Beyond Fossil Fuels

A technical, social and political evaluation of alternatives

by

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Introduction

This paper is a response to what the author considers are not opinions, but near facts, with respect to the ongoing use of fossil fuels: namely that, irrespective of any climate change implications, the world is, if not running out of fossil fuels, running into an area characterised by high costs of fossil fuels, and that a transition to alternatives to fossil fuels, as the alternatives become cost competitive, is inevitable.

Whilst it is not possible to say in any great detail what the final shape of the transition will look like, it is possible to define broad areas of it that have serious implications, as well as indicating which areas have few implications, for society and politics.

Above all it represents a serious, pragmatic and cautious approach to change, in direct contrast to the UK governments 'Carbon Plan' which to the author, represents both a dangerously complacent and arrogant prediction of what *will* come to pass, complementing an equally dangerous and fantastic vision of a massively complex high technology suite of solutions (most of which are untried, untested and do not yet exist) as well as being (in many cases) demonstrably beyond the ability of man to construct in the first place!

As such the primary purpose of this paper is to indicate where it is demonstrably not worth expending effort, as well as outlining the few areas where forward investment in either specific areas of technological research, or specific changes to UK lifestyles, may ease the transition towards a post modern industrial society, beyond fossil fuels.

Because of the difficulty of prediction, numerical analysis has been kept simple: Unlike the 'Carbon Plan' this paper does not attempt to second-guess exactly what the future holds: numerical analysis goes far enough to eliminate the impossibles, and leave behind a selection of possibles, that are worth further investigation.

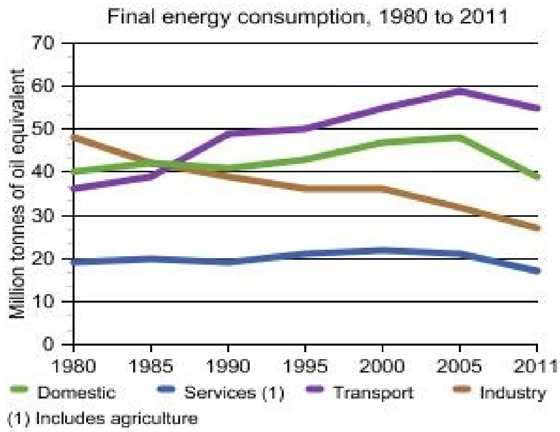
Other assumptions are also made: Namely that common sense will ultimately prevail, that populations in the UK will not grow exponentially into a collapse type scenario, and that whilst growth may in fact be something that is a rare and precious thing in the 21st century, at least (following the Red Queen's [1] example) by running very hard, we may at least manage to stay in the same place.

1 "Well, in our country," said Alice, still panting a little, "you'd generally get to somewhere else if you run very fast for a long time, as we've been doing."

"A slow sort of country!" said the Queen. "Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

Importance of primary energy

One of the more egregious results of deep and intense political involvement in the arena of primary energy, has been to disguise and obfuscate the problem. We are told that such and such a policy will 'only put £100 on your domestic fuel bill' without being told that, since only about 38%[2] of energy is consumed domestically, at least where electricity is concerned, that on balance for every £100 on your direct energy bill, you may reckon on at least another £200 on your general bills for other products and services you consume, that also have high energy costs associated with them.



Worse, high energy costs impact in other ways. High energy costs can drive entire industries to other geographical locations where energy costs are lower. Thus impacting employment and balance of payments. If that leads to a falling national currency, that also will result in inflation of the now needful imports – including energy. Apart from energy companies themselves, it is clear that high energy prices benefit no one at all.

Finally, and most chillingly, there is little recognition for the fact that a high density post industrial society like the United Kingdom is *utterly dependent* on cheap energy to maintain any existence at all. Imagine a large city like London or Manchester without water, sewage disposal facilities, heat, light or fuel. Within days food would be spoilt due to lack of refrigeration, with no power to pump water or sewage, public health would collapse into an epidemic of disease – for which the equally powerless hospitals and emergency services would be utterly unable to provide any solution. The half life of an urban inhabitant without the infrastructure that the cities depend on, is not years, months, or even weeks, ***it is days.***

We are constantly bombarded with propaganda about the dangers of burning fossil fuel, but the harsh reality is, if we were to stop, most of us would be dead inside a year. And the rest would have to revert to a hunter-gatherer or peasant hand-agriculture lifestyle. Realistically the United Kingdom reached its pinnacle of 'sustainability' just prior to the Black Death, with an estimated population of 6 million[3]. Unused to that sort of life, a modern person would probably have trouble sustaining a population much beyond 3 million, And with an estimated current 70 million population, that means a death rate way beyond anything that nuclear accidents or global warming might achieve.

The author cannot stress this point enough: **Our society is absolutely built on a foundation of cheap energy**. Without it, it will – it **must** – collapse.

And whilst there is always scope for energy efficiency to improve per capita energy consumption without impacting lifestyle adversely, there the low hanging fruit have already been, or are being, plucked. All of such measures help a little, but a lot of very littles, as Professor MacKay once said, are still just a little. The unrealistic expectations of people raised and educated, to a real deep ignorance of the massively vital and important part technology based on energy has in simply keeping them alive, are a major part of the political problem facing anyone who attempts to put policies to address energy shortages into place.

2 Source: http://www.statistics.gov.uk/hub/business-energy/energy/energy-production-and-consumption
3 Source: http://en.wikipedia.org/wiki/Black_Death_in_England

Alternative primary energy technologies

Fossil fuel owes its importance and its value largely down to one thing: it is the simplest and easiest way to obtain, store and utilise primary energy. Its benefits hugely outweigh its disadvantages, and today we have a word population of billions, whose lives literally depend on it. What alternatives are there to it?

The author has researched this subject in depth elsewhere[4] and therefore only the conclusions will be presented here. Which are essentially that so-called 'renewable' energy has so many drawbacks that it will never be – can never be – an adequate way to sustain the worlds population at even its current levels and lifestyles, let alone the elevated lifestyles of the West. In essence this boils down to three insuperable obstacles.

- **Energy density**: Essentially renewable energy by its nature is diffuse and thinly spread across the Earth's surface. Capturing enough of it to be useful requires that massive land and/or sea areas are modified substantially to do this. In direct competition with other land uses.
- **Intermittency**: Renewable energy is fickle. Unlike other primary energy sources one has to 'use it or lose it'. We have built a society that completely depends on energy 'being there' when we need it and that implies storage. Whilst there are solutions to intermittency involving storage, or trying to match demand to supply (rather than the reverse), all of these add massive complexity, even more infrastructure and, worst of all, added costs – both financial and energy.
- **Costs**: Ultimately renewable energy must fail because the overall *holistic*[5] costs associated with the panoply of bolt on fixes to make it work reliably simply push the already excessive costs to the point where it is doubtful that any realistic energy return on investment (EROI) can result. And, most tellingly, the costs far exceed the costs of the other alternative. Nuclear power.

