ITER

The urgency for Nuclear Fusion

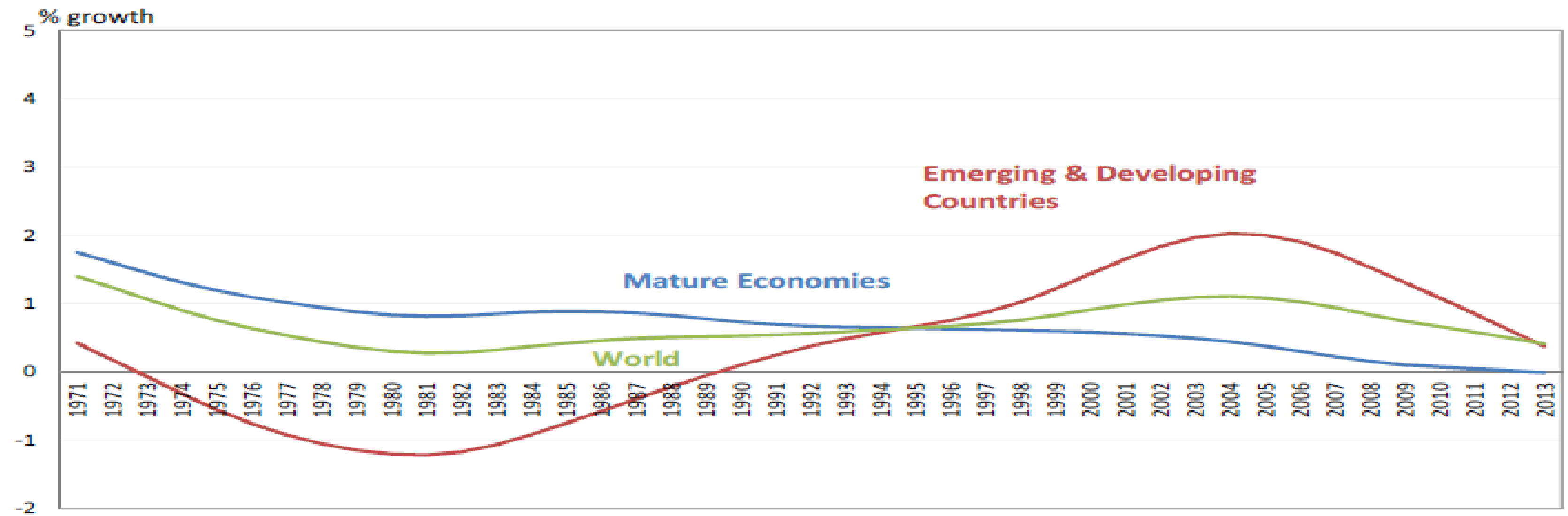
Andrew Lees 3rd December 2013

Total Factor Productivity

- US nominal GDP growth is the lowest outside of recession since records began in 1947. It is lower than the entry point into every single recession over that period and it is lower than the lowest point of every recession from 1974 to 1994. World nominal GDP growth over the last 5 years is the lowest since the 1930's.

- World Total Factor Productivity growth slowed to just 0.19% in 2012. Productivity itself (not productivity growth) is declining in various parts of the world. Brazil, Spain, Italy have all suffered falling productivity since before 2000, US productivity growth in 2012 was just 0.2%, every single European country bar Norway suffered a decline in productivity in 2012 and China's productivity growth has slumped from 7.9% in 2003 to just 2.14% in 2011.

- Without productivity – (less output for every unit of input) –growth is increasingly dependent on accessing the limited and declining pool of external capital through currency wars or internal devaluations etc.



Total factor productivity growth (US Conference Board)

Blockages to Growth

- Economists talk of an output gap, suggesting high unemployment is indicative of a shortfall of demand. In 1972 the UK suffered a miners strike which resulted in the 3 Day Week. This was obviously not due to a lack of demand, but insufficient productivity to pay the wages the miners demanded. There is a similar productivity shortfall today to make up for the shortage of energy and support full employment.

- More than 50% of energy efficiency gains over the last 50 years in the States are said to have come from using higher density energy. This is now unwinding; the portfolio is gradually becoming less dense. We hear that alternative energy is becoming cheaper, but data in Germany clearly shows otherwise; the larger the alternative energy portfolio, the greater the volatility, and the more storage is needed or conventional plant has to be kept idling to compensate.

