Are We Ready for Energy Change ?

Joanne Abbess

MSc Climate Change Management

Birkbeck College
University of London

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I certify that the work submitted is my own and that I have duly acknowledged any quotation from the published or unpublished work of other persons.

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Are We Ready for Energy Change ?

1. Introduction

1a. What is energy change, and how ready do we need to be for it ?

This study is an exploratory enquiry into preparedness for potentially profound, discontinuous change in energy production and supply systems in industrialised economies (PwC, 2011). The key modes of this study are scoping evidence of energy change from published research and opinion, and analysing invited reaction from both experts and non-experts. Conducting a review of authoritative discussion and commentary leads to the proposition that the decline of production capacity, and the weakness of alternative resources, are emerging as common themes throughout the energy sector. This is partly due to high levels of fossil fuel consumption (BP, 2011b; EIA, 2010; EIA, 2011a; EIA, 2011b; Enerdata, 2011; ExxonMobil, 2011; Garnaut, 2011; IEA, 2010a; Royal Dutch Shell, 2011), but also due to residual strong dependence on these high-density energy resources (Bornkessel 2010; Ottman, 2010).

1b. The assumption of continuity is open to question

The most serious element identified in the literature is concern over energy security in the near future, which may be encountering initial boundaries in hard resource terms, but is anyway showing vulnerability in production (Simmons, 2004; Stevens, 2008). Robust demand for crude petroleum oil, Natural Gas and coal and their by-products is conjectured to lead to a depletion of good quality, accessible proven reserves, which could result in an erosion of production capability (EWG, 2007; Heinberg and Fridley, 2010; Hirsch, 2005; Hook et al., 2009a; Patzek and Croft, 2010; Roper, 2011). For crude petroleum oil in particular, despite estimates of ultimately recoverable reserves growing over time (Sorrell and Speirs, 2009a) indications of a lack of flexibility in production flow rates (Sorrell and Speirs, 2009a) could make markets more sensitive to marginal alterations in supply, therefore more volatile (Frankel, 2011; IEA, 2010b; ITPOES, 2010; IHS CERA, 2010a; JODI, n. d.; OPEC, 2011a).

1c. Keeping up supplies could be challenging

Given the projected depletion of oil and gas wells in production in major OPEC nations in the Gulf of Arabia and elsewhere (Aleklett et al., 2010; Hook et al., 2009b; IEA, 2011; Macalister, 2009b), without adequate levels of reserves replacement or compensation from unconventional resources (GWPC and ALL, 2009; HoC, 2011a; Vidas and Hugman, 2008; Wood et al., 2011) the dampening effect on global supplies could be considerable (Bentley, 2002; Guseo, 2011; Soderbergh et al., 2010). Despite current optimism regarding unconventional gas reserves (e.g. Hiserodt, 2011; Holditch and Ayers, 2008; Kerr, 2010; Myers Jaffe, 2010; Yergin, 2011; Yergin and Ineson, 2009), production could be constrained by economics outside of "sweet spots" (HoC, 2011b). This means that proposals to use compressed Natural Gas or Gas-to-liquids chemical conversion to replace depleting vehicle fuel could be jeopardised. In addition, strong global demand for coal (BP, 2011a), yet poor prospects for extensive new reserves (Patzek and Croft, 2010), could keep the market niche small for substitution of crude oil-based vehicle fuels with Coal-to-liquids. From this, it appears that it is no longer possible to assume continuity in the trends of supply of energy.

1d. The view from here - a spectrum emerges

Some view recent production difficulties (BP, 2011b; Macalister and Stewart, 2011; The Guardian, 2011) as a short-term hiatus within the context of economic readjustment, and project rising prices will spur increased exploration and discovery, in both oil and gas provinces, but also into unconventional fossil fuel resources (BP, 2011b; IEA, 2011; IHS CERA, 2010c; Mohr and Evans, 2011; Smith, 2009; Yergin, 2006). Others think energy production futures will go through a "zone of extraordinary opportunity or misery" (Royal Dutch Shell, 2011), having to navigate an extended energy supply crisis, and open up new resources, whilst simultaneously avoiding dangerous climate change risks. Yet others claim that evidence indicates the imminent arrival of, or even established reality of, a "peak" in production in terms of geophysical limits, in all forms of fossil fuel energy, which cannot be overcome (Aleklett and Campbell, 2003; Hamilton, 2008; Hughes, 2011; Owen et al., 2010; Rutledge, 2011; Sorrell et al., 2009; Strahan, 2007).

1e. The wider energy security implications - the next few critical decades

If new fossil fuel and alternative energy developments cannot bridge an ever-increasing disparity between demand and supply, then not only are future projections of growth in energy use unrealistic (BP, 2011b; ExxonMobil, 2011; IEA, 2010c; Royal Dutch Shell, 2011), but current levels of energy use will not be sustainable. This scenario would have serious and undesirable ramifications for governance, industry and society. Indications of disruption in energy supplies within the next few decades naturally lead to questions of preparedness. Publics in developed countries have been nurtured to consider rationalising their use of energy and revising attitudes to energy technologies (Ipsos MORI, 2009), and aspiring to the lower carbon life (DTi, 2003a; DTi 2003b; DTi, 2006; nef, 2009); but so far the open policy conversation has been couched in terms of voluntary behaviour change in response to climate change. Given the possible extent of energy change arising from limits in production capacity rather than a low carbon transition (Giannakidis, 2010), and the scope and reach of ensuing social impacts, what people think about energy change could be expected to be of policy importance, and it might be appropriate to consider raising public awareness of the risks and outcomes of energy shortages.

1f. Sounding out what people think about energy change

In this study, a review of the literature on energy change unpacks a number of issues related to energy change, including the prevalence of trust in energy engineering and technology, despite recent well-publicised failings (BP, 2011d; TEPCO, 2011); and the long-avoided simple remedy of the rationalisation of energy use. The results of a survey enquiring into preparedness for energy change are reported, along with outcomes from a simple modelling exercise based on global energy data (ESDS, 2010) and expert opinions about growth and decline in production. The survey asks questions along two dimensions, a range of energy technologies and a spectrum of future scenarios, gauging preparedness for change along both axes. Discussion of the survey results is done in the light of the energy modelling, and recommendations for both further work and policy are suggested.