Whilst all the arguments against renewable energy are valid, deep and intrinsically insoluble, all the arguments against nuclear power are superficial, emotional and not founded in fact. We cannot improve either the energy density or the intermittency of renewable energy. At best we have to add palliatives to provide additional storage to alleviate intermittency, at considerable costs in terms of efficiency and energy used to build them. Whereas all the 'problems' of nuclear power turn out to be soluble to adequate levels and no great expense.

The author therefore does not concern himself with further looking at the alternatives: there is only one technology, or suite of technologies capable of mostly replacing fossil fuel as a primary energy source and that is **nuclear power of one sort or another.** It is simply overwhelmingly the '***least worst'*** alternative to fossil fuels. Nor do arguments about diversity of supply cut any ice. It is possible to build cars with polygonal shaped wheels and complex cams to modulate the ride height and drive torque, but there seems no point in *diversity* in wheel shape *for its own sake*. We use round wheels simply because where wheels are concerned, round wins hands down. So it is with power. Fossil or nuclear are so far ahead of renewables in terms of cost, simplicity, footprint and overall tractability that renewable energy, outside of a few niche areas where local geography and demographics makes it viable[6], is simply not worth pursuing.

Ergo the rest of this paper concerns itself with looking at the broad shape of a nuclear based society and economy, and in particular addressing itself to the few things that nuclear power cannot now (and probably will never be able to) do.

4 See: http://www.templar.co.uk/downloads/Renewable%20Energy%20Limitations.pdf

5 i.e. the **total** costs involved in constructing, supporting and compensating for its deficiencies, and the societal costs of hosting it.

6 The United Kingdom is ***not*** such an area.

Examination of secondary energy storage technologies

Whereas primary energy sources are those which, having delivered their energy in some useful form cannot then be reversed back to their original states, secondary energy sources are those which can. A discharged electrical capacitor or a battery, may be recharged. Water than has run down a mountain, can be pumped up again. A flywheel or clock spring that have slowed to a halt, may be spun up or rewound. A steam boiler that has been taken up to pressure, having delivered that steam to a turbine, may be re-heated again. There are, at first glance, so many ways of storing energy temporarily that it seems trivial to just pick one, and make it work. Indeed so trivial is it, that many are tempted to ask why it has not been already done. It would obviously make at least half the issues with renewable energy go away. Intermittency simply is not a problem with enough cheap storage.

And yet, strangely *no one has done it*. Although there area thousand companies vying for seed capital and government grants claiming that they will be able to do it, real soon now, if only they get enough of someone else's money...

The reality is, that all these technologies are relatively mature. How they work, is well understood. And they are all lacking in terms of the massive requirements needed. They suffer problems of energy density (too big, or too heavy, which almost all forms of secondary storage are) or poor turn-round efficiency[7] (storing energy as heat is a classic example of this maybe 30% efficiency: even storing water up a hill is at best only 75% efficient), or frankly dangerous (anything that is capable of taking energy in, quickly, is capable of letting it out, quickly, as well, and that means it can literally explode. Even more measured things like pumping water up a hill represent a real threat to life: a typical dam contains similar energy to a nuclear weapon. If the dam breaks that is channelled directly to destroy anything downstream). Even synthetic fuels – like making hydrogen or methane or indeed synthetic diesel or petrol using electrical or heat energy – whilst obviously being reasonable to store (they are after all exactly the same as fossil fuels) suffer poor turn-round efficiencies. And hence cost-wise they are (currently) uncompetitive with drilling for the same stuff under the ground. Or using the primary energy to do the final job without the need to use them as an intermediate step.

So while we have access to a wide array of secondary energy storage devices, none are anywhere *near*[8] the size, scale, cost and safety we get from primary energy stores. So unless the application is so uncritical of cost and modest in its power requirements they are of no real substantive[9] help.

And none are likely to be either. The limiting calculations on storage are easy to apply: we may not be able to predict exactly how good they will be, but we can predict how good they can **not** be. That is, we can say that a given technology can never be *better* than a certain figure, because it limited by the laws of physics and chemistry.

The implications of this are, that without some radical breakthrough in *how* we might store energy – something at the quantum level perhaps – we cannot assume that any technology to store energy radically different from what we already know (well), will be available, and to predicate policy based on such, is criminally irresponsible.

That means in practical terms that energy policy that relies implicitly, or explicitly, on the availability of cheap mass storage of energy, is **inherently duplicitous and impractical.**

7 How much you get out compared to what you had to put in.

8 One may be. Lithium air technology is **theoretically** *just* good enough. See appendix.

9 Our biggest secondary energy store is Dinorwig. It 'saved us a nuclear power station' because in essence it can supply about 5% of the UK's electricity needs for about two hours, after being recharged at night when demand is low. Owing to the particular geography it has, it was not that expensive either, and there is scope for a bit more pumped storage by retro converting some of Scotland’s plethora of small hydroelectric installations to pumped storage. However the scope for more is severely limited.

Fossil fuels as chemical feedstock

One of the arguments put forward by peak oilers is that not only will we not have cheap energy, but that we will also not have any more petrochemicals - all those lovely things like plastic bags, synthetic rubber tyres, epoxy glues and so on. The author does not consider these to be serious problems for the following reasons.

- Oil ceases to be useful for energy when it either takes more energy to extract it than it gives up when burned, or when it becomes more expensive than the next most expensive alternative. In this case nuclear power. There will still be enormous quantities of oil left in the ground at this stage. If plastic quadrupled in price, would we really notice?
- Even if oil in the ground runs out, it can still be made synthetically, albeit at an even higher price.
- Many uses to which we now put petrochemicals, could be done in other ways. Petroleum is a useful and inexpensive feedstock, but others exists. Biomass for example is a rich source of organic chemicals – and indeed early organic chemistry used many organic starting points
- Actual use of oil and coal as chemical feed-stocks is limited. Maybe 1% of petroleum consumption is used to make something else out of it, rather than burn it.

What this means is that there are two points at which oil (or coal) as a feedstock become less of an issue. The first is when oil production *for energy* reduces, simply because it is now so expensive that other alternatives come into play. The second is when it is so much *more* expensive than synthetic products made from e.g. water, CO_2 and cheaper energy, that it simply isn't worth extracting any more at all.

For example a litre of diesel represents water + CO_2 + about 10kWh of energy. Say £1.00 of nuclear electricity. If we had a 100% efficient process of zero capital cost we could **make** diesel for £1 a litre. Even a 33% efficient process would only be £3 a litre. That's too much to run a car on currently, but its not too much to prevent it being used as a way to make a chemical feedstock. Commercial operations to make petroleum like products from coal and water – coal being a bit more abundant than CO_2 – already exist.

So whilst high fossil hydrocarbon prices will affect costs of downstream products, it won't mean the end of plastics. Plastics will no longer be the cheap disposable material of choice, true, but they will still feature.

