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Reserve Driven Forecasts for Oil, Gas & Coal and Limits in Carbon Dioxide Emissions

Peak oil, peak gas, peak coal and peak CO_2

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ABSTRACT

The increase of carbon dioxide (CO_2) in the atmosphere is coursed by an increasing use of fossil fuels; natural gas, oil and coal. This has so far resulted in an increase of the global surface temperature of the order of one degree.

In year 2000 IPCC, Intergovernmental Panel on Climate Change, released 40 emission scenarios that can be seen as images of the future, or alternative futures. They are neither predictions nor forecasts and actual reserves have not been a limited factor, just the fossil fuel resource base.[1]

This paper is based on realistic reserve assessments, and CO_2 emissions from resources that cannot be transformed into reserves are not allowed. First we can conclude that CO_2 emission from burning oil and gas are lower then what al the IPCC scenarios predict, and emission from coal is much lowers then the majority of the scenarios.

IPCC emission scenarios for the time period 2020 to 2100 should in the future not be used for climate change predictions. It's time to use realistic scenarios.

Climate change is current with more change to come, and furthermore, climate change is an enormous problem facing the planet. However, the world's greatest problem is that too many people must share too little energy. In the current political debate we presumably need to replace the word "environment" with "energy", but thankfully the policies required to tackle the energy problem will greatly benefit the environment.

[1] Resources and reserves are described in the paper "Peak-oil and the evolving strategies of oil importing and oil exporting countries" presented at this research round table, "OIL DEPENDENCE: IS TRANSPORT RUNNING OUT OF AFFORDABLE FUEL?", Organized by the Joint Transport Research Centre of the OECD and the International Transport Forum, IEA, Paris, 15-16 November 2007

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1. INTRODUCTION

The issues of climate change and future increases in temperature have become part of our everyday life and central to this debate is the role of carbon dioxide. The fossil fuels we use contain both carbon and hydrocarbon compounds and when we burn these products carbon dioxide is released together with a certain amount of energy.

However, in the climate debate that now rages, it appears that existing quantities of fossil fuels are not perceived as a problem. The issue is always assumed to be the excessive use of hydrocarbons and coal. The idea that the combined volumes of these fuels are insufficient to yield the levels of carbon dioxide (CO2) necessary to cause the changes in climate predicted is not expressed anywhere.

At Mexico's enormous oilfield named Cantarell, production is declining very rapidly. In 2005 the Mexican oil company Pemex presented two scenarios for how much oil Cantarell would ultimately produce; an optimistic estimate with an extraction rate of 50 percent of the original oil in place, and a more pessimistic estimate of only 30 percent. For Pemex and the Mexican government it is, of course a severe blow that reality now appears consistent with the pessimistic scenario, but this may mean our climate stands to benefit. We have now come to an important decision point. Shall we regard the oil that remains underground as a resource that can cause future carbon dioxide emissions or shall we accept that this finite resource is in fact inaccessible? Scenarios used by the IPCC, Intergovernmental Panel on Climate Change, are based upon the consideration that all oil in place is a source for future CO2 emission. Our analysis uses only those reserves judged to be technically and economically available now and in the future, and this makes the predictions "reserve driven".

The production of oil, gas and coal are limited by today's reserves, the fraction of the resources that can be produced economically, and reserves that can be found in the future. You must find oil before you can produce it.

Oil reserves currently displaying declining production have a very limited potential to grow and the fact that the majority of the productive oilfields are now in decline provides us with the possibility of estimating the maximum emission of CO2 from oil.

Natural gas fields on the other hand have a high recovery factors because gas moves easily through rock strata. Enhanced recovery is not part of the future of these fields and discovery trends are the primary driving parameters.

Coal can only be extracted using different kinds of mining. Areas for surface mining are shrinking due to environmental and social considerations. Next generations underground mines will be very expensive. In Germany the mining in modern mines are more then twice as expensive as the market price of coal. Reported new reserves are in general smaller then reported earlier contrasted to a growth in existing oil fields.

If we take the reserves reported in the BP Statistical Review [1] as a potential for future emission we get that gas is 400 billions metric tons CO2, oil 600 billion metric tons CO2, and coal 2000 billion metric tons CO2. It has been said before and we would once again like to point out the fact that coal is the main problem when considering future emissions.

2. EMISSION SCENARIOS BY IPPC

The IPCC Special Report on Emission Scenarios [2] describes 40 scenarios for the future and predicts the extent of greenhouse gas emissions associated with such developments. These scenarios are based on reviews of the literature, the development of narrative ***storylines*** and the quantification of these storylines with the help of six different integrated models from different countries. The report illustrates that future emissions, even in the absence of explicit climate policies, depend very much on the choices people make: how economies are structured, which energy sources are preferred, and how people use available land resources. Restrictions of reserves are not part of the game.

The scenarios can be seen as images of the future, or alternative futures, but they are not predictions and they are not forecasts. Different assumptions about the future help create different images of how the future might unfold. The best way to describe the enormous computer models is to look at them as some kind of giant “IPCC-SimCity-games” [10].

The families in the “game” are called A1, A2, B1 and B2. Every family has a predetermined future in terms of population- and GDP-growth, land use, available resources and technology development. Each family create its footprint in terms of emissions of CO2 from use of oil, gas and coal. The emissions are then used in climate models and at the end a change of global surface temperature is calculated.

3. IPCC CLIMATE MODELLING

In the modelling of climate change the different emission scenarios are the central component with different curves displaying changes in the temperature labelled according to the different family names. The most utilised family scenario showing an unacceptable threat to our planet is the family A2. If this scenario is allowed to develop the temperature by 2100 will be a whole 3.6 degrees higher than today. The most optimistic is B1, and this least troublesome family causes a temperature increase of only 1.8 degrees (figure 1), compared with the reference year 1990[2]. The EU has proposed a target below 2 degrees.