2. Literature Review

2a. Exploring published opinion on key issues

2a1. Conflicting interests over energy consumption could be causing counterfactual narratives

There is a clear fundamental dichotomy between rational governmental policies to address energy security issues and the trading ambitions of energy production businesses. The logical first response to energy security risks would be a strategy for energy conservation, but selling less energy is not in the profit-making interests of corporate energy producers and suppliers, especially since an energy company can only sell you insulation and solar photovoltaic panels once. Maximising energy sales will also be a prime directive of transnational companies that trade and distribute energy; although this may not be the case for major energy resource countries (Waterman, 2008). Energy company shareholders and national energy producers would perhaps be satisfied by smaller volumes in sales at higher prices, but consumer governments have a responsibility to make sure that energy prices are under control, ensuring that energy flows remain consistent, to protect the economy and stave off political revolt (Akinsanmi, 2011; Archibong, 2011; Baird, 2011; Bielecki, 2002; Khan, 2011; Muhammad, 2011; Seager, 2004; Tran, 2008). Furthermore, the potential of energy conservation to affect the profitability of energy companies may have a knock-on effect on other sectors of the economy, since many pension funds and other institutions have investments in energy, and this could run counter to strategies for economic growth. In effect, the profit-making health of energy companies equates to the wealth of a country (Reuben, 2010), and so can expect to be upheld by policy. In addition, since energy consumption underpins economic activity, if energy conservation measures are undertaken without a decrease in the energy intensity of productivity, this could inhibit recovery from recession. It has emerged that energy sector companies, including those in mining and construction, have been financing opinion-formers who undermine the acceptance of climate change science, where energy conservation is a key proposal in policy (Climate Progress, 2010; Hoggan and Littlemore, 2010; Mann, 2009; Oreskes and Conway, 2010). If energy production decline becomes prevalent, energy conservation will be ever more pertinent, and continue to be resisted, perhaps with irrational behaviour by some parties, in terms of reduced authority and accountability. This could perhaps manifest itself in misleading reports on energy supply facts, or their environmental impacts; or unfounded claims being made about the potential of new energy resources. This could apply to new conventional resources (Boyle and Bentley, 2008; CBS, 2009; Cobb, 2011; Crooks, 2009a; de Sousa, 2007; Gue, 2009; Hampton, 2011;

Leggett, 2011; Macalister, 2009a; Schmit, 2009; Vail, 2006) as well as substitutionary resources (Aden, 2010; BP, 2006; Cheng and Timilsina, 2011; Crooks, 2009b; Energy Efficiency News, 2010; EnvironmentGuru, 2011; EuroObserv'ER, 2011; EuropaBio, 2009; Hamelinck and Faaij, 2006; Hybrid Cars, 2011; Korsgaard, 2011; Lane, 2010; NMA, 2011; Oltra, 2011; PR Newswire, 2011; Wetzstein and Wetzstein, 2011; Zhang, 2011). It would be difficult for investors and governments to differentiate between such counter-productive developments in energy company public relations behaviour and reliable information on systemic or technological aspects of energy security. Given the potential for misinformation, it could be advisable to be cautious of exuberant press releases and briefings from energy sector chief executives.

2a2. Energy production plateaux - do they reflect temporary economic difficulties, stretched production capacity, or fundamental depletion, or a combination ?

Since energy is a real, immediate commodity, subjective conjectured risks of energy production decline could convert into harsh objective realities in a short timeframe - the lights are either on or they're not. Complete confidence in market mechanisms to re-equilibrate and correct supply deficits, without intervention, could be misplaced. If there is widescale and rapid emergence of credible threats to energy security, well-developed strategies to navigate the resulting energy change will be highly valuable, especially to energy companies who diversify out of conventional fossil fuels (Ritz, 2008). Whilst there is not yet uniform evidence of a "peak" in crude oil or other energy production, there are indications that production may be unable to rise consistently from this point on, and evolving dialogue that this suggests plateaux in capacity and supply streams (BP, 2011a; Bridge, 2010; Campbell, 2010; Egging et al., 2009; EWG, 2007; Heinberg, 2011; Hook, 2009; Hook, 2010; Hook et al., 2009b; Hook et al., 2010c; Hughes and Rudolph, 2010; IEA, 2010b; Jackson, 2009a; Jackson et al., 2008; Kjarstad and Johnsson, 2009; Mohr and Evans, 2011; NPC, 2007; Rudolf, 2010; Soderbergh, 2010; Sorrell et al., 2010a; Sorrell et al., 2010b; Tverberg, 2010; Zalik, 2010). A levelling-off of production in crude oil and Natural Gas may be attributable to a number of factors, including well and field depletion, high demand for throughput at refineries, repercussions from military conflict, and deficits in exploration and discovery. In parallel, a lack of investment by privatised electricity utilities, resulting from a competitive liberalised operational environment, and a virtual moratorium on new nuclear power for many years, mean that high levels of capital expenditure are becoming urgent to meet lifecycling requirements for new plant and infrastructure (Hodge, 2010; Huhne, 2011; IEA, 2003; IEA, 2009; IEA, 2010d; Ofgem, 2010; Webb, 2010; Yang, 2009). These factors, amongst others, could be hindering capability to increase energy production and supply. Peaking in one energy form can affect others. For example, despite developments in unconventional production, most Natural Gas is found in the same hydrocarbon deposits as petroleum oil, so "Peak Oil", including Natural Gas liquids (NGL), almost inevitably heralds "Peak Natural Gas" in the gaseous fractions; close behind (ASPO, 2008), or several decades later (Burri, 2008; Guinness, 2009; Zerta et al., 2008; Ziegler et al., 2009). This could bring forward "Peak Coal" through fuel switching away from Natural Gas to coal for electricity generation.

2a3. Can we bridge the yawning gap - when it appears ?

