Chapter 2
The Availability of Fossil Energy Resources

Jörg Schindler

2.1 Conventional Wisdom

The *International Energy Agency (IEA)* is the energy watch-dog of the OECD countries. Each year the IEA publishes its *World Energy Outlook (WEO)* report addressing global energy trends and projecting future energy demand and supply. These reports get prominent media coverage and frame the perception of governments, the media and the general public.

In its WEO 2008 report the IEA (2008) describes a reference scenario for global energy demand and supply for fossil, nuclear and renewable primary energy sources (Fig. 2.1).

The energy content of all energy sources is expressed in *million tons of oil equivalent (Mtoe*) to make them comparable. As can be seen, crude oil is the most important energy source, followed by coal and natural gas. The reference scenario up to 2030 sees no change in the ranking and assumes continued growth of all fossil energies. Nuclear and renewable energies will grow a little, but the dominance of fossil fuels remains practically unchanged. This scenario indicates that the future will be more or less like the past, just more of everything. Accordingly, the message is that *business as usual (BAU)* can continue for at least another two decades.

In the past, the IEA scenarios were driven by modelling future demographic and economic developments and – based on these projections – deriving the corresponding energy demand. It was taken for granted that the projected demand could be met by an ever growing energy supply. Until last year the supply side was never analyzed by the IEA itself, the possibility of growing oil supplies was treated as a matter of fact by referring to a study done by the USGS in 2000 (USGS 2000).

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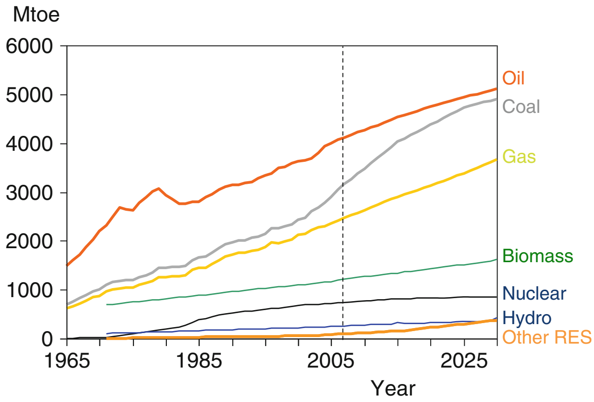


Fig. 2.1 World Energy Outlook by the IEA – reference scenario (Source: Historical data: BP, Statistical Review of World Energy, Projection: IEA (2008))

The 2008 edition of the WEO marks a change in this respect, probably as a reaction to the growing turmoil and price volatility in the oil markets. It analyses for the first time past and likely future production volumes in the major oil fields of the world. An effort is made to quantify the decline in the existing production base. Then possibilities for production from new sources are discussed and also the obstacles are addressed. Yet, this has no visible influence on the reference scenario. But the report also warns of an imminent oil crunch if a number of preconditions for a growing oil supply are not met. The finiteness of oil is not mentioned.

> Quotations from the Executive Summary of the WEO 2008
>
> The world's energy system is at crossroads. Current global trends in energy supply and consumption are patently unsustainable – environmentally, economically, socially. But that can – and must – be altered; there's still time to change the road we're on.
>
> In fact, the immediate risk to supply is not one of lack of global resources, but rather a lack of investment where it is needed.
>
> Preventing catastrophic and irreversible damage to the global climate ultimately requires a major decarbonisation of the world energy sources.
>
> For all the uncertainties highlighted in this report, we can be certain that the energy world will look a lot different in 2030 than it does today.

The WEO 2008 thus is a document full of contradictions: on the one hand, with the reference scenario business as usual is declared as being possible, on the other hand, the energy world in 2030 is supposed to be completely different. Although it is more realistic than preceding issues in many respects, the 2008 report is still very poor guidance for the energy future.

2.2 Crude Oil

The purpose of this chapter is to project the future availability of crude oil up to 2030 based mainly on a study for the Energy Watch Group (EWG) in 2007 (Zittel and Schindler 2007b).

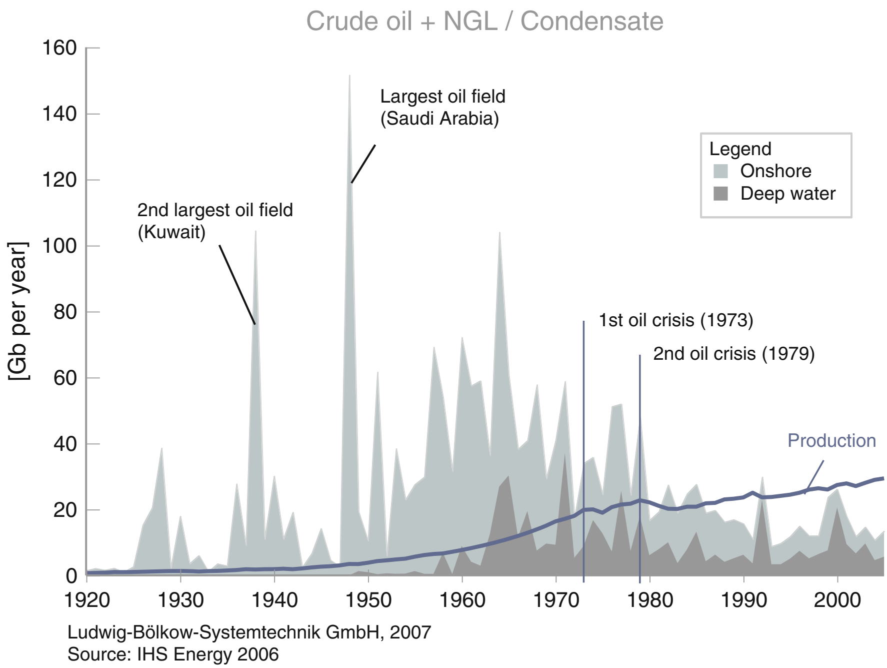


Fig. 2.2 History of oil discoveries and production (Source: IHS Energy 2006)

It is obvious that oil has to be found before it can be produced. Therefore, one has to know how much oil has been discovered and produced to date in order to assess possible future oil production. Figure 2.2 shows annual oil discoveries in terms of proved and probable reserves since 1920 and also annual production rates (IHS 2006). The units are gigabarrels (Gb) per year. Past discoveries are stated according to best current knowledge (and not as the reserve assessments at the time of discovery) – a method described as "backdating of reserves". Therefore, the graph shows what "really" was found at the time and not what people thought they had found at the time.

Discoveries peaked in the 1960s. In the period 1960–1970 the average size of new discoveries was 527 Mb per New Field Wildcat. This size declined to 20 Mb per New Field Wildcat in the period 2000–2005.

