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Commentary

Energy: Life, Power, and Livelihood

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We and our habitat are forms of energy, endowed with life, and irrevocably earthlings. A cosmological-to-locality appreciation of energy in food and nutrition science, practice and policy is overdue. Our livelihood, and any function we have, are energy dependent, as is planetary habitability. Energy cognisance has become an existential necessity in an increasingly self-destructive 'anthropocene' era when our own energy equilibrium is compromised. This is manifest in destruction and loss of our ecology, our livelihood expectations, and practices, and, in turn, our wellbeing and health. Most problematic has been the domination, skewing and loss of biomass caused by humans, both with their over-population of the earth, and their exploitation of its natural resources. These resources provide fuel for warmth, cooking and transport, textiles, and clothing; are subject to land and aquatic harvest, are replaced by dwellings and infrastructural buildings, and yet are recreational assets. Wastage has been of scant regard. Energy misuse besets the entire food system. This has followed the development of the wood and coal-fired steam engine, the advent of gasoline powered internal combustion engines, use and transmission of electricity, and an insatiable arms industry. Now, we are at the brink of extinction. Profiteering and conflict over energy control has fostered unfettered industrial materialism, a major extinction risk factor. Not only is energy the power we need, but it has also underwritten the powerful. Can we be sufficiently insightful and collaborative to change this energy trajectory and survive healthfully on a habitable planet? Individuals, households, and communities, as opposed to unaccountable monopolies, could achieve control of the energy systems on which our livelihoods depend and render them sustainable, accessible, and affordable. Interconnected food and energy system ownership could be devolved to 'The Commons' as a cooperative, sustainability strategy. The social momentum and appropriate technology for energy conservation, renewability and personalisation is now available for mobilisation to address our food, nutrition, and health insecurity.

'ENERGY' DISCOURSE

There is a colloquial use of 'energy' to mean that one has the strength and purpose to perform, a scientific use which purports to quantify a cosmological phenomenon, and an industrial one to identify it as a utility referred to as 'power.' Herein lies the tragic irony, namely that the control of 'power 'has become an overwhelming and powerful economic and jurisdictional force. But the basic definitional ground would be that it is the capacity to do work. Its forms may include potential, kinetic, thermal, electromagnetic, ionisation, electrical, chemical, gravitational, sonic, or nuclear energy. Food and health system mindsets would be more consequential if the nutritional centrality, pervasiveness, and connectedness of 'energy' were recognised and clarified (Figure 1).

A major impediment to the progress and application of food and nutrition science to the avoidance of food system catastrophe is that it simplistically considers energy as the values derived from various forms of calorimetry. Its real simplicity and stupendous implications are to be found in $\mathbf{E = mc^2}$

WE ARE WHO WE ARE BECAUSE ENERGY HAS BEEN TRANSLATED INTO LIFE

As part of a seemingly infinite cosmos, our advent is remarkable. A tiny amount of our body mass or the food we eat has a massive energy potential viewed cosmologically. Cosmologically, energy (E) is simply and profoundly formulated interchangeably with mass (m), dependent on the speed of light (c), and implicitly time, according to Einstein as:

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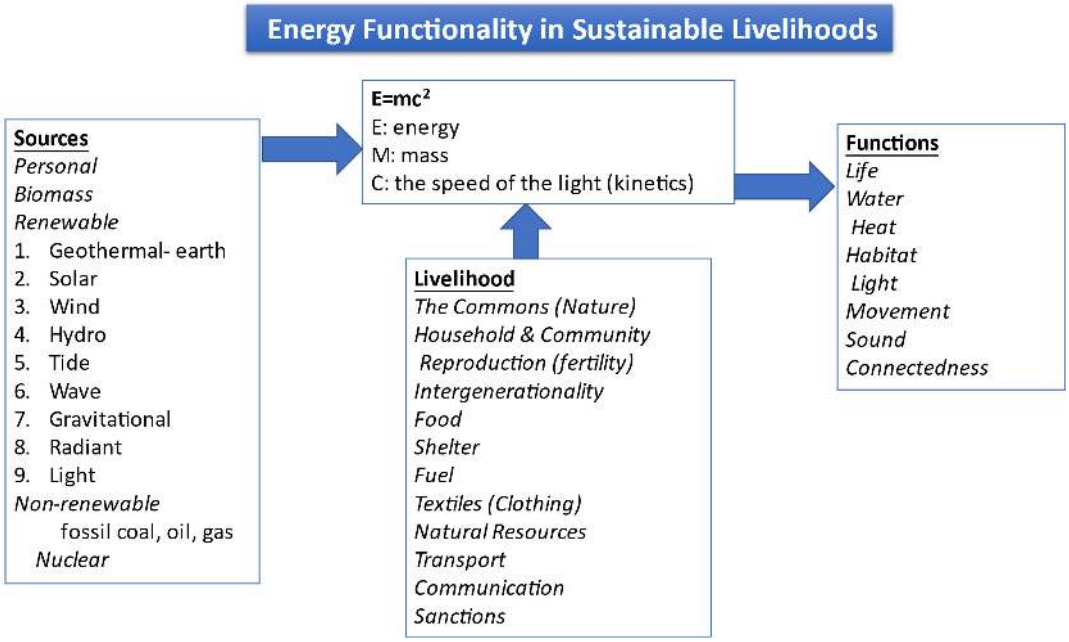