Unconventional and alternative sources of energy may not be able to bridge a gap between increasing demand and cresting or volatile energy supply. Renewable energy technologies are starting from a very low market share, and so even the current exponential growth (BP, 2011a) may not be sufficient to compensate for an energy supply deficit caused by declining fossil fuel production. Energy utilities and primary energy producers are keen to talk about their renewable energy ambition (McCarthy, 2009), but their green power and fuels still constitute minor percentages (REN21, 2011; RESTATS, 2011). Some renewable energy technologies, such as marine energy designs and algae biodiesel, are still in the research and development phase; and in a similar way to energy efficiency approaches, such as Combined Heat and Power, may suffer from reduced financial investment flows, owing to the depressed economic climate. Importantly, predicted moves into unconventional fossil fuels, such as heavy oil, Arctic oil and shale gas, resulting from concerns about the supply profile of good quality conventionals, may not make the level of returns in energy supply anticipated (New Scientist, 2011b). Furthermore, besides causing localised environmental damage, plans to exploit unconventional or "frontier" resources (BP, 2011c; Werdigier, 2011), to make up for a fuel shortfall, will almost inevitably cause a greenhouse gas emissions burden, which may not be counterbalanced by the parallel development of cleaner alternatives (BP, n. d.; Hunt, 2011; New Scientist, 2011a). This could therefore prove problematic as it would run contrary to global ambition for climate change management.

2a4. Are we thinking the unthinkable yet ?

Significant energy change is probably underway. The components of the global energy supply, and their volumes, will likely change. Supply deficits in conventional fossil fuels may not be bridged by the stimulus of energy price increases, development of alternatives, nor renewed oil and gas exploration. The same could be true in electricity generation, resulting from stress on supply; caused by necessary decommissioning of ageing plant, financing replacement programmes, renovation of ageing infrastructure and grid networks, and the added burden of the commissioning of renewable energy assets; all within a restricted investment atmosphere. Impactful energy change should be anticipated, and if supply deficits become critical, risks of energy insecurity could cause governments to impose energy price controls, and regulate for energy conservation, or even re-nationalise energy industry, especially if parts of the privatised energy sector look liable to become bankrupt (DECC, 2011; Ofgem, 2003). Governments could perhaps be forced to issue energy investment bonds to address the impasse (Bradbury, 2009). Such turbulence would likely affect every area of trade, production and society, and threaten the integrity of industrialised economies especially.

2a5. All change - how do we ask the right questions about the re-structuring of the energy economy ?

The unsettling effect of severe energy insecurity and the scale of the investment response required could mean more than merely utility bill increases, as the prospect could be of faltering economic growth. This consideration widens the scope of questioning, for example, are we ready for economy change ? Questions about energy change are different to asking whether people are "doing their bit" for climate change. They are broader than asking if people are "saving" energy, because the UK has become a net energy importer. Energy change questions encompass more than technology choices, such as the ongoing debate about choosing a nuclear power plant replacement programme over wind power development (Porritt, 2011). Energy change questions centre on the anticipation of a systemic alteration, regardless of the choices that individuals, companies and governments make. It might be that energy change means reduced energy supply, even if only temporarily, and require publicly financed investment, which will impact the tax regime; or perhaps even spur energy rationing, as well as higher bills. Energy change questions may push wider the usually acceptable limits of concern in the public realm, and so should be designed to elicit analytic rather than affective responses (Hulme, 2009). Certain aspects of energy change will undoubtedly encounter resistance from the population, but energy change is more complex than navigating public opposition to new renewable energy installations, new cabling, pylons and pipelines (Monbiot, 2011), and the continuing media disparagement for renewable energy (Clark, 2011). It will certainly imply major infrastructural and technology changes, and cannot be made invisible, even if new energy farms are very rural, at the coast or offshore (Hardman, 2011).

2b. Reading some possible signs of a decline in production capacity

2b1. The possibilities of discontinuous change

The moment the bough breaks, or a nuclear reactor core attains critical mass can to a certain extent be projected. Despite this, the profound system-wide change of state that emerges is not necessarily comprehensible if conditions are only monitored at close range, or in short time slices. The rate of global production of crude oil has kept on rising generally, and so there is little to suggest it may have peaked (DiPaola, 2011; OPEC, 2011b). However, there can be indications of different trends at the cusp of change, for example, the moment river floodwaters overtop a levee, or a parked car starts to roll - things that wouldn't be happening in a normal situation. It is worthwhile to recognise this category of signals, to enable determination of optimal pathways for adaptation and risk avoidance. Foundational knowledge in most cases would come from establishing boundary conditions or limits.

2b2. A key driver of energy change - the geology and geography of coal

Since catchments of oil, Natural Gas and coal in the Earth's crust result from epochal great extinctions, and the subsequent carbon burial, eventual depletion of useful hydrocarbon and coal energy is a geological fact. Although humankind is very unlikely to completely exhaust highly dispersed, hard-to-produce, low quality resources, such as heavy oil, gas shales and methane hydrates, it is conceivable that the majority of easily accessible and high-density deposits will be. In some places, reserves are being consumed at high rates; for example, since much coal in Pennsylvania was sequestered around 300 million years ago, one could say that 150 million years of anthracite have been burned through in the last 15 decades (Edmunds, 2002). New discoveries of coal and reassessments are not generally translating into higher proven reserves (Mohr and Evans 2009). The World Energy Council (WEC) significantly raised proven coal reserves figures from its 2009 interim report to its 2010 report, but the 2010 figure is still less than the 2004 report figure, and all other revisions since 1998 have been downward, apart from a minor upgrade in 2001 (Table 1). In addition, good quality coal reserves are reported to have been shrinking since the WEC 2001 report (Table 1, "A/B"), and the upgrade in 2010 is only due to a revision of poorer quality coal reserves (Table 1, "S/L"). The reserves-to-production ratio calculated by BP has been decreasing for the last decade, from 227 years in 2001, to 118 years for the 2011 report (Table 1, "R/P"), which suggests that conversion of known resources into proven reserves is not keeping pace with consumption, and "Peak Coal" may arrive in the very near future

(Mohr and Evans, 2009). The problems this could pose for worldwide energy supplies are amplified because coal is not the only resource of energy with indications of worsening prospects.