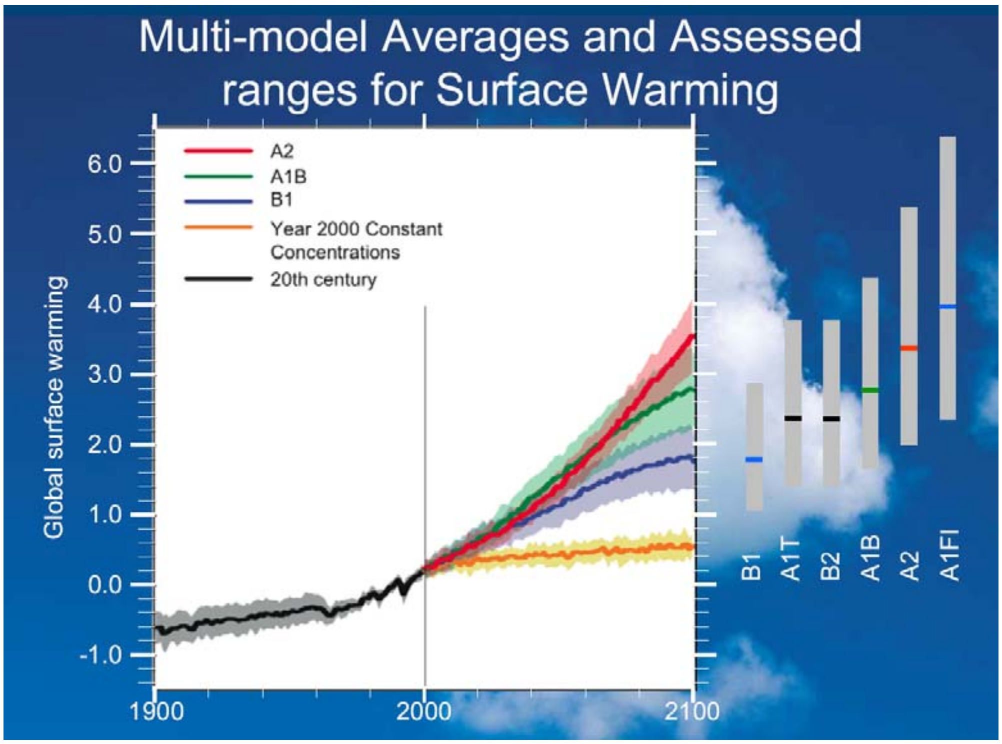


Figure 1. Modulated averages and assessed ranges for Surface warming according to IPCC.

The prerequisite for each of these scenarios and the subsequent temperature increase they represent is that we consume large volumes of oil, gas and coal. The fact that the IPCC calls upon our politicians to make decisions that will discourage use of fossil fuels creates an impression that the requisite fossil fuel reserves exist on a large enough scale.

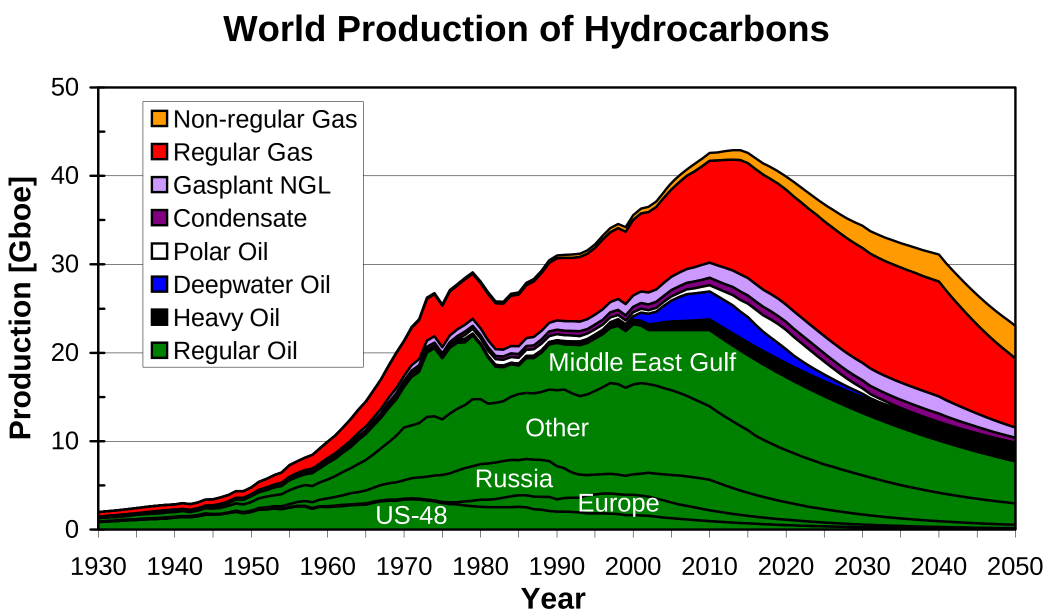


Figure 2 *The world's production of all hydrocarbons excluding tar sand, bitumen, oil shale and methane hydrate according to the 2002 scenario [2]. Regular oil production is divided into production from different regions. US-48 represents the USA excluding Alaska and Hawaii, and the group **other** represents the rest of the world.*

4. FUTURE OIL, GAS AND COAL PRODUCTION AND IPCC EMISSION SCENARIOS

In 2003 the Uppsala Hydrocarbon depletion study Group (UHDSG) performed a detailed study of World Oil Reserves with a Comparison to IPCC Emissions Scenarios [3]. The different IPCC emission scenarios are detailed in this work. Oil and gas production were determined according to the depletion model (DM) described in the paper "The Peak and Decline of World Oil and Gas Production" [4], and the sum of the oil and gas production is illustrated in figure 2.

The IPCC describes the fraction of different fossil fuels used in the scenarios in terms of primary energy per year, and the production figures shown in figure 2 can be transformed into energy distributions. Figures 3 and 4 show these distributions as a comparison with the IPCC emission scenarios.

Just take a glance at figures 3 and 4 and you will realize that the planet cannot provide the amount of energy from hydrocarbons (oil and natural gas) that the IPCC needs to drive the scenarios presented in 2000.

