ecolonomics[14]

*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

# 'Fracking' our food and farming system: "Extreme agriculture" and the politics of denial

*ecolonomics journal no.14*, Paul Mobbs, Mobbs' Environmental Investigations, 18th April 2014

*It might seem a bit of a jump – talking about "fracking" and food production in the same article. However, when we look at what's planned for the next phase of intensive agricultural development, what we find is the same economic and political theories at the root of the measures proposed.*

*As we approach the ecological limits to growth, and the measures to maintain "business as usual" become even more extreme, the latest technofix "solutions" to our needs have as much to do with denying the existence of those limits, as they are intended to provide more food or energy.*

*The problem with the debate over fracking is that it has become highly insular. It focusses on drilling, or pollution; and fails to make the wider connection to the issues of lifestyle and resources which – arguably – represent the deeper motivation behind the political support for extreme energy sources.*

*The same is true of the current debate over farming. We argue about one form of agriculture or another, or different consumer products; but without reference to the wider patterns of lifestyle which predetermine the form of that discussion.*

*In contrasting fracking and food, I hope to highlight – through the commonality in underlying causal factors – the wider analysis which we need to bring to the ecological debate.*

"Fracking" is a label that's become associated with highly polluting sources of oil and gas. Too often what this debate misses are the deeper political and economic imperatives behind these processes. Conventional sources of oil and gas are hitting geophysical and geopolitical bottlenecks which limit production[1]. That in turn raises energy prices, which has a deleterious effect on economic growth[2].

As a result energy companies are going to greater extremes to produce oil and gas, using options which would never have been viable ten or fifteen years ago. It's not simply because of some new, miraculous drilling technology. It's because the economics of limited oil and gas availability make these new "extreme" extraction methods[3] – irrespective of their higher carbon and pollution footprints – an acceptable option to maintain production levels.

So it is with new agricultural technologies. Changes in agricultural practice over the next decade or so have the potential to radically change the global environment[4]. This is being done in the name of "feeding a growing global population"[5]; but in reality it is all about the politics and economics of agribusiness. And – as with fracking and the climate – the diminishing returns of this new agenda will drastically change the ecological footprint[6] of agriculture[7].

Let's begin with meat production[8]. The price of meat is rising[9] – due to a greater demand for meat, and as the costs of the inputs to meat production rise. Those costs are rising because the prices of cereals and soya, increasingly consumed in meat production, have risen along with oil prices. Does that mean there is an incentive to de-intensify meat production[10] – *no, it's the exact opposite*.

Where America has led in the last two decades[11], Asia, Europe, and in particular the UK now follow. For example, in October 2013 the Welsh Government gave the go-ahead, against the decision of a

planning inspector, for a 1,000 head dairy farm at Lower Leighton[12], near Welshpool. So called "super farms"[13] benefit large agricultural interests– which why they are supported by the agribusiness industry[14] – and make life harder for smaller, less intensive farmers[15]. According to the Welsh Minister for Housing and Regeneration, the "social and environmental implications were outweighed by economic benefits"[16]. That decision has now been called-in for a judicial review brought by the World Society for the Protection of Animals[17] – the group whose previous challenge helped halt a 8,100 cow dairy in Lincolnshire in 2011[18].

What does the intensification of animal units entail? Holding more animals in a smaller space increases the economies of scale for the farmer – meaning that a greater return can be made from a the same amount of land and/or buildings[19]. That is the economic attraction. However, more animals in a fixed space means the point source of pollution generated is greater[20] – creating difficulties in disposing of the waste and handling the odour and effluent run-off[21]. The animals cannot be easily grazed, so greater inputs of compounded food are required to supplement the animals' diet, or silage and fodder crops have to be produced mechanically and transported greater distances. Holding more animals in a small space also increases the likelihood of cross infections between them – not just of pathogens which are bad for them, but also pathogens which might be relatively harmless to the animal but highly damaging to us[22].

Put simply, to improve the economic returns, both high-density animal units and extreme energy projects: intensify inputs, which necessitates a greater energy expenditure for the return; increase point sources of pollution above the capacity of the local environment to buffer it; and thus create other environmental problems compared to if the site had operated within the capacity of the local environment. That's because, if we let nature handle the externalities sustainably, we do not have to expend resources in order to deal with them.

