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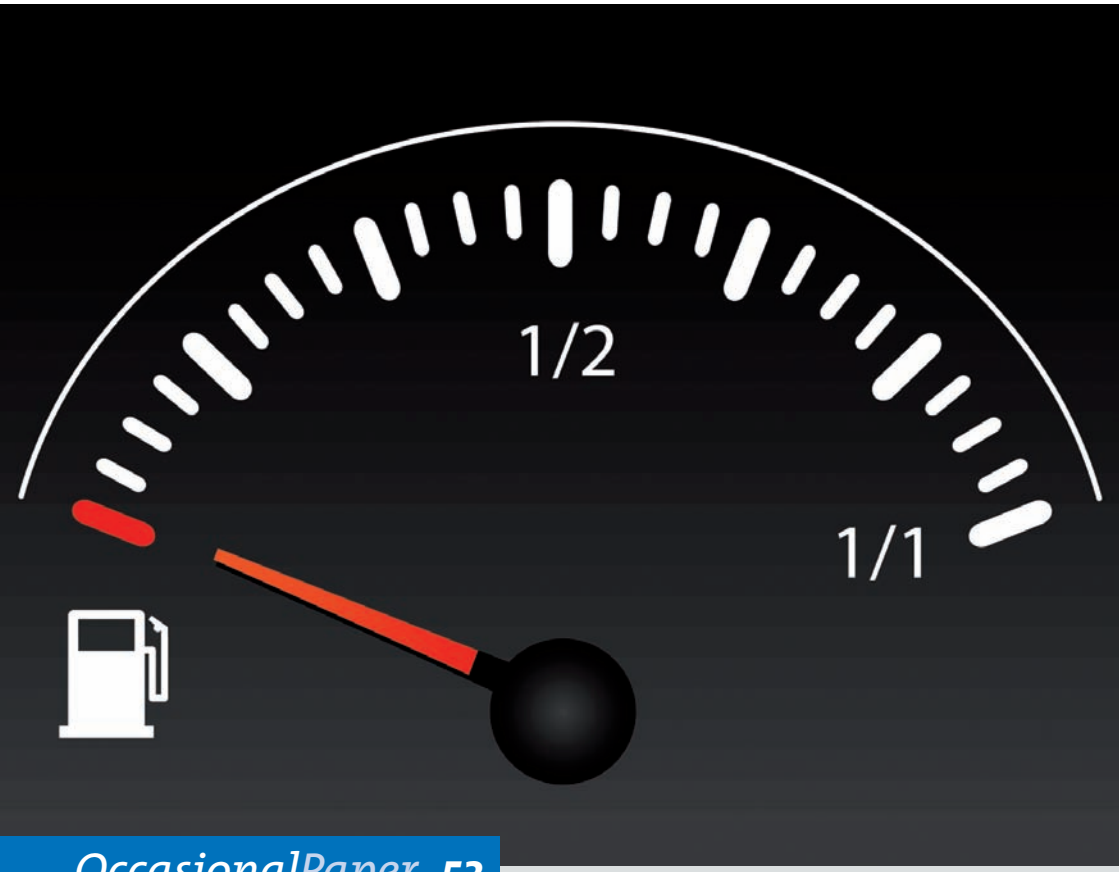

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Will we ever run out of energy?

The history and future of technological progress and energy supply

Dan Lewis

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WILL WE EVER RUN OUT OF ENERGY?

The history and future of technological progress and energy supply

Dan Lewis

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Introduction

Will we ever run out of energy?

To ask the question, is to answer it. Most of us have all too much experience of running out of time or space but not of energy, unless it's the physical kind- perhaps after a long day at work.

And yet, worldwide, energy policy is imbued with pessimism. The strong conviction is that population and economic growth are so great that not only will we run out of hydrocarbons, minerals or land before technology can save us from an impending climatic apocalypse but probably all three will run out simultaneously - and soon.

Yet as we will discover, the real constraint is not our finite physical energy resources, but human intervention of the statist kind.

A careful look at the history, present and future of our energy supply paints a much more positive picture. Over hundreds of years, some crucial megatrends are clear; increasing consumption, progressive decarbonisation, the emergence of energy service clouds and a growth in the breadth of energy ownership and consumer choice.

So what does the history tell us?

