The Many Dimensions of Energy

A Green House Gas by

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August 2024

1. Introduction:

Many people recognise anthropogenic global warming (AGW) to be one of most urgent and demanding issues ever faced by humanity. To some it is but one of several examples of human activities exceeding safe environmental planetary limits[1] while also reflecting deep-seated social and economic issues. To others it is a temporary, albeit pervasive, mishap which can be technologically corrected.

Most governments, across the political spectrum, are of the second persuasion. They seek to resolve the continuing need for cheap and convenient energy by a mixture of low carbon energy from renewable sources. Significant contributions from forms of nuclear power and possibly novel sources, such as geological hydrogen, are widely anticipated. Most also assume a recourse to carbon capture and storage (CCS) and, possibly, planetary geo-engineering to allow continuing fossil fuel use, to maintain an adequate food chain and, *in extremis,* to lower atmospheric CO_2 levels.

The fundamental policy presumption is the continuation of the current socio-economic model, based on continuous material growth with concomitant and increasing demands for energy and other planetary resources. This approach is embedded in the UNCOP process and, to an extent, in the IPCC deliberations.

The market-liberal paradigm and its statist variants are not challenged. Growth, as measured by GDP and other cognates, is deemed essential to meet civic expectations and mitigate many of humanity's problems including poverty. Continuing consumer growth is deemed to be politically inescapable. New game-changing technologies are anticipated to emerge which will increase human resilience to inevitable climate change.

The slow rate of emissions decline is recognised to be incompatible with the COP 21 Paris ambition [~ +1.5°C] and likely to result in mean global atmospheric temperature increases in excess of 2°C. The record atmospheric and oceanic heating in 2023 and atmospheric CO_2, CH_4 and N_2O levels in 2024 could and should be a wakeup call. Nevertheless the growth scenario is the preferred option as it allows, at least hypothetically, the perpetuation of the current geopolitical and personal power structures and the socio-economic model of human beings as 'possessive individuals' and representatives of the *Homo economicus* construct.

[1] Katherine Richardson et al. (2023) 'Earth beyond six of nine planetary boundaries'. *Science Advances* 9. 37. https://www.science.org/doi/10.1126/sciadv.adh2458

A number of commentators, including heterodox economists, are challenging this view and the feasibility of indefinite GDP growth.[2] [3] Variously, green growth, doughnut economics, eco-socialism and, more radically, no and de-growth are being advocated. Some authors, reviving the earlier insights of Bob Ayres and others,[4] place energy supply at the core of their analyses and recognise that economic growth, as currently practiced, is a function of energy and its exploitation and that such growth cannot continue indefinitely.

Here I am advancing another, arguably more fundamental, set of propositions about the relationship of humanity's current dilemma to energy use, work and power.

A wealth of evidence from a range of disciplines underscores the central role of 'energy' not only narrowly in the market economy but to all aspects of life. I will argue that many of the problems of 'advanced' societies, such as our own, arise from their dependence on an accelerating exploitation of energy *per se* **irrespective of its source** and on ever-more rapidly evolving technologies. Some of these, such as computing and its infra-structure, incur a heavy energy demand. The consequential problems, indeed these addictions, are manifested not only in growing complexity. And in an accelerating rate of change. In economic inequality, in 'silo' effects, in social divisions and alienation and in a mounting ambivalence towards our inherited democratic institutions.

In this essay I locate AGW at the apex of the millennial history of planetary energy exploitation and in doing so, challenge the conventional wisdom alluded to above. I assert that energy, more properly 'free energy transformations', lie at the heart of both evolutionary history and modern human society, including, of course, our civilizations, our great cities and our global economy. Further, humanity's problems cannot be understood or mitigated without an appreciation of the fundamental relationships between energy transformations, work, power and complexity in both the biological and human spheres.

I will first outline briefly the background in the physical, biological and behavioural sciences, expanding on the analysis in my book "Energy The Great Driver" [5] before turning to the impacts of energy-driven power and complexity on human wellbeing and culture, in general, and AGW, in particular.

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[2] Dieter Helm. (2024) *Legacy: How to build the Sustainable Economy* CUP

[3] Peter A Victor. (2023) *Escape from Overshoot: Economics for a Planet in Peril*. New Society Pub.

