OIL IN THE 21ST CENTURY AND FUTURE CHALLENGES

Ray Leonard: Anglo Eurasia LLC
Art Berman: Labyrinth Consulting
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Oil in the 21st Century and Future Challenges

The oil world has existed for the past 150 years on “boom and bust” cycles of shortage and oversupply, including two such cycles in this century. However, external factors such as global warning and the coming associated peak oil demand have the potential to finally break the pattern.
The current oil age actually dates back to the oil shock of 1973 when OPEC assumed control of the market. The “boom and bust” cycles of the past 44 years have been a consistent story of shortages resulting in price increase, leading to overproduction causing a price collapse. To understand these cycles, geology, technology, economics and politics must be taken into account.
The Oil World in 2003

- Oil prices had averaged $22/bbl. (2017 dollars) since the price collapse of 1986.
- Non-OPEC production had risen for 10 consecutive years but would plateau in 2004.
- 86% of oil production is low-cost conventional in 2003. Most of unconventional in form of NGL’s.
- New Technology has been developed for deep-water and heavy oil production but economics have been marginal at current price.
- Increases in demand had been matched by supply increases in various non-OPEC countries since 1993; the latest was the production renaissance in Russia with 50% rise in 2000-2003, a majority of the non-OPEC increase in that period.
End of the glut and the price spike of 2003-2008

• In 2004, with the acquisition/purchase of YUKOS and Sibneft, the two fastest growing Russian oil companies, by state entities, Russian production growth dramatically slowed.

• With only minimal Russian production growth after 2003 and steady decline in other non-OPEC conventional production, oil production reached a peak and began to decline in 2005.
End of the glut and the price spike of 2003-2008

• With strong GDP growth (averaging over 4%), world demand continued to grow and with OPEC discipline holding, significant shortages resulted in a price rise from $30/bbl. in late 2003 to $132/bbl. in September 2008.

• The price rise supported the growth of high cost exploration and production. In particular, these years can be viewed as the “golden age” or breakthrough years of deep-water production, which increased 280% in the 5-year period.
The price collapse of 2008-9 and rapid reaction of OPEC

- Demand significantly exceeded supply in 2007 to 1Q 2008 resulting in price rise from $54-$132/bbl. in 3Q 2008.

- Three consecutive quarters of oversupply, along with demand reduction due to world economic crisis resulted in price collapse to $43/bbl. by January 2009.

- OPEC cut production (Saudi Arabia 40% of cut) in Q4 2008-1Q 2009 to restore market balance, leading to recovery to near $80/bbl. by end 2009.

- Price fluctuation was due to one specific event (demand reduction due to world economic crisis) that could be handled by OPEC reaction.

Source: IEA, Capital Economics, Bloomberg
The rise of high price oil (2011-2014)

Five factors led to an unprecedented period of continued high oil prices and resultant increase in of high cost unconventional production. By late 2014, one third of world oil production was deep-water + unconventional.

- **World economic growth:** Led by China, the world economy expanded reaching almost 5% GDP growth in 2010. World oil demand expanded dramatically that year, restoring the $100/bbl. price by Q1 2011.

- **Political turmoil:** Various factors, from revolution and civil war to sanctions, removed about 3 MMBOD production from the Middle East and North Africa in the 2010-2012 period. This production loss was largely maintained through 2015.

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**2015 World Oil Production**

- Conventional Oil
- NGL's
- Deepwater
- Shale Oil
- Heavy Oil

Source: IEA

**World GDP**

% change on a year earlier

- Rich countries
- BRICS
- Other emerging countries
- Total

Source: The Economist

**Production changes (MMBOD) since Q1 2010**

- Libya
- Iran
- Yemen
- Syria
- Canada
- USA

Source: The Economist

**Libya**

- 2013/3
- 2013/4
- 2014/1
- 2014/2
- 2014/3
- 2014/4
- 2015/1
- 2015/2
- 2015/3
- 2015/4
The rise of high price oil (2010-2014)

- Low interest rates: Led by the USA, starting in 2009, low cost financing was available for development projects that were only marginally profitable even at high oil prices.