Figure 1. Energy functionality in Sustainable Livelihoods

The boxed formula is that of Einstein which shows that together, mass (m) and the speed of light (c) explain the universality of energy. This energy has a variety of sources, renewable and non-renewable, while convertible and never lost from the cosmos; persons and their ecosystem are themselves energy units. In turn, energy can subserve a number of functions. These are required for the several elements of human livelihood. Conversely, our livelihood characteristics determine the profile of our energy dependency, its sources and functionality. Much detail relevant to daily life and livelihood, such as sustenance and socialisation, is reflected in the categorisations, although not itemised.

$$\mathbf{E = mc^2}$$

Life is evident when energy or mass is operationalised with a lifespan and reproduction; through intergenerationalism; accompanied by various chemical or physical transformations; through movement; is associated with the production of heat, light, or sound; involves habitat modulation; and requires connectedness. Some of these accompaniments or attributes of energy as life introduce the notion of time, giving us a sense of past, present, and future. Einstein, however, remarked that "the past, present and future are only illusions, even if stubborn ones." Insofar as energy depends on light and time, it is a stubborn dilemma for our present identity, well-being, and health. Whether or not time is illusional, the passage of humanity in it has generated the anthropocene geological period from about the 18th century. This alone defines how terminal our planetary habitability might be, on account of the misuse of our energy status (Pielke, Burgess, and Ritchie 2022; Rockström et al. 2009; Steffen et al. 2011). It is at once reassuring and salutary that, in accordance with the laws of thermodynamics, we, with our ecosystem, are a form of energy, indestructible, but mutable and provisional.

LIVELIHOODS AND ENERGY

In one way or another, all of what is basic to our livelihood is energy dependent (Figure 1). When we were few (at the beginning of the agricultural revolution some 10,000 years ago, about a million people), pre-materialistic, keenly naturalistic (often animistic), and tribally sanctioned if collaboration failed, we would have been energetically sustainable, although at-risk from being exploratory and migratory and subject to climate, weather, and other perils of nature. The development of a sustainable livelihood framework allowed societal and technological innovation and development (Wahlqvist and Gallegos 2020). This became problematic, excessive at nature's expense and competitive, with a societal cost through greed, power play and conflict.

Even in the present, Ostrom and others have shown that "The Commons" could be operational in the community and planetary interest, as long as sanctions are agreed for those who do not subscribe (Ostrom 2009; Ostrom et al. 1999). Current economics, and especially surface trade, challenge 'The Commons,' however. They are dominated by energy in the form of fossil fuels, food, arms and weapons, illegal drugs, and precious metals and gems, illustrating how the commodification of energy has perverted humanity. This global energy disorder is a powerful argument for persons and communities to regain control of who they are as 'energy-dependents,' not enslaved by monopolistic theft of the natural world and its corruption of energy distribution.

When transferred from one form to another, some energy cannot be used in the same fashion. This poses challenges to living systems, livelihoods, and planetary habitability.