Fossil fuels as chemical reducing agents

Apart from energy and as a direct chemical feedstock carbon based fossil fuel has one other important characteristic. It is a reducing agent. That means it has an affinity for oxygen and can be used to strip oxygen out of materials to make, for example, metallic elements out of oxide ores. Coal and coke are more generally used than petroleum or gas but the principles apply to either. Steel making uses masses of coal to turn iron oxide into high or low carbon steels.

But we are not short of carbon. In fact we are constantly told we are making too much of it as carbon dioxide! So in principle again all it takes is energy to turn it back to carbon. We can't get a net energy ***gain*** by doing that and then burning it, but we can in principle use it to reduce iron oxides to steel. Or any other metallic oxides. But in fact, who needs steel anyway? If steel became massively more expensive, aluminium compares very favourably for many applications. And aluminium is made by a purely electrical process[10] anyway.

10 The Bayer process uses electrolytic smelting and a lot of electricity!

The same is true of cement production., Heat is all that is required, and heating the calcium carbonate of the limestone ingredient makes a calcium oxide, and produces CO_2. No fossil fuel is required (though a lot of limestone is). Oddly enough, over time the cement reabsorbs the CO_2.it lost in manufacture, from the air, making it overall carbon neutral chemically, if fossil fuel is *not* used to manufacture it.

Once again, given an adequacy of *energy* at a cheap enough price, none of these processes need to come to a halt because we move away from fossil sources of carbon. We are not short of carbon, We are finally short of ***energy*** alone.

Heating

Currently not much space heating – one of our largest usages of primary energy – is done electrically. We tend to burn gas where we can oil where we can't, and very occasionally coal or biomass.

Some industrial heating is done with electricity, especially where its combined with air conditioning and refrigeration.

But in fact electrical heating – given unlimited access to *cheap* electricity – is trivial. In fact one of the easiest things to make is an electric boiler. It is more or less a big electric kettle. Heat pumps are likewise ways of improving efficiency by partially cooling one part of the environment to heat another part of it. Indeed at current prices in the UK an off peak heat pump is very cost competitive with gas or oil heating, on fuel pricing anyway. Installation and capital costs for heat-pumps is however non-trivial, and its inability to easily produce *hot* water, rather than a lot of *warm* water, also has an impact on retrofitting it to existing installations: But for new build, however, it has to be a highly cost effective way to heat domestic and industrial/commercial spaces.

Once again, lack of fossil fuel, *provided we have access to cheap electricity*, is absolutely no problem at all.

Mechanical energy – on grid.

One of the reasons that nearly all mechanical power in a fixed installation is now electrical, is because by and large if there is one thing nearly as efficient as turning electricity into heat, (effectively 100% efficient) it is turning it into mechanical power (probably never less than 50%, usually 80-90% or more) . It doesn't matter whether the power is use to cut, saw, mill, turn, shear, stamp, forge bend or press, to weave or to spin, to extrude or to draw, electrical power is the simplest way to do it. Sometimes that may use hydraulics as an intermediary, but the prime motive power is generally electric. Even non time-critical mechanical work – such as pumping water into tanks etc. – is now done, not by intermittent windmills, but by electric pumps. In fact our manufacturing industry runs almost entirely on electricity to *manufacture* items, as opposed to prime *production* of raw materials: it would be almost entirely unaffected by loss of fossil fuels.

That is all very well, but it leaves a huge area that is NOT catered for, the 'off grid' situation. And this is where ultimately the impact of the loss of fossil fuels becomes most keenly felt.

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http://en.wikipedia.org/wiki/Aluminium_smelting

Mechanical energy – off grid.

If anything characterises the transformations effected by the 20th century uptake of fossil fuels, it has to be the transformation effected by the wide availability of a cheap, energy dense, relatively safe and lightweight liquid fuel. Oil, kerosene (diesel) and petrol (gasoline). Storage and transport of liquids is easier than of solids by and large, and they can be supplied to engines automatically. The invention of the internal combustion engine - initially piston, then gas or jet turbine, made aviation possible. It also made the motor vehicle universally accessible.

This point cannot be emphasised enough ***without access to cheap hydrocarbon fuel, there is no motor transport, there is no aviation, there is no mechanised military.*** This has profound and far-reaching implications. Of all the impacts transitioning to a society where nuclear electricity is several times cheaper than fossil fuel, would have, the effect on *portable power* is by far the greatest, and so it will be examined in some detail.

The easy problems: ships and trains.

Some issues of portable power are easily solved. Nuclear ships and submarines already exist, and there is no intrinsic technical reason why all cargo ships, passenger liners and so on could not run on nuclear power: Nuclear power has two defining features technically. It needs to be large enough to get to critical mass, and carry shielding, and it needs access to a lot of coolant. Medium to large ships are ideal platforms, and indeed Russian icebreakers are already nuclear, at the smaller end of the scale.

Currently nuclear submarine reactors are classified as to exact output, but it is known that Rolls Royce has 'lifetime fuelled' reactors that must be operating at suitable levels for medium sized ships: they are however not currently cheap: But there is no reason why a 'sealed for life' unit should not be considerably cheaper if mass produced.

What is not currently known is how *small* a reactor it is possible to produce for a ship. There must be a lower limit and that may well impact smaller ships – tugs and service vessels for offshore installations, and fishing vessels may well be highly adversely impacted. There are also some interesting possibilities of using essentially high level nuclear waste which has a lot of 'decay heat' generation to power steam plants: the basic problem here is that the nuclear reaction cannot be throttled – it will produce power all the time which must be used, or thrown away . But that allows smaller plants well below critical mass to be constructed.

So whilst the introduction of nuclear ships may be expensive, it is not an insurmountable problem. One might expect as fuel prices continue to rise, coal and nuclear will start to make inroads into the largely oil fuelled ship market. However the impact of higher transport costs on global trade needs to be considered, as we will do later when we consider the social and economic impacts of a non-fossil economy.

The harder problem: motorised land transport.

Looking back before the 'age of oil' - which essentially started around the turn of the 20th century, we see the predominance of the horse and the coal powered steam locomotive as the preponderant forms of surface transport. Steam land vehicles did exist, but they were heavy, slow and unsuitable in many applications. So the challenge is to apply nuclear power – directly, or via electricity, or via synthetic fuels – to the area of transport that we can broadly class as 'land based and off-grid'. It has to be said that none of these solutions (and I can see no others) represent more than a more expensive and less useful way to solve the problem.

For this reason, when examining the impact of spiralling costs of hydrocarbon fuels, this is the area where societies and economies will have to make the greatest transitions.

Synthetic fuels

The synthesis of hydrocarbon fuels from essentially any carbon feedstock, up to and including CO_2 (carbon dioxide) and H_20 (water) is *possible*. In the limit the reason it is not done commercially is a simple one of cost. The yields of most processes in terms of energy input to usable energy out, are poor. Only when there is either no access to hydrocarbon fuels (as happened in Germany in WWII, and in S. Africa under embargo) or the price of hydrocarbon fuel energy is much more expensive than – say – nuclear electricity, does it make sense to synthesise hydro carbon fuel from – usually, but not necessarily – coal.