[4] Robert Ayres. (1988) 'Self organisation in biology and economics' https://pure.iiasa.ac.at/id/eprint/3068/1/RR-88-001.pdf

[5] R Gareth Wyn Jones. (2019) *Energy The Great Driver: Seven Revolutions and the Challenges of Climate Change*. UoWP.

2. The Basic Conjectures:

Well over a century ago the Nobel Laureate, Wilhelm Ostwald, recognised the centrality of 'energy' to life and all activity.[6] *This crucial* insight is perhaps best summarised in a quote from the respected physicist and author Vaclav Smil:

> *"All natural processes and all human actions are, in the most fundamental physical sense, transformations of energy. Civilization's advances can be seen as a quest for the higher energy use required to produce increased food harvests, to mobilise a greater output and variety of materials, to produce more, and more diverse goods, to enable higher mobility, and to create access to virtually unlimited amounts of information".*[7]

Smil focusses on the human condition but this observation has much wider applicability. *Over planetary history,* additional exploitable sources of free energy and/or novel ways of coupling energy to work have allowed more and more work to be carried out per unit time. In terms of physics, they have generated more **power.** Each transaction, however, leads to a decrease in the available 'useful' free energy and releases a small quantity of 'unusable', low-grade, entropic [heat] energy. These processes result in a gradual increase in the universal disorder and, ultimately, the 'heat death of the Universe".

However, in systems far from equilibrium, free energy transactions may lead, **spontaneously**, to the emergence of self-organised, increasingly complex, ordered but unstable [dissipative] structures – be they biological, social or material - with increased embodied energy and information.[8] Such ordered structures, islands of dynamic order, depend on continuous and steady energy fluxes for their stability. Otherwise they are intrinsically unstable (viz. hurricanes).

These observations do not violate the underlying long-term thermodynamic trend towards gradually increasing entropy and disorder. Critically the longer-term stability and sustainability of ordered structures, such as cells and cities, depend on the parallel emergence of stabilising, regulatory/homeostatic mechanisms, which must include energy management and storage.

In 'Energy The Great Driver' I suggested that, over the eons of time, a series of energy-dependent step-changes in the evolution of biological and human social and material complexity can be recognised. These are noted below. In their work

[6] Wilhelm Ostwald. (1912) *Der energetische Imperativ*. Leipzig Academische Verlagsgesseiahaft. https://archive.org/details/derenergetische00ostwgoog

[7] Vaclav Smil. (2017) *Energy and Civilization: A History*. MIT Press.

[8] Ilya Prigogine. (1972) *La thermodynamique de la Vie. La recherché*. Also: https://www.nobelprize.org/nobel_prizes/chemistry/laureates/1977/prigogine-lecture.pdf

Robert Ayres, Eric Chaisson[9], Tim Lenton and Andrew Watson[10] and Olivia Judson [11]make similar but not identical proposals. Yadvinder Malhi[12] discusses the last three of the step changes in terms of major changes in planetary biological and socio-metabolism. Since he defines this metabolism as the energy exchange between an organism and, including in humans all their resource demands, and their environment, 'metabolism' is identical to 'free energy transformations' in my usage.

1. Evolution of first living cell	(~3.8 billion years ago)
2. Solar energy capture and oxygenic photosynthesis.	(~2.7 billion years)
3. An energy revolution with appearance of the first eukaryotic cell.	(~2-1.7 billion years ago)
4. Energy expended on brain development, hominid intelligence and communication skills.	(~1.8 million year ago)
5. The agricultural revolutions with improved solar energy capture by humans and more dense and permanent settlements.	(~8-10 thousand years ago)
6. Industrial revolution based on fossil fuel exploitation.	(~250 years ago)
7. Energy sources allowing the discarding of fossil fuels.	(current/next 10/20 years)
8. (Tentatively) New coupling of energy to work through Artificial Intelligence (AI)	

Space does not permit a discussion of the individual revolutionary step-changes or the myriad of smaller and additional energy step-changes that can be identified. Sufficient to note that, after the second revolution, thermonuclear reactions in the Sun and the capture of incident solar radiation by photosynthesis has become the common source of the free energy transactions sustaining virtually all organisms on Earth including us. In thermodynamic terms, the Earth became an open system.

