ASSOCIATION FOR THE STUDY OF PEAK OIL AND GAS

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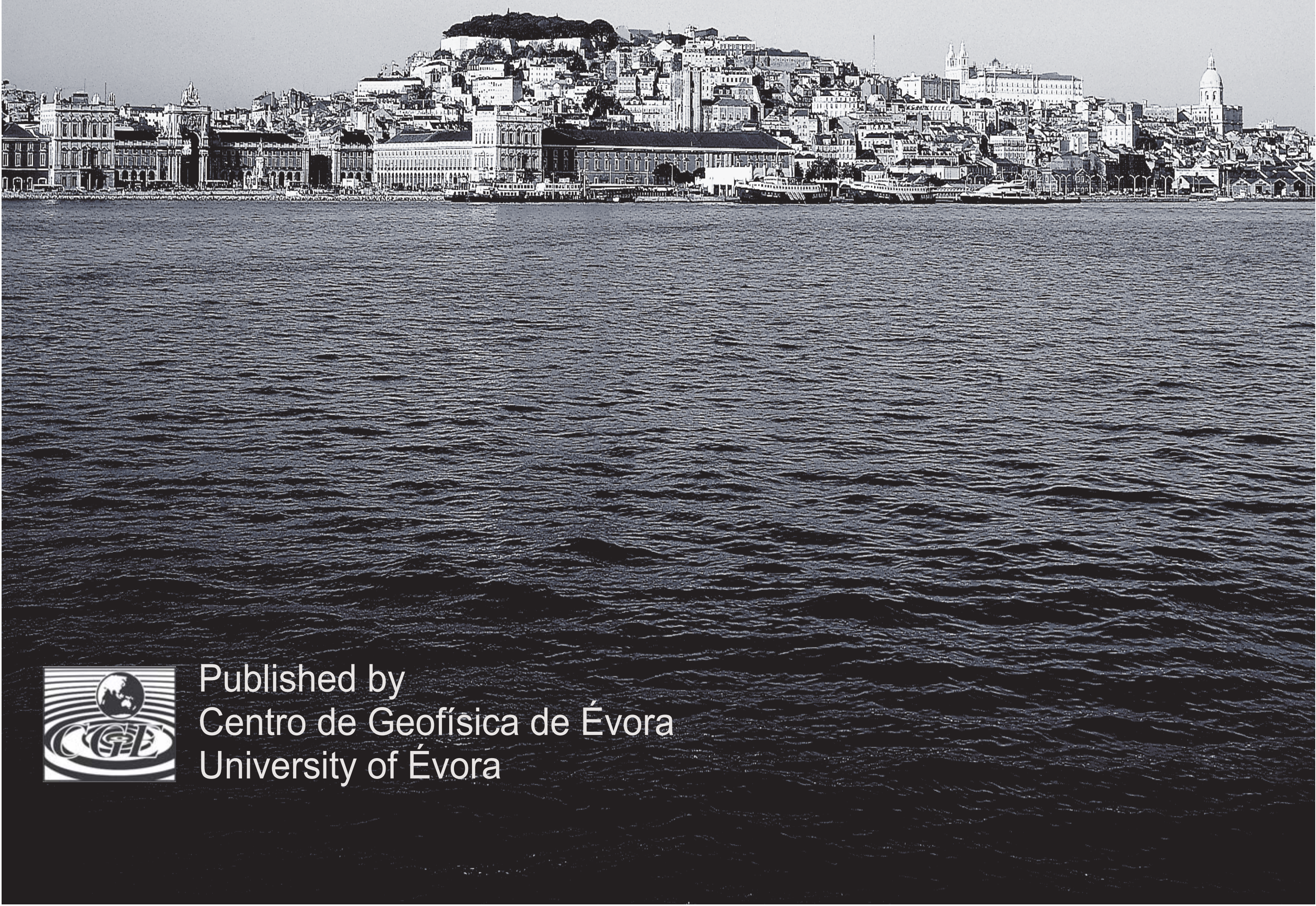
IV INTERNATIONAL WORKSHOP ON OIL AND GAS DEPLETION

19-20 May 2005, Lisbon, Portugal

Proceedings



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IV INTERNATIONAL WORKSHOP ON OIL AND GAS DEPLETION

Conference hosted by

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Conference Organization

Centre de Geofísica de Évora (Universidade de Évora)

Centro de Geofísica de Évora
Universidade de Évora

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PARTEX OIL AND GAS

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INTRODUCTION

The IV International Conference on Oil and Gas Depletion

The IV International Workshop on Oil and Gas Depletion, that is held at Gulbenkian Foundation in Lisbon on the 19th and 20th May, 2005, is the fourth annual meeting promoted by ASPO, the Association for the Study of Peak Oil and Gas, with the organizing support of Geophysics Centre of Évora.
Previous meetings were held at the University of Uppsala in 2002, Institut Français du Pétrole, Paris in 2003, and Bundesanstatt fur Geowissenschaften und Roshtoffe, Berlin in 2004.

In this fourth annual edition, the core topics chosen for our works are**:**

- Reality in Oil Exporting Countries: The Supply Limits
- Impacts of Depletion in Oil Importing Countries: The Demand Pressure
- How-Much Regular Oil and Non-Conventional Oil: Utopia versus Reality
- The Case for Political Action: The *Depletion Protocol*
- The World Past Peak Oil Age

From Uppsala to Lisbon, the public perception of the serious threat impending on humankind as a result of the growing scarcity of fossil fuels has increased. And national and international authorities have slowly but perceptibly admitted and changed their discourse on the problematic availability of the energy required to run the world economy. But political consequences have not yet been addressed straightforwardly – when political action is ever increasingly urgent for putting in place the economical and social changes and technological infrastructure required for preserving wellbeing if not survival itself.

For this reason, in this fourth edition of ASPO's annual meetings we called upon members of the political community to share their views on how political action might be taken at the required international level. As the starting point of this debate we have the *Depletion Protocol* - first proposed by Colin Campbell 10 years ago at a conference in London. It has surfaced in various guises since, named the Uppsala Protocol in 2002, on the occasion of the First International ASPO's Workshop, later also referred to as the Rimini Protocol.

The organizers of this Workshop welcome all participants and thank all speakers who kindly accepted to contribute to this event and those participants who also offered their contributions.
They thank Calouste Gulbenkian Foundation and Partex – Oil and Gas, for generously hosting this event and offering the valuable sponsorship which makes it possible.
Thanks are also due to the staff of the Geophysics Centre of Évora and University of Évora who, along the past few months, has worked in preparation of the conditions to hold this event now and who, together with the staff of Gulbenkian Foundation, are making it through.

The Organizing Committee
May 2005

THE ASSOCIATION FOR THE STUDY OF PEAK OIL AND GAS

ASPO is a network of concerned scientists in European Universities and Government Departments with the following declared mission:

1. ***To evaluate the world's endowment and definition of oil and gas;***
2. ***To study depletion, taking due account of economics, demand, technology and politics;***
3. ***To raise awareness of the serious consequences for Mankind.***

It has been in existence for four years, putting out a monthly newsletter, operating a website www.peakoil.net and holding annual conferences. It is by all means a Network, lacking a formal establishment, but that adds to its strength allowing the national committees to do what is appropriate in their own countries.

It is said that from small acorns, large oak trees grow, and from a small beginning ASPO has certainly enjoyed a remarkable success, with its voices now being heard throughout the world. This year is the turn of Lisbon to host the conference with the generous support of the Gulbenkian Foundation.

In large measure, this success is due to events beyond its control, for the notion of Peak Oil, which has been obvious to the scientist for so long, now captures popular imagination and rises to the head of political agendas everywhere.

PEAK OIL

The Concept of Peak Oil can be explained in a few words:
Oil was formed but rarely in time and place in the Earth's geological past, meaning that it is a finite resource subject to depletion. It has to be found before it can be produced. The peak of discovery in the 1960s therefore heralded a corresponding peak of production. The larger fields were found first in most areas. Production is also constrained by the physics of the reservoir. The production profile in a country or region with a large population of fields is normally symmetrical, with peak coming when half the total has been produced. Gas follows a different trajectory with a steep terminal decline, with the World peak coming a few years after oil.

Public data on oil and gas reserves are grossly unreliable, subject to both over- and under-reporting in different countries, which allows economists to argue that production is simply a function of investment and technology. The true state of affairs would otherwise be almost self-evident.

The World is in fact now very close to Peak, spelling the End of the First Half of the Oil Age. It lasted 150 years and saw the growth of industry, transport, trade, agriculture, and financial capital, made possible by an abundant flow of cheap oil-based energy. The Second Half now dawns, and will be characterised by the decline of oil and all that depends upon it. Peak Oil is accordingly an unprecedented historic discontinuity with grave consequences.

This Conference brings together participants from many countries to dig behind the many veils of confusion and misrepresentation in an effort to identify the contributions of all the different categories of oil and to identify the regional issues. It moves beyond the simple acceptance of the reality of peak oil as imposed by Nature, to model more exactly the depletion profiles and political impacts, which may also affect demand.
A panel of prestigious politicians evaluate the scope for new initiatives to put demand in better balance with the supply as constrained by Nature. The transition to decline will undoubtedly be an epoch of grave tension and geopolitical conflict as consumers vie with each other for access to supplies. With about half of what is left lying in just five countries bordering the Persian Gulf, the Middle East is an obvious flashpoint. But in the longer term, there are hopes for sensible responses putting people into a better

relationship with themselves, their neighbours and the Environment within which Nature has ordained them to live.

The Conference gives people the chance to come together in the ancient city of Lisbon that has experienced many vicissitudes during the long history etched into the stones of its fine buildings. The formal programme sets the scene, but much is also achieved in informal meetings and discussions.

The World's media has cast a serious eye on the previous ASPO conferences in Uppsala, Paris and Berlin, and will no doubt follow the proceedings in Lisbon with a sharpened interest as the storm clouds gather above an uncertain world.

Colin J. Campbell
November 2004

THE DEPLETION PROTOCOL

WHEREAS the passage of history has recorded an increasing pace of change, such that the demand for energy has grown rapidly in parallel with the world population over the past two hundred years since the Industrial Revolution;

WHEREAS the energy supply required by the population has come mainly from coal and petroleum, having been formed but rarely in the geological past, such resources being inevitably subject to depletion;

WHEREAS oil provides ninety percent of transport fuel, essential to trade, and plays a critical role in agriculture, needed to feed the expanding population;

WHEREAS oil is unevenly distributed on the Planet for well-understood geological reasons, with much being concentrated in five countries, bordering the Persian Gulf;

WHEREAS all the major productive provinces of the World have been identified with the help of advanced technology and growing geological knowledge, it being now evident that discovery reached a peak in the 1960s, despite technological progress, and a diligent search;

WHEREAS the past peak of discovery inevitably leads to a corresponding peak in production during the first decade of the 21st Century, assuming no radical decline in demand;

WHEREAS the onset of the decline of this critical resource affects all aspects of modern life, such having grave political and geopolitical implications;

WHEREAS it is expedient to plan an orderly transition to the new World environment of reduced energy supply, making early provisions to avoid the waste of energy, stimulate the entry of substitute energies, and extend the life of the remaining oil;

WHEREAS it is desirable to meet the challenges so arising in a co-operative and equitable manner, such to address related climate change concerns, economic and financial stability and the threats of conflicts for access to critical resources.

NOW IT IS PROPOSED THAT

1. A convention of nations shall be called to consider the issue with a view to agreeing an Accord with the following objectives:
    a. to avoid profiteering from shortage, such that oil prices may remain in reasonable relationship with production cost;
    b. to allow poor countries to afford their imports;
    c. to avoid destabilising financial flows arising from excessive oil prices;
    d. to encourage consumers to avoid waste;
    e. to stimulate the development of alternative energies.
2. Such an Accord shall have the following outline provisions:
    a. No country shall produce oil at above its current Depletion Rate, such being defined as annual production as a percentage of the estimated amount left to produce;
    b. Each importing country shall reduce its imports to match the current World Depletion Rate, deducting any indigenous production.
3. Detailed provisions shall cover the definition of the several categories of oil, exemptions and qualifications, and the scientific procedures for the estimation of Depletion Rate.
4. The signatory countries shall cooperate in providing information on their reserves, allowing full technical audit, such that the Depletion Rate may be accurately determined.
5. The signatory countries shall have the right to appeal their assessed Depletion Rate in the event of changed circumstances.

In: "The Truth about Oil and the Looming Energy Crisis", Colin Campbell (Eagle Print, Ireland, 2004)

IV INTERNATIONAL WORKSHOP ON OIL AND GAS DEPLETION
ASPO LISBON MEETING

PROGRAM

THURSDAY 19TH MAY 2005

8:00 - 9:00 - REGISTRATION

9:00 – 9:45 - OPENNING SESSION
Rui N. Rosa (Chair of Organizing Committee, ASPO and Geophysics Centre of Évora, Portugal): *Welcome address*
E. Rui Vilar (President, Fundação Calouste Gulbenkian, Portugal): *Calouste Sarkis Gulbenkian: a pioneer in the Oil Industry*
Kjell Aleklett (ASPO President and University of Uppsala, Sweden): *ASPO: From Uppsala to Lisbon*

9:50 – 10:30 – KEYNOTE ADDRESS
C. J. Campbell (ASPO Chairman and ODAC, Ireland): *The End of the First Half of the Age of Oil*

10:30 – 10:45 - COFFEE BREAK

10:45 – 12:00 – WORKING SESSION
Jean Laherrère (ASPO and ex Deputy Exploration Manager, TOTAL, France): Forecasting production from discovery
Roger W. Bentley (ASPO and University of Reading, UK): *Global Oil Depletion: Methodologies and Results*
Chris Skrebowski (editor of Petroleum Review, UK): *The Emerging Reality of Oil and Gas Depletion – Where Reality Meets Theory*

12:00 – 12:30 - SELECTED COMMUNICATIONS
Marcel Schoppers (Prospective Modeling, Pasadena, California, USA Jet Propulsion Laboratory, NASA, USA): *Uncertainty in Peak Oil Timing*
Ugo Bardi (ASPO and Dipartimento di Chimica – Università di Firenze, Italy): *How General is the Hubbert Curve?*
Marek Kolodziej (University of Illinois at Chicago, Department of Economics, USA): *Former Soviet Union Oil Production and GDP Decline: Granger Causality and the Multi-Cycle Hubbert Curve*

12:30 – 14:00 – LUNCHEON BREAK

14:00 – 14:30 - SELECTED COMMUNICATIONS
Pedro Almeida (Dep. de Informática and Dep. de Electromecânica, Universidade da Beira Interior, Covilhã, Portugal): *Peak Oil and the NYMEX Futures Market: Do Investors Believe in Physical Realities?*
João Matias (Technological Forecasting and Innovation Theory Working Group (TFIT-WG), University of Beira Interior, Covilhã, Portugal): *The Fifth Kondratieff Wave – The Fossil Fuels Apogee*
Charles A. S. Hall (State University of New York, College of Environmental Science and Forestry. Syracuse N.Y.; USA): *The need for biophysical economics*

14:35 – 16:00 – WORKING SESSION - Chair **J. Peter Gerling**
A. Costa Silva (Chairman of Management, Partex Oil and Gas, Portugal): *A Vision of the World Market and the Role of Gas as a Substitute for Oil*

Herman Franssen (President, International Energy Associates, USA): *The End of Cheap Oil: Cyclical or Structural Change in the Global Oil Market?*
Matthew Simmons (Chairman and Chief Executive Officer of Simmons & Company International, USA): *US Energy Policy and Foreign Policy*

16:00 – 16:15 - COFFEE BREAK

16:15 – 18:00 - The Depletion Protocol: Panel Discussion on Political Action
Chair: **Kjell Aleklett** (ASPO President and the University of Uppsala, Sweden)
Yves Cochet (MP, former minister of Territory and Environment, France)
Michael Meacher (MP, former minister of Environment, UK)
Rudolf Rechsteiner (MP, Switzerland)
Edward Schreyer (former Governor General, Canada)

18:00 - 18:30 **-** Question and Comment Time

19:00 – SOCIAL PROGRAMME

FRIDAY MAY 20TH

09:00 – 11:00 – WORKING SESSION - Chair **Mariano Marzo**
Jack Zagar (Independent petroleum reservoir engineering consultant, an associate of MHA Petroleum Consultants, Inc. of Golden, Colorado and partner with noted author and world oil reserve expert, Dr. Colin Campbell): *Saudi Arabia - Can It Deliver?*
Ali Samsam Bakhtiari (Iranian analyst of Middle Eastern oil affairs, Iran): *Iran and Iraq: Oil Reserves, Production Capacities and Future Output*
Ray Leonard (Senior Vice President, International Upstream, MOL, Hungary, and ex Vice President for Exploration and New Ventures, Yukos, Russia): *The Reality of Russia*
Kristin Rønning (Staff geologist, Statoil, Norway): *Exploring the basins of the Arctic*

Carlos Bruhn (Petrobras E&P Corporate Manager for Reservoir Characterization, Petrobras, Brazil): *How Much Oil and Gas from Deepwater? The Experience of Brazil*
11:00 – 11:15 - COFFEE BREAK

11:15 – 12:45 – WORKING SESSION
Eddy Isaacs (Managing Director, Alberta Energy Research Institute, Calgary, Canada): *Canadian Oil Sands: Development and future Outlook*
Manuel Collares-Pereira (ASPO, INETI and IST, Portugal): *Past Peak Oil: the Alternatives*

Rolf Willkrans (AB Volvo, Göteborg, Sweden): *Future Fuels for Commercial Vehicles*

Robert L. Hirsch (Senior Energy Program Advisor at SAIC - Science Applications International Corporation - and consultant, USA): *Peaking of World Oil Production: Impacts, Mitigation, & Risk Management*

12:45 – 14:15 – LUNCHEON BREAK

14:15 – 15:40 – WORKING SESSION - Chair **Ugo Bardi**
Xiongqi Pang (Director of Laboratory of Hydrocarbon Migration and Accumulation Mechanism, University of Petroleum, Beijing, P.R. China and Editor Director of Petroleum Science): *Impact of Oil Depletion in China*
Bruce Robinson (Sustainable Transport Coalition, Australia): *Impact of Depletion on Australia*

Richard Heinberg (author, professor and educator, USA): *The Likely Impact of Peak Oil on the United States*

15:45 – 16:00 - COFFEE BREAK

16:00 – 17:40 – WORKING SESSION
Rui N. Rosa (ASPO and Geophysics Centre of Évora, Portugal): *The Urgency for Energy Economics*
Klaus Illum (ECO Consult: Systems Analysis. Energy, Ecology, Economy, Denmark): *Strategies for the Future Development of Energy Systems*
Robert U. Ayres (Professor (and Novartis Chair) Emeritus, INSEAD, Fontainebleau, France, and Institute Scholar at the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria): *Implications of Higher Oil Prices for Future Economic Growth*

Chris Sanders (Sanders Research Associates, UK): *Energy Economics in the Second Half of the Age of Oil*

17:45 - 18:00 – SUMMING UP
C. J. Campbell (ASPO Chairman and ODAC, Ireland)
Manuel Collares-Pereira (Co-Chair of Organizing Committee, ASPO, INETI and IST, Portugal)
E. Marçal Grilo (Fundação Calouste Gulbenkian and Partex Oil and Gas, Portugal)

END OF THE WORKSHOP PROGRAMME

INVITED PAPERS

The ASPO Road from Uppsala to Lisbon

Kjell Aleklett, President of ASPO
Uppsala Hydrocarbon Depletion Study Group
Uppsala University, Uppsala, Sweden

The missions of the ASPO Network have been declared: (1) To define and evaluate the world's endowment of oil and gas; (2) To model depletion, taking due account of demand, economics, technology and politics; and (3) To raise awareness of the serious consequences for Mankind.

Reading the growing number of articles on the subject from around the world might suggest that these missions have been accomplished, but that is no reason for complacency as there is much left to do. Even though enormous progress has been made since the first workshop in Uppsala three year ago, we still have important steps to make. The road from Uppsala to Lisbon has not been a smooth one.

It is evident to most thinking people that the World will very soon have to change its habits and consume less oil. Meeting the challenges of threatened climate change is one good reason for doing so. According to the Kyoto Protocol we need to return to the emission levels of 1990 when the world was consuming 23.8 billion barrels of oil per year. Since consumption today has reached 30 billion per year, an imminent PEAK OIL may turn out to be a salvation, because in due course it will cause production to return to the level of 1990. In a certain sense, PEAK OIL may reduce the risks of climate change and is to be welcomed in that regard.

Those of us working on the PEAK OIL issue have been nick-named "Peakers", although more often are described derisively as Doomsdays Prophets. Personally, I would prefer to be termed a Missionary because we most certainly have a most important mission to accomplish. I am optimistic because we are making progress and being recognized by the decision makers. The Deutsche Bank, for example, has released a research report about Peak Oil and supports our position with the comment:
"The end-of-the-fossil-hydrocarbons scenario is not therefore a doom-and-gloom picture painted by pessimistic end-of-the-world prophets, but a view of scarcity in the coming years and decades that must be taken seriously. Forward-looking politicians, company chiefs and economists should prepare for this in good time, to effect the necessary transition as smoothly as possible."

When we discuss the consumption of oil, we must address the United States in particular because it is consuming more oil then any other country, and in terms of consumption per person has no rival. In pointing this out, we are exposed to risk of being identified anti-American, which is by no means the case. We do however remain puzzled that the responsible American agencies do not do more to serve their country by explaining the true position instead of raising false hopes. The Energy Information Administration, which was established by Congress in 1977, posted on August 18, 2004 a report entitled Long-Term World Oil Supply Scenarios, containing the statement *In any event, the world production peak for conventionally reservoired crude is unlikely to be "right around the corner" as so many other estimators have been predicting. Our analysis shows that it will be closer to the middle of the 21st century than to its beginning."*

It is obvious that ASPO still has an important mission to counter this misleading position.

We felt that good progress was being made at the workshop in Berlin which was attended by the International Energy Agency. It was disappointing therefore to read in its World Energy Outlook 2004 *that we don't need to worry before 2030*. Given its authority, as an arm of the OECD Governments, such a statement could certainly be described as a step backward for Mankind. Yet in December I had the privilege to discuss the Outlook with François Cattier, who is responsible for the oil chapter, and I asked him if he himself believed in the forecast? The answer he gave was: *This is not a forecast, it is a scenario"* which was a telling answer in itself. It was at least a positive indication that WEO 2004 mentioned peak oil at all even to the extent of stating that it could arrive in 2015 in the event that the optimistic reserve forecasts from USGS were not fulfilled.

We have had several signs that Peak Oil now starts to be on the political agenda of world leaders. On 4-5th February 2005, the G7 Finance Ministers and Central Bank Governors met in London and following statement confirms their new concerns. *We discussed medium-term energy issues and the risks of current oil prices. Market transparency and data integrity is key to the smooth operation of markets. We welcomed concrete actions in improving data provision to oil markets and encouraged further work, including on oil reserves data, by relevant international organisations"* We in ASPO may therefore feel gratified that our work begins to command their attention and support.

Other signs that peak oil starts to have impact is the fact that, the US Department of Energy (DoE) has called for an investigation entitled the *Mitigation of the Peaking of World Oil Production*, and that the IEA on March 7th 2005 organized a workshop for OECD Ministers of Transport, whose main objective was *To identify and review cost-effective actions for reducing transport oil demand.* The report to the DoE states that action must start 20 years before peak oil. We in ASPO know now that the World does not have 20 years, but must act now.

Finally, I draw attention to the Depletion Protocol that will be discussed on this workshop. It offers a framework under which governments may manage the depletion of oil as imposed by Nature in an orderly and systematic fashion, reducing thereby the inevitable tensions that otherwise must accompany a discontinuity of this historic magnitude.

The End of the First Half of the Age of Oil

C.J.Campbell
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Petroleum geologists know that oil and gas were formed but rarely in time and place in the Earth's long geological history, which means that that they are finite resources, subject to depletion.

In brief, oil is derived from algae that proliferated in certain geological and climatic settings. The great bulk of the World's oil comes from two brief epochs of extreme global warming, 90 and 150 million years ago, which coincided with the development of stagnant rifts as the continents moved apart. Gas is derived both from plant remains and from ordinary oils that been overheated on deep burial. Peak generation commenced when the organic material had been buried beneath younger sediments to depths of about 2000m

Once formed in these exceptional conditions, oil and gas migrated upwards through the rocks to zones of lesser pressure. Some was dissipated; some escaped at the surface, leaving behind a heavy tarry residue; and some was trapped in geological structures large enough to become oil and gas fields.

The first step to find oil and gas is to secure the rights to do so. Geologists then examine the area searching for the rare right combination of circumstances. They are aided by geochemistry to determine the effective source rocks and geophysical surveys to map the structures beneath the surface. Petroleum geology has itself made great strides. Prospects of varying degrees of scientific assurance are identified and then tested by an exploratory borehole, known as a *wildcat.* It determines whether or not the prospect is valid, also providing more information with which to evaluate the remaining prospects.
Exploration proceeds in any area until a moment-of-truth is reached either by a discovery or by the realisation that the area lacks the essential geology, in which case it remains forever barren. Normally, the larger fields were found first, being too large to miss.

When a promising discovery is made, responsibility passes from the explorers to the engineers, charged with implementing an efficient scheme of production to maximize profit against investment. Huge investments are at stake offshore and in remote areas, so it makes good sense to work on a cautious step-by-step basis.

There is a polarity about oil, being either there in profitable abundance or not there at all, that distinguishes it from coal and other minerals, where concentration is the key factor.

There are many different categories of oil and gas, each having its own costs, characteristics and depletion profile. Some are cheap, easy and fast to produce, whereas others are the precise opposite.

To avoid confusion, it is useful to identify *Regular Conventional Oil (and Gas)*, and define it to exclude:

- Oil from coal and "shale"
- Bitumen
- Extra-Heavy Oil
- Heavy Oil (10-17.5° API)
- Deepwater Oil and Gas (>500m)
- Polar Oil and Gas
- Natural Gas Liquids from gas plants
- Coalbed methane, "tight gas" etc.

It has contributed most to-date, and will dominate all supply far into the future, determining the peak of all production.

Production has to mirror earlier discovery after a time-lag. Discovery in any field or area comprises the sum of past production and estimated future production of known fields, termed *Reserves*.

The determination of *Reserves* poses no particular scientific challenge, but the reporting of reserves is subject to much confusion. Oil companies generally under-reported to comply with strict Stock Exchange rules. The practice led to a comforting but misleading impression of *Reserve Growth* that has been mistakenly attributed to technological progress and extrapolated into the future. Certain OPEC countries over-reported, as they vied with each other for production quota, based on Reported Reserves. Many countries have failed to update their estimates.

If valid information were in the public domain, the issue of peak production and decline would be entirely self-evident. As it is, the skills of a detective have had to be used to obtain the assessment of *Regular Oil* as follows:

Produced	944 Gb (billion barrels)
Reserves	761
Discovered	1705
Yet-to-Find	145
Yet-to-Produce	906
Total	1850

There are various ways by which to forecast production, but theoretical and empirical evidence indicate that the peak in any country normally comes close to the midpoint of depletion when half the total has been consumed. On this basis, and making allowance for the special circumstances of the Middle East, the global peak of oil production is forecast for 2005/6. Gas depletes differently, being more influenced by infrastructure, but is expected to reach a plateau of 125 Tcf/a (trillion cubic feet a year) from 2025 to 2045.

After peak, oil production declines at 2-3% a year, such that the production of *Regular Oil* is set to decline from 66 Mb/d (million barrels a day) in 2005 to about 45 Mb/d in 2020 and 20 Mb/d by 2020. It is not about to run out.

The evaluation implies that the World reaches the end of the First Half of the Age of Oil, which lasted 150 years. It was an epoch in history that saw the rapid expansion of Industry, Transport, Trade, Agriculture and Financial Capital, made possible by an expanding supply of cheap oil-based energy. The population increased six-fold in parallel.

Of particular importance is the issue of Financial Capital, which is not easily grasped. Banks lent money in excess of what was on deposit and charged interest, creating money out of thin air, but the system worked because confidence in Tomorrow's Expansion provided collateral for To-day's Debt. In addition, world trading currencies, now the US dollar, delivered a hidden flow of new capital to the issuing country. The current high oil prices reflect profiteering from shortage by oil companies and producing governments, as production costs have not changed materially, providing yet more unearned Capital.

The Second Half of the Age of Oil now dawns, and will be marked by the decline of oil and all the depends upon it. This includes Financial Capital as the decline of oil-based energy removes the essential confidence that there will be Expansion Tomorrow to support To-day's Debt, a critical relationship. It spells, in other words, the End of Economics, as presently understood and practiced. That in turn calls for entirely new political structures and policies to replace those based on out-dated economics.

The evidence accordingly suggests that the World faces a discontinuity of unprecedented magnitude, undermining the very fabric of society and economic wellbeing. In short, it faces a Second Great Depression, triggered not by Peak Production itself but by the perception of the long downward slope that follows it.

An economic downturn will be accompanied by a fall in the demand for oil and gas such that prices may collapse, rendering the development of *Non-Conventional Oil* and Renewable Energies uneconomic, compounding the problem.

