

ecoLonomics

Paul Mobbs' newsletter of thoughts, ideas and observations on energy, economics and human ecology

<http://www.fraw.org.uk/mei/ecolonomics/>

ecolonomics@fraw.org.uk

“When the facts change, I change my mind. What do you do, sir?”

I met George Monbiot many years ago, during the various roads and land campaigns of the early 1990s – not long after the security guards at the Batheaston/Swainswick bypass used “minimum reasonable force” to bust his foot, after which he limped from event-to-event on a crutch. As far as nuclear power goes, George has been sitting on the fence for a while now; this week he fell off, on the pro-nuclear side.

Banbury, Tuesday 22nd – Friday 25th March 2011.

Given his previous opposition, [George Monbiot's](#)¹ shift towards a [blithe acceptance](#)² – if not full support – for nuclear power, in spite of the Fukushima Daiichi [nuclear accident](#)³, has left many environmentalists feeling a little betrayed; I've even had a few emails today, due to my long history of working on energy and nuclear issues, asking me to vociferously “take him on”. I don't see the point of a personalised attack, or what purpose it would serve to advance the debate – although it might act as a conduit for people to vent their fear and angst at the seeming collapse of the ecological alliance against nuclear power.

Right or wrong, George's opinions are rightly his own. However, if he is representing “opinion” as some sort of “fact”, using his “green icon” status to lend credibility, then that's an entirely different matter (I'm not entirely sure if he is, given his rather diffident views on the whole nuclear issue of late). What matters are the facts; George is free to interpret these as he wishes, although, in that context, I'd expect him to apply the oft-quoted phrase from [John Maynard Keynes](#)⁴; “When the facts change, I change my mind.”

So, looking at the whole nuclear issue, what “facts” have possibly changed to make us, or George, believe that nuclear power today – in contrast to last week, last year, or even thirty years ago (when I was presented with the arguments at school) – has any better chance of solving our various ecological problems?

I'm in full writing flow at the moment. For that reason I've been trying to avoid involvement in any “distractions” – any work engagements, queries or debates, or writing another issue of *ecoLonomics* – in order to speed the completion of my new tome. After wrestling with “the beast” (the draft of my next book which at one point, unfinished, weighed in at a mind-numbing 285,000 words) for many months I've finally made headway; I now have something that looks vaguely publishable.

I log-on to my network and download today's news headlines, collected by my automated on-line information collection system... Oh dear; oh dearrrry dear! *George Monbiot has “fallen”*; off the fence, that is. That's really going to stir the crowd.

A few years ago another member of the Oxford eco-set, Mark Lynas, did something similar, and has now made quite a comfortable niche for himself in the “business” of climate change. He was following other leading “environmentalists” who, over recent years, have embraced a more non-confrontational viewpoint that seeks a truce with politics and industry in order to try and create change. Stewart Brand, for example, once the darling of the American counter-culture, has since morphed into a vendor of big solutions to the problems of the human ecological crisis. Interestingly, following on from last year's Channel 4 documentary, [What the Green Movement Got Wrong](#)⁵, Monbiot criticised both Lynas and Brand for the role they played in the programme, and their massaging of objective fact in order to make an ecological perspective fit within the [paradigm of corporate power](#)⁶. In reviewing the documentary, and the

content of Brand's recent "eco-pragmatist" book⁷, he made a very erudite [observation of their roles](#)⁸ –

Brand and Lynas present themselves as heretics. But their convenient fictions chime with the thinking of the new establishment: corporations, think-tanks, neoliberal politicians. The true heretics are those who remind us that neither social nor environmental progress are possible unless power is confronted.

I've read today's article through, twice; I find myself thinking of [Ed Murrow's incisive jibe](#)⁹ against Senator McCarthy – "The fault, dear Brutus, is not in our stars, but in ourselves". I to proceed forward the details on, with a covering note, around the virtual networks I support. A short while later comments start to flow back. Generally, people are not pleased. Some accuse him of "losing the plot". At this point, rather grudgingly I must admit, I'm moved to stop editing my book and make a more lengthy reply. The difficulty is, George offers so much to write about.

As I look at this issue, "losing it" depends upon whether or not you're asking the right questions in the first place. If the original assumptions behind the debate that inspired George's *volte-face* were wrong, the entire plot (not just George's, but the development of the whole pro-nuclear environmentalist think-tank) was a lost cause before it even got going.

I think George is framing the questions according to a set of pre-conceived ideas about energy and the economic process that are demonstrably invalid. In fact, I think the whole carbon/climate debate has "lost it" of late. In part, I believe that's because the mainstream of the environment movement can't deal with the political realities (such as the adherence to the principles of the market in all matters of public policy) so vividly expressed at the [Copenhagen Climate Conference](#)¹⁰ in 2009. For example, Mark Lynas started his [revisionist assault on environmentalism](#)¹¹ shortly after Copenhagen concluded.

As I see it the debate over climate change, and in fact on environmentalism in general, has become disassociated from the economics and thermodynamics of the way society operates. Consequently the options offered, by both environmentalists and the corporations or governments they seek to oppose, will be flawed from the outset. All sides adopt common assumptions about the operation of the world, the fiscal and the material economy, that – if we look at various research studies on these topics and the trends in economic and material flows – cannot be validated. As a result these flawed assumptions, the "questions" being posed, or the "opinions" being promoted, are arguably wrong.

Ultimately what this debate adheres to, seemingly on either side of the environmental divide, is the concept of maintaining our modern, technological civilisation; but that again is to some extent misunderstood. Technology is a tool shaped by human cre-

ativity; literally, *that's all it is*. What makes certain technologies viable or not are the economic and thermodynamic relationships that their operation allow or inhibit. Such questions go beyond the specific forms, functions or purposes of the technological artefact, and are instead functions of the human ecological system from which they spring¹².

As demonstrated in the failure of leadership by the break-away group of [wealthy nations at Copenhagen](#)¹³ (despite the clear evidence for the need to act [before the Copenhagen conference](#)¹⁴ was opened), we have a fundamental problem of process; all options to solve the carbon (or any other problematic) issue are required to conform to the existing standards and principles of the Post-World-War technological economy. If we look at this in terms of the historic process of human development, that's analogous to asking the founders of the industrial revolution to conform to the economic principles of the Medieval economy – for example, *would the modern world exist as it does today if the laws against usury had been left intact?*

In terms of developing the "next" low energy, resource efficient economic system, such prohibitions are not going to produce a viable alternative to today's economic process. Carbon emissions and growing resource consumption are, for a variety of reasons demonstrated by recent economic research, essential parts of the creation of economic growth – *no new energy and mineral resources, no growth*. Consequently, no matter how much effort we put into renewable energy, or even nuclear, there's a clear mismatch between the capacity of the human system to maintain current consumption levels, let alone increase them to meet the needs of the world's developing nations.

Let's put this conundrum within another moral issue, echoing George's observation on the need to challenge power in order to have a true resolution to the ecological crisis: *If it's a choice between power and influence but cow-towing to conventional wisdom, or representing the best "truth" of our situation but risking unpopularity, which should you choose?*

George might have lost a lot of friends writing that article, although he's probably gained a whole lot more, but for me that's immaterial when the technical energy and economic questions that such fickle relationships are based upon are, at the outset of the debate, so clearly misunderstood.

"A mystic is a person who wants to understand the world without using science"; I purposefully threw that statement into the draft of the new book, if only to provoke a response from those within the environment movement who see science as a threat – when in fact it is simply a human tool with which they could provide compelling evidence to support their values and goals. There's absolutely nothing wrong with mysticism; it's an

important part of human culture, and one that allows us to narrate the story of our existence in ways that resolve uncertainty and conflict over the true nature of our lives. However, if we're going to take-on the opponents of an ecological viewpoint of human existence, we have to engage with science not simply as a means of taking part in the dominant media or policy agenda, but as a means to frame that agenda by challenging some of the central myths that are perpetuated by industry and governments.

Unfortunately such an approach no longer leads the vision that mainstream environmentalists present. As pressure group campaigning has shifted from a knowledge-based activity to one that dominated by media lobbying, the environment movement has lost control of the news agenda because they are no longer able to frame the interpretation of facts; they are continually reactive rather than being proactive and thus cannot guide events; more problematically, this media-friendly, popularised notion of environmentalism has become part of the wallpaper of the media landscape, where it can be difficult to differentiate its purposes from the other competing messages it sits alongside. That, in a sense, and certainly in relation to the nuclear issue, is George's problem as much as the rest of us.

The stark choices presented by environmentalism during the 1970s, between ecological Armageddon or economic expansionism, no longer form part of the image of environmentalism depicted in the media. Campaign groups shy away from any position that detracts from the reassuring messages of affluence promoted, from low-brow fashion to high-brow entertainment, across the media; preferring instead to talk about "[sustainable consumption](#)"¹⁵ or "[green new deals](#)"¹⁶. When such stark, counter-culture messages are presented in the media it is often as a curio, usually representing a pre-conceived notion of a [quirky or eccentric lifestyle](#)¹⁷, but stripped of any challenging or [incisive critique of modernity](#)¹⁸ from a [deep ecological perspective](#)¹⁹.

Which brings us back to George's shift towards an acceptance of nuclear energy in today's article –

Yes, I still loathe the liars who run the nuclear industry. Yes, I would prefer to see the entire sector shut down, if there were harmless alternatives. But there are no ideal solutions. Every energy technology carries a cost; so does the absence of energy technologies.

Reading this made me think of Saint Augustine's famous [prayer](#)²⁰, "Give me chastity and continence, but not yet". However, I would interpret it within the terms of Paracelsus' maxim stated nearly five hundred years ago, "All things are poison, and nothing is without poison; only the dose permits something not to be poisonous."

When George speaks of the "absence" of energy technologies bearing a cost he's entirely correct; but

how do we square that with the inevitable costs of keeping our current lifestyles when, on a whole range of indicators [other than](#) climate change, human society is heading for [ecological collapse](#)?²¹

What's implied in this statement is some appeal towards stasis – an idea that society today represents the "best of all possible worlds", and, therefore, that anything which detracts from the continued support and enjoyment of our present day world must be an aberration. He echoes this idea two paragraphs before, when he states –

Deep green energy production – decentralised, based on the products of the land – is far more damaging to humanity than nuclear meltdown.

So, what we have is a [message of conformity](#)²²; a plea for the maintenance of today's perhaps imperfect system that, even with "all of the corner-cutting that we've become quite familiar with", preserves the trappings of our glorious civilisation... *but what if that whole outlook is in ignorance of both the ecological and the historical facts?*

Let's ask some troubling questions. Let's take a broad swathe of information on the ecological effects of human society and test George's contention that today's world must be better than the "deep green" alternative – and, therefore, that we must justifiably undertake certain risky measures to preserve the material trappings of our modern way of life.

In doing this I'll not just reference George's article, but also Stewart Brand's book which pre-dates, and prefigures, many of the points George seeks to make. In contrast we'll look not at the political opinions of environmentalists, but at scientific research and academic studies covering the fields of energy resources, economics and [health physics](#)²³ (the health impacts of radiation). However, first we need to consider the context within which these issues are contested – *what's my interest in this?*

Much of the research I carry out is a sort of "watching brief" – being aware of developing trends, seeking out the information and technical facts behind them, and then trying to develop information, support services for campaign groups, and ultimately articles and presentations that explain these to a non-technical public audience. This is what I have always done, as an environmental campaigner from the 1980s and as a professional consultant during the 1990s; since 2002 I've become independent of any organisation in order to give myself greater freedom to explore and develop new ideas. Over the last few years, at the suggestion of a number of people, I've described the work I do as "[ecological futurism](#)"²⁴. In a sense I try and see trends within environmentalism, but also within the wider world of politics and economics, that have a bearing on how humanity negotiates its existence within the world that we live upon.

As part of this desire to be “ahead of the curve” I try and keep an eye on what the opinion formers within different movements are doing. It’s for that reason that I’ve been keeping up with the work of Stewart Brand and the groups that he is associated with – such as the [Global Business Network](#)²⁵. In 2009, Brand published what he describes as an “eco-pragmatist manifesto”, entitled *Whole Earth Discipline*⁷. In the book he seeks to slaughter many of the sacred cows of the green movement; urbanisation, genetic modification, intensive farming, big technologies and, of course, nuclear power. On the nuclear issue, Brand makes an interesting observation on how the philosophical positions of leading environmentalists are likely to change –

There is a category of prominent environmentalist that I predict will increase in the coming years – the reluctant tolerators. When they express support of nuclear, they are careful to use sentences too complex to be quote-worthy.

If Brand’s got where he is today it’s by spotting trends; that certainly fits George’s expressed position, and his seeming “conversion” was echoed around the world by the business and [right-wing media](#)²⁶ as a demonstration, although often devoid of any direct reference to his actual words, that the supporters of nuclear power had been right all along.

In a sense, Brand’s *whole earth discipline* is an exemplar of the need for discipline within public communications, to manage the message of environmentalism in order to make it acceptable for a political or business audience. The iconoclastic themes of his book, focussing on narrow issues that mirror the stripped-down sound-bite media culture they are designed to interface with, are an extension of the simplified and commodified mind-set of consumer-oriented environmentalism. During the 1990s, these changes excluded many excellent campaigners from the grass roots of organisations, and who might have represented “loose cannons”; and ultimately the effect was to elevate the profiles of certain groups or individuals who fitted the pre-conceived roles of this engineered debate – creating, like celebrity chefs or footballers, “iconic” figures who are perceived to speak for everyone.

