission trading scheme is not taken into account in the reference scenario. It has been taken into account in the alternative scenario. IEA, World Energy Outlook 2004, p251

[3] IEA, World Energy Outlook 2004, p 367

[4] E.g. in the reference scenario the renewables share of EU Electricity generation will be 18.3% in 2010.There are no targets beyond 2010. In the alternative scenario renewables share is assumed to be 34% in 2030.

[5] E.g. China's 25-year plan for energy conservation aims at increasing the fuel efficiency of new motor-vehicles. When the standards are implemented fuel efficiency will increase by 10% by 2008. New vehicles will then be as efficient as Japanese and more efficient then these is the US !. These improvements are taken into account in the reference scenario. The alternative scenario assumes a 10% further improvement between 2008 and 2030.

Table 2: World Energy Demand (Mtoe) - OPEC Reference scenario

	Levels mtoe			
	2000	**2010**	**2020**	**2025**
Oil	3614	4225	5059	5492
Solids	2341	2818	3435	3750
Gas	2101	2800	3808	4453
Hydro/nuclear/renewables	953	1065	1153	1195
Total	**9008**	**10908**	**13455**	**14890**

Source: OPEC, OPEC Review, September 2004, p160.

The average annual growth rates derived from table 2 are 1.7% for oil, 1.9% for coal and 3.1% for gas.

1.2 European primary energy demand

For the European Union primary energy demand is expected to rise 0.7%/year (table 3). European demand growth is thus expected to be lower than world demand. This holds true for all fuel types.

By 2030 oil will represent around 36% of European primary energy demand (38% in 2002), coal will represent 'only' 13% (18% in 2002), and Natural Gas is expected to have a share of 32% in European primary energy demand (23% in 2002).

The share of nuclear energy will go down from 15% in 2002 to 7% in 2030, renewables' share doubles from 6% to 12%.

Table 3: Primary Energy Demand in the European Union (Mtoe) - IEA Reference scenario

	1971	**2002**	**2010**	**2030**	**2002-2030***
Coal	426	303	307	274	-0.40%
Oil	633	648	687	743	0.50%
Gas	93	389	468	649	1.80%
Nuclear	13	251	251	146	-1.90%
Hydro	20	26	30	33	0.80%
Biomass and waste	25	65	84	147	3.00%
Other renewables	2	8	21	57	7.20%
Total	**1211**	**1690**	**1848**	**2048**	**0.70%**

Source: IEA, World Energy Outlook 2004, p. 251.

The European Commission also makes projections on primary energy demand (see table 4).

Table 4: Primary Energy Demand in the EU-25 (Mtoe) - European Commission baseline scenario

	Gross Inland Consumption					
	Solids	**Oil**	**Gas**	**Nuclear**	**Renewables**	
2000	*303*	*636*	*376*	*238*	*96*	**1649**
2030	*300*	*674*	*628*	*185*	*170*	**1957**
Annual growth	*-0.04%*	*0.20%*	*1.73%*	*-0.83%*	*1.91%*	***0.57%***
	Imports					
2000	*91*	*520*	*186*			
2030	*197*	*651*	*511*			
	Import dependence					
2000	*30.15%*	*81.75%*	*49.52%*			
2030	*65.82%*	*96.52%*	*81.36%*			

Source: European Commission DGTREN

The EC expects the primary energy demand growth to be lower than IEA's. Growth per fuel type is also a little different from the IEA reference scenario. The EC's projections are based on the PRIMES model.

The EU 25, being already heavily dependent on imports, will even become more dependent. This holds for all primary energy sources.

1.3 The IEA alternative scenario

Just to be complete the results of the IEA alternative scenario are mentioned. About this scenario the IEA says that *"larger capital needs on the demand side would be entirely offset by lower investment needs on the supply side ..... Electricity prices would rise. ... It is uncertain, however, whether all the investment in the Alternative scenario could actually be financed, especially in developing countries. This is because end-users, who would have to invest more, are likely to find it harder to secure financing than would suppliers, who would need to invest less"*[6]

In other words the alternative scenario is not considered to be very realistic. The results are shown in table 5. Annual growth of world demand is 1.3% on average. The shares of the different fuel types in 2030 become 19% for coal, 34% for oil, 25% for gas and 16% for nuclear.

