TECHNOLOGY INTRODUCTIONS

IN THE CONTEXT OF DECARBONISATION

Lessons from recent history

Professor Michael J Kelly

The Global Warming Policy Foundation

GWPF Note 7

GWPF REPORTS

THE GLOBAL WARMING POLICY FOUNDATION

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Introduction

The climate science community has convinced many policymakers and politicians of the need to decarbonise the world economy in short order. Their case, and whether it is credible or not, is not the issue in this paper, but rather some of the lessons of the recent history of technology evolution that should not be lost in the rush.

There are rules concerning the introduction of new technologies, and there are penalties for flouting them. If we are setting out to decarbonise the world economy, we should set out as if we mean to succeed, and not, as now, take actions that will certainly not succeed. Indeed, if we look at the introduction of Watt's coal-fired steam engine, and the rise of electricity as an energy source, we can see why they succeeded and then divine what is needed in the decarbonisation project. From recent history I introduce nine lessons that are germane to any programmes we undertake, plus a tenth if the scientific consensus on climate change should shift over the next decade. I also make three concrete suggestions relating to the way forward.

Lessons

Lesson 1: Successful new energy technologies improve the lot of mankind

Energy from steam engines and electricity from turbines have enabled many features of the present lifestyles of the developed world. One only has to go to a remote mountainside community that is off-grid in a developing country to see that life choices, health risks, food security and variety, transport and indeed life expectancy itself are all inferior to those enjoyed in the UK. No-one or no community turns down the option of access to electricity or fossil-fuel powered amenities on the basis of being better off without them.

In our modern era, the smart mobile phone is the contemporary exemplar of improving mankind's lot and reducing materials consumption: it consists of a piece of plastic, some metals, liquid crystals and semiconductors that fit in the palm of one's hand. However, 20 years ago the functions of the phone would have filled a table-top with bulky items - camera, radio, telephone, answer-machine, photo-album, dictaphone, music centre, satellite navigation system, video camera and player, compass, stop-watch, Filofax, and more. The mobile phone is now used in Africa and India to let farmers choose when to go to market to best effect in terms of getting a good price for all they bring – this in turn relieves them of the need to overproduce to compensate for being at the market at the wrong time.[1]

Within about 20–30 years of Watt's steam engine being available to support agriculture, the windmills of the UK stopped turning. Here was a new source of energy that was reliable, movable, convenient, affordable and low maintenance. The relative positions of fossil fuels and wind energy have not reversed in terms of human convenience ever since. There is no contest between a generator from Aggreko and a windmill from Vestas in serving a community reliably.

The achievement of a decarbonised economy will require improvements to be made to today's technology, with the production of lighter-weight objects, travel becoming a choice rather than a necessity (i.e. use of the tele-presence option for the conduct of national and international trade), greater recycling as a more efficient use of resources, development of easier ways to navigate life for the aged, much cleaner air in the urban environment, and other advances. However, the circumscription of existing activities will only be permitted by popular demand: the ban on smoking in public confined spaces was successful because it enjoyed significant public support. Similarly, the curtailment of the profligate consumption of energy and resources will occur only once that profligacy is considered deeply antisocial.

Lesson 2: Since 90% of the global improvement in mankind's estate since 1800 has been enabled by burning fossil fuels, the scale of the decarbonisation project is without historical precedent

A person in Western Europe typically uses about 6–7 times as much energy per day as someone living there in 1800.[2] In those days the energy was used in heating one room of a house, in local transport and in the purchase of locally made tools and food etc. Taking the whole of that 1800 energy consumption per person per day, we now use the same amount of that energy on private motoring, and an approximately equal amount on public transport. We use three times the per-capita energy of 1800 in the manufacture, logistics and purchase of things including food. It is no exaggeration to state that civilization as we know it is based on fossil fuels, which have produced over 90% of the energy consumed in the intervening period. Even today, biomass (the historic wood and straw energy of 300 years ago and more), hydroelectricity, geothermal energy, and nuclear energy provide less than 15% of the world supply, and first-generation renewables (wind, solar and cultivated biomass) provide less than 1% of global energy supply. We also have seven times as many people in the world as in 1800.