Since the 1980s yearly oil production exceeds the volume of new discoveries and the discrepancy is growing over time. Only when oil has been found can it be produced. Therefore, the peak of discoveries which took place a long time ago will someday have to be followed by a peak of production ("Peak Oil").

World oil reserves are estimated to amount to 1,255 Gb according to the industry database (IHS 2006). There are good reasons to modify these figures for some regions and key countries, leading to a corresponding EWG estimate of 854 Gb (Table 2.1). The greatest differences are the reserve numbers for the Middle East. According to IHS, the Middle East possesses 677 Gb of oil reserves, whereas the EWG estimate is 362 Gb.

Table 2.1 Oil reserves – EWG assessment vs. IHS energy data

Region	Remaining reserves EWG [Gb]	Remaining reserves IHS [Gb]	Production 2005 Onshore [Gb/year]	Production 2005 Offshore [Gb/year]	Consumption 2005 [Gb/year]
OECD North America	84	67.6	3.20	1.71	9.13
OECD Europe	25.5	23.5	0.1	1.94	5.72
OECD Pacific	2.5	5.1	0.025	0.18	3.18
Transition economies	154	190.6	4.1	0.18	2.02
China	27	25.5	1.1	0.22	2.55
South Asia	5.5	5.9	0.11	0.16	0.96
East Asia	16.5	24.1	0.3	0.65	1.75
Latin America	52.5	129	2.0	0.61	1.74
Middle East	362	678.5	6.97	1.97	2.09
Africa	125	104.9	2.03	1.53	1.01
World	854	1,255	19.94	9.15	30.3

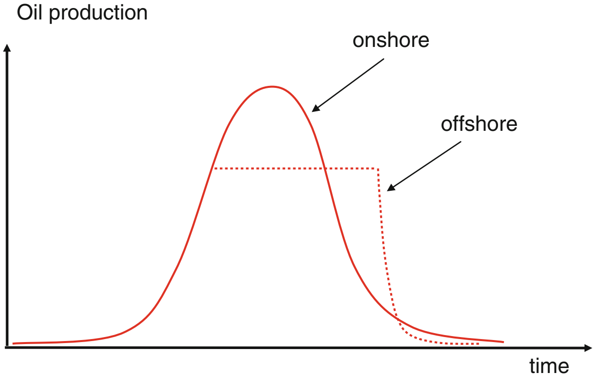


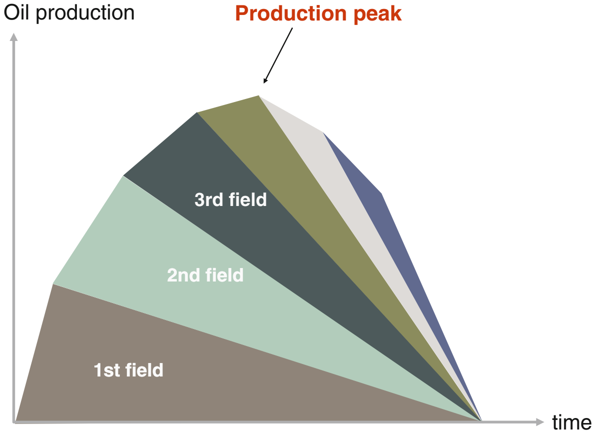
Fig. 2.3 Idealized oil production profile

Remaining reserves are only one parameter for projecting future oil production. Another approach is the analysis of production patterns, i.e. profiles of production rates over time of individual oil fields and production profiles of individual oil basins.

Figure 2.3 shows the idealized production profiles for onshore and offshore wells. It shows that every oil well eventually reaches a peak of production and afterwards the production rate will inevitably decline.

This is one important cause for the occurrence of typical production patterns also in oil provinces. As is schematically shown in Fig. 2.4, the biggest fields in a province will be developed first and only afterwards the smaller ones. As soon as the first big fields of a region have passed their production peak, an increasing number of new and generally smaller fields have to be developed in order to compensate the decline of the production base. From then on, it gets increasingly difficult to sustain the rate

Fig. 2.4 Typical oil production pattern for a region



of the production growth. More and more large oil fields show declining production rates. The resulting gap has to be filled by bringing into production a larger number of smaller fields. But this is not possible anymore at a sufficient rate once the rate of discoveries has fallen. These smaller fields reach their peak much faster and eventually amplify the overall decline of the production rate of the region. The region's production profile will become more and more "skewed".

This pattern can be observed very well in many oil provinces. But in some regions this general pattern was not prevalent, either because the timely development of a "favourable" region was not possible for political reasons or because of the existence of huge surplus capacities so that production was held back for longer periods of time (this being the case in many OPEC countries). However, the more existing surplus capacities are reduced, the closer the production profile follows the described pattern.

Production in the United Kingdom (UK) is a good illustration of the production pattern described above (Fig. 2.5). The production decline in the late 1980s was due to necessary safety work on the platforms following the severe accident at the platform Piper-Alpha. Similar patterns can be shown for many regions in the world.

Oil production in regions which have passed their peak can be forecasted with some certainty for the next years. In these cases remaining reserves are no longer the decisive parameter for projecting future production rates.

Figure 2.6 shows past and projected future oil production in the USA. Forty years ago, the USA were the world's largest oil producer, contributing almost 50 % to the world's oil production. However, since the peak in 1970 the conventional production has been in decline. The development of Alaska (made possible by the higher oil prices resulting from the oil price shocks in the 1970s) could stop this decline for a few years, until this region also passed peak production. Offshore oil from the continental shelf has been produced since 1949, but turned into decline around 1995. Oil fields in the deep water areas of the Gulf of Mexico were only