- EROIE – (energy return on invested energy) – is in rapid decline, which means energy production is becoming far more capital and resource intensive leaving less net energy available to the economy and less capital. This is reminiscent of the collapse of the Soviet Union, where oil production absorbed an ever larger percentage of investment undermining industry.
- The majority of the jobs created in the US over the last few years have been in shale production. Employment in downstream manufacturing industries has underperformed the broader economy and capex has actually fallen.

Oil as % World GDP +6.5% pa since 1995 to 5.35%

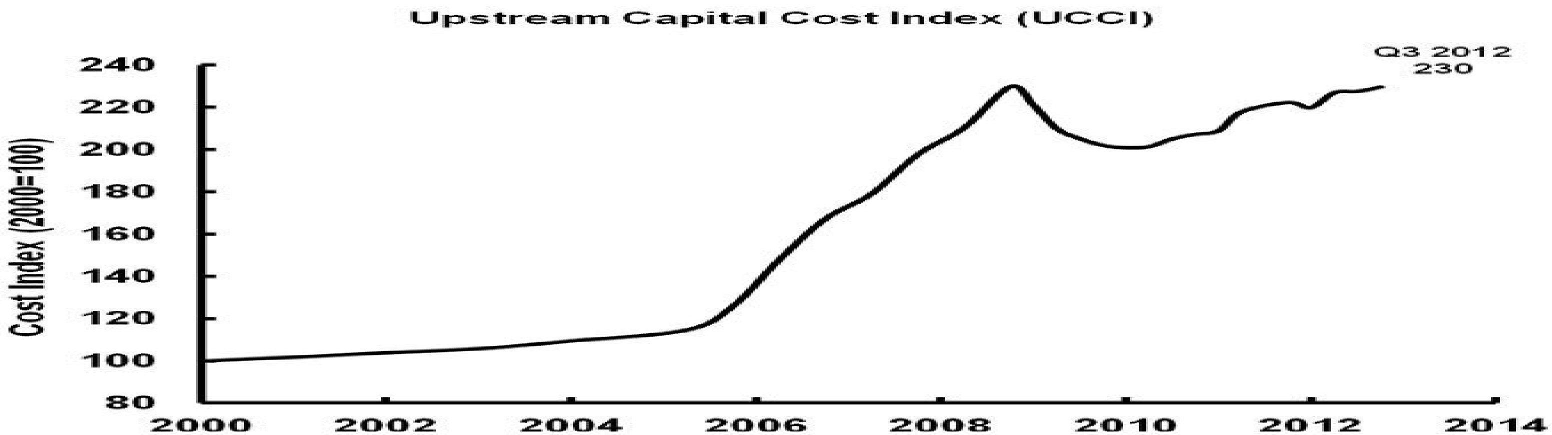
The rising cost of production

- From 2005 to 2012 annual global expenditure on oil projects jumped 100% from USD300bn to USD600bn per annum, yet oil production (oil, shale oil, tar sands and NGL's) grew by 0.7% pa compared with 1.9% pa in the 10 preceding years. We have lost 7.4mpd over those 7 years vs the preceding trend, or about 9% despite the shale revolution. China, India and the Middle East have consumed a growing percentage of the production leaving less available for the rest of the world. E&P expenditure is estimated to have been USD678bn this year and USD750bn in 2014.

- Biofuel production lifts the overall liquids growth rate to 0.83% pa since 2005., however ethanol production has reached its non-cellulosic caps. Tight oil production, which accounted for 40% of the overall liquids growth must therefore accelerate its growth to compensate, yet while shale production is still growing rapidly, its growth rate is falling. In the 12 months through September, Bakken production grew by 204,290 bpd, some 22.8% lower than the previous 12 months when it grew by 264,720bpd.

- Bernstein calculates that the marginal cost of production rose 13% last year to USD104.15bbl. Net income margins have dropped to the lowest level in a decade and reserve replacement costs surged 45%.

- Return on capital employed has fallen from 15% six years ago to 9% now. Spending is so high that cash flow from operations cannot cover dividends. Net cash flow has been negative since 2009. Net debt is 1.44 times cash flow. The price of oil is not keeping pace with the cost of production.



Shale

- Bakken and Eagle Ford, which account for 90% of US shale oil production, are not shale reservoirs but rather a sandy dolomite reservoir between two shale formations. Over millions of years the oil had already leaked out of the shale. Outside of these two fields, shale oil production continues to disappoint.