Prior to step change 2, Earth was, for hundreds of thousands of years, an energetically-closed system. The earliest living cells derived their energy, chemotrophically, from planetary geochemical sources. Such life forms persist to this day in some lightless mines and caves.

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[9] Eric Chaisson (2001) *Cosmic Evolution: the rise of complexity in nature*. HUP. also https://lweb.cfa.harvard.edu/~ejchaisson/reprints/nasa_cosmos_and_culture.pdf

[10] John Lenton and Andrew Watson. (2011) *Revolutions that made the Earth*. OUP, Oxford

[11] Olivia Judson. (2017) 'The energy expansions of evolution'. *Nature Ecology and Evolution* https://www.nature.com/articles/s41559-017-0138

[12] Yadvinder Malhi (2013) 'The Metabolism of a Human-dominated Earth', pp. 142-163. in *Is the Planet Full?* Ed. Ian Goldin. OUP

Although the revolutions, listed above, differ in important ways, they also reveal consistent patterns of change as I explore below. I would argue, however, that the current, conflicted 7th revolution, is unique. It has arisen, not because of accessing a new source or a novel coupling of energy to work, but from our human realisation of a serious and growing risk - AGW. It seeks to replace one free energy source (fossil fuels) with others.

Nevertheless the techno-optimists and, to a significant extent the political mainstream, hope and expect further large rises in global energy availability and use. In this reading this revolution can be viewed as an attempt to rectify a major regulatory failure; a reluctant decision, by humanity, to minimise damage but **not** a serious change of course.

Tentatively the impacts of AI/ nanotechnology/robotics may be identified as heralding an 8th revolution, portending a new relationship between energy use, work, information flow and complexity in human society.

As mentioned a number of emergent characteristics can be identified from a consideration of the six revolutionary events and the background science and history.

Firstly and crucially, a huge increase in the complexity and in the embedded information in living systems over 4 billion years; Chaisson refers to an "arrow of complexity". The living world has evolved from a single cell with little apparent internal structure to comprise multi-cellular, multi-organ, intelligent creatures living in huge material, energy and information-rich conurbations of great social diversity.

This sequence also reveals the successive emergence of new biological and social possibilities, including, recently, human consciousness and our cultures in all their profusion.

The emerging multi-component structures have, of course, made growing demands on planetary resources - initially on photosynthate, essential nutrients and water. Latterly a much wider range of materials have been sourced and exploited by humans, including, of course, other organisms and other humans. Nevertheless, as Ostwald, Smil and many others have asserted *all events and all activities require and depend on free energy transactions*. *Conversely,* the exploitation of more and more energy will inescapably make more and more resource demands as well as generating more complexity and offering new possibilities and new risks. These process will also inevitably produce more waste and entropy.

Secondly, the remarkable acceleration in the rate of change, especially since the emergence of hominins and *H. sapiens*. The early revolutionary step-changes, as recorded above, were separated by hundreds of millions of years. Now major changes in the energy socio-economy are occurring and indeed must occur, given AGW, over a few decades. This trend can be seen as a function of the basic physics. More energy allows more work to be carried out per unit time (i.e. power) and therefore the time which elapses between 'events' diminishes.

An examination of the energy step-changes also suggests that, on each plateau between major energy steps, energy availability and efficiency have constrained the level of permitted complexity [see Mahli, *op.cit*.]. Each step-change leads not only to the emergence of a new level of complexity but a new, organisationally more complex 'elites' e.g. eukaryotes, early hominins, *Homo sapiens* itself and now human societal elites: each encapsulating and better able to exploit the new possibilities.

Nevertheless the newly emergent 'elites' remain dependent on the efficient functioning of the 'lower', precursor levels and the integrated planetary system. Simple examples would be the near universal dependence of planetary life on photosynthesis and our human dependence on our gut prokaryotic microorganisms. This suggests that Chaissons' metaphor of single 'arrow of complexity' may not be an entirely appropriate. Over time, new organisms and systems of greater complexity and emergent potential have appeared but remains dependent on the health of the previously levels of complexity.

Overall within this system, a fine balance between cooperation and competition can be observed, as exemplified by the endosymbiotic emergence of eukaryotic cells from their Archaean and Bacterial ancestors, later photosynthetic plant cells incorporating cyanobacteria. Other examples include multi-organism lichens and corals, the colonisation of land by lichens, fungi and higher plants, and of course, social communities, especially human. In noting these events, I am not questioning the importance of competitive natural selection but recognising that cooperation can and has contributed to competitive success.