What this means, in essence, is that synthetic hydrocarbon fuel might in the limit be some multiple of the price of the same energy delivered as nuclear electricity[11] That directly closes the CO2 carbon cycle, by removing it from the air or sea to make fuel, in a process analogous to photosynthesis that created hydrocarbon fuels in the first place. Or indeed huge tanks illuminated by electrical power could be used to grow biofuels that do not require sunlight per se, but respond to artificial light.

All of these things are theoretically *possible,* but are simply not currently competitive, with drilled oil and gas, or mined coal.

So we can in theory see that hydrocarbon fuel in a society essentially underpinned by *nuclear* power as the prime energy source, would still have hydrocarbons, just at a massively increased price. For example at a notional nuclear electricity price of 8p, and a conversion efficiency of 30%, raw fuel would have an energy cost of around £2.70 a litre. Plus O & M[12] and capital costs. Compared with an ex tax price of refined fuel of around 50p a litre now. Obviously that is enough of a change to take most of the domestic traffic off the roads, and whilst it might allow military transport to prosecute wars, and farmers to still use mechanised transport to prosecute agriculture, it's still a very high price to be paid.

The impact on aviation – which realistically has no option **but** hydrocarbon fuels[13] – would also be great.

Battery electric vehicles

Where battery electric vehicles (BEVs) are concerned, the analysis suggests 'so close, and yet so far'. Although energy density of readily available batteries leapt by a factor of two with the transition from lead acid, to nickel based electro-chemistry, and again by a factor of three using lithium based electro-chemistry, that is nearly it. Lithium is not only *the* best possible element in the periodic table, but analysis also suggests that at best there is only a factor of two between the theoretical limit of battery performance and what is available now. In short we have plucked the low hanging fruit of battery technology, and any improvements will be more focussed on cost, charge rates, safety and longevity, not on a fundamentally more energetic battery. Lithium batteries are in essence already nearly as good as it gets.

And it simply isn't good *enough*[14].

The implications of that are wide reaching: personal motorised transport is either going to be the

11 Although it MIGHT be possible to use nuclear *heat* to directly synthesise hydrocarbon fuel, cutting out the 65% loss in efficiency that is implied by using that heat to generate electricity in a steam turbine. It is a long way from even being considered as a possibility, but a combined fuel synthesis and electrical generating nuclear plant could, in simplistic theory, generate fuel when electricity demand was low, by switching heat output to fuel manufacture.

12 Operation and Maintenance: The cost of keeping an industrial plant operational.

13 Aircraft rely on a high energy density power source. Whilst direct nuclear fuel has the energy density, it is destroyed in practice by the requirement for shielding. Hydrogen as fuel is expensive, too bulky and very dangerous. Even the best energy density battery is an order of magnitude below hydrocarbon fuel.

14 Or is it? Lithium **air** which doesn't have to carry its own oxidant, may just be. See Appendix.

luxury fuelled car or hybrid, available to those only with expense accounts (or a huge disposable income), or a short range BEV able to do short hops between charging points. Mass transport will have to switch to electric rail, with only the last few miles being undertaken by electric van or similar. This will have a profound impact on national infrastructure and on viable lifestyles for the nation.

Other storage options

At its most fundamental a tankful of diesel or petrol represents a handy reasonably safe and reasonably portable store of energy, for which a widespread distribution infrastructure already exists. Electricity represents a barely portable but widespread source of energy for which no equivalent storage exists[15]. In reviewing *all* the alternatives, none show promise to revolutionise the mainstream. They may, (and indeed almost certainly will), find niche applications where a unique set of advantages outweigh massive disadvantages in other parameters, but that is it. It is certainly not an arena where large sums of public money should be spent on developing technology that almost creation has no real practical hope of impacting the storage problem. Such strategies have no value beyond the cosmetic[16]. In all such cases one may simply calculate the limiting energy density[17] and conversion efficiency to mechanical work and place the effective energy density in a scale: and that is precisely putting such technologies 'in their place'. At the top we find liquid hydrocarbon fuels with ancillary simple tanks to hold it in. And chemical motors. For sure nuclear *fuel* is far more energy dense than diesel *but* by the time the ancillary equipment to turn it into mechanical or electrical power, contain the radiation and allow safe operation is considered, the overall package is not so good.

The hardest problem: air transport.

If the options for motorised land transport are limited, the options for air transport are almost none.

The energy requirements of aircraft are well known, and they boil down to a fairly simple equation of 'so much energy to carry so much weight for so many miles'. The slicker and more streamlined the aircraft, is the less energy it needs, true, but once again we are close to the limits of what is achievable – Airliners already resemble (and for sound technical reasons) very large gliders equipped with engines. Each new design shaves a few percent of drag off the older designs, but only a few percent.

Yes, battery powered aircraft exist, and can actually fly for an hour or two carrying a single or couple of people 50-100 miles. Even solar powered aircraft can fly almost indefinitely above the clouds, but they can't carry any useful payload. They are not the way of the future: they are marvellous examples of the bleeding edge of technology that **just** manage to fly.

The stark fact is that hydrocarbon fuel is really the *only* viable option for aircraft. And that means that in the end it will have to be synthetic or biofuel, whichever turns out to be the cheapest. For sure there is not enough land area in the world to grow biofuel from the sun's energy to power all the things we need fuel for: but using artificial light from nuclear power, it might be cheaper to

15 Nor, despite claims to the contrary by every single company trying to get grants or raise funding, is actually likely to: the principles of energy storage were well understood 100 years ago. Nothing new is in the wings – when examined closely all 'breakthrough' technologies are really simply refinements of existing ideas, carried a bit further by advances in material technology. Super-capacitors are just capacitors, made a bit smaller/lighter. Flywheels are flywheels, spinning a bit faster due to better materials. Compressed air is compressed air, and so on.

16 I use the term *cosmetic* to apply to a range of solutions – especially government inspired solutions – that do not in fact address the underlying problem, merely serve to give the **impression** that is is being addressed. The primary example of this being such initiatives as 'renewable energy' and its ancillary baggage like smart grids ...

17 Energy density is the amount of available energy per unit weight, or volume. Usually weight is the limiting factor with vehicles, although volume does rule out hydrogen in the case of aircraft.

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grow biofuel than synthesise it from elements, However the existing conversion efficiency of sunlight to energy using biomass is pitifully low. Something like 0.1%. So it seems unlikely that 'synthetic biofuel' could compete with straight synthetic fuel.

Direct impacts on infrastructure

Having examined (and discarded most of) the alternatives it becomes clear that the only remotely viable solution to maintaining a substantial population on limited land area at anything like the current (material) standard of living, given zero access to fossil fuels, will depend on the massive deployment of nuclear energy, primarily served to industry and the consumer, as electricity. This in itself will not be cheap[18] but it is within reach.