The primary challenge is to deal with the transition. One simple and straightforward mechanism is for the countries of the world to cut their demand to match world depletion rate. A Depletion Protocol to so achieve needs to be implemented as a matter of urgency

The transition will be a time of great tension and difficult adjustment, with a strong possibility of more resource wars. But as the Century passes, the survivors will come to terms with their new environment. It may herald a new regionalism as world trade declines, and people again come to live within their own resources. It might indeed be a time of happiness giving people a new-found respect for themselves, each other and the environment within which Nature has ordained them to live.

Forecasting Production from Discovery

Jean Laherrere
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Since oil has to be found before it can be produced, production mimics discovery after a time-lapse. The relationship is well illustrated by the example of the US Lower-48, provided backdated *Mean* reserve estimates, as opposed to current *Proved Reserves,* are used. The distinction is important because the term *Proved* is a financial term defined by Stock Exchange rules. We seek the best estimate of what is physically producible, described in technical terms as having a *Mean Probability*.

The first step in forecasting world production is to define what to measure, as there are different categories of oil, including conventional and non-conventional crude oil, synthetic oils, natural gas liquids and processing gains. The second step is to obtain a complete database, with revisions properly backdated to discovery date.

Published data on reserves, as compiled principally by OPEC, the Oil & Gas Journal, World Oil and the BP Statistical Review, are grossly unreliable. Many countries, especially those vying with each other for OPEC quota based on reported reserves, have implausibly failed to revise their estimates for years on end, despite production.

Individual oilfield estimates are confidential in most countries except the United Kingdom, Norway and US federal lands. Such information is available only at great expense from commercial databases from spying (scout) companies, such as IHS or Wood Mackenzie, and is of variable quality. These databases differ greatly between themselves, and there are differing treatments. Some list all discoveries while others report only those worth developing. Unconventional reserves vary largely. The discrepancy between the several scout world present cumulative discoveries is larger than my estimate of undiscovered reserves.

US *Mean* discovery prior to 1990 is contained in a US DoE report giving the oil and gas reserves by year of field discovery, whereas that after 1990 can be found in the MMS field estimates and the US DoE/EIA annual reports. The reserves reported by the Soviet Union were based on the maximum theoretical recovery, and have to be reduced on the basis of field production decline analysis to obtain a *Mean* value.

So-called *Reserve Growth* is another source of confusion. Revisions to *Mean Probability* reserves are statistically neutral, whereas *Proved Reserves* tend to grow over time as they become commercially confirmed for financial purposes. The probability of the US DoE *Proved Reserves* estimates has decreased since 1970 from 75% to 50% now. Negative revisions now exceed positive ones in US offshore areas.

For these reasons, it is a major challenge to select from different technical sources the most reliable input data for study and analysis. I have gathered my own world field inventory of mean values, which differ from other sources, being a synthesis of all.

Once the best available information has been selected, it can be analysed with the help of *Creaming Curves*, which plot cumulative discovery against cumulative *New Field Wildcats,* to estimate the ultimate potential recovery by country and region. Such plots display several hyperbolic cycles.

Future production can be forecast from *Ultimate* values using several bell-curves. In the case of the United States, M.K Hubbert in 1956 showed that, with only one curve, an *Ultimate* of 150 Gb (billion barrels) (his estimate) delivered a peak of production in 1965, whereas an *Ultimate* of 200 Gb (highest estimate from an enquiry) produced one in 1970, which proved to be correct.

Another simpler approach is correlate smoothed annual discovery and production trends after a time-lag, which may vary from 5 to 40 years depending on circumstances. It gives satisfactory results except where production has been artificially constrained by for example OPEC quota or war. A variant of this approach is to compare cumulative discovery with cumulative production.

Studies based on these methods indicate that the World Ultimate Recovery for crude oil is about 2 Tb (trillion barrels), with a further trillion comprising Extra-Heavy oil, Natural Gas Liquid, Synthetic oil and Refinery Gains.

Forecasting Natural Gas production by these methods is less satisfactory as it is more regional in character and subject to local market constraints. But it is clear that supply is set to fall steeply in North America and later in Europe.
Careful study of existing date can provide a useful indication of future production, but more reporting transparency is needed to refine the analysis. Production forecast will improve only when field reserve data is more reliable, in particular in OPEC countries, but it will only occur when quotas are definitively abandoned.

Global Oil Depletion – Methodologies and Results

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I. Introduction

This paper describes methodologies used by a variety of individuals and organisations to predict future world production of oil and gas.

The models fall into three broad groups based on how the authors see future oil production:

Group 1 calculations indicate that global oil production will reach a resource-limited maximum sometime between the years 1996 and 2020, and thereafter decline. Some of these calculations relate to conventional oil only, others to both conventional and non-conventional oil.

Group 2 forecasts terminate in 2020 or 2030, and find that the resource base is sufficient for global oil production to meet anticipated demand to these dates. These 'business-as-usual' forecasts give no indication if a resource-limited peak is subsequently expected.

Group 3 analyses dismiss the possibility of a hydrocarbon resource-limited peak occurring in the near or medium term, and hence see no need to quantitatively assess future oil production.

II. Discussion

The various methodologies are documented in the full paper. Results from the calculations of Groups 1 and 2 are given here in Tables 1 and 2.

Most Group 1 authors assess the oil resource base by adding discovery given by industry data '2P' reserves to an estimated yet-to-find. They then use one of:

- 'mid-point' peaking (e.g., early Hubbert, Petroconsultants '95, or Uppsala/Campbell);
- some other production profile (EnergyFiles);
- field-by-field modelling (Miller, PFC);

to calculate future production.

Alternative powerful techniques are to use a linearised production plot based on the logistic curve (later Hubbert, Deffeyes), or to model production as an approximate mirror of discovery (Ivanhoe, Laherrère).

Group 2 forecasts either assume that large quantities of non-conventional oil will come smoothly on-stream as conventional declines (Shell; maybe Exxon), or have - in my opinion - a very poor knowledge of the resource base (IEA, US DoE, 'WETO' study). In these latter cases reliance is placed on USGS 'total oiliness' data, paying no attention to discovery rate or reserves growth data outside the US.

The 'WETO' model for example assumes a conventional oil resource of 4500 Gb. This should be compared to the global discovered to-date (incl. NGLs) of only 1950 Gb, and the annual discovery rate of about 10 Gb on a declining trend. Authors who propose conventional oil ultimates much above ~2300 Gb (incl. NGLs) must explain the discovery data and anticipated recovery factors that support their estimates.

Group 3 analyses include those by Paul Stevens, Peter Davies, M. Adelman, Michael Lynch, Peter McCabe and Leonardo Maugeri. These analyses rule out the need to examine the oil resource base for a variety of reasons:

- Some assume that higher prices will bring on sufficient new conventional oil to prevent difficulties in supply;
- Others assume high prices will reduce demand, thus bringing supply/demand back into balance;
- Still others consider conventional and non-conventional oil to be economically indistinguishable, and that the non-conventional resource (including shales, and perhaps hydrates) is so large that limits to conventional oil production will have no economic significance.

III. Acknowledgements

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Date	Author	Hydrocarbon	Ultimate Gb	Date of global peak
1972	ESSO	Pr. Cv. oil	2100	"increasingly scarce from ~ 2000."
1972	Report: UN Confr.	Ditto.	2500	"likely peak by 2000."
1974	SPRU, UK	Ditto.	1800-2480	n/a
1976	UK DoE	Ditto.	n/a	"about 2000"
1977	Hubbert	Cv. oil	2000	1996
1977	Ehrlich et al.	Ditto.	1900	2000
1978	WEC / IFP	Pr. Cv. oil	1803	n/a
1979	Shell	Ditto.	n/a	"plateau within the next 25 years."
1979	BP	Ditto.	n/a	Peak (non-communist world): 1985
1981	World Bank	Ditto	1900	"plateau ~ turn of the century."
1995	Petroconsultants, '95.	Cv. oil (xN)	1800	About 2005
1996	Ivanhoe	Cv. oil	~2000	About 2010.
1997	Edwards	Pr. Cv. oil	2836	2020.
1997	Laherrère	All liquids	2700	n/a
1998	IEA: *WEO 1998*	Cv. oil	2300 ref.case	2014
1999	Magoon of the USGS:	Pr. Cv. oil	~2000	Peak ~ 2010.
2000	Bartlett	Ditto.	2000 & 3000	2004 & 2019, respectively.
2002	BGR (Germany)	Cv.&Ncv. oil	Cv.: 2670	Combined peak in 2017.
2003	Deffeyes	Cv. oil*		'Later-Hubbert' method ~2005.
2003	P-R Bauquis	All liquids.	3000	Combined peak in 2020.
2003	U. Uppsala / Campbell	All h'carbons		Combined peak ~2015.
2003	Laherrère	All liquids	3000	n/a
2003	Energyfiles Ltd.	All liquids	Cv: 2338	2011 (if 2% demand growth).
2003	Energyfiles Ltd.	All h'carbons		Combined peak ~ 2020.
2003	Bahktiari model.	Pr. Cv. oil		2006 - 7
2004	Miller, BP- own model	Cv.&Ncv. oil		2025: All poss. OPEC prodn. used.
2004	PFC Energy	Cv.&Ncv. oil		2018 - base case

Table1: Results of some 'Group 1' calculations.

Notes: Table is not complete; one notable omission is the WAES study from the late 70s / early 80s. Pr.: Probably; Cv.: Conventional; xN: ex-NGLs; +N: incl. NGLs; All liquids: Conv. and Non-conv. oil plus NGLs; All h'drocabons: Conv. and Non-conv. oil and gas. * = and probably all-oil.

Date	Author	Hydrocarbon	Ultimate (Gb)	F'cast date of peak (by study end-date)	World prod. Mb/d 2020	2030
1998	WEC/IIASA-A2	Cv. oil		No peak	90	100
2000	IEA: *WEO 2000*	Cv. oil (+N)	3345	No peak	103	-
2001	US DoE EIA	Cv. oil	3303	2016 / 2037	Various	
2002	US DoE	Ditto		No peak	109	-
2002	Shell Scenario	Cv.&Ncv. oil	~4000*	Plateau: 2025 - 2040	100	105
2003	'WETO' study	Ditto	4500**	No peak	102	120
2004	ExxonMobil	Ditto		No peak	114	118

Table 2: Results of some 'Group 2' calculations.

Notes: *Shell's ultimate of 4000 Gb is composed of: ~2300 Gb of conventional oil (incl. NGLs); plus ~600 Gb of 'scope for further recovery' ('SFR') oil; plus 1000 Gb of non-conventional oil. **WETO's ultimate of 4500 Gb is for conventional oil only; it starts with a USGS figure of 2800 Gb, then grown by assuming large and rapid recovery factor gains to 2030.

Emerging Signs of Oil Depletion – Where Reality Meets Theory

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The aim of the analysis is to establish data that shows oil depletion is a real and increasing reality and to determine the likely timing of 'Peak Oil'. It remains a fact that overall production will decline once the overall volume of production coming from countries that have declining production exceeds that from countries where production is still expanding. This point is what is usually referred to as 'Peak Oil'. Even at this point oil will be being discovered and put into production and roughly half the world's producing countries will still be expanding their production.

The approach used relies on the fact that production data, within definitional constraints, is the most reliable and least contestable of all the datasets used to analyse oil depletion. Careful comparison of production data from the BP statistical Review 2004, the latest IEA production data and the production figures printed in the Oil & Gas Journal was made. This showed that in both 2003 (all three sources) and 2004 (only the latter two) the loss of production in countries where production decline is already established were running at 0.9-1.1 million barrels/day in both years. An analysis of the BP Statistical Review data published in the August 2004 edition of Petroleum Review Established that in 2003 around 28% of production was already coming from countries where production decline was clear and sustained. In 2003 some 18 major producers were in decline. In fact nearly 60 oil producing countries are now in decline but the BP Statistics confine themselves to itemising the larger producers. The producers that, in 2003, were in decline were (2003 production in parenthesis): USA (7.45mn b/d); Norway (3.26mn b/d); Venezuela (2.99mn b/d); UK (2.25mn b/d); Indonesia (1.18mn b/d); Oman (0.82mn b/d); Argentina (0.79mn b/d); Egypt (0.75mn b/d); Australia (0.62mn b/d) and Colombia (0.56mn b/d) as well as the smaller producers Gabon, Cameroon, Congo (Brazzaville), Tunisia, Peru, Romania, Yemen and Uzbekistan. Collectively these eighteen countries produced 22.13mn b/d in 2003 or 28.8% of total production. Examination of alternative production data leads to similar conclusions. Exact comparison is not possible because of variations in definitions and countries covered.

The analysis is then progressed by examining the likely way that depletion will progress in the countries where production is in established decline. In the case of the BP Statistical Review data it is found that in 2003 annual decline rates averaged 4.91% but that this concealed a wide decline range from Gabon's 18.64% and Australia's 14.64% to the USA's 2.26% and Egypt's 0.4%. Taking a three year average narrows the range of depletion rates but does not significantly alter the pattern or the countries affected.

The next stage in the analysis was to look at producers that are likely to move into decline in the next few years. There are good reasons for believing that Denmark and probably Malaysia will move into decline in 2005. The expectation is that Mexico and China, both producing well over 3mn b/d, will start to decline in 2005 or 2006. They are likely to be followed in 2006 or 2007 by India. In 2003 these five countries produced 9.2mn b/d.

It should be noted that because the volume being produced by countries in decline is by definition reducing, it is difficult to calculate with precision what percentage of total production would be in decline by a certain date. We can, however, say with some confidence that by 2007/2008 close to 40% of global production will be coming from countries where production is declining.

At this point sustaining production levels will become virtually impossible as the countries that still have expansion potential will have to expand unsustainably fast to offset depletion and meet demand growth. In fact rapid production expansion will accelerate depletion and tip an increasing number of of both Opec and non-Opec producing countries into outright decline. Indications of this are not yet showing up clearly in the production data although countries that have had difficulty expanding production are likely candidates.

It is possible, even likely, that this effect (accelerated depletion leading to decline) could mean that by 2007/2008 rather more than 40% of the world's production will be coming from areas in decline.

In 2003 world oil production growth was 3.66% (BP Statistical Review 2004). However, if the countries in decline are separated from countries still expanding a different picture emerges. The 28% of global production in decline were reducing at an average rate of 4.9% but were more than offset by the 72% of production coming from countries where production was expanding.

In 2003 the 72% were, on average, expanding by 7.5%. As we now know, this was achieved in large measure by a dramatic reduction in the amount of spare capacity around the world. This process of using up spare capacity was effectively completed in 2004 which means that, going forward, virtually all incremental demand will have to be met by new incremental capacity.

If the analogy of a scales or a seesaw is used then in 2003 the tilt was clearly towards expansion. The question at issue is how rapidly does this situation move towards the one where overall production decline -'Peak Oil'- is the likely outcome?

Simple arithmetic shows that if 40% of production is declining at 5%/year then the 60% still expanding production will have to grow by 3.33% just to offset the production lost by the 40% in decline.

If demand growth is 2% the 60% still expanding would have to produced a further increment of 3.33%. Thus to meet an apparently undemanding 2% growth in demand the countries with expansion potential would have to raise their production on average by 6.66%.

If, however, demand growth was running at 4%/year the countries with expansion potential would have to grow at an average of 9.9%.

Examination of the production data shows that only around 12 countries have expanded at these sort of rates in recent years and only about 6 countries have been able to sustain such rates for more than a year or two.

A complimentary analysis is to list all the larger upcoming oil production projects as these provide virtually all of the incremental supply. Analysing these shows that there are large numbers of projects coming starting up in the 2005, 2006 and 2007. However, after 2007 there are very few new projects. There is, however, an average 6-year gap between discovery and first oil in these larger projects. This means that any new projects that are to come into production by 2010/2011 would be known by now.

This approach can be viewed as reasonably reliable because stock exchange disclosure rules and companies need to reassure stockholders means that most companies actively publicise their future production projects. Similarly Opec producers are keen to reassure the world that they have the capacity to continue as reliable suppliers.

We can therefore conclude with some confidence that most projects out to 2011 or even 2012 are known. It is already clear that the future projects production profile confirms the analysis based on production data in showing that after 2008 meeting likely demand will become difficult.

However, any form of crash investment programme would be unlikely to deliver any significant increment in production before 2011/2012. Such programmes would undoubtedly raise development costs as both skilled manpower and field development construction capacity are constrained.

A possible conclusion is that 'Peak Oil' will be in 2008+/- 2 years with further analysis needed to establish the factors that would accelerate or delay it.

The strength of an analysis based on production data and future production projects is that the information and data is less contestable and easier to validate than reserves data but it is one that complements and confirms the view from the more complex reserves based analysis that 'Peak Oil' is just a few years away.

Partex Oil and Gas: A Vision of the World Market and The Role of Gas as The Future of Oil

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2004 witnessed a consistent trend of high oil prices explained by a combination of factors ranging from a strong increase in the world demand, the rapid economic growth of Asian countries specially China and India, the erosion of the spare capacity of OPEC countries and political instability induced by geopolitical factors namely in the Middle East, West Africa and South America. Most of these factors will remain in 2005 and it is unlikely that the oil prices could return in the short-term to the previous lower level.

This paper discusses the consequences of the current price trend for the oil and gas industry on various issues, such as the current level of proven oil and gas reserves, the role of probable and possible reserves which can not be ignored, the high technological intensity of the industry that can drive it to new appealing breakthroughs, the triggering of Research and Development projects on new forms of energy like hydrogen, renewables and nuclear.

In particular an analysis of the current crisis and its roots will be performed highlighting its specific content: it is a crisis induced by the demand not by the supply and, in this context, economic growth will remain the main driver of oil demand. The expansion of oil and gas production and supply capacity will call for an huge amount of investment, much of it in developing countries.

In the recent years, industry investments were more focused on existing assets. Investments in exploration did not deserve enough attention, as it is the case of the Middle East producing countries. A good example of this trend is that the last big field discovered in the world was Kashagan in Kazakhstan in 2000.

In terms of the oil and gas industry, a new approach to this problem is required and the increase in world demand combined with high oil prices opens new opportunities to less conventional projects like the extra-heavy oil of the Orenoco belt in Venezuela and the Tar sands of the Alberta province in Canada. Parallel to that, a more aggressive exploration policy combined with the acceleration of the oil and gas projects in the deep offshore areas of Angola, Niger delta and Brazil, is important to cope with the world demand.

However these investments will take time to produce a consistent output and most of the companies and Governments are reluctant to embark in huge expensive projects when there are still plenty of cheaper opportunities. It is understandable that the Middle East Governments strategy focus on the preservation of their resources, namely the optimization of the oil and gas production and the reservoir management policies. In this context, the openness to foreign investment remains a challenge and a balance is required between Middle East Government interests, world demand and the role of international oil companies.

PARTEX OIL AND GAS has a long tradition in the oil and gas industry since its inception by Calouste Gulbenkian as partner of Iraq Petroleum Company in the first decades of the twentieth century. In this regard PARTEX vision has its roots in a realistic assessment of the Middle East oil and gas reserves which are far away from being depleted. A discussion of their role in the future is a must.

The gas world demand is booming and this trend will continue in the future. In this regard, the LNG market and other possibilities like GTL are options to be pursued by PARTEX.

In parallel the notion of a diversified energy company will be introduced with the need to balance the energy portfolio encompassing the development of other resources with special focus on renewable energies.

Within this framework it is clear that this century will witness a new mix in the energy portfolio with a new equilibrium between oil, gas, hydrogen, coal, nuclear and renewable energies. PARTEX vision is to position itself accordingly through the participation in new business opportunities, creating a balanced and solid portfolio of assets.

The End of Cheap Oil: Structural or Cyclical Change in the Global Oil Market?

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Some twenty five years ago, BP predicted the stagnation of global oil production in the 1980's and an actual production decline by the 1990's. A careful reading of the BP study shows that BP assumed 5.5% growth in oil demand outside of the Centrally Planned Economies (then USSR, Eastern Europe and China). Under those assumptions, global oil production (including the CPE's) would have added up to some 100 million b/d by 1990. Petroleum Finance Corporation, an energy consulting company in Washington, DC , completed a detailed analysis of future global oil production in 2004 and concluded that world oil production (including heavy oil and tar sands from Canada) would probably not exceed 100 million b/d.

The US government issued a report in 1980 which stated that …"the predominant view among geologists is that the chances of discovering enough quickly exploitable oil to offset declines in the known fields are slim. If the Persian Gulf countries and some non-OPEC producers continue to limit production, as we expect, world production of oil probably will begin to decline in the mid 1980's…"

As a result of the high oil prices of the decade of the mid 1970's to the mid 1980's, oil demand collapsed in the OECD and the exclusion from much of the Middle East, forced the IOC's to focus on new discoveries in Alaska, the North Sea and later deep water off Africa and the Gulf of Mexico. Although oil reserve numbers in many oil producing countries are highly suspect, BP statistics show global oil reserves at 569 billion barrels in 1980 and 1148 billion in 2003, while some 550 billion barrels were produced throughout that period.

The development of Alaska, the North Sea, deepwater deposits off West Africa and in the Gulf of Mexico coupled with the experience of low average annual oil consumption growth in the 1990's led to perception in the oil industry that $ 18-$ 20/bbl was the long term equilibrium price of oil because at that price almost all of the world's oil was perceived to be exploitable. As late as the autumn of 2003, Wall Street oil analysts were very bearish about the five year oil price outlook.

Oil market developments in 2004, spearheaded by huge growth in Chinese oil consumption in a year of above average oil demand growth elsewhere in the world, turned the previous consensus view around. When oil prices reached $ 40 and later $ 50 a barrel even the skeptics became aware that the entire oil supply chain, from the upstream to refining, was extremely tight.

By late 2004 there was no usable oil production spare capacity left and deep conversion refining capacity was fully utilized. The forward cover of the NYMEX reflects the current industry view that oil prices are likely to remain high for years to come and an IMF study released in April of this year is even more bullish.

What has changed? On the demand side, the emergence of China (and later India) as a major industrial power, requiring ever larger volumes of oil to fuel its growing economy. On the supply side, the growing realization that non-OPEC oil production outside of the FSU has probably already peaked and that total non-OPEC oil production may peak in the early or middle of the next decade. The realization that from that time onward incremental demand will have to be met from OPEC sources and in particular Middle East OPEC sources, has once again focused global attention what producers can and will be able to produce in the future. Perhaps close to half of OPEC's members may also be faced with reaching peak production capacity by the turn of the decade (some already have) and the data on reserves and production capacity in the public domain are very poor, leaving observers dependent on official sources. What is known is that most of the major oil producing fields in the Middle East are old and while many smaller fields are likely to be discovered in the years and decades ahead, the question remains when the major fields will reach peak capacity.

Aside from the technical issue of peak production, there are socio-economic and political considerations to be taken into account. Almost all oil producing countries in the Middle East are entirely dependent on oil revenue for government revenues and foreign exchange requirements. It would make sense for each one of those countries to plan on a very long (twenty to thirty years) production plateau based on conservative technical data. Conservative, because producing countries run the risk of over-estimating the duration of the technical production plateau. Oman, for example, almost had a policy of increase production only if a ten year plateau can be maintained at the higher production level. The production collapse of its prized Yibal light oil field, resulting in a 20-25 percent production decline over the past few years, was entirely unexpected.

On the political side, Iraq is a good example. Some Think Tanks in Washington DC argued prior to the Iraq invasion that the oil sector in Iraq should be privatized, leading a quick build up of capacity to 5-6 million b/d by the end of this decade. In reality, production capacity two years after the war started is considerable lower than it was prior to the war and the outlook for political stability, needed to create an environment for upstream investment to increase capacity, is very cloudy at best. Iraq is unlikely to achieve anywhere near the oil production capacity in this decade estimated by experts only a few years ago, further reducing the volume of Middle East potentially available to the global oil market.

The timing of oil peaking from both the purely technical and socio-economic/political point of view, is of crucial importance. Those analyzing technical oil peaking, have concluded that global oil peaking (depending on their definition of oil) will occur anywhere between a few years from now (pessimists) and two decades from now (optimists). Global production could peak long before the ultimate technical peak will be reached for reasons described above.

The timing of oil peaking (technical and other) is of great importance. If the pessimists were to prove correct, there is little the oil industry and policy makers will be able to do to mitigate the situation and the consequences for the global economy could be brutal for years to come. If the optimists prove correct, the world will have two decades to make the necessary investments in alternative sources of transportation fuel to enable a less disruptive transition away from complete reliance on conventional oil for the transportation sector.

The paper will discuss the future outlook of the global oil market in the contexts of a rapidly expanding Asian economy and the impact of the timing of oil peaking (dependent in part on the oil demand outlook) on the entire oil supply chain (from upstream to downstream); prospects for a smooth or disruptive transition to alternative sources of transportation fuels; and, the geopolitical consequences of oil peaking. The paper will conclude that the changes in the global oil market since 2004 are structural in nature and that we are unlikely to see a return to the oil price cycles of the 1985-2000 period unless the world were to enter into a major global recession. In contrast to the decade from the late 1970's to the mid 1980's, high oil prices are not likely to lead to a sharp contraction of oil demand (no near term substitution for transportation fuels) nor to a sharp increase in oil production. The author concurs with the view expressed in the 2004 upstream analysis by Petroleum Finance Corporation which concluded that world oil production may not increase much above 100 million b/d.

Redefining Peak Oil

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The technical analyses that Dr. M. King Hubbert and others who endorse this key discipline have been anchored by an analysis of the ultimate recoverable reserves an oilfield, basin, country or the world has, and the extent to which these reserves have already been produced. Once the 50% mark nears, Peaking is also just ahead.

Given a host technological advances and the quality of the data the world now has on reserves, the use of this theory might have accidentally become misleading and even obsolete. The loudest critics of Peak Oil analysis have constantly made this claim.

I am beginning to also support this thesis, but from an entirely different perspective. Rather than postponing or obsoleting Peak Oil as an event, modern oilfield technology and **very poor data** on both the quality and quantity of reserves may have totally masked the conventional predictability of when Peak Oil will occur. If my thesis is correct, rather than postponing the event, it makes it harder to predict and probably creates a more rapid decline once Peaking has occurred.

The great sweep of modern oilfield technology received almost as much hype about changing energy supply as the Dot.Com boom did to the stock market. Too many energy executives and energy analysts began to believe that these new tools made Peak Oil obsolete as an event, or at least postponed when the event would happen for decades. In reality, the opposite occurred. Rather than recovering vastly greater amounts of oil in place, multi-lateral horizontal well completions created super-straws to extract a higher portion of the post 50% recoverable reserves far faster.

The widespread use of 3 and 4-D seismic analysis and reservoir simulations as a substitute for the far more costly process of drilling a multiple number of appraisal wells that were cored and flow-tested to really understand the true nature of reservoirs then created a decade-long illusion that proven reserves were far greater than the steadily lower production growth most oil companies were reporting.

OPEC's reported proven reserves almost tripled in the 1980s, not as a result of technology or added discoveries but through simply "changing the numbers." Then, ironically, as OPEC oil production
grew for the past 15 to 20 years, virtually no OPEC producer ever reported a decline in proven reserves. Magically, the reported proven reserves stayed constant.

Another issue that should have anchored the whole Peak Oil analysis also got lost. The question of Peak Oil is not about the single highest amount of oil a well or reservoir can produce in a single day or even year. Defining the arrival of Peak Oil should have addressed the peak rate of production that a reservoir could safely sustain for a decade or more.

All pressurized reservoirs have a rate sensitivity to the amount of oil that can be produced by the miracle of natural reservoir pressures instead of a pump. As the practice of water and gas injection into pressurized fields to maintain high reservoir pressures for longer times grew, this created an artificial sense that rate sensitivity or what some called "conservation of oil" faded away.

I have now come to the conclusion that global oil production has passed sustainable peak output if properly defined. The world has created an illusion that Peak Oil is years away, when we might have already passed the real peak.

Saudi Arabia – Can It Deliver?

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I. Introduction

Increasingly, the world is looking to OPEC and specifically to Saudi Arabia to increase oil exports to cool soaring oil prices and to foster continued growth in global economies. With perhaps as much as a quarter of the World's remaining conventional oil reserves, can Saudi Arabia provide the additional oil production?

II. Political Will and Economic Incentive ?

In the late 1970s during the final stages of the nationalization of the Arabian American Oil Company (ARAMCO), plans were in place to increase Saudi Arabia's daily oil production capacity from 10 million barrels to 16 million barrels. The oil minister at the time, Sheik Yamani, disagreed, stressing that "we are going to need oil for future generations of Saudis". Since that time nearly 30 years ago, the capacity of Saudi Arabia has remained about 10 million barrels of oil a day.

It is presumptuous of the rest of the World to assume that Saudi Arabia will produce additional oil to meet its needs. To do so must also meet the needs of the Saudi people and its government. It is a complex issue. For example, Saudi dollar-based oil revenues have increased more than 50% in the last 12 months without substantially increasing production. Why increase production to lower prices and realize the same or perhaps lower revenue? What is the incentive for Saudi Arabia?