The additional expenditure to produce the oil or gas, or food, is at the expense of lowering the overall return on the resources invested. This concept, *Energy Return on Energy Invested*[23], is at the heart of the increasing unsustainability of the human system; and from gadgets[24] to gastronomy[25], we see this same trend occurring across many different industries as they try and fight the limits to their continued growth.

Next, what about genetic modification? The development of "Round-up ready" crops has allowed farmers to eliminate all competing weeds by spraying crops with herbicides which the plants themselves are immune to. The problem is that nature isn't stupid, and readily adapts to such changes in ecological diversity[26]. In the regions where GM crops are widely used the weeds are becoming resistant to the herbicide. So, does the industry adapt cultivation practices to manage weeds? – *no, it's shifting to even more toxic compounds to kill the weeds*.

More studies are finding that *Round-up* is toxic[27] – not simply the active ingredient glyphosate[28], it's all the other chemicals which are packed with the product to enable its use[29]. And research suggests that these toxins build-up in the crop[30]. To combat superweeds both Monsanto and Dow are re-engineering their corn and soya crops, and what they propose to replace Round-up with is even more toxic – 2,4-dichlorophenoxyacetic acid[31], or "2,4-D"[32]. Due to its long history of use there's a lot of information about 2,4-D, but it's impacts on the environment, especially soil bacteria and fungi, are still not fully understood[33].

Another example of the ideas which fail to grasp the restrictions of ecological limits are the recent proposals for "vertical greenhouses"[34] – city centre tower blocks which are constructed as multi-story greenhouses[35]. There are two basic issues here:

Firstly, cost. The cost of land in the city centre compared to rural horticultural land can be twenty or forty times more. Meaning that to have parity on land values you need a twenty or forty floor tower block to have an equal land value. Even then, there is a far higher infrastructure cost due to the additional engineering it takes to build a structure of that size. Of course, you could have 'mixed use' developments – taking a standard tower block and having just one or two floors as greenhouses. The difficulty there is that the earnings from commercial or residential letting are still likely to provide a more lucrative return for the floor space than growing food[36].

Secondly, and arguably more importantly, chances are that the "energy return" figures will be far less favourable for a multi-story greenhouse compared to a rural one. Water, workers and materials have to be hauled up the building – most likely lifted/pumped using electricity. Waste has to have space to be composted. And all those climate control and ventilation systems demand yet more power. All this does is add more complexity to the food system rather than making it more streamlined and resource efficient[37].

Underlying many of the proposed "solutions" to our present ecological difficulties – such as vertical farming, or fracking – is a basic misunderstanding about the thermodynamics of life. In the 19th Century, the physicist Ludwig Boltzmann[38] looked at the properties of matter, and realised that a simple definition of life – irrespective of its form – must be that it constituted an assemblage of molecules which defied the expected pattern under the *Second Law of Thermodynamics*[39]. Life concentrates energy against the background trend of entropy, organising inert molecules into a non-inert structure. This idea was later followed-up by Erwin Schrödinger[40], who

coined the term "negative entropy"[41] to describe how life functions within thermodynamic principles.

Cities are assemblages of energy and resources which stand against thermodynamic entropy – and they can only exist because of the large and consistent supplies of energy which supply their operation. Take that supply away, and their emergent complex patterns[42] begin to fail – falling back towards their natural entropic ground state. At present it is not only the scale of our future energy resources which is in doubt. Their high reliability is also in doubt as society struggles to reconcile the effects of scarce and expensive energy on economic growth, which limits infrastructure investment. This isn't an abstract issue; it's already a reality in the near future due to current uncertainties about future investment[43].

Therefore, in a age of tightening ecological limits, we have to question the current form and structure of cities, and urban areas in general – focussing on how we meet the needs of people[44], rather than requiring predetermined expectations to be met regarding social or economic organisation. As "resource islands"[45], cities demand a concentration of resources and energy which might not be possible in the future. They are in a highly tenuous position if those supply chains fail[46]. Unless the community moves to a location where it is possible to find energy via other mechanisms (e.g. tidal or hydro power), they have no future in their current form.

There is a belief that cities are somehow "innately green" because of their density of resource use[47]. What this concept entails is that cities are the most efficient mode if – *and the proviso here is this self-referential "if"* – you compare someone living an affluent lifestyle in an urban versus a rural location. Living a simple, non-consumer lifestyle is not an option under this assessment; even though it is the high-resource lifestyle which is in doubt due to ecological limits, irrespective of *where* it takes place.

