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New signals from an old industry – AAPG Convention Denver, June 7-10, 2009 A selective resumé of highlights and comments

Peter Burri[1]

1. General remarks

The Convention was very well attended; with almost 7000 professionals the number was close to the 2008 event in San Antonio. This is surprising since many companies have at present travel restrictions, and in Europe the EAGE (European Association of Geoscientists & Engineers) conference took place in the same week (an amazing demonstration of European-American miscommunication).

The quality of lectures by Majors was often disappointing. There was too much fear to give away proprietary thinking, too much motherhood. The best presentations came from small and medium sized independents. It looks as if the Majors have still not fully understood that they do no longer control the world activities in oil and gas and that the companies need to be more nimble and cooperative. However, presentations by the National Oil companies (NOCs) were even more disappointing.

The E&P Industry is brimming with activity and self-confidence. There was a sort of «crisis? – what crisis? - attitude» in the air and the exhibition had the highest number of exhibiting companies ever. In spite of the slowdown in the Industry there is in the US still a shortage of skilled and experienced people. Not enough students are taking up earth sciences and engineering. Asians will most likely fill the gap. Most companies have a strongly two peaked age distribution, a peak between 50-60 years and a peak between 30-35 years. By 2020 much of the present long-term experience will be gone.

A strong focus was, as in the previous year put on unconventionals and alternative energy: lectures on shale gas and tight gas, oil shales and tarsands drew always large crowds. New was, that topics like coalbed methane, CO_2 sequestration, renewable energies and discussions on global warming were included and found a lot of attention. There was for the first time a special session on geothermal energy. Contrary to some 10 years ago, the US are turning their attention in a big way to alternative sources of energy.

The AAPG is also moving away from being a pure oil and gas society towards being an association of energy related geologists. It is felt by many that we need to think «energy» rather than oil, gas, coal or nuclear. Only few companies, like Exxon, still resist such a move.

The present oil and gas companies will have to play a lead role in the development of alternatives, they have the technical know-how and the financial resources to initiate and achieve the change.

The worrying thing is, that only 10-20 years away from the point when fossil fuels will no longer be able to cover the rising energy demand, we still have no alternative energy that has a high energy density, is universally available, easily storable/transportable, environmentally accepted and affordable.

General message

We are not running out of oil but we are running out of cheap oil for 10-15 USD/bbl. A very significant production of oil and gas will have

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to be maintained over this century and even well into the next century, if only as a chemical raw material. Alternative, renewable energy needs still decades of development and only fossil fuel is capable to provide the bridge to new energy. It is oil, gas and coal that give the world the breathing space to achieve a smooth and economically affordable transition. E&P investments of several 100 billion USD/year are necessary over the next decades to achieve this. The willingness to invest such sums into very longterm projects and the supply of skilled people may eventually be the limiting factor.

The following comments are structured such that «diagonal reading» is possible.

2. Status of the Oil and Gas Industry

(Key note address by AAPG president Scott Tinker)

An excellent paper, detailing the special challenges the E&P Industry is facing at present and an outlook on the world's future energy supply and demand.

- The Industry has to work on its reputation which is dented by past omissions and insufficient communication. The oil and gas industry has proven to be much more responsible to the public than many other industries. Contrary to e.g. the financial industry and the car industry it has always been solving its challenges and problems itself («Any other industry that would have seen the price of its product fall by 75% in 6 months would have been crying for government help!»).
- Energy, economy and the environment are inextricably linked, they cannot and should not be played against each other. Without sufficient and affordable energy supply the economy suffers and a weak economy cannot invest in environmental improvements.
- Fossil fuels are the bridge that allow the world a safe transition to new and renewable fuels. The world needs this bridge to be able to develop the new technologies; without such a buffer economic and political turmoil is likely. The option is not fossil fuels or renewables but fossil fuels and renewables.
- Fossil fuels have decreased from over 90% of global primary energy demand before 1980 to now 87% and a reduction to 80% by 2030 appears achievable. Gas and coal will in future play a much larger role than oil.
- Forecast of demand/supply (Fig. 1): For oil, a minor (~ 5 %) increase to 2015 is foreseen by Tinker, followed by a plateau until 2030 with subsequent decline. The growth of gas and coal will continue at the rates achieved in the last two decades. The share of renewable energy will double every 7 years (but from a very low level).
- Renewable energy is today not limited by its availability but rather by its energy density and storability. Wind, solar, biomass and hydrogen are low density «fuels» (Fig. 2) and require very large investments in infrastructure; they demand often tremendous land surface and need a quantum leap in storage possibility (batteries).
- Investments of many hundreds of billions of USD per year are needed to develop fossil fuels and renewables in parallel.
- The present oil and gas companies are becoming energy companies and will play a very important role in the development of alternative energy sources.