III. Access to Technical People ?

From the earlier days up through the 1980s, life for a Western or Asian expatriate oil field engineer and his family was small town-like and safer than most major cities in the United States, Europe and Asia. The same cannot be said today. In the post-9/11, post-Iraq war world, there continues to be a volatile, and some times violent, climate for non-Arabs and non-Muslims within Saudi Arabia.

The willingness for people to live and work in the country is directly related to their security. Attracting these people is extremely important for the future operations of ARAMCO. The "easy oil" in Saudi Arabia has already been developed in a few super giant fields. Now, these same world-class oil fields are reaching "middle-age" when the second half of their reserves demand much more work to mitigate natural decline and the onset of increasing water production. Any expansion in production will come from a host of smaller fields scattered among the oil province. Additional drilling, facilities and transport infrastructure—and people—will be required for all these new developments.

IV. Publicly Quoted Oil Reserves and Production Potential—How Valid ?

Unlike energy companies publicly traded on financial stock exchanges, ARAMCO does not conform to the rigors of SEC guidelines, for example, for oil and gas reserve reporting. Nor does ARAMCO submit its reserve estimates to the analyses of independent third party auditors.

In an extraordinary meeting hosted by CSIS in Washington D.C. last year, executives from ARAMCO rebutted concerns voiced by Matt Simmons, a leading world energy economist, regarding the sustained viability of Saudi's oil reserves.

While Messrs. Baqi and Saleri painted a "conservative" picture of ARAMCO's oil reserves, let's assume the role of devil's advocate to question whether or not estimates portrayed are indeed conservative.

A. Discovered OIIP of 700 Gb

ARAMCO reports an oil initially in place (OIIP) value of 700 billion barrels (Gb) for all discovered fields. From 1982 to 2003, the OIIP uniformly increased at about 5 Gb/year from about 580 Gb to 700 Gb. During this same 20-year period, only 11 Gb of new reserves were reported by the industry. Assuming a 50% recovery factor, the new reserves represent 22 Gb of OIIP versus the 120 Gb increase reported. Why the discrepancy? If the additional OIIP does not come from new discoveries, then it could come from re-evaluation of existing discoveries. Applying recovery factors of 50% to 60% to reserves reported to industry yields a reasonable OIIP close to 600 Gb.

Of the nearly 100 oil field discoveries reported to industry, only 17 have been produced and only perhaps eight have oil production in excess of 1 Gb. But, the 17 fields (most of the giants and super giants) that have been produced have a total OIIP of about 500 Gb. Given that the OIIP of an active field is typically known early in its life, most of the OIIP growth must have come from the undeveloped fields. Is this plausible? Has ARAMCO been actively evaluating undeveloped fields?

Or is ARAMCO under pressure like the rest of the industry to demonstrate reserve replacement?

B. Recovery Factors of 60% to 75% OIIP

Giants and Super Giants the major fields of Saudi Arabia may be; but there are many fields in the world that have the same or better reservoir quality. Recovery factors of 50% are reasonable for these reservoirs. Higher recoveries are possible and typically require many, many pore volumes of water throughput injected. In other words, many years of high water production after the onset of decline are required to achieve recovery factors approaching 60%. While the Ain Dar/Shedgum area has the best reservoir properties of Ghawar, it is unrealistic to assume an ultimate recovery factor of 75%.

C. Proved Reserves of 260 Gb

ARAMCO reports that its remaining proved reserves are 260 Gb, and that proved reserves are 28% depleted. Dividing the estimated cumulative oil production total of 100 Gb by 28% yields total proved reserves of 357 Gb which is consistent with the historical production and remaining reserves.

However, if one assumes a conservative OIIP of 600 Gb and a 50% recovery factor, total proved reserves are 300 Gb. Subtracting the 100 Gb of historical production gives a remaining proved reserve estimate 200 Gb, 60 Gb or 23% less ARAMCO’s estimate. This difference is equivalent to 16 year’s production at 10 million barrels a day.

D. Undiscovered OIIP of 200 Gb

ARAMCO predicts 200 Gb OIIP for new discoveries in the next 20 years. Assuming a 50% recovery factor, gives an undiscovered reserve estimate of 100 Gb. This is equivalent to all the reserves reported for Saudi Arabia since the late 1950s. ASPO estimates undiscovered oil potential of 15 Gb which is equivalent to all reported reserves since 1979.

E. Production Capacity Beyond 10 Million bbls/day

ARAMCO has stated their long-term potential for 12 million barrels a day and perhaps 15 million barrels a day. While these production levels are technically possible, they may fall short of the suggested 50-year horizon based on the conservative analyses of this paper.

Will another 5 million barrels of oil a day ten years from now have any impact on today’s rocketing oil prices? Production of oil and natural gas liquids is estimated at 82 million barrels a day (30 Gb/year) for 2004. Production demand is forecast to increase 2 million barrels a day in 2005 with production from existing fields declining at 5% or 4 million barrels a day. This means demand from new field production is 6 million barrels a day. Declining discoveries the last 10 years have averaged 12 Gb/year. Assuming an optimistic plateau rate of 10% of reserves per year equates to 1.2 Gb/yr or 3.3 million barrels per day. This still falls short of demand by 2.7 million barrels per day. With a declining oil discovery trend and an increasing demand trend, this running deficit of 27 million barrels a day ten years from now suggests a 5 million barrel a day increment from Saudi Arabia must be joined by similar, earlier production increases from several oil exporting countries to have any impact on slowing oil prices.

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Iran And Iraq: Oil Reserves, Production Capacities and Future Output.

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INTRODUCTION

A 'horseshoe' covering some 900,000 square kilometres around the Persian Gulf is the *locus* of all of the Middle East's supergiant oil fields andaccounts for over 95% of regional oil reserves including those of Iran and Iraq.

Historically, oil was first discovered in the Middle East at Masjid-i Sulayman in Iran (by George Bernard Reynolds in 1908), to be followed in 1927 by the strike at Kirkuk in Iraq (due to the stubborn efforts of the legendary Calouste Gulbenkian).

Both Iraq and Iran were among the five founding members of OPEC at Baghdad in 1960, but they always remained the most adamant of regional rivals going on to fight an eight-year war (1980-1988).

OIL RESERVES

At present, the question of oil reserves estimates has risen to the top of the industry's agenda and even been the subject of headlines (eg, Shell).

Reserves estimates for both Iran and Iraq vary along a wide spectrum. The current Iranian range covers from 30 to 130 billion barrels (bnb); and the Iraqi range goes from 80 to 220 bnb (with a major question mark hanging over its Western Desert).

Dr. Campbell's published reserves still do provide the best estimates available and therefore they have been adopted here.

CUMULATIVE PRODUCTION

Iraq has one of the lowest ratio of cumulative production to proven reserves amongst all of OPEC members --- having only produced some 29 bnb so far.

In stark contrast, Iran has one of the highest ratios with an overall output double that of Iraq with some 58 bnb.

Consequently, on this criterion alone, Iraq seems better placed for playing a much larger role in the future of the international oil industry.

PRESENT CAPACITY

Notwithstanding its current security problems, Iraq has been able to more or less maintain its production capacity at 2.2 mb/d in 2004. It now has earmarked some $ 3bn capex for expanding its capacity to around 3.0 mb/d by the close of 2005.

On the other hand, the Islamic Republic of Iran (IRI) officially places its present capacity at 4.0 mb/d, but many experts believe it to be markedly below that. Any prediction of higher capacity in the future should be discarded out of hand.

FUTURE PRODUCTION

In the near future, Iranian oil production can only go on declining (at a yearly rate of 5%-6%). Only fresh output from the two new oil fields 'Azadegan' and 'Yadavaran' could come to dampen the fall --- but even these fields will not be as prolific as officially announced.

As for Iraqi, its oil output can only go on rising stepwise --- with the incremental rate depending directly on domestic security developments and consequent oil industry project implementations.

GEOPOLITICS

However, geopolitics could still come and upset all regional plans and programmes --- as current or future conflicts bring about momentous changes in existing equations.

In these critical times of imminent 'Peak Oil', everything seems possible in the turbulent and oil-rich Middle East region --- especially as it comes to focus the energies of the 'powers that be' like never before.

CONCLUSION

Both Iran and Iraq are major pillars of the international oil industry. And both stand to playa major role after the inevitable and imminent peaking of global oil production. Intrinsically, Iraq's future oil prospects are far superior to Iran's --- if only domestic security would allow it to develop its full potential, especially bringing its eleven fresh fields to fruition, not to mention stepping up exploration in its Western Desert. As for Iran, it would be well advised to cater to its four old supergiant fields and accelerate exploration in order to be able to partly compensate for its dwindling oil output.

Exploring the Basins of the Arctic

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DISCOVERED PETROLEUM RESOURCES

Exploration for oil and gas has been taking place in the Arctic since the early parts of the last century. Several thousand wells have been drilled, but still the area remains one of the least explored on the planet - with some of the largest remaining resources. Most databases agree that less than 5 % of the world's discovered volumes to date are within the Arctic, adding up to 150 BBOE. About 1/5 of these volumes are produced. Today, production takes place from the North Slope of Alaska, the Sverdrup Basin and the Timan Pechora. All of this production is onshore or from very shallow waters. When the Statoil operated Snøhvit Field comes into production in 2006, as the first in the Barents Sea, it will thus be the first truly offshore production in the Arctic. The Prirazlomnoye oil discovery in the Russian Pechora Sea is also scheduled to commence production in 2006/2007, and will be the first offshore oil field. Further development of production in the Arctic is dependent on decisions on infrastructure, including plans for the giant Shtockmanovskoye gas-field in the Russian Barents Sea and the gas discoveries in Arctic Canada.

UNDISCOVERED PETROLEUM RESOURCES

Statoil has over the last few years assessed most of the basins of the Arctic. The amount of geoscientific data available for each basin varies greatly though, and play-analysis methods applicable to proven basins cannot be used in many of the Arctic basins. In some basins, lack of seismic and outcrop-data makes it challenging to even know which petroleum systems are working - far less attempt to quantify the possible resources in traps and structures. New methods are required, and Yet-to-Find (YTF) resource estimates in the Arctic are currently at best speculative. Statoil agrees with the USGS estimate that some 25% of the world's remaining YTF resources are located in the Arctic, though we have different absolute numbers. Approximately half of the YTF resources will be offshore. A large proportion of the future Arctic resources are located in Russia, but considerable volumes are also thought to be present in Norway, Greenland, Arctic Canada and Alaska.

FUTURE EXPLORATION

The challenges to explorers in the Arctic are numerous:

- Vulnerable habitats - protection needed for flora, fauna, culture and landscape.
- New technology needed for most operations and a considerable risk concerning cost is attached.
- High cost levels require very large discoveries to break thresholds for infrastructure development
- Harsh tundra environment onshore with deep permafrost.
- Offshore basins covered or affected by sea-ice year round.
- Prolific basins with more benign access have been able to satisfy global markets so far

The Arctic will only become a true exploration ground when the latter issue starts to change.

Areas permanently covered by sea-ice are not likely to be explored for many years. Monitoring the annual movement and thickness of the ice and prognoses for yearly retreat or advance will become increasingly important in the future. Fluctuations in sea-ice thickness and extent are dependent on air-/seawater temperature and oceanic currents. The importance of close relationship with academic institutions and cooperation on geology, oceanography and environmental research, cannot be underestimated. Cooperation across international borders is essential.

Polar projection of the basins included in Statoil's Arctic Assessment

How Much Oil and Gas from Deepwater? The Experience of Brazil

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I. FROM ONSHORE TO DEEP WATER EXPLORATION

The first petroleum discovery in Brazil dates from 1939, when a small oil accumulation was found in Lobato, nearby Salvador City, northeastern Brazil. This finding represented the beginning of a phase of oil exploration and production (1939-1967) mostly focused on the onshore basins from northern- and northeastern Brazil. Oil fields that individually contain original reserves over 400 million bbl were found during this phase, but the Brazilian oil production and oil reserves never exceeded 200,000 bopd and 1,2 billion bbl, respectively.

Offshore oil exploration started in 1968, when a first (dry) well was drilled in the Espírito Santo Basin (southeastern Brazil), followed by a well drilled in the Sergipe Basin (northeastern Brazil), which found Guaricema, the first Brazilian offshore oil field.

The first oil discovery in the very prolific Campos Basin (offshore southeastern Brazil) dates from 1974, when the ninth well drilled found Albian carbonate reservoirs (Garoupa Field) under a water depth of 120 m. This first finding in the Campos Basin was extremely important for a country with an oil consumption of 500,000 bopd and a production of only 170,000 bopd. Oil production from the Campos Basin started in 1977, from the Enchova Field, which produced to a semi submersible platform moored at a water depth of 124 m. This was the beginning of a successful history that led Petrobras to become a world leader company in petroleum exploration and production in deep (300 – 1,500 m) and ultra-deep (>1,500 m) waters. Forty-four oilfields were found in the Campos Basin, between 50 and 140 km off the Brazilian coast (under water depths between 80 and 2,400 m), which produce from a variety of reservoirs, including Neocomian fractured basalts, Barremian coquinas, early Albian calcarenites, and (mostly) late Albian to early Miocene siliciclastic turbidites.

Deep and ultra-deep water giant fields started to be discovered only in 1984. There was a succession of large discoveries, including Albacora, Marlim, Albacora Leste, Marlim Sul, Barracuda, Caratinga, Roncador and, more recently, Jubarte and Cachalote. Turbidites are, by far, the most important petroleum reservoirs in the Campos Basin. They comprise reservoirs in 40 oilfields, including Marlim, Marlim Sul, and Roncador fields, with original oil reserves of 2.7, 2.5, and 2.3 billion bbl, respectively.

II. TECHNOLOGICAL CHALLENGES FOR RESERVOIR CHARACTERIZATION AND MANAGEMENT IN DEEP WATERS

The development of deep and ultra-deep water fields has continuously provided new challenges for reservoir characterization and management. These fields are developed with fewer, horizontal and high angle wells, drilled into poorly consolidated reservoirs. The extensive use of 3D seismic as a reservoir characterization tool has optimized well location and allowed the reduction of geological risks. Integration of high-resolution stratigraphic analysis with 3D seismic inversion, geostatistic (stochastic) simulation of reservoir properties constrained by seismic, well log and core data, 3D visualization, and voxel-based automatic interpretation has guided the positioning of long (>1,000 m) horizontal wells through thin (<10-15 m) reservoirs. Additionally, 3D visualization techniques have provided a new environment for teamwork, where seismic, well log, and core data are interpreted and added to detailed 3D geological models and, subsequently, to robust reservoir simulation models.

The deepwater subsea wells must be designed to allow high production rates (typically >10,000-15,000 bopd), with lifetime completions to avoid costly interventions. In order to assure high productivity, pressure maintenance must be efficient; if water injection is planned, the hydraulic connectivity between injector and producer wells must be guaranteed by high-quality 3D seismic, well log correlation, and observed pressure profiles. Detailed studies have been made in order to define the distribution and number of wells, since the number of wells strongly affects the net present value of deepwater projects. Wells with expected oil recovery of less than 10-15 million bbl are not drilled in the beginning of the projects, and remain as future opportunities to increase oil production and recovery.

About 16 billion bbl of heavy (13-17°API) and high viscosity (20-400 cp at the reservoir conditions) oil have been found in the deep and ultra-deep waters from the eastern Brazilian continental margin. The economic oil production from these accumulations relies on a group of new production technologies including mainly: (1) long horizontal or multilateral wells (producing with high power electric submersible pumps, hydraulic pumps or submarine multiphase pumps) to compensate the decrease in productivity caused by the high oil viscosity), (2) efficient heat management systems, and (3) compact oil-water separation systems. In October 2002 was created the Petrobras Offshore Heavy Oil Program (PROPES), who is responsible for the development of new technologies to optimize the development of the large volumes of heavy oil discovered in offshore Brazil.

Some of the new technologies devised for the characterization and development of deepwater oilfields include reservoir imaging with pre-stack, depth-migrated seismic, 4D seismic, real-time well steering and updating of geological/reservoir models, extended reach wells, selective completion in gravel-packed wells, isolation inside horizontal, gravel-packed wells, intelligent completion, subsea oil-water separation, re-injection of produced water, scale prevention and treatment, and improved recovery techniques for heavy and/or viscous oil.

III. ASSURING INCREASING PETROLEUM PRODUCTION AND RESERVES

Deep and ultra-deep water fields are responsible for about 70% of the current Brazilian oil production of 1.7 million bopd, which should grow to 2.3 million bopd by the year 2010. Meanwhile, the Brazilian self-sufficiency in oil should be achieved in 2006.

Despite a total cumulative production of 9.1 billion boe, the Brazilian proven reserves have continuously grown since the first oil discovery in the country, reaching 13.0 billion boe in 2004 (84% oil / 16% gas; 80% in deep- and ultra-deep waters). Also in 2004, the reserves/production ratio reached 21.7 years. In the last 3 years, despite the production of 1.8 billion boe, Petrobras proven reserves have increased by 3.4 billion boe (a growth of 35%). Petrobras strategic plan forecasts that this trend of growing proven reserves will persist for at least the next 5 years, reaching 17.3 billion boe in 2010.

Large deep and ultra-deep water petroleum discoveries recently made outside the very prolific Campos Basin (including light oil in the Sergipe and Espírito Santo basins, and gas in the Santos Basin), make very difficult to forecast when the petroleum production and reserves will reach their peak in Brazil.

In order to assure the historical trend of increasing petroleum production and reserves in Brazil, Petrobras intends to keep (1) strengthening expertise in deep and ultra-deep waters, (2) producing oil and gas from onshore and shallow-water fields with the focus on profitable opportunities, (3) implementing practices and new technologies in areas with high exploitation degree in order to optimize recovery factor, and (4) developing exploratory efforts in new frontiers in order to guarantee a sustainable reserves/production ratio.

Canadian Oil Sands: Development and Future Outlook

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I. UNCONVENTIONAL OIL SUPPLIES

The worldwide global demand for oil has grown by 150% since 1965 and 20% in the past 20 years to the current 80 million barrels per day, and is projected to grow by 50% more in the next 20 years [1]. The growth in global demand for oil comes at a time when the supply from relatively cheap conventional sources is declining, and reserves are not being replaced with new discoveries [2]. However, the world has over twice as much supply of heavy oil and bitumen than it does conventional oil. Not including hydrocarbons in oil shale, it is estimated that there are 8-9 trillion barrels of heavy oil and bitumen in place worldwide, of which potentially 900 billion barrels of oil are commercially exploitable with today's technology [3].

Canada alone has, by some estimates, 175 billion barrels of bitumen reserves that can be processed with today's technology, making it second only to Saudi Arabia in proven oil reserves in the world [4]. This figure remains controversial; a more cautious estimate has been of the order of 17 billion barrels as recoverable [5]. Regardless of the 'true' number, it is most important to assess what impact unconventional oil will have on the world oil supply and in what time frame, given the financial, economic, environmental, engineering and technological constraints. In this regard, the Western Canadian Sedimentary Basin, with its declining conventional oil and gas resources and its replacement requiring large investments in higher-risk but vast oil sands resources, provides a vital case study.

II. "TECHNOLOGY OIL"

It is important to consider that the definition of "conventional oil" is not constant. As has been pointed out by Jaccard [6], offshore oil was not considered conventional 40 years ago, and technological development shifts using enhanced recovery techniques, including thermal production, have moved unconventional sources to the conventional category. For example, in the Faja del Orinoco of Venezuela, 10^0API crude can be produced at economically attractive rates using long horizontal well technology, because of the high native reservoir temperatures (60 – 80^0C). In Canada, progressive cavity pumps have made it possible for Cold Production Technology (co-production of oil and sand with foamy oil drive) to produce heavy oil at 10 times higher rates than is possible by conventional means. In California, thermal heavy-oil projects are already mature, having been produced since the 1960's; oil production peaked in 1986 at 480,000 and declined to the current 340,000 barrels per day [7].

While the Canadian oil sands industry should still be considered "unconventional", the past 20 years have witnessed several major successes, all triggered by technological innovations [8]. The Athabasca is the single largest oil sands deposit, occurring from the surface to a depth of 750 m. In surface mining applications at depth of up to 100 m, new technologies include truck and shovel mining, cold-water extraction, slurry pipelining, mechanical separation and the potential recovery of by-products. In *in situ* operations in the Athabasca, Cold Lake, Peace River and Lloydminister deposits, commercial operations have emerged using cyclic steam stimulation, cold production, and steam assisted gravity drainage (SAGD). VAPEX, the solvent analogue to SAGD, is in the piloting phase. Significant advances have also been made in 'enabling' technologies such as horizontal well drilling, multilateral well technology, instrumentation, automation and telemetry, 3-D and 4-D seismic, pumping systems for sand and fluids, and reservoir simulation and prediction techniques.

These breakthroughs have been the culmination of aggressive public and private investments in research and development and field trials, and have led to a heavy oil and oil sands industry on the verge of a major growth period.

The current production of bitumen and synthetic crude oil from the Canadian Province of Alberta averages 1 million barrels a day and, by 2005, oil sands production is expected to represent 50% of Canada's total crude oil output, and 10% of North American production [9]. Given existing and announced investments (over $50 billion U.S.) as well as projects under development, production is expected to triple to 3 million barrels per day by 2020.

III. CONSTRAINTS ON OIL SANDS GROWTH

The oil sands and heavy oil industry in Canada is facing severe constraints that, without new technology, could jeopardize the above growth scenario [10].

There is an increasing cost for natural gas, currently the fuel of choice for steam generation, upgrading, heat, and power. This comes at a time when natural gas supplies have reached their peak and are expected to decline. Currently oil sands operations consume 5% of Canada's natural gas supply. With growth in production and without fuel substitution, it is expected that oil sands operation will be using approximately 1 billion cubic feet of gas per day, or the major part of the Arctic gas expected to come to market over the next 10 years.

There is a significant dependence on water used for separation of oil from the sand in surface mined operations and for *in situ* steam generation. To produce a barrel of bitumen or synthetic oil requires some 10 barrels of water for mining operations and 3 barrels of water for *in situ* operations. Although most of the water is recycled, there is still about 20% of potable make-up water that is required, and this creates concerns over the need for conservation and sustainability.

The amount of energy required to produce a barrel of synthetic crude oil is about a third of the energy in a barrel of bitumen. This makes oil sands operations large single source emitters of greenhouse gases. The need to reduce CO_2 emissions, as concern about climate change grows and reduction targets come into effect; add considerable additional risks to oil sands investments.

The investment costs and time to bring typical oil sands projects into production is also a major risk. Typical mining, extraction and upgrading projects require about $3 billion U.S. investment to produce 100,000 barrels/day of high quality refinery ready synthetic crude oil. The operating cost is typically $10 U.S. per barrel. The time to bring mining projects into production is approximately six years, including engineering feasibility, regulatory approval, equipment purchases, construction and start up. *In situ* operations have the advantage that they can be designed to come on stream in modular fashion; however, the per barrel supply costs are similar to that of surface mined operations.

As production of upgraded oil increases, there is a strong potential for market limitations for exported synthetic crude oil. This is because of the high aromatic content of the synthetic crude oil produced from bitumen, and U.S. refineries are currently not designed to mix more than 10 to 15% into their conventional crude supply to meet end product quality specification.

Despite these challenges, several factors have made investments in oil sands very attractive given world oil prices above about $25 U.S. per barrel WTI. There are no "finding costs" since the oil sands are well delineated. There is ready access to the largest market in the world, the U.S., via established pipelines. New technology has reduced operating costs by at least a factor of two.

IV TECHNOLOGY INTEGRATION – THE KEY TO THE FUTURE

While non-conventional oil is emerging as a new major source of oil, even an aggressive worldwide development scenario can only capture some 10 – 15% of the required new oil supply in the next 20 years. In addition, non-conventional oil by itself cannot make up for the decline in world conventional oil production. Thus, there is a growing recognition that solutions to the pressing global energy needs and the challenges described above emerge when we understand the energy industry as one interconnected system, integrated horizontally along the various energy sources and vertically along the value chain [11].

This integrated energy approach resists the temptation to argue for any one type of solution and assumes that no one single source of energy will be sufficient to meet world demand. Canada, being well endowed with primary energy sources, has one of the largest supplies of hydrocarbons in the world. The country is currently the 5th largest energy producer in the world (considering hydroelectric and nuclear along with fossil fuel production) and is a net exporter of energy. Most of the energy consumed in Canada comes from fossil fuels (oil: 32%, gas: 24% and coal: 13%). Canada also has huge coal resources.

A good example, of technology integration in the oil sands is the Opti-Nexen Long Lake project, which represents the future of Canadian oil sands expansion. This project uses SAGD technology to produce the bitumen, with the interesting feature that no natural gas is consumed to supply the high energy demand for steam injection and upgrading. Instead, the bitumen is deasphalted and the bottoms gasified to produce hydrogen for upgrading the deasphalted crude, steam for SAGD production, along with power and heat sufficient for all operations.

V. THE ENERGY INNOVATION NETWORK

To address the challenges of ensuring an abundant supply of environmentally responsible energy, a process is well underway in Canada to construct a network organization and facilitate a long-term (20- to 25-year) effort to implement an integrated energy innovation strategy.

This collaborative initiative (known as EnergyINet) is being built on the premise that strategic investment in a balanced portfolio of energy innovation – with a focus on common technology platforms and points of leverage across the portfolio – has the greatest potential for returns in economic, environmental, and social terms.

Given the rich diversity of resources available in Canada and in other parts of the world, and the need to maintain a competitive energy supply while ensuring environmental protection, the best investment strategy appears to be at the forefront of shifts in energy systems:

- From a reliance on conventional oil and gas recovery, to emerging unconventional sources such as oil sands and coal bed methane
- From conventional coal burning to near-emission-free clean coal technology
- From a relatively low to a much higher proportion of renewable and hydrogen energy options in the mix of energy production
- From a focus on separate energy sources to an integrated energy system.

The transformative strategy that is being implemented through EnergyINet speaks to an important scenario for the world's future energy economy. The goal is to highlight the innovation needed together with government policies and actions to stimulate such a transition and establish scenarios to inform priority areas for technology development.

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Past Peak Oil: The Alternatives

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In this presentation a brief review of possible energy alternatives will be presented. However the energy question is not reduced to the announced depletion of fossil fuels. It is also linked to the need to take into consideration climatic changes and other severe impacts associated with fossil fuels consumption.

At the outset there is the temptation to say that if oil and gas are soon gone, there will be no more greenhouse effect to worry about. But this is not so, since a very likely substitute for many years to come is coal, transformed and used in many ways. This enhanced use of coal is inevitable and must be done in the cleanest way possible.

Certainly energy efficiency and Renewable Energies (all forms) are also to be used, since they are benign from an environmental point of view and quite capable of a significant contribution. In particular the developing nations, today with 4/5 of the World population and consuming only 1/3 of the accounted energy, without fossil fuels of their own, without infra structures for energy distribution (roads, pipe-lines, electricity grid) and money to build them from scratch , have a lot to gain if they invest seriously on Renewables, already distributed and abundant . I.e. they should be encouraged not to follow our expensive and dirty fossil fuel path and jump right away into the future. Somehow that is already happening with telephones, with mobile and mobile networks growing everywhere, bypassing the development of the cumbersome and expensive traditional telephone grids.

New energy vectors will emerge, like hydrogen, or electricity for vehicles obtained and stored by other means. However we need to produce these new vectors in a sustainable and clean way as well. Otherwise there is no advantage.

Nuclear energy is a controversial issue, but will certainly be called upon to play a role in the future, in particular if we find a truly safe way to deal with U238 (more than hundred times as abundant as U235, a real finite resource in a short time scale, if nuclear is to be used extensively). We also need a really safe and a sure way to deal with the problem of nuclear wastes, in particular of U238 power stations. Nuclear fusion is always a hope for the future and should be kept in mind.

However it will be argued that beyond the new mix of technologies, we need to deal with the energy matter in a different way and from the demand side, i.e. the point of view of the consumer or of the service it provides.

Ultimately energy is no more than a mean to an end. From a consumer point of view the end that really matters is quality of life, comfort associated with convenience.

In a World running out of fossil fuels it is time to snap out of the prevailing attitude (supply side driven) that leads us into dealing with energy as if it is just a product like any other, promoted for ever growing consumption. Certainly this approach is not sustainable.

The solution will push us beyond energy efficiency, into the realm of avoided consumption, perhaps requiring from the start a whole set of new values, compatible with the best management of what we now know will soon be exhausted, while learning to live with energy forms and energy vectors which are better suited to the new attitude that must be adopted.

Ultimately this change of attitude is a cultural change. It takes time. Thus the sooner we start the better.

Future Fuels for Commercial Vehicles

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AT A VITAL CROSSROADS

The consumption of energy is increasing all over the world. At the same time, the available resources are declining. There will eventually be a shortage of some of the types of energy we use. At the same time, these energy sources are making a significant contribution to the increase in global warming. Joint intervention and activity on the part of everyone involved is needed to solve these problems.

Most stakeholders – vehicle manufacturers, fuel producers, politicians and researchers – agree about the problems. Our current use of fossil energy types is not sustainable in the longer term. In overall terms, almost three billion tonnes of crude oil are consumed every year and 60% of it is used by the transport sector. Most people also agree that time is a critical factor. The measures that are being suggested differ, however.