- New Technologies: Breakthroughs in deep-water and heavy oil production technology from the previous decade continued to show results, due to long cycle time of projects. Canadian synthetic crude and crude bitumen production doubled in 2010-2015.
The rise of high price oil (2010-2014)

5th point: Fracking

- Fracking: the marriage of fracking and horizontal drilling technology resulted in a production boom in the USA, facilitated by good fiscal terms, availability of capital and service companies and public databases
- By February 2014 production rose to approximately 3.7 MMBD crude + 1.5 MMBD NGL in the US and Western Canada
- Approximately 60% of reserves and production came from two plays; the Eagle Ford and Bakken
- Production is characterized by high capital costs and rapid well decline rate (60-70% in first year)
- Even with the high oil prices, capital expenditures exceeded cash-flow pushing producers in debt
- How did the production boom occur? E&P Companies focusing on the shale plays became the sub-prime derivative of the post-Financial crash period. Shale oil projects had access to almost infinite capital with no short term performance requirements other than making interest payments and avoiding debt covenants

Figure 2: Financial survey of 35 US shale gas/tight oil companies

Source: Energy Aspects; In focus – the other tale of shale, Oct 2013; Other analysis EY
The rise of high price oil and the positive economics of Fracking (2014) at $100/bbl. oil

- Ultimate recovery per well varied widely in all of the plays, even in the Bakken and Eagle Ford, so a single “break-even” price cannot be accurate. Often what was quoted is the “break-even” price for the best quality reservoirs.

- All shale plays are characterized by “sweet spots” with higher ultimate well recoveries.

- In both Bakken and Eagle Ford, the most efficient operators on best acreage had a “break even price” around $45/bbl. Most producers needed $55-70/bbl.

- Many operators, caught with acreage out of “sweet spots” lost large amounts of money.

- These were the two best shale plays. Break-even costs on other plays were generally higher.

Contour maps show amount of recoverable oil per well. (Labyrinth Consulting)

**Eagle Ford Shale**

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>EUR BOE</th>
<th>BE OIL PRICE</th>
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<tbody>
<tr>
<td>Anadarko</td>
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<td>BHP</td>
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<td>Conoco</td>
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<tr>
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<tr>
<td>Marathon</td>
<td>290,940</td>
<td>$54.16</td>
</tr>
<tr>
<td>Pioneer</td>
<td>345,192</td>
<td>$45.68</td>
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</tbody>
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Break-even price does not include cost of acquisition of acreage. At $20,000/acre, rough calculation is approximately $30/bbl. for high quality acreage.

**Bakken Shale**

<table>
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<tr>
<th>COMPANY</th>
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<th>GAS</th>
<th>BOE</th>
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<td>$55</td>
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The oil price collapse in late 2014 ended the production growth of high cost unconventional production and caused a buildup of excess inventory generated by overproduction from 2010-2015.

- OPEC production significantly increased in 2015-6, extending the price collapse and contributing to inventory build-up.

- A closer examination of the unconventional production reveals the “winners and losers” at this price level during the 2015-2017 period.

- The OPEC/NOPEC production cut enacted in November 2016 initiated a reduction of excess inventory which ended the current cycle and led to an upward pressure on oil prices by end 2017.
World oil production increase in 2010-2014 was driven by advances in technology supported by the high ($100/bbl.) oil price. The drop to the $30-60/bbl. range in 2015-2017 period had a number of major effects:

• The dramatic unconventional production growth almost halted, with an increase of 45% in 2010-15 reduced to 4% in 2015-17.