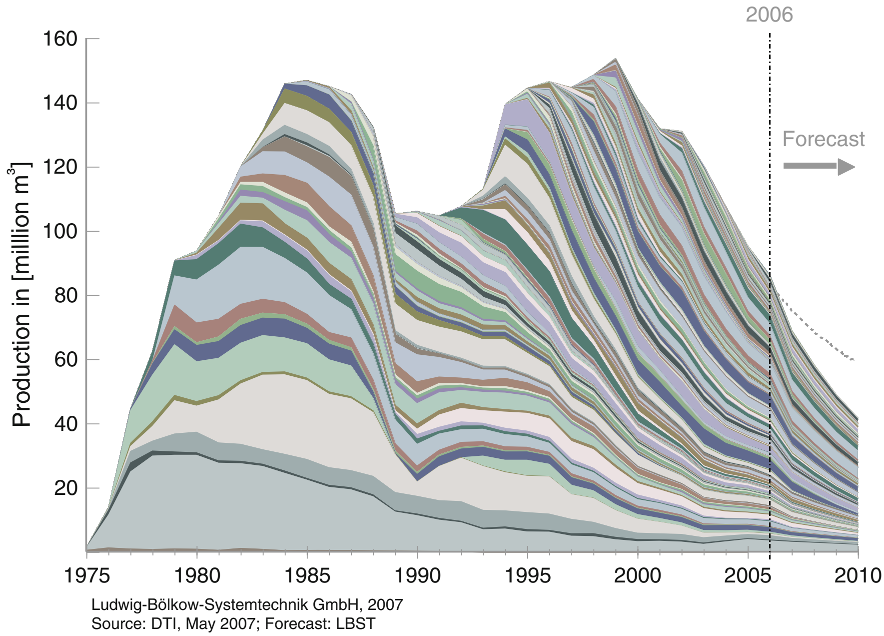


Fig. 2.5 UK – yearly oil production of individual oilfields. The unit m³ for oil production per year is used because the official production statistics for all oil fields published by the UK DTI (Department of Trade and Industry) in the early years only used this unit. 1 m³ oil = approx. 6.3 barrels oil (Source: DTI (2007). Forecast: Ludwig-Bölkow-Systemtechnik)

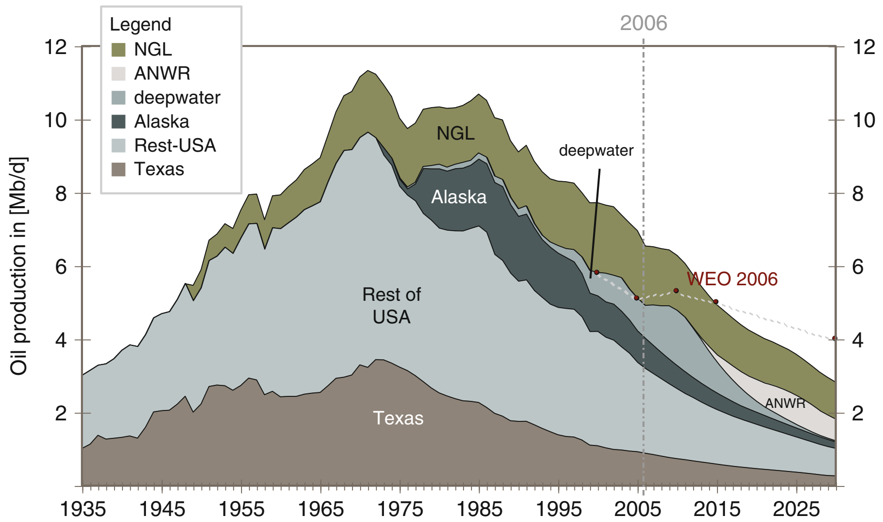


Fig. 2.6 Oil production in the USA

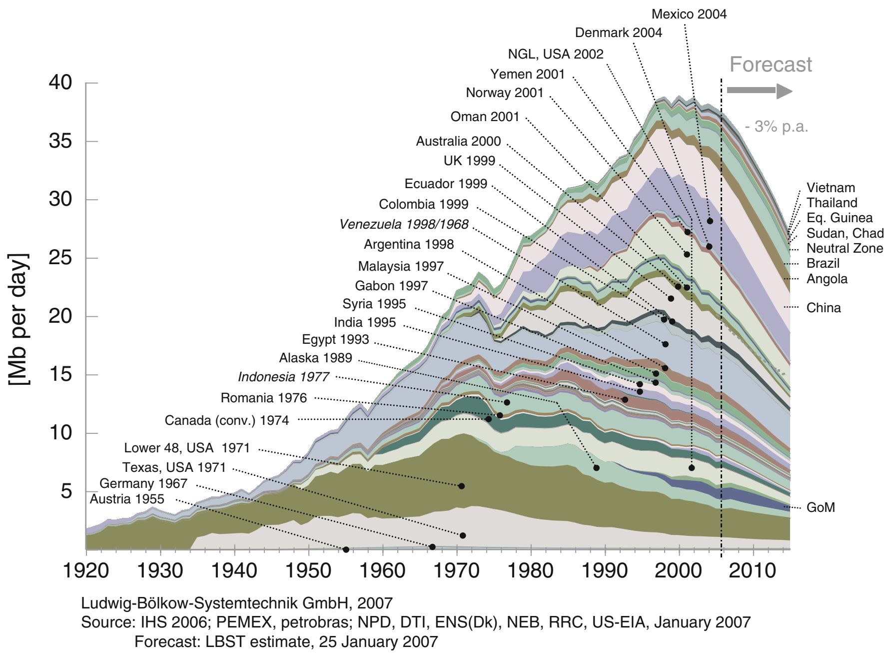


Fig. 2.7 Oil production of countries outside (core) OPEC and FSU (Source: IHS (2006), PEMEX, petrobas, NPD, DTI, ENS (Dk), NEB, RR, US-EIA (2007). Forecast: Ludwig-Bölkow-Systemtechnik 2007)

developed in the late 1990s and early 2000s. The large contribution of natural gas liquids (NGL) can also be seen. NGLs are liquid components of natural gas which are separated in the production process.

The example of the USA demonstrates that once peak oil is reached in a region the subsequent decline cannot be reversed, even when there are no limitations regarding access to capital or technologies.

Figure 2.7 lists the production profiles of all oil producing countries apart from the OPEC countries in the Middle East and countries belonging to the former Soviet Union (FSU). Countries with a year behind the name are countries past peak, the year indicates the year of peak production. These countries are ordered in the figure according to their peak dates. The other countries (without a year) on the right-hand side of the figure are countries whose production is regarded as being more or less on a plateau. Total production of these countries accounted for about 35–40 Mb/day in the beginning of 2007 – being already in decline it was projected to decline further.

One and a half years later, in mid 2008, the group of countries shown in Fig. 2.7 was joined by additional countries, most prominently by Russia where production peaked in 2007. But also Angola and Nigeria joined the club of countries past peak. These countries then accounted for a production of approx. 50 Mb/day which will in future also decline every year.