The time has therefore come for us to join forces and produce a picture and a vision of the possible routes and the action we should take. Transforming an energy system comprising vehicles, fuel and infrastructures takes a long time and requires extensive resources from everyone involved – from producers to consumers.

There is no question that the need to transport food, people and goods is going to increase. For many years now, Volvo has been working to find the best solutions for the future. Our starting point is that every decision and action should be based on scientific data and have a holistic perspective that includes all energy-using sectors. This provides a platform for sustainable long-term decisions.

POWERFUL DRIVING FORCES

There are three principal factors that drive the need for alternative fuels.

- The increase in global warming to which the burning of oil is a contributory factor.
- Our enormous dependence on fossil fuels. Some 97% of all the energy that is used for transport comes from crude oil.
- Crude oil is a finite resource and its availability is steadily declining.

The global need for energy is increasing by more than two per cent a year. This represents almost a doubling of energy consumption over a period of 30 years. Of the total volume of energy, around 80 per cent comes from fossil energy, such as coal, oil and natural gas.

Most researchers generally agree that human activities have increased global warming. An increase of a few degrees in the worldwide mean temperature threatens water resources, raises the level of the sea, affects vegetation and precipitation, increases the spread of tropical diseases and changes the conditions for agriculture.

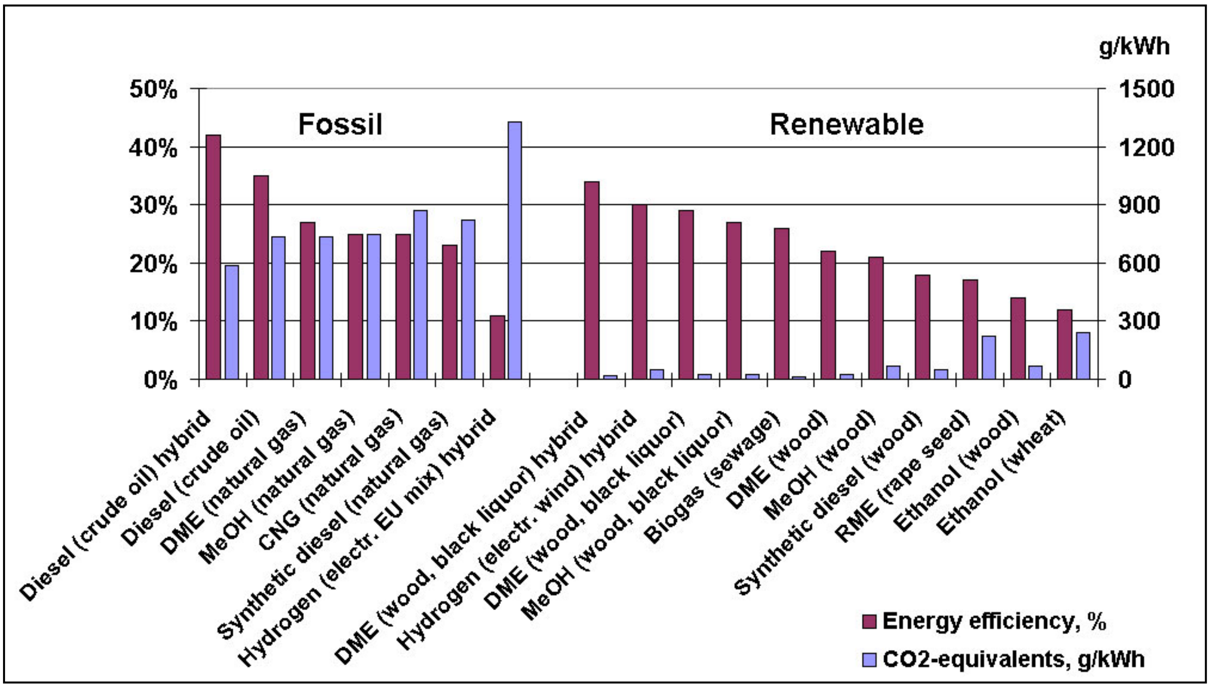
The main reasons for the increase in global warming include the burning of coal, oil and natural gas, which are used for transport, heating and industry.

Low regulated emissions, first and foremost nitrogen oxide and particulate matter, have often been put forward as an argument for introducing alternative fuels for vehicles. This is no longer such a powerful argument. Current and future engines are far cleaner than before and will soon reach emissions levels that will be acceptable in the long term.

WHAT DETERMINES THE CHOICE OF FUTURE FUEL?

The alternative we choose depends, among other things, on availability, environmental impact and fuel efficiency. Cost and customer acceptance are also important parameters.

One good way of comparing and assessing different fuel alternatives is to analyse the total energy efficiency and the emission of greenhouse gases, measured over the entire life cycle, from the



1. Diagram showing the well-to-wheel performance of each fuel regarding energy efficiency and emission of greenhouse gases

production of the fuel to the usable effect on the driven wheels, a well-to-wheel analysis. The analysis should include all relevant activities, including the complete production of the fuel, transport of the fuel to customers and the vehicle's powertrain efficiency.

WHAT ARE THE ALTERNATIVES?

The following fuels are included in the alternatives we at Volvo have been studying in greater detail:
· Ethanol (EtOH)
· Methanol (MeOH)
· Diesel (conventional and synthetic)
· Rapeseed methyl ester (RME)
· Dimethylether (DME)
· Methane (natural gas and biogas)
· Hydrogen

VOLVO'S POSITION

Volvo's position when it comes to future fuels for commercial vehicles is based primarily on an analysis that has known and established scientific data as its starting point. Volvo applies an holistic approach, in which greenhouse gases, energy efficiency, energy availability and cost are prioritised. Volvo's position is as follows:

- In spite of CO2 emissions, increasing costs and declining reserves, conventional diesel fuel – gradually improved, including possibly synthetic fuel components – will probably remain the dominant fuel for commercial vehicles for at least two decades.
- Fuel efficiency for the complete vehicle operation will be an area of focus, regardless of the choice of fuel.
- The cross-sector optimisation of energy and fuels should be used to ensure the effective use of available energy, the highest potential for CO2 reduction and the lowest cost.
- Methane (natural gas and biogas, compressed or converted) will be used as a fuel for vehicles, due to increasing regional availability and expanding pipeline grids. Biogas is close to being CO2 neutral.
- DME is a strong candidate for a longer term future fuel:
  – Best well-to-wheel energy efficiency from bio source.
  – Close to CO2 neutral if produced from biomass.
  – Highest efficiency, lowest GWP and cost of the gas to liquid (GTL) fuels.
  – Very low exhaust emissions.
  – Energy dense and liquid at low pressure.
  – Non-toxic, biodegradable and harmless to the atmosphere.

Peaking of World Oil Production: Impacts, Mitigation, & Risk Management

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The peaking of world oil production presents the U.S. and the world with an unprecedented risk management problem. As peaking is approached, liquid fuel prices and price volatility will increase dramatically, and, without timely mitigation, the economic, social, and political costs will be unprecedented. Viable mitigation options exist on both the supply and demand sides, but to have substantial impact, they must be initiated more than a decade in advance of peaking.

In 2003, the world consumed nearly 80 million barrels per day (MM bpd) of oil. U.S. consumption was almost 20 MM bpd, two-thirds of which was in the transportation sector. The U.S. has a fleet of about 210 million automobiles and light trucks (vans, pick-ups, and SUVs). The average age of U.S. automobiles is nine years. Under normal conditions, replacement of only half the automobile fleet will require 10-15 years. The average age of light trucks is seven years. Under normal conditions, replacement of one-half of the stock of light trucks will require 9-14 years. While significant improvements in fuel efficiency are possible in automobiles and light trucks, any affordable approach to upgrading will be inherently time-consuming, requiring more than a decade to achieve significant worldwide fuel efficiency improvement.

Besides further oil exploration, there are commercial options for increasing world oil supply and for the production of substitute liquid fuels: 1) Improved Oil Recovery (IOR) can marginally increase production from existing reservoirs; one of the largest of the IOR opportunities is Enhanced Oil Recovery (EOR), which can help moderate oil production declines from reservoirs that are past their peak production: 2) Heavy oil / oil sands represents a large resource of lower grade oils, now primarily produced in Canada and Venezuela; those resources are capable of significant production increases;. 3) Coal liquefaction is a well-established technique for producing clean substitute fuels from the world's abundant coal reserves; and finally, 4) Clean substitute fuels can be produced from remotely located natural gas, but exploitation must compete with the world's growing demand for liquefied natural gas.

Dealing with world oil production peaking will be extremely complex, involve literally trillions of dollars and require many years of intense effort. To explore these complexities, three alternative mitigation scenarios were analyzed:

- Scenario I assumed that action is not initiated until peaking occurs.
- Scenario II assumed that action is initiated 10 years before peaking.
- Scenario III assumed action is initiated 20 years before peaking.

Estimates of the possible contributions of each mitigation option were developed, based on an assumed crash program rate of implementation. Our approach was simplified in order to provide transparency and promote understanding. Our estimates are approximate, but the mitigation envelope that results is believed to be directionally indicative of the realities of such an enormous undertaking. The inescapable conclusion is that in the most optimistic case, more than a decade will be required for the collective contributions to produce results that significantly impact world supply and demand for liquid fuels. Under real world conditions, mitigation will surely require more time.

Important observations and conclusions from this study are as follows:

1. When world oil peaking will occur is not known with certainty. A fundamental problem in predicting oil peaking is the poor quality of and possible political biases in world oil reserves data. Some experts believe peaking may occur soon. This study indicates that "soon" is within 20 years.

2. The problems associated with world oil production peaking will not be temporary, and past "energy crisis" experience will provide relatively

little guidance. The challenge of oil peaking deserves immediate, serious attention, if risks are to be fully understood and mitigation begun on a timely basis.

3. Oil peaking will create a severe liquid fuels problem for the transportation sector, not an "energy crisis" in the usual sense that term has been used.

4. Peaking will result in dramatically higher oil prices, which will cause protracted economic hardship worldwide. However, the problems are not insoluble. Timely, aggressive mitigation initiatives addressing both the supply and the demand sides of the issue will be required.

5. In the developed nations, the problems will be serious. In the developing nations peaking problems have the potential to be much worse.

6. Mitigation will require a minimum of a decade of intense, expensive effort, because the scale of liquid fuels mitigation is inherently extremely large.

7. While greater end-use efficiency is essential, increased efficiency alone will be neither sufficient nor timely enough to solve the problem. Production of large amounts of substitute liquid fuels will be essential. A number of commercial or near-commercial substitute fuel production technologies are currently available for deployment, so the production of vast amounts of substitute liquid fuels is feasible with existing technology.

8. Intervention by governments will be required, because the economic and social implications of oil peaking would otherwise be chaotic. The experiences of the 1970s and 1980s offer important guides as to government actions that are desirable and those that are undesirable, but the process will not be easy.

Mitigating the peaking of world conventional oil production presents a classic risk management problem:

- Mitigation initiated earlier than required may turn out to be premature, if peaking is long delayed.

- If peaking is imminent, failure to initiate timely mitigation could be extremely damaging.

Prudent risk management requires the planning and implementation of mitigation well before peaking. Early mitigation will almost certainly be less expensive than delayed mitigation. A unique aspect of the world oil peaking problem is that its timing is uncertain, because of inadequate and potentially biased reserves data from around the world. In addition, the onset of peaking may be obscured by the volatile nature of oil prices. Since the potential economic impact of peaking is immense and the uncertainties relating to all facets of the problem are large, detailed quantitative studies to address the uncertainties and to explore mitigation strategies are a critical need.

The purpose of this analysis was to identify the critical issues surrounding the occurrence and mitigation of world oil production peaking. We simplified many of the complexities in an effort to provide a transparent analysis. Nevertheless, our study is neither simple nor brief. We recognize that when oil prices escalate dramatically, there will be demand and economic impacts that will alter our assumptions. Consideration of those feedbacks will be a daunting task but one that should be undertaken.

The key to mitigation of world oil production peaking will be the construction a large number of substitute fuel production facilities, coupled to significant increases in transportation fuel efficiency. The time required to mitigate world oil production peaking is measured on a decade time-scale. Related production facility size is large and capital intensive. How and when governments decide to address these challenges is yet to be determined.

Our analysis was not meant to be limiting. We believe that future research will provide additional mitigation options, some possibly superior to those we considered. Indeed, it would be appropriate to greatly accelerate public and private oil peaking mitigation research. However, the reader must recognize that doing the research required to bring new technologies to commercial readiness takes time under the best of circumstances. Thereafter, more than a decade of intense implementation will be required for world scale impact, because of the inherently large scale of world oil consumption.

In summary, the problem of the peaking of world conventional oil production is unlike any yet faced by modern industrial society. The challenges and uncertainties need to be much better understood. Technologies exist to mitigate the problem. Timely, aggressive risk management will be essential.

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The Impact of Oil Depletion on Australia

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I. Summary

The impact of global oil depletion on Australia is likely to be very severe, unless substantial mitigation and adaptation policies are implemented urgently. Many available options will have substantial social and economic benefits as well as reducing oil dependence. However, the likelihood of significant Government action before an oil depletion crisis is currently very low.

Hirsch et al., [1], have outlined for the US DOE the requirements to start countermeasures 20 years before the peak of global oil production. This is in line with the Noah analogy presented at the first ASPO workshop [2]. It is best to finish the ark before the flood. Western Australia's Minister for Planning and Infrastructure, Hon. Alannah MacTiernan has said *"It is also certain that the cost of preparing too early is nowhere near the cost of not being ready on time."* [3]

Australians are largely urbanised with 66% of the population living in sprawling cities along the south and east coast. The rural and remote parts of the country are very sparsely populated, and are highly dependent on oil for transport. The countermeasures suggested here for Australia could be applicable in many other countries, both those with largely urbanised populations and those with large land areas and long transport distances.

II. Australia's Oil Production

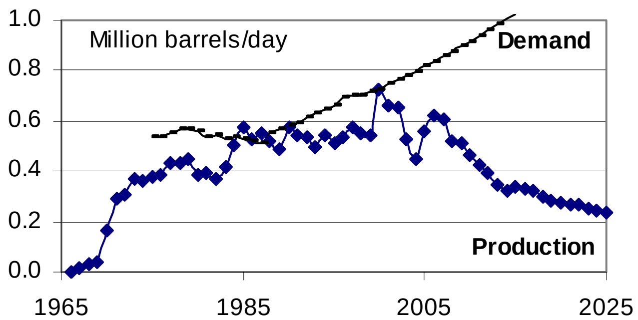

Fig.1. Australian crude oil and condensate production and demand to 2004, and forecasts [4,5,6].

Australia's domestic oil and condensate production became significant in 1967, reached a peak in 2000, and is now starting a post-peak decline phase.

III. Oil Consumption And Transport

Australia's population is 20 million people and there are 13.2 million motor vehicles, each travelling an average of 15,300 kilometres pa. Petrol taxes are the lowest in the OECD outside North America. About 80% of Australia's petroleum liquids use is in road transport and 10% for aviation.

Australia uses about 0.74 million barrels of oil products each day, about half as much oil per capita as does the United States. Crude and condensate production in 2004 was about 0.45 M bbl/day, imports were 0.63 M bbl/day and exports 0.34 M bbl/day [5]. Australia is still about 60% net self-sufficient in oil, but our imports are currently about 85% of daily usage, and balanced by high exports. This high import dependence makes us vulnerable to short-term international supply shortages.

Two recent Government reports summarised Australia's petroleum use. The Energy White Paper, [7] is not forthright about declining future domestic oil supplies and completely avoids mention of global oil depletion. It may come to be regarded as a significant "intelligence failure". The review of the Liquid Fuel Emergency Act [8] concentrates on short to medium term supply disruptions and our responsibilities under IEA agreements.

Australia is extremely "automobile-dependent" [9]. Our cities and transport-intensive economy have been shaped by cheap oil. There are innumerable policies which heavily subsidise car use, the domestic car industry and road freight, and which penalise users of more sustainable transport modes. Subsidised freight transport centralises production at the expense of local industries. Some of these "perverse policies" are outlined by Denniss [10]. Even our supermarkets offer petrol discounts so that those without cars subsidise heavy fuel users through increased food prices.

Australia is a dry continent and its soils are generally nutrient deficient. Agriculture in Australia is dependent on increasing fertiliser inputs, mechanised farming and long distance transport. It is becoming a way of using land to convert petroleum into food. Encouraged by cheap oil and fertiliser, these practices have depopulated many rural communities. Australian farmers will be faced with re-inventing their industry including returning to using natural nitrogen fixation with legumes.

IV MITIGATION AND ADAPTION OPTIONS

A: Post-Peak Options

A simplified diagrammatic scenario, Fig. 2, shows how the growing gulf between current demand trends and forecast supply might be accommodated. It is important to realise that there can be no single panacea, but there will be many partial solutions. Some options could be implemented quickly (for example tax changes and rationing), but many will require a very long time and much capital investment.

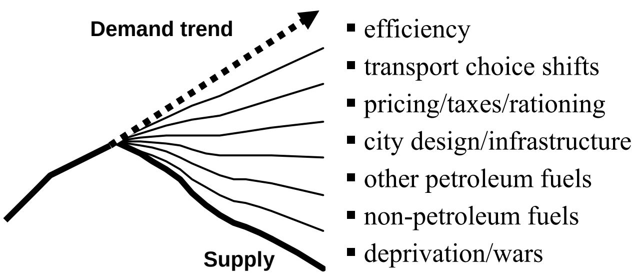

Fig.2. Post-Peak scenarios, filling the gulf between demand trend and forecast supply [11].

Some unusual strategies used successfully in Perth are included here as analogies for what could be achieved to reduce oil consumption.

B Public discussion and debate

Australian Governments at all levels have been reluctant even to mention the taboo topic of our oil vulnerability. The Western Australian Government leads marginally, with oil vulnerability discussed in its State Sustainability Strategy [12] and its Cabinet briefed by Dr Samsam Bakhtiari. However, even in WA there has been little done to discuss publicly the risks of oil depletion. USGS geologist Les Magoon [13] suggests correctly that the first thing to do is to "*Talk about it, talk about it. You can't solve a problem until you know you have one.*"

A substantial Government communication programme is needed to make the community aware of approaching oil depletion and its impacts before action can be implemented to reduce our oil vulnerability. Participatory democracy strategies like public forums will be essential to engage the community. These can empower people and businesses to work for the greater common good and find equitable ways to make the difficult changes needed. Such forums are being used in Western Australia to solve complex issues in transport and planning [14].

Once the community is aware of the risks of oil vulnerability, governments must lead with policies and countermeasures to minimise future impacts, providing the framework for crucial individual, community and corporate initiatives. Then stakeholders can actively consider possible oil shortages when buying a house or a car, expanding a business or restructuring neighbourhoods.

C: Rational Pricing Structure: The Water Analogy

Water has long been recognised as scarce in many parts of Australia. Perth, like other cities, has a rational pricing structure for household water use.

A basic household water allowance is relatively cheap, and increasing consumption above that is on a sliding scale where the higher the water use, the more the cost per kilolitre. Watering gardens with sprinklers is also restricted to two days per week in the morning or evening. These sensible water conservation measures are now well accepted by the community.

Similarly, when the community fully understands the risks of oil depletion and its possible impacts, an analogous incremental fuel pricing system and usage restrictions would also be accepted, as was wartime fuel rationing.

D: Individualised Marketing Demand Management

A significant proportion of Perth has seen successful cheap travel demand management (TDM) implemented, reducing car-kilometres by 13% on average. These Individualised Marketing programs, (TravelSmart) are being used in other Australian cities and around the world [15], with benefit-cost ratios of 30:1.

Empowering individuals to change oil-intensive travel habits is a "No-Regrets" option, already justified on health, social and economic grounds. Globally, TDM could save 5-10% of transport oil consumption.

E: Government Policy and Action Possibilities

A list of some possible actions is provided to show the wide range of options available to ameliorate the impacts of oil depletion often while enhancing community wellbeing.

Governments should :-

1: Issue repeated credible warnings that oil shortages are approaching us. Advise the community openly of the various estimates of the timing and the impacts of peak oil.

2. Engage the community, through participatory democracy, to create practical, equitable options and countermeasures, and to select preferred steps. Many perceived "options" like the "hydrogen economy" are most unlikely to be realistic until long after oil shortages impact and should be identified as such.

3. Dismantle the many "perverse polices" [10] that subsidise heavy car use and excessive freight transport. Examine all subsidies taxes and charges to weed out those that encourage car-dependency.

4. Instigate policies, taxes and pricing regimes that encourage frugal use of fuel, and disadvantage profligate users. A fuel tax escalator such as that introduced by the UK Thatcher Government in 1988 is a proven example. Australian fuel taxes should be incrementally raised to European levels to reduce usage, and to provide funds for improvements to health and education and for the needed sustainable transport infrastructure.

5: One novel policy would be to set up a SmartCard personal fuel allocation system. This would provide a modern adaptable mechanism for handling short-term oil shocks, similar to those of 1973 and 1979 and as well for encouraging people to reduce their fuel usage. Each person would receive an allocation of an amount of fuel sufficient for modest car travel at a base price. Increasing amounts of fuel would be available at an increasing tax-rate per litre. In addition, those who are able to avoid using their entire allocation would be encouraged to trade the unused rights on an open electronic market.

5. Recognise the psychological and social dimensions of automobile dependence as well as the physical aspects, and implement the cheaper people-oriented solutions as well as technologically based alternatives. Focus on the social benefits of reduced transport use.

6. Implement nationwide "individualised marketing" travel demand management campaigns.

7. Divert infrastructure funding to less oil-dependent urban structure and transport options. Rail, cyclepaths and public transport will be far better investments than more urban roads.

8. Priority access to remaining oil and gas supplies must provided for food production and distribution and other essential services. Remote indigenous communities will have special needs. Practical, flexible priority fuel allocation mechanisms can utilise the electronic Smart-Card system.

9. Promote through the United Nations a Kyoto-like protocol to allocate equitably the declining global oil production among nations. An international tradable sliding scale allocation mechanism is one hypothetical option. Every nation would be entitled to a base amount of oil, on a per-capita basis at a modest cost. Increasing amounts per capita would be available at increasingly higher costs to encourage conservation. Nations which use less than their base allowance can trade the excess to their more profligate or wealthy neighbours. This provides a significant incentive for demand reduction and conservation everywhere. This is an international equivalent of the system suggested above. Global oil allocation procedures are now based solely on price, so rich nations get the bulk of the oil and the poor countries get very little. Another undesirable but quite possible future allocation mechanism is the real threat of resource wars over the remaining oil.

F: Conclusion

Many of the policy options to reduce fuel usage and the impact of oil depletion on Australia will also lead to healthier, happier and more equitable communities and improve local and global pollution levels. Failure to take action now will lead to severe future economic and social impacts on Australia.

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A full list of references and links is available at www.STCwa.org.au/aspo

The Challenge and Countermeasures Brought by the Shortage of Oil and Gas in China

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1. GREAT DEMAND OF OIL AND GAS RESOURCES FOR THE ECONOMIC DEVELOPMENT

Since the 1990s, the fast growth of the economy of China has taken house property, automobile, capital construction trade as the leading factors, regarding such trades as the steel, nonferrous metals, building materials, chemical industry, etc. as support, entering a high-sustainable developing stage of heavy-chemical industry. The expanding basis for these industries lies in abundant oil energy and they will suffer great impact without stable supply of oil and gas. In this way, to guarantee the economic development of our nation needs a certain mount of oil supply.

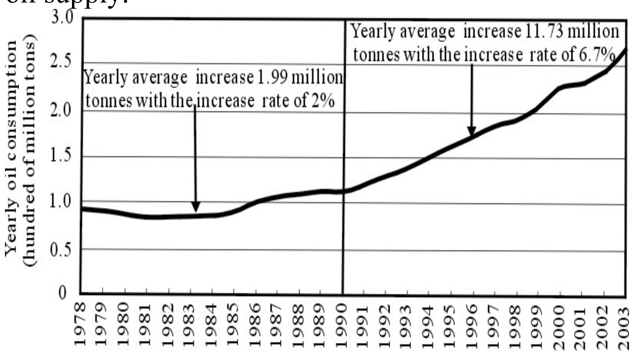

Figure 1 China's oil consumption increase figure in recent years

2. THE OIL AND GAS PRODUCTION IN CHINA CANNOT MEET THE DEMAND OF ECONOMIC DEVELOPMENT

The sustainable and rapid development of China's economy and its growing mode all need a large number of oil and gas resources as guarantee. But meanwhile, though the exploration level in China belongs to medium-ripe stage compared with the whole world, the main oil fields of our country have entered a descending stage in production generally. It is harder and harder to steady the production. And the exploration difficulty of other new oil fields is also increasing with bigger cost of exploration. This results in the great shortage of oil and gas resources, which fails to meet the demands of economy development

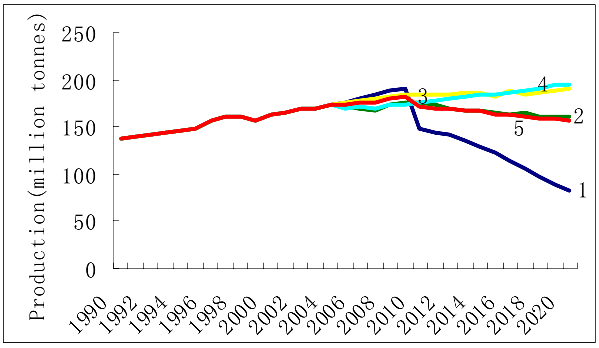

Figure 2 Prediction on China's oil production by different scholars. 1.Baoshen Guo's Prediction 2.Wenrui Jia's prediction 3.Shuling Mou's prediction. 4. Pingping Shen' prediction 5.average production

3. CHALLENGE BROUGHT BY THE SHORTAGE OF OIL AND GAS AND COUNTERMEASURES

The great demand of oil and gas caused by the rapid development of economy and the slow increase of domestic oil and gas production have resulted in the shortage of oil and gas in our country. Meanwhile it is a difficult problem and challenge faced by us. So it is a task of our petroleum staff to fully realize the severity of this problem and take effective measures to solve it in time.

The solution to this problem is: While keeping a steady production of the domestic crude oil and fastening the development of natural gas, improving the utilizing efficiency of oil and gas resources, looking for substitute energy resources and the fundamental solution is to save oil and gas resources for the sustaining development of our country.

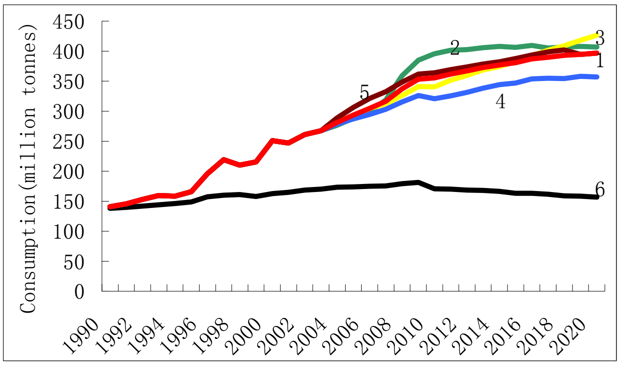

Figure 3. Prediction on oil demand in China by different scholars and departments. 1. Average prediction 2.Tsing Hua University's prediction 3.Rong Zhang's prediction 4. Shuling Mou's prediction 5.Mineral Ministry's prediction 6. Average production

3. CONCLUSION

Oil and gas resources are the most important strategic materials to ensure the national economy, politics and military security. Since the foundation of the state, the oil industry of our country has made enormous achievements. The annual production of crude oil rises to 1700 million tons in 2003 from 120,000 tons in the early days of our liberation, making important contribution to national economic and social development. However, with the ever-increasing growth of national economy, the imbalance between supply and demand of energy especially oil and gas resources is becoming more and more severe, which has already become the main bottleneck restricting economic and social development.

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The Likely Impact of Global Oil Peak on the United States

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Throughout most of the late 19th and early 20th centuries the US was the world's foremost oil producing and exporting nation; it was also the first important producing nation to pass its all-time oil production peak, which occurred in 1971. Thus America is emblematic for understanding world oil history and the approaching global extraction peak.

While each nation will be impacted differently by global oil peak, the types of effects that are likely to be seen in the US can be extrapolated elsewhere; however, effects in this instance will be more pronounced because of America's extreme and arguably unmatched economic dependence on petroleum.

America's original endowment of oil is estimated at somewhat less than 200 billion barrels, of which 170 billion (or about 90 percent) has been extracted (ASPO, 2002). Current production of conventional oil, including offshore areas and Alaska, is about 5.5 million barrels per day; non-conventional sources yield a little more than 2 million barrels per day. Present US consumption stands at 20 million barrels per day; imports account for nearly 60% of usage. (EIA, 2005) The US has the highest per-capita consumption of oil of any large country, and is the world's foremost oil user and importer. Well over 97% of US transportation energy comes from petroleum, and Americans are the most mobile people on the planet: there are more autos in the country than there are licensed drivers—about 210 million total. Americans drive an average of 12,000 miles yearly at an average fuel efficiency of 20.8 miles per gallon (3.2 kilometers per liter) (EPA, 2005).