2b3. The Law of Diminishing Returns and time-dependent behaviour

After some time extracting oil and gas from a fossil fuel field there is depletion, a continuous decline in the quantities that can be produced within that particular locale. Recourse is often made to the idea that better, as-yet-undeveloped, technology will be able to significantly hold back well, field or seam depletion, but outcomes are minor, or two-edged - greater extraction may cause faster depletion (Aleklett et al., 2010; Sorrell and Speirs, 2009b). Another four-dimensional geography is that some large, proven fossil fuel reserves can only be produced at very low rates, such as heavy oils (Dusseault, 2001; Whaley, 2009). Time questions also figure when questioning production capacity in the face of strong demand; the so-called "above ground" issues, such as how many refineries are in operation. However, the most significant time-sensitive problem is likely to be that production from the world's active "giant" oil and gas wells is decelerating (Hook et al., 2009a). These resources could be impossible to replace in a timely manner. Although the situation could be improved by immediate measures on energy conservation and the development of alternative energy sources; if depletion rates steepen, a range of economic indicators could ail. Following on, if the global economy loses momentum, stimulation of new energy production could face barriers. It cannot be assumed that energy production technology can improve to compensate (e.g. Al-Bahlani and Babadagli, 2011), especially when considering the greater energy losses from the production of lower quality, more dispersed reserves. The Energy Returned on Energy Invested (EROEI), or Net Energy Gain (NEG), of most fuels is decreasing, both conventional and unconventional (Bull, 2010; Coggan, 2010; Hall and Murphy, 2009) and this challenges the assumption that lower grade, more complex and increasingly inaccessible energy resources can become more economic to develop. Falling EROEI effectively means that more input energy is being expended to go after less energy output. It could be said that as mined reserves are effectively free of charge, extra energy to produce lower quality resources is only a marginal cost, and decreasing energy "return on investment" need not impact profitability. However, a decreasing EROEI lowers efficiency, and therefore productivity. Also, affordability can be affected when one form of energy is used to produce another, for example, if Nuclear Power is chosen to produce Canadian tar sands (Gue, 2010; IHS CERA, 2009).

2b4. Firefighting from the supply side

Peak Oil is not simply about depleting oil wells - warfare and non-violent international diplomacy play their role (Boselli, 2011; Saadi, 2004). There are indications that oil and gas companies are making use of such situations, even whilst governments and leaders are firefighting to keep oil and gas supplies dependable, secure and affordable (Muttitt, 2011a). If actions are taken to encourage high production and stem speculation on the energy markets, whether overtly or discreetly, it can be predicted they will not be uniformly successful. Oil and gas companies and producer countries (e.g. OPEC) need to raise more revenue to finance new exploration, in the hope of keeping reserves and production adequate. They are therefore going to resist pressure to "open the taps"; to ensure oil prices stay "robust" enough to pay for exploration. This is perhaps more likely for consumer countries with an ambivalent relationship to their producer nations, such as between the United States of America and Saudi Arabia, and Venezuela. However, international relations are not always relevant, since a large proportion of oil production and refinery is conducted by vertically integrated supermajors, even in countries where the oil businesses are nationally owned and controlled (Muttitt, 2011b). Cessation in the growth of energy production could endanger top-level plans for economic development, in which case it would be unlikely that any part of the global order will avoid experiencing side-effects (Bundeswehr, 2010). The most appropriate form of firefighting could be in taking a rational and pragmatic approach, by preparing for the decarbonisation of trade, industry and society, as only the low carbon energy sector would be capable of growth.

2b5. Peaks of various kinds could be witnessed

A decline in energy supplies would suppress trade, which would represent the cessation of growth in wealth creation; and coupled with speculation and scarcity pricing, would signal "Peak Economy". Current turbulence in the markets for crude petroleum oil, the workhorse of transport, suggests "Peak Globalisation", with significant negative contraindications for the development of economically disadvantaged countries. These peaks may be recognised within a decade, but "Peak Profitability" could be seen sooner, as those corporate actors not actively displacing hydrocarbons and coal from their business models could suffer contraction. Despite renewed focus on fossil fuel exploration, as discoveries have been tailing off, there could be a trade-off between the need to increase reserves and pay dividends to shareholders (Ibanez, 2011; Pfeifer, 2010; Swint, 2011; Waller, 2011). This potential for "de-growth" could increasingly risk major investment funds, which would mean

"Peak Pensions". The current and ongoing catalogue of accidents and other failures in the fossil fuel industries (and in nuclear power), suggests some kind of "Peak Competence" (Grinzo, 2011) in energy engineering, which could be an outcome concomitant with energy change impacting the commodities supply chain and operating margins.

Any consideration of energy futures is not complete without addressing risks from climate change, which if significant, are urgent; whence the need for "Peak Emissions" to be an element in every energy decision. Movement towards exploiting unconventional fossil fuels could indicate failure to reach the point of "Peak Denial" about climate damages and other environmental risks from lower quality energy sources (HoC, 2011a; IHS CERA, 2010c; Jiang et al., 2011; McKellar et al., 2009; Pieprzyk et al., 2009; Santoro et al., 2011). The alternative would be to increasingly utilise low carbon energy resources; as investment in renewable and sustainable energy would prevent "Peak Economy" as well as "Peak Energy", whilst preventing further climate deterioration. Another facet of "Peak Denial" can perhaps be detected in the gradual introduction of unconventional fossil fuels into energy reporting as the "new normal", accompanied by a buoyancy in production data and quoted proven reserves which may not be fully justified (BP, 2011a; Lacalle, 2011; Mitchell, 2006; Salameh, 2005). Further "Peak Denial" may arise as governments and shareholders in large energy companies find news of energy production losses unwelcome, and treat the message as unreliable (Badal, 2009; DECC, 2009; Macalister, 2011; Mearns, 2011; RES, 2007; ITPOES, 2010).