3. Global Energy – Management Forum: Challenges for global energy demand

BP (Mike Daly; Group VP Exploration)

- Many key areas are far from being creamed; e.g. GOM, Lower Congo, Brazil, Southern Atlantic.
- BP shot recently its largest 3D survey ever (17'000 km^2 offshore Libya).
- Advanced seismic and drilling technology are the main drivers for success. Seismic

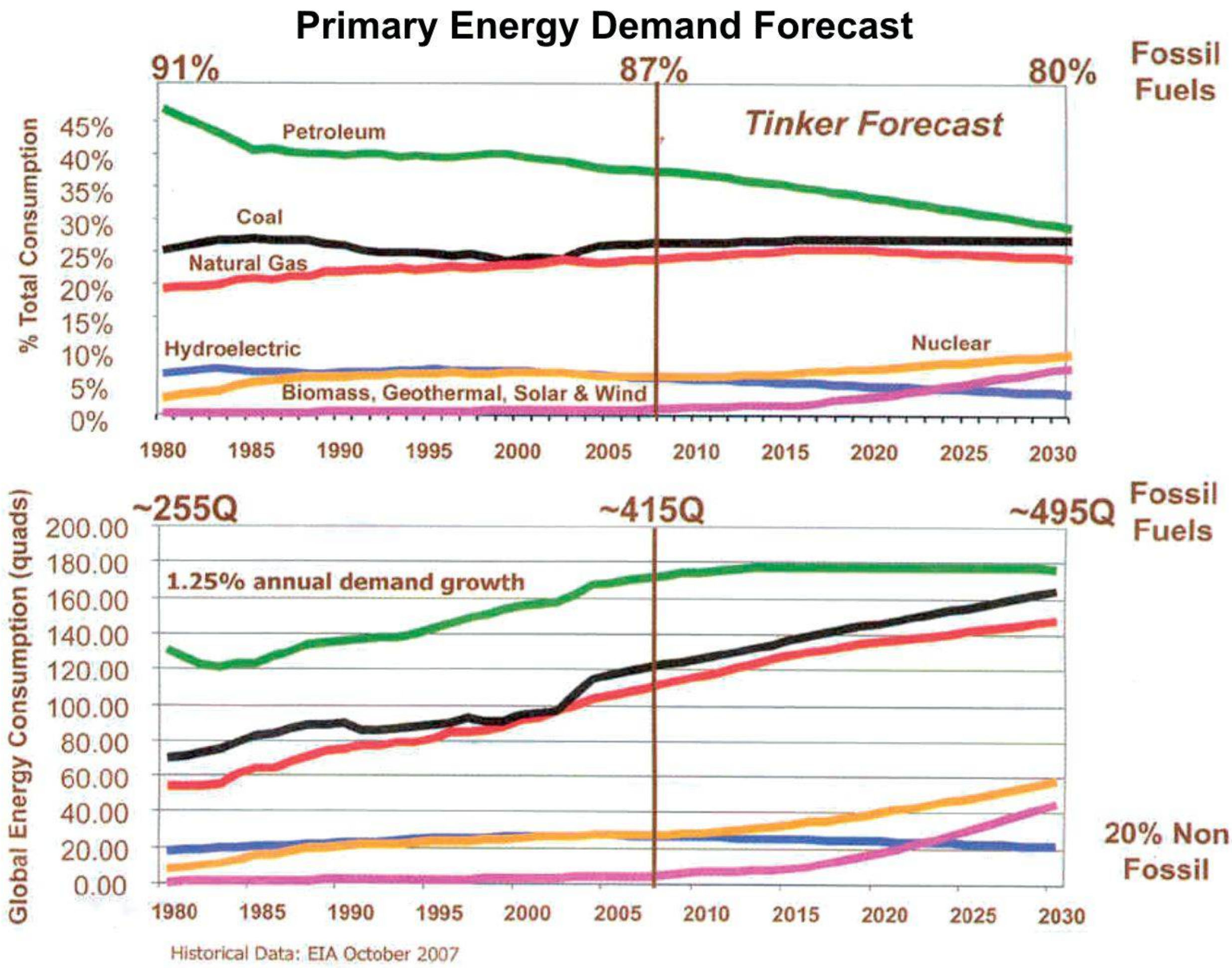

Fig. 1: World Primary Energy Forecast until 2030, absolute energy per source and relative shares per source. With an annual growth of 1.25 % the AAPG forecast is much more moderate and more sustainable than the 2 %/annum forecast by the International Energy Agency, IEA (one Quad equals one quadrillion BTU (British Thermal Units) or 293'000 GWh or 36 million tons of coal). Source: Scott Tinker AAPG, 2009.

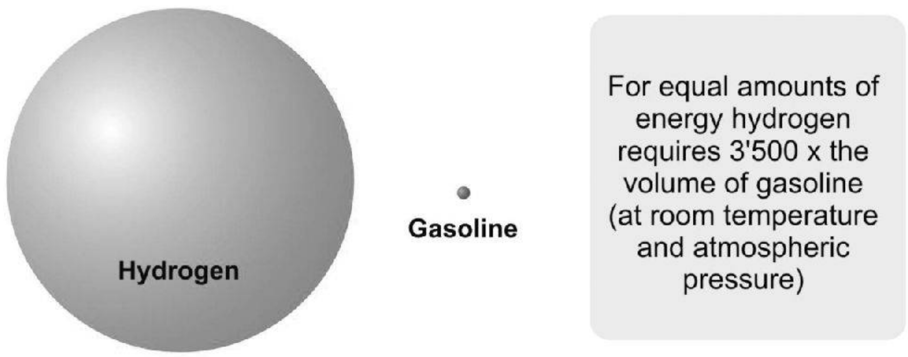

Fig. 2: Alternative energy – the main challenge: energy density and transportability, here demonstrated at the example of hydrogen.

land crews in Libya are now able to record > 10 000 vibrations a day, allowing acquisition of several 100 km^2 of 3D per month.

- Longest well in GOM is now 11'000 m (still with sufficient reservoir quality at depths of > 10 000 m).

Shell (Lynda Armstrong, until early 2009 Head gas worldwide)

- Cost inflation in E&P is the biggest challenge. Costs increased by 120% from 2003 to 2009 and are even now still far above early 2000 levels.

- A concern is the OPEC spare capacity: It was only some 0.5 MMBO/d in 2003-04 and probably one of the main triggers for the oil price explosion. OPEC spare capacity is now some 4 MMBO/d, giving a sufficient cushion.