This can be shown in an even more convincing way by adding each year's consumption as presented in figure 5. The time structure of the distributions given in figure 3 and 4 can differ, as well as the total energy consumption given in figure 5, and if the numbers are to low by a factor of 50% we may just about attain the best-case scenario presented by IPCC

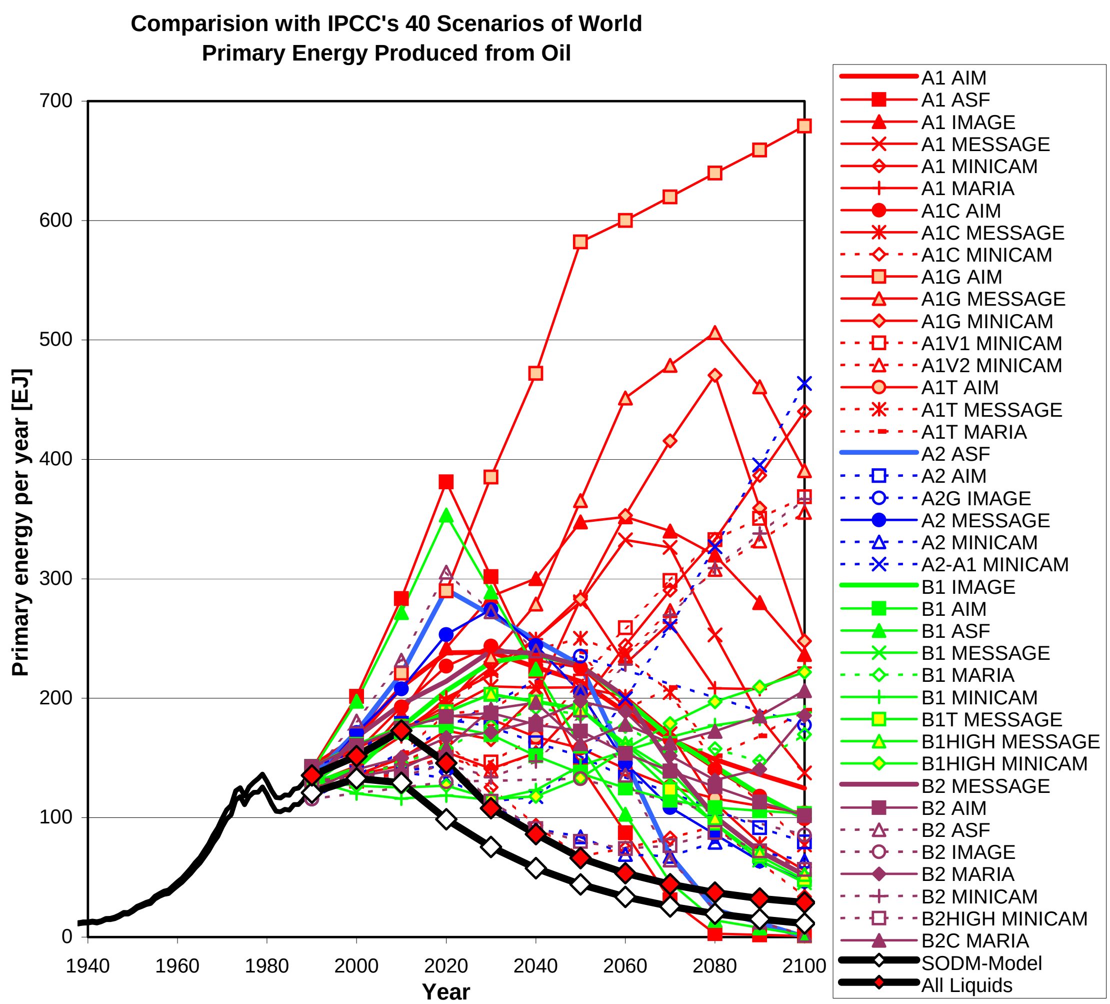
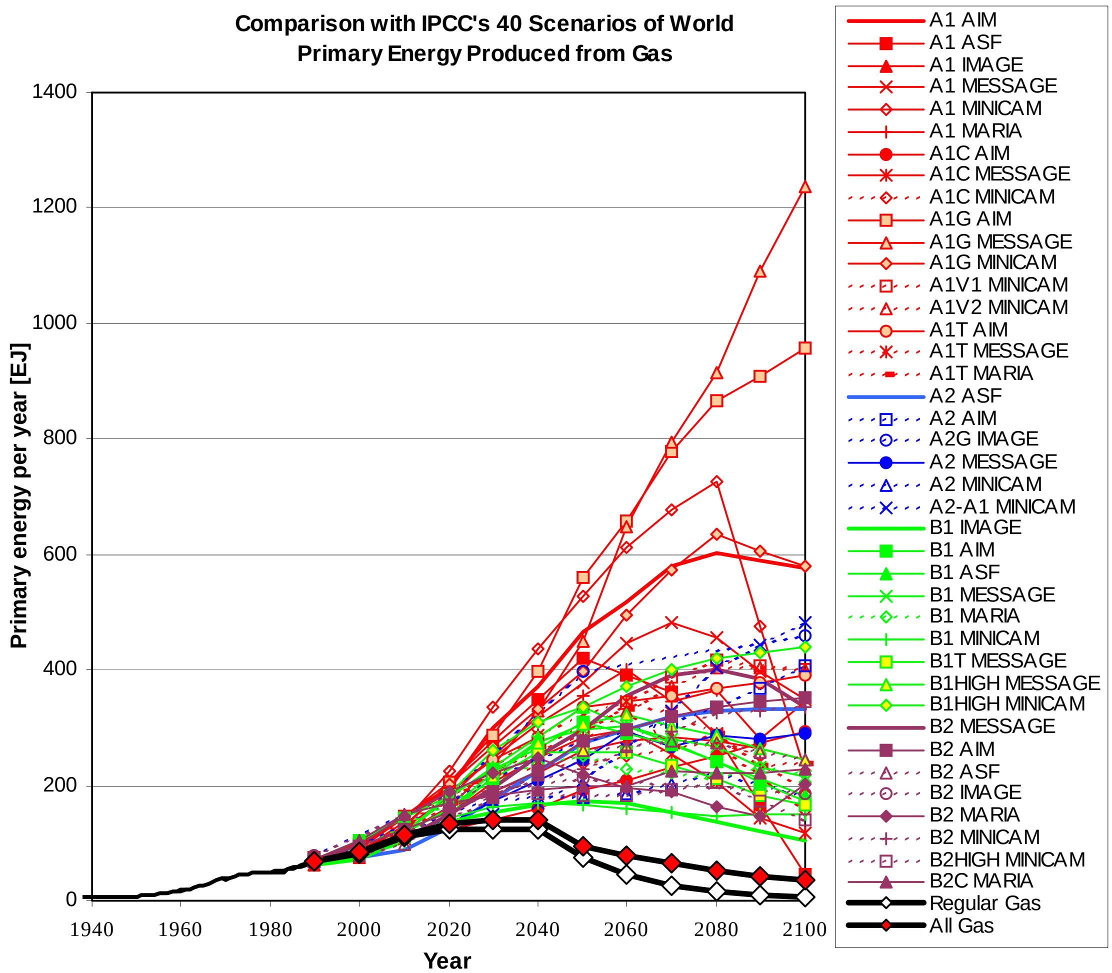


Figure 3. IPCC's 40 scenarios on world primary energy produced from oil 1990-2100 compared to the oil production according to the oil depletion model 1930-2100. The group ***all liquids*** includes heavy oil, extra heavy oil, deepwater oil, polar oil, gas plant NGL, and condensate.