Arguably neither fracking, nor intensive agricultural production can sustain that lifestyle. Limits on essential energy and technology minerals, and their importance to the economic processes which support urbanism, make the affluent lifestyle[48] unsustainable – not just limits to gas or food supplies.

It's this failure to consider all environmental limits, and focus on a single variable of sustainability – *climate change* – which is driving the environment movement in to questionable campaigns. Climate change is important, but soon we'll run out certain minerals essential to our technological society[49]. For example, hafnium, neodymium, indium or gallium – which are instrumental to creating "green" energy devices, such as wind turbines or solar photovoltaic panels, which alternative "green" models of urban living (including vertical farming) rely upon.

In his recent book, *A Rough Ride to the Future*[50], James Lovelock proposes a kind of ecological "Pascal's Wager"[51]. He contrasts our future choices as (to paraphrase): a life of hard work living in rural areas supporting yourself; or a more comfortable lifestyle living in a purpose designed ecocity[52]. And, as he points out, even if climate change doesn't happen this is a good idea to carry out in any case, because it would make society more efficient.

Of course, like *Pascal's Wager*, this is a logical fallacy[53]. Due to his one-dimensional focus on climate, he ignores other ecological limits which prevent such a transformation. It's not just that the economics are difficult. Like those super farms, any city, because it concentrates human demands for water, food, energy and resources into a small space, cannot supply itself from it's geographical footprint.

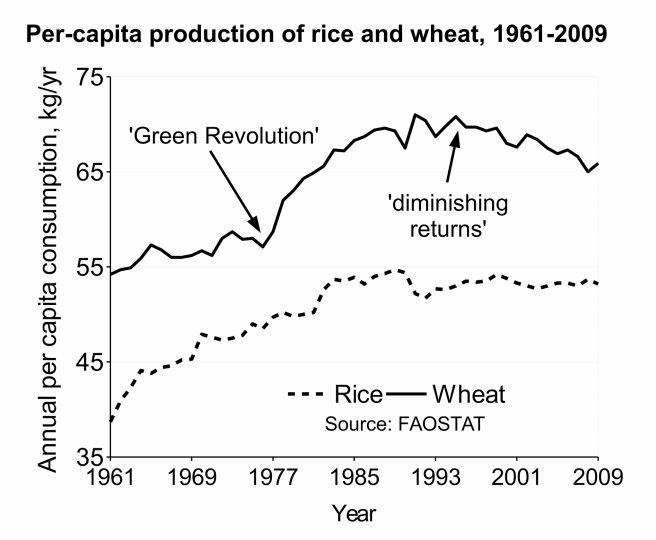
Yes, you can recycle, or have green energy technologies, but that also requires energy and rare mineral resources. Thermodynamics dictates that recycling can never be 100% efficient, and it will always need a proportionately greater energy supply the more efficient that process becomes. Thus even a compact ecocity still exists out of balance with the ecological limits of the local environment.

Lovelock's argument is an appeal to the "comforts" of present lifestyles – rather than a rational assessment of what is necessary within a world constrained by ecological limits[54]. If a low impact existence requires more work, it is precisely because that labour is not being supplied by virtual "energy slaves"[55], as it is in the city. But the inherent efficiency of living simply under your own shared energies, rather than relying on external resources to supply those needs, is what differentiates the sustainability[56] of the low impact rural versus the compact city mode of living.

You can maintain fallacies about the efficiency of cities when the *only issue* you consider is climate change. That is also the political attraction of the climate issue over the broader "limits to growth" argument. Once you accept that ecological limits are multivariate, and dynamic, then you can appreciate the complexity of our predicament[57]. But then status quo preserving solutions are no longer tenable.

The reality is that, in terms of the human system, we're reaching the limits of the Earth's biosphere – as predicted by the "limits to growth" report of the 1970s, reconfirmed by recent research[58]. And as we push those ecological limits, we have to use more resources to achieve less. In the end, as in the economic theory of "diminishing returns", trying to grow further results in a far worse outcome.

The best agricultural example of this is cereals production. Back in 1968, Paul R. Ehrlich predicted a crash in the human system in his book, *The Population Bomb*[59]. It didn't materialise. What happened instead was the "Green Revolution"[60]. New crops were introduced, but more importantly the amounts of artificial fertiliser and fossil fuel energy inputs to agriculture radically changed. The extra production averted human ecocatastrophe, at the cost of a catastrophe for rest of the natural world[61].