The question which them arises, is how much will be needed, and what will the impact be - primarily on the grid – to deliver it.

One thing to be noted straight away, is that whilst we talk about the UK **gross** energy consumption in million tonnes or barrels of oil equivalent, we talk about nuclear power **output** not in gross, but in net terms. Because electricity can be converted very efficiently into heat and mechanical power, we do not have to generate that much electricity to replace fuel used in transport, for example. For heating the figures are however very similar[19]. Likewise although energy efficient technologies can and probably will shave maybe ten or twenty percent of some sectors, others are already realistically as energy efficient as they can be. So the overall impact of such measures, whilst useful and often very cost and energy effective in themselves, cannot impact the final energy requirements of the nation by more than maybe 20%.

So we have, in essence a total UK energy requirement of 200 million tonnes of oil (equivalent) a year. Around 30% of that goes on transport, (and 30% on heating and 30% on existing electrical generation) By moving the transport to electrical we can save about ¾ of that 30%, or bring the NET requirement for energy down by 45 million tonnes, leaving us a net primary energy requirement of 155 million tonnes of oil equivalent. We might also posit that efficiency savings and lifestyle changes might net us a nice round 150 million tonnes of oil equivalent, assuming no major increase in population.

One *toe*[20] is 11.63MWh of energy, so that nets out at around about an average of 205GW of electrical power needed to *entirely* run the country. We currently have a grid sized to handle peak requirements of about 60GW, and that much generation capacity.

One result therefore, is that the National Grid will need to approximately treble or quadruple in size to handle the move to almost total reliance on electrical power. That is of and by itself a massive undertaking and will alone represent something that ultimately consumers will have to pay for either through increased bills, or by increased taxation. Having said that, electricity bills will rise anyway as electricity becomes the common source of energy, and therefore the rise will not be as large expressed in percentage terms.

The next question to address is how many nuclear power stations we might in fact need. We probably need a margin of capacity over and above the *average*[21] of at **least** 60%. So at a rough

18 Although the dire predictions of the Awful Cost of nuclear power are largely unfounded.

19 Electrical heat-pumps can theoretically reduce heating energy needs – essentially by refrigerating the environment – by as much as 75%, however having examined the actual energy (and financial) costs of retrofitting these to existing properties, the benefits whilst definitely there for new builds, are far less clear on older properties. Therefore in this broad-brush analysis of energy requirements they will be ignored.

20 Ton Of Oil Equivalent: see http://en.wikipedia.org/wiki/Tonne_of_oil_equivalent

21 Currently UK capacity stands at about 62GW of power stations whilst the average consumption is 36GW. That reflects the fact that most of the electricity is needed and consumed in dark cold winter months when lighting and heating are at a premium. A lot of that capacity is very old, and almost never used, except in exceptional times. In a future nuclear scenario it might make sense to retain some old fossil burning stations 'in case of emergencies' and stockpile them with e.g. waste biomass, or simply burn (by then very expensive) oil or gas ..for example it is

estimate that means 300GW of nuclear *capacity*. A typical reactor is around 1.6GWe, 4 per site is not unknown worldwide, so if we work on an average of 4 reactors per site giving a a total 6.4GWe per power *station* that equates to around 46 sites, worst case.

In practice, as detailed in the footnotes we would probably not go quite that far. The cost benefits of nuclear power against what fossil fuel there might be still available and also against the distinct possibility of using off-peak nuclear power to synthesize synthetic fuels which could be stockpiled to cover peak needs, means that perhaps only half that number of power stations would be needed. Still, building 150GW of nuclear power over the next few decades is still a challenging problem.

We would need to start building many, many nuclear power stations. If we estimate one per year for the next 40 years, we would probably not be far out in our estimates. That represents something like an ongoing £20bn per annum investment in nuclear power for the foreseeable future.

That is a substantial sum: but the alternatives are worse[22]. And at least mass construction of nuclear power over a period of decades would circulate some of the money through UK construction and manufacturing sectors, which spending it on imported oil, gas , coal and imported 'biofuels' does not.

What we see in this projected scenario, is the following:

- Gradual increase in electricity demand as it becomes cheaper than the fossil fuel alternatives.
- Ongoing increases in nuclear power capacity as nuclear now out performs fossil fuel in economic viability.
- Ongoing increases in grid capacity to handle increased demand for electricity.
- Winding down of no longer profitable fossil fuel distillation and distribution networks
- **Probably** at some point use of off peak (nuclear) electricity or nuclear waste heat to synthesise fuel for those applications which cannot do without it.

These are the direct and most obvious impacts of this inevitable change. A winding down of the fossil industry over a period of several decades complemented by a rise in the nuclear electric industry as this becomes a more attractive investment.

There is in fact little need for government to interfere with this process: merely by removing subsidy from inappropriate 'renewable ' technologies, the incentive to develop nuclear power will return. If there is a need to 'front load' the markets to further incentivise nuclear power, a simple tax on carbon based *fossil* fuels would suffice. And a zero tax on synthetic carbon fuels would encourage investment in that technology, at such time as it became near cost competitive..

But above all removal of punitive restrictions on nuclear power is needed urgently. And a program of education into the realities of it, as a genuine practical solution, rather than the cosmetic solution of renewable energy.

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cheaper to have a gas power station - even one that burns very expensive (synthetic) gas, if its only used a few hours in a year, rather than another nuclear power station which is similarly underutilised.

22 Some estimates of the total cost of grid upgrades *alone* to handle Germany's *energiwiende* – its transition to 'renewable' energy – put the figure at close to a trillion Euros - £600bn or so. Neither does an all nuclear (or largely nuclear) grid need to be 'smart' – people are themselves smart enough not to use high priced peak electricity when they don't need to and by removing intermittent renewable electricity from the grid, the sudden massive loss of capacity that a smart grid is intended to handle simply wouldn't take place.

Indirect effects on infrastructure

Whilst the larger part of the transition beyond fossil fuels in in the replacement of a fossil fuel extraction and distribution system on a more or less direct one-to-one basis, by a nuclear electric generation and distribution system, there are other indirect effects that need to be noted, especially in the area of transport, which, as has been indicated, is the one area where massive and deep transformations are *inevitable.*

These will be driven by the need for at least some transport – particularly freight – to replace the car, and to an extent the aircraft. Whilst it may be assumed with some degree of certainty – and it is happening already – that personal car use will fall in line with rising motoring costs, and air travel, as fuel costs rise, will be reduced to the essential, not the optional, there will still be a need for some. And the logical substitute is the electric train, fed by fleets of short range electric vehicles. Perhaps a trip to London in 2030 will be a matter of getting out your battery car, unplugging it from its off peak charger, and driving to the nearest railway station where as part of the ticket price, it can be left on charge, the railway having *de facto* access to large amounts of electricity anyway by virtue of it being equipped with power for the trains. Disembarking in London, you will catch an electric bus or taxi, or take an electric tram to your destination.