*F**igure 4.** IPCC's 40 scenarios on world primary energy produced from gas 1990-2100 compared to the gas production according to the oil depletion model 1930-2100. The group **all gas** includes non-regular gas e.g. coal bed methane.*

When this data was presented in 2003 New Scientist wrote an article concerning our findings [5] (se Appendix 1):

"Nebojsa Nakicenovic, an energy economist at the University of Vienna, Austria who headed the 80-strong IPCC team that produced the forecasts, says the panel's work still stands. He says they factored in a much broader and internationally accepted range of oil and gas estimates than the "conservative" Swedes.

Even if oil and gas run out, "there's a huge amount of coal underground that could be exploited", he says. Aleklett agrees that burning coal could make the IPCC scenarios come true, but points out that such a switch would be disastrous."

The same day as this article was released CNN interviewed me live and wrote about the article on their website [6].

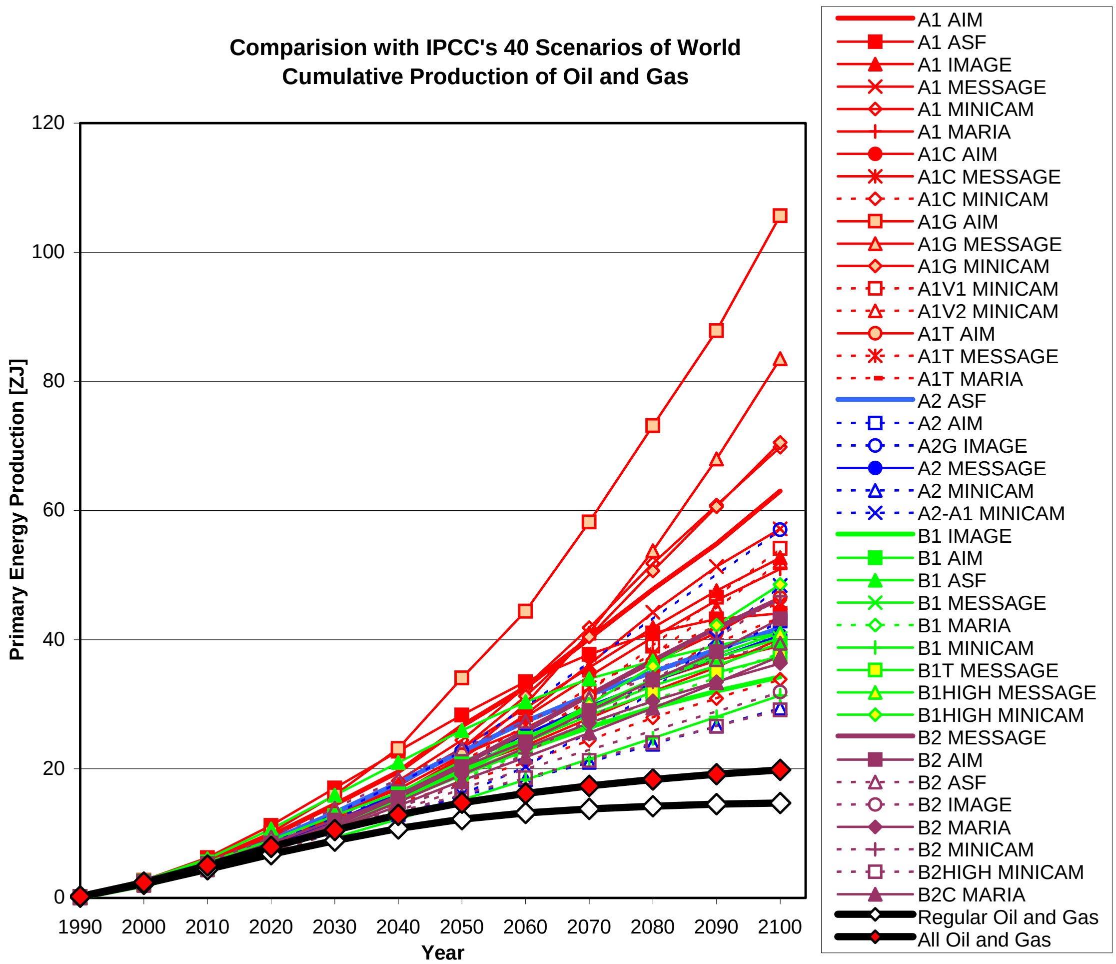


Figure 5. *IPCC's 40 scenarios on world cumulative primary energy produced from oil and gas compared to the cumulative oil and gas production according to the oil depletion model. The group* ***All Oil and Gas*** *includes heavy oil, extra heavy oil, deepwater oil, polar oil, gas plant NGL, condensate, and non-regular gas e.g. coal bed methane.*

Most puzzling is that Nebojsa Nakicenovic can reaffirm the panel's work in light of the results shown in Figures 3, 4 and 5. At that time everybody felt that that it doesn't matter if you are right or wrong about oil and gas because there is so much coal, and coal emits much more CO2 then oil and gas. This is correct and comparatively for

2005 all of the emissions produced by burning gas in the world only equate to the emissions from burning coal in China. On the basis of this UHDSG decided to do an even more detailed study that included figures from coal.