The physical concept of 'power' - i.e. work done per unit time – can, I would argue, be extrapolated from physics to biology and, indeed, to human society. In evolutionary biology, Odum postulated *"During self-organization, system designs develop and prevail that maximize power intake, energy transformation, and those uses that reinforce production and efficiency"* [13]i.e. systems that maximise their power flow survive in competition (see also Lotka's Principle[14]).

Hominid success has, indeed, depended on a mixture of competition and cooperation within which social and economic power, in the three senses employed by Lukes[15] (see also Foucault[16] and Russell[17]) , as well as physical power must have played a vital role. Individual physical power exemplified by a great warrior defending a tribe or securing extra food and other resources, has featured

[13] Howard T. Odum, *Environment, Power and Society* (1971 New York: Wiley-Interscience. p. 43.

[14] A. J. Lotka (1922a) 'Contribution to the energetics of evolution' [PDF]. *Proc Natl Acad Sci*, 8: pp. 147–51. A. J. Lotka (1922b) 'Natural selection as a physical principle' [PDF]. *Proc Natl Acad Sci*, 8, pp 151–4.

[15] Steven Lukes (2005) *Power: A Radical View* Second Edition, Palgrave Macmillan

[16] Michel Foucault. https://en.wikipedia.org/wiki/Power-knowledge#References

[17] Bertrand Russell (1938) *Power: A New Social Analysis*. Allen and Unwin

strongly in human history and mythology. However with the energising of brain power (post *H. erectus*; 4th energy step-change above), social power, tribal cohesion and cooperation and layers of influence, including charismatic leadership, have become more critical. Power in human society now arises, sometimes obliquely, from social interactions which allow some to the control of the work of 'others'. In doing so, goods and services, weaponry and money, as a potent conduit of power, are directed to the satisfaction of the 'powerful'. That said, for any human to be totally powerless is a pathology. Everyone depends a modest 'sphere of influence' as well as on certain entitlements.

It is clearly possible to trace a set of step changes in the energising of the weapons of war from fists and spears and cudgels to ballistic missiles with nuclear war heads [see Chaisson, *op.cit*.], but this lies outside the scope of this essay.

Human influence, as well as the tools born of human ingenuity, have levered more and more power but all remain dependent ultimately on free energy transactions. Often this power appears to be corralled by specific groups. If Odum's postulate can be extrapolated legitimately from ecology to human behaviour, then the pursuit of power is deeply embedded in our evolutionary and social history as well as being manifested in the human domination of this planet and in local and geo-politics. Whether such power is maximised or optimised remains to be debated.

As noted earlier, complex structures emerging, spontaneously, in energy fluxes are unstable ('dissipative' in Prigogine's terms). Amazingly even the simplest organism has evolved mechanisms to stabilize itself energetically and to respond to external stimuli. A hierarchy of such mechanisms, homeostasis, can be traced from a single cell to highly complex organisms. Following Antonio Damasio[18] I contend that this homeostatic hierarchy apparent in, and essential to, the stability of all living organisms, can be extend to human interactions (feelings and emotions) and, indeed, to the stabilisation of modern social, material an urban structures.

Humans are the inheritors of near-invisible physiological and behavioural regulatory mechanisms reaching back to our ancestral hominids. At the cellular, organ and organismal levels they can be traced even to our prokaryotic ancestors. However, with the emergence of complex societies and, very recently, huge conurbations and sophisticated technologies, humans have themselves had to devise a range of mechanisms to stabilise complexity, seek to control conflict and promote cooperation. These range from behaviour norms, though social and political systems, to national and international law. All are attempts to stabilise the growing and accelerating complexity inherent in our free energy dependent, socio-cultural, political and material structures. All also have increasing embedded energy and information content.