Brand’s statements also reflects the way in which certain people have been co-opted by the “political-economic consensus” to reflect certain acceptable views; and in return, they’re promised illusory reforms to the workings of the modern world to reflect a more “green” agenda. I’ve seen this happening ever since environmentalism became an “issue” in the late 1980s. For example, when I was on the board of Friends of the Earth, great pressure was being applied to adopt a more conciliatory approach to politics and business in return for “access” to decision-making; and in fact, after I left, a friend resigned from the board because of such com-

promises between funding sources and the message the organisation was seeking to promote. Some groups succumbed to that process far more quickly than others and learnt to operate their aspirations for change within it – such as the example I gave from the speech by Duncan Green, from Oxfam, in one of my previous editions of [ecolonomics](#)²⁷.

More and more, environmentalists have become well dressed talking heads in the media, expressing opinions rather than, as was the case 20 years ago, *actually trying to live a different kind of lifestyle*. That, in a sense, has been the flaw of treating environmentalism as a kind of consumer product – which people conspicuously consume to express lifestyle preferences, rather than adopting as a more fundamental philosophic outlook that informs and guides their decisions over how to live and work.

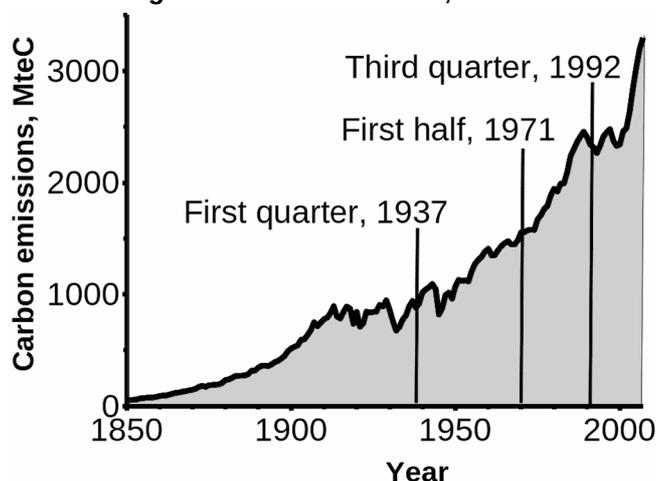
Anyway, let’s get back to the heart of the issue...

George’s main contention is that the damage created by coal is worse than the damage created by nuclear power. That argument can be assessed in many ways:

- ◆ We can look at the effects of climate change on the human population, and the role of coal-fired electricity within this trend;
- ◆ We can look at the effects of nuclear power on the human population; and, finally,
- ◆ We should also test George’s assumptions about our present way of life – that “*Deep green energy production... is far more damaging to humanity than nuclear meltdown*”.

Coal burning has been taking place for a long time, without a doubt; but the fact that coal is being burnt, and that coal-burning produces toxic and globally harmful by-products, isn’t the issue we should concern ourselves with. As noted in Paracelsus’ maxim earlier, the issue at the heart of whether coal-burning is creating harm must begin with the scale upon which the activity takes place.

Carbon emissions (as mass carbon equivalent) from global solid fossil fuels, 1751-2007

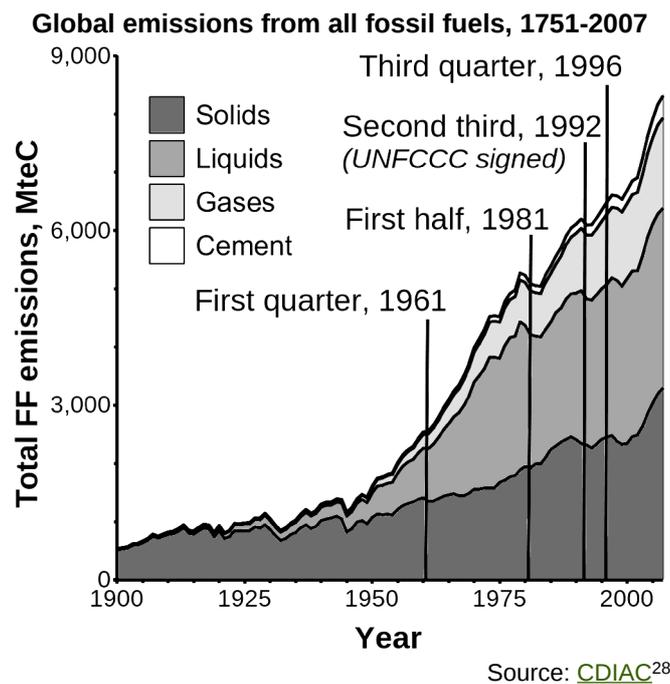


Source: [CDIAC](#)²⁸

There are various databases around about coal consumption today, but to make sense what we really need is an historic database. We're primarily concerned about carbon emissions, and usefully the US Oak Ridge National Laboratory's Carbon Dioxide Information Analysis Centre has a [database of carbon emissions](#)²⁸ that's been researched back to the beginning of the Industrial Revolution in 1751. If we graph the data for "solid fossil fuels" (which includes both coal and lignite) we get the result shown above.

It's an unwelcome fact for many – *I know, as I've explained the facts in many of my presentations* – but the majority of the carbon emissions that are driving climate change *are not historic*; they've occurred within the lifetimes of many of the people living today. As the graph above shows, half of the carbon emissions from solid fossil fuel use, and by implication the amounts burnt, have taken place *since 1971*. If we were under the misapprehension that the Industrial Revolution, powered by coal, was the cause of our problems today, we can dispatch that idea too as three-quarters of the emissions from solid fossil fuels have taken place since 1937.

Let's widen our view and look at all fossil-fuel carbon emissions –



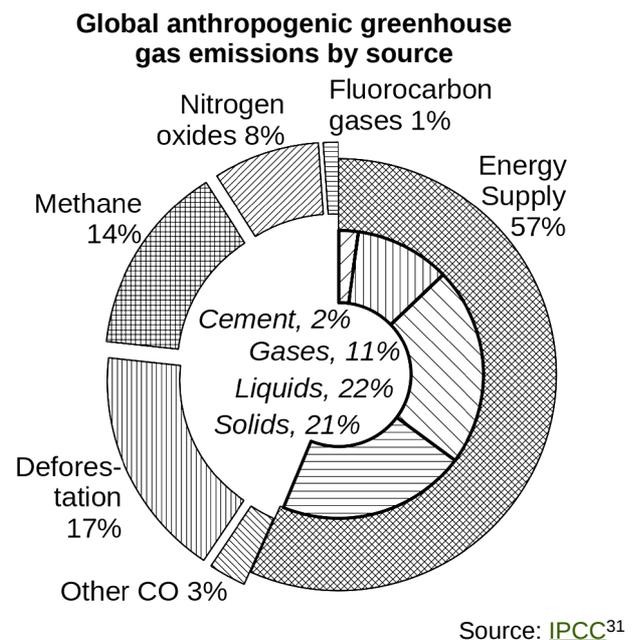
At the beginning of the Twentieth Century solid fossil fuels (coal and lignite) represented almost 100% of the carbon emissions burnt around the globe. By 1962, at the height of the post-War boom, it fell to 50% of fossil fuel emissions. By 1973, as we reached the *First Oil Crisis*²⁹, it was liquid fuels that represented almost 50% of fossil fuel emissions, and solid fuels had fallen back to second place with around a third. The high price of oil following the Oil Crisis drove down the use of oil, and in part led the "dash for gas" of the 1980s; and by 1989, as China

and other developing nations industrialised, the emissions from liquids and solids drew equal once again – representing about two-fifths of emissions each. By 2007 solids has edged ahead; at that point solid fuels represented 39% of emissions, liquids 37%, gases 19%, and cement manufacture (included in the figures by as it's one of the more significant energy-related sources of carbon) and gas flaring made-up the other 5%.

What's perhaps more significant is the overall proportions of all the emissions since the beginning of the Industrial Revolution. *Three-quarters of all the carbon emissions from fossil fuels, since 1751, have taken place since 1961; half since 1981!* What's really quite enlightening is that, on the data that stretches from 1751 to 2007, a third of all emissions have taken place since 1992, the year that the [United Nations Framework Convention on Climate Change](#)³⁰ (UNFCCC) was signed. **In other words, over the last 20 years, the most significant achievement of the world's political leadership in relation to climate change – since they agreed that action on climate change was a global priority in 1992 – has been to increase global carbon emission by 50% more than had been released over the 240 year history of industrialisation before that date.**

If we move away from the slogans and the noise of the present debate on climate, and just look at the raw data about what's happening with carbon emissions, coal is not a significant problem; *or rather, to qualify that statement, coal is no more a significant problem than the use of liquid fuels, or other human activities that drive anthropogenic greenhouse gas emissions.*

Of course, fossil fuel use is not the only source of carbon emissions³¹ –



Looked at in this way, the significance of coal *per se* again blends into the other trends within anthropogenic climate change. Energy represents around 57% of human greenhouse gas emissions; adjusting for each individual fossil fuels that means solid fossil fuels, in 2004 (the date of the IPCC's data), represented 21% of greenhouse gas emissions and liquids 22%. Deforestation, methane and nitrogen oxide emissions collectively make up 39% of emissions, and are largely created by one dominant human activity – *agriculture*. For example, livestock for *meat production*³² takes up 26% of the agricultural land area of the globe, consumes a third of all arable crops, and livestock produces 9% of greenhouse gas emissions directly. If we look from the other end of the equation, taking the example of a *typical Western consumer*³³, food consumption is their largest single source of greenhouse gases – representing, in carbon equivalent terms, 35% to 40% of their total annual emissions – far more than the coal-fired electricity they consume directly.

Agriculture is the dominant driver of both greenhouse gas emissions, but also the destruction of the Earth's natural habitats that are able to store and fix carbon in soils and biomass. The total amount of biomass produced each year, representing the output of the biosphere's life systems which cycle carbon, is called the *net primary productivity*³⁴ (NPP). There are various studies which examine how much of the world's NPP the human species uses each year. *One study*³⁵ suggests that we consume between 14% and 26% of global NPP. *More recent research*³⁶ puts the figure at around 24% – just over half of that figure due to human agriculture, another two-fifths was land management, and just under a tenth was due to forest fires. *Another*³⁷ puts the use of NPP on the land as high as 40%. The problem is that human agriculture is only able to buffer and fix a fraction of the carbon compared to natural habitats – and consequently we're negating the ability of the biosphere to cleanse its own wastes.

The significance of NPP, and its ability to cycle carbon from the atmosphere into biomass, is more apparent if we look at a related issue – *renewable energy*. There is a common fallacy promoted by environmentalists that humans, “*only use X% of the energy that Earth receives from the Sun*” – the implication being that we could utilise a large proportion of this energy to meet our needs. It might be that we don't utilise much renewable energy, in terms of our present conventional energy use, but that very statement represents a critical misjudgement about the point it seeks to make; *if we were to use a large proportion of the Earth's solar energy input, rather like the agricultural impacts issue, the effects would be devastating to the natural environment*.

Currently the world uses *467 exa-Joules (EJ) of primary energy*³⁸; 35% is crude oil, 24% natural gas,

29% coal, 6% nuclear and 6% is renewable hydro-power. Other studies, that give greater weight to collecting *data on renewable energy production*³⁹, put the figure for renewable energy utilisation at 19% of global energy consumption. The Sun powers the Earth's biosphere, delivering 5,400,000EJ of energy into the Earth system. Therefore the use of 467EJ of conventional energy sources represents about 0.9% of the Sun's solar input.

In reality that's not strictly a valid comparison because of the other renewable plant-based materials the human system consumes in addition to the “technological” sources of renewable energy. Various estimates put the energy contained within the Earth's biomass at around 4,200EJ; if we multiply this by the fraction of net primary productivity utilised by humans, that adds around 1,000EJ, *more than 200%*, to our energy utilisation – and almost all of that figure is renewable energy (“almost” because we could, for example, quibble about the amounts of fossil fuel being used in agricultural production).

If we think of the related drivers of human unsustainability – habitat destruction and species loss, soil erosion, water depletion, *eutrophication*⁴⁰ of the aquatic environment, as well as greenhouse gas emissions – *then agriculture is top of the list*. It is the single most significant driver of greenhouse gas emissions, and other agriculture-related impacts (such as deforestation) which damage the ability of the biosphere to buffer and absorb carbon. Consequently addressing our agricultural systems would put us a long way towards solving a great many of the other drivers of ecological collapse (which we'll return to later), *not just the climate issue*. Across all environmental media agriculture has a much greater impact than coal; *why then do certain leading environmentalists have an obsession with coal?*

One of George's justifications to support nuclear being qualitatively better than coal-fired plants is that it releases less radioactivity into the environment. That's an interesting issue in and of itself because it represents a contradictory argument: if low level emissions from coal-burning are significant, then the activities within our everyday lives that have a higher radiological impact are also significant; but if low level radioactivity is an issue for coal then it must be an issue for nuclear too – ultimately it comes down to the level of the *qualitative difference* in emissions (back to Paracelsus again!).

In his article George states that –

...expanding the grid to connect... to rich, distant sources of ambient energy is also rejected by most of the greens who complained about the blog post I wrote last week in which I argued that nuclear remains safer than coal.

Referring back to the *previous week's article*⁴¹, the

offending statement he uttered was –

An article in Scientific American points out that the fly ash produced by a coal-burning power plant “carries into the surrounding environment 100 times more radiation than a nuclear power plant producing the same amount of energy”.