Freight likewise, might arrive at a major port like Felixstowe, be unloaded from a nuclear container ship, using electric cranes and placed on a flat bed railway wagon and a bar code destination and urgency code applied to it. Trains would be assembled from the most urgent containers for a given destination by automatic machinery – either by shuffling containers on the trains, or by shuffling the wagons in marshalling yards. The train would then leave, and proceed to drop off at any junctions, the appropriate wagons. And collect any destined for anywhere along its designated route. Others might them be assembled for minor railway routes, until at the nearest point to the intended recipient, the containers are opened, the contents sorted – again probably automatically by barcode, and dispatched by fleets of independent couriers using electric vehicles to their final destination. All charged at the railway interchange point. A postal system write large, probably using techniques adapted from Internet routing and switching technology.

Such a system is technically entirely feasible, but requires some infrastructure changes to operate.

- The railway system would need massive extensions. Not in terms of high speed flagship routes, like HS2, but in terms of not necessarily fast, but ubiquitous penetration to all areas.
- As motor vehicle use diminished, this could be achieved by using the pre-existent road network to convert to trains. For passenger use (driver-less) trams might ply many of the roads instead of cars.
- Large marshalling yards and interchange depots would need to be built to service a given geographical area. The switch of freight from rail to road in the 50's and 60's mean the destruction of many of these, but they would need to be reinstated in some form With rail the default method of medium distance transportation it becomes necessary to leverage the network for as much capacity as it will stand. People by day, freight by night, and many many more alternative routes to allow for maintenance on any given section.
- High speed trunk routes would be needed, but with the decline in road transport these could easily utilise part of the motorway network, this leveraging the investment into the road system back into rail.
- Integrated joined up thinking would need to link road and rail – not in terms of placing stations and car parks in town centres but where road communications existed. i.e. near to main roads and current motorways. Towns would be stub branches off the man backbone network, not an intrinsic part off it.,

- The railways would be not only transport highways, but also integrated with electricity distribution, featuring substations to charge the local electric vehicle fleets, and, since they also represent de facto way-leaves across the country, and would need their own extensive data network to co-ordinate, they would also form ideal natural routes to run optical fibre networks to push ultra high speed networking across the country.

This view of the road network being integrated with the rail network, and indeed the electricity distribution network and optical fibre data network is, I feel a most useful one. Because it illustrates one way in which existing infrastructure can be leveraged into solving some of the issues already mentioned, namely how to upgrade the grid, and transfer as much traffic from road to rail as possible. The data networking aspect is another issue which has not so far been touched on, but will be.

This is one area where I also feel that direct government intervention in a very planned and systematic way is needed. The proposed grid/data/rail network is too vital a national resource to be left entirely to the whim of commercial operators. They should be allowed unrestricted access to it, but the notional idea would be of a *network* which was essentially under central control more or less, or at least constrained to operate in accordance with central policies. As an instinctive libertarian I have no objection to individual companies or even local councils building and maintaining such infrastructure, but only if they can conform to strict guidelines that prevent their *de facto* local monopolies from abusing their position.

In a sense, a way of looking at this is that we will need to replace a given way of doing things, - road transport, petrol stations, pylons across the countryside, and buried copper (data) wires and gas pipes with something that reflects the reality of the 21st century. Namely (nearly) all electric, and heavily computerised and data oriented. This is not a change that needs to be *imposed* ahead of time by central *diktat*, of course, but it is a change that needs some planning, to ensure that when it starts to happen, the transition is as smooth and painless as possible.

Most of this could be achieved by regulatory approach at little cost. E.g. if a strong case could be made to extend a section of railway, planning law might dictate that any stations must be equipped with adequate freight marshalling yards or other facilities, that as part of the development adequate charging spaces for short range electric vehicles be provided, that the national grid would have *de jure* rights to run power distribution cabling (preferably underground) down the routes, and suitable ducting be provided, and that ducting suitable for optical fibres would also be mandatory. A sort of building regulations for the railways. Even provision of a walkway and cycle track along the route might be deemed a worthy adjunct! And possibly water and sewage pipes made mandatory if the relevant companies deemed it needful. A rolling 'mixed infrastructure' Bill would be implemented, detailing what the conditions for building any extension to the transport and electrical infrastructures would be, in order to minimise costs and environmental impact and leverage the investment to the maximum.

What this amounts to is a view of all the things that need to be moved across the country – power, water, sewage, electricity, freight, people, data – into defined channels in a pan national network. Government itself should not necessarily plan it, almost certainly should not pay for it or implement it, but it should set the rules by which it is planned implemented and operated. On the basis of minimum environmental and physical and energy costs, and maximum benefit to the area in which it is implemented. For which the local inhabitants should have the final say unless it was of overwhelming national importance.

Impacts on lifestyles

So far I have confined the analysis to the simple problem of sustaining some kind of post industrial society at similar populations levels to those currently extant, without considering the impact that this will have on the daily lives of those who, whilst still alive, will find themselves in a radically different world than that of the 20th century.

It is not a joyful prospect in its entirety. Rising energy prices, capped only by the emergence of nuclear power as the *de facto* cheapest form of energy overall, will mean less material goods that require high energy inputs to manufacture, much less travel and a rather narrower physical existence. Work too, will be different. Heavy industry will continue to decline in the UK, expect in those areas directly involved in the transformation to the infrastructure outlined previously.

The impact of the Internet on social and working practices

One industry can be expected to increase, and that will be anything connected to data. Moving *information* around, as opposed to physical goods or people will become ever faster, cheaper and easier as more of the word becomes 'on grid'. In fact many people may well – faced with a rather dismal physical word around them – choose to spend more time in virtual world, meeting and socialising online, playing elaborate real time interactive games and so on.

Faced with extremely expensive travel anything that can be done 'online' will be done 'online' . Already we see remote controlled drones prosecuting war. We have seen surgeons operating on patients miles way using micro manipulators controlled from elsewhere. The internet in general means you don't need to be there. Sales meetings can be video conferenced. Many jobs that are semi-skilled manual jobs could in theory be done wither under remote instruction, or by remote robot control. The *de facto* place of work will be at some kind on internet connected work station appropriate to your job, in your own home. And you will be paid by electronic transfer into your bank account. Probably in any currency you care to mention.

This disjunct between where you live and where you work will vanish. They will be one and the same place, and that has important social ramifications. You will have two sorts of friends, those online and those that you live nearby. Being at home, and not necessarily tied to fixed working hours, will allow a different approach to things like keeping an eye on your own community and acting to counteract crime, and also such things as child care. You won't *need* to go out to work, and you won't *need* to go out to shop. Such things as you *need* will be available online or by a white (electric) van delivering them to your door... Even education can in many cases be carried out online. One can imagine someone in Nigeria with a decent internet connection signing up for a university course at a prestigious UK university, and listening to all the lectures and submitting written work over the Internet. And even performing experiments in a lab somewhere across the other side of the world, remotely.