Table 5: World Primary Energy Demand (Mtoe) - IEA Alternative scenario

	Energy Demand (Mtoe)			Shares (%)			Growth (% p.a.)
	2002	**2020**	**2030**	**2002**	**2020**	**2030**	**2002-2030**
Total Primary Energy Supply*	**10200**	**13345**	**14654**	**100**	**100**	**100**	**1.3**
Coal	2389	2726	2744	23	20	19	0.5
Oil*	3530	4600	4995	35	34	34	1.2
Gas	2190	3254	3701	21	24	25	1.9
Nuclear	692	816	868	7	6	6	0.8
Hydro	224	322	367	2	2	3	1.8
Biomass and Waste	1199	1433	1648	11	11	11	1.4
Other Renewables	55	195	330	0.5	1	2	6.6

* International marine bunkers are not included.
Source: IEA, World Energy Outlook 2004, p. 416.

The European demand under the alternative scenario is given in table 6.

6 IEA, World Energy Outlook 2004, p368

Table 6: Primary Energy Demand in the European Union (Mtoe) - Alternative scenario

	Energy Demand (Mtoe)			Shares (%)			Growth (% p.a.)
	2002	2020	2030	2002	2020	2030	2002-2030
Total Primary Energy Supply	**1690**	**1881**	**1872**	**100**	**100**	**100**	**0.4**
Coal	303	242	177	18	13	9	-1.9
Oil	648	663	636	38	35	34	-0.1
Gas	389	541	574	23	29	31	1.4
Nuclear	251	205	195	15	11	10	-0.9
Hydro	26	31	33	2	2	2	0.9
Biomass and Waste	65	152	189	4	8	10	3.9
Other Renewables	8	46	68	0.5	2	4	8.0

Source: IEA, World Energy Outlook 2004, p 421.

1.4 Belgian primary energy demand

DGTREN also published estimates for the Belgian demand growth over the period 2000-2030 (see table 7).

Table 7: Primary Energy Demand Belgium (Mtoe) - European Commission baseline scenario

	Gross Inland Consumption					
	Solids	**Oil**	**Gas**	**Nuclear**	**Renewables**	
2000	*8*	*22*	*13*	*12*	*1*	**57**
2030	*10*	*24*	*23*	*0*	*2*	**60**
Annual growth	*0.81%*	*0.31%*	*1.89%*	*-100.00%*	*3.79%*	***0.20%***

Source: European Commission DGTREN

Demand for all primary energy sources is expected to rise, except for nuclear energy, as a result of the law, voted by the Belgian parliament in January 2003, on the nuclear phase out. If no change is noticed in the political decisions then demand for nuclear energy will fall to zero.

For all energy sources Belgium is completely dependent on imports.

The Belgian "Federaal Planbureau" also published projections for the period to 2030. These are based on and in line with the EC's projections.

The transport sector is the only cause for the growth in oil demand. Industrial, residential and tertiary demand for oil is expected to decrease.

In 2003 Belgium imported most of its oil from Russia (40.6%) and North Sea countries (23.6%). 35.3% is imported from OPEC countries of which 30.8% comes from Middle East countries (Source: Belgische Petroleumfederatie, Jaarverslag 2004). At current (2003) production levels the Norwegian reserves are sufficient for another 8.3 years (i.e R/P = 8.3 years), the R/P ratio for the UK is 6 years (source: BP statistical review of World Energy, June 2005).

Belgian demand for gas increases throughout the projection period. This is due to an increased use of gas in electrical power generation as well as a switch from coal and oil to gas in the industrial sector and for residential heating.

In 2003 Belgian gas imports came from the Netherlands (35%), Norway (34%), the UK (12%) and Algeria (18%) (source: FOD Economie KMO,Middenstand en Energie). It should be mentioned that the two main suppliers of natural gas, i.e. Norway (at 2003 production levels R/P = 30 years) and the Netherlands (R/P = 22 years), are expected to 'run out of gas' near the end of the projection period. As such Belgium will become more dependent on imports from distant regions[7].

[7] In this context the planned construction of a fourth LNG-container and installations for gasification of the LNG in Zeebrugge should be mentioned. Until today long-term contracts covering the period 2007-2027 for a total volume

In the reference scenario of the EC, Belgian nuclear electricity production will be replaced by gas- and coal fired stations[8], hence the growth in demand for coal near the end of the projection period. In 2003 coal was mainly imported from South Africa (37%), Australia (24%) and the USA (18%) (source: FOD Economie KMO,Middenstand en Energie).

around 9 billion cubic meters of LNG per year have been signed. Half of this LNG will come from the Qatar North Field (see also Vlaamse Havencommissie, 'Jaaroverzicht Vlaamse Havens 2004')

[8] Just to give an idea for Belgium; nuclear production was around 45TWh in 2002. Replacing this by CCGT production with an emisson of 346kg/MWhe - the numbers come from NBB WP 59 - represents an additional 15.6 Mt of CO2. To be compared with a total Belgian CO2 emission 147Mt in 1990.