We have now completed this study based upon a detailed analysis of future oil and coal production, the two major CO2 emitters [9]. By breaking down oil production into seven well-defined parts we can now give a timeframe for the moment when we will reach the maximum production rate for oil, "Peak Oil", the historical peak in production. It will occur between 2008 and 2018. If the world's giant oilfields (those fields that produce 60% of the world's oil) behave in a similar manner to Mexico's Cantarell field we have the basis for a "worst case scenario" with a production peak in 2008. If instead they follow the best prognosis for Cantarell, and we simultaneously reduce our consumption, then we get a "best case scenario" with maximum production in 2018. When discussing CO2 emissions we better use a "High Case" (figure 6), a picture as comparable to the depletion model [2].

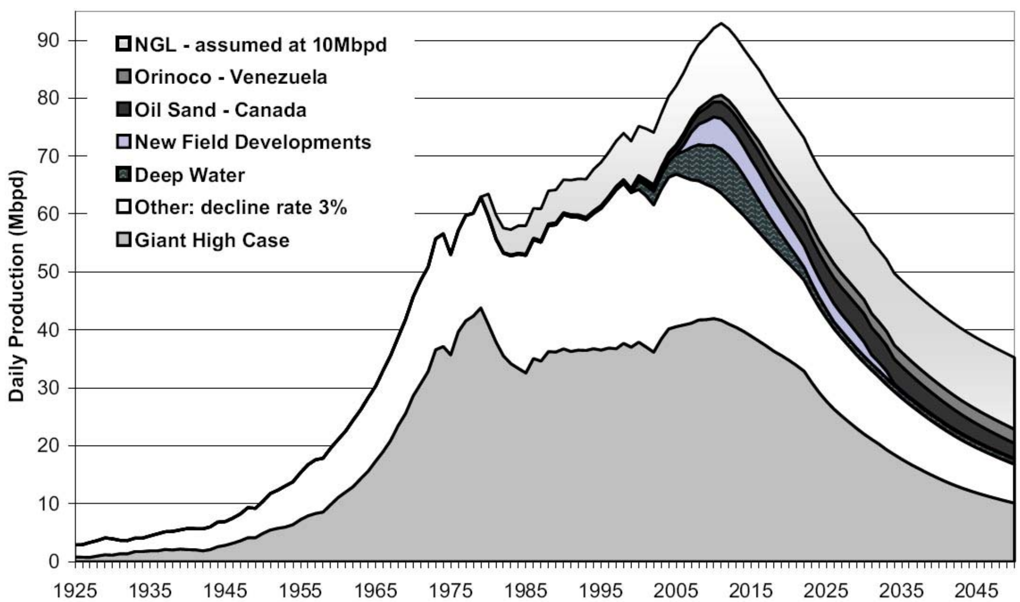


Figure 6. The sum of the production from the seven different parts as defined in the figure with the "Giant High Case" scenario. This is a rather optimistic scenario.

We can now, according to our forecast, calculate how much energy/carbon dioxide we can expect to produce this century if oil is used accordingly, and compare it with the energy requirements of the IPCC-families. To our amazement we see that families A1, A2, B1 and B2 require more oil than is realistic.

If we extend our analysis and study future natural gas production with what the IPCC-families require we get an even clearer picture. Natural gas production is declining in

North America as is production in the gigantic Russian gas fields in northwest Siberia that today account for 90 percent of Russian production. Projects planned for the production of diesel fuel from natural gas in Qatar are being cancelled, and the intended construction of liquefied natural gas reception terminals in the USA and Europe are being downsized because global production of liquefied natural gas is now not expected to reach levels planned for a few years ago. Natural gas is considered by many to be a ”transition fuel” to a future renewable-based society. Today the transition seems to be shorter than previously believed, but in terms of carbon emissions once again we may stand to benefit.

The third component to be considered when discussing carbon dioxide emissions is coal. The common belief is that virtually unlimited quantities of coal exist, but when we make detailed analyses of production profiles in those six nations that have 85% of the world’s coal reserves (see figure 8), USA, China, Russia, Australia, India and South Africa, we soon discover clear signs that coal production in particular regions has reached maximum capacity [7]. Furthermore, we see a decline in production of the best coal, i.e. that which has the highest energy content. In the USA, the world’s second largest coal user, the volume of coal consumed is increasing but the actual energy content of the coal used is decreasing. The USA has reached a coal maximum, “Peak Coal”, in terms of energy content.