- Growth areas in Shell are: Exploration, LNG, Gas to Liquids (GTL), Oil Sands, and Deepwater. Contrary to others, Shell increased its R&D and Exploration Budget in 2009. Exploration takes 20% of total investment. Over 100 MM USD are spent annually for the improvement of computer power.
- What does it take to win:
  - more R&D;
  - Exploration differentiators (trying different paths);
  - Increased efforts for enhanced recovery;
  - Higher efficiency, lower energy use, lower environmental impact in unconventionals (big progress has already been made).
- Shell estimates the yet to find volumes of oil and gas at 1600 Billion BOE *[remark: this checks well with recent figures released by IHS who arrive at 1700 Billion BOE. Worldwide already produced volumes amount at present to slightly over 1700 Billion BOE and remaining, already discovered reserves to some 2400 Billion BOE]*.
- Finding costs of Shell are in the range of 1.5 - 3 USD/BOE.
- EOR: today only 4% of world production comes from EOR. Shell's average worldwide recovery rate is at present 35% which is relatively low. Recovery in mature areas is, however, in the range of 40-50%. A worldwide EOR potential of some 300 Billion BOE is seen *[i. e. over 10 years of present world oil consumption]*.
- Alberta Oil Sands: Shell has 90'000 BOPD on stream and 60'000 BOPD under development. The potential for Shell is seen as >300'000 BOPD. Managing the costs is the main challenge.