ENERGY, LIFE, AND HEALTH

Currently acceptable ***health system policy*** purposes universal healthy longevity. Yet its realisation with optimal individual, collective and ecological energy inputs, outputs, and

equilibria is exceedingly complex. It is therefore both curious and surprising that preventive and therapeutic health care have become more singular, precisional and reductionist in orientation. The justification of such operational simplicity requires the benefit, risk and cost analysis to favour the single or precisional factor approach (Wahlqvist 2020), more easily achievable with therapeutics than prevention. By contrast, energy regulatory dietary patterns and the simple physical activity of walking, both with underlying complexity and contextuality, confer health advantage in wellbeing and disability adjusted longevity (Wen et al. 2011; O'Mara 2021). For healthy longevity, enough physical activity must be employed to allow for an adequate and varied diet to be eaten without excessive or inappropriate fat storage (Y.-C. Huang et al. 2018; K. Li et al. 2020; Pan et al. 2012). A higher plane of biodiverse energy nutrition with greater energy expenditure and physical activity is the preferred human nutritional state. It diminishes the need for dietary precision to achieve a healthy body composition, innate immunity-appropriate inflammatory responses, a sense of wellness and minimal disability with longevity (Wahlqvist and Specht 1998). Accordingly, virtually all bodily functions and systems require ecological inputs, from the complex sensory to the immune-inflammatory and bioenergetic, with their homeostatic modulation and integration in defiance of unifactoriness. In addition, we are composite beings, both prokaryotic and eukaryotic, with cross-kingdom microbiomes involving bacteria, archaea, fungi, and viruses, collectively, corroboratively, and bioenergetically involved in our well-being and health (Shuai et al. 2022). Thus, we are ecologically derivative and dependent for life and health (Wahlqvist 2014). It is a forbidding and resource-intensive prospect to gather the extensive data sets to individualise health care with precision and also comprehensively. After all, while a physicist may expect to problem-solve with predictability by formulation and equation, the province of the biologist and health worker is managing uncertainty. The mind-journey from energy cosmology to bioenergetics and health illustrates this point.

Environmental energy enabled life when a redox system could generate a transmembrane proton (hydrogen) gradient, avail itself of the energy transfer molecule ATP (adenosine triphosphate), and provide for its own renewal with organic carbon (sugars) (Koch and Schmidt 1991). Chloroplasts and mitochondria were probably assimilated microorganisms with ATP generative capacity by endosymbiosis (Margulis 2004). Thus, life evolved ecologically. It required an optimal self-regulatory milieu characterised by temperature, pH, and osmolality (homeostasis), environmental sensitisation, the ability to defend and repair, and regenerate. For life to have evolved in any form, its energy dependency has these characteristics, which underscore our planetary and environmental connectedness.

Incidentally, the essentiality of phosphate for life, along with other elements, from wherever they ultimately derived in the Cosmos, assembled on and in the Earth, prescribes our habitat and the impracticality of seeking it elsewhere in the universe. The energy system which is the basis of our existence, can be considered our irreplaceable ***Commons*** in accord with socioeconomic concept of Ostrom (Ostrom et al. 1999). Whether the Commons can provide enduring energy sustainability for humankind depends on the limits to population growth and planetary exploitation as costs for private profit which are agreeable or enforceable (Hardin 1968)

The first law of thermodynamics states that *'Energy can neither be created nor be destroyed, it can only be transferred from one form to another.*' Thus, not just the quantity, but the sources, accessibility, utility, and renewability of our energy sources are important and are conjoint with every other form of life in an ecological sense (Trichopoulou et al. 1995; Wahlqvist and Specht 1998). Hence, ***our socioecological identity*** (Wahlqvist 2016a).

THE ENERGY COMMONS AND GOVERNANCE

As indicated above, people have the inclination and capacity to function collectively in their common interest, especially as this relates to the use of natural resources. Considered as 'The Commons' (Ostrom et al. 1999), and subject to sanctions for the non-compliant , this would include energy with its various functionalities (Figure 1). Hardin (1968) and others have identified over-population, the need for basic livelihood priority over excess and the commodification of land entitlement as threats to the Commons which have been dispelled in some historical and contemporary settings .Indeed, it is argued that energy is a basic human right, although the conceptualisation of an Energy Commons ought to suffice (Löfquist 2020). Margaretha Wewerinke-Singh makes it clear that this right would contribute substantially to the achievement of the Sustainable Development Goals (SDGs) by 2030 (Wewerinke-Singh 2022).