2b6. Synergistic effects - energy, economy and climate change

The root causes for inadequacies in engineering safety highlighted in the 2010 Gulf of Mexico oil spill and the 2011 Fukushima Dai-ichi multiple nuclear power plant accident remain to be identified. Rising maintenance and operations costs within competitive privatised industries are perhaps taking their toll on the integrity of the energy production fabric, including transmission and pipeline networks; and if so, without appropriate intervention, there could be a higher frequency of major engineering aberrations as time passes. What is clear however, is the potential for energy disruption to have a significant effect on wide portions of the economy, besides disastrous impacts on the environment and society from spills, leaks and meltdowns. As depletion scenarios gain traction, it will be no surprise should energy security become paramount (Fairey, 2009).

The G20 call to end fossil fuel subsidies (OECD, 2010) appears at first to be a move to "level the playing field" between high and low carbon energy technologies, but the rationale could have more to do with "liberating" fallow Iranian oil and gas for world markets than an attempt to stimulate "greener" energy and conservation (The Economist, 2009). The most effective way to add appreciable supplies to the world's energy markets would be to exploit known but undeveloped large oil and gas fields, such as in Iraq (Aleklett, 2007b) and Iran, where fossil fuel subsidies support economic development. If energy subsidies became disallowed under free trade agreements, citizens would be less able to buy energy, and the government would find the advantage in exporting energy; a situation which would perpetuate the "resource curse" of developing nations - selling commodities abroad for less than their true worth (Riemer, 2009). Despite exports of energy creating national revenue (El-Gamal and Myers Jaffe, 2009), it could still be sold under-priced in global markets, so the full value would be lost from the producing country. Pressure to sell oil and gas cheaply on the global markets could also partly come because resource-rich under-developed countries continue to have high levels of international debt (CIA, 2011), a situation that would only be exacerbated by climate change adaptation needs.

One recent news narrative influencing energy markets is that global production of Natural Gas has never looked more promising; possibly a strategy to justify keeping its price low, as this would ameliorate energy security. Raising confidence in Natural Gas, partly because of climate change considerations, could increase demand, and encourage countries like Iran to raise production. If market prices can be kept subdued, then producer countries like Iran could be exploited at low cost. Natural Gas use is emerging as a default position, amidst the maelstrom of arguments over energy technologies. This "second dash to gas" is accompanied by recurring themes, exemplified by the media memes "gas glut" (e.g. Hoyos, 2010; Miller, 2011a), "shale gale" (e.g. McNulty, 2010), "Golden Age of Gas" (e.g. IEA, 2011), and "game changer" (e.g. Newell, 2010). Business commentators and consultants are calling Natural Gas a "bridging fuel" to a low carbon energy future (e.g. Kirkland et al., 2010), and even using the construction that poor quality rock gas, such as tight gas, shale gas and coalbed methane, are "clean" (Arthur et al., 2008; CSSP, 2010) because they too are "Natural" Gas (MIT, 2010). Shale gas production is only critical for the USA (DOE, 2011; EIA, 2011c), and its development is resisted elsewhere (Patel, 2011; Vidal, 2011). This rash of public relations may result partly from American attempts to convince the Middle East of their oil and gas independence, thereby keeping import prices under control. Another alternative reading is that championing the "wonderfuel" shale gas might be a vehicle for selling hydraulic fracturing technology to China (e.g. Bloomberg, 2011; Dyer, 2010; Foster, 2011), alongside other "technology transfer" options (DECC, n. d.).

2b7. Triple Crunch - it's all about the price of oil

If both conventional crude oil and conventional Natural Gas are undervalued in global markets, this could apply a tourniquet to unconventional energy production, which has been relatively more expensive (Weijermars et al., 2011). If production levels of unconventional oil and gas do not meet expectations, and exhaustion of conventional reserves continues, trading price adjustments could cause a "Triple Crunch" (Energy Bulletin, 2011), as economy, climate and energy concerns have synergistic mutual impacts : with a poorly functioning economy, it will be hard to finance the low carbon energy transition (Harvey, 2011; Yang, 2010). This risk is higher because, since the global collapse in financial services for property loans, energy has become a prime investment vehicle, as one of the few sectors still producing healthy returns (Konrad, 2011). However, energy share value increases may be due to stresses in the supply chain, and this would represent underlying inflation in the economy, rather than asset-based growth. If significant scarcity were to be experienced, without price controls, the markets could hyperinflate. Rather than production failures, currently the largest potential for scarcity appears to be coming from competition to acquire the same resource supplies (Kebede and Taylor, 2011). Despite the continuing recession in many industrialised countries, the consumption of energy has remained firm, or "inelastic"; and there is rapid demand increase in some developing countries such as China, particularly for coal and petroleum oil products (McNulty, 2011). The recent release of Strategic Petroleum Reserves (Andrews and Pirog, 2011; Scherer, 2011) and subsequent easing of oil markets, suggest that price control strategies could become sanctionable in order to keep the global economy stable. There remains the option to suspend energy trading, to protect the global economy if changes in energy production cannot match the rate of price volatility.

2c. The failure of innovation

2c1. The myth and failure of progress - the shale gas bubble

Limits to growth in fossil energy production may cause mankind to reflect on the ideology of technological innovation (Becker, 1949). This is not a war of the optimist versus the pessimist; there are genuine gains and losses taking place together, sometimes in the same field. By definition, technological discoveries are in the realm of "unknown unknowns", but innovation is not a sure route to progress, and technology may fail. It is wise not to make light of the risks. "Rational optimist" Matt Ridley has claimed technological "scare stories" are baseless, "When I was student here in Oxford in the 1970s the future of the world was bleak. The population explosion was unstoppable. Global famine was inevitable. A cancer epidemic caused by chemicals in the environment was going to shorten our lives. The acid rain was falling on the forest. The desert was advancing by a mile or two a year. The oil was running out and a nuclear winter would finish us off. None of those things happened" (Ridley, 2010). The reason why some projected disasters have not happened, or been so severe, has been that humanity has organised against them : increasing famine, acid rain, desertification or "dustbowl-ification" (Romm, 2009) are all real, and have prompted action. Since Ridley appears to be incorrect about Peak Oil, could he be over-optimistic about shale gas too (Ridley, 2011) ? Some have highlighted the disappointingly high rates of well depletion in shale gas plays in North America (Kaul, 2010; Urbina, 2011a). Regarding other unconventionals, it is not certain that fuels derived from refined kerogen and bitumen from low-grade oil shales and tar sands can be advanced from small market percentages (EIA, 2011a; Urbina, 2011b; USGS, 2011). Significant environmental concerns about unconventional fossil fuel exploitation indicate it could be legislated against (ENVI, 2011). Expectations for polar oil and gas are low (USGS, 2008) and primarily expected to be offshore, therefore hard to access. There are continuing problems with deepwater oil and gas drilling (Flynn, 2011; MSNBC, 2010; Offshore Energy, 2010; Shetland News, 2011), and the hostile environment of the Arctic could exacerbate them (IOL, 2011). New fossil fuel finds are frequently small (Royal Dutch Shell, 2007), leading to a drop in return on investment, unless new technology can compensate (BBC, 2011a).