The threat of coal exhaustion was first raised in 1868, and peak oil before 1900, and has been repeated regularly ever since. However, the level of discovery is such that we now have more proven reserves of fossil fuel energy, which will cover future energy needs for longer than ever before in history.[3] Since the industrial revolution we have used as little as 10% of the known reserves of conventional and unconventional forms of fossil fuel.[4]

A decarbonised global economy is going to have to outperform the achievements of fossil fuels. If not, mankind's progress will have to go into reverse in terms of the aggregate standard of living. We should be honest and upfront about the sheer scale and enormity of the challenge implied by decarbonisation. Resentment at token gestures has already contributed to the level of backlash seen in some western countries as they withdraw from interim decarbonisation targets (see, for example 2013 and early-2014 news items relating to Japan, Australia, Germany, Canada, and the EU).

The British economy during World War II was entirely focussed on winning the war. Manufactures of weapons and munitions and their transport were compelling priorities; manpower was directed under a command economy. Similarly, the sheer scale of a change of the UK to an 80% decarbonised economy by 2050 will probably require elements of a command economy too. As an example, the retrofitting of 25 million homes and 5 million other buildings would cost of order £1.7 trillion over 40 years,[5] and represent an operation equivalent in manpower (>1 million people) to the National Health Service. This would halve the energy consumption of buildings in terms of heating and lighting and reduce the nation's carbon emissions by 23%. A restructuring of all the sources of energy and its distribution, and the electrification of ground transport would have to take place in parallel, and all this on top of business as usual.[6]

And the problem with such extraordinary levels of spending is that it is hard to discern whether it is worthwhile. What do you actually get for £1 trillion or £10 trillion spent on climate mitigation? The answer is no one knows. If there is catastrophe later, we clearly underspent; if there is no catastrophe, we will never know whether we can claim credit for having averted it. So in either case the money is spent to no known good effect, despite there being competing calls for the money that would at least have measurable positive consequences. That may in fact be the rational reason for past inaction.

Lesson 3: Since over 50% of the global population in 2050 will live in megacities, that is the problem to be tackled first; 35% of all world energy today is used in buildings, mainly for heating and cooling; current-generation renewables cannot energise megacities

Renewable energy sources are all intrinsically and commensurately dilute at source.[7] If we harvested, year round, miscanthus (a rapidly growing grass[8]) and burned it, it would be possible to generate 0.8–1.0 GW of electricity by diverting 1000 km^2 of the Fen Country from food production. However, we can already get 1.3 GW from the Sizewell B nuclear plant, which occupies less than one tenth of a square kilometre. The factor of 10,000 in efficiency of the use of land is not something that can be closed by tinkering with the renewable energy efficiency. Furthermore, one can grow food or miscanthus or cover the land with solar panels, but not do more than one of these with the land at any one time.

Table 1: Energy densities of different fuels

Fuel type	**Energy density** MJ/kg
Wind	0.00006
Hydro	0.001
Battery	0.72
TNT	4.6
Wood	5.0
Petrol	50
Hydrogen	143
Nuclear fission	88,250,000
Nuclear fusion	645,000,000

More generally, Table 1 shows energy densities for different fuel types.[9] The figures span thirteen orders of magnitude, with nuclear processes being about a million times more energy-dense than the chemical process of a fossil fuel, and with the chemistry of fossil fuels about a million times more energy dense than exploiting gravity in hydro-systems. These are non-trivial ratios, which are ultimately reflected in the cost, scale, safety and other factors of energy infrastructure, and mobile energy in particular.

The city of Shanghai today has 22 million people, and occupies 6000 km^2 of land. In order to provide all their *electricity* needs from renewable sources, about four times that area would be needed for wind-farms, solar panels and biofuels.[8] To provide *all* their energy from renewables would require ten times more land than that. The land in the immediate vicinity of Shanghai is used for food production, which takes priority over energy, and energy transmission losses accumulate when electricity is transmitted over longer distances. Even if these numbers were halved by improvements to the thermal envelope of existing and planned buildings and other energy efficiency measures, the required land area would at most halve.