[18] Antonio Damasio. (2004). *Looking for Spinoza*. Vintage Books, London

Nevertheless our instinctive feelings, emotions and reactions to external and internal stimuli with their attendant biases and heuristics, retain a significance. They evolved, originally, to adapt us to life in small, often mobile, sometimes isolated communities for hundreds of generations over several hundred thousand years. Behaviour psychology has revealed a wealth of evidence that under most circumstances our behaviour is still dominated by instinctive reactions (e.g. Daniel Kahneman[19]). However, superimposed on these are most of our devised laws, regulations and social practices which are of recent origin and remarkably variable. To an extent these are the result of deeper, more reflective consideration (Kahneman's system 2 thinking) but they are not immune to our instincts and biases. Conversely, societal norms and expectations feed-back onto the workings of our instinctive reactions e.g. individuals born in corrupt communities may be more tolerant of corrupt practices.

The energy revolutions also involved significant changes in information processing e.g. Revolution 3 - more energy per unit of inherited unit of information i.e. ~ per gene ; Revolution 4 - additional brain power permitting greater interpersonal and intergenerational information transfer and possibly early language. The Agricultural Revolution (5th) led to record keeping, numeracy, literacy, documentation, libraries. The 6th Industrial Revolution, although preceded by important innovations – e.g. the printing press scientific enquiry and capitalism, has led to a massive increase in global information flow even before the emergence of modern digital technologies (possible 8th Revolution).

Famously Schrödinger[20] suggested that the first cell, and indeed all living organisms, should be thought of as using an external source of free energy to acquire 'negative entropy' i.e. internal order, at the expense of their environment. As more information is required to define a given ordered state than a disordered one with high entropy. Thus, a firm link between energy and information can be established and, to an extent, energy and information are overlapping and intertwined concepts.

To summarise: I am proposing that, in the first six revolutions, broad patterns can be discerned. Major increments in harnessed free energy result in increased complexity in living systems and their constructs with new potentials and instabilities but growing resource demands. Homeostatic adjustments occur in parallel resulting in 'regulated' quasi-stabilisation and plateauing in a new but, dynamic, order. Each step is characterised by a higher degree of both complexity and embodied information and flow, as well as new power relationships & differentiations. Nevertheless each new order remains dependent for its success and future on the continuing health of each of the preceding orders.

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19 Daniel Kahneman. (2011) *Thinking Fast and Slow*, Penguin

20 Erwin Schrödinger. (1944) *What is life?* reprinted Erwin Schrodinger. (1967) *What is Life? and Mind and Matter*, CUP.

3. Some Implications:

Embedded within these multi-disciplinary scientific conjectures and extrapolations lies a fresh way of understanding both the issues and the huge practical challenges now facing human societies world-wide. The analysis argues that humanity needs to be understood as wrestling with the consequences of a sequence of '*energy revolutions'*, characterised by features which flow out of the very fabric of life.

Our current intellectual, political and economic dialogue is focussed on the environmental consequences of our exploitation of **specific** energy sources, mainly fossil fuels, and, to an extent, nuclear fission and fusion and, locally, wind and solar. The fundamental significance of energy – of ever more rapid free energy transformations - scarcely registers. The social, cultural and environmental impacts of this accelerating energy use are rarely discussed. This is a grave omission with potentially disastrous consequences. Energy exploitation and a consequential ability to do work and generate power result in concomitant complexity and speed of change, **irrespective of the source of that energy;** these should be recognised as critical issues.

We are direct inheritors of the 6^{th} fossil fuel revolution, superimposed on the 4^{th} (hominid brain) and 5th (agricultural) revolutions. But, in many ways, the consequences of the last step change remain unresolved. In terms of the hypothesis outlined above, no new quasi steady state has been reached. We continue to experience 'the great acceleration' and a fossil fuel-fired, technological revolution.

Many environmental activists and scientists highlight the threats from AGW as well as from other forms of 'overshoot' such as pollution, biodiversity loss, oceanic acidification and resource competition etc. But in the popular imagination a limitless supply of cheap pollutant-free energy will allow undreamt of prosperity – streets paved with gold. Formally, business and government policies assume and covet huge increases in energy and resource use in this and even into the next century. Not only, or even necessarily, to help the poor but to further enrich the already well-off. Vast sums are being invested in harnessing nuclear fission, and the dream of fusion. All in pursuit of such this vision with little thought given to its human or planetary implications - no due diligence.