2c2. The failure of technology with its feet of clay - spills, leaks, crumbling concrete and rusting pipes

Belief in uniform and unconflicted progress, particularly in energy technology, is not borne out by historical evidence. Discoveries of genuinely new and successful energy technologies are infrequent. Of the recent developments in atomic energy and photovoltaic cells, nuclear power fortunes may be waning, as, amongst other concerns, its economics are repeatedly questioned (De Roo and Parsons, 2009; Du and Parsons, 2009; Winston, 2011). Furthermore, the optimisation of energy systems shows a tendency towards fixed limits; for example the Laws of Thermodynamics mean that combustion technologies cannot expect significant improvements in efficiency (EurActiv, 2006; IEA, 2010e; Sargent & Lundy, 2009; Turns, 2006).

Pragmatists suggest there are drawbacks to trust and optimism in technological advance (Gray, 1999). Experience of the impacts of energy systems would seem to validate this position over that of confident futurists (e.g. Kurzweil, 2001). Confusion can possibly be traced to a fallacy about what technology is : science is not the same as technology, and theoretical designs do not always translate into actual working systems. The crucial factor is often the quality of the natural resources available. Newton's science comprehended gravity, but Newton's technology could not have predicted that rockets would one day thwart gravity by using modern high-density fuels to reach escape velocity. The success of intense efforts, such as the USA's NASA Space Program, relied on vast injections of capital, manpower and raw resources, including cheap oil - something not guaranteed in a possible energy-constrained future, despite Barack Obama's "Apollo" "moonshot" aspirations (Gustin, 2011).

Not all technologies can be developed significantly as designs do not always translate into successful, durable engineering : technology is not the same as engineering. For example, despite the knowledge and expertise developed during the "space race", sometimes rockets crash. Additionally, accruing "externalities" may preclude exploitation of some options - it may seem pragmatic to turn to unconventional fossil fuels to make up for depletion in good quality resources, but there are unpleasant and possibly counter-productive side effects (Shankleman, 2011; Williams, 2011). Complexity can generate the potential for catastrophic failure and a cocktail of devastating repercussions (Osborn et al., 2011), resulting from pervasive ignorance and the neglect of risk (Allenby & Sarewitz, 2011); but by far the most serious issue is the vulnerability that comes to all energy engineering with time. All energy exchange processes are subject to age-related problems, some not anticipated when machines, engines and plant are constructed; and often due to material fatigue and worsening safety management (AP, 2011; BBC, 2011b; Behr et al., 2011; Daily Mail, 2011; Lemonick, 2011; Makhijani, 2011; Smith et al., 2011; The Fukushima Project, 2011).

The more time passes without a truly new innovation, the more unlikely that there will be an energy "silver bullet" or "black swan" technology (FORA, 2008; Harris, 2011), that can be delivered at scale and in time to meet an energy crisis. A good first principle to adopt would be simplicity, avoiding risks of overreach or "aiming for the moon" in energy engineering. One approach which incorporates simplicity and reduces impacts is engineering for ambient, renewable power technology such as wind and solar, which alleviate the risk of mismanagement, accidents, pollution events and shutdowns as experienced in the current fossil fuel and nuclear energy industry. By contrast, offering solutions using conventional technology may not hold out improved potential. Carbon Capture and Storage (CCS) and new generations of nuclear power are proposals which ignore current energy technology failings, and trust in the improvement of engineering capabilities. It is uncertain if these "technofixes" can succeed (Fauset, 2008). For example, the industrial sector that proposes to develop CCS is mostly comprised of actors responsible for major oil and gas spills (Decom World, 2011; ExxonMobil, n. d.; Kansas, 2011; Oil Voice, 2011). The lesson that could be drawn from an accurate assessment of the failures of innovation, technology and engineering is, if genuinely facing a crisis in energy production and delivery, it would be best to question platitudes about what progress can bring, and determine to apply proven remedies of renewable energy and energy conservation, rather than living in hope that an under-funded research laboratory somewhere creates a miracle, or oil and gas flow rates break the Laws of Petrogeophysics. It would be best for the long-term to adopt rational, independent governance (David-Barrett, 2011), and give a wider berth to public relations people representing energy technology start-up companies, and established energy companies touting re-packaged wares.

2d. Cracking old and new resource paradigms

If fundamental resource concerns continue to suggest an energy supply crisis, a considerable amount of common and even expert knowledge could be challenged. This cracking of the old "resource paradigm" will need to be complemented by the fracturing of new resource and technology myths, since it will be no easy matter to replace declining high quality fossil fuel resources. Futures thinking will need to show great transparency as regards factual bases - opinions promoting various technologies should always be viewed in the context of the evidence of failed engineering and resource depletion. However, asking for views on a range of technologies, such as the survey in this study, is a useful starting point to gauge awareness of energy change, as people seem to have readily accessible opinions about technology in their internal reference frame, even if they lack in-depth knowledge (Corner et al., 2011; Devine-Wright, 2007).

3. Methodology

3a. Is there likely to be significant change in energy systems ?