On a global scale, the prime concern is to power the megacities in which over half the world population of around 9 billion are expected to live by 2050. Current renewables, even if they become locally economic, are only suitable for rural and village life in off-grid locations. The only technologies available today that meet the conditions for a low-carbon megacity in 2050 are nuclear energy and any fossil fuels that are accompanied by carbon capture and sequestration, and the latter is not proven safe and economic at the scale required, with only about 20 Mt CO_2/yr out of a global total of 50,600 Mt CO_2/yr[10] sequestered at present. Even if a breakthrough scientific idea for a new energy technology were discovered now, it would take 40 years for it to contribute as much as 10% of a developed nation's energy demands. It is salutary to recall that the current wind and solar energy schemes got their technology boost from the oil shocks 40 years ago!

Note that the present fixation for the date of 2050 in the public debate on carbon emissions comes from the work in 2000 of the Royal Commission on Environmental Pollution, which took evidence that nuclear fusion energy would not reach 10% of the energy supply of any country before then, and we had to get there without it.[11]

Lesson 4: Successful new infrastructure and energy technologies are to be widely deployed only when they are both mature and economic, and there are penalties for flouting these conditions; any lessons from software, such as getting the customers to perfect the product, simply do not work with infrastructure projects

During the oil crises of the 1970s, the Japanese deployed solar thermal panels. They were black and oblong, and were put on the brightly coloured curvilinear roofs of Japanese domestic buildings. Once the oil prices dropped, so too did the rate of installation of such panels. Over the last decade, the oil price has spiked again, but the rate of installation of solar thermal panels still declines.

The Japanese have fallen comprehensively out of love with ugly, rusting additions to their roofs, particularly since they never produced the energy levels that were promised. This is a 40-year-old bad memory syndrome.[12]

Over the last 40 years the software industry and other advanced parts of the rapidly developing information and communications technology sector have relied on customers to report back on experiences and lessons; these can be used to improve the next generation of product offerings, and on a timescale measured in months. This is simply not possible for new energy infrastructure, which has payback periods as long as 40 years.

The bulk storage of electrical energy is not generally available, and at all times a balance must be maintained by the generators of electricity to meet instantaneous demand. Already some heavy energy users, such as metal smelters, are contracted to turn down or off their furnaces/reactors at times of peak domestic demands. In the near future, the smart grid may ease the balancing problem slightly by being able remotely to turn off some sources of demand in the home: appliances such as washing machines, refrigerators and freezers, and even central heating/air conditioning, which do not need to be on all the time, will be turned off remotely – and presumably temporarily – to relieve pressure on the generators. This possibility, which requires two-way secure transmission and reception of signals between supplier and consumer, will also allow generators to avoid the expense of covering rare demand peaks with expensive infrastructure that sits idle for most of the time. Note that one of the downsides of the higher cost of energy is the closure of two out of three aluminium smelters in the UK, leaving adjacent communities with higher bills as the load balancing is no longer available to lower and even out the costs of electricity production.[13]

Large-scale battery storage is likely to take some time to develop.[14] Even with 30 years of effort to provide batteries suitable for portable electronic devices, the advances are modest compared with the technology of the devices themselves. Low-power devices have been developed to lengthen the time between recharges. The materials used for rechargeable automobile batteries for electric cars are intrinsically unstable, as they swell and shrink as ions enter and leave the electrodes during charging and discharging. Their lifetimes are therefore short under heavy-duty operation. In addition, any shock, such as that caused by a minor accident, can rupture their internal membranes and lead to breakdown via the creation of local hot spots, which can eventually erupt as a fierce fire several hours later. The battery materials, usually rich in oxygen, feed the fire. Such fires in new batteries are therefore particularly fierce, and difficult to put out.[15] At the basic science level we are probably within 30–50% of the ultimate power density of energy storage using solid-state materials. Above this level, the inherent instabilities of the materials cannot be managed to make a viable technology. The large volume of the batteries that would be required to load balance between night and day or windy and calm conditions at a national scale is likely to remain prohibitively expensive for the foreseeable future.