George repeated this statement on the BBC's [Daily Politics](#)²² programme on the 17th March – ...in the normal course of their operations, per unit of electricity that they produce, coal turns out a hundred times more radiation than nuclear

The article in [Scientific American](#)⁴², published in 2007, does indeed state that –

...the waste produced by coal plants is actually more radioactive than that generated by their nuclear counterparts. In fact, the fly ash emitted by a power plant – a by-product from burning coal for electricity – carries into the surrounding environment 100 times more radiation than a nuclear power plant producing the same amount of energy.

The article continues by stating –

In a 1978 paper for Science, J. P. McBride at Oak Ridge National Laboratory (ORNL) and his colleagues looked at the uranium and thorium content of fly ash from coal-fired power plants...The result: estimated radiation doses ingested by people living near the coal plants were equal to or higher than doses for people living around the nuclear facilities... and when all food was grown in the area, radiation doses were 50 to 200 percent higher around the coal plants.

If there's one thing I've learnt over years of research, never trust a third-party report; always go back to the original source – *not the 1978 Science article from which this article is derived, but the original 1977 research paper*⁴³. This states –

The maximum individual dose commitments from the model coal plant were greater than those from the pressurized water reactor, except for the thyroid dose, but were less than those from the boiling water reactor, except for the bone dose. In general, however, the whole-body and all organ doses for both the coal and nuclear plants were in the same order of magnitude.

Not 100 times greater (two orders of magnitude), the difference between the two different nuclear technologies and coal are within *one order of magnitude* (ten times) of each other – and in fact for the effect on the thyroid the impact of nuclear was always greater than coal.

Comparatively, the most important variable within the model used as the basis for this study is the amount of ash released from coal burning. In the study it was assumed to be 1%; that's pretty typical

of the [electrostatic precipitators](#)⁴⁴ used to clean the air emissions of power plants at that time. Move forward to today, with better precipitators, but more importantly with the use of wet scrubbers or [flue-gas desulphurisation](#)⁴⁵, and the amount of ash being released is less than in the 1970s – perhaps 10 to (at most) 100 times less. Consequently, running the same model, the impacts would be much less and thus the effects of nuclear power would be far more significant; albeit, again because of the change in standards, not directly proportional to the reduction in ash emissions because of the lowering of some nuclear power emissions over the same period.

In 1988, Britain's National Radiological Protection Board carried out a study⁴⁶ of the radiological impacts of the emissions from the coal-fired Didcot power station, in Oxfordshire. Their analysis suggested that the most exposed individual would receive a dose of 0.5µSv (micro-Sieverts) per year – *that's 0.02% of the average annual 2,600µSv radiation dose in Britain from all sources*. A subsequent and [more detailed study](#)⁴⁷ by the NRPB put the dose at between 5µSv for the most exposed individual and 0.1µSv for the average person (0.2% to 0.004% of the annual dose). More recently there was concern that as the coal burnt in power stations no longer came from the UK there might be a difference in the impact. In 2006 the Health Protection Agency carried out a study on the use of fuel ash as a building material. [Their conclusion](#)⁴⁸ was that –

“it is considered unlikely that there is a significant increase in the radiological hazard from the use of [pulverised ash] in building materials.”

Note that these results are also in agreement with the findings by the US Geological Survey which were also quoted in the Scientific American article from which George quotes. The article itself qualifies the risks by stating –

Dana Christensen, associate lab director for energy and engineering at ORNL, says that health risks from radiation in coal by-products are low. “Other risks like being hit by lightning,” he adds, “are three or four times greater than radiation-induced health effects from coal plants.”

Clearly the figure that George quotes – “100 times” – is a distortion of the findings of the original research paper; it is also a misrepresentation of the various research studies that have been conducted since the 1970s. The difference between the radiological impacts of coal-burning and nuclear power are nowhere near as great and, with intervening changes, are likely to be less today. In any case, the study at the heart of this debate showed that whilst the impacts of coal are greater for some effects, the impacts of nuclear were, and for the thyroid always, greater. I think that in light of this George might like to reassess his use of this argument.

The Fukushima Accident

According to George's article –

Atomic energy has just been subjected to one of the harshest of possible tests, and the impact on people and the planet has been small. The crisis at Fukushima has converted me to the cause of nuclear power.

Perhaps it would have been wiser to wait and see what the outcome of a developing situation was before passing a judgement upon it. The evidence for the impacts of the partial meltdown has only come to light in the days since he made this point on the BBC's *Daily Politics* programme last week.

Chernobyl was a serious accident because the reactor was operating near to full power, with the control rods withdrawn, when the explosion took place. As a result there were no safety measures in operation to limit the nuclear chain reaction. At Fukushima Daiichi, the [reactors tripped](#)⁵³ the moment the earthquake was detected; this [cut heat production](#)⁵⁴ to less than 10%, and after 3-4 hours the heat might only be 1% of the reactor's design load. Three of the damaged reactors have a generating capacity of 784 mega-Watts, meaning the thermal load will be around 2 giga-Watts. After a few days the heat being produced is likely to be around 5 to 10 mega-Watts – still enough to gradually cause the fuel in the core to heat up, extending the duration of the accident whilst permanent cooling cannot be maintained.

Perhaps the greater problem are the spent fuel rods housed in ponds on the site. The reactors house the nuclear fuel in a strong concrete and steel casing – the *primary containment*. In contrast, the spent fuel taken from the reactor has to be cooled for a number of months in [ponds of water](#)⁵⁵, to allow the level of heat production to fall to a point where they are safe to be transported off-site. During this time they have to be kept under water, to both cool them and reduce the amount of radiation entering the environment. The cooling water must itself be cooled or, just like a kettle, it will boil away to expose the spent fuel – and compared to the reactor's primary containment the fuel ponds have a minimal barrier between the fuel and the environment. If the cooling water heats and boils away, the spent fuel itself can heat up, rupturing the casing of the fuel rods and releasing their intensely radioactive load into the environment.

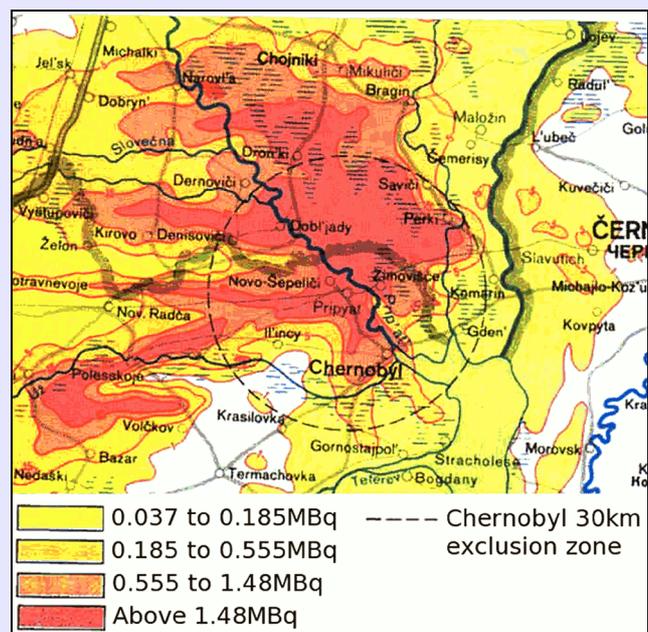
Initial reports indicate the the company operating the site, Tepco, had lax controls over [spent fuel handling](#)⁵⁶ and consequently there may have been a build-up of spent fuel in the ponds on the site – worsening the radioactive release after the power to the cooling pumps was lost.

The *New Scientist*, six days after the earthquake and tsunami that initiated the accident, stated that "*Fukushima Daiichi won't be another Chernobyl*"⁵⁷. George Monbiot may have been echoing these comments in his article. Whilst the causative mechanisms

of the accident are distinct compared to Chernobyl, the loss of primary cooling and the radioactive release this initiated are disturbingly familiar. During this week the IAEA have been releasing beta-gamma radiation measurements from around the area as part of their daily reporting. Taking the reports from day before, on and after George's article:

- ◆ [21st March](#)⁵⁸ – *High levels of beta-gamma contamination have been measured between 16-58 km from the plant... results show contamination ranging from 0.2-0.9 MBq per square metre;*
- ◆ [22nd March](#)⁵⁹ – *...additional locations between 35 to 68 km... contamination measurements ranged from 0.08 to 0.9 MBq per square metre;*
- ◆ [23rd March](#)⁶⁰ – *...additional measurements at distances from 30 to 73 km... measurements ranged from 0.02 to 0.6 MBq per square metre.*

At the moment this contamination will be a mixture of short-lived radionuclides, such as iodine, and longer-live ones, such as caesium; as yet there is no data on the composition of the contamination so its difficult to say what the level will be in a month or so, or in the longer-term. Compare these levels to the caesium contamination around the Chernobyl site – as shown in the map below (a larger, less detailed map is available from the [EU Greens report on Chernobyl](#)⁶¹). 0.9MBq per square metre is comparable to the readings well inside the Chernobyl exclusion zone; not as high as the highest levels immediately around the site, but it approaches those level of contamination. **So, at this early stage, whilst the mode of the accident at may not be the same as Chernobyl, the radiological impacts of the accident may be approaching similar levels.**



Map of Chernobyl caesium contamination and the site exclusion zone

In probabilistic terms the likelihood that humans are causing climate change (greater than 90%³¹) is much greater than the chances of being struck by lightning. However, the role of coal in the process of driving climate change is *only one of a number of* contributory factors, not a controlling factor. We could eliminate all coal use tomorrow and the results wouldn't be significantly different in a century if we did not change those other factors too.

George doesn't deal with the precise impacts of the radiation from nuclear power on health – other than the comparison with coal emissions. Therefore I won't go into any detail about the issue of nuclear power and health as he did not directly consider this in his article. However, to answer a statement in the article about environmentalism's treatment of radiation and health, there is one area we must focus upon. Over the last few years there has been a debate about the scientific basis on which the risks of radiation upon health are assessed, and the implications of this redefine the reignited debate over nuclear power.

In his article George states, in relation to the Fukushima accident –

Yet, as far as we know, no one has yet received a lethal dose of radiation.

That of course could be interpreted as an acute dose of radiation, which could kill within days, but what about the longer term mortality of chronic radiation exposure? Is this a statement that the radioactive releases from the site *are not significant enough* to cause any deleterious effects on life?

The consensus view on radiation and health is largely informed by studies of the survivors of the atomic bombs in Japan and the military personnel involved in bomb testing in the 1950s and 1960s. These represent very short, acute doses of radiation on the body. In contrast the effects of low-level, chronic exposure to radiation are very different. Recent research suggests that the dose models used to assess the impact of radioactive discharges are wrong because they can't approximate the impact of such [long-term exposures](#)⁴⁹. For example, the damage from long-term, chronic radiation exposure can slowly accumulate within DNA, and so be passed to future generations. What's most important is the difference between largely *external* radiation doses, and the *internal* dose from materials that have been ingested – so called, **internal emitters**. Where this debate is most contentious, and has the greatest relevance to the Fukushima accident, is in relation to the impacts of the Chernobyl fire.

At present the ["science communication" world](#)⁵⁰ is going into overdrive to state that Fukushima is not like the Chernobyl accident; for example, in this weeks [New Scientist](#)⁵¹ –

Obviously there are threats from the nuclear

power station, but they are limited and they are quantifiable. It's not a Chernobyl. Though the 1986 explosion at Chernobyl was a terrible event for many people, the lasting effects were nothing like as bad as expected.

Whilst the causative mechanisms of the accidents are very different, the data released thus far by the [International Atomic Energy Agency](#)⁵² (IAEA) paints a rather different picture (see the [Fukushima Accident](#) box). The official, [IAEA view point of view on the Chernobyl accident](#)⁶² is that –

...the possible increase in cancer mortality due to this radiation exposure might be up to a few per cent. This might eventually represent up to four thousand fatal cancers in addition to the approximately 100 000 fatal cancers to be expected due to all other causes in this population. Among the 5 million persons residing in other 'contaminated' areas, the doses are much lower and any projected increases are more speculative, but are expected to make a difference of less than one per cent in cancer mortality.

This determination is based on existing models of radiation and health, reflecting the acute doses of radiation from atomic bombs rather than chronic, longer-term exposure. However, more recent research on the effects of low-level radiation on health throws the established view on radiation impacts into doubt. For example, in the years after Chernobyl: there was a sharp change in [neo-natal mortality rate in Germany](#)⁶³ which coincided with the Chernobyl accident; other studies suggest that the exposure of unborn children to radiation may have also caused a [change in leukaemia rate in the US](#)⁶⁴; and more recently, changes in cancer rates in north Sweden suggest a [correlation to Chernobyl fallout in the region](#)⁶⁵. What's important about these findings is that, because the existing dose models can't explain them, there must be another causal mechanism at work – one that cannot be explained within the existing approach to radiation exposure and health risk.

This goes some way to explain why, whilst the IAEA put the excess deaths from Chernobyl at around 4,000, other research quotes higher levels. For example, a recent volume of academic research, published in the *Annals of the New York Academy of Sciences* (note, clearly not the most radical band of environmental activists), and reviewing the evidence of over 5,000 research papers on the impacts of the Chernobyl accident, puts the figure at 985,000 excess deaths⁶⁶.