2 Analysis by fuel type

2.1 The Oil market

2.1.1 Demand for oil

The International Energy Agency expects that demand for oil will grow by 1.6% per year, from a 77 million barrels a day (Mb/d) in 2002 to 121 Mb/d in 2030 (WEO2004). These figures have been revised in WEO2005 to 1.5% for the annual growth rate and to a consumption level of 115.4Mb/d in 2030. Details per region are given in table 8.

Under the alternative scenario oil demand will be 13Mb/d lower in 2030, mainly due increased fuel efficiency in vehicles.

Table 8: World Oil demand (Mb/d)

	WEO2004					WEO2005	
	2002	**2010**	**2020**	**2030**	**2002-2030***	**2030**	**2002-2030***
OECD North America	22.6	25.5	28.7	31	1.1%	30.6	1.1%
OECD Europe	14.5	15.3	16.3	16.6	0.5%	15.7	0.3%
OECD Pacific	8.4	8.9	9.4	9.5	0.5%	8.8	0.2%
OECD	**45.4**	**49.7**	**54.4**	**57.1**	**0.8%**	**55.1**	**0.7%**
Transition economies	4.7	5.5	6.5	7.6	1.8%	6.2	1.0%
Russia	*2.7*	*3.1*	*3.6*	*4.2*	*1.6%*	*3.5*	0.9%
Other transition economies	*2*	*2.4*	*3*	*3.4*	*2.0%*		
China	5.2	7.9	10.6	13.3	3.4%	13.1	3.4%
Indonesia	1.2	1.6	2.1	2.6	2.9%		
India	2.5	3.4	4.5	5.6	2.9%	5.2	2.7%
Other Asia	3.9	5.1	7	8.8	3.0%	9.9	3.4%
Latin America	4.5	5.4	6.8	8.4	2.3%	7.5	1.8%
Brazil	*1.8*	*2.3*	*2.9*	*3.6*	*2.4%*		
Other Latin America	*2.7*	*3.2*	*3.9*	*4.8*	*2.1%*		
Africa	2.4	3.1	4.4	6.1	3.4%	5.7	3.1%
Middle East	4.3	5.4	6.8	7.8	2.1%	9.4	2.8%
Non-OECD	**28.6**	**37.5**	**48.8**	**60.4**	**2.7%**		
Miscellaneous**	3	3.2	3.5	3.8	0.9%		
World	**77**	**90.4**	**106.7**	**121.3**	**1.6%**	**115.4**	**1.5%**
European Union	*13.6*	*14.4*	*15.3*	*15.6*	*0.5%*		

Source: IEA, World Energy Outlook 2004, p. 82, World Energy Outlook 2005, p. 83, own calculations

World oil demand will grow most quickly in developing countries, in particular in China (3.4%/year)[9]and in Africa (3.4%/year). Demand growth in OECD Europe is expected to be 0.5%/year.

From a sectoral point of view the increase in oil demand will be highest in the transport sector. In the power sector demand for oil will fall.

The transport sector represents about half of all oil demand. It will absorb about two thirds of the total demand growth, mainly due to expansion in developing countries. In China e.g. the potential for expansion of the car fleet is enormous; there are only 10 cars per thousand inhabitants, while in North America this ratio is 770 per 1000, for Europe it is 500 per thousand.

The transport sector is also the second source of CO2 emissions, after power production. There exist solutions for CO2 reduction in the power sector (CO2 sequestration e.g.), but these are hardly implementable in the transport sector due to its specific nature. Moreover it should be noted that the countries where the highest growth in transport is expected are not submitted to Kyoto.

[9] This is well below the growth rates in 2003 (11%) and the first half of 2004 (15%).

The share of oil in energy demand for transport is around 95% today and the IEA expects this share to remain constant until 2030.

Alternative motor fuels exist (i.e. the production of synthetic fuels from gas - Gas to Liquids (GTL) - or from coal - Coal to Liquids (CTL)). They are however costly, especially CTL. Moreover their production has rather high CO2 emissions. Furthermore as a result of a conversion process they can increase 'oil reserves' but in the same time they decrease gas and/or coal reserves.

In a more distant future Hydrogen combined with fuel cells might be a solution. Heavy infrastructure investments (Hydrogen production, distribution and storage) are needed.

2.1.2 Oil supply

Oil is considered to be an exhaustible resource, i.e. oil reserves are finite. It is also widely accepted that most of the oil reserves are situated in the Middle East (55% of the remaining oil reserves are located in the OPEC-zone, 45% in the NOPEC zone)[10].

What is less known is that the estimates of ultimate oil reserves contain a lot of uncertainty. Reserves data are regularly revised downwards.