Lesson 5: There are salutary lessons from the first round of renewables technologies, which date back to the reaction to the 1970s oil crises

In the USA in the 1970s, there was a rushed programme of research and development, examining alternative energy sources that might help insulate the economy from oil shocks. This was an entirely appropriate response. The premature roll out of some of these technologies in California in particular in the late 1980s provides a stark lesson. By googling the terms 'abandoned solar farm' or 'abandoned wind farm' one can see square kilometres of derelict solar panels and over 14,000 abandoned wind turbines in the Mojave desert alone. It would appear that, in the absence of subsidies, the solar panels and windmills did not generate enough usable electricity to cover the cost of maintenance and interest payments on capital. Since the recent financial crises there have been many bankruptcies in the USA and Europe of renewable energy companies, and all such industries in China are producing at a substantial (~30%) loss, which would also result in bankruptcy in a capitalist economy.[16] Over time, the removal or reduction of subsidies in the USA, Spain, Germany and the UK will lead to similar green industrial graveyards, in which the intrinsic diluteness of the energy source means that vast areas will be blighted in the continuing absence of clean-up commitments. The Renewable Energy Industrial World Index of renewable energy companies lost over 80% of its value between 2009 and the start of 2013, although it has recovered to a 60% loss during 2013: this is not a place for pension funds to invest (which it would be if the economics of renewable energy infrastructure made sense).[17]

Lesson 6: Government subsidies for premature roll-out are a recipe for disaster, whereas they are appropriate for R&D and trials at scale

There is no global counter-example to the statement that government subsidies for new energy technology deployment into liberalised energy markets have produced and will continue to produce a litany of failure. By contrast, every developed nation is supporting energy technology research and trials at a sufficiently large scale to learn lessons for commercial roll-out. For governments to learn such lessons is particularly important when the whole world energy system needs changing, and taxpayers and consumers must between them pay the bills.[18] The reduction in solar panel costs seen over the last two decades will, if continued for another two decades, produce panels with whole-life costs low enough to make their electricity competitive with the fossil fuels of today. That said, the total power derived from this technology will remain small compared to the global energy demand. While the costs of new energy production remains quite uncompetitive compared with fossil fuels, and the in-service lifetime of new equipment is not proven in the field, which investors would risk their money? Since governments cannot bind their successors and policies might and probably will change over the 40-year payback period of energy infrastructure, the risk is just too high. One simply must wait until the new technology is mature and competitive over its in-service lifetime.

Lesson 7: Technology developments are not usually pre-programmable

Why do new technologies emerge when they do? Why was steam power not available a century before it was? In general, new technologies emerge from new scientific understanding, but the timescale for them to mature sufficiently to be deployed is measured in decades. A new technology that is replacing an incumbent technology faces other problems too. The owners of existing working assets are loath to see them stranded, and this is a particular concern with energy infrastructure, which is expected to last for decades. A new technology must therefore be comprehensively superior in some respect to overcome this challenge. The world has been seeking useful energy from nuclear fusion for over 60 years now, and success is nowhere in sight. Indeed, as of 2013/4 only nuclear fission and fossil fuels have the capability to provide the world with the power it requires now and in 2050.

In contrast to the lack of prescience implied above for radical breakthroughs in technology, it is possible to project forward the likely evolution of existing technologies,[19] at least until some fundamental cost/technical barrier intervenes. Moore's law for electronics will come to an end because of the same combination of costs and technical difficulties that ended the equivalent advances in marine steam turbines and jet passenger aircraft.[20]

Lesson 8: Nothing will happen if the population is not trusting

There have been many reports of the low take-up of offers of even public-funded energy efficiency measures.[21] Cambridge City Council encountered this problem a few years ago when it tried to give away insulation to the public, an offer that did not even achieve a 5% uptake. The hassle factor, the mistrust of 'men in white vans' and the absence of a 25-year guarantee against unintended consequences were more powerful deterrents that the attraction of lower energy bills and 'saving the planet'. The UK's 'Green Deal' has had not only these problems but also encountered an unwillingness to incur extra debts in a time of credit squeeze.