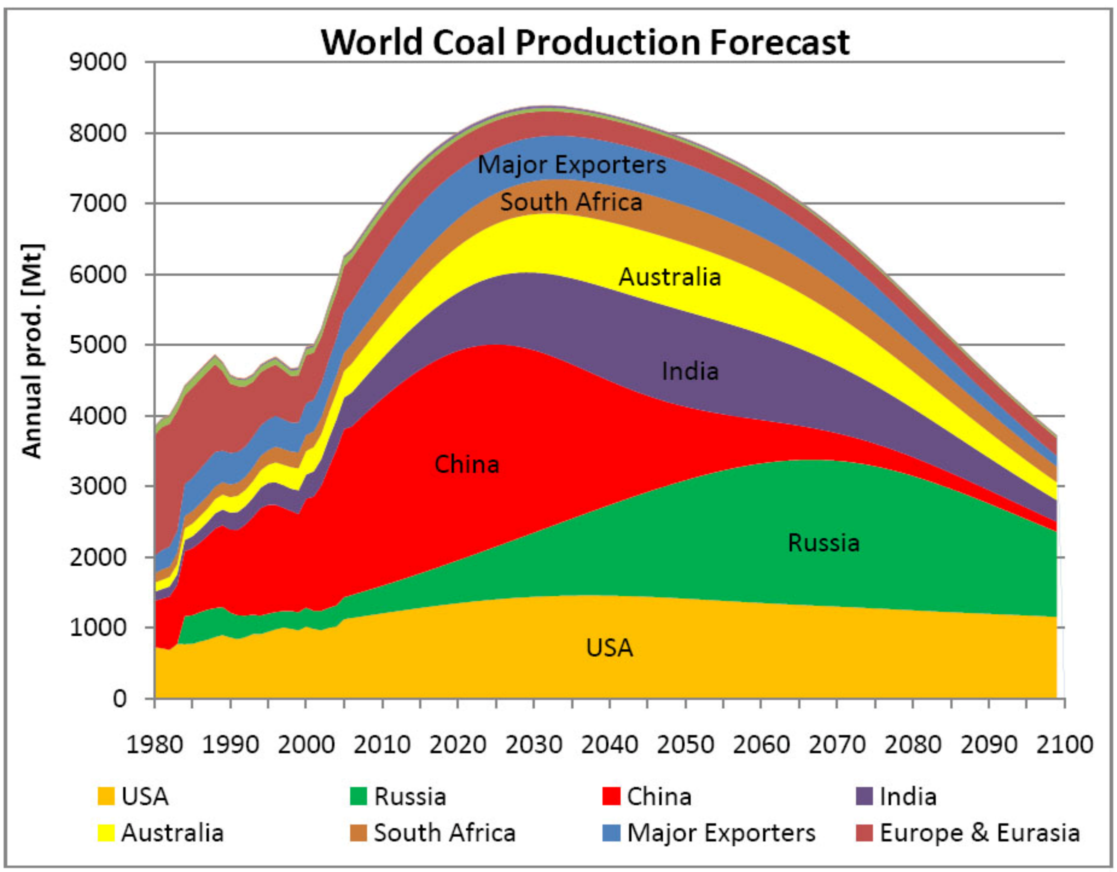


Figure 7: World possible coal production [7].

China will soon reach its maximum coal production capacity too and we will then be in a situation where Russia alone sits on the last great coal reserves. That moment in history when we reach ”Peak Coal” is determined by Russia’s future coal production. This forecast is based on open data and what we see in our analysis is that every country that makes a new reserve estimate are downscaling their reserves. Finally these production profiles are compared with the IPCC emission scenarios for coal (as for oil and gas most of the scenarios would not be fulfilled).

The total sum of all fossil fuel resources that industry considers accessible is reported every year in the BP Statistical Review. If we use this optimistic value then the total energy available from all reserves of oil, natural gas and coal equals 36 ZJ (zettajoules, 1×10^{21} joules), a massive quantity. This is more than our research group considers possible but is still less than that reported for all of the scenario families, A1, A2, B1 and B2. The available energy from fossil fuels is insufficient.

Family A2 is our “worst case” in terms of temperature increase so let us take a look at its thirst for energy. In the years to 2100 the IPCC estimates that A2 requires between 70 and 90 ZJ, in other words double the amount that industry believes is accessible. There is then another small detail that is never discussed, namely that all of the IPCC-families require fossil fuel energy subsequent to the year 2100 (see Figures 3, 4 and 8).

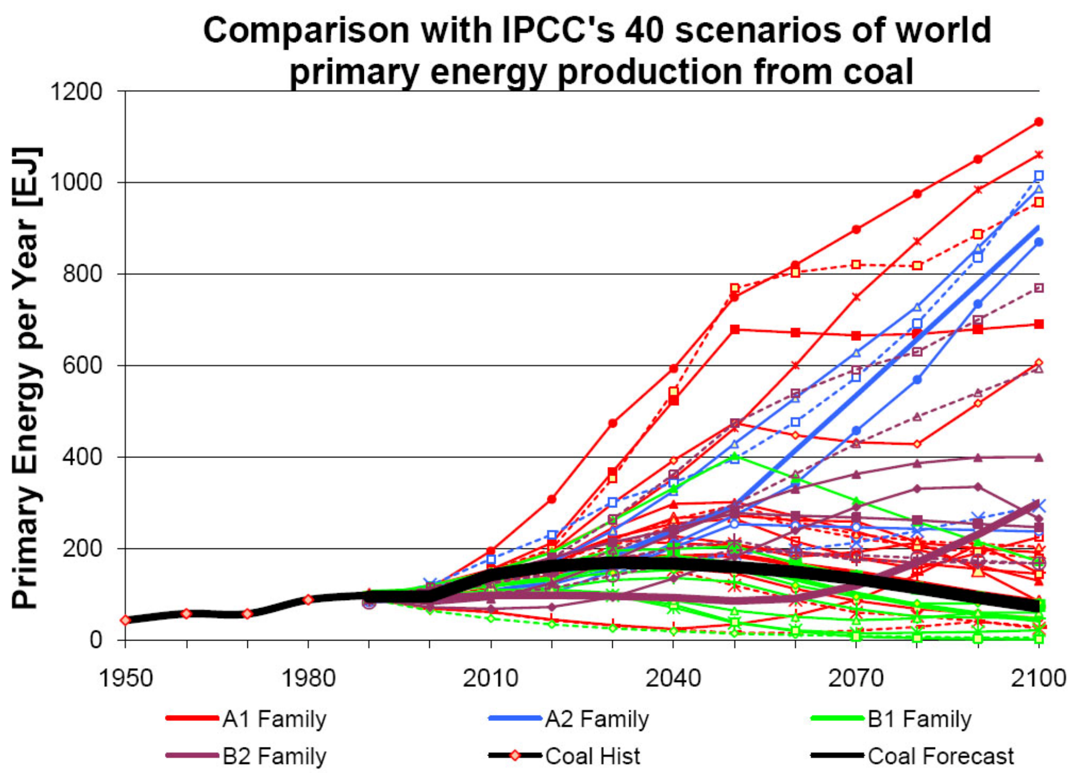


Figure 8: IPCC's 40 scenarios on world primary energy produced from coal 1990-2100 compared to the coal production according our data.