- Bakken suffers a 69% first year decline in well productivity and a 94% decline over 5 years by which time it is in the category of a stripper well. Eagle Ford suffers a first year well productivity decline of 60% and an overall decline rate in the first 2 years of 86% putting it in the category of stripper well within 3 years.

- To try and get oil out of genuine tight reservoirs, a technique called “matrix acidisation” is being tested, but concentrations of around 30% hydrofluoric acid are still failing and is dissolving the double or triple steel walls of the well casings. The acid’s boiling point is 67.1 degrees when it vaporises and forms acid clouds.

- US shale gas has risen from 2% of total production in 2000 to nearly 40% today, more than offsetting the decline in conventional gas. Conventional US gas production is now suffering a 33% well decline rate up from 22% 10 years earlier. The Haynesville, Barnett and Marcellus fields account for 66% of US shale gas production with the top 6 plays accounting for 88%.

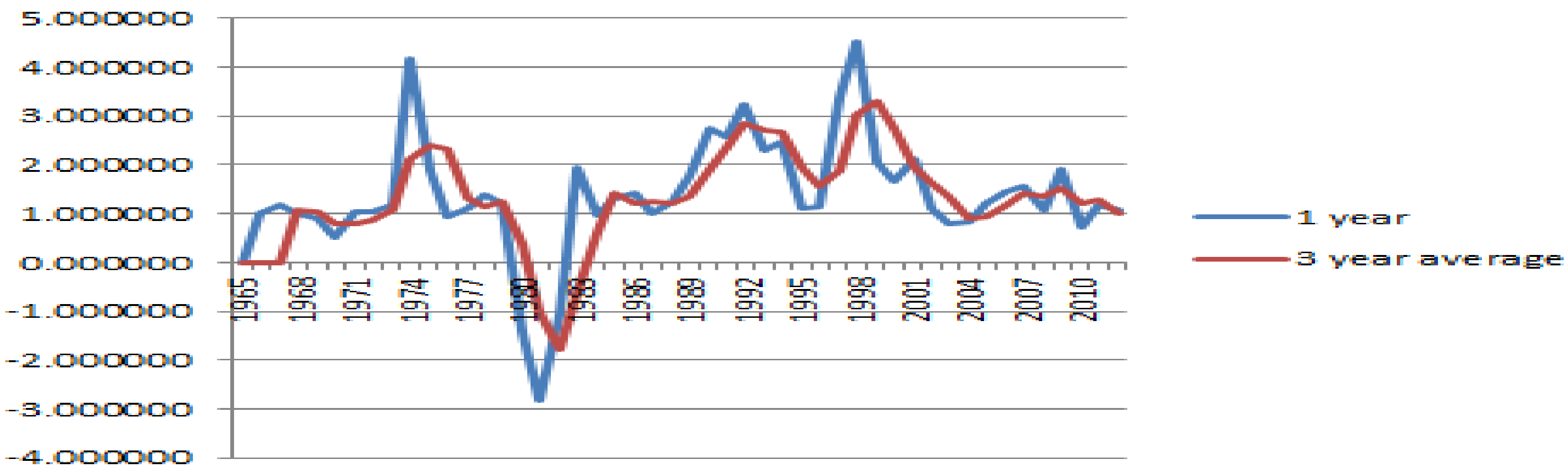
- The first year decline rates are between 47% and 68% with wells being exhausted within 2 – 3 years. Initial productivity is declining in 5 of the top 6 plays which means that more and more wells are required to offset the overall field declines. Without a massive amount of new wells production will go into terminal decline. The wells will come on board but gas prices will rise.

- In 2012 the EIA revised down its estimate of unproved technically recoverable reserves by 42% to 482tcf which equates to just 20 years of present consumption. The EIA gets its data from the USGS which puts the estimated technically recoverable reserves at 378tcf, equivalent to just 16 years of present consumption. It estimates that 410,722 wells will need to be drilled. Whatever the correct figure, the declining initial production rate means most of the gas will not be economic to extract anywhere near present prices.

Efficiency

- World energy efficiency peaked in 2008 @ USD599.10 boe and has since slipped by 49bpts pa to USD587.51boe. GDP growth per additional percentage of energy has deteriorated ever since 1998, sliding from 4.6% for every additional 1% of energy to just 0.96% pa over the last 3 years as the world has shifted to using less dense energy such as coal as well as renewables. Global economic growth is becoming increasingly energy intensive to achieve.