• While the overall increase dropped precipitously, there were “winners and losers”, as the most efficient unconventional sources, whether geographic areas, geologic formations or technologies, were differentiated

• Technology continued to advance, with new techniques evolving to reduce drilling time and development cycle time and increase operating efficiencies under the pressure of the low cost environment.
Deepwater Production: Transform Margin is the Winner

- About 90% of deep-water oil is produced in four provinces along the Atlantic Margin.
- Utilizing a deep-water field (Plutonia, Angola) produced in each of the provinces (adapted from the McKenzie study) “breakeven prices” range from $43/bbl. to $65/bbl.
- In 2015-2017, projects are moving forward in the Transform Margin as are selected projects in the US GOM, limited earlier sanctioned projects are being completed in Brazil and in Nigeria and Angola, only projects well into construction at time of price collapse are being completed, while no new projects are being sanctioned.
- Decline rate is high for deep-water fields, so in 2015-7 environment, deep-water production growth (pre-2014 sanctioned projects are still coming on line) halted with the limited new projects only replacing production decline.
Heavy Oil Production

- 80% of the world's heavy oil and bitumen in place is found in two countries, Venezuela and Canada.
- Venezuela was overwhelmed by political crises, falling production, and lack of capital. Its production is not responsive to the oil price now, and further loss of production due to political crises is likely.
- Canadian heavy oil production comes mainly from two sources; subsurface production (mostly steam assisted gravity drainage, or SAGD) and surface mining. Surface mining projects were uneconomic at 2015-17 prices and no new projects sanctioned while a very few selected SAGD projects and expansions did go forward.
- Many international oil companies sold their surface oil sands assets.
- Sovereign wealth funds, investment groups, pension funds, and insurers began divesting from companies participating in oil sands projects.
- Legislation in Canada imposing greenhouse emission caps provided political barriers to increasing heavy oil and bitumen production.

Heavy Oil and Bitumen in Place (BBO) World Energy Council 2007

- Venezuela 2,250
- Canada 1,600
- Rest of World 800
Tight Oil (fracking)

Permian is winner, Eagle Ford and Bakken less attractive at $50/oil

- Tight oil production is dominated by US, with most production in three plays: Permian, Bakken and Eagle Ford
- Cost of production dramatically increased during 2010-2014, but the high oil prices could absorb it
- Following the oil price collapse in late 2014, increased operational efficiencies and oversupply of services caused a price collapse of about 45% in operations cost
- The Permian proved a low-cost play with a production increase even with the low prices
- The higher cost Eagle Ford and Bakken plays were hurt by low cost but production stabilized with lower drilling costs

Source: AGSIW
Tight oil plays have defined areas that are commercial, even at $40/bbl. oil, due to effective technology, reduced costs and increased geological understanding.

- All three plays have significant well defined commercial areas at $40 wellhead prices.
- Bone Spring (Permian) commercial area is almost twice as large as Bakken or Eagle Ford.
- Bone Spring has 1/3 the well density of the Bakken or Eagle Ford.
- Bone Spring and Eagle Ford have lower break-even EUR than Bakken.
- Higher early rates and lower well costs largely account for advantages to Bone Spring and Eagle Ford.

**Break-even price does not include cost of acreage acquisition**
NGL production growth slows due to reduction in natural gas and tight oil production growth

- The fall in oil price led to a dramatic drop in the price of gas outside of the USA which was a factor in a slowdown in gas production increase and reduction in the associated NGL production increase.


- NGL production growth in USA and Canada was also tied to tight oil production which was flat in 2015-2017 compared to explosive growth in 2010-2014.

- World gas production increase in 2016 compared to 2015 of 2.3% was lowest since financial crisis of 2008-9.

- Predicted world NGL growth in 2015-2020 period is 300,000 BOPD per year, (2.3%) or 28% below 2000-2015 average. (3.2%)
Will tight oil (fracking) production increase kill a price recovery in 2018?

Maintaining the price recovery depends on three main factors:

• The extent of US production recovery with prices in the $60/bbl. Range
• OPEC/NOPEC continued compliance with agreed production cuts
• Continued robust world oil demand growth

Three factors will work to keep US growth at steady but not extreme rate:

1. Lack of fracking crews: the gap between wells drilled and completed is growing due layoff and bankruptcies of the past three years.
2. Only the Permian has the prospectivity for significant growth. The sweet spots of the Bakken and Eagle Ford are too densely drilled
3. Capital discipline: many firms are still paying down debt and are cautious about ambitious spending in 2018
Will tight oil (fracking) production increase kill a price recovery in 2018? Probably not