Petroleum dependency has been systematically encouraged through suburban design and the lack of public transportation alternatives to the private automobile. The peak of per capita public transportation usage occurred in the 1940s; following this, the nation invested hundreds of billions of dollars in its Interstate Highway System, effectively a subsidy to the auto and oil companies; simultaneously, it invested heavily in civilian air transport while systematically dismantling its interurban rail and urban light rail systems.

The US was also the center of modern agricultural developments—the widespread deployment of petrochemical fertilizers, pesticides, herbicides, and powered farm machinery—that have made the nation's food system overwhelmingly oil-dependent.

Oil currently accounts for 40 percent of total US energy usage, making it the nation's primary energy source. Domestic production of natural gas, the nation's second most important energy source, is also in decline. The US has large domestic coal reserves; however quality is highly variable and a recent Hubbert curve analysis suggests a domestic production peak in as few as 20 years (Vaux, 2004). The nation derives 8 percent of its energy from nuclear power; that amount could be increased substantially, but the cost would be enormous and the development time would be considerable. Only 6 percent of US energy production is from renewable sources, most of that being hydroelectricity and the burning of biomass, with solar, wind, tidal, and wave energy combined contributing less than one quarter of one percent.

All of this is well known. What is less often discussed is the challenge that will be presented by global oil peak.

The US was able to make up for its domestic oil peak by means of four primary strategies:

- Importing more oil from other nations,
- Relying on the US dollar denomination of global oil sales to bolster the value of the dollar and therefore to make imports artificially cheap,
- Using military power to defend access to oil-producing regions and to enforce stability in those regions,
- Partial efforts to increase energy efficiency.

When global oil production peaks some of these strategies will likely begin to fail.

Imports will become more expensive, in both absolute and relative terms. Of course, prices for oil itself will be much higher, but so will prices for nearly everything else (due to rising energy costs for manufacturing and transportation); thus consumer purchasing power will be strained, making higher fuel costs harder to absorb. At the same time, the continuing declining relative value of the dollar measured against other currencies will add to the real cost of fuel.

The prevalent denomination of oil sales in US dollars may cease, due to the dollar's declining value, which is due to bloated US trade deficits, which are themselves at least partly attributable to the high rate of US oil imports. If oil does come to be sold more frequently for other currencies, this will merely add to the downward pressure on the dollar's value, creating a reinforcing feedback loop.

America's military strategy in Iraq—which appears to be part of a larger design to dominate oil-producing regions globally—is already significantly challenged by armed resistance in that country. Attempts by the US to pursue a similar military strategy in other countries are likely to be resisted not only by the people of those countries but also by other nations averse to the notion of a unipolar world. China, Russia, India, Venezuela, and Iran appear to be engaging in economic and in some cases military alliances in an effort to counterbalance US hegemony in the Middle East, Central Asia, and Latin America, with the future of Africa also in dispute.

Meanwhile the consequences of America's lack of vigor and thoroughness in pursuing energy efficiency and conservation domestically over the past two decades will hamper its ability to adapt to a low-energy future. Already Germany, Spain, Netherlands, and Japan have leapt far ahead of the US in per-capita production of solar and wind power. The US may find itself needing to invest heavily in new energy infrastructure at a time when its economy will be hard pressed to maintain emergency services for its increasingly unemployed and desperate population. The nation's relative success in its energy transition will thus hinge on whether the global peak occurs sooner (2005) or later (the extremely unlikely date of 2020), and whether leaders accept the energy transition as their immediate top priority and make maximum use of whatever time is left, or continue to postpone the effort (Hirsch et al., 2005).

In the more likely case that peak occurs soon and few efforts at transition are made prior to the event, there will be profound economic impacts (Hirsch et al., 2005). Within years, the average American will have less opportunity, purchasing power, and mobility. Food will cost more and consumer choices will be severely constrained. Life expectancy may decline markedly, and America's cities will likely fall into decay.

While US policy makers have squandered opportunities to avert such scenarios, even after the peak they will still face important choices, and their decisions will continue to be fateful both for US citizens and for the rest of the world.

With regard to foreign policy, decision makers must choose whether to seek military solutions to what is essentially an economic problem. If they pursue militarism, this could set loose a chain of violence throughout western Asia, Africa, and South America. The ultimate consequences are frightening to contemplate.

With regard to domestic policy, decision makers must choose whether and how to intervene in the economy. Economic contraction will occur, whether planned and coordinated or forced and improvised. If the government takes a hands-off approach, the suffering of the citizenry will be acute and will eventually lead to organized protests on a massive scale. Yet if the government chooses active strategies—rationing, creating employment in the agricultural sector, subsidizing alternatives, and mandating radical conservation measures—its efforts will still be subject to harsh criticism. Hence in either case it is likely that decision makers will respond by curtailing civil rights and expanding police powers

If the 20th century saw America's economic and geopolitical ascendancy, the 21st will almost certainly see its decline. The problems created for the US by peak oil will no doubt eventually be solved; however, the process will entail profound changes at every level of American society.

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The Urgency for Energy Economics

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Mainstream literature favours a number of widespread ideas which are essentially flawed and block the public perception of reality. One is that material production can be conceived outside the physical world, as result of the sole combination of capital and labour, unconstrained by physical laws. Another is that environmental scarcity and impacts are external to the economic process, sufficing to be internalized to account for sustainability and social responsibility. By failing to account for limitations to growth and recognize impending threats on survival, theoretical and practical consequences issue which deserve urgent consideration.

I. ECONOMY AND NATURAL LAW

Material production is a human and social process which develops in a natural framework, making abundant use and being strictly subjected to natural laws. Conservation of mass and of energy, energy and information degradation, are the most evident of such natural laws. The econosphere exists as an open and non isolated subsystem within a much larger but finite geosphere. Economic production is the process of transformation of materials into products, and results from the application of energy and information to such materials, by the human factor labour. Machines employed to that effect embody materials, and both spend and convey energy and information in the process.

The idea of economic dematerialization is a misconception that appears closely associated with the ignorance of the prevalence of natural law. Monetary value per unit mass of finished product and mass embodied in finished product per unit mass of raw material might both increase in some sectors or in some developed economies, but are not global trends.

When observing a particular product one might be mislead to abstract it from the chain of individual technical steps that anticipated and eventually lead to it. Being hardly able to seeing a microchip, one plainly ignores the tons of rock from where tiny amounts of rare substances where extracted, the large concentration plants where they were separated, the chemical reagents and the heat and work spent, the intermediate products in which they were converted, and the complex installations where they were finally fabricated. One ignores the usually much larger "invisible" or "indirect" flows of materials generated and discarded upstream, at the stage of raw material and energy extraction from natural resources, as much as one used to ignore or keeps ignoring the waste flows that are generated downstream, at the successive stages of transformation right till final use and deposition back to nature. One ignores also the means which necessarily supported the whole chain of social and technical steps - including the resources consumed in sustaining and qualifying the labour force as well as the energy spent in carrying products and workers along such "invisible" economic flow.

Another misconception, according to which information would be void of material content, is akin to the idea of economic dematerialization. Information can be stored, as energy can be, in very compact ways, what might once again delude the observer. One is lead to take it for granted - ignoring the possibly huge amount of human labour, assisted by proportional amounts of other production factors, spent and embodied in the particular information data base collection, discovery or invention process.

As a falsely logical consequence of the said misconceptions, another one emerges and is widely spread, namely that all-powerful and pervading technological innovations would solve all economic problems at limitless natural costs.

II. ENERGY AT THE CRUX OF GROWTH

Material flow analysis (MFA) is recognized as a useful framework to assess economic throughput in relation with material flows between econosphere and geosphere. Total material requirement (TMR) is one of the telling indicators of the magnitude of that interaction [1]. Fuel flow is not only among the largest but also the one that necessary drives the remaining flows.

Energy is an essential production factor on its own whose importance has increased continuously, in step with the growth in available work extracted from nature in the form of fossil fuels, as compared to the somatic work performed by man and to the solar energy man makes use of – and on which was entirely dependent up to the early stages of the industrial revolution. The increasing amount and the improving quality of "produced" and "consumed" energy have been shown to have great explaining potential for the economic product growth which was observed during the past century [2]. In particular, the high grade and the improved quality of the energy resources mix allowed for progress in energy extraction, conversion and use efficiencies.

However, the ultimate reserves of the present main primary energy sources are limited. The exhaustion of particular geological fields or provinces have been observed and documented. Geological and physical arguments and criteria, such as yield per effort in prospecting and energy return per energy investment in extracting, are recognized as un-surmountable constraints at planetary level.

That essential role of useful energy in the economic process and its likely central role in propelling economic growth confer to the energy availability a crucial importance. The real size of reserves and the impending scarcity of present primary energy sources are questioned and appear to threaten our common future well-being. The dematerialization misconceptions appear as contributing to obscure this dire reality.

III. ACCOUNTING AND LIFECYCLE

The perception of impending scarcity of resources and of increasing environmental impacts of wastes has eventually led to a Natural Resource Accounting system (NRA), revising the System of National Accounts (SNA). NRA should be a means of monitoring and understanding the relationships between human, economic and natural systems.

Nature is the source of both raw materials and of non-consumptive largely non-marketed resources which traditionally belonged to the realm of common property rights. But this is a sensitive borderline that moves at the rate that commons and natural heritage are of late being privatized. Anyway, assessing and maintaining the value of a country's natural system, as part of the national accounting system, should be a useful tool for preserving the population's wellbeing and welfare.

To fulfil that need, an Integrated Environmental and Economic Accounting System (SEEA) was conceived and eventually adopted by the United Nations Statistical Office in 1993 as a supplement to the SNA. SEEA provides a framework for assessing physical stocks and flows of forest, ocean or mineral resources and their monetary consequences. It aims at compiling physical accounts with linkages to monetary accounts; completing monetary accounts for both depletion and degradation in resources and environment; extending the concept of capital to include natural assets. SEEA, being implemented in the form of satellite accounts to the core accounts of the SNA, maintains the central concepts and principles embodied in it, however, there is not universal agreement as to how the adjustments to the SNA should be made to reflect economic externalities. This is another very sensitive issue indeed. For instance, economic progress measured by GDP per capita, when adjusted by subtracting the net national resource depreciation, produces an estimate of NDP that demonstrates that GDP overstates net income level and its growth rate [3].

The natural resource flow through the economy starts at the natural source hasting its depletion and, after production and consumption, ends by waste emission and pollution. A resource tax at the point of extraction can reflect external costs of scarcity and waste impact, in addition to capturing rent. Taxing at the beginning or at the end of the resource throughput, lead to quite different consequences. A resource tax at the point of eventual depletion induces greater efficiency in production, consumption, and in final waste disposal, it leads to internalizing external costs and benefits throughout the economic lifecycle of raw-materials and fuels. Higher resource prices force production technologies to use the resources more efficiently and also force more frugal and efficient patterns of consumption. And as further extraction of resources from nature becomes more expensive, recycling of wastes is stimulated because it is a less costly alternative; recycling reduces both depletion and pollution.

The real productivity of energy should be recognized and its actual availability accounted for, so that sound policies and attitudes can be rooted and would be adopted, for general welfare and survival perhaps.

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Strategies for the Future Development of Energy Systems

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The cheap-oil era is a short anomaly in the Earth's history. In this short period, practically unlimited access to the hitherto unimaginable physical power which oil so easily provides has changed the world and transformed modern man's concepts of the economic and ecological conditions of life. As this era is now coming to an end, we face global technological, ecological, economic, and, hence, political challenges unparalleled to those of any other cultural transition in the history of mankind. The technological and ecological nature of these challenges cannot be apprehended within the framework of concepts inherent in the mind-set of the cheap-oil era. In particular, the concept of "energy" as tradeable commodities must be revised in order to establish a rational conceptual framework for the analysis of feasible strategies for the future development of energy systems.

I. THE ORIGIN OF THE COMMERCIAL ENERGY CONCEPT

After World War II when the military and civilian use of atomic energy became a political issue in the West, the US Atomic Energy Commission of 1946 and similar administrations in other countries were created to take charge of atomic energy programmes. However, "energy" was not generally used as a political and economic term before the mid-1970's when the oil crisis unveiled the Western economies' crucial dependency on oil and the needs for coal, natural gas and nuclear power as substitutes for oil. Instead of the explicit but awkward term "fossil fuels and nuclear power", the term "energy" was introduced in the naming of institutions and governmental departments, e.g. the International Energy Agency (1974), the US Department of Energy (1977), and energy agencies in many countries.

Thus, as a result of the Opec-staged oil crisis in the mid-1970's, "energy" became the general term for tradeable commodities: fuels and electric power - a simplistic concept only vaguely related to the thermodynamic meaning of the term. This concept contrasted with several physical and biological analyses of energy flows in natural and industrialised ecosystems, published in the 1960's and early 1970's, in which energy (and entropy) is defined as a thermodynamic systems property (e.g. Odum 1971, [1]).

II. THE ENERGY BOOKKEEPING OF A WASTEFUL ENERGY ECONOMY

In the cheap-oil era, oil - the precious resource for the powering of vehicles on land, at sea and in the air - has been cheap enough to be burned in simple boilers for low-temperature heating or, wasting even more of its thermodynamic potential, in thermal power stations whose contribution to sustaining the electric potential (voltage) of the power grid is annihilated in electric resistance coils (mere entropy generators) for room heating and warm water.

Because such waste of the thermodynamic potentials of oil, gas and coal has not been an important economic issue, energy statistics generally make no thermodynamic distinction between the different forms of energy. Energy statistics are simple bookkeeping accounts of chemical, electric and thermal energy, denominated in calorimetric values. For example, the potential power of one kilogram of oil or 11 kWh of electric power is equalled to the heat from a solar collector raising the temperature of 1 cubic metre of water by 10 degrees C.

Such simplistic bookkeeping of energy supply and demand conforms to the pecuniary bookkeeping accounts in which the supply and demand for all sorts of various goods and services is measured in some currency. It requires no insight in the basic principles of thermodynamics and is therefore easily grasped and applied in general economic theories.

The simplistic energy bookkeeping method was adopted also by the advocates of "renewable energy", a term introduced into the vocabulary in the 1980's as an expression for any source of power or heat other than fossil fuels or nuclear power. Renewable energy is thought of as something which can replace fossil fuels and nuclear power within the fossil-fuel infrastructure framework, not as endogenous energy flows in new energy systems which facilitate the efficient utilisation of various scarce resources with very different properties. Thus, in 2001 the European Union formally approved a directive on renewable energy which required member states to ensure that 12% of gross internal energy consumption and 22% of electricity consumption would come from renewable sources by 2010. [2]

Such percentage accounting is ostensibly easy to grasp but makes little sense with respect to the formulation of a goal-directed policy aiming at reducing dependency on fossil fuels. First, if energy consumption according to the simplistic bookkeeping grows by 10%, the dependency on fossil fuels is only insignificantly reduced if this growth is covered by renewables. Second, and more importantly, it does not make sense to replace heat from oil or gas boilers by heat from solar absorbers or biomass fuelled boilers as long as the resource economy of replacement by heat from cooling circuits of power generating units (cogeneration) is much better.

III. ECONOMIC THEORY VERSUS CONCRETE COST ANALYSES

It is a general assumption of economic equilibrium theories that the market ensures that demand and supply is balanced at minimum costs and that, therefore, any politically regulated shift away from the state of equilibrium will be costly. Accordingly, macroeconomic analyses such as Nordhaus & ZiliYang [3] show that the transition to new energy systems which fulfil the needs of industrialised societies at substantially reduced fossil fuel consumption and CO_2 emission will be costly. However, these results are not confirmed by the results of cost computations in specific cases of concretely specified technological investment programmes which lead to substantially reduced fossil fuel consumption.

On the contrary, computations based on models which in detail represent the physical properties of national or regional energy systems as a whole - including energy sources, the energy conversion and transmission system, and the end-use complex - show that under any reasonable assumption as to future fuel prices, the well-engineered technological transition to energy systems much less dependent on fossil fuels is economically advantageous for the community as a whole. This is demonstrated by comparative economic cost analyses for concretely specified transition scenarios (investment programmes) for Denmark and the Nordic Countries, [4], [5].

IV. BUSINESS AS USUAL IS NOT AN OPTION

The history of the industrialised world powered by fossil energy sources, which begins when Thomas Newcomen set up the first successful steam engine in 1712, has culminated in the all-embracing cheap-oil technological complex upon which all functions of our societies now depend. The transformation of the energy systems of this complex to systems much less dependent on fossil energy sources is a task of engineering of a magnitude never before encountered by mankind. The time available may be too short but in the Western civilisation the barriers for change are cultural and institutional rather than technical. Coherent technological strategies for the transformation of energy systems in the affluent industrialised countries can be spelled out. But in the political economies based on the consumerism culture and liberalised markets extended to the basic energy infrastructures upon which the economy depends, there is little scope for the political pursuance of technological strategies for the common good.

However, business as usual is not an option. Either energy policies based on coherent technological strategies for the reduction of oil and gas consumption and CO_2 emission are formulated and forthwith pursued in order to sustain the welfare of our societies. Or the basis of our economy will be eroded when the supply of oil and gas can no longer meet the demand.

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On the Relationship between Energy, Work, Power and Economic Growth

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There are strong empirical arguments for the so-called `Hubbert thesis', namely that global petroleum output is now approaching its peak. Recent (2004-2005) sharp increases in oil prices, which show no signs of being a temporary `spike', make the Hubbert theory increasingly plausible. This event would have obvious implications for prices and economic activities directly dependent on oil products, especially petrochemicals and transportation. While the Hubbert arguments are not (yet) universally accepted by oil geologists or by the oil industry – at least in public – they cannot be dismissed lightly. One reason, among several, is that economic incentives facing powerful economic interests strongly favor continuing indefinitely on the `business as usual path'. For instance, the stock market valuations of major oil companies, such as Shell, BP and Exxon are directly dependant on proven reserves. This fact, alone, makes the public pronouncements of the established petroleum interests suspect. Another reason for skepticism is the obvious competition for influence among members of the OPEC cartel. Finally, among the economic incentives for refusing to acknowledge the reality – perhaps the only one that restrains the largest producers, and the OPEC cartel from price gouging – is the fear that, if oil prices were to rise too high (and remain high), the industrial countries might get serious about reducing consumption through taxation or regulation such as extended CAFÉ standards. An even scarier scenario for the oil exporters is the prospect – however dim – of rapid development of viable technological energy alternatives.

This paper suggests another, perhaps even more potent, reason for concern. The standard neoclassical theory taught in the economic departments of major universities and accepted by most of the economists who advise governments (and business leaders) attributes economic output (GDP) and economic growth to only two so-called `factors of production' namely capital and labor, which are also assumed to be substitutable for each other. The reasons for this are primarily historical. Natural resources or `gifts of nature' were originally attributed to `land' which later in the 19th century was absorbed into the larger category `capital'. Whatever the reason, standard economic theory does not treat energy *per se* as a factor of production. Energy is treated, instead, as an intermediate product of labor and capital. The arguments for and against this odd notion are not central to the current situation. What is central is that, if energy is *not* a primary input to the economy, it follows that the availability of energy, and the price of energy, are not critical to economic activity or economic growth. For instance, if expenditures for energy are only a small percentage – say 4% – of the total GDP, it seems to follow (from the neoclassical theory) that raising the price of energy by even a factor of two would only reduce the GDP (if at all) by a negligible amount. The established theory assumes that growth is mostly attributable to technological improvement, which is assumed to be exogenous and automatic.

This paper argues, to the contrary, that while `raw' energy inputs (as raw materials and sunlight) are not drivers of economic output, energy converted into `*useful work*' in the physical sense, is indeed a factor of production, along with traditional capital and labor. Useful work can be thought of as the product of raw energy (exergy) inputs, such as biomass and fossil fuels, multiplied by the efficiency of conversion into useful forms, such as electric power and useful heat. Of course, adding a third factor of production undermines the substitutability assumption in the neoclassical theory. However, on reflection, it seems obvious that capital, human labor and useful work are both substitutes and complements.

The qualitative argument for introducing useful work as a factor is that economic growth has always been a positive feedback cycle, in which lower costs lead to lower prices (of goods and services) which generates increased demand and – through economies of scale, R&D and learning from experience, lower costs again. Evidently the costs of useful work as produced by so-called `prime movers' – such as the steam engine – has fallen by orders of magnitude since the industrial revolution began. These declining costs have caused lower costs of iron and steel, engineering products, structures, and so on. More convincing, perhaps, is the fact that when the new three-factor approach is introduced quantitatively, it is possible to explain historical growth of the US economy since 1900 with a remarkably high degree of accuracy – allowing for some recent contributions from information technology – without the uncomfortable and unrealistic assumption that technological progress is introduced from outside the system like `manna from heaven'.

Apart from the above theoretical arguments, the key implication of the new theory is that continued US economic growth – widely acknowledged to be the `locomotive of global growth, at least for the immediate future – depends upon continually increasing inputs of useful work (as defined above). In the past, the costs of useful work declined in part because of the discovery of cheap sources of energy (such as Persian Gulf oil) and partly because of improved extraction and recovery technology. However, these sources of lower costs appear to be nearly exhausted. The second source of declining costs has been from increasing efficiency (and scale) of energy conversion technologies, notably internal combustion engines and electric power generation. However, future increases in primary conversion efficiency show every indication of being slower and more costly than in the past. Moreover, the obvious technological alternatives to fossil-fuels (including nuclear power) do not show any promise of declining costs.

Where can we look for the gains in conversion efficiency that will (hopefully) drive future economic growth? The obvious candidate is energy policy. The paper concludes with a few personal comments on this topic.

Energy Economics in the Second Half of the Age of Oil

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The prospective evolution of energy economics in the second half of the Age of Oil cannot be understood without some understanding of the first half of the Age of Oil, which began in the late 19th century and is going to end, more or less, now. The reasons for this are various, but fundamentally boil down to the complex interaction of technology, population growth, energy, finance, and economic activity. Technology in the form of improved medical care and public health had by the end of the 18th century considerably accelerated the pace of population growth in the newly industrialising world. For the provision of energy, which up to that time had been largely provided by muscle and wood, societies turned to coal, and by the late 19th century, were beginning to convert to petroleum.

Finance too began to change in a process that began with the Glorious Revolution in England, a hostile takeover, if you will, by military and commercial forces that had coalesced around William of Orange. This resulted very quickly in the "liberalisation" of British finance with the creation of the Bank of England. For the purposes of this discussion, this was important because it revolutionised the process of raising money by the state for war or other purposes by effectively swapping the credit rating of the sovereign for that of the Bank's owners, and so set in motion the most efficient means of financing war hitherto known to man. From that point to the end of the 19th century at least, finance was still generally ruled by the notion that the monetary system had to be based on a unit of exchange with a commonly agreed value, either gold or silver or both. Credit growth was thus dependent on the supply of these metals that could be mined or stolen, as the history of early European exploration and conquest shows us. The holy grail of finance was then, as it still is today, a means of liberating finance from this constraint while still keeping control of credit.

The invention of the internal combustion engine and the resulting leap in the demand for petroleum interacted with these developments in ways that are both obvious and subtle. Just as finance was first revolutionised by the creation of a more efficient means of financing war, long before citizens had almost universally traded ownership of house, car, and refrigerator for a leasing contract, petroleum did not really burst on the scene until the Royal Navy adopted it in place of coal. This ignited a world-wide arms race and inadvertently ceded to the hydrocarbon self-sufficient United States a critical strategic advantage. Britain with this fateful choice went from being self-sufficient in energy in the form of coal to being utterly dependent on the oil resources of the Middle East thousands of miles away and threatened by competitive interests in Germany and France which likewise needed it.

The foundations of contemporary emerging energy economics cannot be complete without a nod towards the development of the corporation, especially in the United States, and the revolutionary changes that this brought to the American society and political economy. In 1887 JP Morgan brought the eight men who controlled virtually all of America's energy transportation and basic industrial processes into a room at his Fifth Avenue mansion in New York and hammered out a non-compete agreement that, by and large, defined the future path that the country would take. Only a few years later, the US had become an Asian colonial power, and within three decades had signed what amounted to a non-aggression pact with Britain, had established a central bank, completing de jure what had been de facto control of American finance, and emerged as the world's most formidable financial power. Much of this it owed to oil, being the world's biggest producer and exporter. This made the strategic problem of establishing hegemony one of denying free access to oil to those European and Asian powers that were, and are, net oil importers.

American victory in the Second World War completed this process, setting the stage for several decades of American dominance of the world scene with one notable exception, the USSR, which was also energy self-sufficient. The collapse of the USSR is usually attributed to factors such as its lack of free markets, the inability to match American military spending and so on, but almost certainly it also was due to the collapse of oil prices in the middle 80s which severely impacted its hard currency earnings and decimated state revenue while increasing the financial burden of supporting its Warsaw Pact allies.

These days it is fashionable again to worry about debt levels in the industrial world. For two decades or so this was not the case as the political marketplace was dominated by ideas of government budget discipline and disinflation as fiscal and financial priorities. These priorities were honoured more in the breach than in the observance, but they are relevant to our discussion of energy economics for the simple reason that it highlights the truth that it is not finance that makes economies “grow” but real factors such as population growth and energy availability. The attractiveness of hydrocarbons has always been predicated on their uniquely productive energy release characteristics, as well as the fact that their chemical makeup has rendered them useful to the production of fertilisers among other products. Mechanisation and chemical fertilisers have transformed the political economy of agriculture by stripping agriculture of workers, and thus neutering political movements as diverse as Ukrainian Kulaks and American populists and progressives.

Hydrocarbons are useful to the corporate state not just because of profit, which tends to be the view of what remains of the modern left, but also because they have simultaneously liberated the state from concern about serious political opposition while simultaneously ratifying growing debt burdens. The mechanism for doing the latter has been predicated on cheap and abundant oil which has held the promise of high future output rates that could be relied on to service debt assumed in earlier years.

A world in which oil is priced for scarcity instead of the rhythms of cyclical supply and demand represents a very different world than the one which we live in today, in which oil and gas are priced as if they are infinitely renewable. We live in a world of temporal limits and limitless possibilities. The conflation of these two, well, limits, is a source of limitless confusion. The choice is not between a world with and a world without oil, but (among other choices) between a world organised around oil as the primary propellant for growth and military and political supremacy, and a world organised around people as the organic driver of growth. This point can be illustrated by the concept of “growth” itself, which we measure by an additive function called gross domestic product. Being additive, GDP tells us nothing about the quality or the nature of the actions of real people that added together are GDP. Investment in a factory is not the same as swapping fixed for floating debt, but add up enough of the latter and you can arrive at the same GDP figure. In the United States, where the financial sector’s profits are half of those of the rest of the economy, this matters.

It is a fact that it is more productive to conserve oil than to consume it. Look out of the airplane the next time you travel to Los Angeles or Dallas, and you will see why the US political system refuses to conserve. Energy economics in the second half of the age of oil require a profound change in the way we and our corporate institutions imagine the world. Look at Iraq, and you can see what the response of our leadership is to this challenge.

SELECTED COMMUNICATIONS

Uncertainty in Peak Oil Timing

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*Being careful with assumptions and statistical techniques, we find that **a**: least-squares fitting makes assumptions that are implausible in this case; **b**: global oil discovery can justifiably be regarded as stochastic, but **c**: global production is not stochastic, it could be a sum of bell-curves or simple exponential growth, and also shows 10-year cycles; **d**: fitting a sum of two bell-curves (vs only one) delays the production peak by 2–3 years; **e**: different types of bell-curves make peaks from 2004–14, with later peaks going higher and then declining faster; **f**: each such fit yields a 95% confidence interval that its peak is correct ± ½ year, thus reminding us that fitting does not make a model true (but fitting badly does matter); **g**: Gaussians are a poor fit to oil production, and we argue that the Central Limit Theorem does not apply; **h**: the Burr, Bass, Logistic, Weibull and exponential models fit well and suggest causal theories; **i**: the models' predictions can only be tested by time passing, so we can't be sure any model is right until the oil production peak is past, but that will be much too late to be useful; **j**: higher prices may occur for many reasons (such as dollar-devaluation or high demand) so do not prove the peak is imminent.*

I. Why Analyze Uncertainty

Jumping to conclusions is so easy, we often don't know we've done it. It avoids a lot of work, too.

The timing of the conventional-oil production peak depends *inter alia* on the size of the (global) Ultimately Recoverable Resource (URR). Back-of-envelope math (next section) reveals that ±1% error in the URR implies ±⅓ year in timing the peak. Unless the URR is known with unusual accuracy, and all other uncertainties are negligible, peak oil predictions that omit error bars run a very large risk of "crying wolf", even if they're approximately correct. On the scale of 150 years of oil production, "approximately correct" might mean 20 years. Responsibility to the public demands an explicit analysis of uncertainties. This is the task we set ourselves.

Royal Dutch/Shell lowered its reserves estimates 33% in one year (2004). The URR might be unreliable to a similar degree, and for similar reasons – it is probably much smaller than the USGS estimate of 2.6×10^{12} barrels. We appreciate that geologists like Campbell, Deffeyes and Laherrère have worked hard to correct various data, but how much uncertainty is left? If 1% error in the URR implies peaking ⅓ year earlier, "the peak" might even be behind us (but for the advent of horizontal drilling?). Without knowing the spread of possible times, a pin-point date is worthless. Mathematically, every real number (time) has zero chance of being correct.