Saudi Aramco (Abdullah Al Nain, VP Exploration)
- Total discovered resources are at present 722 BBO.
- Targets for Aramco are:
  - To maintain a spare capacity of 1.5 - 2 MMBO/D. Total capacity 2009 is 12 MMBO/D.
  - Increase total recovered resources to 900 BBO in 20 years.
  - Increase Recovery Factor by 20% in 20 years. Ultimate recoveries of up to 70% are targeted in some major fields.
  - Become Industry Leader in Technology.
- Major exploration successes are still expected in gas. Example: S of Ghawar field a giant gas accumulation has recently been found in the Khuff, after 75 years of exploration (at 5000 m depth).
- The country is under-explored, only some 500 wildcats have ever been drilled in Saudi Arabia. Exploration is picking up: 6 exploration wells were drilled in 2000; target for 2011 is 40-50 exploration wells. Exploration rig use per year has increased tenfold since the late 80's.

Exxon Mobil (Sue Payne, Exploration Resources Manager) *[the weakest presentation in the forum]*
- Predicted demand growth according to Exxon from 2009 to 2030:
  - + 20% for oil
  - + 50% for gas
  - + 10% for coal

Exxon sees no problem in supplying this demand. *[Note: this forecast contradict the recent growth patterns and the forecast of most other companies who expect for the same period a smaller growth or even a flat curve for oil, only a 20-30 % growth for gas and a much stronger growth for coal. The fact: Coal consumption has in the last 10 years been growing 3× faster than oil]*.
- 10 years ago unconventional gas was an exotic minor business; it will soon supply up to 50% of the gas demand of the US.

Apache (Mike Bahorich, Senior VP Technology)

- The present financial turmoil is not a crisis but the welcome return to reality!
- US financial problems were inevitable:
  - Since 1979 the household incomes in the US have increased by 81%, but private household debt is up by 284%.
  - US debt was 150% of GDP in the 70's, 350% of GDP now.
  - Compared to previous crisis times this is the worst US public/private debt ever recorded.
- E&P Challenges:
  - Compared to 2009 China and India will consume 50% more hydrocarbons by 2030.
  - Basin maturity is increasing, especially in North America and Europe.
  - 4 USD gas and 80 USD Oil prices are according to Apache not sustainable (there are >> 100 years of remaining supply of gas, measured on present consumption).
  - Fields are declining by 4% annually in average. By 2030 we need a new Middle East to replace this decline.
- Drivers for Apache: Exploration and Acquisition. Producing now 534'000 BOE/d (50/50 oil and gas). Main technology driver is in unconventional gas (see chapter on unconventional gas).

CGG Veritas

- World Energy consumption will grow 30% by 2030.
- Liquid production to grow a further 22 MMBO/d to some 106 MMBO/d by 2030.
- Big progress in seismic coverage and resolution. CGG is using arrays of up to 16 streamers for marine acquisitions.

4. Countries – Areas

4.1 Africa

OMV (G. Tari et al)
OMV sees a large potential offshore NW Egypt. The area looks structurally similar to W Africa, growth faulting and antithetic fault blocks. Very large fourway dip closed structures. Thick, stacked clastic reservoirs. So far only one well was drilled offshore, none in deep water.

Several presentations stressed the new and exciting potential of the SE Mediterranean (Pre Messinian Salt Play).

4.2 Arctic

Arctic exploration and potential was a big topic at the conference. There are wide discrepancies when it comes to total expected volumes. The lectures did not, however, specifically address the Siberian offshore (There is a forthcoming AAPG conference on the Arctic Potential in Moscow autumn 09).

Assessing under extreme uncertainty (R. Charpentier, USGS Circum Arctic Resource Appraisal, see also http://energy.usgs.gov/arctic)

- USGS is evaluating all sedimentary basins N of the Arctic Circle and with > 3 km of sediments.
- Many of these basins have no wells and little or no seismic.
- 246 assessment units worldwide (outside US), representing 95% of world oil and gas discoveries have been used as analogues (IHS Geneva data base is being used by the USGS). Oil and gas volumes in basins were related to basin type, structural style, trapping mechanisms, source and reservoir rock characteristics. The resulting prediction tool is especially suited for little explored basins.
- Potential of Arctic basins: 90 BBL oil and 1670 TCF or 320 BBOE gas and 44 BBNGL (total 412 BBOE, about 8.5 × present annual world production).

Volume of undiscovered Petroleum Resources N of the Arctic Circle (Grantz et al., Cambridge Univ. UK, Exxon, USGS and others)

- Area assessed slightly bigger than N of Arctic Circle (N of 64^{th} degree).
- Undiscovered resources: 1970 TCF gas, 114 billion bbl oil.
- Highest potential: East Barents Basin and Arctic Alaskan basins.
- Deep-water ocean basins not assessed, could add 10%.