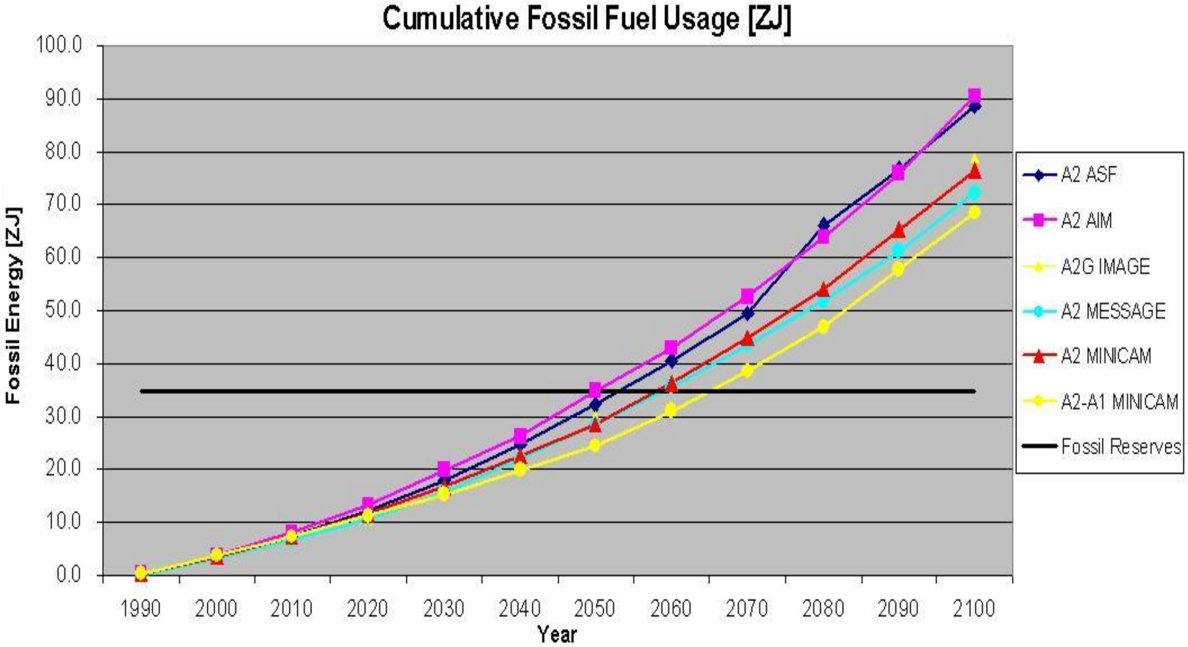


Figure 9: Cumulative fossil fuel usage for family A2, 70 to 90 Zeta Joule, compared with the total fossil reserves according to BP Statistical Revue, 36 Zeta Joule.

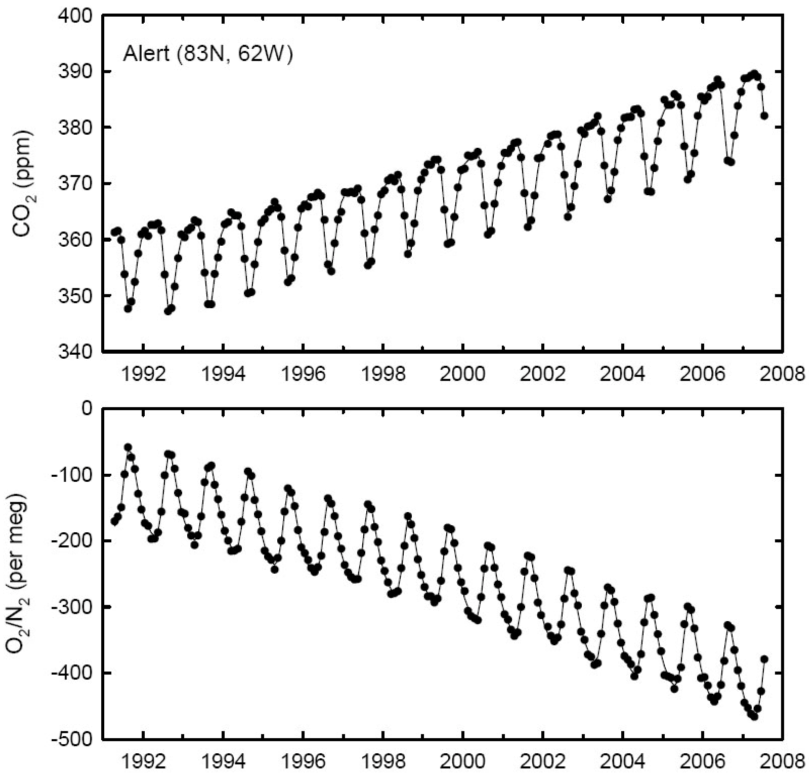


Figure 10. Correlations between concentration of carbon dioxide (CO2) in parts per million (ppm) and the ratio between oxygen and nitrogen per meg in the atmosphere [8].

5. CONCLUSIONS

It is not necessary here to enter into the debate about fossil fuels as the cause of increased CO2 concentration in the atmosphere. When burning fossil fuels oxygen (O2) in the atmosphere is consumed and CO2 produced giving rise to a decline in O2 concentration, a fact illustrated in figure 10 [8]. Furthermore, it is known that CO2 is a greenhouse gas and that a higher concentration will yield an increase in the surface temperature of the planet. The increase of CO2 during the last 100 years may already be more than the climate can take. During the period 2008 – 2020 we will see a plateau (or a small decline) in the production of oil, but an increase in gas and coal consumption will lead to a combined higher emission of CO2 by 2020 than seen today. **The conclusions of this paper do not mean that we should not worry about emissions. The big question is what will happen after 2020 and for the duration of the 21st century?**

The IPCC states that their scenarios can be seen as images of the future (or alternative futures) and that they are neither predictions nor forecasts but different assumptions about the future that can help us understand how the future might unfold. **My conclusion is that the IPCC emission scenarios are absolutely unrealistic about the time frame 2020 to 2100 and these 'alternative futures' should not be given credence any longer.** We need a realistic emission scenario. Uppsala Hydrocarbon Depletion Study Group have now combined all of its research for oil, gas and coal and propose that this is much more a realistic starting point time frame 2020 to 2100 [9].

Climate change is current with more change to come, and furthermore, climate change is an enormous problem facing the planet. However, the world's greatest problem is that too many people must share too little energy. In the current political debate we presumably need to replace the word "environment" with "energy", but thankfully the policies required to tackle the energy problem will greatly benefit the environment.