Nevertheless the IEA assumes that oil will not peak before 2030. This is heavily in contrast with the view of other analysts (e.g. ASPO - the Association for the Study of Peak Oil and Gas).

The R/P ratio for oil reserves is estimated at 36 years. This means that at the current level of production (P) the reserves (R) are sufficient for another 36 years of production. The average production over the projection period (i.e. (77+121)/2 = 95Mb/d) is 23% higher than 2002 production, so at that level of production reserves are sufficient for 36/1.23 years is 29 years of production. Just sufficient to cover the period !

So besides the geopolitical problem that oil is heavily concentrated in certain regions, there is also a lot of uncertainty with respect to the total amount of oil available, as well as the moment at which the oil production will peak. Many believe that we are close to the peak of NOPEC production today and refer to current oil prices to argument that.

As already said, the IEA assumes that oil production will not peak before 2030 if necessary investments in supply infrastructure are made. It is indeed evident that sufficiently high reserves are not the only condition, in addition investments must be made in order to 'pump up' these reserves at the same rate as demand growth. The necessary condition is thus that investments are made in time.

The required investments amount up to $3 trillion over the period 2003-2030. Most of this amount will go to exploration and development, but an important amount will also go to transport infrastructures - pipelines and tankers. As supply chains will lengthen in the future, tankers will play a dominant role.

Considering the uncertainty in reserve estimates and the increased volatility in oil prices it is far from certain that these investments will take place. Neither is it certain that the required funds will be available in these countries were they are needed. This is the main reason why many start to make a plea for deepening the dialogue between producing and consuming countries (see e.g. World Energy Outlook 2005, p 50).

Moreover due to these geopolitical reasons NOPEC production is (and will continue to be) at its maximum, the OPEC cartel plays the role of the residual supplier (and thus of price setter, see also the theory of the dominant firm). This implies that NOPEC reserves will be depleted faster and that the 'call on OPEC' will further increase.

As an example table 9 shows the origin of oil supplies to the EU-15. The most important supplies come from the Middle East (23%), North Sea production (37%) and Africa (18%). North Sea production increased from almost zero to 37% after the two oil crises, at the cost of Middle East imports. The reasons are political (aim for independence) and economical (high price make high-cost reserves economically interesting).

Since for geopolitical reasons these resources will be depleted first, one can expect an increased dependence on Middle East oil, or/and a further price increase.

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[10].Pauwels J.P., "Géopolitique de l'approvisionnement énergétique de l'union Européenne au XXIe siècle". p215

Table 9. Oil supplies to the EU-15.

Origines \ Année	1973	1978	1983	1988	1993	2001
Consommation de pétrole brut (*) (en 000 tonnes)	705 677	657 309	441 187	474 524	551 445	579,819
Moyen-Orient	66.6%	65.6%	30.9%	28.5%	33.2%	23.4%
dont Iran	13.9%	16.1%	8.4%	7.9%	9.6%	5.3%
Irak	7.0%	11.0%	3.2%	6.6%		3.4%
Koweit	11.0%	5.8%	1.0%	3.0%	3.6%	1.4%
Arabie Saoudite	25.6%	24.5%	13.2%	8.7%	16.1%	10.1%
Autres Pays	9.1%	8.2%	5.2%	2.3%	3.9%	3.3%
Afrique	24.4%	17.5%	23.4%	23.6%	20.8%	17.9%
Ex-URSS	3.1%	4.7%	8.7%	10.4%	9.4%	17.0%
Amérique latine	1.8%	1.0%	7.2%	5.7%	4.3%	3.4%
OCDE (Mexique exclu)	2.2%	9.8%	29.6%	32.0%	31.7%	37.7%
dont Royaume-Uni (Prod)		8.1%	25.3%	23.1%	17.0%	18.9%
Norvège	0.2%	1.1%	4.3%	8.5%	14.7%	18.4%
Autres Pays	2.0%	0.6%		0.4%		0.4%
Non-OCDE Europe				-0.1%	-0.6%	0.2%
Asie	0.1%	0.7%	0.2%	0.0%	0.0%	-0.1%
Non spécifiés	1.8%	0.7%	0.0%	0.0%	1.0%	0.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100%

(*) Importations + Production - Exportations

Source: Pauwels J.P., "Géopolitique de l'approvisionnement énergétique de l'union Européenne au XXIe siècle". p2

2.1.3 Oil refining

Crude oil has to be refined before it can be consumed. From the mid-70's to the mid-90's refinery was characterised by excess capacity. As a consequence margins were low and so were investments.

Today's undercapacity allows higher margins but will not immediately lead to increased investments as refiners want to compensate for losses incurred in the past.