The most important feature of recent research into radiation and health is the role of the *internal emitters* – radiation taken into the body, either from natural or man-made sources. In 2001, the environment minister, Michael Meacher, set up the *Committee Examining Radiation Risks of Internal Emitters*

(CERRIE) to review the health risks from internal emitters. The purpose of the committee was to look at the reasons why disagreements over the impacts of low-level radiation upon health existed, and to contrast the science behind these different viewpoints in order to suggest “what we know”, and thus how government might proceed in the future.

Right from the start CERRIE experienced difficulties because – as this issue is so significant for the nuclear industry as well as for many aspects of public policy – the workings of the committee were politicised; not least when Michael Meacher left his post and a less sympathetic minister, Elliot Morley, took over. What followed was tragic farce, with committee members receiving [legal threats from government lawyers](#)⁶⁷ to prevent the inclusion of certain evidence in the final report. In the end, whilst the committee chairman [issued a report](#)⁶⁸, the alternative viewpoint on the validity of radiation dose models had to be issued as an independent “minority report”⁶⁹. Evidence was presented to the committee to suggest that present radiation dose models, which are set by the International Commission on Radiological Protection (ICRP), could underestimate the risks by a factor of 300 or more⁷⁰. Unfortunately, the politicisation of the committee's work meant that this information could not be properly investigated.

In his article George states –

Some greens have wildly exaggerated the dangers of radioactive pollution.

That echoes Stewart Brand's viewpoint in *Whole Earth Discipline* –

Fear of radiation is far more important health threat than radiation itself.

Unfortunately, as noted earlier, the problem is that the way these arguments are discussed in public does not address itself to the available evidence, but rather to the personalities involved. What this descends into is a battle between pitched camps who trade opinions rather than trading blows, with the public in the middle – essentially its the politics of the school-yard expressed within a tit-for-tat “my expert's bigger than your expert” dialogue.

Science is not the preservation of a particularly acceptable “truth” against all contrary speculation; what it seeks to do is match demonstrable theory to the mechanisms we see taking place in the environment. Consequently the scientific process is not about seeking to maintain the dogmatic primacy of certain facts over others, but to demonstrate the validity of our knowledge by showing that it correlates to the events taking place within the natural world around us. That process breaks down when existing theories fail to explain events, but a revision of the consensus view is blocked because it has such significant political or social implications – the CERRIE review being but one example. As a result we not only degrade the validity of science, we also

risk perpetuating damaging ideas or practices because, irrationally, the impacts of the need to change our views are considered unacceptable.

That said, it is perhaps significant that in 2009 the head of the International Committee on Radiological Protection's [scientific secretariat](#)⁷¹ (the notional “keepers” of the accepted radiation dose model), Dr Jack Valentin, resigned his post; he stated that the ICRP's risk model could not be employed to predict or explain the health effects of radiation exposures to human populations. This was because the uncertainties for internal exposures were too great, perhaps by [two orders of magnitude](#)⁷². If true, this would endorse the minority case within the CERRIE committee. On that note, perhaps we should also consider the words of the administrator, Marion Hill, who resigned from CERRIE – and, whilst not “an environmentalist”, [stated to the Sunday Times](#)⁶⁷ that –

It's a complete failure when you have a scientific committee that is not allowed to write anything about disagreements over science.

Logically, if low levels of radioactive contamination are significant to health then *all such emissions* of low level radioactivity are significant; that includes coal as well as nuclear power. However, the reason this is such a political issue is that, if the alternative dose models suggested by research into low level radiation are enacted, it's the end of the nuclear power industry. In turn, if the nuclear power industry shuts down then the military use of nuclear materials and atomic weapons will become prohibitively expensive – *because of the cross-subsidisation of military nuclear systems through the funding of university training for nuclear/radiation physics, and research and development by the civil engineering industry for civil nuclear facilities*. That, of course, would upset the present global balance of power; but, in any case, that's what the existence of the civil nuclear power industry helps to support through its everyday activities.

Nuclear power is not a “carbon free” source of electricity; and for nuclear power generally the carbon issue is related directly to the quality of uranium resources. In fact, due to the reliance of all human processes upon fossil fuels, even the greenest solar panel, the cutest water turbine or the most elegant wind turbine all, *to some extent*, embody a certain amount of carbon as part of their production and, in most cases, operation.

First of all, let's look at the resource argument from the coal point of view. There's a lot of coal around, so we are told. In fact, Stewart Brand, in *Whole Earth Discipline*, states –

The problem is not that nuclear is expensive. The problem is that coal is cheap.

When the scientists of the Intergovernmental Pan-

el on Climate Change project future carbon emissions they take values for the amount of coal, oil and gas that the International Energy Agency or the World Energy Council say exist and then factor out what that means for emissions; but, what if those resources didn't, in geological or economic terms, "exist"? If the quantities of fossil fuels available are smaller, the level of carbon emissions would be lower, which would hopefully mean that – excepting the dire consequence that we [trigger feedback loops](#)⁷³ within the climate system – the effect on temperatures would be lower too. We could of course try to use clean coal or carbon capture systems to ameliorate the effect of burning coal; but in a way I believe that the fall-back to supporting nuclear is an unspoken acceptance by the industrial establishment, and by leading environmentalists, that these ideas just [won't work effectively or economically](#)⁷⁴.

Rather like the issue with radiation dose models, there is evidence that not just the amount of coal, but also the amount of oil, that is producible is restricted – and so existing reserve estimates are exaggerating future energy supply. For example, a recent study by the US Geological Survey of the [Gillette Coalfield in Wyoming](#)⁷⁵, the USA's most productive coalfield, found that only 6% of the coal resource there is viable to mine. Rather like the politicised issue of the dose models, the established view of energy resource economists, and their projections of future energy sources, are being accepted as fact when there is a great deal of evidence to suggest that these figures are wrong.

In 2007, the German-based [Energy Watch Group](#)⁷⁶ (EWG) produced a report on the [future of coal production](#)⁷⁷. Their conclusion was that –

The first and foremost conclusion from this investigation is that data quality of coal reserves and resources is poor, both on global and national levels. But there is no objective way to determine how reliable the available data actually are.

However, after looking at the history of production trends their conclusion was that –

Global coal production to peak around 2025 at 30% above present production in the best case

Rather like the debate around the issue of [peak oil](#)⁷⁸, the debate on [peak coal](#)⁷⁹ generates opposition from many vested interests – *even from those who oppose the use of fossil fuels because, they believe, if resources are limited it might negate the impetus to take action sooner rather than later*. However, the issue is more complex, since energy supply is implicitly related to economic growth. Also, this isn't just an issue of peaking production, but also the changing quality of resources. For example (see figure A5 of Annex 3 of EWG's report) in the USA, Poland and Brazil, whilst more coal is being dug, the actual level of energy delivered is falling because the quality of the coal produced is dropping, and this off-sets the

increase in production. Of course, this would appear to strengthen the position of nuclear power, but in fact the problem of supply and falling quality *is an even more pressing issue* with uranium supplies.

Let's assume that we can develop a "nuclear renaissance"; we build many more nuclear power stations. That will reduce carbon emissions, but it will also drive up the demand for nuclear fuel, and thus uranium ore. In 1999 the Organisation for Economic Cooperation and Development (or OECD – *again, not exactly radical environmentalists*) published a volume of research on [future energy trends](#)⁸⁰. On the nuclear renaissance issue the report stated –

If nuclear power were to become a major component... then the number of nuclear power plants would need to increase 30 times, leading to a total of 12 000 plants. With an estimated life expectancy of forty years for every plant, each year 300 plants would have to be replaced in order to keep production capacity constant. Known uranium reserves would then last only for about a decade...

The problem is that the energy economics of nuclear are dominated by the high costs of construction and waste disposal; even though the plant may produce a lot of power from very little fuel, in terms of the [energy return on energy invested](#)⁸¹ (EROEI) nuclear isn't as good as other [conventional or renewable energy sources](#)⁸². More problematically, as noted in the previous quote, as new nuclear plants demand more uranium the depletion of resources will, as with oil today, force the mining industry to use lower quality sources. That doesn't just reduce the energy return; there is a point at which nuclear power will produce no energy return, and we might get to that point quickly if many states expand nuclear energy production. As outlined in a report by the [Oxford Research Group](#)⁸³ –

The quantity of energy that can be generated from one kg of natural uranium has a fixed value. The energy needed to recover the uranium from the rocks in the earth's crust increases with decreasing ore grade. At a certain grade the extraction energy equals the gross energy produced in the reactor. Using ore at that critical grade (0.02% U₃O₈, compared to an average today of 0.15%) the nuclear system as a whole produces no net energy.

The Energy Watch Group also carried out a study of [future uranium resources](#)⁸⁴, and they too found great problems within both the way reserves are assessed, but more significantly how the ore quality issue will affect production levels. Summarising the future outlook for uranium supply, which they predict is likely to peak around 2030, they stated –

In the short term until 2012 the world nuclear capacity will rather decline than increase due to

ageing reactors and too few new reactors under construction. In the long term beyond 2030 uranium shortages will limit the expansion of nuclear power plants. However, even to meet the demand until 2030 the present uranium production capacities must be increased by at least 30%. Due to the delays in new projects and the severe problems at the new Cigar Lake mine, the largest mine under development, probably these uranium supply restrictions will limit the available nuclear capacity way before 2030.

It's one thing to advocate a few new nuclear power stations, but if you follow-through on the logic of the carbon reduction argument then the number of nuclear plants that would have to be built is far larger than I believe the public, and many who currently support nuclear, anticipate. What really shifts the balance is how "low" the "low carbon" technology of nuclear really is. There are various studies of the carbon emissions from the nuclear fuel cycle, and the impact that the changing quality of uranium ore has on the levels of carbon produced (note that it isn't just the use of fossil fuels that's the issue, uranium enrichment involves large quantities of chemicals that are themselves greenhouse gases). [One of the better studies](#)⁸⁵, undertaken for the Department of Prime Minister and Cabinet of the Australian Government, was produced by the Department of Integrated Sustainability Analysis at Sydney University; this concluded that at present the carbon impact of nuclear generated electricity was 60gCO₂ equiv/kW-h.

If we look at carbon emissions just in the UK, the situation is rather different to the graph of all fossil fuel emissions shown earlier. Britain emitted 574.6MteCO₂ (million tonnes of carbon dioxide) in 2009, 480.9MteCO₂ from the use of fossil fuels. Britain's nuclear power plants are going to be retired by 2035, so just to stand still in terms of present carbon emissions we would need to build at least 9GW to 10GW of new nuclear right away. ***That means the existing plans for a new nuclear build won't reduce carbon emissions because they'll largely be replacing existing nuclear plants, not substituting for coal or gas.***

If we take the breakdown of [carbon emissions by fuel](#)⁸⁶, and then the [relative amounts of the total fuel](#)⁸⁷ used to [produce electricity](#)⁸⁸, we find that 77.7MteCO₂ were emitted from coal generation and 73.7MteCO₂ from natural gas (we'll ignore oil as it's so small as to be insignificant for this process). ***In other words, just over a quarter of Britain's carbon emissions from the use of fossil fuels are the result of electricity generation, and of that figure it's almost split half-and-half between natural gas and coal-fired generation sources. Consequently, if we're just targeting the coal, that's only going to address 14% of Britain's total carbon emissions.***

In 2009, [Britain generated](#)⁸⁸ around 105TW-h (tera-Watt-hours) of electricity from coal, 165TW-h from natural gas and 69.1TW-h from nuclear; this was produced from 23.1GW (giga-Watt) of coal-fired plants, 27.9GW of gas-fired and 10.9GW of nuclear [generating capacity](#)⁸⁹. Let's ignore the projected rise in electricity demand; and we'll base the new build nuclear on the [1.6GW nuclear plant](#)⁹⁰ proposed for [Hinkley Point](#)⁹¹. Each 1GW of nuclear power plant capacity generates (at 80% capacity) 7TW-h, and produces, converting the value for nuclear generation from the University of Sydney data, 0.06MteCO₂/TW-h. Putting these myriad numbers together to express our "options":

1. We do nothing to replace existing nuclear (saves 0.7MteCO₂) and build 11GW of new gas capacity (costs 4.9MteCO₂), so carbon emissions from fossil fuel use rise by 4.2MteCO₂, roughly 1% of total UK carbon emissions;
2. To replace existing nuclear we build 7 new 1.6GW plants and emissions do not change;
3. To replace nuclear and coal plants (34GW, saves 78MteCO₂), build 22 new nuclear plants (costs 6.3MteCO₂) and emissions fall by 71MteCO₂, or 12%;
4. To replace nuclear, coal and gas plants (62GW, saves 151MteCO₂), build 39 new nuclear plants (costs 16.1MteCO₂) and emissions fall by 135MteCO₂, or 24%.

The media debate on nuclear assumes that the nuclear power stations produce no carbon; the plant might not, but the fuel cycle does. Whilst nuclear saves carbon, it can't eliminate it. If we look at official studies, such as the IEA's [World Energy Outlook](#)⁹² when they considered the need for reducing carbon from energy use in 2006, over all the various measures they considered and the most likely scenario for their deployment, nuclear produces the lowest savings in emissions. Also, to put these figures for the rise or fall in emissions into perspective; from 2006, before the economic crisis, until 2009, total British carbon emissions [dropped by nearly 12%](#)⁸⁶

Another issue with nuclear is that unlike coal or gas, where the fuel make-up most of the cost of the system, with nuclear it's the up-front capital costs of the plant that's significant. This means that changes in raw material costs, such as those we've been experiencing for the last few years, can quickly [drive up the cost](#)⁹³ of the plant and the power it produces. The existing plans for a new nuclear build in the UK could cost [£6 billion per plant](#)⁹⁴. The greater issue for the economy is that this £6 billion per plant doesn't just appear from nowhere; through higher prices it will be extracted from the economy and that will affect the performance of the economy in general.