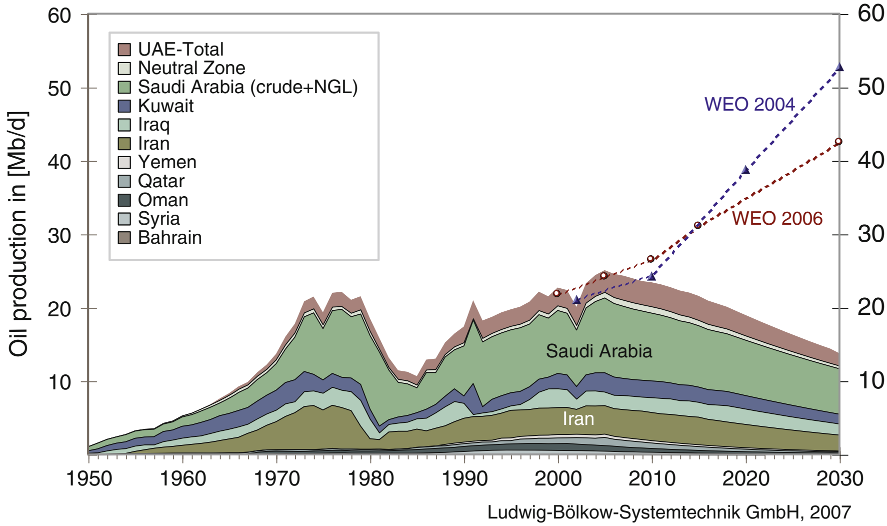


Fig. 2.8 Oil production in the Middle East (Source: Ludwig-Bölkow-Systemtechnik 2007)

If world oil production is to stay constant in the coming years or even is to grow, then only the oil producing countries in the Middle East (ME) remain to eventually increase their production in order to compensate for the decline in the rest of the world. That this will be possible is assumed by the IEA, for example. Figure 2.8 shows past production and future projections by the EWG for the ME countries, projecting a peak in the near future followed by a gradual decline. The main reasons are that EWG thinks that ME reserves are grossly overstated (cf. Table 2.1) and that the bulk of current production comes from very few very old oil fields which already have trouble maintaining production levels (Simmons 2005). This is in sharp contrast to the IEA which in its World Energy Outlooks (WEO) in 2004 and 2006 projected steep rises in the production of the region.

But there are also other reasons. Saudi Arabia, being the key country in the region, has announced that it is aiming at a long term production capacity of 12.5 Mb/day. This is far off the projections by the IEA and the hopes of major oil importing countries. Even if Saudi Arabia were able to increase production above this target (which is very doubtful), it is questionable whether this really would be in its national interest.

Based on the data and assessments outlined above, the EWG study describes a scenario of the possible future oil supply up to 2030 (Fig. 2.9). As in the previous figures, "*oil*" comprises *conventional crude oil* including *lease condensates, heavy oil* and *oil derived from Canadian tar sands*, and also LNG. Not included are refinery gains, gas-to-liquids, coal-to-liquids, ethanol as well as other biofuels (all of which are often counted in an aggregate termed "all liquids", but which certainly are not crude oil; LNG is only included because it is included in most statistics and available statistical data do not allow a differentiation for all countries).

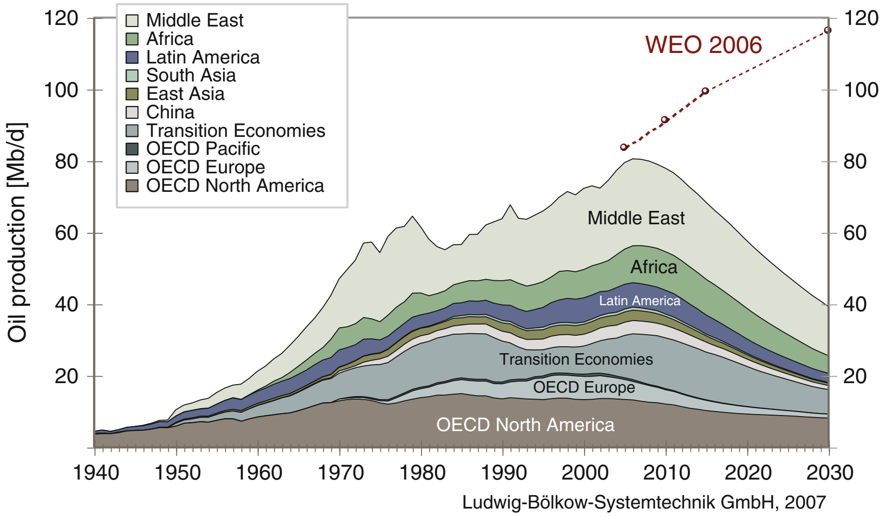


Fig. 2.9 The EWG scenario – Peak Oil is "now" (Source: Ludwig-Bölkow-Systemtechnik 2007)

These are the key findings of the EWG study:

- "Peak oil is now" (the scenario has 2006 as date of peak oil)
- The most important result of the study is the steep decline in oil production after peak.
- The projections for the global oil supply are:
  - 2006: 81 Mb/day (peak)
  - 2020: 58 Mb/day (IEA: 105 Mb/day)[1]
  - 2030: 39 Mb/day (IEA: 116 Mb/day)
- By 2020, all world regions except Africa will produce less than they did in 2005; by 2030 all regions will produce significantly less.

The difference to the projections of the IEA could hardly be more dramatic (IEA 2004, 2006, 2008).

The EWG study was based on data up to 2005. What was the actual development since then? The available production data compiled by the US Energy Information Administration (EIA) are shown in Fig. 2.10 (Energy Information Administration (EIA) 2006). World oil production plateaued in mid 2004 and remained at this level for 4 years (in a bandwidth between 72.5 and 74.5 Mb/day); since the onset of the financial crisis in the autumn of 2008 production is now declining. This plateau is all the more surprising (from the perspective of conventional wisdom) since oil prices surged from 2004 to mid 2008 to unprecedented levels. Obviously, supply could no longer keep up with the demand.

[1] Referring to IEA projections in the WEO 2006. IEA values for 2015 are interpolated.

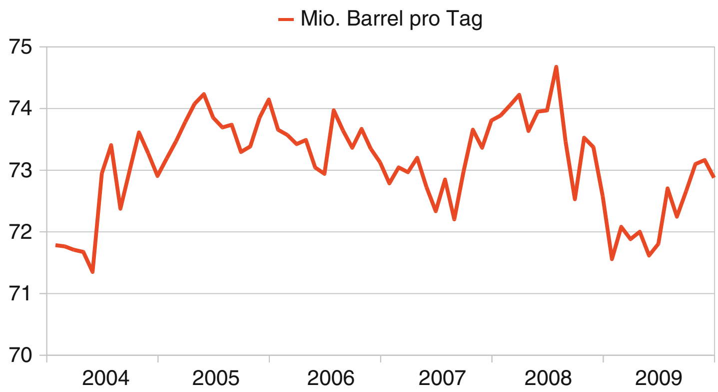


Fig. 2.10 Plateau of global crude oil production since mid 2004 (Source: US EIA Koppelaar (2009))