The first piece of research was to design a simple model, using Microsoft Excel, to obtain a rough landscape for energy futures, for use as a benchmark in analysis of further findings. The International Energy Agency (IEA) Extended Energy Balances data set was downloaded (ESDS, 2010) to chart historical production. The most recent data was from 2008, apart from a few figures from 2009. Production data was divided into three groups : those constituents making up liquid fuels, those being gaseous fuels, and those used to generate electricity. The modelling was rudimentary, and the technique used was to apply an estimate of projected growth or decline on an annual percentage change basis. Patterns of historical production were used as a guide to modulate the future production for some items, such as crude oil. Possible effects resulting from market or regulatory price regimes, the conversion of resources into reserves (McGlade, 2010; Meng and Bentley, 2008), and technological advancement, were mostly left unconsidered. Very optimistic growth was estimated for renewable energy and new fossil fuel resources, both conventional and unconventional.

The production of new unconventional resources was considered separately to the calculations for other resources, as there is significant interest in their potential, and developments which may overturn calculations based on data from earlier assessments (Seljom and Rosenberg, 2011; USGS, 2000). There are indications of near exponential growth in unconventional gas production in the United States of America in recent years, and anticipation that this could be reflected worldwide (e.g. EIA, 2011c; GWPC and ALL, 2009; IEA, 2011; IHS CERA, 2010b; Kuuskraa and Stevens, 2009).

Estimates of growth and decline for the model were drawn from estimates from a range of references, and the resulting charts were checked for consistency with other projections (Aftabuzzaman and Mazloumi, 2011; Aleklett, 2007a; Aleklett, 2010a; Bakhtiari, 2006; Bardi, 2011; Becker, 2006; Chen, 2011; de Almeida and Silva, 2009; EWG, 2007; Fisher, 2011; Gallagher, 2011; Greene et al., 2006; Guseo, 2006; Guseo and Dalla Valle, 2005; Guseo and Guidolin, 2008; Guseo et al., 2007; Hefner, 2002; Hirsch, 2007; Hook et al., 2010a; Hook et al., 2010b; Imam et al., 2004; Jackson et al., 2008; Kerr, 2011; Kontorovich; 2009; Koppelaar, 2010; Kummel, 2011; Laherrere, 2004; Laherrere, 2006; Maggio and Cacciola, 2009; Marchetti, 1977; Miller, 2010; Mohr and Evans, 2009; Mohr and Evans, 2010; Patzek and Croft, 2010; Roper, 2010; Shafiee and Topal, 2009; Teggin et al., 1994; Thakur and Rajput, 2011; Tinker, 2003; Tinker, 2009; Tinker and Kim, 2002; Tsoskounoglou et al., 2008).

[…]

4. Results

4a. Modelling energy production for use as a comparator to the survey

Figure 1. World Liquid Fuel Energy Production (thousand tonnes of oil equivalent)

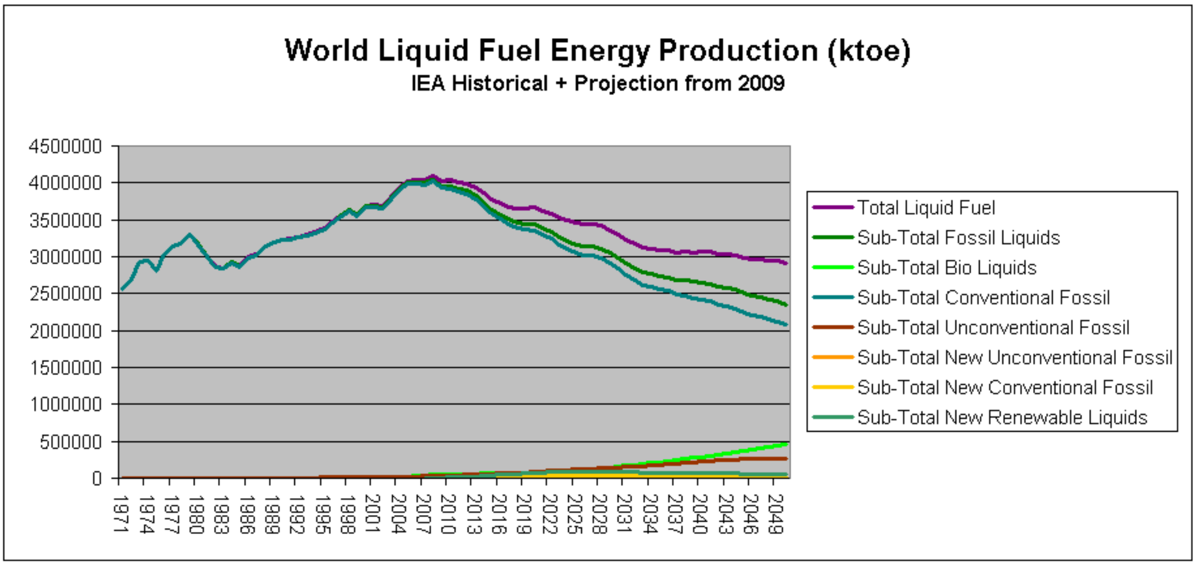


Figure 2. World Gas Energy Production (thousand tonnes of oil equivalent)