4.3 Brazil

Brazil was a hot topic at the conference. Estimates of new reserves found to date in the pre-salt play range from a few billion bbls to several 10 billion bbls. The total potential could eventually lie between 50 and 100 BBOE. Brazil is a textbook example how technological progress (here the only very recently available accurate seismic imaging of structures below the salt) has opened a major new play. In a similar way the availability of affordable prestack-depth-migration has added hundreds of million BOE a decade ago in the North Sea.

Breaking Paradigms (P. Estrella, Petrobras, Director E&P)

- Petrobras drilled in 2008 a total of 8 giant discoveries with no dry hole.
- Offshore Basins cover 1.5 Million km^2.
- Petrobras steps:
  - 1975: First offshore field in turbidites;
  - 1980's Learning Phase: understood that migration is vertical along faults through windows in salt.
  - 1990's: First deepwater giant: Marlin 2.7 BBO.
  - 2000: Petrobras engaging worldwide, learning from other basins. At home expanding outside Campos Basin and «going back to the rocks».
  - Early 2000: acquisition of over 20'000 km^2 3D offshore in spite of low oil prices.
  - 2006: Brazil reaches self sufficiency at 1.75 MMBO/D.
  - 2007-09: Breakthrough in seismic resolution in sub salt and discovery of several super giant fields.
  - 2009: Proven reserves Petrobras now > 14 BBO (without Tupi).
  - 2009-2012: Petrobras will spend > 4 Billion USD/y on exploration and > 20 Billion USD/y on development.
- Tupi, first field in pre-salt has min. 5-8 BBO recoverable (28°API) at 5000 m depth under > 2000 m of salt. Reservoir is a stromatolithic carbonate.
- Estimated potential for pre-salt play in Campos Basin: > 60 BBO.

5. Unconventional Gas

5.1 Shale Gas

Technical progress (Apache)

- Barnett Shale gas supplies now 8 % of US production. The Marcellus Shale is many times bigger and is only just starting to be developed. Marcellus alone might be able to supply over 1/3 of the US gas consumption in future.
- Main challenge is the drilling capacity (thousands of wells need to be drilled in large plays): only few percent of the acreage can be drilled during lease time, most shale gas acreage will expire undrilled. At present 31 MM acres are leased.
- Progress in Technology (Barnett):

5.2 Tight Gas – Deep Basin Gas

Most presentations concentrated on lessons learnt from the Barnett Shale and on the much larger potential in the Marcellus Shale.

Developments in Shale Gas:

2000	2010
Mainly vertical drilling	Nearly all horizontal drilling
1 Frac per well	Average 15 fracs per well
Average UR: 0.5%	Average UR: 15%
F&D costs 3 S/BOE	F&D costs 1 $/BOE

Pinedale Gas Field, Wyoming, Making the Unconventional Conventional (S. Kneller)

- Old field discovered in 30's, declared uncommercial. Overpressured, no down-dip water. Permeability average 1.3 Micro Darcy. Over 1000 wells drilled, now 4th biggest gas field in US (UR 38 TCF).
- 4000 m wells with sizeable horizontal part drilled in 24 days, costs per well average 5.5 MM USD. Recovery 6 BCF per well *[worth 15-18 MM USD at today's very low gas price]*.

US Unconventional Gas Resources (J. Curtis, Colorado School of Mines)

- Shale gas alone may account for 50% of US gas production by 2030 (Presently only 7-8%).
- Present total gas production of the US is 22 TCF/y and is projected to grow very little over the next 10-20 years (23 TCF in 2030).
- Domestic US Gas production will increase with imports from Canada declining.
- Most tight gas projects perform over time significantly better than originally assumed.

Shale Gas in Europe (Schultz and Horsfield, GFZ Potsdam)

- The European potential for shale gas is smaller than that of the US but is still estimated at 510 TCF recoverable.
- Study of shale gas in Europe is still in its infancy but GFZ is compiling an atlas on European Black Shales. The study will be extended by a study of the US Barnett shale as a reference set.
- Areas/formations with potential for Shale Gas are:
  - The Cambrian-Ordovician Alum Shale in Northern Europe;
  - Carboniferous marine shales in Germany and the Netherlands;
  - Silurian shales in Poland and Lithuania;
  - Vienna Basin Mikulov Marl (1500 m thick).