- People look at the Toyota Prius and other such technologies and assume huge energy efficiency gains. Unfortunately they are confusing end-use efficiency and ignoring the energy required to make lighter, tougher, more temperature resistant materials, or the energy required to develop and manufacture new technology that allows those energy efficiency gains., or the energy required to make an industry and market that makes the technology economically available; the so-called Jevons Paradox.

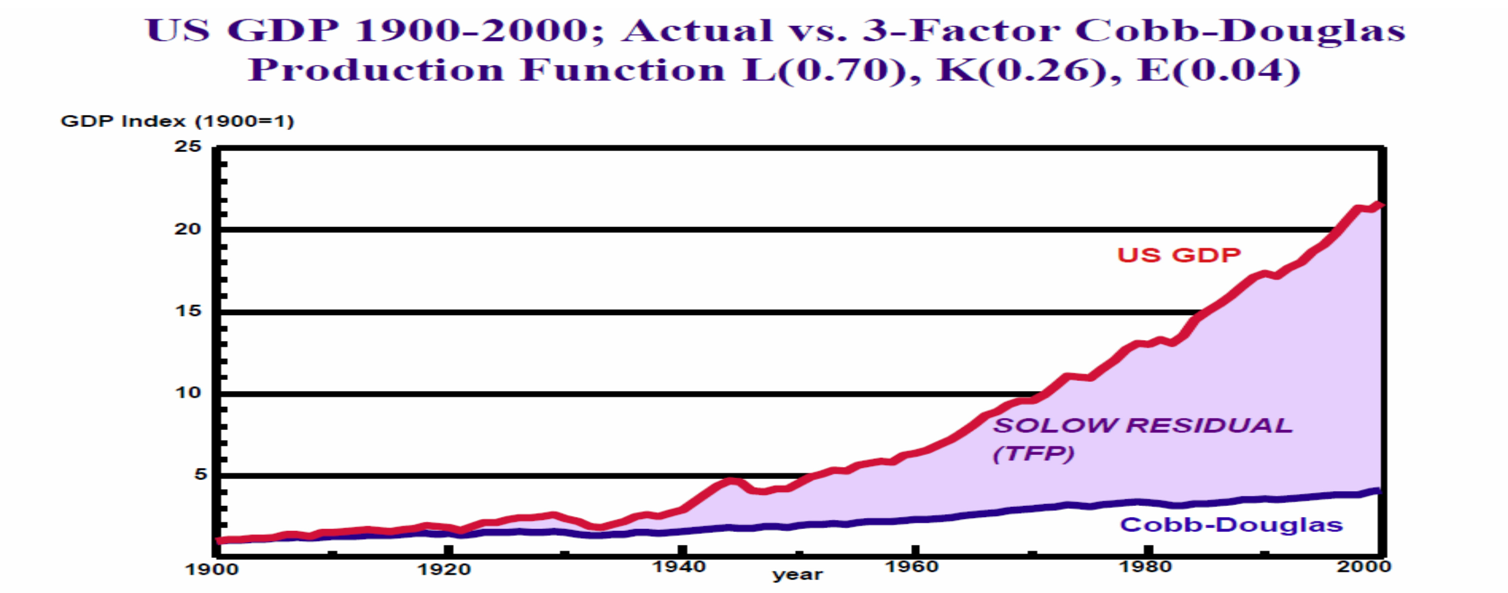


Real World GDP growth (%) per unit (%) of energy growth

Solow Residual or Total Factor Productivity

The traditional 2 factor economic models only explain around 14% of economic growth. The 86% balance is known as the Solow residual or “a measure of our ignorance”. In recent years it has become known as Total Factor Productivity, but traditional economic theory does not have any explanation for what drives productivity.

Physicist Robert Ayres’ 3 factor model, based on thermodynamic efficiencies of the whole production chain, explains 100% of growth. The model is based on capital, labour and “exergy” or the amount of energy actually used productively. The Solow Residual or Total Factor Productivity is a measure of the thermodynamic efficiency with which energy is converted into useful work, and therefore a measure of the total work done.



Jevons Paradox

- Not only is economic growth dependent on energy inputs and the thermodynamic efficiency of using that energy, but so too is innovation and productivity. Just as a virus can only mutate if there is sufficient supplies of energy, so the mutation of technology is also dependent on supplies of cheap energy.