An existential energy constraint on human health and survival, whatever the ethical considerations, arises when population exceeds, in number or demand, the bioenergetic ecology. That is the crisis in which we now find ourselves where societal governance fails on fronts such as family planning and unrestrained materialism and the earth becomes increasingly uninhabitable (World Health Organization 2021).

IMPAIRED ENERGY REGULATION (IER)

Disordered fat storage in the omentum with increased flux of free fatty acids in the portal circulation to the liver, together with increased nocturnal hepatic gluconeogenesis, and endogenous triglyceride synthesis manifest as hypertriglyceridemia are indicative of impaired energy regulation (IER) (Wahlqvist et al. 2010). In addition to hypertension, which has its independent association with overweight and obesity, these 3 features constitute what is commonly referred to as the Metabolic Syndrome, usually regarded as indicative of insulin resistance. That IER is a common finding with health adversity, particularly in socioeconomically compromised settings, underscores that 'energy health' is fundamental to wellbeing and healthy life expectancy (Y.-C. Huang et al. 2018). It is a field of nutritional biology

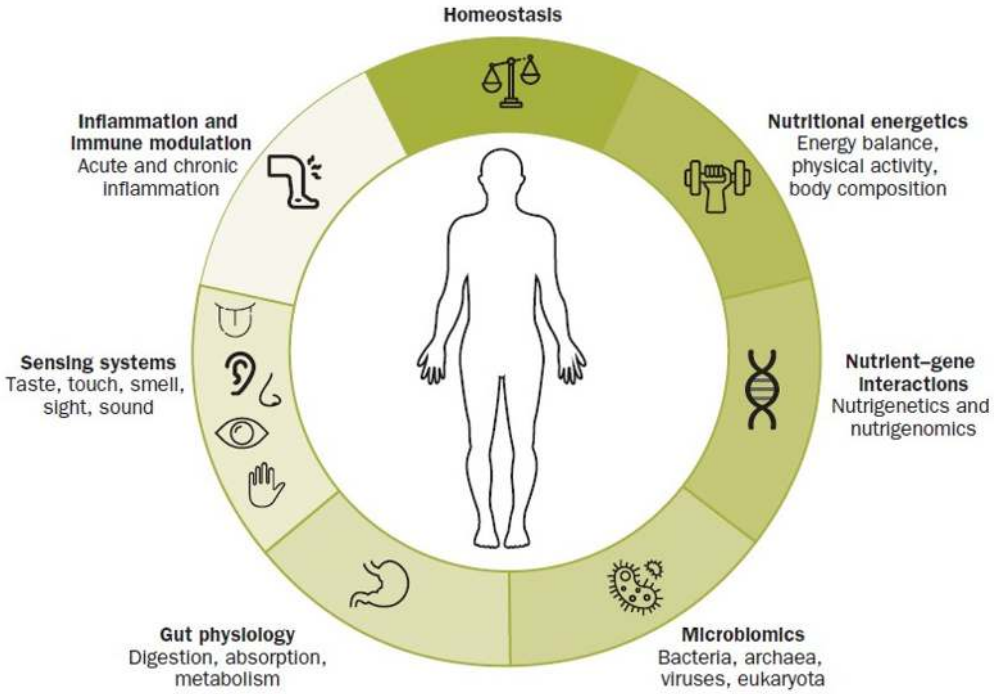

Figure 2. Fields of Nutritional Biology (by courtesy of Wahlqvist and Gallegos 2020)

These fields are each and severally connectors between us and our environment as well as descriptors of our intrinsic ecobiology, evidently cross-kingdom. They depend on our anatomy (organs as in heart, musculo-skeletal, adipose and brain) and systems (as in haemopoietic, immune, endocrine). They allow for constructs like 'the mind' which is more than the brain. (Bahn et al. 2007; Wahlqvist 2016a; Shuai et al. 2022)

with ecological interdependence (Figure 2). Of particular interest in this regard is how diabetes as an energy regulatory disorder increases the risk of neurodegeneration as evidenced by dementia, Parkinson's disease, and affective disorders (Hsu et al. 2011; Wahlqvist, Lee, Hsu, et al. 2012; Wahlqvist, Lee, Chuang, et al. 2012). In turn, metformin therapy for diabetes, which upregulates AMP kinase, the key regulator of cellular bioenergetics, is associated with reduced risk of each of these health problems. It also reduces the risk of several cancers (Lee et al. 2011) As is often the case as we change our relationship with food and distance our control over its system, we have ignored its structure in favour of energy sufficiency and micronutrient adequacy, exacerbating energy dysregulatory disorders like obesity and its consequences (Wahlqvist 2016b).