Megatrend 1: Rising Energy Consumption

Since the end of World War Two, there has been a six-fold increase in global energy consumption from approximately 100 to 600 exajoules per year. Back in 1820, it was approximately 20. This is a huge increase driven by population growth and more particularly, the nature of new economic demand. Perhaps one modern analogy would be to compare energy consumption growth with the early introduction of the dial-up internet. I can remember in the late 1990s being very pleased at having an upgrade from a 16k to a 48k dial up modem. Today of course, the norm is closer to 5 MB and in countries like South Korea, something like 18. The point here is that the more energy we have, the more

we can do with it. Energy – like internet bandwidth – is an economic input; and there are billions of people who will want more.

Megatrend 2: Decarbonisation

Hard as it may seem to appreciate for many greens, a breakdown of the fuel we use for energy consumption demonstrates a long term trend towards decarbonisation, at least by breakdown rather than quantity. This is a simple matter of chemistry – how much carbon there is per unit of fuel relative to the combustible amount of hydrogen – driven by economic necessity.

Hundreds of years ago, pretty much the only fuel was wood which has ten carbon atoms for every single hydrogen atom. Wood energy of course was also augmented by human labour, draught animals and water power. During these years global economic growth was roughly less than one percent per year.

Huge progress came with the Industrial Revolution which was based on coal containing two carbon atoms for every single hydrogen atom. For the first time, very great heat could be generated, fuelled by almost limitless quantities of coal which is essential to large-scale iron and steel production. Clearly, without coal, there would have been no industrial revolution – there simply wasn't enough charcoal available to fire the furnaces.

At the turn of the 20th century, another major step towards decarbonisation came with oil. Oil contains just one carbon atom to every two hydrogen atoms. Germany of course developed the Fischer-Tropsch process that allowed it to extract oil from coal and in so doing prolonged its war efforts after the loss of the Caucasus. Equally, South Africa during the time of apartheid, was able to keep functioning as an economy despite a large number of sanctions.

The next major step in decarbonisation from oil to gas has been a little bit slow in coming. Natural gas or methane – CH4 – could have played a role a couple of decades before the late 1960s in the USA. Arguably, in certain countries this last decarbonisation step has been held back because of vested coal interests and today, powerful nuclear and renewable advocates. It is a great irony that today, thanks to green scepticism of shale gas in Europe, coal consumption and CO_2 emissions are going up. This is because US Shale gas has driven gas prices so low that American power buyers have been dumping coal they were

contracted to buy on world markets, undermining the cost-case for natural gas in Europe at a stroke – even including the legislated carbon costs. Nonetheless, huge deposits of yet to be exploited shale gas have been found outside of America and Canada which will accelerate the move away from coal.

The final trend of course for decarbonisation is, and will probably continue to be, from gas to nuclear and renewables and other energy technologies yet to be invented, or those brought to market at a reasonable price. As incomes rise, the demand for cleaner energy generally rises too. Arguably however what has undone this final stage of transition has been the introduction of government subsidies that picked winners and reduced innovation right across the technology spectrum. Today's current crop of subsidised, renewable energy technologies – wind, solar and biomass – are anything but game-changers. They are simply too intermittent and land-intensive to have a proper displacement effect. Equally, Europe's post-war nuclear boom led by France that peaked in the 70s, has since gone awry. And yet, it is in parts of the world where economic growth is highest that progress is being made. China has 25 gigawatts of nuclear power under construction with a further staggering 180 gigawatts planned or proposed.

Of course, none of these transitions have been smooth and in many countries they have gone into reverse. Germany, in the wake of Fukushima, has elected to close down all its nuclear power stations, presumably out of fear of a tidal wave reaching Munich, and is now planning to build additional coal-fired stations to make up for the power shortfall. However, all too many people neglect the impact of hydropower, a 160 year old renewable technology that still creates fractionally more power than nuclear worldwide.

Overall, there is still a very long-term trend towards decarbonisation.