It should also be obvious that we cannot locate the peak ahead of us with better accuracy than we can locate it behind us. If we believe that there's so much noise in the world that we won't know we've passed the peak until a year or two later, then with even less information now, "a year or two" would be the smallest possible uncertainty. (NB we said "If".)

II. Back-of-the-Envelope

Supposing global oil production is a bell-shaped function of time (a Gaussian), how much would the peak move if the URR were actually smaller/larger? On this model, the quantity of oil produced each year would be

$$p = \int \frac{URR}{\sqrt{2\pi}\,\sigma} e^{-(t-T)^2/2\sigma^2} dt$$

The quantity under the integral sign is instantaneous production, and the integral is over one year. Now if we vary the URR, the peak of production moves … not at all. We omitted to nail down the *beginning* of the bell-curve. We can accomplish this by making

$$\frac{\sigma_2}{\sigma_1} = \sqrt[3]{\frac{URR_2}{URR_1}} \quad \text{and} \quad T_1 - 3\sigma_1 = T_2 - 3\sigma_2$$

With $URR_2 = (1+\varepsilon)\times URR_1$ a Taylor series expansion yields $\sigma_2/\sigma_1 \approx 1+\varepsilon/3$ (for $\varepsilon \ll 1$) so the peak moves by

$$T_2 - T_1 = 3(\sigma_2 - \sigma_1) = 3\sigma_1(\sigma_2/\sigma_1 - 1) \approx \sigma_1 \times \varepsilon.$$

Our Gaussian model of global production found $\sigma_1 \approx$ 30 years, so ±1% of URR → ±0.3 years, or 5.5 days per billion (10^9) barrels. Same answer as in [1].

That was easy, but only because we assumed a lot. Is global oil production a bell-curve? (We can't be sure.) Is it Gaussian? (Unlikely.) If not, can we still use σ_1? (No. Our models say 2×10^{12} barrels ±1% → peak ± 0.42 years, or 7.7 days per 10^9 barrels.)

III. STATISTICS RESULTS

We have a relatively uncontroversial record of past global oil production. It reflects oil fields and technologies brought on-line along the way, contributions from marginal fields, fields already in decline, decline of the British Empire and rise of the American, two world wars, two oil shocks, and population growth. *We view our analysis as extrapolating all the uncertainties of the past century, into the future up to the peak, with no need to go further.*

A. Bell Curves?

Goodness-of-fit tests (Wilcoxon-Mann-Whitney, Kolmogorov-Smirnoff, Kuiper) are not valid when applied to models whose parameters are estimated from the data. We did it anyway, and got "null" results: there is insufficient evidence to reject bell-curve models. This doesn't mean that some bell-curve model is correct.

"Pearson's r" test found no correlation between oil discoveries from one year to the next, i.e. discoveries appear to be random. But there is > 99% confidence that annual oil production is not a random process. (It looks like a bell-curve, not very noisy.)

After we had fitted our best models to the oil production data, the residuals (data – model) were not random noise (> 99% confidence from autocorrela-tion with Pearson's r), so none of our models are complete. The residuals hint of a 10-year cycle.

B. Least-squares And Chi-squares

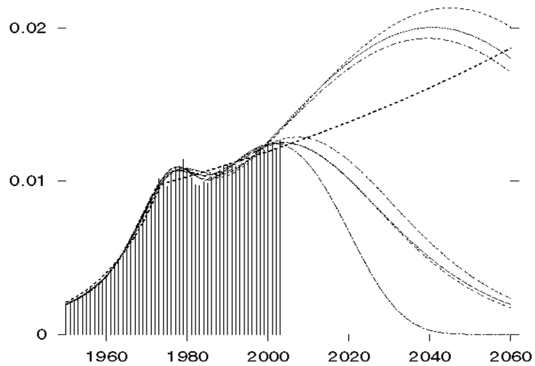
Least-squares fitting presumes that all data have equal significance, i.e. equal-size error-bars. This is highly unlikely, as annual production has grown from 0 to 25×10^9 barrels. More likely, the annual variance (σ^2) is proportional to annual production (no production, no uncertainty), and the cumulative variance is the sum of annual variances. Weighting the model's fit to each year's production p_i by a confidence $\propto 1/p_i$ leads to the "chi-square" goodness-of-fit criterion $\chi^2 \propto \Sigma\ (p_i - fit_i)^2/p_i$. (The proportionality constant is unknown, and is not needed to compare models.)

Despite the preceding point, we used both least-squares and χ^2 criteria to fit models to both annual and cumulative global oil production. Their scores correlate well.

The models we fitted included single bell-curves, weighted sums of two bell-curves, and two exponential-growth curves laid head-to-toe. We used 8 key types of bell-curves, which behave like several dozen other types under suitable choices of their parameters. For example, Student's t distribution can behave like the Cauchy and Gaussian distributions (but we fitted a Gaussian also, to see how it scored).

C. Devilish Details

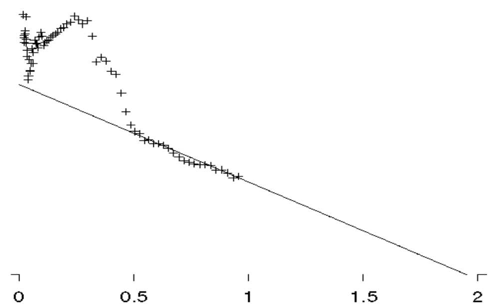
If the URR was allowed to vary as part of fitting, one model moved it to 1.5×10^{12} barrels and peaked around 1995; some models moved it to $\approx 5\times10^{12}$ and peaked around 2045 (see figure below)! The latter behavior arose for models with too-thin tails on the left side; it suggests that the Gaussian-related bell-



curves (Gaussian, lognormal, gamma, Student's t) are not very good models of annual oil production.

To prevent such extremes, the URR had to be pinned down, so we charted *y* = annual production / cumulative production against *x* = cumulative production (see below). Laherrère had written that if the production curve was a Logistic, this would produce a straight line having the URR as its x-intercept. This turned out to be true of all the bell-curves we examined. The URR implied by production data is slightly less than 2.0×10^{12} barrels. We used 2.0×10^{12} to fit all our models.

The next difficulty was that when we fitted pure



bell-curves to annual production data, the models' *cumulative* production far exceeded real cumulative production. This occurred because the production bump in the 1970s pulls the left side of the models upward, so that the models' annual production is too high for many years before and after that bump (figure below). We fixed this by a) forcing all the

Solid lines show 1-bell models, dotted lines show

corresponding weighted-sum-of-2-bells models.

models' cumulative production to equal real cumulative production in 2003, and b) modeling annual production as a weighted sum of two bell-curves, a big one ≈ 93%, plus a small one ≈ 7% for the 1970s bump.

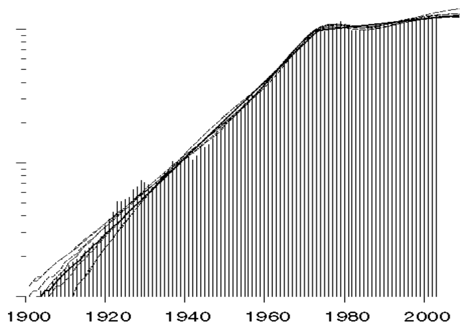
Thus we discovered that the 1970s bump was not only pulling the models upward, it was pulling them left-ward too: the peaks of the 1-bell-curve models came 2–3 years earlier than they deserved. Not only was this an easy mistake to make, it also shows how far peaks can move, over a technical detail.

D. Selected Insights

The best-fitting 2-bell models were (best first) the Burr, Bass, Logistic and Weibull models. The Bass [3] Product Diffusion Equation's p parameter went to zero so it equaled the Logistic. Their peaks came in early-2005, 2008, 2008, and 2014 respectively. That's quite a spread! The later they peaked, the higher they went and the faster they declined.

The worst-fitting models were the normal, lognormal, gamma and Student's t – all cousins. To figure out why, we made a semi-log chart of the annual data:

This revealed that the Gaussian *et al* left tails were



too thin (below real production in the early 1900s).

This chart led to another insight: the data looks like two straight lines joined at the mid-1970s. When we fitted such a model (two exponential growth curves joined end-to-end) it scored a better χ^2 than the Gaussian! From this model we realized that

- Global oil production grew very steadily 6.5 % per year for all of 1900–75, but only 1.2 %/year since 1982. That would explain how China's 9 %/year growth and demand could pull up the price of oil.
- The current oil price rise could also be due to US dollar devaluation, or fear of terrorism, or… Peak Oil may or may not have anything to do with it.
- Contrary to popular belief, Gaussians are not good models for time series. The Central Limit Theorem applies to random walks through *controllable* dimensions. To apply to oil production, the theory would have to be that God dropped 2 trillion barrels directly above the year 2008, and the barrels scattered forwards and backwards through time from there. That's obviously silly.
- The theories behind the well-fitting Burr, Bass and Logistic models are economic. Indeed, Peak Oil can be regarded as a change of regime, from economic choice to natural physical limits.
- The (extreme-value) theory for the Weibull model is that we pump the easy oil first, until production becomes difficult everywhere and many major fields peak at about the same time. This model fits well, predicts zero production before the mid-1800s (without being told that it's so), is comfortable with a URR of 2 trillion barrels, and predicts the last peak (in 2014) and fastest decline.
- The model consisting of two exponential-growth curves joined at the 1970s implies that there must be a third curve eventually to model falling production, but the transition can occur anytime up to (a vertical drop in) 2040, no way to predict when. Yet we have no reason to discount this model.
- *A good fit neither makes a model true, nor implies a better prediction, but a bad fit is a contradiction.*
- *Therefore, a single model can neither prove nor disprove any URR number. But* all *our bell-curve models validate the nearly-straight line that projects to* < $2{\times}10^{12}$ *barrels of "conventional" crude.*

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How General Is The Hubbert Curve? The Case of Fisheries

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The Hubbert model of crude oil production can describe several regional cases, but it is not yet generally accepted as being of validi for all cases, especially for the worldwide case of oil extraction. The present paper shows that the model is of general validity to describe cases in which a resource is depleted faster than it can be replaced, as in the case of biological resources. In some cases, historical fishery data appear to be relevant for understanding the present price trends of crude oil.

I. INTRODUCTION

In the 1950s, M. K. Hubbert was the first to use a symmetric bell shaped curve to fit the production trends of crude oil. The method turned out to be successful in describing the production of the 48 lower US states and in predicting the peak year (1971). There are several other regions of the world where oil production also followed a single bell shaped curve and others where a number of bell curves can be identified (1).

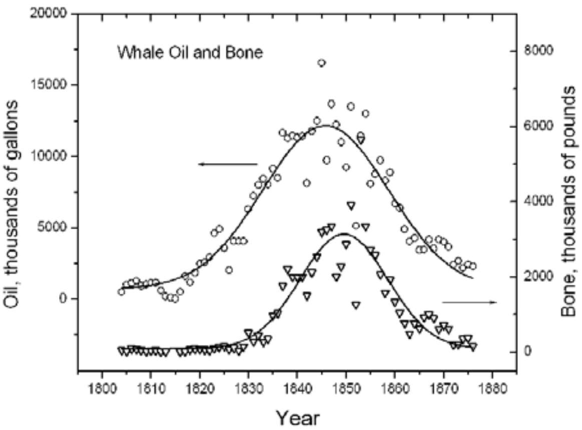
If the global oil production curve will follow Hubbert's model, that is it will follow bell shaped, symmetric curve, the consequences on the global economy are potentially enormous. However, doubts have been cast on the general validity of the Hubbert model (see, e.g. (2)).

As shown in (3,4) the Hubbert model can be derived from general assumptions. Nevertheless, the confidence placed on the use of a specific model to describe a system ultimately derives from its successful use in describing historical cases. There is no doubt that Hubbert curves describe *regional* cases of the extraction of crude oil and of other mineral resources, but there no precedent, so far, of a mineral resource terminally depleted worldwide.

However, since the Hubbert model is of very general applicability, it should be valid not only for mineral resources but for all cases in which a resource is depleted much faster than it can be replaced. This is the case of some biological resources, e.g. fisheries, where several examples of total, or nearly total, depletion of the resource are known. Cases which are especially interesting for a comparison with worldwide crude oil depletion are those where a) a resource went through a complete depletion cycle b) the market for that resource was global, or at least limited to a closed economic region and c) there was no equivalent resource able to substitute the depleted one. From these cases we can also obtain relevant information about price trends over the whole depletion cycle. We show here that for the cases for which data exist, prices show a tendency to exponential growth after the Hubbert peak.

II. HISTORICAL CASES

A complete Hubbert cycle can be observed for whale hunting in 19th century (data from ref. 5). (fig.



1).

Fig. 1 Production of whale oil and whale bone (baleen)

As reported in more detail in (6), the production curves for both whale oil and "whale bone" (or "baleen") followed a symmetric bell shaped curve The market of whale oil was global already in 19th century and its decline was caused by depletion and not, at least at the beginning, by the shift to a different resource. Here, the data have been fitted with a simple Gaussian curve which was shown to provide a good approximation for the Hubbert model (3)

The price data for whale oil (corrected for inflation (7)) are reported in fig 2 as a function of depletion. The data show a considerable upwards jump at ca. 60% depletion, i.e. some time after the Hubbert peak, followed by a plateau. Plotted as a function of time, the price of whale oil shows an exponential rise after the peak.

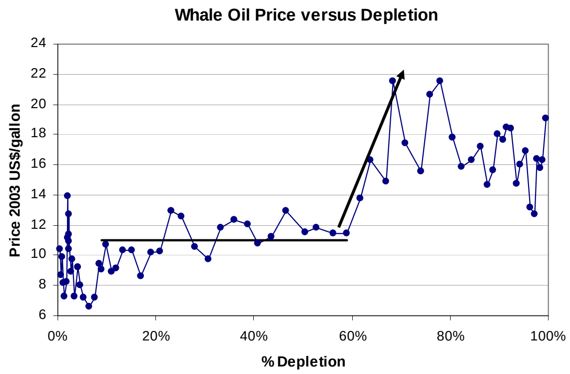


Fig 2: Whale oil price versus depletion

Another case, similar to that of whales, is that of the Caspian sturgeon, the source of caviar. The data for worldwide sturgeon landings (8) are shown in fig. 3.

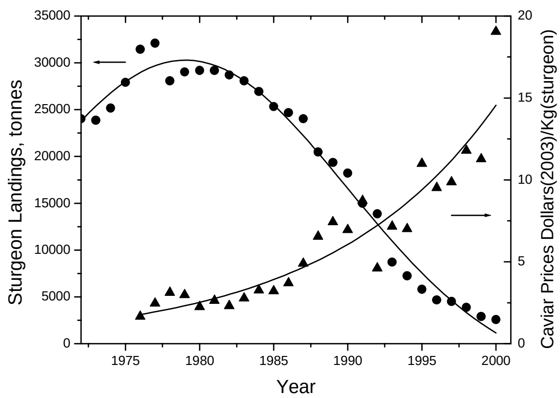


Fig 3. Prices of caviar and sturgeon landings

The production data have been fitted with a Gaussian function. Inflation corrected prices for caviar (7) show a rising exponential growth starting after the Hubbert peak. Here, the price plateau observed for whale oil does not occur. The difference can be explained considering that the plateau for whale oil prices may be due to the development of crude oil as a replacement for whale oil, whereas no such replacement exists for caviar.

Examining fishery data, several other cases of bell shaped production curves can be found. For the case of Tasmanian scallops, three distinct bell shaped production curves can be observed. Also in this case, price data exist and do indicate an exponential growth after the production peak. Even the global fisheries production may be following a bell shaped curve which may have peaked in the early 1990s (9).

III. CONCLUSION

The comparison of fisheries and of mineral extraction shows that the human pressure on the environment is causing a wide range of resources to go through a depletion cycle which follows Hubbert's law. The case of some fisheries; sturgeons 19th century whales, and scallops may be especially relevant for the comparison with conventional crude oil extraction. In all these cases, we have a non-replaceable, or at least not easily replaceable, resource being depleted worldwide. If these are representative examples of price trends for resources which undergo total depletion, we may expect the price of conventional crude oil to start an exponentially rising trend in the vicinity, or slighlty after, the Hubbert peak. The fact that such an exponential rise may have already started is an indication that we may be close to, or have already passed the peak

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Former Soviet Union Oil Production and GDP Decline: Granger Causality and the Multi-Cycle Hubbert Curve

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This paper discusses the transition of the Former Soviet Union (FSU) from a communist country to a set of capitalist and mostly democratic countries. The prevalent explanation of the break-up is that economic inefficiencies and Reagan Administration policies caused a fall in Soviet GDP that subsequently created political discontent and a move toward individual sovereignty. The model shown here looks at the fall of Soviet and former Soviet GDP in relation to oil and energy. The analysis shows that the fall in Soviet and former Soviet GDP in the 1980s and 1990s did not Granger cause the decline in oil production, but that a decline in oil production did Granger cause the fall in GDP. However, the coal to GDP relationship shows the opposite and the natural gas to GDP relationship shows no Granger causality at all. This puts into question the normal inefficiency argument and suggests that oil had something to do with the break-up.

If indeed we are to believe in the pure Soviet inefficiency argument as the main cause of the Soviet decline, then a theory must be shown as to why only one year before the Soviet economy began to unfold, its oil production started declining. Yet coal production declined after the fall of the Soviet GDP as we would expect. Natural gas production on the other hand stayed relatively steady during the turmoil due to high fixed costs of production that were already sunk costs and due to low marginal costs of continued production. Both the coal and natural gas production histories would make sense for oil, yet oil shows neither of these characteristics. Instead oil decline happens before the fall of GDP.

Over and over again the emphasis in the fall of the Soviet Union, and even the decline in oil production, is on communist inefficiency and a lack of technology. Yet communist inefficiency was in play when the Soviet economy and Soviet oil production were all increasing in the 1950s, 1960s and 1970s. Therefore, communist inefficiency in and of itself could not have caused the decline of the Soviet Union or of Soviet oil production. There has to have been another factor.

Resource scarcity is that factor. Within a consistently communist system oil production managed to go up as long as oil reserves were relatively abundant. However, once scarcity increased substantially, the communist system saw declining oil production which in turn caused their inefficient economic system to finally decline. It required scarcity and inefficiency together to create the fall, not inefficiency by itself. Nevertheless, it is still not clear in the West whether an efficient, high-tech economy can withstand an oil shortage. Evidence shows that oil scarcity has been more powerful than technology in adversely affecting economic growth in North America, Japan, and Western Europe. As for the Soviet Union, the overwhelming evidence is that there was an oil scarcity problem within its economic system before the fall of Soviet GDP, and because the USSR was a virtually closed system, that oil shortage caused its fall and decline.

Interestingly, U.S. oil production peaked in 1970, but since the dollar was the global reserve currency in the post-Bretton Woods world, the United States could “import its way out of the problem.” The USSR did not have the “seignorage” option of just sending its own money abroad in exchange for commodities, so once its oil production peaked, the economic system had to decline to accommodate an oil shortage.

A Hubbert forecast of oil production shows that Soviet and former Soviet oil production is following a multi-cycle Hubbert trend and that the region's oil production is forecast to peak in 2009.

Peak Oil and the Nymex Futures Market: Do Investors Believe In Physical Realities?

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Peak oil recognition is growing both among the oil experts and the generalist media. However the world crude oil markets and in particular the NYMEX futures market seem to point to prediction of long term inexpensive crude. In this paper we analyse the price curve of the NYMEX crude oil futures contracts for different dates and we compare the results with Peak Oil projected time frames as presented by several researchers. From this study we conclude that, at present, the market traders don't expect a future rise in the crude oil prices. This way, the market investors seem to be at odds with the – by now clearly accepted – peak of oil production.

I. Introduction

Crude oil futures contracts for distant time horizons are the main quantitative measure to ascertain the perspectives of the economic entities interested in this commodity (for example oil companies, large oil consumers – e.g., air transport companies – and investors). The most important of the markets that trade these futures contracts is NYMEX.

This way, considering the growing awareness of the incoming peak of oil production (usually known as *Peak Oil*) it seemed reasonable to expect that the market participants would recognize a future supply problem through higher prices for long term contracts.

In this work we use the NYMEX futures prices distribution over time and the Peak Oil date projections of several authors to evaluate the awareness of the market participants to this important phenomenon that seems certain to happen in a not distant future.

II. Peak Oil Date Predictions

There are multiple date predictions for Peak Oil. In this paper, instead of searching independently for this kind of predictions, we used a table indicating the most important recent predictions for this date from a February 2005 report sponsored by an agency of the United States Government [1]. This table (Table 1 in this paper) is used because it seems to be a reliable information source to study the time distribution of the most relevant Peak Oil predictions.

Author	Date
Bakhtiari, A.	2006-2007
Simmons, M.	2007-2009
Skrebowski, C.	After 2007
Deffeyes, K.	Before 2009
Goodstein, D.	Before 2010
Campbell, C.	Around 2010
World Energy Council	After 2010
Laherrere, J.	2010-2020
EIA – reference case	2016
CERA	After 2020
Shell	After 2024
Lynch, M.	No peak

Table 1. Peal oil projected dates from several authors (table extracted from [1]).

It should be noted that Campbell's estimate (around 2010 in Table 1) was recently brought forward to 2008 [2].

The data in Table 1 shows that the majority of the experts in this field point to a peak occurring before 2010 and the most optimistic predictions point to a date between 2010 and 2025 (with greater incidence in dates up to 2020). Our personal perspective agrees with the average point of view referenced in this table and points to a peak between 2008 and 2012.

III. Nymex Prices Analysis

In Table 2 we present the closing prices (in USD) and the number of open contracts for the 2005-03-11 session for several future contracts traded in NYMEX. This data was obtained from the NYMEX website [3]. The number of open contracts up to December 2010 is clearly significant and so should

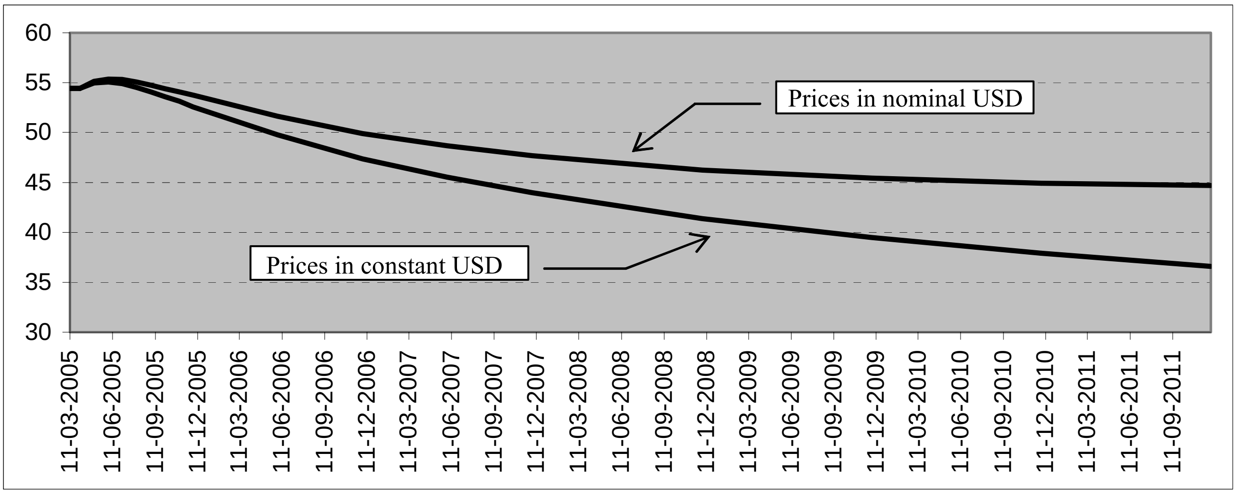

Figure 1. Price in USD of crude oil futures contracts for different time frames

represent a consistent market perspective. The open interests for December 2011 are significantly lower. This is due to the fact that the trading of this contract has begun very recently.

Contract	Last	Open Int.
Cash (CLY00)	54.43	0
April '05 (CLJ05)	54.43	133313
May '05 (CLK05)	55.12	179552
June '05 (CLM05)	55.35	90462
July '05 (CLN05)	55.31	37394
August '05 (CLQ05)	55.07	28379
September '05 (CLU05)	54.75	24223
October '05 (CLV05)	54.41	19905
November '05 (CLX05)	54.07	18153
December '05 (CLZ05)	53.75	68297
June '06 (CLM06)	51.62	19948
December '06 (CLZ06)	49.88	44912
June '07 (CLM07)	48.65	9067
December '07 (CLZ07)	47.67	27562
December '08 (CLZ08)	46.22	26860
December '09 (CLZ09)	45.42	14498
December '10 (CLZ10)	44.93	17670
December '11 (CLZ11)	44.68	4238

Table 2. NYMEX crude oil future contracts: close values in 2005-03-11, in USD.

Figure 1 presents two curves that illustrate the prices of the contracts listed in Table 1. The first represents the nominal USD prices as they appear in Table 1. The second represents the same prices but corrected (at a very conservative rate of 3% per year) to reflect the usual contango situation of futures markets (due to the value of the postponement of the payment and of the cost of the commodities storage).

These curves show that the market participants expect crude prices to drop significantly in the long term in relation to today's prices. However, accepting the reality of the Peak Oil and the prediction dates shown in Table 1, one could expect for December 2011 a significant rise in crude prices.

In fact even if the market participants adopted an optimistic perspective about the peak date (for example in line of EIA's prediction for 2016) several reasons would still imply that the December 2011 prices should already be at a higher level. So, the prices evolution shown in Figure 1 clearly points to a 'business-as-usual' ignorance of the Peak Oil problem from the part of the market participants.

IV. Conclusions

This work shows that even the persons and companies directly involved in crude oil trading have a deficient understanding of the supply problems that should be expected to happen in a not distant future.

However, considering the recent crude price increases and the recent media awareness for this problem, we believe that this market misconception will tend to be corrected relatively fast.

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The Fifth Kondratieff Wave: The Fossil Fuels Apogee

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I. STRUCTURAL WAVES AND THE ROLE OF THE PRIMARY ENERGY SOURCES

Energy needs are related to three main factors: population growth, economic development and technological progress. It is convenient to enhance two great transitions that were responsible for the structural transformations that occurred in energy systems. First, the steam engine (associated to coal) and, second, the increase of diversification of the final use technologies and the energy sources diversification. The first transition is related to the first and second technological transformations, while the second transition is, even if not exclusively, linked with the third and fourth technological transformations, to highlight electricity as means of energy transportation and internal combustion engine associate to oil. In technological terms, it was during the last 250 years that five major technological transformations happened. These transformations appeared intermittently within a period of about a half-century and are linked with waves in the economic activity, and that result from the convergent development on several fields during the past 250 years. The first transformation (1770-1800) was linked with the substitution of wood for coal as a primary energy source, with consequences in iron-making, in fuelling the first steam engine, in building the first canals and in mechanizing cotton spinning. The second transformation (1830-1850) was related to the use of the steam power to the textile industry and to transportation (railways and steam boat). The third transformation (1860-1900) was a complex one: it centered itself on steel making and on the mechanization of manufacturing, on illumination, telephones, electrification and on the internal combustion engines. It was also characterized by the beginning of the substitution of coal by oil as primary energy source. The fourth transformation (1930-1950) was centered on synthetic materials and electronics. Finally, the fifth, beginning around 1990, centers itself on the convergence of computers, telecommunications and news technologies. This is to say, the first three had a greater influence on industry, being nicknamed as "industrial revolutions". However, the fourth transformation had larger impact on the consumer, given the great amount of new products. The fifth one will influence the industry as much as the consumer, due to the emergence of new products and industrial technologies (also new industries) that will lead this wave.

Bearing in mind these data, there are no doubts that the primary energy sources are associated to the major technological transformations and consequently associated to the structural long waves (frequently known as Kondratieff Waves or simply K-waves). Coal began to substitute wood in the eighteenth century (1st technological transformation, responsible for the economic expansion of the 1st K-wave), being diffused in the nineteenth century (it surpassed wood in the peak of the 2nd K-wave), reaching the stagnation (beginning of the decline) in the twentieth century (it reached the maximum point in the peak of the 3rd K-wave). During the period from 1800 to 1920, coal went from providing around 10% to over 60% of the word's total commercial energy requirements, being linked to the iron and steel industries, being the primary energy source of the first and second technological transformations. However, the non-solid fossils (NSF - oil and natural gas) began to substitute coal in the nineteenth century (3rd technological transformation, responsible for the economic expansion of the 3rd K-wave), being diffused in the twentieth century (they surpassed coal in the peak of the 4th K-wave), being foreseen the reach of stagnation in the present century (the maximum point (turning point) in the peak the 5th K-wave). During the period from 1920 to 1973, the oil market share grew from 10% to around 50%, being mainly linked to the automobile industry, being the primary energy source to the 3rd and 4th technological transformations.