Lesson 9: Finance is limited, so actions at scale must be prioritised

A figure of £200 billion is used in the public domain to give a sense of the scale of the investment needed in this coming decade to renew the energy infrastructure in the UK. Much of this is required because of a backlog of replacements and upgrades to parts of the existing infrastructure: many energy sources are reaching their end of life. A national-scale retrofit of buildings will cost several times that amount over 40 years. These sums have to be raised on the international money markets in competition with all other investments.[22] In order to to ensure the availability of finance, the interest rate offered must be high, and this challenges the creditworthiness of the nation. It is clear that much of what has been done with renewables is unlikely to repay the investors. To see this, one only has to consider the plight of farmers in Spain who converted to solar and wind energy from agriculture and who are now nursing very large debts in the wake of the Spanish Government's decision to renege on the generous terms that attracted the farmers in the first place. The remaining indebtedness of Spain because of commitments in the energy sector is larger than the sums involved in the recent bail-out of their banking system. It is likely to be several decades before the memory of this present state of affairs is forgotten and before the sums of money required to decarbonise the economy in Spain might be forthcoming.

Meanwhile, German carbon emissions have started to rise and will continue to rise as new brown-coal-fired power stations come online, firstly to replace the nuclear fleet, which has been switched off without compensation to the investors, and secondly to provide load balancing for Germany's large renewables sector. Even highly efficient gas-fired power stations are being turned off, mothballed or decommissioned in Germany, partly because they are uncompetitive when being run as back-up for load balancing rather than providing the baseload for which they were designed, but also because of the very low price of coal on the international market, as the USA switches to shale gas[23] In the absence of a credible energy policy in the UK and EU, and in a world of rapid change that still has to pay off the massive debts incurred because of quantitative easing, it is by no means certain that the money required to decarbonise our share the world economy will be forthcoming.

Lesson 10: If the scientific basis of the present climate imperative changes in the next decade, all the present constraints concerning urgent decarbonisation are greatly weakened

The Fifth Assessment of the Intergovernmental Panel on Climate Change reports that in the period 1950–2012 the temperature rose at 0.12°C/decade,[24] which is a 40% reduction on the 0.2°C/decade shown the previous assessment.[25] In fact there has been no surface temperature rise since 1997. If the current temperature hiatus continues all the earlier sting of claims of catastrophic anthropogenic global warming will have been removed.

There is currently a divide within the climate science community between those who rely on computer models and those who continue to study the empirical data when making future projections of global temperature. The latter predict another century like the last, with a 1°C warming, while the former produce estimated temperature rises of 3–6°C via an *acceleration* in warming of a kind that that has not been seen since a brief period in the late 1970s. The empiricists' predictions of a cessation of warming followed by a plateau or fall starting about the year 2000 and lasting anywhere up to 30 years have been fully borne out by the data so far. If their predictions continue to prove correct, then within a decade there will be a widespread agreement that, whatever the merits of the models themselves, they will have proven fundamentally incapable of predicting future climates on the scale of decades as a guide to devising the wise human response.

There are already early signs of a changing perspective on the principal drivers of climate change. In 2013 over 70 papers appeared in the peer-reviewed literature suggesting that the sun, rather than man-made CO_2, is the main driver of recent climate change,[26] with a quietening sun leading to temperature stasis or falls. If this counterview gains traction, there may well be a new consensus, as is the way of science. I personally rate the likelihood of this happening as greater than 50%, as we are 17 years into a stasis which, if it lasts for 25 years, would discredit the models as useful guides to the future – in the eyes of the public, if not perhaps in the eyes of climatologists.

The reliability of the models, or more precisely their unreliability, is a known problem: James Hansen's 1988 'Scenario C' prediction for the future temperature has been borne out in remarkable detail: a continuing rise until 2000 and a flattening thereafter. The only problem is that the input to his model was a CO_2 emission level linearly decreasing from its 1990 level to zero in 2000 and remaining zero thereafter, which of course did not happen. This is proof of the inherent fallibility of models.