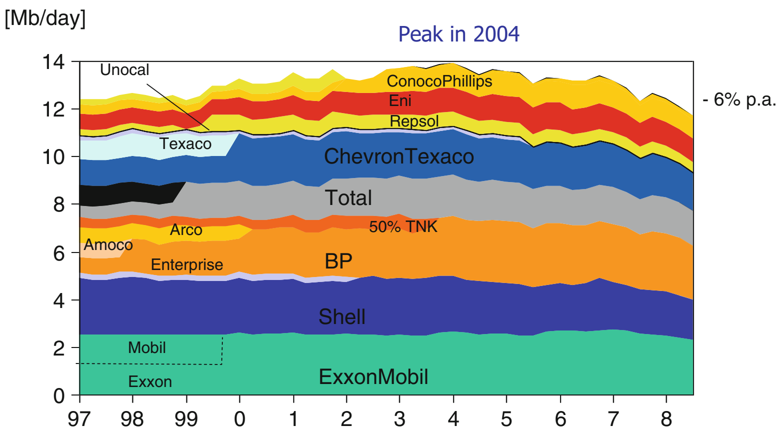


Fig. 2.11 Oil production of the eight largest international oil companies since 1997

Looking at the operations of major international oil companies over the last 10 years, two developments are striking (Fig. 2.11):

- the wave of mergers, and
- the inability of these companies to substantially raise their aggregate production.

The mergers were necessary to compensate for the declining production in individual companies. Rising expenditures, especially for production, just led to a peak in 2004 of aggregate production, but since then production has been declining at an increasing rate. The significant production increases repeatedly announced by the super majors since 2000 never materialised.[2] This is all the more remarkable in view

[2] Recently, the "lack of access" to more promising oil regions has been blamed by the international oil companies for their disappointing performance regarding production volumes.

of the dramatic rise in oil prices since 2004. This is another strong indication for "peak oil is now".

To sum up this chapter on oil: Oil supply has reached a plateau since mid 2004. The onset of the ultimate decline is imminent. This will signal the beginning of the end of the era of fossil fuels.

2.3 Natural Gas

The availability of natural gas can be investigated on a global and a regional level. Because of the infrastructure requirements for the transport of natural gas, there is no sizeable world market (different to crude oil). The shipping of natural gas between continents requires the liquefaction of the gas (LNG – liquefied natural gas) and the transport of the gas in special LNG carriers. Most natural gas is consumed in the wider region of origin. At present, there are three big regional markets: (1) North America (Canada, USA, Mexico), (2) Europe, Russia, Central Asia, North Africa, (3) East Asia.

A supply scenario for natural gas on a global level takes into account past production profiles and remaining reported reserves for the ten world regions (as defined by the IEA). According to a scenario by Ludwig-Bölkow-Systemtechnik shown in Fig. 2.12 future growth in supply is deemed possible mainly in the Transition Economies and the Middle East. Reserves in the Middle East are concentrated in Iran and Qatar. Fitting the production profiles with a logistic curve to match the reserves leads to a

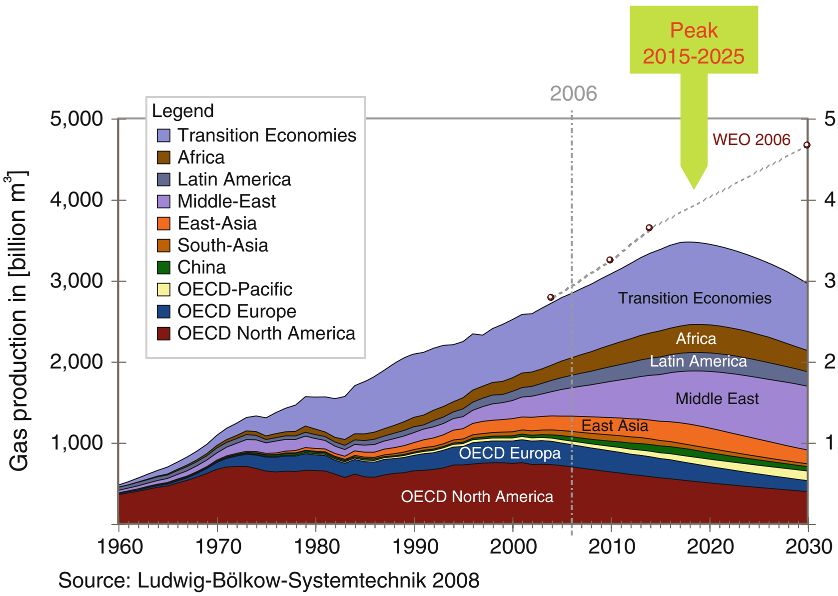


Fig. 2.12 Natural gas production – history and scenario (Source: Ludwig-Bölkow-Systemtechnik 2008)

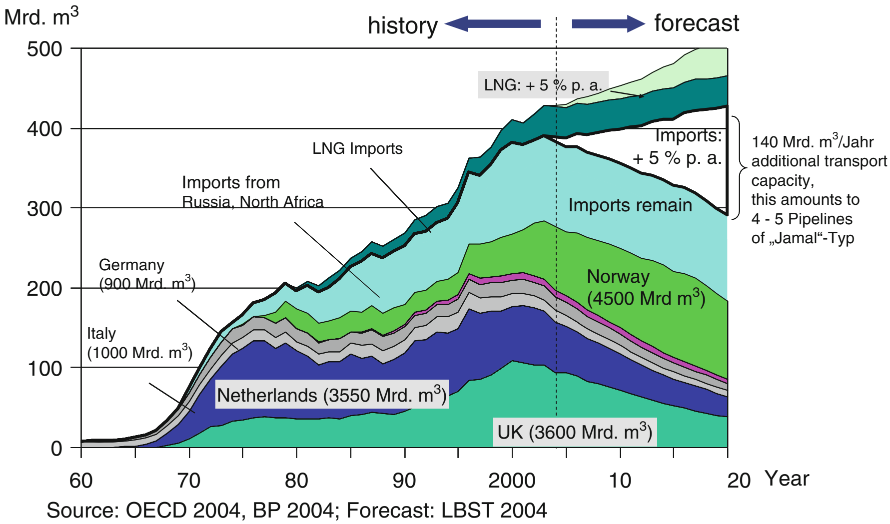


Fig. 2.13 Europe: natural gas production (Source: OECD (2004), BP (2004). Forecast: Zittel and Schindler (2004))

projected peak of global natural gas production between 2015 and 2025. This scenario shows what is possible, not what is likely. The scenario would require Qatar and Iran to expand their natural gas production dramatically in a very short time.

Also shown in Fig. 2.12 is the projection by the IEA in its WEO 2006 which has no peak up to 2030. We do not think that this increase in natural gas production will be possible if reported reserves are even remotely believable.