As far as the future is concerned a capacity expansion will be needed due to several reasons:

- a shift in demand towards lighter products, mainly for transport
- a shift in the quality of crude oil towards heavier and more sour oil (read OPEC oil)[11].
- tighter product specifications due to environmental constraints.
- ...

As such refinery capacity will need to rise from 83Mb/d in 2004 to 93MB/d in 2010 and up until 118Mb/d by 2030.

A shift in the trade pattern of refined products is also expected to occur. Today refineries mostly supply their domestic markets, in the future regional imbalances will lead to an increased trade and also an increased competition.

In the second half of the projection period refineries will feel increased pressure from alternative products like GTL and CTL, although their market share will remain substantial (over 90%).

[11] European and more in particular Belgian refinery capacity seems to be better suited for these kinds of crudes.

2.1.4 Oil prices

In its World Energy Outlook 2004 the IEA assumes oil prices to fall back from current heights to around 22$ (year-2000-dollars) in 2006. They would then remain stable until around 2010, and after that increase to 29$ in 2030. It should be mentioned that in the "World Energy Outlook 2005" the price assumptions of the IEA have been revised upward by 24% (see table 14 in paragraph 2.2.3).

IEA also has a 'high price scenario' (35$/barrel). In that scenario demand will grow slower. More NOPEC reserves would become available but for geopolitical reasons these would be depleted faster than OPEC's.

OPEC's share in total oil supply would grow slower than in the reference scenario. OPEC's oil revenues over the period would be lower (due to a higher price but at the cost of a lower production).

The advocates of an oil production peak (ASPO) predict dramatic oil price increases in the years following the peak.

To conclude, even if it is hard to predict whether and when oil production will peak, several points can be raised against the assumptions of the IEA. E.g. the fact that most of the increase in oil demand will stem from the transport sector expansion in developing economies, while there are little substitutes for oil in this sector. This raises questions whether the 3.4% growth for China is not underestimated, particularly when compared to the growth numbers for 2003 and 2004, and to the current state of the Chinese car fleet compared to Europe and North America. Just combining a few numbers from IEA's World Energy Outlook:

- The transport sector accounts for half of world oil demand, assume this is valid for China as well. From table 8 it can be seen that Chinese oil demand for transport is then 5.2 x 50% = 2.6Mb/d.
- There are about 10 cars per 1000 Chinese people, for Europe this ratio equals 500. Assuming that by 2030 Chinese car fleet is at the same level as the European this means that Chinese oil demand for transport will be 2.6 x 50 = 130Mb/d.
- This is higher than the total world oil demand as projected by IEA, while we took only the demand by the Chinese transport sector
- Under the alternative scenario world demand for oil is 13Mb/d lower. This scenario accounts for high fuel efficiency increases of cars. Assuming that all 13Mb/d is due to increases in car efficiency this means that (on a total of 121.3 half is transport demand) increased fuel efficiency decreases oil use in transport by 13/60 = 22%.
- Thus Chinese transport demand with highly efficient cars could rise to(1-0.22)x130Mb/d = 101Mb/d

In this (simplistic) reasoning Chinese oil demand would increase from 5.2Mb/d to 101Mb/d between 2002 and 2030. This is an average growth rate of around 14%/year !

Furthermore there is a high degree of uncertainty on the available estimates of crude oil reserve data. Also the necessary investment conditions must be fulfilled will IEA predictions be realised. These investments must be fulfilled in the context of highly volatile oil prices (we are currently above 54$/barrel).

Further arguing that OPEC's share in oil supply will increase, and that for geopolitical reasons NOPEC countries will try to avoid this at any cost, but will only be able to do so if more NOPEC oil becomes available, i.e. if oil price rises, the only possible conclusion is that oil prices will be higher than in the past.

As a conclusion the projections for the oil price made by several institutions is shown in the following table (IEA: International Energy Agency, EIA: Energy Information administration of the US Department of Energy, . EC: European Commission, IEEJ: Institute of Energy Economics Japan, CGES: Centre for Global Energy Studies):

Table 9. Comparison of Long-Term Oil Price Assumptions (year 2000 dollars).

Source	2010	2020	2030
IEA	22	26	29
EIA	23.3	25.1	
EC*	27.7	33.4	40.3
OPEC	19.3	19.3	
IEEJ	24	27	
CGES	20.5	15.1	

Source: IEA, World Energy Outlook 2004, p. 529.

Other estimates for future oil prices are given by Goldman Sachs (60$/barrel in the long run), Arab Petroleum Research Center (between 40$ and 50$ per barrel), Pauwels J.P. et al. estimate a price around 40$ after 2010 going up to 70$ after 2020, Prof Criqui (EPE-LEPII) estimates, using the POLES model, the price at 40$/barrel by 2010 and rising up to 100$/barrel by 2050.