ENERGY AND BIORHYTHMS

Perhaps the most obvious association between the environment and human bioenergetics is in sleep and seasonal behavioural patterns with slower basal metabolism overnight and changed work patterns by season. That there are clock genes has now been demonstrated although a 'pacemaker' and its whereabouts incites controversy, given that organs from the gut and its microbiome to the brain are involved (Bilal et al. 2022). Appetite, dietary biodiversity; and well-being, acute and chronic disease, and longevity are also connected with these biorhythms (Bilal et al. 2022; Han, Yuan, and Zhang 2022; Y.-C. Huang, Wahlqvist, and Lee 2013, 2014; Jagannath et al. 2017; Kanikowska, Sato, and Witowski 2015; Sgro et al. 2021; Stenvers et al. 2019; X. Zhang et al. 2021). All fields of nutritional biology are not only energy connected, but ecologically dependent (Figure 2).

ECOSYSTEM HEALTH DISORDERS

The classification of health disorder and disease is prescribed by WHO in accordance with ICD 11 (International Classification of disease) (World Health Organization 2018) and the American Psychiatric Association for Mental Health as DSM-V (Regier 2007). These, and more direct classifications of nutritionally related disorder and disease (Wahlqvist and Lee 2006), do not drill sufficiently deep to identify how consequential ecological disarray, including its energy framework, is of causal and pathogenetic relevance (Wahlqvist 2014). In turn, the problem is not confronted and addressed.

CLIMATE CHANGE AND ENERGY

Multiple reports and lines of evidence by Hansen et al. (Hansen et al. 2016), IPCC (IPCC 2021) and at COP21 in Glasgow 2021 (World Health Organization 2021) make clear that the use of fossil fuels as an energy source must cease if the earth is to avoid further global warming and remain habitable. The asymptotic loss of ecosystems documented by Rockstrom et al. (Rockström et al. 2009), Steffen et al. (Steffen et al. 2011) and others proceeds relentlessly out of a 'safe operating space' towards an uncertain future untenable for socioecological beings. In that case, the tenure of *Homo sapiens* among hominids will have been probably the shortest in evolutionary history, others having lasted

countless millennia, and ours no more than a few hundred thousand years.

It is a tragedy we might yet avert if we take control of our present energy dysfunction. The rapid interrogation of massive data sets with quantum computing insofar as energy and the related systems of food, health, ecology, along with climate and governance are concerned, should accelerate progress toward he SDGs (Sustainable Development Goals) by the 2030 target (Pathstone 2021).

WORKFORCES NEED TO BE LIVELIHOOD-DIRECTED AND COMMONS-COMPATIBLE

If we are to address with due expedition the existential threat of climate change, we need to gather expertise together and make use of it so that our misuse of energy can be rectified locally and globally. However, global institutions and trust in them are faltering. Most damagingly, they have been undermined and corrupted by the vested interest of the fossil fuel industry. But wherever a livelihood dimension is intertwined with energy provision or usage, there is an opportunity to mitigate the threat to our energy equilibrium. Diverse expertise and pluralistic engagement at every organisational level is to be encouraged irrespective of customary occupational designation. The societal stratification by employment and unemployment is judgemental of role and value, and anathema to the creation of a purposeful livelihood workforce.

Materialism encourages wastefulness and is counterproductive to the need to acknowledge that enough is enough, especially where energy distribution is in disarray (Skidelsky and Skidelsky 2013). Educational curricula should explore alternative approaches to life.

SURVIVAL

Not only is individual healthy longevity dependent on bioenergetic functionality, but so is population stability and planetary habitability. While mindfulness of local ecology encourages sustainable livelihoods, globalisation has made it necessary to cross jurisdictional and ethnocultural boundaries and connect widely to ensure energy equity and adequacy. Energy connectedness and prudence contributes to food and habitat security. It is highly dependent on water – no water, no food, no life.