- World demand increase for 2018 is estimated at 1.4 MMBOD (IEA March 2018 report)
- Decline rate in existing conventional fields results in 3 MMBOD loss of production in 2018
- Reduced capital budgets of 2015-17 mean fewer new projects coming on stream
- US production increase in 2018 assuming oil price holds at $60/bbl. is estimated at 1 MMBOD crude. (+0.3 MMB NGL/D)
- Production outside the OPEC/NOPEC group not including USA is estimated to be flat, with additions balancing declines
- The OPEC/NOPEC group has agreed to extend cuts through 2018. This is made easier by the production decline in Venezuela, actually allowing some increases elsewhere keeping the total steady.
Rebalancing the Market: OPEC reaction and result

- In response to two years of low oil prices, in November 2016, OPEC plus other major exporters agreed to a 1.8 MM production cut in an attempt to rebalance the market and cause prices to rise above the $50/bbl. level.

- While there was an initial price rise, the optimism led to increased tight oil production in North America, replacing about half of the cut.

- Increased production from Libya and Nigeria, two nations exempted from the cut replaced a portion of the other half.

- However, increased world demand plus an end to the increase of US tight oil production as the realization of $50/bbl. oil and no higher resulted in supply deficit in 2017 as the excess inventory was exhausted.

- All of the comparative excess inventory was removed by January 2018.
What oil prices are likely in 2018?

- The OPEC/NOPEC cuts took effect in January 2017. Compliance has been generally good and has resulted in drawdown of comparative inventory, the best indicator of future prices, starting in February 2017.
- By the end of 2017, the excess comparative inventory had been removed.
- If OPEC/NOPEC compliance continues, upward pressure on prices may continue in 2018.
- Based on recent data, yield curve is $10/bbl. lower than 2011-14 trend, so prices in $60’s/bbl. range more likely in market balance scenario.
Future Challenges: the changing world circumstances may end the 44-year OPEC dominated order

- Lack of investment and exploration during the price collapse years of 2015-2017 will likely result in lack of new supply coming on stream in the near term. While prices are recovering, companies are still paying down debt and are cautious in increasing investment in the immediate future.

- Global warming, the inevitable response to emission of greenhouse gases, will force both changes in the amount of consumption of oil and favor the lower GHG emission types of oil.

- The pressures of global warming and the development of cost competitive new technologies will lead to peak oil demand in the foreseeable future.

- Elements of each of the three above points will favor the production of light hydrocarbons as opposed to heavier hydrocarbons, leading to an imbalance that will challenge the industry to provide the oil products needed.
Effect of 2015-7 period of low prices

- 2016/7 recorded lowest 2-year discovery of oil and gas since WW II (2017 results were 80% compared to 2016)
- Production for 20 billion barrels on commercial oil reserves projects were deferred
- Upstream investment levels in 2016 and 2017 were only about ½ the level of 2014 with exploration spending disproportionally even lower
GLOBAL WARMING

- Obvious correlation between CO2 concentration in the atmosphere and global temperature.
- Effect was relatively minor until around 1950, when post WW II expansion in OECD countries and Soviet Union resulted in dramatic increase in petroleum use and emissions.
- Acceleration in emission increase taking place in 21st century mostly due to increased emissions from China burning coal and petroleum.
- While China emissions have "plateaued" at high level increase continues in India and the rest of developing world.
- Currently, 41% of global CO2 emissions come from coal, 34% from petroleum and 18% from natural gas.

Source: CDIAC, US DOE
Factors accelerating Global Warming

- Temperatures rising more rapidly in polar regions than tropics
- Last week of February 2018 greatest heatwave in recorded history at north pole; 60 hrs. consecutively above freezing in February
- Ice free along NORTH coast of Greenland
- Polar caps melting, with artic ice free in summer around end of next decade
- Diminishing polar ice cap will cause major changes in northern hemisphere climate
- Permafrost melting in extensive areas of Siberia, Alaska and northern Canada releasing significant quantities of methane, 85x more potent GHG than CO2 in short term (25X in long term)
- Antarctic ice sheet reached historic low in November 2016

Images courtesy of NASA
What will be the results of the rise in CO2 in the atmosphere?