The problem with the "swap this for that" approach is that we're perpetuating existing unsustainable practices – as noted towards the beginning of this

paper, it's an appeal towards stasis rather than change. A far more sensible approach would be to look at the problem from the demand side (the use of energy) rather than the supply side (the source). For example, to replace the coal and existing nuclear plants with new nuclear would cost £132 billion; that's almost £1,900 per person (or £4,000 for the average household) for everyone of Britain's projected 70 million population in 2030; the alternative options we could employ to use these funds would buy significant levels of carbon reduction too.

To examine the alternatives we need to consider a rather geeky economic concept called *marginal cost abatement*⁹⁵. The idea is to look at the different options to reduce carbon, and how much they cost in terms of the amounts of *carbon saved per unit of cost*⁹⁶. Then you rank them all from the lowest to the highest, and by starting with the cheapest measures you are able to deliver savings in emissions more efficiently than simply adopting a certain technology on a whim. Various studies for marginal abatement costs have been produced recently, and most rank nuclear as one of the *more expensive options*⁹⁷ – above options such as changing or improving agricultural land management or reforestation.

We are subliminally informed each day that economic growth is the cornerstone of the modern world; that there is nothing which cannot be solved if we can have enough growth: poverty, both here and in the developing world; unemployment; environmental problems; peace and human prosperity – irrespective of the deleterious consequences of our modern society, we can solve them all with economic growth.

However, such a viewpoint has significant flaws. For example, in order to grow the global economy in a manner which generates a “trickle-down” of \$1 of wealth for the poorest citizens of the world, you must create *\$166 more for the richest*⁹⁸. All that we achieve by viewing economic growth as the means by which we can solve human problems is to further enrich a minority, marginalising the greater majority, whilst at the same time we're depleting the stock of the Earth's resources. Whether we like it or not *the human system cannot keep growing*⁹⁹ because we're just going to run out of “stuff”. We're like hamster's on the treadmill of growth – *except that in real life hamsters know when to get off the wheel!*¹⁰⁰

One of the most interesting aspects of George's article is the seeming disdain that he has for “alternative” visions to the present structure of industrial society. Reading through the whole piece, and stringing together various sections (see quotes below), we could infer that he is promoting the idea that only mainstream solutions, that accept the consumption and affluence of society as they are today, are acceptable –

What they want, they tell me, is something

quite different: we should power down and produce our energy locally. Some have even called for the abandonment of the grid. Their bucolic vision sounds lovely, until you read the small print...

At high latitudes like ours, most small-scale ambient power production is a dead loss. Generating solar power in the UK involves a spectacular waste of scarce resources. It's hopelessly inefficient and poorly matched to the pattern of demand...

Deep green energy production – decentralised, based on the products of the land – is far more damaging to humanity than nuclear meltdown...

That's an entirely valid commentary *provided that* the extant structure of society today, highly energised and with high levels of resource consumption, is sustainable; that there were mechanisms to keep our affluent system ticking over, allowing the poorest around the globe to have these same opportunities; and which would also solve the drivers of human unsustainability and, ultimately, ecological collapse. Unless, even at a most general level, this principle can be demonstrated, it's not possible to dismiss alternative, lower consumption options to changing our world – purely because they hold no interest for the political and business lobby; especially if, in fact, on a rational evaluation of the material and energy flows concerned, such “bucolic visions” were the only realistic options to support us in the future.

What we find within this argument is something very similar to the approach taken by Jonathon Porritt in his book, *Capitalism as if the World Matters*¹⁰¹, six years ago. He stated –

Incremental change is the name of the game, not transformation...

And that, of course, means that the emerging solutions have to be made to work within the embrace of capitalism. Like it or not, capitalism is now the only economic game in town...

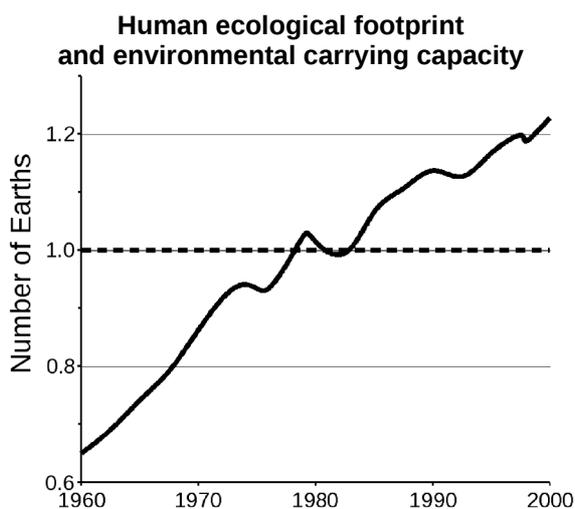
For fear, perhaps, of arriving at a different conclusion, there is an unspoken (and largely untested) assumption that there need be no fundamental contradiction between sustainable development and capitalism.

What this passage (and in some ways the entire book it is taken from) is promoting is not a compromise, it's a rationalised accommodation with an assumed and unproven set of scenarios about how our world operates – on the grounds that this will produce a better outcome. What Jonathon Porritt advocates is that we consciously disregard any questions, misgivings, or even contradictory evidence in order to ensure that we can be “players” rather than “by-standers” within the processes of politics and the business world. Personally, I think this is analogous to handing a grenade to a chimpanzee

as a toy; we can assume that everything will be OK, and that's entirely possible, but it's a highly questionable scenario that has a high probability of an alternative, and rather serious, outcome.

I refer you back once again to the question I posed toward the beginning of this paper: *If it's a choice between power and influence but cow-towing to conventional wisdom, or representing the best "truth" of our situation but risking unpopularity, which should you choose?* How we treat the issue of ecological capacity; and how our choices relate to the evidence we are able to demonstrate about our circumstances today; and, like it or not, what practical realities this portends for our future development; hinge on this moral issue – of either accepting the evidence for what it is, or denying our capacity for rational judgement in order to fit in with the false or delusional reality imposed by mainstream politics and economics.

At the simplest level we can illustrate the limits to human development by projecting future demand against the known finite capacity of the planet to meet those needs – a process refined by Professor William Rees and Mathis Wackernagel in the 1990s to produce the concept of the ["ecological footprint"](#)¹⁰². By combining various impacts and the capacity of the environment to sustain them, we can gauge the demands of the human ecosystem on the whole environment. For example, the graph below shows the "number of Earths" required to support the [demands of the human species](#)¹⁰³. The fact that we are already in a serious deficit, as outlined earlier in relation to factors like net primary productivity, is the reason that we have problems with climate change, species loss and pollution. This approach has also been used, by groups such as WWF, as a means of illustrating the impact of different nation states on the [global environment](#)¹⁰⁴.



Source: [Wackernagel et. al.](#)¹⁰³

[Thomas Malthus](#)¹⁰⁵ produced his [Essay on the Principle of Population](#)¹⁰⁶ in 1798, and the way that it

explained how populations change in response to their environment inspired later scientists in their discoveries, especially Charles Darwin and his work on the evolution of life. The core of Malthus' argument related to the way in which the scale of change in population affects its food supply –

Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio. A slight acquaintance with numbers will shew the immensity of the first power in comparison of the second.

A hundred and seventy years after Malthus' essay [Paul R. Ehrlich](#)¹⁰⁷ resurrected the debate. His book, [The Population Bomb](#)¹⁰⁸, predicted a [Malthusian catastrophe](#)¹⁰⁹ as the growth in the human population outstripped the ability of the Earth to provide the resources we require. For a variety of reasons the human apocalypse predicted by Ehrlich did not take place, but the logic of Malthus and Ehrlich's arguments remain; population is increasing exponentially, but the resources we require for survival are not. At some point, if the population is not consciously checked, the shortage of resources will impact our ability to sustain human society. However, this is not just an issue of biology and population – whilst humans have been ingenious in adapting their environment, we cannot escape the thermodynamic restrictions that will eventually limit our growth.

Following on from the controversy created by Ehrlich's [The Population Bomb](#), members of [The Club of Rome](#)¹¹⁰ (a global think tank on international issues) commissioned a scientific study of the trends that Ehrlich and other highlighted. In 1972, Donella Meadows, Dennis Meadows, Jørgen Randers, and William Behrens published their research under the title, [The Limits to Growth](#)¹¹¹. The group developed a computer model that simulated, in a very simple way, the demands that humans put on the environment as a result of population growth and greater industrialisation. With the knowledge of the environmental limits that existed at that time, the results of these impacts could be weighed against the capacity of the environment in order to determine the likelihood of a "Malthusian catastrophe". The conclusions of the report were, in terms of the general exuberance about the Technological Revolution of that time, rather [stark](#)¹¹² –

1. If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity.

2. It is possible to alter these growth trends and to establish a condition of ecological and eco-

conomic stability that is sustainable far into the future. The state of global equilibrium could be designed so that the basic material needs of each person on earth are satisfied and each person has an equal opportunity to realize his individual human potential.

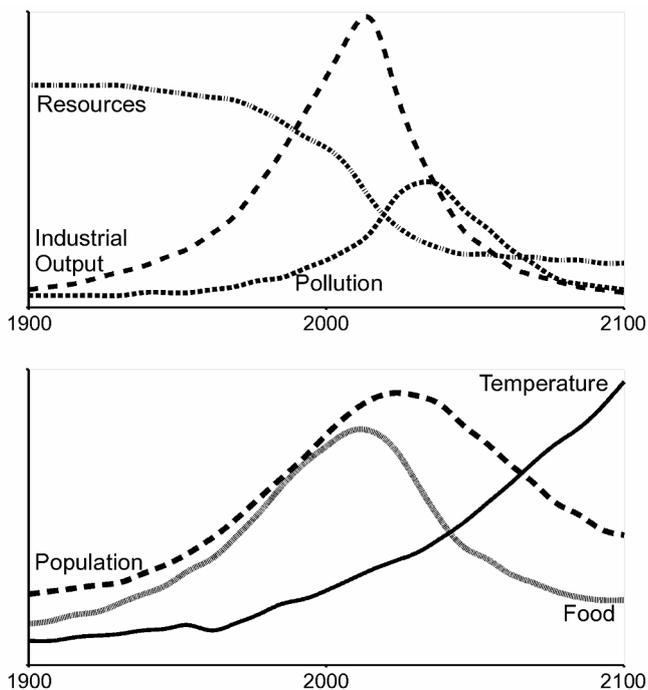
In 2004, the group published *Limits to Growth – The 30-Year Update*¹¹³. This study included new information, and a refined computer model, and the results proved to be broadly similar –

Much that we wrote in *Limits to Growth* 30 years ago remains true... The data, the computer, and our own experience tell us that the possible paths into the future have narrowed since we first addressed limits to growth in 1972.

In 2008, the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO – *again, not a bunch of radical environmentalists!*) published an independent, critical evaluation of the Limits to Growth hypothesis, [which concluded](#)¹¹⁴ –

As shown, the observed historical data for 1970–2000 most closely matches the simulated results of the LtG 'standard run' for almost all outputs reported; this scenario results in a global collapse before the middle of this century”... contemporary issues such as peak oil, climate change and food and water security resonate strongly with the feedback dynamics of 'overshoot and collapse' displayed in the LtG standard scenario.

An illustration of the Limits to Growth's World³ model outputs



Source: *Limits to Growth – The 30 Year Update*¹¹³

By combining different impacts, and the ability of the environment to sustain them, the *Limits to Growth* study projected the change in human population, industrial output, food production, non-renewable resources and pollution. An illustration of these results is shown above.

For the purposes of this discussion I've also added an indication of the rise in global temperature predicted by the IPCC's [Fourth Assessment Report](#)³¹. By adding temperature to the Limits to Growth impacts we can understand something very important about the impacts of population and resource depletion – *well before climate change becomes seriously problematic to the whole human species, the effects of population and resource depletion are likely to have already caused a disruption in the operation of human system* (which, of course, the early stages of climate change are likely to exacerbate).

The fact that serious effects *other than climate change* will impact the human system before the climate heats-up is significant; the current infatuation of environmentalism with climate represents a major flaw in their reasoning of how we might solve environmental problems in general. By reducing the bulk of our debate to one factor, climate, and avoiding any discussion of the other aspects of human unsustainability and future instability, we skew the debate on how we tackle these problems. For example, if you knew that you might run short of resources within three decades, *you definitely wouldn't, simply to address carbon emissions, want to build lots of nuclear power stations producing an intractable and hazardous waste stream!*

Following the peak of oil and gas production human society will have physically less energy each year to operate with. At the same time studies of the depletion of other mineral resources highlight the middle of this century as the time at which some essential metals will begin to [experience production difficulties](#)¹¹⁵. Others, relating the fact that the issues of population, energy production, food production, water supply and climate change will all begin to have a serious impact around the middle of this century, instead talk of a “spike”¹¹⁶ in the human system. Although not directly based upon the Limits to Growth study, these other investigations broadly mirror its findings. As a result some commentators, looking back at the history of this debate, talk of Ehrlich, and even Malthus, being ['vindicated'](#)¹¹⁷ by the emerging body of evidence on the fate of humanity over the coming century.