The graph above is compiled from the UN Food and Agriculture Organisation's statistical database – *FAOSTAT*[62]. It shows the annual global per-capita production of the two main food staples, rice and wheat. You can see how from the mid-1970s global production suddenly jumped. In part, that's why the price of commodities fell over this period. Greater mechanisation, better transport, processing technology and increased productivity also had a role. That also drove up the energy demands, especially oil and gas, of agriculture. But what's less well known is that density of micronutrients[63] in many food crops, essential to the maintenance of our health, has diminished as a result of increased yields[64]. Current health issues are not simply due to a worse diet of processed foods – *the quality of intensively produced crops has fallen too*[65]. Again, this has parallels with extreme energy sources – where often the products produced are of a lower quality, or have a lower energy density, than the conventional fuels used over the past century.

Now we're in a different era. As population growth catches up, in part fuelled by this new supply of food, the gains of those twenty years have disappeared[66]. As a result food prices are rising once more[67]. It's not just that the 'diminishing returns' of the Green Revolution have taken hold[68]. The intensification of agriculture – with all that mechanised equipment and artificial inputs[69] – has begun to degrade the land which, along with climate change, is lowering yields[70].

And the idea that genetic engineering will feed the world? – that's a marketing myth. Increasing the *yield* of crops requires changes to complex networks of multiple genes, which is beyond our technical capability[71]. To date, most genetic engineering has been centred on small changes, to simple gene sequences, in order to confer an economic monopoly over the exploitation of the new crop[72].

More importantly, the Green Revolution required a large increase in artificial inputs and oil-fuelled machines. We're now at the peak of oil production, which is why oil prices stubbornly refuse to fall[73]. But perhaps the greater difficulty is the supply of phosphorus[74]. Unlike nitrogen, which, providing you have the energy to do so, can be pulled from the air; phosphorus must be mined from phosphate rock deposits – *and those deposits are running out*[75]. Without sufficient phosphorus, even if we have the oil for the machines, we can't maintain current levels of production using intensive methods.

There are solutions to our ecological woes – based first and foremost on the security and sustainability of our food. You can have all the wind turbines and eco-products that you desire; but without a sustainable food system, all those “green gadgets” make very little difference to a sustainable lifestyle. It's not just that food is essential. When we look at the lifestyle of people in the developed world, *food is the biggest part* of their ecological footprint[76].

Perhaps one of the most comprehensive studies to date was the *International Assessment of Agricultural Knowledge, Science and Technology for Development*[77]. What this report said was that addressing poverty[78], development[79], food supply[80] and quality of life[81] are all inextricably linked. That means the solutions are not about economic growth[82], or genetic engineering[83], or chemical inputs[84] – it's all about people, and people finding their own local solutions to the related issues of food, lifestyles and the environment[85].

*We know what the solutions are!* They're out there, being practised today[86], but only in small and obscure parts of the economy. The reasons they are not being adopted globally is not technical, or scientific. It's because they do not suit the purposes of a small group of people for whom economics has become a secular religion – and to whom the abstract values of wealth and power mean more than life[87].

Extreme energy and “fracking” is an ecologically heinous act; but the philosophy which underpins its adoption is the same as that which is driving agriculture towards an ecological precipice too. Imminent changes in agricultural practices – from self-driving robotic tractors to technologically controlled multi-story urban greenhouses – will have as bad if not worse impact upon the global environment as those extreme energy technologies. And to change that outcome we have to have a movement for change. Not to blockade the fields or the laboratories – we have to stop the ecocidal[88] economic fundamentalists whose abstract theories are forcing the planet into ecological collapse.

What that involves the “politics of your mouth”. Not just the stuff that you put into it. What's even more important are the words that come out of it – and how you direct them to the politicians who believe economics can solve everything, and who deny that there are physical limits to anything. Our future relies upon us each accepting, and adapting to the ecological limits which are already shaping our lives today.