On a regional level the supply outlook can be very different from the global picture. Figure 2.13 shows natural gas production and consumption for Europe in Mrd. m^3 (= billion m^3).

Natural gas production is in decline in all European countries except Norway. The projected increase in Norwegian production cannot compensate this decline. Europe already relies heavily on imports from Russia and North Africa. If European gas consumption is to remain unchanged or increase in future, then imports will have to grow steadily.

It is a controversial issue whether Russia will be able to increase its natural gas exports at the required rate in the coming years. The big producing natural gas fields and their production profiles are shown in Fig. 2.14 (the unit Tcf/year stands for Tera cubic feet per year). Also shown are big known gas fields which are not yet developed and their required production. In 2009 it was already clear that some of the new fields will not be developed in time. Therefore, a decline in Russian gas output in the coming years is likely.

In theory, global natural gas production can grow for another 5–15 years by approx. 25 % until production peaks and the decline starts. Whether this projected growth will actually happen is an open question at the moment.

In any case, a switch from oil to natural gas to substitute the future decline in oil is not a very convincing short term option and certainly not a long term option – anyway

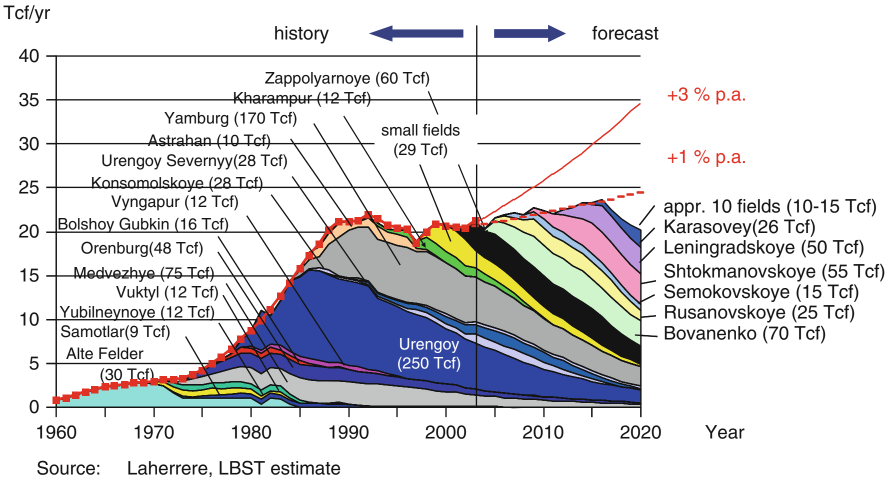


Fig. 2.14 Russia: natural gas production (Source: Laherrere and Campbell 1995)

not globally and not for Europe (there might be some regions in the world with ample natural gas resources where locally things look different). This is the reason why the European Commission has dropped its strategy to introduce natural gas as a fuel for transport.

2.4 Coal

When discussing the future availability of fossil energy resources, conventional wisdom has it that globally there is an abundance of coal which allows for increasing coal consumption far into the future. This is either regarded as being a good thing as coal can be a possible substitute for the declining crude oil and natural gas supplies or it is seen as a horror scenario leading to catastrophic consequences for the world's climate. But the discussion rarely focuses on the premise: how much coal is there really?

This chapter is based mainly on the EWG study on coal (Zittel and Schindler 2007a). One important finding of this study is that the quality of data on coal reserves and resources is poor, both on global and national levels. But there is no objective way to determine how reliable the available data actually are.

The timeline analyses of data elaborated in the study suggest that on a global level the statistics overestimate the reserves and the resources. In the global sum both reserves and resources have been downgraded over the past two decades, in some cases drastically.

Figure 2.15 shows the changing estimates of world coal resources[3] over time by the German *Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)*.

[3] Resources are defined as amounts of coal that are either discovered but cannot be produced economically, or are expected to be discovered in future based on geological indicators. Coal resources are "in-situ" amounts irrespective of production possibilities.

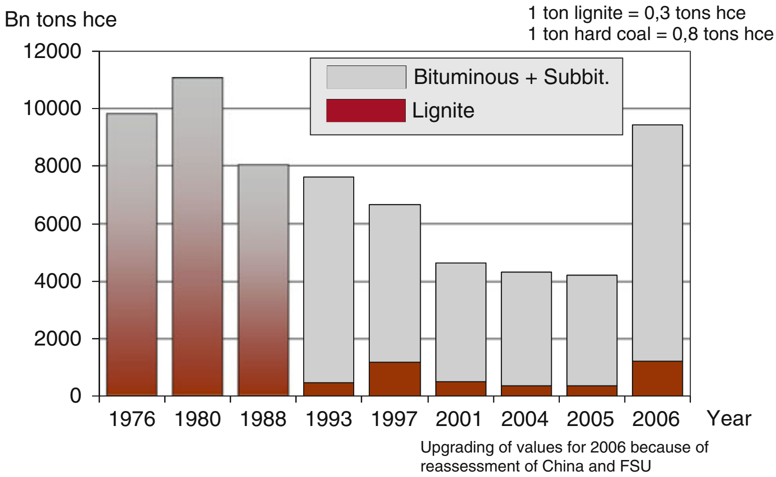


Fig. 2.15 World: Coal resources estimates by BGR (Source: BGR 1995, 1998, 2002, 2005, 2006, 2007). Analysis: LBST (2008))

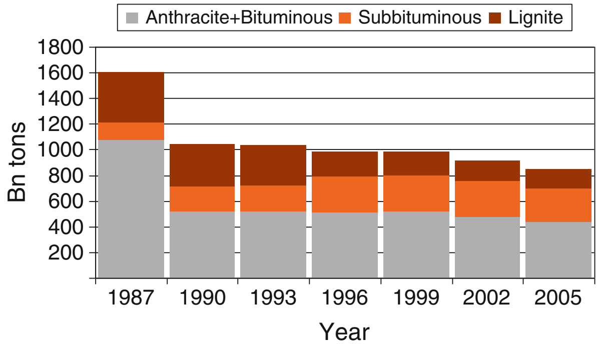


Fig. 2.16 World coal reserves (*Reserves* are defined as well explored amounts of coal that can be produced economically with current technologies. WEC differentiates between "Proved Reserves in Place" und "Proved Reserves" and has boundaries for maximum depth and minimum seam thickness) as reported by the WEC (2002, 2004, 2007)

Three categories are used for describing different coal qualities: bituminous and subbituminous being one group, lignite the other.

The unit *hce* stands for *hard coal equivalent* accounting for the different energy contents (heating values) of different coal qualities.