The vision of a technological utopia, based on limitless energy, is given unbridled expression in Marc Andreessen's Techno-Optimist Manifesto. His argument will appeal to many committed to a particular version of 'progress' and a belief in technical fixes. Others will see it as a nightmare fearing planetary collapse and/or a 'Novacene' dominated by Lovelockian cyborgs [21]or AI-human hybrids. This manifesto presages the rapidly approaching 8^{th} revolution, which I tentatively allude to earlier, in which the relationships between energy exploitation, work and

[21] James Lovelock (1988) *The Ages of Gaia*. OUP and (2010) *The Vanishing Face of Gaia*. Penguin.

power are transformed by AI. Unfortunately more detailed consideration of these aspects lie beyond the scope of this essay.

4. Reflections:

Several major issues deserve examination.

i] Do we have effective regulatory systems to cope with and to stabilise our societies based on a huge and continuing growth in energy exploitation, work, power, and complexity and in resource demands and their inevitable environment impacts?

ii] Do we, as humans, have the ability to adapt to and even embrace growing complexity and its new potentials and instabilities and, crucially, handle the current and potentially accelerating rate of change itself?

iii] What might be the impacts of asymmetrical power and emergent new elites, implicit in new revolution, arising from exploiting new abundant new, low-carbon energy sources e.g. fusion and/or radical new AI-induced ways of coupling energy sources to work and power?

iv] How might these changes will impact on our understanding of our own humanity?

Following Antonio Damasio, I have suggested that a hierarchy of biological homeostatic regulatory mechanisms can be traced from the simple unicellular prokaryotes through to human society. But, with the emergence of hominins, stabilisation has assumed a social dimension. Initially social conventions, now enforceable laws underpinning political governance, all-be-they highly variable around the world. These processes are laborious often slow and distorted by special interests.

The rate of change is now such that all responses rest on human agency. Nevertheless our ancient, inherited and embedded patterns of social homeostasis may still influence our innate behaviours and have, likely, left their mark on the priorities and biases inherent in any legalistic, regulatory systems. There are scant reasons to expect our systems to cope well.

Of relevance in this context is, I suggest, the pursuit of 'power'. Power, in the physical sense of exploiting energy to optimise work per unit, is a driver in biological survival as well as the economy. In a more subtle sense, it is also expressed in human ambition and influence and in our desire for social and material status as well as to have dominion over the natural world. Seen in this light the deep-seated pursuit of power is and will continue to be an impediment to any efforts to reduce energy use.

In seeking a palatable solution to AGW, we are contending, primarily of course, with the deficiencies of our power-related, modern, regulatory economic and legal constructs. However it is arguable that part of our recalcitrance arises from deeply embedded behavioural traits which have served hominins and early humans well for over million years. The latter tend to be tribal, risk averse and power seeking, with a distinct reluctance to relinquish advantage and status. These traits reflect, significantly, the interests and power of dominant elites as well as broader societal traits.

Data from Oxfam show a clear relationship between both personal and national wealth and *per capita* GHG emissions. We, ourselves, are part of the large and growing global class living well within a high-energy dependant, man-made and remarkably successful socio-economic framework. It's human-devised but environmentally-failing regulatory systems have served some well.

Consequently we are faced with an unpalatable dilemma.

The basic mathematics of the distribution of GHG emissions means that the bulk of any meaningful cuts must be made by this group. But this group has the most power and has the most to lose.

We must also recognise that an 'adequate' energy supply is a necessity to any organism and recognise the strong and legitimate political-economic desire in the poorer countries to increase energy use. Without it political stability and any reduction in global poverty are impossible. The existing gross inequalities of wealth and energy use are potent issues which cannot be ignored locally and internationally.

Given that, in resisting deep and rapid GHG cuts, the interests of the power-elite and the emerging middle class, often subjected to pervasive 'denialist' propaganda, roughly align, and reflect some of our most basic instincts, unsurprisingly, too little is happening too slowly. The outlook is dire.

This quote from Frédéric Bastiat in 1857 is remarkably apposite, "When plunder becomes a way of life for a group of men in a society, over the course of time they create for themselves a legal system that authorizes it and a moral code that glorifies it." And 'experts to help justify it' - added Kevin Anderson.

The evidence of the inadequacy of our regulatory structures and laws in curbing environment damage is too well known to require further elaboration. More contentious is an assertion that energy-driven and accelerating growth is also inflicting social damage, likely reducing human wellbeing and exacerbating injustice.