Water (H_20) probably arrived on the earth via asteroids (Morbidelli et al. 2000). It has a remarkable number of physical forms from liquid to solid and vapour, even allowing life in liquid below its less dense frozen form. It is chemically cyclable in various forms of energy in conjunction with atoms like carbon. It is a source of hydrogen and oxygen. In today's world, its governance as part of the Commons is fundamental. But we face glacial loss, its disappearance as a hydro energy source, and even ground water (subterranean) disappearance with global warming. This will also result in a rise in sea levels, a loss of arable land, and of some of the natural and habitable environment. It is not surprising that a sense of urgency is informing massive desalination projects to provide potable and agricultural water. Will we resort to nuclear desalination (Association World Nuclear Desalination 2020)? We may have no choice. No water presages food insecurity, hunger, population displacement and high mortality. In those regions dependent on the rivers emanating from the Tibetan plateau alone, it is estimated that, by 2030, more than 2 billion people, at least a quarter of the world's population will be affected. The nexus between water and energy security is inextricable, and in desperate need of immediate attention to global energy management.

TAKING PERSONAL AND COMMUNITY ENERGY CONTROL

Our dependence on energy that comes from irreversible or lasting environmental destruction and on others for energy and its application in virtually every aspect of livelihood is the prime source of personal, community and international insecurity (Wahlqvist 2009). However, we inadvertently alter long-term planetary trajectories for short term or parochial gain (Wahlqvist 1992). To mitigate this risk, we need less energy dependence, and renewability or inexhaustibility for what we do need.

Theoretically, solar, wind, the movement of water (particularly tides and waves) or geothermal sources would meet this requirement, but each has environmental consequences on account of its capture, transmission, storage or refuse to greater or lesser extents and suffers from an inadequately funded research agenda (Geothermal 2022). Fossil fuels have the additional dire consequences of atmospheric pollution and global warming through greenhouse gas production. Moreover, fossil fuel sources and trade have been monopolised, monetised, and profiteered at the expense of local, community and jurisdictional interests. More attractive would be the microbiological production of 'green hydrogen,' where the manufacture could be an integral part of a circular energy economy or livelihood arrangement; competitive risks would ideally be mitigated within 'The Commons.' The microbial, enzymatic, or electrolytic production of hydrogen from water (H_2O), or non-fossil sourced ammonia (NH_3) is technologically practical locally or at a distance. If from H_2O, the toxic oxygen by-product could be handled microbiologically.

For energy generation, there needs to be a distinction between *biofuel* which requires the use of otherwise green public open space, arable land, or the natural environment, each conducive to health and well-being on the one hand, and that derived from recyclable materials and waste on the other. In particular, we need to develop *self-managed systems*, off grid, that can power our rechargeable devices when energy can be an essential part of a *circular economy*. The latter would begin to address the major burden of waste from textiles, plastic, and food.

Walking avoids the need for fossil-fuel dependent transport and is favourable to health in many ways, both physical in terms of body compositional and metabolic fitness; and neurobehavioral insofar as gut and brain function are concerned (O'Mara 2021). *Personally generated productive energy* is perhaps best illustrated by the *bicycle*. *Wearable nanogenerators* (triboelectric nanogenerators, TENG) are

becoming a practical approach to personal energy generation (Aazem et al. 2022; T. Huang et al. 2015; Khandelwal, Maria Joseph Raj, and Kim 2020; Z. Li et al. 2017; Wang et al. 2022; Zou, Raveendran, and Chen 2020). Textile transduction of movement to electric current is available for clothing or other mobile fabric (Aazem et al. 2022; T. Huang et al. 2015; Khandelwal, Maria Joseph Raj, and Kim 2020; Z. Li et al. 2017; Zou, Raveendran, and Chen 2020). Window glass as a solar transducer for home, school or workplace is now manufactured. Rechargeable, *domestic thermoelectric generators to power portable devices* (MOST, molecular solar thermal system), have also been developed conjointly in Sweden (Moth-Poulsen at Chalmers University of Technology) (Wang et al. 2021) and at Jiao-Tong Shanghai University in China (Q. Zhang et al. 2019).

CONCLUSIONS

Life is not only a form of energy, but an integral part of its ecological, societal, and cosmological essentiality. Our bioenergetics are narrowly synchronised with our planetary home. The excessive use of fossil fuels as an energy source, and ecosystem loss and dysfunction have taken *Homo sapiens* perilously close to extinction. There remain some opportunities through changed consumption patterns, with energy source personalisation and diversification, to rescue humanity at the brink (Wahlqvist 2021).

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