2.2 Natural Gas market

2.2.1 Demand for gas

Consumption of Natural Gas will almost double between 2002 and 2030, driven mainly by power generation (see table 11). In the alternative scenario world demand will be around 10% lower than in the reference scenario in 2030.

Gas demand will grow by more than 5% per year in China and India where it will gain market share from coal in power generation. Under the alternative scenario China's gas demand would still be higher due to a switch from coal to gas.

Natural gas is expected to remain the most competitive fuel in power generation, despite rising prices after 2010. This is due to the increased use of CCGT and to the environmental advantages of gas. CCGT's also have lower capital costs and lower lead-times compared to other thermal power stations.

Table 11: World Natural Gas Primary demand (bcm)- Reference Scenario

	WEO2004					WEO2005	
	2002	**2010**	**2020**	**2030**	**2002-2030***	**2030**	**2002-2030**
OECD North America	759	866	1002	1100	1.3%	1039	1.1%
OECD Europe	491	585	705	807	1.8%	778	1.7%
OECD Pacific	130	173	216	246	2.3%	244	2.3%
OECD	**1380**	**1624**	**1924**	**2154**	**1.6%**	**2061**	1.4%
Russia	415	473	552	624	1.5%	591	1.3%
Other transition economies	220	254	311	360	1.8%		
Transition economies	**635**	**728**	**863**	**984**	**1.6%**	**925**	1.4%
China	36	59	107	157	5.4%	152	5.3%
Indonesia	36	53	75	93	3.5%		
India	28	45	78	110	5.0%	98	4.6%
Other Asia	109	166	242	313	3.8%	387	4.6%
Brazil	13	20	38	64	5.8%		
Other Latin America	89	130	191	272	4.1%		
Africa	69	102	171	276	5.1%	232	4.4%
Middle East	219	290	405	470	2.8%	615	3.8%
Developing countries	**597**	**864**	**1307**	**1753**	**3.9%**		
World**	**2622**	**3225**	**4104**	**4900**	**2.3%**	**4789**	2.2%
European Union	471	567	684	786	1.8%		

Source: IEA, World Energy Outlook 2004, p. 130, World Energy Outlook 2005, p. 84, own calculations

Cheap reserves located far from consumer markets can not be transported economically by pipelines. These reserves will push the use of GTL (Gas to liquids) in the transport sector, as well as transport under liquid form (LNG - Liquid Natural Gas).

GTL capacity is projected to increase to 0.4mb/d in 2010 and to further increase to 2.4 Mb/d in 2030. Due to reserve depletion transport distances will increase and pipeline transport will become economically inefficient. Liquification and transport by tanker will increase and enhance competition (increased flexibility compared to pipelines) potentially leading to higher prices in periods of high demand.

2.2.2 Gas supply

Gas is an exhaustible resource, but reserves are considered to be important. As such gas production is not expected to peak during the projection period. At current levels of production gas reserves are sufficient for another 66 years of production. Thus even if production should double over the projection period, then there would still be reserves for 33 years. Thus one can assume that reserves are sufficient.

Gas reserves are less concentrated than oil reserves. Nevertheless three countries (Russia, Qatar and Iran) hold about 55% of all reserves.

Gas reserves are however located far from consuming markets and transportation costs are an important part of gas prices. These are expected to rise as the reserves located closest to the consumers will be depleted first. As such the European union will import around 80% of its gas needs by 2030, compared with 50% in 2002 (table 12). The two major gas producers - the United Kingdom and the Netherlands - are assumed to be over their production peak.

Table 12. Gas Import dependence

	2002		2010		2030	
	Bcm*	**%****	**Bcm***	**%****	**Bcm***	**%****
OECD North America	0	0	33	4	197	18
OECD Europe	162	36	267	46	525	65
OECD Asia	98	98	130	97	183	94
China	0	0	9	15	42	27
India	0	0	10	23	44	40
European Union	*233*	*49*	*342*	*60*	*639*	*81*

Source: IEA, World Energy Outlook 2004, p 140.

As can be seen from table 12, most regions will become dependant on imports by the end of the projection period. This will lead to an increased demand for more concentrated reserves and, combined with an increased use of LNG, potentially to higher prices. Europe for example will probably compete with China and the US (LNG) in demand for Russian gas.

Gas reserves are considered to be sufficient, but huge investments in production capacity will be needed ($2.7 trillion over the projection period). Exploration and development of gas fields will absorb half of this. The other half will go to investment in transport infrastructure (pipelines and LNG).

The geopolitical risk is also rising because of the obligation of passing with gas-(and oil) tankers through narrow straits (see table 13).