Perhaps, within the framework that George intimates is required to create change (such as supporting new nuclear), we might view all this talk of “limits” and “collapse” as just the ranting of “radical geenies”. Possibly; but then you might have also read Jeremy Warner's column (reporting on HSBC's

recent global commodities conference) for [The Telegraph On-line this week](#)¹¹⁸ –

The big picture is that with an additional one billion cars on the road, demand for oil would grow 110pc... Total demand for energy would rise by a similar order of magnitude... It scarcely needs saying that regardless of the environmental consequences, energy industries would struggle to cope, and more likely would find it impossible. We may or may not already be perilously close to peak oil – or maximum productive capacity – but nobody believes the industry could produce double what it does at the moment... We are fast approaching an era when energy will have to be rationed. This can either be done in a peaceful manner, or we can carry on as we are, in which case it is all too likely to end up being settled down the barrel of a gun.

Well, OK; so journalist's might get a little bit extreme at times in order to grab the headline. However, *there's no possible way* that rational and measured “establishment” organisations, for example the US National Intelligence Council, would upset the apple cart by [issuing a report](#)¹¹⁹ highlighting the relationship between energy, food, water and climate change, and the problems that are likely to arise over the next few decades... *is there?* –

Resource issues will gain prominence on the international agenda. Unprecedented global economic growth – positive in so many other regards – will continue to put pressure on a number of highly strategic resources, including energy, food, and water, and demand is projected to outstrip easily available supplies over the next decade or so...

The World Bank estimates that demand for food will rise by 50 percent by 2030, as a result of growing world population, rising affluence, and the shift to Western dietary preferences by a larger middle class. Lack of access to stable supplies of water is reaching critical proportions, particularly for agricultural purposes, and the problem will worsen because of rapid urbanization worldwide and the roughly 1.2 billion persons to be added over the next 20 years. Today, experts consider 21 countries, with a combined population of about 600 million, to be either cropland or freshwater scarce. Owing to continuing population growth, 36 countries, with about 1.4 billion people, are projected to fall into this category by 2025.

OK, obviously we've got some problems, and no amount of nuclear power can help; in fact, arguably significantly extending nuclear power from its existing levels might actually exacerbate the problem: partly as a result of the waste issue; partly because

it's a potential source of materials for nuclear weapons; but principally because, if the world does undergo a long-term economic contraction, states might be tempted to continue operation of the plants even though they might not have the necessary resources to maintain them safely.

Flick back and take a look at the graphs of global carbon emissions; notice those little saw-teeth in the data? Every now and then the production of carbon dips and then recovers. Now look at the graph of the human ecological footprint – again, wiggles in the data, showing periods where the ecological footprint situation improved, and then returned to its previous trend. Also, remember the statistic earlier – *the fact that between 2006 and 2009, over the economic crisis, Britain's carbon emissions shrank by 12%*.

Do you really want to solve the climate crisis, George? If you were not already aware¹²⁰, ***there's a simple trend we can find from within the data... economic contraction works!*** Earlier I stated that, in relation to George's rejection of the “deep green” message on energy, “*That's an entirely valid commentary provided that the extant nature of society today, highly energised and with high levels of resource consumption, is sustainable*”. If we look at various sources of information cited in this paper, the answer to that question is that clearly that *the present form of our human society is not sustainable*.

If no one, honestly and clearly, tells the public the demonstrable facts of our situation, whether they like it or not, but instead we market or promote solutions within the existing paradigm that do not really address the problems before us, what possibility of realistic change is there? That of course leads us to a perhaps flippant, although entirely valid, question; “*Do you want to experience a dire economic collapse where everything in your life ceases to be predictable, or are you willing to accept less?*”.

I'm looking for a way to bring this little exploration of human ecology to an end; some thought or idea to sum it all up in one all-encompassing statement that can simultaneously unite and juxtapose all the elements I've explored... I must say, I've been stuck on this, but then I had a feeling, an inspiration, and went to my book wall to find my favourite Marcuse¹²¹ –

The power over man which this society has acquired is daily absolved by its efficacy and productiveness. If it assimilates everything it touches, if it absorbs the opposition, if it plays with the contradiction, it demonstrates its cultural superiority. And in the same way the destruction of resources and the proliferation of waste demonstrate its opulence and the “high levels of well-being”.

I'm really sorry, but at some level I can't help feel-

ing that, rather like the famed [Borg](#)¹²² of the *Star Trek* series, George has been “assimilated” by the misinformation of the nuclear-industrial lobby; add to that Stewart Brand, Mark Lynas and others of their ilk. Faced with the dilemma between representing a hard, unpopular truth; or, like Jonathon Porritt, trying to make some perhaps positive but ultimately futile steps (in terms of the ecological trends and where they are heading) towards accomplishing some change – they have decided not to stand for an interpretation of the data that makes the best sense because it represents such a challenge to existing political orthodoxy. Whether the facts be popular or not, we must bring closure to the suicide cult that is the neoliberal political-economic system.

Of course, as we've seen this week, George's article has created rather a clamour; and that, if nothing else, is really what I believe the nuclear lobby wish to do. It's not so much that George's efforts make any difference to the bulk of the population; but amongst the environment lobby, the people who are likely to make trouble in the next few years as EDF and others apply to build new nuclear plants, it creates doubt and division – and that, more than anything, is what vested interests seek to create today.

Doubt is a powerful psychological mechanism not just because it obstructs certain actions; it also allows people to consciously trade-off the continuation of a certain course of action today because there is no clear evidence that change is required tomorrow – especially if acting on the information requires difficult lifestyle changes. The use of doubt as a means to obstruct action was highlighted in documents disclosed as part of legal actions against the [tobacco industry](#)¹²³ –

Doubt is our product since it is the best means of competing with the "body of fact" that exists in the mind of the general public. It is also the means of establishing a controversy... If we are successful in establishing a controversy at the public level, then there is an opportunity to put across the real facts about smoking and health... If in our pro-cigarette efforts we stick to well documented fact, we can dominate a controversy and operate with the confidence of justifiable self-interest.

Remember what I said at the beginning about campaign groups not using knowledge-based tactics as part of their work any more? Contrast this to the tobacco industry's chosen method of attack; having control over the facts to frame events, rather than simply appealing to altruism or conscience, is the way to control the overall perception of the debate.

Today we see the same mechanisms at work, from climate change denialists to the machinations of lobbyists and public relations agencies in the media¹²⁴. When it comes to critical economic questions the stakes are even higher; not only are the potential changes to our lifestyles much greater, but

political leaders around the globe have promised us “more”, and have justified the difficult changes required under neoliberal economic policy because the promised results would be “better for everyone”.

As noted in the quote from the tobacco industry above, by creating a controversy in the media the public are presented with two, seemingly contradictory points of view – and this dissonance is the basis upon which those seeking to obfuscate an open presentation of the evidence can play upon. Whilst those with certain interests may take sides, the majority of the public will be unsure which view of “reality” to believe. That, ultimately, is the greatest benefit to the pro-nuclear lobby from George's change of mind on nuclear power.

What's important is that we seek to “understand” the complexity and inherent inter-relatedness of these problems, rather than just “knowing”; it is only by understanding that can we realise the pressing need for change. There is a general, driving trend behind this argument, and one that's presenting itself today in many, varied ways – from high food prices to unpredictable traffic jams. If we continue without significant change, human society cannot continue to operate in its present form because the principle trend that supports it – *economic growth* – cannot function reliably due to the finite limits of energy and resource production.

Oh yes, and the most important point – *this change is inevitable*. That's because the root of these problems are not related to technological, social or political factors that *operate within* human ecology; they *originate from outside* human ecology (and thus, influence), and are primarily related to the universal thermodynamic principles that operate across the natural world. For this reason we will have to manage the [ecological overshoot](#)¹²⁵ of our species, one way or another, and whether we wish to or not, at least until such a time that we can [sustainably reconcile](#)¹²⁶ the demands of the human species with the ability of the Earth to support them.

That's not to say that “modern” society would come to an end; as [T.S. Eliot said](#)¹²⁷, “*What we call the beginning is often the end, and to make an end is to make a beginning... The end is where we start from*”. The mechanisms that enable modern society to function depend directly on our growing use of finite energy and mineral resources. It's not that we're “running out” of these finite resources, it's that production of certain essential resources will reach a [peak and then decline](#)¹²⁸ over the course of this century. We will not be forced to return to some pre-industrial past – *as those who seek to obfuscate or deride this discussion usually claim*; but it does mean that we cannot continue to live in a way that – within the aspirations of the Western world which are depicted through the mass media today – most people consider to represent “normality”.

So, to conclude: As I assess the facts about carbon emissions, or environmental degradation in general, coal is being made into a scapegoat by many environmentalists; and of course, the reason that you need a scapegoat is to deflect criticism from the less palatable reality of where the blame truly lies... *the way human society in general operates today.*

The popularised, media-led message of environmentalists might seek to demonise coal but, as outlined earlier, Britain's coal consumption does not inflict a significantly worse impact upon the environment than many other aspects of our modern culture. Environmentalists might obsess about climate and carbon, but the fact is that resource use, ecological damage, the growth of human population, and more importantly the growth in human affluence, are what is driving the present crisis of human ecology. And whilst certain leading environmentalists might try and qualify their support for certain mainstream technological or political solutions to these problems, ultimately it's the economic process that demands their adoption in order to continue the trend of expansion – and it is this that's truly driving the processes of degradation and depletion.

Given the evidence, it's possible to see how, as Marcuse outlines, the “system” is seeking to nullify the critical and prescient critique that environmentalism continues to present to the modern economic process. To refute or ridicule the “deep green” philosophy that created many aspects of modern environmentalism – and which, from bushcraft to permaculture, still nourishes its vision today – will not change the outcome of the processes that are taking place around us. Some might say that within modern society, *“we have a greed with which we have agreed”*¹²⁹; I, and many others, not just from an environmental perspective but also for *spiritual or social motivations*¹³⁰ would beg to differ. **This is a problem that cannot be solved by different methods of producing “more”; we must instead adapt to “less”.**

As shown in the graphs on carbon emissions earlier, the fact that high levels of energy and resource consumption are a relatively recent phenomenon means that our society *can exist* without the mass consumption that we are told is essential to our well-being today. Nuclear power can't even begin to address these problems – we need the opposite kind of measure, *we need contraction*¹³¹.

Again, trying to think of a descriptive phraseology within which to capture this idea, one of the foundational truths of an ecological perspective was expressed most succinctly by John Seymour, in his book, *The Ultimate Heresy*¹³² –

When you come finally to accept the belief that Man is a part of Nature you have completely to overhaul every one of your previous ideas about what it is right to do.

As individual environmentalists we are called upon to witness the world as we experience it, and to share that insight with others; there should be no expectation that we represent “the facts” – such evidence, freely available, should stand for itself without any nuancing of its content. Of course, taking such a view can be challenging for many people; unpredictable change is so much harder to think about than a reassuringly predictable and reliable stasis. Environmental philosophy challenges us to understand and solve this dichotomy. The question we have to resolve is a value judgement over which is the best option for us to adopt: Is it better to serve under an order that is delusional (in the face of the evidence, perhaps suicidally so), and by taking no action risking that if it collapses your lifestyle will be seriously compromised; or, by accepting the need for change, risking the seeming chaos of trying to adapt your lifestyle to escape that outcome?

The solutions to the problems that the human species is experiencing today are bound within the broad philosophy that environmentalism has held since its beginnings. Not just in the 1960s or 1970s, but in the decades and centuries before; within the writings of *Thoreau*¹³³, or the *Diggers*¹³⁴, and before them many of the world's great religions and ancient philosophers – who saw that simplicity, and concentrating on the small human-scale systems that we are able to relate to and thus maintain, was a means to achieve personal satisfaction. In a similar manner, we should, interdependently with those around us, seek an understanding of the minimum and sufficient resources that we need for life, and how we may best attain that... *and I find nothing in the advocacy of nuclear power, certainly when set in contrast to the very real problems we face today, that in any way fulfils such a purpose.*

Finally then, a description of our predicament that expresses the testing, and sometimes paradoxical, relationship between the pressures of our modern existence, and the inner perceptions that stir our yearning for a *more “civilised” way of living*¹³⁵ –

We live in a dream world. With a small, rational part of the brain, we recognise that our existence is governed by material realities, and that, as those realities change, so will our lives. But underlying this awareness is the deep semi-consciousness that absorbs the moment in which we live, then generalises it, projecting our future lives as repeated instances of the present. This, not the superficial world of our reason, is our true reality. All that separates us from the indigenous people of Australia is that they recognise this and we do not.