- Current CO2 level (4/18) is 410 ppm, increasing 3 ppm per annum at 40 GtCO2 emissions/annum
- +2 deg C only possible if immediate major action taken which is unrealistic
- +3 deg C would require phasing out coal by 2040
- +4.5 deg C is “business as usual” case

With CO2 level above 400 ppm, we have already reached point at which north polar cap will disappear in summer within 20 years, causing major climate shift

Difference between taking action in the near future and “business as usual” is saving the Antarctic ice sheet which holds 90% of the world ice and would be the cause of major sea level rise

Adapted from I. P. Menendez 2018
Greenhouse Gas Emissions for oil are less than coal and greater than natural gas. However, there is a wide difference in Greenhouse Gas Emissions for different Oil Types!

Adapted from Carnegie Endowment Oil Climate Index
High Greenhouse Gas Emissions Oils
- Extra heavy oils: (<10 API) surface mining is highest. High GHG from burning the heavy oil plus energy required to produce.
- High flare: greenhouse gas emissions from flaring natural gas is extensive and worldwide; est. 5 TCF annually. (see map) Unfortunately, it is closely associated with US shale production
- High Steam: Heavy oil production associated with steam injection (SAGD). High emissions both from type of oil burned and energy required for production

Moderate Greenhouse Gas Emission Oils
- Depleted/Watery oil: this refers to secondary and tertiary recovery. While oil quality can be good and burning of oil may not be high GHG emission, energy needed for production is high
- Shale/tight oil: most tight and shale oil is actually light with low GHG emission. However, fracking is an industrial process requiring high energy. In cases where gas flaring occurs, it can be considered high GHG
- Heavy oil: (10-20 API) where heavy oil can be produced without steam or surface mining, (CHOPS) the GHG emission can be considered moderate

Low Greenhouse Gas Emission Oils
- Conventional oil: normal grade (20-35 API) oil primary production onshore or in shallow water. Low to moderate GHG emission and low energy to produce
- Ultra-deep oil: light to normal grade, because heavier oils with lower flow rates will inherently be uneconomic to produce
- Light oil/condensate: lowest GHG emissions, close to level of natural gas/LNG
PEAK OIL DEMAND

The pressure of global warming and the advancement of new technologies will result in peak demand occurring in the foreseeable future. While “common wisdom” estimates point to 2040, it could occur as early as 2025-2030 if one or more of the very plausible scenarios takes place:

• Natural gas replaces oil as a petrochemical feedstock for ethylene and polyethylene
• Electric vehicles replace internal combustion engines in significant proportion
• Significant improvement takes place in internal combustion efficiency
• Average annual world GDP growth is lower than the 3.5% prediction


1 Average GDP growth of 3.5% until 2040. Assumed long-term real oil price at $60/bbl. Low internal combustion engine efficiency of 6.3 L/100 KM.
2 Gas replaces oil as petrochemical feedstock for ethylene and polyethylene. In North America and Middle East, gas takes 80% share; in Asia, it takes 50% share. No change in other regions (other parameters the same as reference case).
3 EVs replace vehicles powered by internal combustion engines for light-duty vehicles. OECD has 90% EV penetration by 2040; non-OECD has 90% by 2050 (other parameters the same as reference case).
4 Expected global GDP growth of 3% vs. 3.5% for the reference case. Improvements in internal combustion efficiency of 4.3 L/100 KM by 2040 in OECD countries.
How realistic are the scenarios that lead to an early Peak Demand? **Very realistic**

- Road transportation consumes 40 MMBO/D, greater than 40% of all oil use. Penetration of the market by electric vehicles and/or significant internal combustion improvements is actually taking place.
- Total stock of plug-in hybrids and electric vehicles are increasing at a 40% per year pace.
- The EU, China and California are setting ambitious targets for sales of zero carbon emission cars.
- The projection of 3.5% annual GDP growth depends heavily on continued high growth in China. China demographics (aging population) plus the necessary shift to more expensive energy consumption due to global warming from cheap coal to natural gas and renewables makes lower GDP growth highly likely.
- With the reduction of natural gas prices in 2009, natural gas became much cheaper than oil for petrochemical feedstock. With oil prices stabilizing around $60-65/bbl. in 2018, 2X oil/gas price ratio on value basis will encourage continued shift to natural gas as feedstock.