Table 13. Oil and LNG tanker traffic through Strategic Maritime Channels

		2002		2030	
		Volume oil (mb/d) gas (bcm)	Share of global inter-regional net trade (%)	Volume oil (mb/d) gas (bcm)	Share of global inter-regional net trade (%)
Straits of Hormuz	**Oil tankers**	15	44	43	66
	LNG carriers	28	18	230	34
Straits of Malacca	**Oil tankers**	11	32	24	37
	LNG carriers	40	27	94	14
Suez Canal	**Oil tankers**	1	4	3	4
	LNG carriers	4	3	60	9

Source: IEA, World Energy Outlook 2004, p 119.

2.2.3 Gas prices

Gas prices are expected to decrease from current heights and then remain stable until around 2010. Afterwards they would go up slightly (see table 14).

Gas prices are closely linked to oil prices. This link between gas and oil prices is expected to decouple as competition in the gas markets increases. This competition would exert a downward pressure on gas prices, but this would largely be compensated by an increase in supply costs.

Under the alternative scenario gas demand would be markedly lower, as well as gas prices.

IEA assumes that gas prices will rise due to increased production and transportation costs, but that they will decrease as a consequence of an increased competition. The last point is questionable because gas reserves will become more and more concentrated, most zones become import dependent. As a consequence gas supply will become more oligopolistic and the number of players on the demand side will increase. As such (demand) competition might just as well lead to higher prices.

Table 14. IEA Gas price assumptions (year 2000 dollars)

	WEO2004				WEO2005 (USD2000)			Deferred Investment
	2003	2010	2020	2030	2010	2020	2030	2030
IEA crude oil imports ($/barrel)	27	22	26	29	32	34	36	48
Natural gas ($/MBtu):								
US imports	*5.3*	*3.8*	*4.2*	*4.7*	*5.4*	*5.5*	5.7	
European imports	*3.4*	*3.3*	*3.8*	*4.3*	*4.6*	*4.8*	*5.2*	
Japan LNG imports	*4.6*	*3.9*	*4.4*	*4.8*	*5.5*	*5.6*	*5.7*	
OECD steam coal imports ($/tonne)	38	40	42	44	*45*	*46*	*47*	

Source: IEA, World Energy Outlook 2004, p. 47, World Energy Outlook 2005, p. 49 & 64, own calculations.

2.3 Coal market

2.3.1 Demand for coal

With a share around 20% in 2030 coal will continue to play an important role in primary energy supply. In 2002 power generation was responsible for 69% of the total demand for coal. This will increase to 79% in 2030. The share of coal in electricity generation will remain constant (around 40%). Especially in China coal will continue to play a dominant role in electricity generation.

China and India will be responsible for 68% of the demand increase over the projection period.

There is renewed interest in coal fired plants in the United States because of the sharp increase in gas prices.

The main impediment to the use of coal are environmental concerns, as coal-fired plants have higher carbon emissions than gas fired plants and even than oil fired plants. Near-zero-emission technologies seem technically feasible but cost is a main barrier. Moreover, due to the long life of coal-fired plants, it can be assumed that these technologies will only gradually enter into operation.

Table 15: World coal demand (Mt) - reference scenario

	2002		2030		Average annual rate of growth in demand, 2002-2030
	Million tonnes	Coal's share of electricity generation %	Million tonnes	Coal's share of electricity generation %	%
OECD North America	1051	46	1222	40	0.5
OECD Europe	822	29	816	24	0
OECD Pacific	364	36	423	29	0.5
OECD	**2237**	**38**	**2461**	**33**	**0.3**
Russia	220	19	244	15	0.4
Other transition economies	249	27	340	18	1.1
Transition economies	**469**	**22**	**584**	**16**	**0.8**
China	1308	77	2402	72	2.2
East Asia	160	28	456	49	3.8
South Asia	396	60	773	54	2.4
Latin America	30	4	66	5	2.8
Middle East	15	6	23	5	1.6
Africa	174	47	264	29	1.5
Developing countries	**2085**	**45**	**3984**	**47**	**2.3**
World	**4791**	**39**	**7029**	**38**	**1.4**
European Union	*767*	*31*	*716*	*25*	*-0.2*

* Including hard coal (steam coal and coking coal), brown coal and peat.
Source: IEA, World Energy Outlook 2004, p 170.

In Europe the use of coal for power production will fall back.

2.3.2 Coal supply

Coal reserves are abundant. The R/P ration is around 200 years. The biggest reserves are located in the US, Russia and China.

Transport costs account for a large price in the coal price. As such rising oil prices will push coal prices upward.