References

1. *George Monbiot* – http://en.wikipedia.org/wiki/George_monbiot
2. *Why Fukushima made me stop worrying and love nuclear power*, George Monbiot, Guardian On-line, Monday 21st March 2011 – <http://www.guardian.co.uk/commentisfree/2011/mar/21/pro-nuclear-japan-fukushima>
3. *Fukushima I nuclear accidents* – http://en.wikipedia.org/wiki/Fukushima_I_nuclear_accidents
4. See John Maynard Keynes' quotes at Wikiquote (source, p. 220, History of the Modern Economists, Alfred L. Malabre, 1994) – http://en.wikiquote.org/wiki/John_Maynard_Keynes
5. *What the Green Movement Got Wrong*, Channel 4 Television, November 2010 – <http://www.channel4.com/programmes/what-the-green-movement-got-wrong/episode-guide/series-1/episode-1>; watch the documentary online at <http://www.channel4.com/programmes/what-the-green-movement-got-wrong/4od#3156490>
6. *What the Green Movement Got Wrong: A turncoat explains*, Mark Lynas, The Telegraph, 4th November 2010 – <http://www.telegraph.co.uk/earth/earthnews/8108090/what-the-green-movement-got-wrong-a-turncoat-explains.html>
7. *Whole Earth Discipline: Why Dense Cities, Nuclear Power, Transgenic Crops, Restored Wildlands, Radical Science, and Geoengineering are Necessary*, Steward Brand, Viking Books, 2009; UK paperback edition, Atlantic Books, 2010. ISBN 9781-8435-4816-4. £8.99.
8. *Channel 4's convenient green fictions*, George Monbiot, Guardian On-line, Thursday 4th November 2010 – <http://www.guardian.co.uk/commentisfree/cif-green/2010/nov/04/channel-4-convenient-green-fiction>
9. *A Report on Senator Joseph R. McCarthy* (script), Edward R. Murrow, See it Now, CBS-TV, 9th March 1954 – <http://www.plosin.com/BeatBegins/archive/Murrow540309.htm>
10. *COP15: United Nations Climate Conference, 2009* – http://en.wikipedia.org/wiki/2009_United_Nations_Climate_Change_Conference
11. *Why we greens keep getting it wrong*, Mark Lynas, New Statesman, 28th January 2010 – <http://www.newstatesman.com/environment/2010/01/nuclear-power-lynas-greens>
12. *A Pattern Language: Towns, Buildings, Construction*, Christopher Alexander, Sara Ishikawa and Murray Silverstein, OUP USA, 1977. ISBN 9780-1950-1919-3 (hardback). £40.
13. *Copenhagen Accord* – http://en.wikipedia.org/wiki/Copenhagen_Accord
14. *Key Messages from the Congress*, final press release from the Copenhagen Climate Congress, December 12th March 2009 – http://climatecongress.ku.dk/newsroom/congress_key_messages/
15. *Sustainable consumption* – http://en.wikipedia.org/wiki/Sustainable_consumption
16. Green New Deal Group – <http://www.greennewdealgroup.org/>
17. E.g., *Lost middle-class tribe's 'secret' eco-village in Wales spotted in aerial photograph taken by plane*, Luke Salkeld, Daily Mail, 17th September 2008 – <http://www.dailymail.co.uk/news/article-1056637/Lost-middle-class-tribes-secret-eco-village-Wales-spotted-aerial-photograph-taken-plane.html>
18. E.g., see John Zerzan's presentation, *The Earth's Global Crisis*; video available from YouTube – <http://www.youtube.com/watch?v=G5TaadkSL4g>
19. *Deep ecology* – http://en.wikipedia.org/wiki/Deep_ecology
20. Book 8, *The Confessions of Saint Augustine*, translated by Edward Bouverie Pusey – <http://sparks.eserver.org/books/augustineconfess.pdf>
21. *Ecological collapse* – http://en.wikipedia.org/wiki/Ecological_collapse
22. George Monbiot speaking about the Fukushima accident on the BBC's *Daily Politics* programme, 17th March 2011 – <http://www.bbc.co.uk/news/uk-politics-12773996>
23. *Health physics* – http://en.wikipedia.org/wiki/Health_physics
24. See my web site for a more elaborate description of my activities – http://www.fraw.org.uk/mei/ecological_futures.shtml
25. *Global Business Network* – <http://www.gbn.com/>; see also http://en.wikipedia.org/wiki/Global_Business_Network
26. E.g.: *A Seismic Moment*, Rod Liddle, The Spectator, 23rd March 2011 – <http://www.spectator.co.uk/rodliddle/6808353/a-seismic-moment.shtml>;
27. *"We're all planetary hospice workers now": From local currencies to planning for life beyond the growth paradigm*, Paul Mobbs, *ecolonomics* no.5, 26th September 2009 – <http://www.fraw.org.uk/mei/ecolonomics/00/ecolonomics-20090926.shtml>
28. *Global Fossil-Fuel CO2 Emissions*, Carbon Dioxide Information Analysis Centre, US Oak Ridge National Laboratory, August 2010. http://cdiac.ornl.gov/trends/emis/tre_glob.html
29. *1973 oil crisis* – http://en.wikipedia.org/wiki/1973_oil_crisis
30. *United Nations Framework Convention on Climate Change* – http://en.wikipedia.org/wiki/United_Nations_Framework_Convention_on_Climate_Change
31. Data adapted from figure 2.1 (p.36), *Climate Change 2007: Synthesis Report*, Assessment Report 4, Intergovernmental Panel on Climate Change, 2007 – http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf
32. *Livestock's Long Shadow – Environmental Issues and Options*, UN Food and Agriculture Organisation, 2006 – <http://www.afpf-asso.org/afpf/vie/images/FAO-Livestock-Environment.pdf>
33. *Environmental Load from Dutch Private Consumption: How Much Damage Takes Place Abroad?*, Durk S. Nijdam, Harry C. Wilting, Mark J. Goedkoop, and Jacob Madsen, *Journal of Industrial Ecology*, vol.9 no.1/2 pp.147-168, 2005 – <http://www.fraw.org.uk/f.html?nijdam2005>
34. *Net primary productivity* – http://en.wikipedia.org/wiki/Net_primary_productivity
35. *Global patterns in human consumption of net primary production*, Marc L. Imhoff, Lahouari Bounoua, Taylor Ricketts, Colby Loucks, Robert Harriss and William T. Lawrence, *Nature*, vol.429, 24th June 2004. <http://www.fraw.org.uk/f.html?imhoff2004>
36. *Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems*, Helmut Haberl, K. Heinz Erb, Fridolin Krausmann, Veronika Gaube, Alberte Bondeau, Christoph Plutzer, Simone Gingrich, Wolfgang Lucht, and Marina Fischer-Kowalski, *Proceedings of the National Academy of Sciences (PNAS)*, vol.104(31) pp12942-12947, 31st July 2007 – <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1911196/pdf/zpq12942.pdf>

37. *Human appropriation of the products of photosynthesis*, P.M. Vitousek, P.R. Ehrlich, A.H. Ehrlich and P.A. Matson, *BioScience*, vol.36 no.6 pp.368–373, 1986 – <http://www.biology.duke.edu/wilson/EcoSysServices/papers/VitousekEtAl1986.pdf>
38. *BP Statistical Review of World Energy 2010* (available as both a PDF report and spreadsheet of historical data) – <http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622>
39. *Renewables 2010 – Global Status Report* (revised edition), REN21 Secretariat, September 2010. http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised%20Sept2010.pdf
40. *Eutrophication* – <http://en.wikipedia.org/wiki/Eutrophication>
41. *Japan nuclear crisis should not carry weight in atomic energy debate*, George Monbiot, *Guardian On-line*, 16th March 2011 – <http://www.guardian.co.uk/environment/georgemonbiot/2011/mar/16/japan-nuclear-crisis-atomic-energy>
42. *Coal Ash Is More Radioactive than Nuclear Waste – by burning away all the pesky carbon and other impurities, coal power plants produce heaps of radiation*, Mara Hvistendahl, *Scientific American*, 13th December 2007 – <http://www.scientificamerican.com/article.cfm?id=coal-ash-is-more-radioactive-than-nuclear-waste>
43. *Radiological Impacts of Airborne Effluents of Coal-fired and Nuclear Power Plants* (ORNL-5315), J.P. McBride, R.E. Moore, J.P. Witherspoon and R.E. Blanco, Health and Safety Research Division, Oak Ridge National Laboratory, August 1977 – <http://www.ornl.gov/info/reports/1977/3445605115087.pdf>
44. *Electrostatic precipitator* – http://en.wikipedia.org/wiki/Electrostatic_precipitator
45. *Flue gas desulphurisation* – http://en.wikipedia.org/wiki/Flue_gas_desulfurization
46. *Radiation Doses from Coal-fired Plants in Oxfordshire and Berkshire* (NRPB-R203), S.L. Wan and A.D. Wrixon, National Radiological Protection Board, December 1988.
47. *Assessment of the Radiological Impact of Coal-Fired Power Stations in the United Kingdom*, J.S.S. Penfold, K.R. Smith, M.P. Harvey and S.F. Mobbs, National Radiological Protection Board, 2001 – <http://ii.ii.4.eu-norm.org/index.pdf>
48. *A Radiological Study of Pulverised Fuel Ash (PFA) from UK Coal-fired Power Stations*, T.D. Gooding, K.R. Smith and L.K.A. Sear, Radiation Protection Division, Health Protection Agency, 2006 – <http://www.ukqaa.org.uk/Papers/AshTechA14ARadiologicalStudyOfPFAGoodingEtAl.pdf>
49. For example see: *Radiation roulette*, Rob Edwards, *New Scientist*, pp.36-40, 11/10/97 – http://www.fraw.org.uk/mei/archive/magnox_a1_13.pdf; *A-bomb survivors: factors that may lead to a re-assessment of the radiation hazard*, Alice Stewart and George Kneale, *Int'l Journal of Epidemiology*, vol.29 pp.708-714, 2000 – http://www.fraw.org.uk/mei/archive/magnox_a1_01.pdf
50. *Science communication* – http://en.wikipedia.org/wiki/Science_communication
51. *Risk expert: Why radiation fears are often exaggerated*, Alison George, *New Scientist*, no.2805, 24th March 2011 – <http://www.newscientist.com/article/mg20928050.200-risk-expert-why-radiation-fears-are-often-exaggerated.html>
52. *International Atomic Energy Agency* – http://en.wikipedia.org/wiki/International_Atomic_Energy_Agency
53. *Scram* – <http://en.wikipedia.org/wiki/Scram>
54. *Decay heat* – http://en.wikipedia.org/wiki/Decay_heat
55. *Spent fuel pool* – http://en.wikipedia.org/wiki/Spent_fuel_pool
56. *Japan nuclear firm admits missing safety checks at disaster-hit plant – Documents show operator failed to carry out mandatory checks at Fukushima Daiichi and allowed fuel rods to pile up*, Justin McCurry, *Guardian On-line*, 22nd March 2011 – <http://www.guardian.co.uk/world/2011/mar/22/japan-nuclear-power-plant-checks-missed>
57. *Why Fukushima Daiichi won't be another Chernobyl*, Michael Marshall, *New Scientist*, 17th March 2011 – <http://www.newscientist.com/article/dn20257-why-fukushima-daiichi-wont-be-another-chernobyl.html?full=true>
58. *Fukushima Accident Update Log – 21st March*, IAEA – <http://www.iaea.org/newscenter/news/2011/fukushima210311.html>
59. *Fukushima Accident Update Log – 22nd March*, IAEA – <http://www.iaea.org/newscenter/news/2011/fukushima220311.html>
60. *Fukushima Accident Update Log – 23rd March*, IAEA – <http://www.iaea.org/newscenter/news/2011/fukushima230311.html>
61. *The Other Report On Chernobyl (TORCH) – An Independent Scientific Evaluation Of Health And Environmental Effects 20 Years After the Nuclear Disaster Providing Critical Analysis of a Recent Report by the IAEA and WHO*, Ian Fairlie and David Sumner for the MEP Greens/EFA in the European Parliament, April 2006 – http://www.greens-efa.eu/cms/topics/dokbin/118/118499.the_other_report_on_chernobyl_torch@en.pdf
62. page 15/16, *Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts* (2nd revised edition), The Chernobyl Forum, IAEA, 2006 – <http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf>
63. *Neonatal mortality in Germany since the Chernobyl explosion*, Jens Scheer, *British Medical Journal*, no.304 p.843, 28/3/92 – http://www.fraw.org.uk/mei/archive/magnox_a1_29.pdf
64. *Childhood leukaemia in US may have risen due to fallout from Chernobyl*, Joseph Mangano, *British Medical Journal*, no.314 pp.1200, 19/4/97 – http://www.fraw.org.uk/mei/archive/magnox_a1_17.pdf
65. *Increase of regional total cancer incidence in north Sweden due to the Chernobyl accident?*, Martin Tondel, Peter Hjalmarsson, Lennart Hardell, Goran Carlsson and Olav Axelsson, *Journal of Epidemiol Community Health*, vol.58 pp.1011–1016, 2004 – <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1732641/pdf/v058p01011.pdf>
66. page 210, *Chernobyl: Consequences of the Catastrophe for People and the Environment*, Alexey V. Yablokov, Vassily B. Nesterenko and Alexey V. Nesterenko, *Annals of the New York Academy of Sciences*, vol.1181, 2009. ISBN 9781-5733-1757-3 (paperback). £85.
67. *Government gags experts over nuclear plant risks*, Mark Gould and Jonathan Leake, *The Sunday Times*, 1st August 2004 – <http://www.timesonline.co.uk/tol/news/uk/article464333.ece>
68. *Report of the Committee Examining Radiation Risks of Internal Emitters*, CERRIE, 2004 – http://www.cerie.org/pdfs/cerie_report_e-book.pdf
69. *CERRIE Minority Report*, Richard Bramhall, Chris Busby and Paul Dorfman, Sosiumi Press, 2004. ISBN 9780-9543-0811-7 (paperback). £25.
70. *ECRR: 2010 Recommendations of the European Committee on Radiation Risk*, Rosalie Bertell, Inge Schmitz-Feuerhake, Molly Scott Cato and Alexey Yablokov, European Committee on Radiation Risk, 2010. ISBN 9781-8977-6116-8 (p/back). £75.
71. ICRP Scientific Secretariat – http://www.icrp.org/icrp_group.asp?id=49
72. *Debate with Chris Busby and Dr. Jack Valentin, Stockholm*, 22nd April 2009; video of debate via Vimeo – <http://vimeo.com/15382750>