Megatrend 3: The Emergence of Electricity to Energy Service Clouds

With the emergence of electricity came the first utilities and their related services. Electricity, a carrier of energy, ultimately made possible what is sometimes called the Second Industrial Revolution from the mid 19th century to 1939, powering equipment and electronics. Today we hear much about cloud

computing being the new thing but this is actually a much older business idea than commonly appreciated. Back in 1878, Thomas Edison created the first utility with a 6 megawatt power plant in New York. For the first time, those businesses in the surrounding area were able to buy in electricity as a service from the cloud, rather than produce it themselves in their own basements. In just one year, Edison had 500 customers buying in this electricity.

Megatrend 4: Growth in Breadth of Energy Ownership & Consumer Choice

The decentralisation and increasing availability of energy services has had a profound impact on our energy supplies. They are on a long-term trend to democratisation. At the beginning, in hunter gatherer societies, there was no ownership of the prime energy source, namely wood. Later, with the emergence of farming, monopoly ownership of land assets was established and largely kept within tight family structures. Moving rapidly forward to the 20th century, a number of states took ownership of oil, gas and coal in order to generate tax revenue. In the late 20th century, cash-strapped and/or pioneering states started to sell back these assets into private hands, often via the stock-market. This greatly increased the breadth of ownership of energy assets. Nonetheless, they were often still monopolies. The next stage was set for unbundling – an area where EU governance has done very well.

Unbundling ultimately delivers greater consumer choice by breaking down vertically-integrated monopolies. A real world example of why this matters is the infamous Enron case – an American energy, commodities and services company that was declared bankrupt in 2002 after being exposed for accounting fraud and other irregularities. In extremis, when an electricity producer is owned by a power supplier you get an "Enron situation" (see the film, "The Smartest Guys in the Room"), i.e. the electricity traders phone up the power station operators telling them to shut down the plant so they can sell an electricity contract at a greater profit in an undersupplied market – this actually happened!

No one is actually suggesting that this occurs today in the EU and the EU has made great strides here through pushing the unbundling agenda, but there is still precious little downward price pressure from competition which would help EU consumers secure energy at a lower price.

Of course, we still have many energy monopolies including OPEC, state ownership and a lot of state-regulated investment but the long term trend – driven by efficiency - has been and will continue to be a growth in the breadth of ownership and consumer choice.

Megatrend 5: Increasing Capital Efficiency of Energy

The next megatrend that is consistent throughout history is the increasing capital efficiency of energy that runs hand in hand with the growth in energy consumption. Each year there is economic growth, nations become slightly better at deriving more economic output from each unit of energy input. This is best measured by dollars of output per barrel of oil equivalent input. These results – by country - from 2005 may be quite surprising to some.

Ranking	Country	Dollars of output per Barrel of Oil Equivalent
1	Hong Kong	1,554
2	Switzerland	1,292
3	Japan	1,272
4	Denmark	1,179
5	Irland	1,097
6	Uruguay	1,014
7	United Kingdom	940
8	Israel	881
9	Italy	827
10	Austria	819

Source: Future Energy Strategies based on World Bank data.

The results tend to favour wealthy nations with a high population density that do not have to endure extreme hot or cold temperatures plus nations that do not have a lot of energy-intensive heavy industry. So the UK for example, scores quite highly but not because it is populated by a virtuous people, very concerned with their energy efficiency. It is simply because the climate is mild, commuting journeys are short and much of the working population is concentrated in the southern half of England and employed in service in-

dustries. Meanwhile, at the bottom, you will find nations like North Korea or some African nations, perhaps producing around $200 or less for every barrel of oil equivalent.

As alluded to earlier, you cannot separate rising energy consumption from economic growth through greater energy efficiency. It has never been done. The additional money from GDP growth rebounds as an additional economic input and becomes an indirect additional energy input. As William Stanley Jevons espoused in his 1865 book The Coal Question,

„It is a confusion of ideas to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth."

It has since become known as the Jevons Paradox (i.e that technological progress that increases the efficiency with which a resource is used, tends to increase - rather than decrease - the rate of consumption of that resource).

In modern parlance, micro-savings at the consumer level by switching off lights and TV standby switches, simply rebound in the wider macro-economy. That's why the only event that consistently reduces overall energy consumption is a recession – almost always caused by a collapse in the money supply which reduces available capital for energy use.

The threats and constraints to our energy supply today

So now we have established some long-run historical trends, the question is what are the actual threats to our energy supplies today?