## References


1. *Revisiting the Limits to Growth After Peak Oil*, Charles A.S. Hall, John W. Day, American Scientist, vol.97, May 2009 – http://www.fraw.org.uk/files/peakoil/hall_2009.pdf
2. *Economic vulnerability to Peak Oil*, Christian Kerschner et. al., Global Environmental Change, 13th October 2013 – http://www.fraw.org.uk/files/peakoil/kerschner_2013.pdf
3. For explanations/examples go to The Extreme Energy Initiative – http://extremeenergy.org/
4. *Global food demand and the sustainable intensification of agriculture*, David Tilman et. al., PNAS, vol.108 no.50 pp.20260-20264, 13th December 2011 – http://www.pnas.org/content/108/50/20260.full.pdf+html
5. *How to Feed the World in 2050*, High Level Expert Forum, UN Food and Agriculture Organisation, 2009 – http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf
6. *Tracking the ecological overshoot of the human economy*, Mathis Wackernagel et. al., PNAS, vol.99 no.14 pp.9266-9271, 9th July 2002 – http://www.fraw.org.uk/files/limits/wackernagel_2002.pdf
7. *Achieving food security in the face of climate change*, Commission on Sustainable Agriculture and Climate Change, November 2011 – http://www.fraw.org.uk/files/food/cgiar_2011.pdf
8. *Livestock production: recent trends, future prospects*, Philip K. Thornton, Philosophical Transactions of the Royal Society B, vol.365 no.1554 pp.2853-2867, 27th September 2010 – http://rstb.royalsocietypublishing.org/content/365/1554/2853.full.pdf+html
9. *World agriculture: Towards 2015/2030 – Summary report*, UN FAO, 2002 – ftp://ftp.fao.org/docrep/fao/004/y3557e/y3557e.pdf
   *Agricultural Outlook 2010-2019: Highlights*, OECD-FAO, June 2010 – http://www.fraw.org.uk/files/food/fao_outlook_2010.pdf
10. *Livestock's Long Shadow: Environmental Issues And Options*, United Nations Food and Agriculture Organisation, November 2006 – http://www.fraw.org.uk/files/food/unfao_lls_2006.pdf
11. *Food Safety Consequences of Factory Farms*, Food and Water Watch, March 2007 – http://documents.foodandwaterwatch.org/doc/FoodSafetyFactoryFarms.pdf
12. For more information see the local campaign blog – http://www.support-calfe.org.uk/
13. Wikipedia: 'Intensive farming' – http://en.wikipedia.org/wiki/Intensive_farming
14. *Super farms are needed in UK, says leader of National Farmers Union*, Juliette Jowit, The Guardian, 5th June 2012 – http://www.theguardian.com/environment/2012/jun/05/uk-needs-super-farms-says-nfu
15. *Smallholders, food security, and the environment*, United Nations Environment Programme (UNEP) and International Fund for Agricultural Development (IFAD), 2013 – http://www.unep.org/pdf/SmallholderReport_WEB.pdf
16. *Powys mega-dairy gets go-ahead despite concerns of local villagers*, Sion Morgan, Wales On-line, 31st October 2013 – http://www.walesonline.co.uk/news/wales-news/powys-mega-dairy-gets-go-ahead-despite-6259368
17. *Powys 'mega dairy' plan put on hold by judicial review*, BBC News, 28th January 2014 – http://www.bbc.co.uk/news/uk-wales-mid-wales-25932225
18. *Stopping the 'super dairy' – the inside story*, Johann Tasker, Farmer's Weekly, 24th February 2011 – http://www.fwi.co.uk/articles/24/02/2011/125674/stopping-the-39super-dairy39-the-inside-story.htm
19. *Livestock Super Farms*, POST Note No.404, Parliamentary Office of Science and Technology, March 2012 – http://www.parliament.uk/briefing-papers/POST-PN-404.pdf
20. *Factory farming's hidden impacts*, Friends of the Earth, October 2010 – http://www.foe.co.uk/sites/default/files/downloads/factory_farming.pdf
21. *Pollution from Giant Livestock Farms Threatens Public Health*, Natural Resources Defense Council (undated) – http://www.nrdc.org/water/pollution/nspills.asp
22. *Hogging It!: Estimates of Antimicrobial Abuse in Livestock*, Union of Concerned Scientists, 2001 – http://www.ucsusa.org/food_and_agriculture/our-failing-food-system/industrial-agriculture/hogging-it-estimates-of.html
23. *Energy Return On Investment*, Charles A. S. Hall, Post Carbon Institute, 2012 – http://www.fraw.org.uk/files/energy/hall_2012.pdf
24. *The elephant in the living room: How our appliances and gadgets are trampling the green dream*, Energy Saving Trust, September 2011 – http://www.fraw.org.uk/files/tech/est_2011.pdf
25. *Food production, crops and sustainability: restoring confidence in science and technology*, Huub Spiertz, Current Opinion in Environmental Sustainability, vol.2 no.5/6 pp.439-443, December 2010 – http://www.fraw.org.uk/files/food/spiertz_2010.pdf
26. *The Rise of Superweeds – and What to Do About It*, Union of Concerned Scientists, December 2013 – http://www.ucsusa.org/assets/documents/food_and_agriculture/rise-of-superweeds.pdf
27. *Teratogenic Effects of Glyphosate-Based Herbicides: Divergence of Regulatory Decisions from Scientific Evidence*, M. Antoniou et. al., Environmental and Analytical Toxicology, S4:006, 23rd June 2012 – http://www.fraw.org.uk/files/toxics/antoniou_2012.pdf
28. Wikipedia: 'Glyphosate' – http://en.wikipedia.org/wiki/Glyphosate
29. *Roundup Linked to Global Boom in Celiac Disease and Gluten Intolerance*, Sustainable Pulse, 19th February 2014 – http://sustainablepulse.com/2014/02/19/roundup-linked-global-boom-celiac-disease-gluten-intolerance/
30. *Compositional differences in soybeans on the market: Glyphosate accumulates in Roundup Ready GM soybeans*, T. Bøhn et. al., Food Chemistry, vol.153 pp.207-215, 15th June 2014 – http://www.sciencedirect.com/science/article/pii/S0308814613019201
31. Wikipedia: '2,4-Dichlorophenoxyacetic acid' – http://en.wikipedia.org/wiki/2,4-Dichlorophenoxyacetic_acid