Figure 2.16 shows the development of world coal reserves as reported by the World Energy Council (WEC).

The logic of distinguishing between *reserves*, which are defined as being proved and recoverable, and *resources*, which include additional discovered and undiscovered inferred/assumed/speculative quantities, is that over time production and exploration activities allow some of the resources to be reclassified into reserves. It should be noted that resources are regarded as quantities in situ, of which 50 % at most can eventually be recovered. In practice, such a reclassification from resources to reserves has only occurred in two cases over the past two decades: in India and Australia. Therefore, there is a strong conjecture that coal resource data are not really relevant for the assessment of the future coal production potential.

On a global level, hard coal reserves have been downgraded over the years by 15 %. The same general picture of global downgrading is obtained when including all coal qualities from anthracite to lignite. Cumulative coal production over this period is small compared to the overall downgrading and is thus no explanation for it.

The most dramatic example of unexplained changes in the data is the downgrading of the proven German hard coal reserves by 99 % (!) from 23 billion tons to 0.183 billion tons in 2004. The World Energy Council briefly notes in its "2004 Survey of Energy Resources" (WEC 2004): "Earlier assessments of German coal reserves (e.g. end-1996 and end-1999) contained large amounts of speculative resources which are no longer taken into account". Thus, large reserves formerly seen as *proven* have been reassessed as being *speculative*.

German lignite reserves have also been downgraded drastically, which is remarkable as Germany is the largest lignite producer worldwide. Poland has downgraded its hard coal reserves by 50 % compared to 1997 and has downgraded its lignite and subbituminous coal reserves in two steps to zero since 1997.

For some countries such as Vietnam proven reserves have not been updated for up to 40 years. The data for China were last updated in 1992, in spite of the fact that about 20 % of their then stated reserves has been produced since then, and another 1–2 % has been consumed in uncontrolled coal seam fires.

World coal reserves and production are concentrated in a small number of countries. These countries are shown in Fig. 2.17 with their reported reserves and their production and are ordered by the size of their reserves. The bars show the reserves as indicated on the left axis (1,000 Mtoe = 1 billion tons of oil equivalent). The red line shows the yearly production in 2006 as indicated on the right axis, differentiated between hard coal and lignite (Mtoe/year). According to these data, the (theoretical) global production to reserve ratio (R/P) amounts to 155 years.

The concentration of the coal market on very few countries is further demonstrated in Table 2.2 based on data for the year 2007 (Btoe = billion tons of oil equivalent). This table also displays the exports of the major coal exporting countries. Only approx. 15 % of the coal produced worldwide reaches the world market, 85 % of the coal is used in the countries of origin.

As can be seen from Fig. 2.17 and Table 2.2, China is by far the world's largest coal producer and consumer, using nearly one third of the global total and twice as much as the USA on rank two.

Even though the quality of reserve data is poor, an analysis of possible future production profiles based on these data is still deemed meaningful.

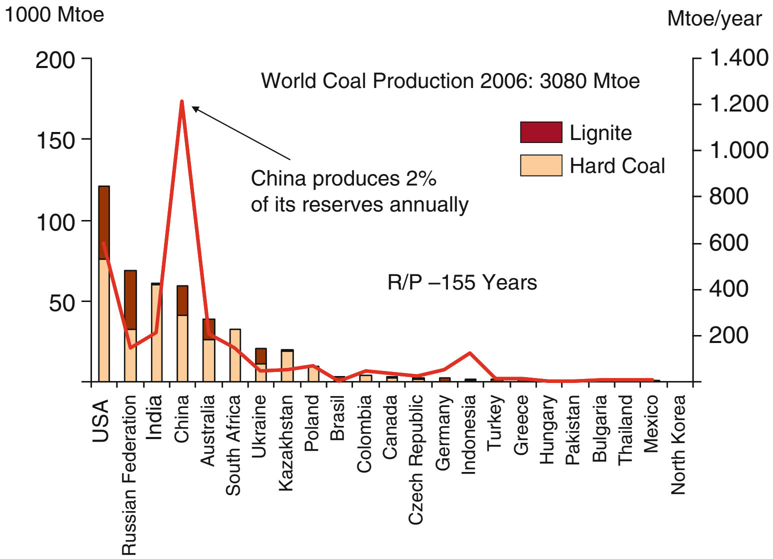


Fig. 2.17 Coal reserves and production by producing countries (Source: BP Statistical Review of World Energy (2007). Analysis: LBST (2007))

Table 2.2 World coal market 2007

	Largest	2nd largest	3rd largest	4th largest	Share of top 4
Reserves 2007	USA	Russia	China	India	67 %
	120 Btoe	69 Btoe	59 Btoe	36 Btoe	
Production 2007	China	USA	Australia	India	>70 %
	1.289 Mtoe/a	587 Mtoe/a	215 Mtoe/a	181 Mtoe/a	
Net exports 2007	Australia	Indonesia	South Africa	Russia	78 %
	162 Mtoe/a	80 Mtoe/a	54 Mtoe/a	54 Mtoe/a	

Source: BP Statistical Review of World Energy (2008). Analysis by LBST

According to past experience, it is very likely that the available statistics are biased on the high side and therefore projections based on these data will give an upper boundary of the possible future development. Accordingly, future production profiles have been developed using logistic fitting to past production.

Figure 2.18 below provides a summary of past and future world coal production in energy terms based on a detailed country-by-country analysis.

This analysis reveals that global coal production may still increase over the next 10–15 years by about 30 %, mainly driven by Australia, China, the Former Soviet Union countries (Russia, Ukraine, Kazakhstan) and South Africa. Production will then reach a plateau and will eventually decline thereafter.

The possible production growth until about 2020 according to this analysis is in line with the two demand scenarios of the IEA in the 2006 edition of the *World*

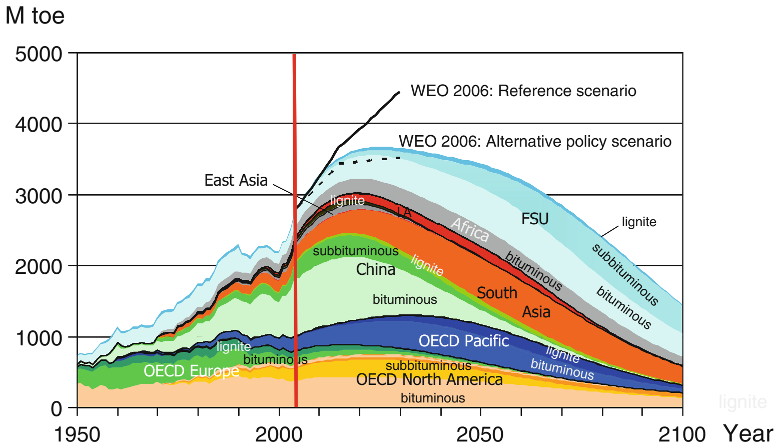


Fig. 2.18 EWG scenario of global coal production (2007) (Source: Zittel and Schindler 2007a)

Energy Outlook. However, the projected development beyond 2020 in the EWG scenario is only compatible with the *IEA alternative policy scenario* in which coal production is constrained by climate policy measures. Whereas the *IEA reference scenario* assumes further increasing coal consumption and production until at least 2030. According to the EWG analysis, this will not be possible due to limited reserves.