Travel will be for pleasure, almost exclusively, for most people. And there will be a lot less of it. Only a few people will need to be 'hands on, *on site'* to perform actual work. That leads the way to transforming the areas in which people live into less roads, less traffic, more areas devoted to leisure activities. And with 'places of work' in decline, huge swathes of office blocks will be redundant. Perhaps they will become – like the old mills of the industrial age – ripe for conversion into hi-tech residential accommodation.

And the out of town malls and 'sheds' will morph naturally into distribution centres.

Once again this is not a process that needs to be imposed or legislated *for* – rather the role of government in this transformation will be to *remove* legislation that makes working from home something that needs in many cases a planning permission change on the property.

In such world the Luddite adherence to fixed working hours, fixed terms and conditions of employment and minimum wages are simply *irrelevant barriers to getting the work and doing it and getting paid for it.*

What emerges from this view, is a vision of a massively wired world, a massively *connected* world, where infrastructure is arranged to supply physical needs, and the work comes to the people: the people don't go to work. This releases a huge amount of time and physical energy from the system, which in itself reduces the need for energy . And increases leisure time. Communities become once again places where people work, play *and* live. Not dormitory suburbs/both partners out to work/ children at play school, with houses empty by day (but still heated), inviting crime.

In conclusion

What I have tried to do here, is to lay out a vision of what changes are necessary in order to continue and develop post modern post industrial societies based on the following premises:

- The current dalliance with 'renewable' energy – at best a cosmetic solution to a very real problem, not of climate change, but of spiralling energy prices – and the rise in fossil fuel energy costs to beyond economic viability, will either result in enormous and widespread poverty and societal collapse, or be scrapped in favour of massive deployment of nuclear power. Nuclear power represents a cap on energy prices: put in simple terms, if it's a more expensive alternative than nuclear, it won't happen[23].
- That transition of and by itself, given the lack of availability of suitable one-to-one alternative technologies, especially in transport, will result in the need to deploy a total change in infrastructure, from a haphazard supply of goods and services that has grown organically, to a definite and preferably more integrated new level of infrastructure capable of solving at the least the basic problems of supplying populations with goods and the necessities of life. That is not to say that a centrally planned solution is to be *imposed* by government, rather that organic growth in new infrastructure be *encouraged* by government de-regulation, and directed into socially positive directions by different *new* regulation.
- Apart from nuclear power, the only other thing we have going for us, is data communications. Of and by itself a seemingly trivial thing, but the impacts of leveraging an increasingly wired world into new lower energy ways of doing things can also, if encouraged and directed as part of the same infrastructure development touched on above, actually improve lifestyle at lower energy usage and give a better quality of life altogether.
- The precondition to allowing these changes, is that we must discard what stands in the way. People in this wired world where no one controls the media channels, can no longer be told what to do, with no idea that an alternative exists: they must be instead exposed to the real facts, and we have to trust in their common sense to select from their available choices the ones that will in the end benefit them the most. Here the greatest barrier to progress comes from those who espouse centralised 'command and control' ideologies and seek to *impose* (often very ill considered) solutions on an uncertain and increasingly recalcitrant world: It seems to me that we cannot second guess the way change will happen, except at the broadest level, therefore to seek to decide what it will be before it happens is to make a huge mistake. This means that a much more 'hands off' style of governance is what is required to allow successful approaches to succeed, and not seek to stifle them, in order to preserve an increasingly oppressive and dysfunctional *status quo* . In short the role of government should be to stop ***blocking*** change, and seeking a return to the way things used to be, and recognise that the *world has already changed,* and will continue to change. We may say, (and I believe it), that the only way forward is massive investment in nuclear power, but we cannot *impose* that solution. It has to be *explained.* And as watertight a

23 Provided governments don't get in the way and ruin the market place again.

case made for it as possible. And if some other option presents itself, then we must accept that we were, as it turned out, wrong. We may say that the only way to solve land transport in an increasingly nuclear electric world, is trains, but we cannot and should not *impose* it. All we can do and all we should do is identify salient issues, place the arguments before the populations and let them decide, because the costs of *imposing* them are massive.

- In particular, we must abandon the idea of 'growth in all things' and seek to stabilise or even reduce populations *by consent,* because consent is cheaper than enforcement, if nothing else.
- Without massive future populations to pay off the debts of this generation we can't 'solve' the debt problem of the developed world by a 'return to growth', either. Perhaps we must acknowledge that these debts never *will* be paid, and change accounting practices to a formalised system of at least paying the interest in perpetuity, or for a fixed period at fixed low rates alone, and after that the slate is wiped clean.

Now whilst it may seem that the overriding position that I feel government should adopt is educational and *laissez faire* there are **some** areas in which government can be proactive in an uncertain world.

- Rather than second guessing solutions and giving direct financial support (as with the disastrous renewable energy policies), it can accept that it actually has no idea beyond the most hazy as to what class of solutions it may need, and no ideas which if any of them will work. So it must simply lay a little money on those who think they know, on a very even handed basis, accepting that 90% of the money so spent will in the end produce no tangible results whatsoever. Out of the cold war and the threat of nuclear destruction came two developments that have changed the world. The microchip, originally designed for missiles guidance systems, and the Internet, originally designed as a distributed network that could withstand an all out nuclear war. But thousands of other projects lie buried in old files because they simply did not work. The role of government here, I feel, should be to fund universities to undertake basic research up to the point where a possible solution is at least recognisably there, at which point venture capital can take over.
- In this context, there are several ideas raised here, that might for example be worth spending time exploring. What for example, is the minimum amount of goods that need to be transported the minimum distance to the point of consumption or use? And what is the most efficient way of doing it? One Ph.D. Student, a year and a computer could supply a better guess than mine. We spend millions on 'climate change research' to identify solutions to a problem we almost certainly cannot solve, that may not actually exist, and to chart the effects of a climate we almost certainly have little control over. We spend nothing on investigating the social effects of declining access to energy. Or indeed on developing *responses* to *natural* climate change that may well be beyond our control. Why spend billions **subsidising** – say – tidal energy – when we could spend a few thousand deciding that it was just another cosmetic solution, and nuclear was in fact way cheaper?
- Information, information, information. The government and its local branches spend millions, if not billions, on collecting statistics and figures and monitoring this and that, but spend almost *nothing* on making it publicly and freely available to anyone who wants it. One example illustrates. Flooding is an increasing problem. The Environment Agency has river level monitors on many rivers that can, given the right software, show exactly the process and danger levels associated with any given river system But that information is presented to the public in terms of a set of pictures that are relatively useless and a set of numbers that are so widely spread across the website that it is impossible to collate them. Viz. :

  "*22. Can I download river level data from your website? You cannot download information from our river level pages. Use of the data is subject to the same terms and conditions as the rest of* *our website. These terms can be viewed on our website."* [24] Why? This is public information, collated using public money, the public **own** that data, why are we not allowed to access it? This deeply anal attitude to public data persists right across government as it it was somehow their private data, and despite the FOIA[25] it takes steel jawed pliers to prise it out of their grubby hands. It is as if the chief danger of releasing public information to the public is that it might expose their decision making processes to public scrutiny. But what, after all is wrong with that? I would wish to see all such public data *required* to be published in a standardised form in all its raw entirety, so that researchers can use it in any way they wish, secure in the knowledge it hasn't been doctored or spun to make a political point.