6. Global warming, Carbon cycle

Discussions on global warming had a high attendance and led to heated and often emotional discussions. There appears to be a consensus amongst most of the presenters that global warming is not triggered by greenhouse gases but by sun activity and possibly changes in planetary orbits. Green house gases are, however, seen as a very powerful amplifiyer of the warming process. As such the rise in greenhouse gas concentrations needs attention and action. The debate was whether we would be capable of stopping the rise (e. g. CO_2 sequestration can at best cope with a few percent of the CO_2 created by human activity) or whether we should better invest in measures to mitigate the impact of global warming and enhance chances of adaptation.
The resumés below may be a bit repetitive but are given in the interest of illustrating the width of the spectrum of opinions and observations.

CO_2 and the oceans (Mackenzie et al., Rice University)

- Oceans store a large part of the CO_2 and are therefore a buffer to CO_2 release into the atmosphere. Oceans absorbed much of the temperature and the CO_2 produced industrially in the past four decades and can store for years before release.
- Oceans have soaked up about $1/3$ of the total CO_2 released by human activity. They introduce therefore a delaying mechanism to global warming.
- Acidification of oceans as a result of the CO_2 absorption will lead to the dissolution of carbonates and eventually reefs. Our oceans could go from precipitating carbonates to dissolution within the next 100 years.

Climate sensitivity in the Phanerozoic, lessons for the future (D. Royer, Dept. of Earth and Environmental Sciences, Weslayan University)

- Studies of relationship of temperature, CO_2, carbonate deposits and glaciations over the last 420 MM years show that continental ice sheets are common when CO_2 in the atmosphere drops below 500 ppm and ice sheets are disappearing at > 500 ppm. Ice sheets are absent when CO_2 exceeds 1000 ppm. Present concentration is 390 ppm and is predicted to be > 600 ppm in 2100.
- Major climatic changes occur when cumulative temperature changes exceed 3°C.
- The concentration of CO_2 is now relatively low, it was 1000-1500 ppm 45-35 MM years ago (no ice).

Relationship Temperature – CO_2 over the last 800'000 years (B. Flower, University South Florida)

- Measurements of gases in air bubbles in ice are not as precise as previously thought. Air in ice can exchange with atmosphere for up to 1000 years before being totally sealed.
- Present concentration of CO_2 in atmosphere is 390 ppm. Expected to be 650 ppm by 2100.
- Initial Antarctic air temperature rise preceded the rise in CO_2. The CO_2 rise in Antartica lags the temperature rise by 800 ± 200 years. The CO_2 rise could therefore not trigger the temperature increase.
- Global temperature rise is triggered primarily by solar activity and orbital/insolation changes and not by CO_2. But CO_2 and other greenhouse gases have a strong positive feedback effect on surface temperatures. Greenhouse gases reinforce therefore a rise that has been set in motion by other causes, greenhouse gases are primarily an amplifier.
- The lag may partly but not entirely be explained by storage of CO_2 in deep oceans and releasing it with a delay of 800-1000 years.
- Glacial-interglacial changes over the last 0.8 Mio. years correspond to absolute changes of CO_2 concentration of 80-100 ppm only.

Satellite evidence against global warming (R. Spencer University of Alabama)

- Global temperature monitoring by satellites shows that the temperature growth is existing but smaller than claimed. The IPPC climate model is wrong, according to Spencer.
- Spencer claims that the measures taken worldwide to contain CO_2 have a negligible impact: all US measures to reduce CO_2 would lead to a reduction by 1% and building 1000 nuclear power stations worldwide by 2020 would reduce CO_2 levels only by 5%.
- Spencer claims that all temperature variations can be explained by variations in annual cloud cover of the earth *[Note: this ignores that cloud cover, humidity and global air- and ocean circulation have all to do with or are triggered by temperature. The title of the talk is misleading.]*

Impact of anthropogenic CO_2 and other greenhouse gases on climate since 1940 (K. Trenberth, NCAR Boulder)