- Individual advances may be lucky, but generally the more abundant the supply of cheap energy, the more mutations will be made. Growth through innovation will be more energy intensive than growth through catch-up productivity as one involves rolling out existing technology to a broader base whereas the other requires new materials, re-tooling and re-skilling.

- Just as there is a negative correlation between mutation rate and genome size, the same must also apply to the economy; the more complex the technology, the more energy is required to advance it to a new level.

- The rising cost of energy relative to GDP indicates that TFP has been insufficient to offset the geological decline. The higher oil price that afforded investment in shale has been at the expense of reduced capital available in the broader economy. We have managed to maintain the supply of oil but cannot afford to use it.

- With the fossil fuel era now mature, and the cost of sustaining production, let alone historic growth rates rising every year, can innovation and the economy find a new form of cheap high density energy to reach escape velocity before the supplies of fossil fuel become exhausted, or are we to repeat the mistake of the Roman Empire?

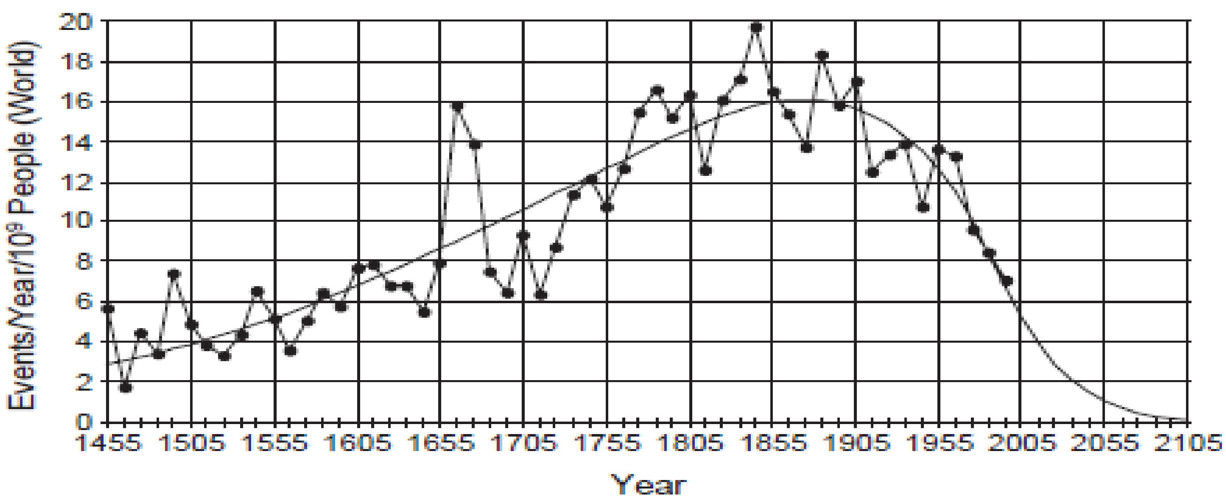
The Singularity is Near

- Global innovation per capita is the lowest for 300 - 400 years. For the purpose of economics, the essential aspect of innovation is the effective expansion of the balance sheet of resources and, available work or factor inputs. The fact that innovation is slowing is being reflected in energy rising as a proportion of GDP – (the cost of "work done" is rising) - with the consequence that GDP growth itself is slowing heavily.

- Whilst the difficulty of the task is getting harder, the computational power to understand and solve problems should also be accelerating, but it is not, or at least not at the pace necessary. This is not due to scientific limitations but rather political and economic choice. The big slowdown in innovation comes on the back of the misallocation of capital that is implicit in debt rising persistently relative to GDP, excessive welfare systems and an uncollateralised fiat monetary system that enables this misallocation of capital to happen.

- The essential requirement for a new industrial or technological revolution is an increase in the order of magnitude of cheap high density energy availability. Whilst it won't necessarily drive the innovation by itself, it is an essential aspect to enable that to happen.

J. Huebner / Technological Forecasting & Social Change 72 (2005) 980–986



The cost of failure

- Like a shark, the economy needs to move forward to stay alive. The carrying capacity of the Earth without fossil fuels or some sort of equivalent is said to be just 10% - 15% of present levels. The latest US and UK census revealed that longevity has already started to fall, although so far this has just affected the number of 90 year olds. In the Soviet Union between 1987 and 1994, life expectancy fell from 64 to 57 as the economy simply could not afford to support this unproductive asset class.