It was proposed that we introduce speed limits in our local area to 'cut down on the number of fatal accidents' . I spent a half day researching. There had been only one fatal accident in the area in the last ten years, and nowhere near the proposed speed limits.

The stock excuse is always that in the wrong hands the data will be misinterpreted and used to make case for things against the public interest. And yet it would seem that is merely a reflection of the way it is in fact used by the government agencies themselves.

What we are facing, is the necessity – the absolute and inevitable necessity – of transforming the whole way we live, and support ourselves, in the face of inevitable change. And we are it seems at every stage denied the possibility of adapting to that change, by governments who seek no more than to preserve a *status quo* that is sliding beyond their grasp. Governments to whom a political solution to a real word problem is seen as a cosmetic fix to underline their 'leadership qualities', their electability, and their popular appeal.

Meanwhile the populations are restless. They know beyond a shadow of a doubt, that change is in the air. And yet while their erstwhile leaders dither and dodge, and burble meaninglessly about 'return to sustainable growth' they are left leaderless and without direction, prey to any snake oil salesman who professes to have the magic pixie dust that will transform the world (given enough access to your funds) into a freer, better, fairer and more simple and natural place to be. But on the ground the reality is that they increasingly not believed, and things just get worse.

I have spent the last few years detailing and explaining and exposing the facts about why I think their solutions will not – cannot work. The stock response is: 'So what is your solution then?'

At first I assumed that was just a way to avoid facing up to the reality of what I was trying to say, but on the chance the question was, in fact, serious, I have written this to explain what, given a deep background in matters technical, and such understanding of politics and society I have, what a possible solution – or set of solutions – might consist of.

Paraphrasing Sherlock Holmes, when you have removed all the impossible options, whatever is left, is probably the way things will have to go. That is what I have attempted to do. From there, the *implications* of the way things will have to go, have been traced downwards to construct a picture of a possible future world, and then, looking at the changes that need to take place, identifying what stands in the way of them and what can be done to expedite them.

And the appalling fact that what stands in the way of them is our government and institutions themselves, is perhaps the most crippling indictment of those institutions, and those who comprise them.

In essence *most* of the needful changes would come about more or less naturally as a direct response by individuals at every level to the rising costs of fossil energy. **Government needs do little more than explain what is happening, present a reasonably clear vision of where things are heading, and cease to obstruct the process of inevitable change.**

24 http://www.environment-agency.gov.uk/static/documents/Leisure/RLOI_FAQs.pdf
25 Freedom Of Information Act

But they cannot do that: it is simply not their style. Parochial to the end they must needs maintain the fiction that nothing happens, can happen or will be allowed to happen except by their consent, their decree, their controlling influence. They think that we expect that of them. But that is no leadership. That is management, and mushroom management[26] at that. That isn't about leading a nation to a better place, that is fear of losing the place in Government you already have.

The point to be made here, is that government response to inevitable change, which is currently characterised by enormous efforts to maintain a comfortable *status quo*, needs to change from an dictatorial approach – telling the nation what it must do, and delivering only the information, that justifies that decision, to a more honest and humble approach, laying out all the information, identifying the more likely changes, and enabling them to take place as a natural response to the changing conditions beyond government's control.

And it must refrain from attempting to second guess the shape of the society and technology that will result as 'best optimised too the new conditions' and only legislate or subsidise or tax where the result is already clear.

That is, if the government wishes to add feed-forward to kick start non fossil technologies, the appropriate instrument is a tax on fossil fuel and that ***alone.*** Accompanied one hopes by a lessening of taxation elsewhere.

That is all that is required to bias development towards non fossil technology.

Likewise the general thrust of regulation should be to remove those that impede change, those that enforce a particular way of doing things, not to regulate *in favour* of the new, but to *remove* regulation that *stands in its way*.

And finally, to refrain from deciding what the answers shall be, and concentrating on constructing a plausible narrative to support the decision, whilst hiding all the information that leads to that decision; Instead publish the information, suggest the conclusion and wait until it has consensus approval.

26 Keep them in the dark, and feed them bullshit.

Appendix I – Lithium-air batteries.

Towards the end of writing this article, I became aware that some developments were taking place in battery technology surrounding the development of lithium-air batteries, which at first glance appeared to be the Holy Grail of secondary energy storage. But we have seen Holy Grails before, in the shape of nuclear fusion – and 60 years later, whilst it still offers access to unlimited energy in theory, the practical problems of containing a small sun inside a reactor vessel still have not been overcome.

The first thing to say about Lithium air is that it has the energy density. Yes, by not carrying its own oxidant and using atmospheric oxygen, the battery is lighter – much lighter, and amusingly, its lighter when charged than when empty[27].

Not only is it light enough for cars, it is light enough for *aircraft* too. It is, in the context of a nuclear electric society, the game changer. Or it would be if....

- It was cheap enough. If it ends up taking more energy to make than it can store over its lifetime it will remain a luxury level item, not a mass market ubiquitous solution to mobile mechanical power. If it turns out more expensive overall than e.g. making synthetic hydrocarbon fuel, it is never going to be a game changer.
- There is enough lithium: visions of fleets of private cars, aircraft, and boats all battery powered lead to visions of massive amounts of lithium being needed. Of course its recyclable, to a degree, but still, that's an awful lot of it needed. It is abundant, but it takes energy to mine and purify.
- It can be made safe enough: lithium as a metal is highly flammable, and so too are the electrolytes used to moderate the reactions. If safety measures result in containment weight increase to the point where its no longer viable, it is of limited use. A was the case in nuclear fissions aircraft engines for example.
- It can be made efficient enough. Currently it is poor. Now low efficiency is not a show stopper, but its another notch away from the theoretical potential and cost to the real life potential and cost.

It is therefore impossible to say with any certainty, if and when the practical problems of lithium-air battery technology will be solved, or even if, ultimately, they will be at all. Nor at what final cost in terms of energy of manufacture and final cost price on the open market.

But along with nuclear fusion, it would seem to be an area at least where blue sky investment could just reap massive rewards. So one policy point would be to throw sensible amounts of money into it at the academic and prototype level.

Contrariwise, it cannot be **relied** upon to deliver a solution, especially not one at low cost. As fossil fuel use declines due to rising costs, the transformations that will inevitably take place in society already outlined, will take place: Lithium air batteries may simply mean that *less* transformation is required.

27 That is good for aircraft. Take off weight is the limiting factor mostly. However it does mean that at the flight end the battery aircraft is still carrying weight that the fuel aircraft would not be.