With climate models discredited, the urgency to achieve a low-carbon future would recede well beyond the timescale of the decisions being taken now in the context of the renewal of the national energy infrastructure. With shale gas coming on stream, the combined-cycle gas turbine systems will likely become the most flexible and economic source of electricity for the next 40 years for the UK and for much of the world. The residual quest for a lower-carbon future is one that will be produced by business-as-usual, for which more efficient energy consumption and lower levels of pollution are already commercial drivers.

Suggestions

Suggestion 1

Stay with business as usual and work to make the economy less needful of carbon. The error of the Malthusians is to overestimate the problem and underestimate the human capacity for ingenuity to solve the problem. Business is always looking for cheaper ways of making better products, and ways to use less material and less energy to achieve a given level of any service. The provision of 1000 passenger miles of comfortable, safe, rapid and timely transport is an example. Just as earlier challenges to humanity have been seen off by human ingenuity, history is on the side of the optimists.[1]

Suggestion 2

The success of any programmes for the deployment of infrastructure assets ought to be virtually guaranteed, in order to justify the use of scarce resources.

It would be better not to start than to start on a project that has a significant chance of failure. Failed projects at the infrastructure scale often leave the evidence of failure to be mocked for decades: witness the windmills and solar panels in the Mojave desert, or motorways that stop and go nowhere. The problem in the public spending sphere, as evidenced by military overspending, is that that full costs of action are not always brought within the initial case for action. At present the extra costs associated with redeveloping the grid to cope with the many new interconnections from solar and wind power sources are not assigned to these power sources, but are added to the general redevelopment costs of the grid. The costs of energy for backing up solar or wind power are likewise not assigned to the solar and wind programmes. Once started, big infrastructure programmes are likely to use a form of blackmail to get the extra funds to complete them. In the private sector, for example the oil companies, the complete whole-life costs are included up front in the discussions over whether or not to proceed. If this discipline informed the public space and political arena, more sensible decisions would be made. The cynic would note that many public projects would not be approved on the basis of whole-life complete project costs, and that advocates have it in their interest to minimise the initial project costs.

Suggestion 3

Human attitudes and personal behaviour are all important. Only once the majority of the world population is convinced that the future dangers are real – and down the last two centuries too many Malthusians have cried wolf only to be proven comprehensively wrong – will action at the scale required to produce a low-carbon economy be undertaken. Public attitudes towards smoking in public confined spaces and drink-driving in the UK have changed in the last 40 years, with legislation following upon popular approval.

It has been estimated[27] that we could live something approaching our current standard of living in the West on about half the energy consumption per person if we became more conscious of energy consumption, taking fewer journeys, buying more locally sourced produce, adopting simpler lifestyles and so on. This approach has more immediate potential, and is immediately economic, than the construction of the infrastructure to support renewable energy generation. Until the profligate consumption of anything, but starting with energy, is considered deeply antisocial right across the world, attempts to tension deep carbon reductions against lower standards of living for most people in the world will be going against the grain of human progress. The

European lead in decarbonisation is penalising the European economy, while China and India pursue progress with the rapid expansion of coal-fired electricity. By the time the developing countries agree to a low-carbon economy, the developed countries should have mature and economic alternatives to fossil fuel technologies available for rapid global deployment. We are not there yet, and based on what is in the pipeline, we will certainly not be there before 2030.

Conclusion

The current trajectory of low-carbon technologies around the world is profoundly mistaken. Earlier generations ignored the warnings of experts of impending doom, and so far they have proved correct to do so.[1] It is highly likely that history is repeating itself. Without major social disruption, the Dutch have adapted to rising sea levels over previous centuries, and they should be a model for the world going forward. Adaptation as necessary should be pursued, while, in my opinion, the necessity for mitigation through decarbonisation of the economy remains unproven in the absence of any reliable alternative technologies that would solve the problem at a global scale.

Notes

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GWPF NOTES

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4	Montford	Climate – Public Understanding and Policy Implications
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Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice. Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

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