- On the very optimistic side, some people think we may be able to delay the peak of fossil fuels for another 20 years or so, but presumably at an increasing cost. With no productivity growth, there is no surplus beyond maintaining existing consumption, so various parts of the world are starting to consume capital. Net investment ratios are negative in several leading countries, and with deteriorating demographics (higher dependency ratios), this will only get worse.

- Fossil fuels are 7.4% world GDP of USD71.67trn. We spend USD5.3trn a year on fossil fuels. Since 2008, the lost GDP globally against the preceding 10 year trend is about 1.2% pa which compounds to about 6.1% or about USD4.6trn of GDP lost. The lack of cheap energy is already costing us a fortune. To parts of the world this is an opportunity cost, but to some parts of the world it is a very real cost.

- The Manhattan Project cost 1.25% US GDP, or about USD200bn as of today's money spread over 5 years. Scientists throughout the country were deployed on this one project. ITER's budget is what; USD20bn over 20 years? Today, 45% of the top graduates are in finance playing with bits of paper. The space shuttle programme from start to finish was USD196.5bn.

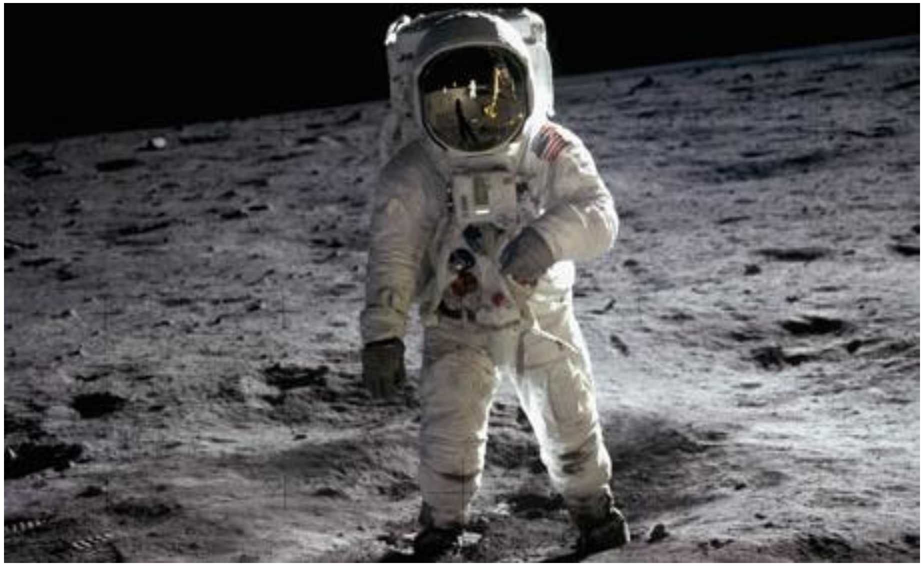
- Quite frankly the lack of financing for fusion is criminal, but it is also criminal that economists, politicians and quite frankly the capitalists of this world don't understand the central role of energy in the economy. We need to get this message across to the broader public if we are to have any chance

Inspire

- In May 1961 John F Kennedy gave one of the most famous speeches of the last century. “First I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him back safely to Earth. No single space project in this period will be more impressive to mankind or more important for the long range exploration of space; and none will be so difficult or expensive to accomplish”. He continued “No nation which expects to be the leader of other nations can expect to stay behind in this race for space” and of course “We choose to go to the Moon in this decade and do other things, not because they are easy, but because they are hard”.

- If ever such commitment was necessary, then it is now. There is nothing more important to the survival and development of the world than getting net energy gain at a cheap price. Perhaps we need quantum computing before we can get fusion or some other technologies, but we seem to be getting to the point where unless we make the breakthroughs fairly soon, we may run out of the resources necessary to make those breakthroughs, at least without a major restructuring and prioritisation programme globally.

- Fusion is the key to the next industrial revolution with all its huge benefits.



- Andrew Lees
  Tel: + 44 (0) 1403 218 883
  Tel: +44 (0) 844 544 6418
  Fax: +44 (0) 844 544 6417
  Andy.lees@MacroStrategy.co.uk

Macro Strategy Partnership LLP
6 Brighton Road
Unit 22, Horsham City Business Centre
Horsham
West Sussex
RH13 5BB
United Kingdom

-