II. FUTURE PERSPECTIVES

In the past, it was possible to observe a relationship between primary energy sources substitution and socio-economic development, and consequently a relationship between primary energy sources substitution and K-waves. And in future how will it be? Making use of two of technological forecasting tools, namely the logistics curve and the Delphi technique, three long-term scenarios were built: an exploratory one, using the multiple substitution logistics, an Delphi-based indicative one, and another one resulting from combination of the two previous one (hybrid scenario) [1]. In general terms, the indications of the Delphi survey confirm the dynamics of the logistic substitution. Thus, it can be concluded that a substitution of the NSF for the alternative energies sources will happen in the future, considering the NSF grouping and the alternatives cluster. Our study points out to the leadership of the alternative energies as the main primary energy by 2050-2070. Even if the long structural waves cannot be considered as a forecast tool, they can aid on tendencies extrapolation, given the substitution of the wood by coal and coal by NSF, such as we can observe in the figure 1. This figure seems to point out a coincidence of the market share peak of a new primary energy source with each third wave, indicating a coincidence of the peak of the alternatives with the peak of the 6th KW. In this sense, we can foresee the fossil fuels apogee for this fifth K-Wave.

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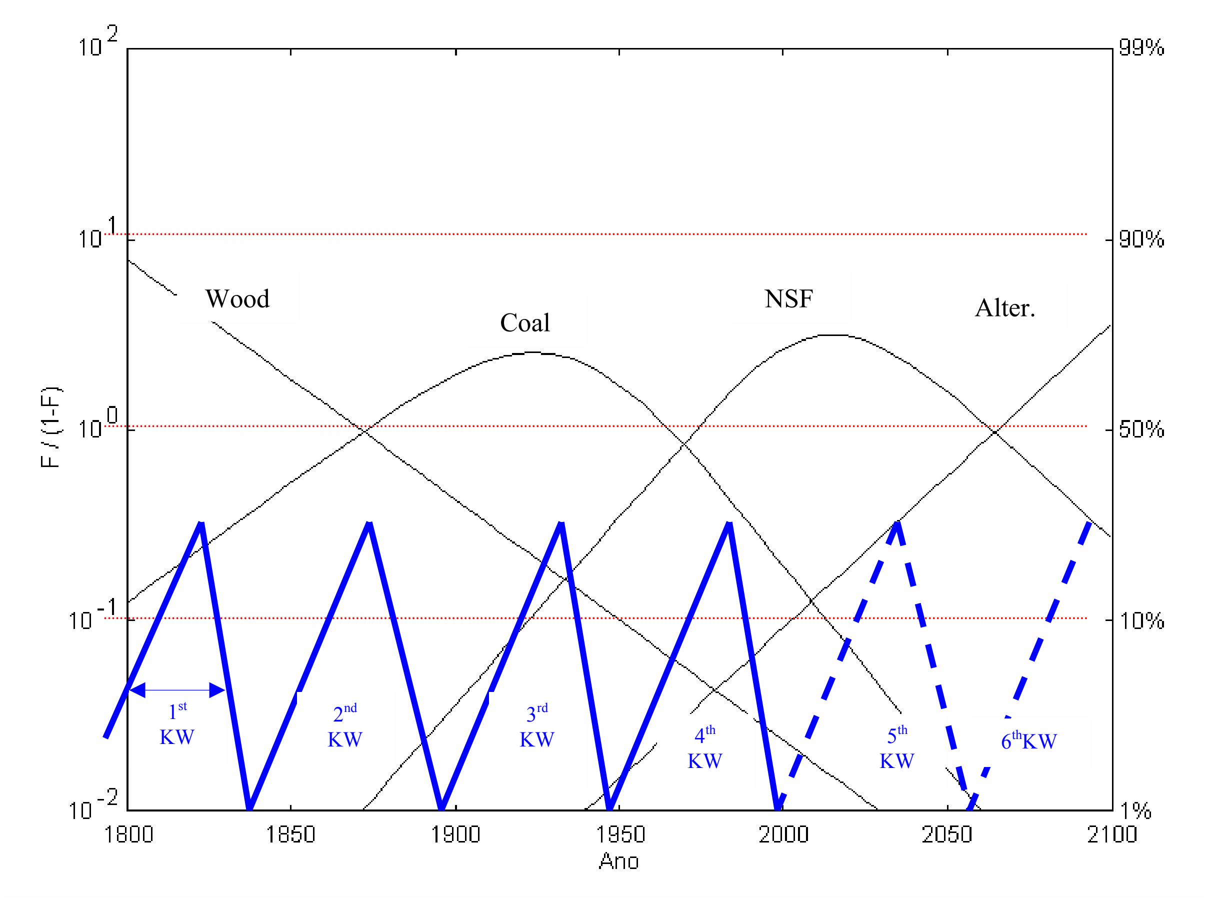

Figure 1 – Correspondence between Primary Energy Sources Substitution and Structural Long Waves (KW – Kondratieff Wave).

The Need for Biophysical Economics

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We are all aware of the limits of conventional (neoclassical) economics (e.g. Hall et al. 2001) but a problem has been whether "internalizing externalities" is enough to resolve the issues. Quite a few of us think that we must start over in deriving a conceptual base for economics. One such possibility is biophysical economics, a description of which follows.

Biophysical economics is a basis for economic analysis that acknowledges, analyzes and uses the biological and physical (as opposed to social) properties, structures and processes of real economic systems as its conceptual base and fundamental model. It acknowledges that the basis for nearly all wealth is nature, and views most human economic activity as a means to increase (directly or indirectly) the exploitation of nature to generate more wealth. As such, it focuses on the structure and function of real economies from an energy and material perspective, but often considers the relation of this structure and function to human welfare and to the money (i.e. dollar) flows that tend to go in the opposite direction to energy (Odum 1972). From a biophysical perspective, one's job is viewed as trading one's time at work (the monetary value of which is related to the energy flows of society controlled by the individual) for access through salaries to the energy flows of the general economy. This "general economy" contains goods and services created from the extraction of energy from the earth in anticipation of some demand for them. At present, each dollar we spend requires roughly 12,000 Kjoules (about an 8-oz. coffee cup's worth of oil or equivalent energy) to generate the good or service purchased. With economic inflation, the energy per dollar decreases over time so that in 1970, one could receive about ten times more energy (as used to generate goods and services) per dollar than he or she could today. The ice cream that fueled my paper route in 1954 cost only 5 cents, but required for production roughly the same amount of energy as today.

Figure 1 is my perception of the simplest diagram that one could use to represent a real economy, although it is far more complex and infinitely more accurate than that what is given in most economics textbooks. It includes (from left to right): (1) energy sources (principally, the sun) that are essential for any economy; (2) the material that circulates upon the earth's surface through natural and semi-natural ecosystems; and (3) the human-dominated steps of exploitation, processing, manufacturing and consumption. Black and white arrows show the transfer of material and energy through the economy. Raw materials are refined by human activities until the heat is dissipated and the materials are either released as wastes to the environment or recycled back into the system. From this diagram, one could argue that the most important activity of the economic process is the proper functioning of the hydrological cycle, since virtually all economic production and manufacturing are extremely water-intensive. From the standpoint of a traditional economist, the hydrological cycle is not important because we pay very little for it. A biophysical economist, on the other hand, would argue that it is critical for many reasons and that it is only because we can extract its services from nature at little direct monetary cost that we can have the high generation of wealth within today's economy.

PRODUCTION FUNCTIONS FROM A BIOPHYSICAL PERSPECTIVE

The source of wealth, according to economists and their explicit mathematical production functions has evolved over time from an emphasis on land to an emphasis on labor to an emphasis on capital. From the perspective of biophysical economics, all three of these miss the boat entirely, for each of these factors is an imperfect representation of the dominant energy source that does the actual economic production for the economy at the time being considered. For example, hunter-gatherer societies obtained food using the energy of each individual's muscular activities and the force-concentrating technologies of spear points and knife blades. The labor of artisans generated items exchangeable for food and other commodities. The concentrated energy of fire led to a large expansion in the food that people could eat, a reduction in the pathogens in that food, and the use of metals.

Farmers redirected the solar energy of ecosystems to human mouths so that land became a source of wealth as emphasized by economists prior to the industrial revolution. The energy of elevated water and fossil fuels generated the basis for wealth during the 19th and 20th century. Over time, landed gentry with access to large solar collectors were replaced by new industrialists who took their place at the top of the financial ladder. Therefore, Quesnay was correct for the time and place in which he lived, when land-derived capture of solar energy generated the most wealth. Adam Smith was correct for the time and place in which *he* lived, when labor was increasingly the main way to generate wealth. Perhaps neoclassical economists are correct to put the focus on capital, i.e. the use of machines and ancillary equipment to do the job, or should it instead be on the energy that actually does the work? What all of these "mainstream" production functions fail to emphasize is what every biophysical economist knows to be the truth: it is the *energy* that does the work of producing and distributing wealth, whether that energy is derived from land, labor or capital-assisted fossil fuels. Ayres (e.g. 2005), Kuemmel (e.g. in Hall et al. 2001) and Hall and Ko (e.g. 2004) have shown that the production of wealth in industrial societies is almost perfectly a linear function of the energy use in those societies, and that the correlation gets tighter and tighter when proper corrections are made for the quality of the energy used (e.g. coal vs. electricity) and for the amount of energy actually applied to the process (e.g. electric arc vs. Bessemer furnaces). Much, perhaps most, technology is ultimately about these things.

It may seem obvious now that wealth is generated by the application of energy by human society to the exploitation of natural resources. Nature generates the raw materials with solar and geological energies, and human-directed "work processes" are used to bring those materials into the economy as goods and services. These processes have been made enormously more powerful over time through technologies that are mostly ways to use more or higher quality energies to do the job. To construct a production equation from a biophysical perspective, energy would be the first element to be considered because it is the most important factor – more important empirically than *either* capital or labor (Hall et al. 2001). It should be emphasized that this view does not negate the

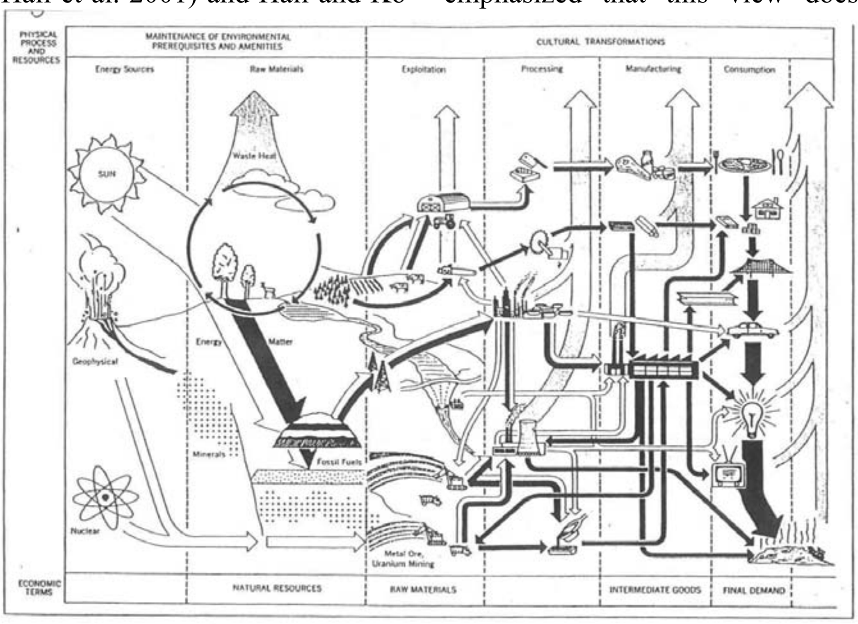

Figure 3A A more comprehensive and accurate model of how economies actually work. The second column of this diagram represents the entire global ecosystem milieu within which the rest of the global economy operates. Natural energies drive geological, biological, and chemical cycles that produce natural resources and public service functions and maintain the milieu essential for all other economic steps. Extractive sectors use economic energies to exploit natural resources and convert them to raw materials. Raw materials are used by manufacturing and other intermediate sectors to produce final goods and services. These final goods and services are distributed by the commercial sector to final demand. Eventually, nonrecycled materials and waste heat return to the environment as waste products. We believe this diagram to be the minimum model of how a real economy works.

importance of human preferences or of the market as a means to allocate goods and services. Rather, it focuses on the source of those goods and services and on our increasing vulnerability to the depletion of the critical high-grade fuels that we rely upon so heavily (Hall et al. 2003, Hallock et al. 2004).

BIOGRAPHIES

KJELL ALEKLETT

Kjell Aleklett is Professor of Physics at the Department of Radiation Sciences at Uppsala University, Sweden. He holds a doctorate degree from the University of Gothenburg, Sweden. His doctoral thesis was titled, 'Total beta-decay properties and masses of nuclei far away from beta stability.'
He worked as a post-doctoral staff scientist at the Natural Science Laboratory at Studsvik. In 1978-79 and again in 1983, he was invited to work with Nobel Prize winner Glenn T. Seaborg at the Lawrence Berkley Laboratory. In 1986 he was appointed Associate Professor at Uppsala University. His main research interest has been nuclear physics.
His interest in the global energy situation started in 1995 and has grown dramatically since then. He organised the First International Workshop on Oil Depletion in May 2002 at Uppsala University. Subsequently, he obtained research grants from the Swedish government and from private industry, which made it possible to start the Uppsala Hydrocarbon Depletion Group in January 2003.

PEDRO ALMEIDA

Pedro Domingues de Almeida, born in 1959 in Porto, Portugal.
Electrotechnical Engineer (University of Coimbra, Portugal), MSc. in Computer Science (University of Coimbra), and Ph.D. in Computer Engineering (UBI – University of Beira Interior, Portugal).
Assistant professor at the Computer Science Department of the University of Beira Interior, Portugal.
Main research interests are intelligent data analysis and knowledge extraction from data, financial prediction, photovoltaic energy systems, and energy use in present and future societies.

ROBERT U. AYRES

Prof. Ayres was trained as a theoretical physicist (BS Chicago, 1954, MS U Maryland 1956, PhD London, 1958). His interest in environmental affairs began in the early 1960s when he worked at the Hudson Institute on environmental implications of nuclear conflict. In the late 1960s he went to Resources for the Future (RFF), to help initiate a new program on environmental economics.
In 1969 he co-founded and managed a small consultancy in Washington DC focused on energy, transportation, and environmental problems, while also writing several books. In 1979 he was appointed Professor of Engineering and Public Policy at Carnegie-Mellon University, where he specialized partly on manufacturing and robotics and partly on industrial metabolism or industrial ecology. A stint at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria (1986-2000) persuaded him to return to his earlier environmental interests. In 1992 he was appointed Sandoz Professor of Environment and Management at INSEAD, in Fontainebleau, France. He retired, as Emeritus Professor in 2000. From 2000 to 2002 he was
Visiting Professor at the Institute for Advanced Study (IAS) of the UN University in Tokyo (part time). In 2000 he was appointed Jubilee Professor at Chalmers Institute of Technology, Gothenburg, Sweden, where he continued as a visiting professor (part time) through 2003. In 2004 he was appointed Institute Scholar, at IIASA (part time) and King Carl XVI Gustav Professor of Environmental Science, at Chalmers, Gothenburg University and Kalmar University in Sweden. He has written more than 200 peer-reviewed journal articles or book chapters, written or co-authored 18 books, and edited or co-edited 12 books. He has also received several prizes for his work, including the Kenneth Boulding Prize of the International Society for Ecological Economics (ISEE) (2002) and the first award for outstanding research of the International Society for Industrial Ecology.(ISIE).

ALI MORTEZA SAMSAM BAKHTIARI

Born in 1946 at Tehran, Iran.

1964-1971: B.Sc., M.Sc. and Ph.D. in Chemical Engineering (Swiss Federal Institute of Technology (ETH), Zurich, Switzerland).
1971-2005: Regular employee at the National Iranian Oil Company (NIOC), Tehran, Iran. Presently 'senior expert' in NIOC's Corporate Planning Division.
1972-1991: Part-time lecturer at the Chemical Engineering Department (Technical Faculty of Tehran University -- TFTU).

1976-2005: Author of dozens of scientific articles related to the international oil and gas industry and participation in many international conferences (all four ASPOs).

2001-2005: Creator and co-director of website <www.samsambakhtiari.com> --- author of "Letter from Tehran" and "Insights".

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Born in Firenze (Italy) May 23rd 1952. Italian citizen, married.

Laurea in Chemistry (27/9/1976) Università di Firenze

Positions Held:

Associate professor in Physical Chemistry, University of Firenze, Italy.

1980-1982: Postdoctoral, University of Berkeley (Ca), USA.

1977-1979: Assistent, faculté de Physique, University of Aix-Marseille, France.

1976-1977: Postdoctoral, State University if New York at Stony Brook

Fellowships Stages in foreign research institutes:

May -Sept 1985: FullBright Fellowship. Lawrence Berkeley Laboratory, USA. Oct 1986–May 1987: Matsumae International Foundation Fellowship, University of Tokyo. Feb 1994-Mar 1994: Fellowship of the Japanese society for the progress of science (JSPS), Universitv of Tokyo. Feb 1997 – Apr 1997: Fellowship of the University of Tokyo

Field of expertise:

Surface chemistry and surface Science, with special emphasis on materials and coatings, especially by electrochemical techniques. From 2001, strategic studies of resource depletion in collaboration with the Association for the Study of Peak Oil and Gas (ASPO)

Other:

Author of more than 100 papers in international reviewed journals. Author of a large number of contributed papers at international conferences, Holder of several national and international grants. International coordinator of NATO, ESF and CRUI grants. Local coordinator of the 4th framework BRITE project DESCO, 5th framework ABRANEW, 6th framework DESIRE, ASTERIXE and REACT. International coordinator of the FW 6 STREP "IOLISURF".

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(Updated Jan 2005)

ROGER W. BENTLEY

Dr. Bentley is CTO of Whitfield Solar Ltd., and Secretary of the Association for the Study of Peak Oil and Gas (ASPO).

Previously he was a Senior Research Fellow in the Dept. of Cybernetics, University of Reading, where he worked on solar energy and oil and gas depletion. He remains a member of Reading's 'Oil Resources Group'. For a year he was Coordinator of the Oil Depletion Analysis Centre (ODAC), London.

Dr. Bentley has given talks on global oil depletion to academic groups, companies, research institutions and governments. He has published some 40 papers, of which 10 are on hydrocarbon depletion. Of the latter, recent ones are:

- *Oil Forecasts: Past and Present*. R.W. Bentley. Energy Exploration and Exploitation, Vol. 20, No. 6, pp 481-492, Multi-Science, 2002.
- *Global oil and gas depletion: an overview*. R.W. Bentley. Energy Policy, February 2002, pp 189-205, Elsevier.
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See also www.oildepletion.org.

CARLOS BRUHN

Carlos H.L. Bruhn was born in February 12th, 1958, in Porto Alegre, southern Brazil. He began his geology studies at the Rio Grande do Sul Federal University in 1976, and graduated with a B.Sc. in Geology from the Bahia Federal University in 1980.

Since joining Petrobras (the Brazilian national oil company) in 1981, he has been working on various exploration and production assignments in eastern Brazilian marginal basins. He obtained his M.Sc. in 1985 from the Ouro Preto Federal University, at which time he studied lacustrine turbidites from the Recôncavo rift basin. He received a Ph.D. in geology from McMaster University (Canada) in 1993, after developing a project on turbidite

reservoirs from the Campos and Espírito Santo passive margin basins. In the same year, he received the Canadian Society of Petroleum Geologists Award for the best Ph.D. thesis in petroleum geology presented in Canada that year.
From 1993 to 2000 he integrated multidisciplinary teams responsible for the management and reservoir characterization studies of the oilfields from deep-water Campos Basin. He has also done consulting work in most of the Petrobras E&P offices across the country, and has taught several courses in the Petrobras internal training program, and in the M.Sc. program on Reservoir Geology and Engineering of the Campinas University, Brazil. In 1998 and 2000 taught courses sponsored by the American Association of Petroleum Geologists (AAPG) on deep-water, petroleum reservoirs.
In November 2000, became Petrobras E&P Corporate Manager for Reservoir Characterization. More recently, he served as 2001-2002 AAPG Distinguished Lecturer.

COLIN J. CAMPBELL

Colin J. Campbell was born in 1931 spending his early years in England. After securing a Ph D in Geology at Oxford in 1957, he joined the oil industry as an exploration geologist, undertaking field work in Trinidad, Colombia and Papua. In 1968, he moved to New York as Regional Geologist for South America, being also involved in an assessment of worldwide oil resources and exploration potential, before being appointed Chief Geologist of a venture in the Amazon headwaters of Ecuador. In 1972, he returned to England as General Manager of an oil company organising exploration ventures in the North Sea and other areas, before ending his career as an Executive Vice-President in Norway, where he was involved in another study of world reserves and depletion for the Government.
In “retirement” he found himself consulting for major companies and governments. In 1995, he co-authored a definitive study by a consultancy, based on details of some 24 000 oilfields, which drew attention to the issue of Peak Oil.
He has written five books on oil depletion, as well as numerous scientific publications. He was the founder of ASPO, and his work now attracts much media interest. He has given presentations to the House of Commons in London and the Irish Senate. He now lives in Ireland.

YVES COCHET, MP

Yves Cochet was born February 15 1946 in Rennes (France). He is widower. He has a daughter, Céline, 31 years, teacher.
President of the science students in the University of Rennes, he finishes his graduate studies in mathematics, 1968. He becomes teacher and researcher in the National institute of the Applied Sciences (INSA) of Rennes in 1969 and supports his thesis in mathematics, June 1971.
During the seventies, he participates actively to the antinuclear fights in Brittany and adheres to the two ecological associations (Living Brittany, Waters and Rivers in Brittany). Simultaneously, from 1976 to 1980, he constructs himself his solar house and intervenes publicly into many meetings on energy.
Member of “Friends of the Earth” as early as 1973, Yves Cochet founds the local group Friends of the Earth in Rennes, 1977. In 1980-81, he participates actively in the national campaign of the ecologists for the presidential elections. He is the kingpin of the negotiations that result in the creation of the Greens, in Clichy, January 1984. He is spokesperson of the Greens from 1984 until 1997.
In March 1989, Yves Cochet is elected town councillor in Rennes, then Member of the European Parliament in June 1989.
On the 1st of June 1997, he is elected Member of the French Parliament, then becomes Vice President of this national assembly.
July 12 2001, he succeeds Dominique Voynet as Minister of the Territory and Environment in the government of Lionel Jospin, until May 6 2002. He participates to the great international meetings of environmental governance and sustainable development (climatic conferences in Bonn and in Marrakesh, G8 Environment in Banff, biodiversity conference in the Hague).
June 16 2002, he is elected Member of the French Parliament (Paris constituency).
October 21 2003, he publishes with Agnès Sinaï the book "Save the Earth" (Fayard Publishing).

MANUEL COLLARES-PEREIRA

Electrotechnical Engineer (IST-Technical University of Lisbon), Ph.D. in Physics (Univ. of Chicago).
Presently Coordinator of Research at INETI (National Institute for Engineering, Technology and Innovation)- Lisbon, Renewable Energies

Department and Professor in the Physics Department (IST, Technical University of Lisbon-Lisbon).
Responsible for the R&D Department of AO SOL, Energias Renováveis, Ltd, manufacturer of CPC type collectors, under a special agreement with INETI to that effect. Founder of SUN CO, Companhia de Energia Solar, S.A., producer of solar cookers. Extensive research in Solar Energy as a specialist in Optics and Thermodynamics, with a large number of scientific papers and other publications in areas like Non Imaging Optics applied to Solar Thermal, Photovoltaics, Illumination and Photocatalysis, Solar Irradiation Statistics, Solar Thermal Systems Design and Engineering, Domestic Hot Water and Heating and Cooling Systems, Absorption and Adsorption Cooling Equipment, Solar Drying, Solar Ponds, Solar Cooking , Greenhouses Heating.
Founder and twice President of CCE- Centro para a Conservação de Energia (the then acting Portuguese Energy Agency), founder and twice President of SPES- Sociedade Portuguesa de Energia Solar, the Portuguese Section of ISES, and twice President of ACTD- Associação para a Ciência, Tecnologia e Desenvolvimento.

ANTÓNIO COSTA-SILVA

António Costa Silva is Chairman of the Management Commission of PARTEX OIL AND GAS Group. PARTEX is involved in oil and gas operations in Abu Dhabi, Oman, Kazakhstan, Brazil and Algeria.
He holds a MSc in Mining Engineering from the Technical University of Lisbon (IST), a MSc in Petroleum Engineering from the Imperial College (University of London) and a Doctorate Degree from the Technical University of Lisbon and Imperial College on "Development of Stochastic Models applied to Oil Reservoirs.
From 2001 to 2003 he worked at French Institute of Petroleum (IFP) in the BEICIP-FRANLAB organization as Director of Operations and Head of Reservoir Engineering Department. He was in charge of the coordination and supervision of the Technical Teams, responsible for the execution of the Hassi-Messaoud Project for Sonatrach in Algeria (encompassing Reservoir Modeling, Reservoir Simulation, Field Development planning, design of the Miscible Gas Injection Scheme), the Cantarel Project for Pemex (Mexico), the El Furrial, Zapatos and Bachaquero projects for PDVSA in Venezuela, the North Harad Project for the Gawhar field in Saudi Arabia and the Gaschran and Salman Projects in Iran. He acted also as the Project Manager for the Determination of the Reserves of an off-shore field in China, being appointed by the Stockholm Chamber of Commerce as the international expert responsible for the arbitration of a dispute on the Reserves issue.
From 1998 to 2001 he was General Manager of CGG (Compagnie Générale de Geophysique) office in Lisbon coordinating E&P activities and projects in the Middle East (Bahrain) and Mexico dealing with Reservoir Modeling, Reserves Evaluation and Field Development Planning. He supported the team involved in the execution of an integrated study for the Awali Field in Bahrain and encompassing petrophysical evaluation, reservoir modeling, dynamic simulation and field development planning for 11 different reservoirs. He developed also the reservoir engineering analysis of the Ogarrio field in Mexico, involving the development of the petrophysical correlations and their integration with the geological model, the pressure behavior and the analysis of the waterflood performance.
In 1980 he started his professional activity in Angola with SONANGOL as a member of the Production Department performing studies of the production profiles, reservoir performance, well testing analysis and interpretation in fields of the Cuanza Basin in Angola.
From 1984 to 2000 he worked at CPS (Companhia Portuguesa de Serviços) and among other projects, executed a Tacis Project "Assistance for New Oil Field Development" supported by the European Commission (DGI) and performed for the Oblast Administration of Western Siberia (Tyumen). He executed also several projects in the Middle East involving modeling and simulation of carbonate reservoirs and optimization of the Field Development Plans.

Dr. HERMAN FRANSSEN

Dr. Herman Franssen is the President of International Energy Associates Inc of Chevy Chase, Maryland since 1996. The group provides energy economic analysis of global oil markets; conducts political risk assessments; assists companies in establishing relationships with NOC's and governments in the Middle East and other oil and gas producing regions.

Dr. Franssen is a Director of Petroleum Economics Ltd (PEL) of London, an internationally well known energy consulting company with considerable expertise in such areas as price formation, competitive positioning, economic and political geography, project evaluation, market regulation, and current and emerging technologies.
He is a Senior Fellow with CSIS in Washington, DC and MEC in London, an Adjunct Scholar at the Middle East Institute in Washington, DC as well as a visiting fellow at the CGES (Yamani Centre) in London.
Prior to establishing IEA Inc., Dr. Franssen was Senior Economic Advisor of H.E. the Minister of Petroleum and Minerals of the Sultanate of Oman (1985-1996), advising the Minister on crude oil marketing, international oil policy, foreign investments in the oil and gas sectors. Acted as principal liaison of the Ministry of Petroleum with the OPEC Secretariat as well as individual oil exporting and oil consuming countries.
From 1980-1985, Dr. Franssen was Chief Economist of the IEA and in this capacity was responsible for energy economic analysis of the IEA and for the first major IEA World Energy Outlook in 1983. Between 1978 and 1980, Dr. Franssen had similar responsibilities in the US Department of Energy as Director of the Office of International Market Analysis.
Between 1974 and 1978, Dr. Franssen was a Research Associate on Science Policy at the Congressional Research Service of the US Congress, providing Senators, Congressmen and Congressional committees with advice on ocean policy, ranging from Coastal Zone Management to mineral exploitation and national security issues.
Dr. Franssen was born in The Netherlands where he attended the University of Amsterdam. He received a BA from Macalester College in St.Paul, Minnesota and an MA, MALD and PhD from the Fletcher School of Law and Diplomacy in Medford, Mass.

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J. Peter Gerling is head of the "Energy Resources" section of the Federal Institute for Geosciences and Natural Resources (BGR), which acts as an advisory body to the German government and conducts aid projects in developing countries. He received his Diplom (equivalent to an MSc) in geology and paleontology and his Dr.rer.nat. in geochemistry from the Westfälische Wilhelms-University of Münster. After three years working as an exploration geologist for a German oil company, he joined BGR as an oil and gas geochemist in 1984, working on a variety of national and international oil and gas basin studies. He was BGR's liaison officer in the German Ministry of Economics in 1996.