32. *Going Backwards: Dow's 2,4-D-Resistant Crops and a More Toxic Future*, Bill Freese, CFS, Food Safety Review, Fall 2012 – http://www.centerforfoodsafety.org/files/fsr_24-d.pdf
33. *The risks of the herbicide 2,4-D*, Lars Neumeister , Pesticides Action Network, January 2014 – http://www.genewatch.org/uploads/f03c6d66a9b354535738483c1c3d49e4/Risks_of_herbicide_2_4_D.pdf
34. The Vertical Farm Project – http://www.verticalfarm.com/
35. Wikipedia: 'Vertical farming' – http://en.wikipedia.org/wiki/Vertical_farming
36. *Vertical farming: Does it really stack up?*, The Economist, 9th December 2010 – http://www.economist.com/node/17647627
37. *The Vertical Farming Scam: Wrong on So Many Levels*, Stan Cox, Counterpunch, 11th December 2012 – http://www.counterpunch.org/2012/12/11/the-vertical-farming-scam/
38. Wikipedia: 'Ludvig Boltzmann' – http://en.wikipedia.org/wiki/Ludwig_Boltzmann
39. Wikipedia: 'Second Law of Thermodynamics' – http://en.wikipedia.org/wiki/Second_law_of_thermodynamics
40. Wikipedia: 'Erwin Schrödinger' – http://en.wikipedia.org/wiki/Erwin_Schr%C3%B6dinger
41. Wikipedia: 'Negentropy' – http://en.wikipedia.org/wiki/Negentropy
42. Wikipedia: 'Complex system' – http://en.wikipedia.org/wiki/Complex_system
43. *British power supply faces close-run thing in 2015*, John Kemp, Reuters, 28th June 2013 – http://uk.reuters.com/article/2013/06/28/column-kemp-britain-blackouts-idUKL5N0F42P120130628
44. *The Great Balancing Act*, Tim Searchinger et. al., World Resources Institute, May 2013 – http://www.fraw.org.uk/files/food/wri_i1_2013.pdf
45. *The Trigger Effect* (series 1, episode 1), *James Burke's Connections*, BBC TV, 1978. Available on-line – http://www.youtube.com/watch?v=hN7Z95cqZx0
46. *Yesterday, Tomorrow and You* (series 1, episode 10), *James Burke's Connections*, BBC TV, 1978. Available on-line – http://www.youtube.com/watch?v=Z0Y5nMlY_Q8
47. *Cities For A Small Planet*, Richard Rogers, Reith Lecture, BBC Radio 4, 12th March 1995 – http://www.bbc.co.uk/programmes/p00gxns8
48. *The grand challenge of the energy transition*, Ugo Bardi, Frontiers in Energy Research, vol.1 art.2, 29th August 2013 – http://www.fraw.org.uk/files/energy/bardi_2013.pdf
49. *Critical Metals in Strategic Energy Technologies: Assessing Rare Metals as Supply-Chain Bottlenecks in Low-Carbon Energy Technologies*, R.L. Moss et. al., EC Joint Research Centre, November 2011 – http://www.fraw.org.uk/files/limits/ec_jrc_metals_2011.pdf
50. Chapter 7, *A Rough Ride To The Future*, James Lovelock, Penguin Books, April 2014. ISBN 9780 2410 0476 0. £16.99. Available on-line at – http://www.hive.co.uk/book/a-rough-ride-to-the-future/18374272/
51. Wikipedia: 'Pascal's Wager' – http://en.wikipedia.org/wiki/Pascal%27s_Wager