**Figure 1: The Relationship Between Oil and Natural Gas Prices**

- **Current $60/bbl. price**

**Future of transport is electric**

- Total stock of plug-in electric vehicles

Source: When will global oil demand peak, Rob West, Redburn, 21 Feb 2017
Heavy oil: Problems with supply growth

- **Heavy Oil**: Oil with API gravity between 10 API and 20 API inclusive and a viscosity greater than 100 cP.
- **Extra-heavy oil**: Oil with API gravity less than 10 API and whose viscosity is commonly less than 10,000 cP.
- Lower H, higher S, N and metals than light crudes.

- 80% of world’s in place heavy oil and bitumen is found in Canada and Venezuela.
- Largest producer is Canada (30% of world total), other major producers include Mexico, Venezuela, USA, Brazil, Russia, Indonesia and Middle East.
- After accounting most of world heavy oil and bitumen production increase in 2010-2015, Canada production growth will virtually stop due to regulation and economics.
- Venezuela and Mexico heavy oil production in steady decline to lack of investment.
- Russia, USA, and Indonesia heavy oil production in decline due to maturity of assets.
- OPEC heavy oil production (in Middle East) disproportionately cut in current reduction as heavy oil is least profitable and first to be cut.

As climate change pressures increase, the needed investment for heavy oil production increases will be more difficult to obtain due to GHG emission levels.
The major new supply of oil, on the other hand, is very light oil and natural gas liquids

- By the end of this decade the US will be the world's largest oil producer, with 2/3 of supply tight (shale) oil and NGL's.
- About 90% of tight oil production is very light oil (>40 API) with 490% growth 2010-2040.
- As tight oil production spreads to other areas, virtually all new production will also be very light oil production.
- As the world shifts to natural gas due to climate change pressures, NGL production will increase accordingly.

World natural gas production by type (2010-40)

- billion cubic feet per day

- history
- projection

- coalbed methane
- tight gas
- other nontight gas
- shale gas

Adapted from eia 2018 outlook

Tight (shale) Oil Production (MMBOD) not including NGL's

- USA
- Russia
- Canada
- Argentina

Adapted from eia 2018 outlook

U.S. Tight Oil Plays Average 2% Intermediate-Heavy Oil (<35°API) & 13% Light Oil (35-40° API) - 85% is Ultra-Light Oil (>40° API)

Source: EnerCorp & Elyria Consulting Services, Inc.
Light vs. Heavy Oil: We have a problem

- Blending of light and heavy oils is essential for the production of the range of petroleum products used by the world today.
- In the high price environment of 2003-2014, all three elements, natural gas liquids (NGL’s), tight/shale oil and heavy oil enjoyed rapid growth.
- With current prices, tight/shale oil production will continue growth in the USA and expand internationally.
- Taking into account climate concerns, gas production will continue steady growth, taking NGL’s along.
- Heavy and extra heavy oil production on the other hand has only minimal growth due to political, economic and environmental factors.
- Changing light/heavy ratio will have pricing implications in heavy discount and Brent/WTI spread.
Summary and Conclusions

In the near term, the US will become the world's largest oil producer, and >70% of production will be light and ultra-light oil, including NGL's. The lack of investment in 2015-7 indicates tight supply and robust prices in the next few years. However, in the longer term, there are challenges that must be faced.

- **Global warming is a certainty and predictable.** The major differences in greenhouse gas emissions in the types of oil production will impact what we produce and how much it will cost. Increased natural gas production to replace coal is likely the best near term solution to slowing GHG emission rise.

- **Peak demand is also a certainty** with the major variable being when it will arrive. The factors pushing it forward to sooner than 2040 are realistic and likely. However, there seems to be a clear difference of opinion and strategy in US majors vs international majors on how to address this point.

- **There is indeed a light vs. heavy oil problem coming** which will either force some compromises in the solution to the global warming dilemma or accelerate the changes taking place.