2.3.3 Coal price

Coal prices have increased dramatically since 2003. The main driver was increasing demand in China where industrial production and electricity use are booming.

Coal prices are assumed to fall back to around 45$/tonne by 2010 (WEO2005) (compared to current heights of 79$). They will rise to 47$ by 2030 (WEO2005). In WEO2004 these figures were respectively 40$/tonne and 44$/tonne.

2.4 Nuclear Energy

The IEA doesn't give detailed projections for nuclear energy. These can be found in 'Nuclear Technology Review' from the International Agency for Atomic Energy. Demand projections are given in table 16. Reserves data can be found in table 17.

In the high scenario the nuclear electricity production increases from 2574TWh in 2002 to 2881TWh in 2030 or about 11% over the projection period. In the high growth scenario the nuclear production increase by around 70% between 2002 and 2030.

Depending on the technology used and on the definition of reserves used the R/P ratio varies between 85 years and 240 000 years.

Assuming the lower value, and taking an average production (instead of the 2002 production) over the projection period (high scenario) this R/P ratio becomes 85*0.74 or 63 years. As such reserves should be sufficient to cover at least the projection period.

Uranium reserves are mainly situated in Australia (28%), Kazakhstan (18%), Canada (12%).

Current market prices are around 60$/kg U. It should be mentioned however that nuclear power generation is characterised by relatively low fuel costs compared to the huge fixed costs. As such, Uranium price increases have only a moderate impact on nuclear production cost[12].

Table 16: Nuclear Energy Projections

Country Group		2002			2010			2020			2030		
		Total Elect. TW·h	Nuclear TW·h	%	Total Elect. TW·h	Nuclear TW·h	%	Total Elect. TW·h	Nuclear TW·h	%	Total Elect. TW·h	Nuclear TW·h	%
North America		4779	851	17.8	5034	874	17	5784	870	15.0	6451	844	13.0
					5444	894	16.0	6709	939	14.0	8146	944	12.0
Latin America		1078	29	2.7	1178	29	2.5	1628	47	2.9	2227	30	1.3
					1427	38	2.7	2291	50	2.2	3758	92	2.4
Western Europe		3084	880	28.5	3352	858	26.0	3634	823	23.0	3942	564	14.0
					3609	893	25.0	4687	961	20.0	6061	1090	18.0
Eastern Europe		1758	299	17.0	1884	319	17.0	2174	423	19.0	2463	378	15.0
					2074	399	19.0	2867	552	19.0	4133	611	15.0
Africa		459	12	2.6	538	13	2.5	699	14	2.0	876	14	1.6
					612	14	2.3	973	24	2.4	1530	60	3.9
Middle East and South Asia		1176	20	1.7	1342	41	3.1	1805	53	3.0	2327	70	3.0
					1626	47	2.9	2596	100	3.9	3946	194	4.9
South East Asia and the Pacific		600			736			934			1162		
					786	1119	5.5	1	1584	18.0	1		
Far East		3157	484	15.3	3399	695	20.0	4199	855	20.0	5073	981	19.0
					4296	702	16.0	6605	1125	17.0	9830	1361	14.0
World Total	Low Estimate	16090	2574	16.0	17463	2830	16.0	20857	3085	15.0	24520	2881	12.0
	High Estimate				19873	2987	15.0	27848	3756	13.0	38989	4369	11.0

Source: IAEA, Nuclear Technology Review 2004, p9.

[12] Federaal Planbureau, "Quelle énergie pour un développement durable", p. 127

Table 17: R/P ratio nuclear reserves

Reactor/Fuel cycle	Years of 2002 world nuclear electricity generation with known conventional resources (1)	Years of 2002 world nuclear electricity generation with total conventional resources (2)	Years of 2002 world nuclear electricity generation with total resources (3)
Current fuel cycle (LWR once-through)	85	270	8200
Recycling fuel cycle (plutonium only, one recycle)	100	300	9200
Light water and fast reactors (mixed with recycling)	130	410	12000
Pure fast reactor fuel cycle with recycling	2500	8500	240000

(1) Known conventional resources include all cost categories of reasonably assured resources (RAR) and estimated additional resources – category I (EAR-I) for a total of 4 588 700 tU.[6]
(2) Total conventional resources include all cost categories of reasonably assured resources, estimated additional resources, and speculative resources for a total of 14 382 500 tU.
(3) Total resources assume conventional resources of 14 382 500 tU, plus 90% of phosphate resources of 22 000 000 tU (= 19 800 000 tU), plus 10 % of the estimated seawater uranium resources of 4 000 000 000 tU (= 400 000 000 tU) for a total of 434 182 500 tU.
Source: IAEA, Nuclear Technology Review 2004, p11.

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