Perhaps the most underrated threat is the financial weakness of our utility companies – those who would invest in our future energy supplies. Across Europe, they are highly indebted and simply cannot raise the funds to pay for all the green investments our politicians would have them do. These companies have to decide on the balance between dividends and investment that will deliver the best value to their shareholders. Today, these balance sheets are painfully lopsided. Indeed, they are in such dire straits that according to Citi research EU Utilities were the worst performing sector in 2010, 2011 and 2012. The debt matters because it reduces the quantity of investment capital available and increases borrowing costs. Arguably, this is what has made nu-

clear construction so much more expensive. The fully privatised cost of capital for a nuclear plant in Western Europe is now expected to be in the region of 15% - not that much different from a credit card.

According to Peter Atherton, until recently, Chief Utility Analyst at Citi, EU Energy targets were set in 2004-2007. Since then, the following financially game-changing events have happened:

- Banking financial crises
- Utility sector credit downgrades
- Sovereign credit crises
- Collapse in value of renewable manufacturing companies
- Rise in renewable costs
- Poor load factor performance data from wind in Europe
- Fukushima
- Tax grab on sector by government
- Recession and reduced demand
- Carbon price collapse
- US shale gas energy revolution
- Falling energy demand
- Green jobs myth

This collection of largely negative circumstances does not bode well for a rapid recovery in the balance sheets of the utilities. In fact, they seem set to continue going deeper into the red. Amongst the worst affected are E.ON, EdF, RWE and Iberdrola which have a combined net debt position of approximately EUR 140 billion. This presents them with three choices:

I) Raise prices to customers and hope they will pay

II) Cut investment and repair balance sheets

III) Change EU energy policy

Only the last two are realistic options and the second will come first. And yet making any of these choices is made difficult by another constraint on our energy supplies;

Believing in Politicians, Energy CEOs and Received Opinion

Politicians unfortunately have a poor record in intervening in energy markets; and they show no remorse or humility when they are proven to be wrong. Permanence is the illusion of every age and while there will be no end, no final point in our energy history or technology, this is lost on our energy policy-making politicians. Nowhere is this more obvious than with EU energy targets. Europe's politically-driven energy targets are essentially a 20 year EUR 3 trillion un-hedged futures bet on high and rising fossil fuel prices and the ability of renewables to scale up and become cost-effective as a consequence. This is one bet that is set to lead to a huge loss.

To be fair, we should not uniquely blame politicians. Even very successful energy company CEOs like Lee Raymond of Exxon can get the big things wrong. In 2005, he said that natural gas production had peaked in America. In every subsequent year shale gas has been brought to market in the USA in such vast quantities that production has been rising consistently. The fact is that all of the big oil and gas companies missed out on the shale gas rush, arriving several years too late.

Received opinion meanwhile is the enemy of reason. The human brain's limited processing power copes with large amounts of information by accepting all too readily what everyone else in it's environment believes to be true. It takes a lot of effort to disagree and to work out why.

Constraints of politically preferred energy technologies

With energy technologies, there is always a hierarchy of need. First they must be available, second affordable and third environmentally clean. Assuming availability and a level playing field, the cheapest energy source would win. What tends to happen is that politicians seek to redress the balance and skew the choice of technology using subsidies towards cleaner sources which invariably has a negative impact on cost and availability. Modern day renewables are a case in point. Across the Western world, subsidies have been put in place to support intermittent renewables that have failed to deliver on scale, financial cost or availability and thus have created a further constraint on our energy supplies.

Even so, one can sometimes get too carried away with the cost of the actual technologies. The cost of the underlying economic system has a much more major impact on the final cost to the consumer. For example, the cost of wind power per megawatt hour with a subsidy in Texas is approximately 60 dollars per megawatt hour. At that price, you could sell into spot European wholesale electricity markets where the price is equivalent to approximately 75 dollars a megawatt hour and make a lot of money. You could go further and compare the cost of nuclear power in France to the cost of nuclear power in Japan. They are clearly not the same.

What needs to happen is to give more prominence to measuring the performance of energy technologies according to their de-rated capacity margins. De-rated capacity margins are the measure that national grids use to measure the effective, reliable contribution at any time. They are measured as a percentage of the installed capacity that they can be relied on to produce – 100% of the time. And they make uncomfortable reading for some green enthusiasts.