52. Wikipedia: 'Ecocity' – http://en.wikipedia.org/wiki/Eco-cities
53. Wikipedia: 'False dilemma' – http://en.wikipedia.org/wiki/False_dilemma
54. *Can a collapse of global civilization be avoided?*, Paul R. Ehrlich, Anne H. Ehrlich, Proceedings of the Royal Society B, vol.280 no.1754, 7th March 2013 – http://www.fraw.org.uk/files/limits/ehrlich_2013.pdf
55. Wikipedia: 'Energy slave' – http://en.wikipedia.org/wiki/Energy_Slave
56. *Peak Oil, Energy Descent, and the Fate of Consumerism*, Samuel Alexander, University of Melbourne,15th January 2012 – http://www.fraw.org.uk/files/peakoil/alexander_peak_2012.pdf
57. *Entropic Disorder: New Frontiers In Environmental Sociology*, Laura A. McKinney, Sociological Perspectives, vol.55 no.2 pp.295-317, 2012 – http://www.fraw.org.uk/files/limits/mckinney_2012.pdf
58. *A Comparison Of The Limits To Growth With Thirty Years Of Reality*, Graham Turner, CSIRO, June 2008 – http://www.fraw.org.uk/files/limits/csiro_2008.pdf
59. Wikipedia: 'The Population Bomb' – http://en.wikipedia.org/wiki/The_Population_Bomb
60. Wikipedia: 'Green Revolution' – http://en.wikipedia.org/wiki/Green_Revolution
61. *Planet Under Pressure*, UNCED, March 2012:
    - *State of the Planet Declaration* – http://www.fraw.org.uk/files/limits/pup_sotpd_2012.pdf
    - Rio+20 video: *We have entered the Anthropocence* –
        - http://www.fraw.org.uk/files/limits/pup_wtta_2012.ogv
        - http://www.fraw.org.uk/files/limits/pup_wtta_2012.mp4
62. FAOSTAT – http://faostat.fao.org/
63. Wikipedia: 'Micronutrient' – http://en.wikipedia.org/wiki/Micronutrient
64. *Still No Free Lunch: Nutrient levels in U.S. food supply eroded by pursuit of high yields*, Brian Halweil, The Organic Center, September 2007 – http://www.fraw.org.uk/files/food/organic_center_2009.pdf
65. *Nutritional Quality of Organic Versus Conventional Fruits, Vegetables, and Grains*, Virginia Worthington, The Journal Of Alternative And Complementary Medicine, vol.7 no.2 pp.161-173, 2001 – http://www.fraw.org.uk/files/food/worthington_2001.pdf
66. *Population: One Planet, Too Many People?*, Institution of Mechanical Engineers, January 2011 – http://www.fraw.org.uk/files/limits/imeche_2011.pdf
67. *The State of Food Insecurity in the World: How does international price volatility affect domestic economies and food security?*, Food and Agriculture Organization of the United Nations, 2011 – http://www.fraw.org.uk/files/food/fao_food_2011.pdf
68. *An Edible Energy Return on Investment (EEROI) Analysis of Wheat and Rice in Pakistan*, Ali S. Pracha, Timothy A. Volk, Sustainability, vol.3 pp.2358-2391, 8th December 2011 – http://www.fraw.org.uk/files/energy/pracha_wolk_2011.pdf
69. *The Energy Cost of Food*, Eric Garza, Aisthetica, 20th July 2013 – http://www.fraw.org.uk/files/food/garza_2013.pdf