- Climate change is primarily triggered by sun orbit, sun output (sunspot activities) and volcanoes. In the hot year 2003 the sun was very active, the cooler 2008 and 2009 correspond to a passive sun phase.
- CO_2 levels have increased by almost 40% since pre-industrial times, half of this occurred since 1970.
- CO_2 is responsible for reinforcement and about 50% of the greenhouse effect.
- What is often neglected is that higher temperature implies more water is absorbed in the air. Air can take up an additional 7% water for every 1°C temperature increase. Water vapour is in itself a powerful greenhouse gas and reinforces thus the warming, resulting in a snowball effect. Globally the number of very wet days/year has increased by 95 % in the last 50 years.
- Global monitoring by satellites is systematically done only since 1992, with following results:
  - Seal levels are rising by 3.2 mm/y;

- 40% of this is due to melting ice and 60% is due to thermal expansion of the warmer seawater;
- All rain over land area from one year adds only 6 mm to sea level (fluctuations in sea level due to annual differences in precipitation are therefore negligible);
- Sea ice is covering now 40% less area than in 1970,
- The biggest warming occurs in the Arctic but generally more warming occurs over land than over sea.

- Prediction: increase in global temperature by 3-5° by 2100. This would lead to virtual disappearance of summer ice in the Arctic and of glaciers in lower latitudes (e. g. Alps and most of the Himalayas).

7. CO_2 Sequestration

CO_2 sequestration commands high attention with governments and increasingly also with the E&P Industry. The question that remains after the talks is whether CO_2 sequestration will ever be capable of absorbing a significant share of the total CO_2 release by human activity, given the huge discrepancy between the storage capacity of envisaged projects and the amount of CO_2 released by human activity. It appears that only a reduction of emissions can have any noticeable impact on the increase of CO_2 in the atmosphere and that sequestration, at least in its present form, could be more a kind of political tranquilizer.

Geosequestration of CO_2 (J. Kaldi, University of Adelaide Global Carbon Capture Storage Institute)

- World's largest R&D project in CO_2 sequestration is underway in Victoria Australia: injection of 100'000 t of CO_2 into a depleted gas field. *[Note: This is only 1/1000 of the annual CO_2 emissions of Australia that stood at 100 MM t/a in 2008.]*
- 19 further projects being planned.
- In Australia there is also a private industry developing CO_2 disposal projects. Kaldi estimates that this industry could in a few decades be larger than the oil and gas industry.
- Over the last 25 years the CO_2 emissions in Australia have risen twice as much as the world average. CO_2 emissions per capita are now 4.5× world average.

Risks and benefits of CO_2 sequestration (S. Hovorka, Bureau of Economic Geology, Austin University)

- CO_2 is a gas that is not ideal for disposal at depth. From about 800 m depth onwards the compressibility of CO_2 decreases noticeably.
- Annual US CO_2 production is 7 billion tons.
- EOR in oil fields can only use a negligible fraction of CO_2.
- Hovorka claimed that there is no risk of induced seismicity when injecting CO_2 into sedimentary reservoirs. *[Note: this is a rather bold/ignorant statement: The disposal of large amounts of waste fluids (millions of m^3) into an aquifer in the Colorado Rocky Mountains Arsenal of the US army is known to have triggered strong induced seismicity of up to Richter 5.4].*

Potential for CO_2 use (D. Nummendal, Energy Research Institute, Colorado School of Mines)

- CO_2 use for tertiary oil recovery is limited in US largely due to lack of available CO_2 (distance to source-sink and lack of transport infrastructure).
- CO_2 can be used to re-vigorate depleted soils, the state of Nebraska alone could absorb 30 MM t/CO_2 per year *[Looks big but is less than $^1/_2$ % of US CO_2 production of some 7 Billion tons/a].*
- Large amounts of CO_2 could be used to manufacture cement. Flue gas from smokestacks in thermal power plants can be put through seawater to produce cement (Cement Industry is today the 3rd largest producer of CO_2).

8. Renewable Energy

Potential of renewable energies (D. Nummendal, Energy Research Institute of the Colorado School of Mines)
A very well researched paper. The only presentation that looked critically at the dimensions of the predicted world energy growth and the possibilities to supply this additional energy. Many of the forecasts are clearly unsustainable, even in the most optimistic scenario. As a plausibility check: A doubling of world energy consumption by 2050 (IEA predicts an annual growth of 2%) would require the equivalent of adding one 1 GW nuclear power plant every day for the next 40 years. Such a scenario would only cover the additional energy growth but it would not cover any substitution: a significant part of the present fossil fuel production will by 2050 have to be replaced by other sources. The forecast by Scott Tinker AAPG (Fig. 1) is much more realistic with a growth of 1.25%/a. This still requires some 30% more energy over the next 20 years.