6. REFERENCES

[1] BP Statistical Review of World Energy, http://www.bp.com/productlanding.do?categoryId=6848&contentId=7033471

[2] IPCC, Intergovernmental Panel on Climate Change, Special Report on Emissions Scenarios: http://sres.ciesin.org/; series; http://sres.ciesin.org/final_data.html

[3] Anders Sivertsson, "Study of World Oil Resources with a Comparison to IPCC Emission Scenarios", Diploma thesis, Uppsala University (2004); http://www.tsl.uu.se/uhdsg/Publications.html

[4] K. Aleklett and C.J. Campbell; The Peak and Decline of World Oil and Gas Production, Minerals & Energy 18 (2003) 5-20 (the article is available at http://www.tsl.uu.se/uhdsg/Publications/Minerals&Energy_2003.doc)

[5] Andy Coghlan, Too little' oil for global warming, New Scientist, 05 October 2003: **http://www.newscientist.com/article.ns?id=dn4216**

[6] Graham Jones, World oil and gas 'running out', CNN, T**hursday, October 2, 2003 Posted: 1245 GMT (8:45 PM HKT), http://edition.cnn.com/2003/WORLD/europe/10/02/global.warming/index.html**

[7] Mikael Höök, Werner Zittel, Jörg Schindler and Kjell Aleklett, A resource-driven forecast for the future global coal production, Submitted to Energy Policy (2007); http://www.tsl.uu.se/uhdsg/Publications.html

[8] Ralph Keeling, the Scripps Institution of Oceanography, USA, private communications; rkeeling@ucsd.edu

[9] K. Aleklett, C.J. Campbell, M. Höök, K. Jakobsson, F. Robelius, A. Sievertsson, and B. Söderbergh, to be published.

[10] SimCity society, http://simcity.ea.com/

7. ACKNOWLEDGMENTS

This paper was written at the request of the Joint Transport Research Centre of the OECD and the International Transport Forum for presentation at a Round Table on “Oil Dependence: Is Transport Running Out of Affordable Fuel?”, to be held in Paris, 15-16 November 2007. I would like to express my thanks to the organizers for allowing Peak Oil and CO2 emissions to be a part of the discussion.

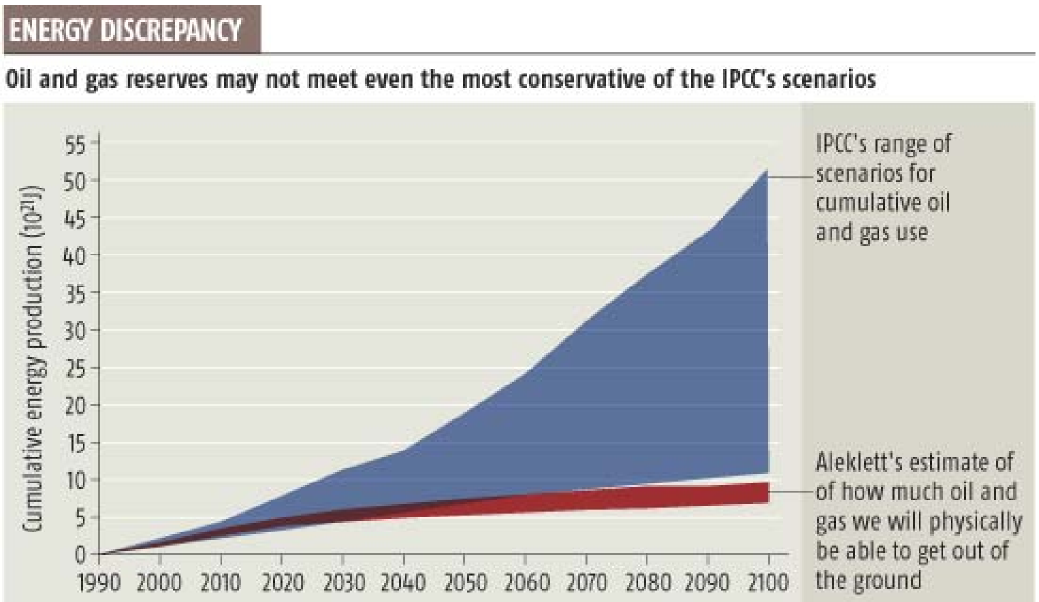
It would not have been possible to present this paper without the outstanding work of my students, Anders Sivertsson and Mikael Höök, who made the bulk of the work with Peak Oil, Peak Gas, Peak Coal and CO2 emissions.

Finally I would like to thank Simon Snowden (University of Liverpool Management School, UK) for proofreading the paper and for the provision of feedback.

APPENDIX 1

'Too little' oil for global warming

- New Scientist
- 10:00 05 October 2003
- Andy Coghlan



Oil and gas will run out too fast for doomsday global warming scenarios to materialise, according to a controversial analysis presented this week at the University of Uppsala in Sweden. The authors warn that all the fuel will be burnt before there is enough carbon dioxide in the atmosphere to realise predictions of melting ice caps and searing temperatures.

Defending their predictions, scientists from the Intergovernmental Panel on Climate Change say they considered a range of estimates of oil and gas reserves, and point out that coal-burning could easily make up the shortfall. But all agree that burning coal would be even worse for the planet.

The IPCC's predictions of global meltdown provided the impetus for the 1997 Kyoto Protocol, an agreement obliging signatory nations to cut CO_2 emissions. The IPCC considered a range of future scenarios, from profligate burning of fossil-fuels to a fast transition towards greener energy sources.

But geologists Anders Sivertsson, Kjell Aleklett and Colin Campbell of Uppsala University say there is not enough oil and gas left for even the most conservative of the 40 IPCC scenarios to come to pass (see graphic).

Billions of barrels

Although estimates of oil and gas reserves vary widely, the researchers are part of a growing group of experts who believe that oil supplies will peak as soon as 2010, and gas soon after (**New Scientist** print edition, 2 August 2003).

Their analysis suggests that oil and gas reserves combined amount to the equivalent of about 3500 billion barrels of oil considerably less than the 5000 billion barrels estimated in the most optimistic model envisaged by the IPCC.

The worst-case scenario sees 18,000 billion barrels of oil and gas being burnt five times the amount the researchers believe is left. "That's completely unrealistic," says Aleklett. Even the average forecast of about 8000 billion barrels is more than twice the Swedish estimate of the world's remaining reserves.

Nebojsa Nakicenovic, an energy economist at the University of Vienna, Austria who headed the 80-strong IPCC team that produced the forecasts, says the panel's work still stands. He says they factored in a much broader and internationally accepted range of oil and gas estimates than the "conservative" Swedes.

Even if oil and gas run out, "there's a huge amount of coal underground that could be exploited", he says. Aleklett agrees that burning coal could make the IPCC scenarios come true, but points out that such a switch would be disastrous.

Coal is dirtier than oil or gas and produces more CO_2 for each unit of energy, as well as releasing large amounts of particulates. He says the latest analysis is a "shot across the bows" for policy makers.