Since the completion of the EWG coal study in 2007 new data have become available leading to a slight reassessment of the EWG scenario. According to the most recent WEC report (WEC 2007), India has downgraded its reserves by about 40 %. In addition, India in recent years has imported coal at increasing rates (so why don't they use their own resources?). Also, current difficulties facing coal production in South Africa make it more likely (irrespective of how big the reserves really are) that coal production will be on a plateau for many years to come rather than being expanded significantly. The result of this reassessment is shown in Fig. 2.19. The timing and the level of peak coal is more or less the same as in the EWG scenario but the decline after peak is much steeper.

Again, it needs to be emphasized that these projections represent an upper limit of future coal production according to the authors' best estimate. Climate policy or other restrictions have not been taken into account.

This chapter can be summarized as follows:

- Global coal resource estimates seem to be of no practical relevance regarding future coal production and as a consequence future coal availability.
- Global coal reserve data are of poor quality, but seem to be biased towards the high side.
- Projections of production profiles suggest that global coal production will peak around 2025 at about 30 % above the current production rate – this being the upper boundary of the possible development.

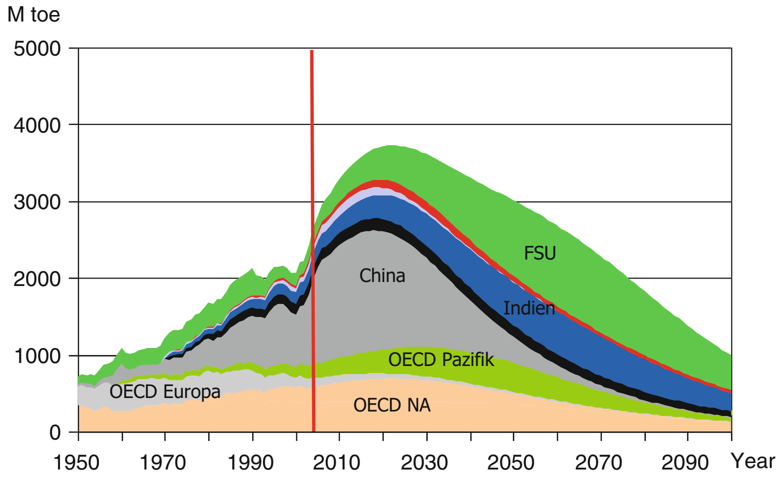


Fig. 2.19 Revised EWG scenario of global coal production (2008) (Source: LBST analysis 2008)

There should be a wide discussion on this subject leading to better data in order to provide a reliable and transparent basis for long term decisions regarding the future structure of our energy system.

The repercussions for the climate models on global warming are also an important issue.

2.5 The Fossil and Nuclear Supply Outlook

The above supply scenarios for crude oil, natural gas and coal can be integrated into a scenario of the future availability of all fossil and nuclear energy sources (Fig. 2.20).

The contribution of nuclear energy is also represented in the scenario, though nuclear energy is not dealt with in this paper. For the assessment of LBST and the Energy Watch Group see the study (Zittel and Schindler 2006). Regarding this point we generally agree with the IEA, which also does not foresee a significant increase in nuclear energy in the coming two decades (see Fig. 2.1). Nuclear energy's share was assumed to remain unchanged in this scenario. As can be seen, nuclear energy is not really relevant for the global picture.

The aggregate scenario shown in Fig. 2.20 is based on data as of 2006, so not all newer assessments are integrated. But in the context of this paper this is not really relevant, the scenario should be read as a qualitative statement with the numbers just indicating the likely magnitudes of possible contributions of individual fossil and nuclear energy sources at specific dates in the future. Though the exact numbers naturally are uncertain (and will remain so), this qualitative description of the future

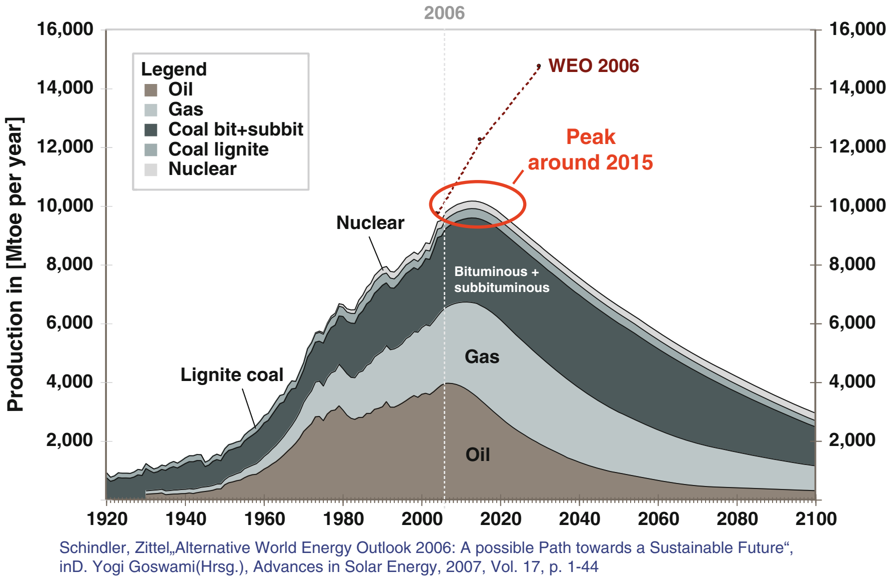


Fig. 2.20 Peak oil will be followed by the peak of all fossil and nuclear energies (Source: Schindler and Zittel 2007)

supply outlook has a very high likelihood of representing the possible availability of fossil and nuclear energy in the coming decades.

The message of this scenario is quite dramatic (and possibly surprising for many observers):

- The current advent of peak oil will lead to the subsequent peaking of all fossil (and nuclear) energy supplies in the very near future.

Even though natural gas and coal are expected to peak respectively one and two decades later than oil, the imminent decline in oil production will have as a consequence the peaking of all fossil and nuclear energy sources in about 5 years time – around 2015.

The twenty-first century will see the transition to a post fossil energy world.

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