73. *Climate change feedback* – http://en.wikipedia.org/wiki/Climate_change_feedback
74. *Greenwash: Why 'clean coal' is the ultimate climate change oxymoron*, Fred Pearce, Guardian On-line, Thursday 26th February 2009 – <http://www.guardian.co.uk/environment/2009/feb/26/greenwash-clean-coal>
75. *Assessment of Coal Geology, Resources, and Reserves in the Gillette Coalfield*, James A. Luppens, David C. Scott, Jon E. Haacke, Lee M. Osmonson, Timothy J. Rohrbacher, and Margaret S. Ellis, US Geological Survey, 2008 – <http://pubs.usgs.gov/of/2008/1202/pdf/ofr2008-1202.pdf>
76. Energy Watch Group – <http://www.energywatchgroup.org/>
77. *Coal: Resources And Future Production*, Dr. Werner Zittel and Jörg Schindler, European Energy Watch Group, July 2007 – <http://www.fraw.org.uk/f.html?ewg2007>
78. *Peak oil* – http://en.wikipedia.org/wiki/Peak_oil
79. *Peak coal* – http://en.wikipedia.org/wiki/Peak_coal
80. *World Energy Prospects to 2020: Issues and Uncertainties*, Jean-Marie Bourdaira, IEA – published in *Energy: The Next Fifty Years*, OECD, 1999 - <http://www.oecd.org/dataoecd/37/55/17738498.pdf>
81. *Energy return on energy invested (EROEI)* – <http://en.wikipedia.org/wiki/EROEI>
82. *EROEI of electricity generation*, by Jamie Bull, Energy Bulletin, 19th May 2010 – <http://www.energybulletin.net/53475>
83. *Secure Energy?: Civil Nuclear Power, Security And Global Warming*, Frank Barnaby and James Kemp (editors), Oxford Research Group, March 2007 – <http://www.oxfordresearchgroup.org.uk/sites/default/files/secureenergy.pdf>
84. *Uranium Resources And Nuclear Energy*, Dr. Werner Zittel and Jörg Schindler, European Energy Watch Group, December 2006 – <http://www.fraw.org.uk/f.html?ewg2006>
85. *Life-Cycle Energy Balance and Greenhouse Gas Emissions of Nuclear Energy in Australia*, Department of Integrated Sustainability Analysis, Sydney University, 2006 – http://www.isa.org.usyd.edu.au/publications/documents/ISA_Nuclear_Report.pdf
86. *Table 1 and Table 2, UK Carbon Dioxide Emissions by fuel, 1990-2009 – 2009 Provisional UK Greenhouse Gas Figures*, Department for Energy and Climate Change, March 2010 – http://www.decc.gov.uk/en/content/cms/statistics/climate_change/data/data.aspx
87. *Table 1.1 Aggregate energy balance 2009*, Digest of UK Energy Statistics 2010, Department for Energy and Climate Change, July 2010 – <http://www.decc.gov.uk/en/content/cms/statistics/source/total/total.aspx>
88. *Table 5.6 Electricity fuel use, generation and supply*, Digest of UK Energy Statistics 2010, Department for Energy and Climate Change, July 2010 – <http://www.decc.gov.uk/en/content/cms/statistics/source/electricity/electricity.aspx>
89. *Table 5.7. Plant capacity: United Kingdom*, Digest of UK Energy Statistics 2010, Department for Energy and Climate Change, July 2010 – <http://www.decc.gov.uk/en/content/cms/statistics/source/electricity/electricity.aspx>
90. *UK New Nuclear*, EDF Energy, June 2009 – http://www.edfenergyconsultation.info/websitefiles/EDF_Energy.pdf
91. *Hinkley Point C nuclear power station* – http://en.wikipedia.org/wiki/Hinkley_Point_C_nuclear_power_station
92. p.190, *World Energy Outlook 2006*, International Energy Agency 2006 – <http://www.iea.org/textbase/nppdf/free/2006/weo2006.pdf>
93. *What history can teach us about the future costs of US nuclear power*, Nathan E. Hultman, Jonathan G. Koomey and Daniel M. Kammen, Environmental Science and Technology, pp.2088-2093, 1st April 2007 – <http://rael.berkeley.edu/files/2007/HultmanetalNuclearViewpoint2007.pdf>
94. *EDF, RWE May Spend \$9.3 Billion Per New Nuclear Plant in U.K., Hendry Says*, Fred Pals and Kari Lundgren, Bloomberg, 25th August 2010 – <http://www.bloomberg.com/news/2010-08-25/edf-rwe-may-spend-9-3-billion-per-new-nuclear-plant-in-u-k-hendry-says.html>
95. *Marginal abatement cost* – http://en.wikipedia.org/wiki/Marginal_Abatement_Cost
96. *Marginal Abatement Cost Curves for Policy Making: Expert-Based vs. Model-Derived Curves*, Fabian Kesicki, Energy Institute, University College London, 2010 – http://www.homepages.ucl.ac.uk/~ucft347/Kesicki_%20MACC.pdf
97. *Pathways to a Low Carbon Economy – Version 2 of the Global Greenhouse Gas Cost Abatement Curve*, McKinsey & Company, 2009 – http://www.mckinsey.com/client-service/sustainability/pathways_low_carbon_economy.asp
98. *Growth isn't working – The unbalanced distribution of benefits and costs from economic growth*, David Woodward and Andrew Simms, New Economics Foundation, January 2006 – <http://www.neweconomics.org/publications/growth-isn%E2%80%99t-working>
99. *Growth Isn't Possible: Why We Need a New Economic Direction*, Andrew Simms, Dr Victoria Johnson and Peter Chowla, New Economics Foundation, January 2010 – <http://www.neweconomics.org/publications/growth-isnt-possible>
100. *The Impossible Hamster* (animation), New Economics Foundation, 2010 – <http://www.youtube.com/watch?v=bqz3R1NpXzM>
101. Page xiv, *Capitalism As If The World Matters*, Jonathon Porritt, Earthscan, 2005. ISBN 9781-8440-7192-0 (hardback), £35; revised paperback edition 2007, ISBN 9781-8440-7193-7, £18.99.
102. *Ecological footprint* – http://en.wikipedia.org/wiki/Ecological_footprint
103. *Tracking the ecological overshoot of the human economy*, Mathis Wackernagel, Niels B. Schulz, Diana Deumling, Alejandro Callejas Linares, Martin Jenkins, Valerie Kapos, Chad Monfreda, Jonathan Loh, Norman Myers, Richard Norgaard, and Jørgen Randers, PNAS, vol.99 no.14 pp9266-9271, 9th July 2002 – <http://www.fraw.org.uk/f.html?wackernagel2002>
104. *The Living Planet Report 2010 – Biodiversity, Biocapacity and Development*, Global Footprinting Network and Zoological Society of London for WWF International, 2010 http://assets.wwf.org.uk/downloads/wwf_lpr2010_lr_1_.pdf
105. *Thomas Malthus* – http://en.wikipedia.org/wiki/Thomas_Malthus
106. Chapter 1, *An Essay on the Principle of Population, as it Affects the Future Improvement of Society*, Thomas Malthus, 1798; a copy of the first edition is available from the Electronic Scholarly Publishing Project – <http://www.esp.org/books/malthus/population/malthus.pdf>
107. *Paul R. Ehrlich* – http://en.wikipedia.org/wiki/Paul_R._Ehrlich
108. *The Population Bomb*, Paul R. Ehrlich, Ballantine Books, 1968; now available from Buccaneer Books, 1995 re-issue edition. ISBN 9781-5684-9587-3 (hardback 'library binding'), £21.95.
109. *Malthusian catastrophe* – http://en.wikipedia.org/wiki/Malthusian_catastrophe
110. *Club of Rome* – http://en.wikipedia.org/wiki/Club_of_rome

111. *The Limits to Growth* – http://en.wikipedia.org/wiki/The_Limits_to_Growth
112. *Limits to Growth*, Donella Meadows, Dennis Meadows and Jorgen Randers, Signet, 1972. ISBN 9780-4510-9835-1 (paperback – out of print). A 28-page summary is available from the Club of Rome's web site – <http://www.clubofrome.at/archive/limits.pdf>
113. *Limits to Growth – The 30 Year Update*, Donella Meadows, Jorgen Randers and Dennis Meadows, Earthscan, 2004. ISBN 9781-8440-7144-9 (paperback), £14.99.
114. *A Comparison of the Limits to Growth with Thirty Years of Reality*, Graham Turner, SEED Working Paper 19, Commonwealth Scientific and Industrial Research Organisation (CSIRO, Australia), June 2008 – <http://www.fraw.org.uk/f.html?csiro2008>
115. Chapter 7, *On Borrowed Time? – Assessing the Threat of Mineral Depletion*, Professor John E. Tilton, RFF Press, 2003. ISBN 9781-8918-5357-9 (paperback), £14.50. For an on-line discussion of technology and resource limits, see my recent research and presentation, *The Limits to Technology* – http://www.fraw.org.uk/workshops/limits_to_technology/
116. *The 2030 Spike – Countdown to a Global Catastrophe*, Colin Mason, Earthscan, 2003. ISBN 9781-8440-7018-3 (h/back), £24.95.
117. *The Vindication of a Public Scholar – Forty Years After The Population Bomb Ignited Controversy*, Paul Ehrlich Continues to Stir Debate, Tom Turner, Earth Island Journal, Summer 2009. http://www.earthisland.org/journal/index.php/eij/article/the_vindication_of_a_public_scholar/
118. *A global energy war looms*, Jeremy Warner, Telegraph on-line, 22nd March 2011 – <http://blogs.telegraph.co.uk/finance/jeremywarner/100009856/a-global-energy-war-looms/>
119. *Global Trends 2025: A Transformed World*, US National Intelligence Council, November 2008 – http://www.dni.gov/nic/PDF_2025/2025_Global_Trends_Final_Report.pdf
120. *In this age of diamond saucers, only a recession makes sense: Economic growth is a political sedative, snuffing out protest as it drives inequality. It is time we gave it up*, George Monbiot, The Guardian, Tuesday 9th October 2007 – <http://www.guardian.co.uk/commentisfree/2007/oct/09/comment.economy>
121. Chapter 4, *One-Dimensional Man – Studies in the Ideology of Advanced Industrial Society*, Herbert Marcuse, Routledge and Kegan Paul, 1964; re-issued by Routledge Classics 2002. ISBN 9780-4152-8977-1 (paperback), £10.99.
122. *Borg* – [http://en.wikipedia.org/wiki/Borg_\(Star_Trek\)](http://en.wikipedia.org/wiki/Borg_(Star_Trek))
123. *Smoking and health proposal*, The Tobacco Institute, 1969 – <http://tobaccodocuments.org/landman/332506.html>
124. Chapter 6, *Doubt is Their Product: How industry's assault on science threatens your health*, David Michaels, OUP, 2008. ISBN 9780-1953-0067-3 (hardback). £17.99.
125. *Ecological overshoot* – [http://en.wikipedia.org/wiki/Overshoot_\(ecology\)](http://en.wikipedia.org/wiki/Overshoot_(ecology))
126. *Sustainable de-growth: Mapping the context, criticisms and future prospects of an emergent paradigm*, Joan Martínez-Alier, Unai Pascual, Franck-Dominique Vivien, Edwin Zaccai, Ecological Economics, vol.69 pp1741-1747, 2010 – <http://www.fraw.org.uk/f.html?martinezalier2010>
127. Part V. 'Little Gidding', *Four Quartets*, T.S. Eliot, 1944; published by Faber Poetry, 2001, £9.99, ISBN 9780-5710-6894-4; available on-line from <http://www.tristan.icom43.net/quartets/>
128. *Hubbert peak theory* – http://en.wikipedia.org/wiki/Hubbert_peak_theory
129. *From Society*, by Jerry Hannan – http://en.wikipedia.org/wiki/Jerry_Hannan
130. For example: *The Quaker Testimonies*, Committee of Quaker Peace & Social Witness, Quaker Books (3rd edition), 2009 – http://www.quaker.org.uk/sites/default/files/Quaker_Testimonies_leaflet.pdf
131. *Degrowth* – <http://en.wikipedia.org/wiki/Degrowth>
132. Chapters 10/11, *The Ultimate Heresy*, John Seymour, Green Books, 1989. ISBN 9781-870-098-242 (paperback – out of print)
133. *Walden* – <http://en.wikipedia.org/wiki/Walden>
134. *Diggers* – <http://en.wikipedia.org/wiki/Diggers>
135. *With eyes wide shut – Climate change threatens the future of humanity, but we refuse to respond rationally*, George Monbiot, The Guardian, Tuesday 12th August 2003 – <http://www.guardian.co.uk/environment/2003/aug/12/comment.columnists>

ecolonomics – Paul Mobbs' newsletter of thoughts, ideas and observations on energy, economics and human ecology – no.10, 22nd to 25th March 2011

<http://www.fraw.org.uk/mei/ecolonomics/> ecolonomics@fraw.org.uk

© 2011 Paul Mobbs. This document has been released under The Creative Commons Attribution Non-Commercial Share Alike License ('by-nc-sa', v. 3) For a copy of this license go to http://www.fraw.org.uk/mei/by_nc_sa-3.html. You are free to copy, extract, translate and distribute this document beyond the extent permitted by your local copyright law for non-commercial purposes, and provided that the source is acknowledged and that all derived works are also issued on this same basis.