70. *Assessing Global Land Use: Balancing Consumption With Sustainable Supply*, International Resource Panel, Working Group on Land and Soils, United Nations Environment Programme, January 2014 – http://www.fraw.org.uk/files/food/unep_land_2014.pdf

71. *Failure to Yield: Evaluating the Performance of Genetically Engineered Crops*, Union of Concerned Scientists, April 2009 – http://www.fraw.org.uk/files/food/ucs_fty_2009.pdf
*Failure to Yield: Biotechnology's Broken Promises – Briefing*, Union of Concerned Scientists, July 2009 – http://www.fraw.org.uk/files/food/ucs_fty_brief_2009.pdf

72. *Genetically Engineered Food: An Overview*, Food and Water Watch, January 2014 – http://documents.foodandwaterwatch.org/doc/Genetically_Engineered_Food_2014.pdf

73. *Oil's Tipping Point has Passed*, James Murray, David King, Nature, vol.481 pp.433-435, 26th January 2012 – http://www.fraw.org.uk/files/peakoil/murray_king_2012.pdf

74. *The Disappearing Nutrient*, Natasha Gilbert, Nature, vol.461 pp.716-718, 8th October 2009 – http://www.fraw.org.uk/files/limits/gilbert_2009.pdf

75. *Projections of Future Phosphorus Production*, Steve Mohr, Geoffrey Evans, Philica, no.380, September 2013 – http://www.fraw.org.uk/files/limits/mohr_evans-2013.pdf

76. *Environmental Load from Dutch Private Consumption: How Much Damage Takes Place Abroad?*, Durk S. Nijdam et. al., Journal of Industrial Ecology, vol.9 no.1/2 pp.147-168, January 2005 – http://www.fraw.org.uk/files/food/nijdam_2005.pdf

77. *Agriculture at a Crossroads*, International Assessment of Agricultural Knowledge, Science and Technology for Development, April 2009:
   - *Executive Summary of the Synthesis Report* – http://www.fraw.org.uk/files/food/iaastd_syns_2009.pdf
   - *Synthesis Report* – http://www.fraw.org.uk/files/food/iaastd_syn_2009.pdf

78. *Agriculture at a Crossroads: Food Security in a Volatile World*, IAASTD Fact Sheet, April 2009 – http://www.fraw.org.uk/files/food/iaastd_2009-3.pdf

79. *Agriculture at a Crossroads: Feeding the World, Greening the Planet*, IAASTD Fact Sheet, April 2009 – http://www.fraw.org.uk/files/food/iaastd_2009-8.pdf

80. *Agriculture at a Crossroads: Human Health and Nutrition*, ISSATD Fact Sheet, April 2009 – http://www.fraw.org.uk/files/food/iaastd_2009-4.pdf

81. *Agriculture at a Crossroads: Towards Multifunctional Agriculture for Social, Environmental and Economic Sustainability*, IAASTD Fact Sheet, April 2009 – http://www.fraw.org.uk/files/food/iaastd_2009-6.pdf

82. *Growth isn't possible: Why we need a new economic direction*, Andrew Simms, Victoria Johnson, New Economics Foundation, January 2010 – http://www.fraw.org.uk/files/limits/nef_growth_2010.pdf

83. *The Lazy Man of Europe: Wake up to what Europe can teach the UK about backing organic food and farming*, Soil Association, February 2011 – http://www.fraw.org.uk/files/food/soil_association_2011.pdf

84. *The Farming Systems Trial*, Rodale Institute, September 2011 – http://www.fraw.org.uk/files/food/rodale_2011.pdf

85. *Feeding people is easy: But we have to re-think the world from first principles*, Colin Tudge, Public Health Nutrition, vol.8 no.6A, pp.716-723, September 2005 – http://www.fraw.org.uk/files/food/tudge_2005.pdf

86. *The Power of Community*, Faith Morgan, The Community Solution, 2006. Available to view on-line at – http://www.youtube.com/watch?v=UUWces5TkCA

87. Universal Declaration Of The Rights Of Mother Earth, World People's Conference on Climate Change and the Rights of Mother Earth, 22nd April 2010 – http://www.fraw.org.uk/files/direct_action/udrmw_2010.pdf

88. Wikipedia: 'Ecocide' – http://en.wikipedia.org/wiki/Ecocide

**ecolonomics – *Paul Mobbs' newsletter of thoughts, ideas and observations on energy, economics and human ecology* – no.14, 18th April 2014**

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