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Graduate & Postgraduate Program: Thesis Director: 13 students graduated (8 in last five years); 4 currently; Dissertation Director: 14 students graduated (7 in last five years); 7 currently.
Honored for exceptional achievement in teaching by ESF Foundation.
Synergetic Activities: Charles A. S. Hall is a Systems Ecologist, hence integration, modeling and energy are his focus always. Many teaching and research activities at Syracuse and throughout Latin America focusing on intersection of environment, resources and economics, resulting in the publication of many papers and books. Many interactive activities with colleagues interested in energetics of both natural and human dominated ecosystems: e.g. measuring total system metabolism of forests in Puerto Rico. Long term studies of aquatic systems in Montana, New York, and entire human economies in the U.S., Costa Rica and Argentina.
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RICHARD HEINBERG

Richard Heinberg is a journalist and educator, and is the author of six books including *The Party's Over: Oil, War and the Fate of Industrial Societies* (2003), and *Powerdown: Options and Actions for a Post-Carbon World* (2004).
He is a Core Faculty member of New College of California in Santa Rosa, where he teaches a program on "Culture, Ecology and Sustainable Community."
His monthly *MuseLetter* (now in its 14th year, www.museletter.com) has been nominated for an Alternative Press Award, his essays and articles have appeared in many journals, and his books have been translated into eight languages.
He travels internationally to speak on the subject of Peak Oil and has given over 100 presentations on the subject before university and general audiences.

Dr. ROBERT L. HIRSCH

Dr. Hirsch is a Senior Energy Program Advisor at SAIC and a consultant in energy, technology, and management. Previously, he was a senior staff member at RAND, where he did energy policy analysis. Prior to that, he was Executive Advisor at Advanced Power Technologies, Inc. (APTI), where he developed and evaluated startup business opportunities and provided programmatic support to the Department of Energy's Environmental Management Program.
His primary experience is in research, development, and commercial applications. He has managed technology programs in oil and natural gas exploration and production, petroleum refining, synthetic fuels, fusion, fission, renewables, defense technologies, chemical analysis, and basic research. Previous management positions include:
- Vice President of the Electric Power Research Institute (EPRI).
- Vice President and Manager of Research and Technical Services for Atlantic Richfield Co. (Oil and gas exploration and production).
- Founder and CEO of APTI, a $50 million/year, employee owned company recently sold to BAE Systems (Commercial & Defense Department technologies).
- Manager of Exxon's synthetic fuels research laboratory.
- Manager of Petroleum Exploratory Research at Exxon (Refining R & D).
- Assistant Administrator of the U.S. Energy Research and Development Administration (ERDA) responsible for renewables, fusion, geothermal and basic research (Presidential Appointment).
- Director of fusion research at the U.S. Atomic Energy Commission and ERDA.

He has served on advisory committees for Department of Energy programs and national laboratories, the General Accounting Office, the Office of Technology Assessment, the Gas Research Institute, and NASA. He holds 14 patents and has over 40 publications. He is immediate past Chairman of the Board on Energy and Environmental Systems of the National Research Council, the operating arm of the National Academies, has served on a number of National Research Council committees and is a National Associate of the National Academies.
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KLAUS ILLUM

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M.Sc., civil engineering, The Technical University of Denmark, 1962.
Ph.D., Energy Systems and Energy Planning, Aalborg University, 1981.
From 1962-74 mainly occupied with the development of educational programs in computer science alongside with studies in systems theory and cybernetics at the Danish Academy of Engineering.
Thereafter, mainly engaged in the development of methods and computer models for the technological, environmental and economic analysis of alternative scenarios for the development of energy systems and agricultural production systems at the Department of Development and Planning, Aalborg University, Denmark.
Since 1984 also engaged in studies of environmental policies and problems in Central and Eastern European countries. 1990-98: programme manager for energy planning projects in Czechoslovakia, financed by the Danish Ministry of Energy and Environment. 1997-98: programme manager for the Nordic Council of Ministers training programme for energy experts in the Baltic States.
Has developed the SESAM model (The Sustainable Energy Systems Analysis Model), an advanced

generic computer model for the analysis of scenarios for the future development of national, regional or local energy systems. The SESAM model has been used and is presently being used for the integrated technological, environmental, and economic analysis of present and possible future energy systems infrastructures in Denmark, the Czech Republic, Slovenia, and the region comprising the Nordic countries.

EDDY ISAACS Ph.D.

Eddy Isaacs is the Managing Director of the Alberta Energy Research Institute (AERI) with a responsibility for Alberta's strategic directions and investments in energy innovation areas that include conventional and unconventional oil and gas, coal, petrochemicals, carbon and water management and alternate and renewable energy.

He has been instrumental in promoting the formation of innovation networks in energy and environment across Canada and the establishment of Energy Innovation Network (EnergyINet).

Previously, Eddy served for more than 20 years with the Alberta Research Council (ARC) where he was responsible for ARC's programs in heavy oil and oil sands.

Eddy holds a Ph.D. from the University of Alberta and a B.Sc. from McGill University and has served for several years as an adjunct professor in the Department of Chemical and Material Engineering, University of Alberta. He has over 50 publications and 5 patents in the energy field.

Eddy serves on the Boards of the Petroleum Technology Alliance of Canada (PTAC), Canadian Oil Sands Network for Research and Development (CONRAD) and NewEra and is the co-Chair of the Energy Technology Working Group of the Canadian Council of Energy Ministers.

MICHAEL T. KLARE

Michael T. Klare is the Five College Professor of Peace and World Security Studies (a joint appointment at Amherst, Hampshire, Mount Holyoke, and Smith Colleges and the University of Massachusetts at Amherst) and Director of the Five College Program in Peace and World Security Studies (PAWSS), positions he has held since 1985.

Professor Klare has written widely on U.S. defense policy, the arms trade, and world security affairs. He is the author of: *Blood and Oil: The Dangers and Consequences of America's Growing Petroleum Dependency* (2004); *Resource Wars: The New Landscape of Global Conflict* (2001); *Rogue States and Nuclear Outlaws* (1995); *American Arms Supermarket* (1984); and *War Without End: American Planning for the Next Vietnams* (1974). In addition, he is the editor or co-editor of several books, including *Light Weapons and Civil Conflict: Controlling the Tools of Violence* (1999); *Low-Intensity Warfare* (1988); and *World Security: Challenges for a New Century* (three editions).

Professor Klare is also the defense correspondent of *The Nation* magazine, a Contributing Editor of *Current History*, and a member of the Editorial Board of the *Bulletin of the Atomic Scientists*. He has contributed articles to these journals and to *Arms Control Today*, *Foreign Affairs*, *Foreign Policy*, *International Security*, *Le Monde Diplomatique*, *Scientific American*, *Technology Review*, and *Third World Quarterly*, among others.

MAREK KOLODZIEJ

Marek Kolodziej is a Ph.D. student in economics at the University of Illinois at Chicago. From the very beginning, his interest within economics was sustainable development and the thermodynamic constraints on economic activity. This interest has naturally led to his focus on global energy supply in general, and oil and natural gas in particular.

Mr. Kolodziej has given a presentation of ASPO's oil supply model at an oil depletion seminar held on July 1, 2004 at the Center for Social and Economic Research in Warsaw, Poland (http://www.case.com.pl/strona--ID-seminaria_wewnetrzne,seminarium_id-2988129,nlang-19.html). Present were several senior Polish economists, including a member of the Monetary Policy Council of the National Bank of Poland.

Mr. Kolodziej, along with Professor Douglas Reynolds from the University of Alaska-Fairbanks, are in the process of publishing a paper about the contribution of the 1987 Soviet oil peak to the collapse of the USSR. The paper also includes a forecast which suggests a secondary peak in 2009. The paper is entitled "Former Soviet Union Oil Production and GDP Decline: Granger Causality and the Multi-Cycle Hubbert Curve" and has been submitted to the Energy Economics Journal. Due to copyright issues, it cannot be posted on-line. However, please contact Mr. Kolodziej at mkolod3@uic.edu if you wish to receive a copy of the article for your personal use. All comments and critiques would be appreciated.

JEAN LAHERRERE

Born May 30, 1931
After graduation from Ecole Polytechnique and Ecole Nationale du Pétrole in Paris, he participated with Compagnie Francaise des Pétroles (now TOTAL) in the Sahara exploration with the discoveries of two supergiant fields: Hassi Messaoud and Hassi R'Mel. He went to explore Central, Southern and Western Australia. He was in charge of exploration in Canada for TOTAL in Calgary where he started exploring Labrador Sea and Michigan.
After 15 years overseas, he went to TOTAL headquarters in Paris where he was in charge successively of the new ventures negotiation, technical services and research, basin exploration departments and finally deputy exploration manager. He was member of the Safety Panel of the Ocean Drilling Program (JOIDES). He was President of the Exploration Commission of the Comité des Techniciens of the Union Française de l'Industrie Pétrolière where he directed the publication of a dozen of manuals. He was director of Compagnie Génerale de Geophysique, Petrosystems and various TOTAL subsidiaries. After 37 years of worldwide exploration with TOTAL, he retired in 1991.
He is now writing articles and giving lectures. He has written several reports with Petroconsultants and Petroleum Economist on world's oil and gas potential and future production. He was a member of the "Society of Petroleum Engineers/World Petroleum Congress ad hoc Committee on joint definitions of petroleum reserves" and also a member of the task force on "Perspectives Energie 2010-2020" for the "Commissariat Général du Plan". His graphs are used in the International Energy Agency 1998 report "World International Outlook" and in the World Energy Council reports 2000 "Energy for tomorrow's world –Acting Now" & 2004 "Drivers of the energy scene". He chaired the 2002 World Petroleum Congress (Rio of Janeiro) panel on hydrates (RFP9 "Economic Use of Hydrates: Dream or Reality?"). He is a member of ASPO (Association for the Study of Peak Oil and gas).

RAY LEONARD

Ray Leonard was born in New York, of a family of Ukrainian ancestry. He received a Bachelor of Science in Geology from the University of Arizona and a Master of Arts in Geology from the University of Texas at Austin.
His 19-year career with Amoco was entirely associated with international projects. Initial assignments were in Trinidad, Norway and West Africa. In 1989, he was appointed the Director of New Ventures for the Soviet Union, Eastern Europe and China. He was in a unique position to view the political and economic changes taking place. In 1995, he was appointed Vice President for Resource Acquisitions, Amoco Eurasia. In June 1998, he accepted a position as Exploration Vice President for First International Oil Company (FIOC), a newly formed company in Almaty, Kazakstan. He accepted a position as Vice President-Exploration and New Ventures in Moscow for YUKOS, the second largest Russian Oil Company in January 2001 with responsibility for diversifying the YUKOS upstream portfolio out of the core areas of West Siberia and Samara, specifically East Siberia, the Russian Shelf and Central Asia, and concluding partnership agreements with non-Russian companies.
In January 2005 he joined MOL, the Hungarian Oil and Gas Company with the highest market capitalization (approx 9 billion USD) of any company in Eastern Europe as Senior Vice President for International Exploration and Production. He now resides in Budapest.

MARIANO MARZO

Mariano Marzo is full professor of Stratigraphy at the Faculty of Geology of the University of Barcelona where he teaches Petroleum Geology and Energy Resources. He received and M.S. degree in geology from the University of Barcelona in 1975 and a Ph.D. in geology from the same university in 1980.
M. Marzo's research interests focus on the application of clastic sedimentology, sequence stratigraphy, reservoir modelling, and basin analysis to the exploration and production of hydrocarbons. He is actively involved in training activities and

research projects funded by oil companies (ConocoPhillips, ExxonMobil, Norsk Hydro, Repsol-Ypf, Shell, Statoil and Total among others). He has worked in southern Europe, North Sea, South America, northern Africa and Middle East.
M. Marzo has authored and co-authored 75 scientific papers, edited 15 books and special issues on sedimentology and stratigraphy, held more than 100 presentations on conferences and workshops and has served in the editorial board of highly-reputed international geological journals like "Basin Research" and "Geology". He is a regular contributor on energy issues to the main Spain's media and newspapers. M. Marzo is member of the American Association of Petroleum Geologists and of the European Association of Petroleum Geoscientists & Engineers.

JOÃO CARLOS de OLIVEIRA MATIAS

João Carlos de Oliveira Matias is Assistant Professor of the Department of the Electromechanical Engineering of the University of Beira Interior and member of the Technological Forecasting and Theory Research Group, being responsible for its foundation.
He has a B.Sc. in Mechanical Engineering (University of Coimbra, Coimbra, Portugal, 1994), a M.Sc. in Quality Management (University of Beira Interior, Covilhã, Portugal, 1997), and a PhD degree in Production Engineering (University of Beira Interior, Covilhã, Portugal, 2003) in Technological Forecasting, conducting research in "Future Scenarios for Primary Energy Sources". He is author of more than 30 articles published in several national and international periodicals and congresses proceedings.

RT HON MICHAEL MEACHER, MP

Michael Meacher was educated at Berkhamstead School, New College Oxford and the London School of Economics.
He joined the Labour Party in 1962 and has been *Labour Member* for Oldham West 1970-97 and *Oldham West and Royton* since 1 May 1997. He contested Colchester in 1966 and Oldham West in 1968.
His political appointments comprise: Under Secretary for Industry, 1974-75; Under Secretary for Health and Social Security, 1975-79; Candidate for Labour Party Deputy Leadership, 1983; Member of Labour Party National Executive Committee 1983-89; Member of Shadow Cabinet 1983-1997; Labour Party Chief Opposition Spokesman on Health and Social Security, 1983-87; Chief Opposition Spokesman on Employment 1987-89; Chief Opposition Spokesman on Social Security 1989-1992; Chief Opposition Spokesman on Overseas Development and Co-operation July 1992 to November 1993; Chief Opposition Spokesman on Public Service and Citizens' Rights 1993-1994; Chief Opposition Spokesman on Transport 1994-1995; Chief Opposition Spokesman on Employment 1995-1996; Chief Opposition Spokesman on Environmental Protection from July 1996 to May 1997. *Privy Counsellor May 1997. Minister of State for the Environment May 1997 to June 2003.*
He was a member of the Select Committee on the Treasury and Civil Service (1981-83). Member of the Environmental Audit Committee since 1997.
His special political interests embrace Environmental Protection and Sustainable Development, Economic Policy, Industry and Trade Policy, Reform of the Machinery of Government, Reform of the Media, Housing, Education and Social Services. His book "Diffusing Power: The Key to Socialist Revival" was published in July 1992.
His other affiliations are membership of UNISON, The Fabian Society, SERA and the Child Poverty Action Group.
His hobbies include sport, music and reading.

RUI NAMORADO-ROSA

Rui Namorado Rosa is full professor of Physics at the University of Évora and a visiting professor at the Technical University of Lisbon, Portugal.
He holds a degree in Physical and Chemical Sciences by the University of Lisbon (1961) and a D.Phil. by the University of Oxford in Plasma Physics (1968).
He has worked in different fields since he started his scientific career in Radiation Chemistry back in 1961. He has done research and published in the fields of Plasma Physics, Micrometeorology, Earth Sciences, Thermal Engineering, Energy Resources, and History of Science. He kept a life-long interest in Energy resources and technologies.
Was attached staff at the Culham Laboratory (U.K.A.E.A.) in 1969. Was member or leader of research teams at the University of Évora, at the

former Nuclear Energy Board (up to 1979) and at the former National Laboratory for Industrial Engineering and Technology (up to 1983). Has published about ninety scientific and technical papers and essays and delivered many more communications, seminars and talks.
He took active part in the foundation of the Portuguese Physical Society (1974) and the Organization of Scientific Workers (1975), as well as of the Geophysics Centre of Évora (1991) and the Centre of History and Philosophy of Science - University of Évora (1995).
He held the presidency of the Scientific Council and the position of Vice-rector of the University of Évora. Is now the director of the Geophysics Centre of Évora (since 1999).

PROF. XIONQI PANG

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Long time working on the teaching and researching of basin analysis, petroleum resources evaluation and petroleum accumulation mechanism. More than 100 articles and 9 monographes published in related researching fields. Leading and Attending 26 projects from the national government, research departments and oil fields. In charge of the construction of Geology Resources and Geology Engineering (the first class subject of University of Petroleum(Beijing)) and Minerals Reconnaissance and Exploration(the key subject of our nation).
PRESENT POSITION
1. Director, Key Laboratory of Petroleum Reservoir Formation Mechanism, Chinese Ministry of Education
2. Research Assistant of the President, University of Petroleum (Beijing)
3. Editor Director of«Petroleum Science» and Editor of«Journal Of the University Of Petroleum, China», «Petroleum Exploration And Development» and «Natural Gas Geoscience».
AWARDS RECEIVED

- Brilliant Talent Award from the Education Ministry in 2003
- Special salary allowance from the China State Government since 2000
- Selected as one of future scientific program leaders in the field of petroleum geology in 1996
- Received the first prize and the second prize of the National Award for Advancing Science &Technology separately once
- Received the first prize, the second prize and the third prize of the Province/Ministry Award for Advancing Science &Technology totally seven times

RUDOLF RECHSTEINER, MP

Rudolf Rechsteiner, 1958, economist (Ph.D.), married, 2 children, lives in Basel/Switzerland
He is a member or the Swiss national Parliament since 1995, a member of the Committee for energy and environment, a member of the social-democratic party of Switzerland and a lecturer on energy and environmental policy at Basel University, Switzerland
Rudolf Rechsteiner is known for his publications on environmental and energy issues.
He is the head of ADEV Energy (http://www.adev.ch/), an Independent Power Producer Cooperative, founded in 1985, with solar, hydro wind and combined heat and power plants.
He also is a member of the Board of the state-owned gas & electricity Company of Basel (Industrielle Werke Basel), serving some 200'000 people and the Chemical Industry of Basel with pure hydro and CHP electricity.
Rechsteiner introduced a budget-neutral electricity tax of some 3 €C./kWh on state level in 1998 as an incentive for energy efficiency. He is engaged in the new law for an open electricity market in Switzerland and tries to introduce fair feed in tariffs for green electricity nationwide in Switzerland by 2007, like the German Model of Erneuerbare-Energien-Gesetz. Since 1975 Rechsteiner is engaged in the anti nuclear power movement that successfully enacted a 10-years stop for new nuclear power plants. In early 2003 he published the book „*Grün gewinnt* " (*Green wins)* where he showed depletion curves on oil and gas of many world areas, based on the work of Campbell and Laherrere.
Rechsteiner thinks that wind energy, geothermal and solar will grow exponentially and will deliver bulk power for most electricity and energy needs cost-effectively, in combination with new storage and continent-wide capacity management. He is pushing

a Renewable Vision politically too and has proposed a stronger integration of Swiss hydro storage within the European electricity market. His findings are based on scientific calculations done by the German physicist Gregor Czisch**.**
Rechsteiner is a strong critic of the International Energy Agency and its misleading pro-oil and pro-nuclear standing. He has some experience with Swiss hydro power and hydro power storage – crucial for wind energy and renewables capacity management. He is convinced that within a good legal framework electricity from renewables will develop as a least cost strategy in economic as well as in ecological perspective, probably within a decade only. Additionally there is vast potential of untapped efficiency gains. These technologies can offset the depletion of oil and gas world wide.

Essays in English: Ten steps to a sustainable energy future; Petroleum and conflicts - Strategies for Industrialized Countries. Downloads in German: http://www.rechsteiner-basel.ch/publikationen.cfm

BRUCE ROBINSON

Bruce Robinson is a member of the Sustainable Transport Coalition, in Perth, Western Australia. He is a physical scientist and has long worked in mineral exploration research. He also founded the WA Cyclists' Action Group in 1979.
Bruce has been studying oil depletion since hearing Brian Fleay talk in Perth in 1996. He helped arrange a visit to Australia by Les Magoon in 2001 He wrote the background paper on Oil Vulnerability for the WA Government's State Sustainability Strategy and presented papers on Oil Depletion at the 2003 International Sustainability Conference in Fremantle and to the Australasian Transport Research Forum in Adelaide in September 2004. He is a member of the Petroleum Exploration Society of Australia and has given seminars to many organisations.
He is a member of the Editorial Committee of "Petroleum Science", the international journal published by the University of Petroleum, China in Beijing.
He is the only Australian to have attended all three of the previous International Workshops on Oil Depletion.
The Sustainable Transport Coalition is a successful community-based group, with input from a range of government, conservation and transport-advocate bodies. It has held two conferences on oil depletion, including "Oil: Living with Less" in August 2004 at which Ali Samsam Bakhtiari was the keynote speaker. www.STCwa.org.au

KRISTIN RØNNING

Kristin Rønning. Born in 1964. Childhood in Bodø (Norther Norway). 2 children.
Staff Geologist. Statoil
1990: Cand Scient (Marine geology). University of Tromsø. Norway.
1990-today: Geologist, Statoil.
Seismic interpretation and stratigraphy. Prospect-, play- and basin-evaluation. Risk and resource assessment.

- Norway (Barents Sea and Norwegian Sea)
- Russia (Barents Sea, Pechora Sea, Okhotsk Sea)
- Screening of Russia and China.

CHRIS SANDERS

Chris Sanders has worked as a private banker and investment manager for twenty six years.
He is the managing director of Sanders Research Associates Ltd., an international consulting firm specializing in the analysis of the global political economy, and is a director of Atlantic Partners Investment Services Ltd., a global investment advisory firm located in Dublin. Sanders Research publishes a subscription based magazine on global economics, politics and markets at www.sandersresearch.com.
Mr. Sanders has spent much of his career in the Middle East, and holds a degree in Arabic Literature from the University of Michigan and a degree in Political Science from Duke University. He lectures on international economics at the University of Gothenburg’s School of Public Administration.

MARCEL SCHOPPERS

Dr Marcel Schoppers' studies took him from physics to applied mathematics to software engineering to artificial intelligence to robotics - all to make real things move well. Along the way he has also mastered electronics, statistics, image analysis,

simulation, decision theory, formal logics, and many other odds & ends.
He now has one eye on the heavens, where he helps operate the Mars Exploration Rovers, and his other eye on depleting natural resources and self-destructing economies. In both directions, he is heard remarking that "Nature doesn't care what anyone wants." He wishes to become involved with a raw materials industry such as energy, mining, fishing, or farming.

The Rt. Hon. EDWARD RICHARD SCHREYER

Edward Schreyer was first elected to the Manitoba Legislature in 1958 at age 22 and reelected in 8 consecutive elections in 21 years. He lectured on International relations at St. Paul's College then was elected NDP Member of Parliament for Selkirk 1965 and reelected in 1968. He became NDP leader 1969 and Premier of Manitoba 1969-77, The ensuing government enacted, for the first time, law and regulations requiring environmental impact assessment. He served concurrently as Minister Responsible for Manitoba Hydro precisely at the time major expansion was required, which in turn required choice between constructing major hydro works as opposed to a series of coal and gas thermal generating stations. His government introduced legislation that expanded public Health Care to include Home Care and Pharmaceuticals. Federal and other provincial governments developed similar programs soon after. Ed Schreyer served as: *Governor General of Canada and Commander-in-Chief 1979-84; as Canadian High Commissioner to Australia, Papua New Guinea, Solomon Islands & Ambassador to Vanuatu 1984-88.* He serves in various capacities in a number of organizations including Habitat for Humanity, The Canadian Shield Foundation, Sierra Legal Defense Fund, Hospital and Nursing Home care organizations, two Canada-based oil/gas exploration companies and a forest-products company. Since 1989 he has been guest professor at 4 universities in Canada and 5 in Europe: the focus throughout has been on Resource Geography, Energy Resource Options and Environmental Impact in Global Context. Mr. Schreyer currently serves on the Port of Vancouver Port Authority and Lake Winnipeg Stewardship Boards and is Special Advisor on Energy, Science and Technology to the Government of Manitoba. He serves as Director of the International Institute for Sustainable Development (IISD). He is a frequent guest speaker at fundraising and other public events relating to energy, conservation, multiculturalism and heritage preservation. He is married to Lily and they have 4 adult children living on 3 continents.

CHRIS SKREBOWSKI

Editor of Petroleum Review.
Chris has spent his entire working career in the oil industry split roughly two-thirds as an oil journalist and one-third as a planner/market analyst within the industry.
He became editor of Petroleum Review in June 1997 having edited Petroleum Economist for the previous three years. Prior to that he had eight years working for the Saudis as an oil market analyst in London.
Chris started his working career in 1970 as a long-term planner for BP and then joined Petroleum Times as a journalist just before the first oil crisis of 1973/74. In the late 1970s he edited Offshore Services, an offshore oil magazine.
As well as writing extensively for a range of oil industry related publications he has also broadcast on radio and TV on oil and gas subjects. One of the founder members of the ASPO (Association for the study of Peak Oil) group he has a great interest in oil depletion and its consequences. He is also a trustee on the board of ODAC (Oil Depletion Analysis Centre)

MATTHEW R. SIMMONS

Matthew Simmons is Chairman and Chief Executive Officer of Simmons & Company International, a specialized energy investment banking firm. The firm has completed over 500 investment banking projects for its worldwide energy clients at a combined dollar value of approximately $60 billion.
Mr. Simmons was raised in Kaysville, Utah. He graduated cum laude from the University of Utah and received an MBA with Distinction from Harvard Business School. He served on the faculty of Harvard Business School as a Research Associate for two years and was a Doctoral Candidate.
Mr. Simmons began a small venture capital, private debt placement, merger and acquisition firm in Boston. Among his early clients was a rapidly growing subsea service company. By 1973, most of his clients were oil service companies. Following the 1973 Oil Shock, Simmons decided to create a

Houston-based firm to concentrate on providing highest quality investment banking advice to the worldwide oil service industry. Over time, the specialization expanded into investment banking covering all aspects of the global energy industry.
Today the firm has approximately 150 employees and enjoys a leading role as one of the largest energy investment banking groups in the world. Its offices are in Houston, Texas; London, England; Boston, Massachusetts and Aberdeen, Scotland.
Mr. Simmons is a Trustee of The Farnsworth Art Museum in Rockland, Maine. He serves on the Board of Directors of Kerr-McGee Corporation (Oklahoma City), Brown-Forman Corporation, The Initiative for a Competitive Inner City (Boston), Houston Technology Center (Houston) and the Center for Houston's Future (Houston). He is Co-Chairman of the National Trust Council and also serves on The University of Texas M.D. Anderson Cancer Center Foundation Board of Visitors (Houston) and a Trustee of the Bermuda Biological Station for Research. In addition, he is past Chairman of the National Ocean Industry Association. He serves on the Board of Dean's Advisors of Harvard Business School and is a past President of the Harvard Business School Alumni Association and a former member of the Visiting Committee of Harvard Business School. He is a member of the Council on Foreign Relations and The Atlantic Council of the United States.
Mr. Simmons publishes numerous energy papers for industry journals and is a frequent speaker at government forums, energy symposiums and in board rooms of many leading energy companies around the world.
Mr. Simmons is married and has five daughters. His hobbies include watercolors, cooking, writing and travel.
(July 2004)

ROLF WILLKRANS

AB Volvo, Environmental Affairs, Dept 961 VHK, SE-405 08 Gothenburg. Phone +46 31 66 1145. email: rolf.Willkrans@volvo.com
Rolf Willkrans has been with the Volvo Group since 1996 starting at Volvo Truck Corporation as Product engineer followed by Environmental coordinator at Volvo Truck Headquarters. He has the position of Director Environmental Affairs at AB Volvo Headquarters in Gothenburg since 2001. His main responsibility is coordination and support of product related environmental issues within the Volvo Group.
Rolf Willkrans has a Master of Science in Mechanical Engineering at Lund University 1988.
He has a broad background from several different companies covering product development, purchasing and environmental care. He was a Design engineer at Svedala Arbra AB and TetraPak AB from 1980 to 1988. Then Purchasing Manager at Alfastar AB until 1990. After that Research Engineer at The Swedish Institute of Production Engineering Research until 1996, working with research projects within the environmental area.

JACK ZAGAR

Independent petroleum reservoir engineering consultant, an associate of MHA Petroleum Consultants, Inc. of Golden, Colorado and partner with noted author and world oil reserve expert, Dr. Colin Campbell.
Jack Zagar has thirty years experience in North Sea, onshore Europe, the Middle East (including 3 years with Aramco in Saudi Arabia), Gulf of Mexico, and onshore U.S.A. operations in petroleum reservoir engineering and reservoir management; economic evaluations of projects, property trades, and asset sales; and corporate planning.
Twenty-two years were with Exxon Corporation and Exxon U.S.A. The last eight years as an independent reservoir engineering consultant, Mr. Zagar has been with MHA Petroleum Consultants of Golden, Colorado and has partnered with noted author and world oil reserve expert, Dr. Colin Campbell.

EAMON RYAN, TD

Is a Green Party member of the Irish Parliment representing the constituency of Dublin South. He is the parties spokesperson on energy, transport and enterprise and he is the opposition convenor on the Joint Committee on Communications, Marine and Natural Resources within the Irish Parliment. He was the founder and managing director of Irish Cycling Safaris Ltd which is a leading activity holiday company and is former chairman of the Dublin Cycling Campaign.
He was elected to Dublin City Council in 1998 prior to being elected to the Irish Parliment 'Dail Eireann' in 2002. He is married to the writer Victoria White with whom he has four young children.