Over many centuries, humans have lived in relatively stable communities giving individuals and their families a clear place within that society and an array of local support mechanisms. No doubt this stability could have been constraining, but coping with rootlessness and very rapid change may well be equally problematical, both to individuals and to society. Community support is now widely contacted out to the welfare state and government institutions.

Paradoxically in a globalised world, many societies are more atomised. Individualism is exalted. Competitiveness is seen as key. Relationships are more transitory. Societies more transient; indeed some deny their importance. Direct local human contact and oversight has been replaced authority perceived as unfeeling as well as by largely unregulated social media and digital transactions. Misinformation is rife.

There are serious concerns about how all this will evolve, given the advent of IT, AI and the dominant social media.[22]

There is no doubt that the devising of effective and just regulations is often failing to keep up with events and the rate of change. These concerns mostly revolve around the social media and AI. However, I suggest, climate change itself can be viewed as a prime example of this phenomenon. James Watt and Mathew Boulton had no inkling that their powerful new steam-engine had within It the seeds of planetary disaster – truly an unknown unknown. Since the threat become apparent, the self-interest of those empowered has succeeded in delaying effective regulatory control. As noted, our wider behavioural traits and socio-economic priorities have tended to reinforced this stasis.

This tale should also warn humanity against an overconfident reliance on technological fixes such as planetary geo-engineering. The dangers of techno-hubris, exemplified in my judgement by Andreessen's manifesto, and of more known and unknown unknowns are very real. Current regulatory failures quite possibly presage Carbon Capture and Storage and global geo-engineering with unknowable risks.

The painful paradox is that increased biological, material and social complexity has bought exciting new potentials to our social and cultural lives as well materially. However such complexity carries risks of catastrophic destabilisation. At a physical level one wonders about the fate of a major city if the electricity supply were to fail. Still worse, if all energy input were to cease totally for even few days. Our energy-dependent complexity renders us exposed to unanticipated 'black swan' events. Examples would include a major solar geomagnetic storms such as the Carrington event of September 1859 disrupting, maybe destroying, much electronic communication, a major earthquake or volcanic eruption and of course wars (cf. Ukraine/Russia) and creeping social unrest if the promises of material progress/growth are not fulfilled.

At socio-political level there are reasons to be concerned as to how well people are coping with the speed with which social mores are changing and with their workplaces being subject to accelerating Schumpeter's 'constructive destruction'. There appears to be growing issues of mental health and stability in

22 See Toby Ord (2021) *The Precipice: Existential Risk and the Future of Humanity*, Bloomsbury.

some societies. Unfortunately the rapid changes required to combat AGW may aggravate these problems as the steel workers of Port Talbot and livestock farmers are experiencing currently.

More detailed consideration of these issues, including the nature and stability of complex systems and the interfaces between energy and information etc., lies outside to scope of this essay and the competence of the writer. Hopefully they will be taken up by others.

5. Possible Futures:

The approach in this essay is evolutionary. It embraces the concept of consilience and an 'arrow, or better divergent but interdependent streams, of complexity' driven by a deep current of accelerating energy transformations. However, with emergence of *Homo sapiens*, a crucial change occurred; biologically, socially and ethically. In evolutionary terms, a small investment of energy in brain function and in our capacity to process information has led, after two more step changes and near 2 million years, to the emergence of consciousness and conscience. It's led to scientific understanding and technological skills , for some, huge wealth and to our arts and philosophies.

These events will be interpreted very differently by individuals of differing political, religious and philosophical persuasions. But, undoubtedly, they refocus all our perspectives.

They create a new context in which to ponder our technological prowess, our socio-political systems and ethical priorities. As humans may be the inheritors of, and likely constrained by, aspects of our long biological history. But we are the devisers of our modern socio-political economic and regulatory systems. We are conscious moral beings and, as such, should be able to exercise some choice and free will. Thus, at least potentially, we are capable of devising new systems and adopting values more compatible with human wellbeing and planetary health.

Clearly a substantive discussion of these timeless issues lies beyond the scope of this short essay. Sufficient to consider contrasting but plausible future scenarios compatible with the energy step change model outlined.