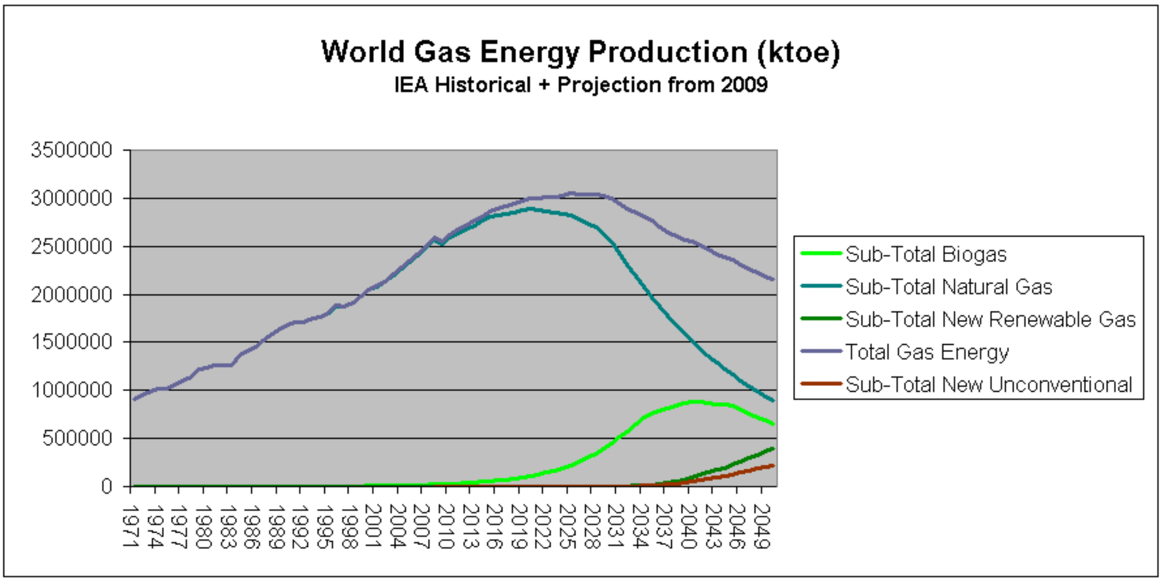
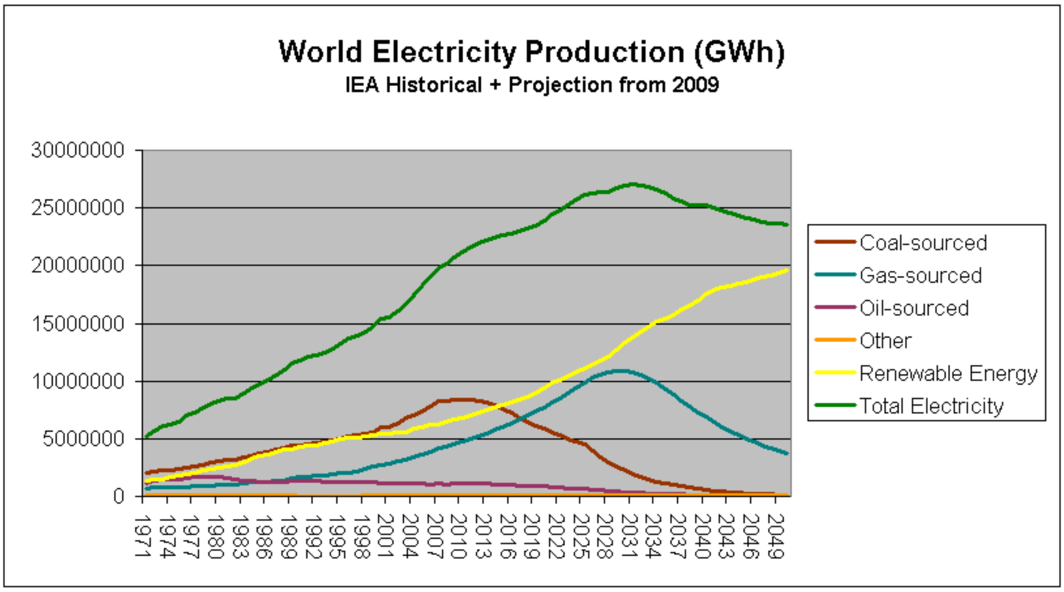


Figure 3. World Electricity Production (gigawatthours)



In the modelling charts, very approximately, a peak or levelling off in production of liquid transport fuels was seen around 2008 (Figure 1); a peak in production of gaseous fuels was seen around 2027 (Figure 2); and a peak in the generation of electricity was seen around 2031 (Figure 3). By tweaking the rates of change, the model revealed that factors affecting growth and decline, in particular perhaps the onset of high prices, may have the effect of creating a plateau in the production of liquid transport fuels, rather than a peak; but it would not prevent declining production from affecting supplies eventually, possibly within a decade of the peaking year. By contrast, the model suggested no factors could delay the peak in production for Natural Gas as conventional sources begin to decline. If the historical low price for Natural Gas were to persist, the peak would come sooner, as more costly unconventional resources would not be brought to market. The close proximity of the peaks for gas and electricity in this modelling reflects perhaps a global "second dash to gas", as power generators turn to Natural Gas from coal because of price and lower emissions. Production of conventional crude oil was seen to drop by roughly 50% by 2050 in the model, whilst conventional Natural Gas production was seen to drop by roughly two thirds by 2050. The projection suggested that it may not be possible to rely on coal to maintain peak levels of electricity generation because of reserves depletion, resulting from high consumption. It must be stressed that these outline results are highly unreliable, as the modelling is primitive. [...]

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Tables

Table 1. World Energy Council Coal Reserves

(BP, 2001; BP, 2002; BP, 2003; BP, 2004; BP, 2005; BP, 2006b; BP, 2007; BP, 2008; BP, 2009; BP, 2010; BP, 2011a; WEC, 2001; WEC, 2004; WEC, 2007; WEC, 2009; WEC, 2010)

WEC = World Energy Council
R/P = Reserves to production ratio
S/L = Sub-bituminous and Lignite coals
Stat Rev = Statistical Review of World Energy
SER = Survey of Energy Resources
A/B = Anthracite and Bituminous coals
BP = Formerly British Petroleum
W98 = WEC SER 1998
W04 = WEC SER 2004
W09i = WEC SER 2009 interim
W01 = WEC SER 2001
W07 = WEC SER 2007
W10 = WEC SER 2010

million tonnes		**A/B**	**S/L**	**TOTAL**	**R/P**
BP 2001	Year 2000 W98	509491	474720	984211	227
BP 2002	Year 2001 W01	519062	465391	984453	216
BP 2003	Year 2002	519062	465391	984453	204
BP 2004	Year 2003	519062	465391	984453	192
BP 2005	Year 2004 W04	478771	430293	909064	164
BP 2006	Year 2005	478771	430293	909064	155
BP 2007	Year 2006	478771	430293	909064	147
BP 2008	Year 2007 W07	430896	416592	847488	133
BP 2009	Year 2008 W09i	411321	414680	826001	122
BP 2010	Year 2009	411321	414680	826001	119
BP 2011	Year 2010 W10	404762	456176	860938	118