- The US have presently 3000 MW of installed geothermal power generation. Target is 6000 MW by 2015.
- The biggest potential for addressing the coming energy gap lies still in conservation and higher efficiency. E. g. Japan has an energy efficiency that is 15-20 times bigger than Russia and about 10 times bigger than China (source IEA).
- The US could achieve energy self-sufficiency in 2030 (target by new administration) only through severe conservation and much higher energy efficiency.
- Efficiency: Energy loss between input and output is in the US:
  - 70% for coal fired powergen;
  - 56% for oil fired powergen;
  - 32% for gas fired powergen.

  Taking the above losses and other factors into account (e.g. energy used for mining), it takes 10 more thermal units of coal than thermal units of gas to produce the same energy. Gas is a much more efficient energy source than coal.
- Each new energy has triggered a revolution: coal, oil, and electricity. The largest energy source we have, apart from the sun, is the heat of the earth itself: The next revolution may well be geothermal, mainly in the form of Enhanced Geothermal Systems (EGS, where permeability is being artificially created in deep, tight reservoirs). EGS may be the most promising energy source of the future.
- EGS should not only look at crystalline basement but also at deep sedimentary basins.
- Hybrid systems may be the solution: wind, solar, geothermal. In the transition period (next 30-50 years), a combination with gas is most likely.
- Solar could be moving from an energy efficiency of presently 6-10% to potentially 60%.
- World's global energy consumption is now 15 TWh. Some of the models for global economic growth predict a total of 45 TWh by 2050. This would imply that twice as much new energy had to be developed in the coming 40 years than the total energy that is available today. The more modest [*but still unsustainable*] predictions by the IEA of a 2% demand growth in global energy, provide a doubling of energy demand every 35 years.
- Prediction Colorado School of Mines: US will shift within next 20 years from oil economy to a gas economy and between 2030-2050 to a geothermal, solar and wind economy. Only a minor role is seen for oil in the US after 2040. No dominant role is seen for nuclear.

US Energy Future: wind, solar, nuclear, coal (with sequestration) (H. Leetaru, Geological Survey of Illinois)

- 75% of US energy is presently oil and gas, 3% are renewables.
- Poor progress on renewables: Solar covers today only 0.001% of US energy needs, after 50 years of research!

- Wind: Washington DC would require some 4000 wind turbines to supply the power required; now there are 44. Wind power has a big problem of acceptability, like nuclear. US could produce 20% of its electricity needs by wind but would (in addition to 10'000's of turbines) need 2100 miles of high voltage lines for distribution at a cost of 60 billion USD.
- Nuclear: no new plant has been built in the US for > 30 years.
- New energies take at least 25 years to develop (hydrogen, geothermal, solar). The plan of the US government to reach 10% renewables by 2015 is therefore unrealistic.

Wind power (T. Boone Pickens)

- The well-known oil entrepreneur plans to install 400 GW wind power in the US Central Plains by 2020 with a total investment of 1000 billion USD (sic!). Present total wind power in US is 4 GW.
  [Note: This plan, announced in grand style at the AAPG conference in early June, has later been abandoned by Pickens in July 09, allegedly due to the credit crunch in the US. It illustrates the still large gap between new energy dreams and reality.]

General impression about US Geothermal energy

Geothermal efforts are in the US almost as poorly coordinated as in Europe. Many scattered and often amateurish efforts by local authorities and local research institutes repeat the old mistakes over and over again in a very wasteful use of resources. There is, however, a strongly revived interest and the realization that geothermal energy is almost unlimited and may therefore play a significant role in the future US energy mix.

Acronyms and terms

BOE: Barrel Oil Equivalent; BBL: Barrel; BBNGL: Billion Barrels Natural Gas Liquids; BBOE: Billion Barrels Oil Equivalent; BCF: Billion (10^9) Cubic Feet; E&P: Exploration and Production; BOPD: Barrels Oil Per Day; EOR: Enhanced Oil Recovery; GOM: Golf Of Mexico; LNG: Liquid Natural Gas; Majors: The group of the largest, multinational private oil and gas companies (Exxon-Mobil, Shell, BP, Chevron, Total); MM: Million; MBO: Thousand Barrels Oil; MMBO: Million Barrels Oil; NOC: National Oil Companies; R&D: Research and Development; TCF: Trillion (10^{12}) Cubic Feet; USD: US Dollar.