Should new sources of plentiful, low-emissions, energy be accessed, then, combined with AI and new ways of processing information, a new step change might arise on the lines of techno-optimists vision and the assumptions of many politicians. Both humans and geoengineered planetary systems would then be controlled by a techno-elite. Their wellbeing, and indeed the future of the species, would depend on error-free management. For the reasons already discussed, there are compelling reasons to doubt the stability, viability and humanity of such a scenario. Democratic freedoms are unlike to survive. The power of digitisation will provide new tools to the ruling elite to allow them to dominate most humans. Possibly cyborgs, as envisaged, perhaps tongue-in - cheek, by Jim Lovelock will emerge. More likely a techno-elite, exemplified by Andreessen, will fit the bill equally well and use their AI prowess and wealth-derived power to 'dominate' Orwellian, climate-stressed underclasses.

My fear is that our current trajectory lies close to this scenario. Effective environmental and social regulation is scarcely keeping up with the rate of change following the 6th revolution. Focussing on AGW, in the second week of May 2024 atmospheric CO_2 level reach their highest in human history and a record rate of annual increase. A version of 7th Revolution is occurring around us but, as widely discussed, too slowly and too reluctantly to avoid major global problems and possibly catastrophe. There is ever prospect of environmental calamities feeding into the techno-optimist agenda.

An alternative scenario depends on a massive exercise human agency and a radical change in human ambitions. It requires a massive, deliberate decision by the better off (us) to invest in use less energy, to forsake the pursuit of power, to slow the world and to prioritise equity. I fear it requires reversing long-term and deeply embedded trends. This reversal means wrestling with the consequences of a sequence of '*energy revolutions',* characterised by features which flow out of the very fabric of life. It means recognising that some of the traits which have allowed *H. sapiens* to flourish contain the seeds of human decline, may be destruction. Given that humanity is currently speeding towards global overshoot, it is improbable that such a "new beginning' will occur in an ordered, humane manner. Sadly even the possibility will be raucously contested.

6. Summary:

The essay has limited but ambitious objectives.

Firstly it seeks to place energy *per se* at the heart of the debate over AGW and the future path for humanity.

Secondly, it emphasises the dangers posed to our humanity by an unthinking assumption that exploiting more and more 'free energy', or the much better coupling of energy to power and complexity, is axiomatically desirable.

Thirdly, as AGW is viewed as the climax of a long history of energy-driven revolutions as well as human failures, these conjectures and evidence quoted provide a framework for understanding and assessing future aspirations and actions.

While it is not possible to conclude that a techno-future can be ruled out, this hypothesis, and the evidence that lies behind it, implies that harnessing more and more energy will impoverish our humanity and, in all likelihood, lead to catastrophe.

The alterative vision can be summarised as "living well on less". This precept is, of course, not new. it could and should be inspirational. This analysis, derived from very basic scientific concepts, may have the merit of building important bridges to the teachings of many great religious leaders and philosophers. So to, to the economists and social scientists critical of our current socio-economic system based on continuous material growth. A small step on long journey.

Bydd mwyn gymdeithas.	*There'll be gentle community,*
Bydd eang urddas.	*There'll be broad dignity,*
Bydd mur i'r ddinas.	*There'll be walls to the city,*
Bydd terfyn traha.	*Arrogance shall fail.*
(Waldo Williams)	(translation by Anthony Conran)

Addendum:

Green House readers may wish to indulge in two speculations:

> Had this planet not been endowed with vast reserves of fossil fuels, how might global society have evolved in the nineteenth and twentieth centuries if based largely on neo-current photosynthate?
>
> Had atomic (fission) power, as Lewis Strauss anticipated in !954, generated electricity 'too cheap to meter', what might have been the outcome for both the global north and south and for our environment?

Acknowledgments:

I am deeply indebted to John Llywelyn Williams, Elin Rhys, Roger Leigh, Tony Rippin, James Intriligator, Jon Gower, Ron Pethig, Bronislaw Szerszynski and, above all, Robin Grove-White for their critical advice, support and insights in developing these ideas.

Green House is a think tank founded in 2011. It aims to lead the development of green thinking in the UK. Green House produces reports and briefings on different subjects. We do not have a party line, but rather aim to stimulate debate and discussion. Politics, they say, is the art of the possible. But the possible is not fixed. What we believe is possible depends on our knowledge and beliefs about the world. Ideas can change the world, and Green House is about challenging the ideas that have created the world we live in now, and offering positive alternatives.

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