Derated Capacity Margins by Technology:

Pumped Storage	100%
Interconnectors	95%
Oil	90%
Nuclear	75%
Coal	70%
Wind	10%
Solar	0%

Some good news that is happening now

It would be wrong however to conclude that we are doomed to idiotic energy policymaking based on flawed assumptions for a long time into the future. We are currently experiencing the greatest shift in energy markets for 50 years driven by massive discoveries of the world's shale gas deposits, and led by the USA, an economic method to extract them using hydraulic fracturing. So immense has been the impact in the USA that natural gas prices that used to cost much the same as in Europe a few years ago, now cost 4 times less. This is because US natural gas prices have delinked from the oil price that traditional suppliers like Gazprom would have us use as the basis for a contract. At the time of writing, as measured per million British Thermal Units (BTUs), the price of natural gas in America is $2.85. In Britain, the National Balancing Point is pricing at the equivalent of $10.24 for the same amount of gas. And in mainland Europe, it is even slightly higher.

That is why there is so much interest in shale gas in Europe as well as around the world. It is about price. But it also offers huge environmental gains over coal and oil. Not just because it has a lower carbon content, but, more tangibly to asthma sufferers, virtually no particulates or sulphur or nitrous oxides. Already in the USA, there are a number of public transport vehicles that run on natural gas and the city centre air is much cleaner for it.

Another less radical but strategically very important change happening now is the successful exploitation of shale oil. With oil prices so high and using exactly the same technique to extract shale gas, US-based oil companies have found it profitable to bring shale oil to market and boost US oil production at the expense of imports. The reason this matters is that until recently, oil was a globally fungible commodity that more or less priced the same the world over. Since the onset of shale oil production in Eagle Ford and the Bakken the spread between Brent Crude and the WTI (West Texas Intermediate) has grown to $20. So $92 for WTI and $112 for Brent. Worldwide, as more shale oil and shale gas are exploited, this has a long-term impact on the pricing power of OPEC and the budget balances of those member states. The re-localisation of oil prices and the divergence of gas prices from oil-linked contract is a huge threat to the budgets of many Petro-States. That's why some think we have only seen Arab Spring 1. Arab Spring 2 is coming and will be much more convulsive and may even lead to new regimes in Russia, Iran, Saudi Arabia and others.

But so much for fossil fuels – what of the alternative energy technologies?

Are there any cost-effective trends to watch out for in the near future?

We have touched on the rise of natural gas as a transport fuel with a global fleet now numbering some 15 million vehicles.

There is also a new type of nuclear reactor that will soon appear called a small modular reactor (SMR). The principal advantage of SMRs is that because they are small, perhaps the size of a house, they can be almost mass produced, inserted and taken away in a modular fashion as, when and where the demand is. Secondly, because they are smaller in size – perhaps 25 – 250 megawatts, they are much more affordable. If you want to invest in nuclear power, you have to take a view on the future direction of the electricity market and crucially, the future direction of political and electoral sentiment. With massive nuclear power plants costing EUR 6 billion, that is a big bet that will require a 30 year pay-off because most of the costs incurred are up front. With a small nuclear reactor fully stocked with fuel for only 10 years before its modular replacement and perhaps costing a few hundred million euros or less, this becomes much more financeable.

Another way of keeping close tabs on near future developments is to pay attention to which technologies are being patented. Right now, there is a huge patent spike in energy storage technology. Typically, patents are registered several years before the technology matures and reaches the market. The prize for energy storage is to store overnight electricity which in many countries costs almost nothing and sell it back during the daytime at peak. This arbitrage would do much to bring down prices and increase stability to electricity markets.

Nor should we underrate the progress being made in software's ability to match supply and demand faster than ever before.

Conclusion

Many things can interrupt our energy supplies but the constraints are man and not nature-made. There is no lack of innovation and imagination. The risks are what they have always been – political and financial. In terms of actual supply, energy is going to become boring again as the pace of discovery heats up. In just a few years we have witnessed the quiet death of the peak oil and gas philosophy. But the changes that are coming and which we will not be

able to predict, will surely be exciting. As a policy goal, the only sustainable way forward is to work much harder at delivering tangible results at lowest cost. Only then will consumers, businesses and markets be prepared to keep footing the bill.

About the author

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