Towards a Science of Energetics

Frank Parkinson

It is important to realise that in physics today we have no knowledge of what energy is.
Richard Feynman, *The Feynman Lectures* (1964)

The laws of thermodynamics control, in the last resort, the rise and fall of political systems, the freedom or bondage of nations, the movements of commerce and industry, the origins of wealth and poverty and the general physical welfare of the race.
Frederick Soddy, *Matter and Energy* (1912)

It must be admitted, I think, that the laws of thermodynamics have a different feel from most of the other laws of physics …. They smell more of their human origins [but] why should we expect nature to be interested in the purposes of human beings, particularly purposes of such an unblushingly economic tinge?

Percy Bridgman, *The Nature of Thermodynamics* (1941)

Time for a Paradigm Shift

The purpose of this chapter is to draw attention to a fact which may seem too obvious to mention, namely that microgeneration is essentially an engineering challenge and thus, like all technology, is ultimately inseparable from the science which underlies it. The obverse of this is that we may expect a better understanding of science to result in more effective engineering. The quotations at the head of this chapter, all from Nobel Laureates, suggest, at the very least that the science of energy is in need of a fundamental reconsideration. There are basically two reasons for this: firstly, the theory was put together piecemeal and, in the words of a present day authority, "from observations on the lumbering cast-iron reality of a steam engine"[1] and, secondly, its foundations were laid during a historical period when the atomic nature of matter was pure conjecture and storage of energy in chemical bonds a very hazy concept. As late as 1900, theorists as eminent as Ernst Mach and Friedrich Ostwald (another Nobel Laureate) believed that the atom was a mental construct or, at best, a provisional model. In Mach's opinion, the atom, which now we can see, thanks to the electron scanning microscope, was "no more than a mathematical fiction,"

Energy management theory has never fully taken into account the revolution in physics that has followed from the new understanding of the atom built up around the turn of the 19th century in a burst of creative experimental and theoretical physics, and later to be enriched through cosmology. The commonsense observation that energy is heat and is produced by burning fuel is still mainstream in energy management, and only slowly giving way to the realisation that unlimited energy is there for the taking in the sun and wind, that it can be supplemented by using energy to release the energy of phase change and break subatomic bonds. Molecular bonds are broken in burning fossil fuel and atomic bonds in nuclear fission, but nuclear fusion is an anomaly insofar as it produces an excess of energy by rearranging subatomic bonds more economically. It is perhaps worth mentioning that the Large Hadron Collider at CERN, which is ostensibly seeking to find the so-called "God particle", can equally be seen as a search for the ultimate bond, the breaking of a primeval symmetry which released all the energy in the cosmos.

The broad relevance of this to microgeneration is that it starts the theoretician thinking about the nature of energy in a different way, and once this process has begun, a theoretical leap forward is made possible. The emphasis on energy science shifts to factors such as phase change energy, energy density and activational (or activation) energy. I have earlier suggested that the latter term, which was coined by Arrhenius, might perhaps be better understood as trigger energy, for this would make clearer that energy management is at certain points critically dependent on the controlled use of small amounts of energy to release larger amounts of potential energy. The broad point may be briefly illustrated by pointing to the way in which the slight pressure of a finger on the trigger of a pistol is both capable of releasing chemical energy in the cordite and necessary to make it happen. At the level of particle accelerators, by contrast, trigger energy is what the engineering is all about: an enormous amount of electromagnetic energy is required to release the even more enormous binding energy of subatomic particles. There were, indeed, fears at one time that the latter would be so great that it might trigger a nuclear chain reaction that would engulf the world. At the level of domestic energy, the significance of using small amounts of energy to release larger amounts has been illustrated in the heat pump, which apparently produces something for nothing by compressing a refrigerant and then allowing it to decompress in order to release the phase change energy locked into the vapour state. The heat pump does not, as most manuals say, extract or transfer heat energy from a ground or air source, and this inaccuracy is just one example of ambiguous theory which fogs vision in energy management.

At a deeper theoretical level creative thinking in microgeneration will call for improvements in dimensional analysis, for theory has inherited a muddled taxonomy and a multiplicity of units, only partly harmonised. The taxonomic muddle at the base of thermodynamics can be appreciated when one considers that *energy* is often used loosely and interchangeably with *tension* and *pressure*, which have no time-dimension, and *power* and *action*, which have. In different contexts all four terms tend also in practice to be taken as synonymous with *force,* and *impulse*. Energy, unqualified, is variously manifested in *potential, kinetic, chemical, thermal, magnetic* and *electrical* form. All of these can be transformed into each other, except potential energy, which is completely anomalous, since it is not transformed but actualized or released. However, the reality that "lies beneath" these forms – i.e., what it is that is being transformed – is rarely, if ever, a subject for discussion. We have no unit for energy *per se*. While systematics, the science of classification, is being vigorously debated in biology, it is largely undeveloped in thermodynamics, which continues to use contradictory, overlapping and often outworn categories, such as horsepower.

The problems of dimensional analysis exist at several levels in energy management, one of them as a practical irritation in the continued use of the Fahrenheit scale and British thermal units in much of the American literature, the USA along with Burma and Liberia being the only countries still holding out against implementing the international agreement in 1960 to make SI units standard. At a deeper level there is opacity, redundancy and limited convertibility in many of the SI units - joules, watts, volts, coulombs, pascals, gauss, teslas and calories, for example, all used to quantify energy equivalence. David MacKay's invaluable source book *Sustainable Energy* is to be praised for deliberately reducing all power units to kilowatt-hours (kWh)in order to simplify comparisons, but it may be that a further stage of unification is desirable, not simply to tidy up the theory but to make the whole concept of energy-in-itself more understandable. It is by no means clear, for instance, how one can equate wind energy in hectopascals with solar energy in watts.

Of all the historical insights into the nature of energy, the fact that it can be transformed is surely the most fundamental and the most fruitful. Count Rumford's address to the Royal Society in 1798, when he gave experimental justification for this principle, may be taken to mark the birth of a unified science of thermodynamics, since it opened the way to integrate all the disconnected knowledge about energy that had emerged and was still to emerge from steam engineering. It could, indeed, be argued that in the history of science Rumford's insight into the transformability of energy was as epoch-making as Copernicus's theory of a heliocentric universe. Its full significance has not yet been realised, however, because energy has been equated with work, and thus thermodynamics became the science of heat energy and useful energy and its direction was set by the need to understand entropic loss. "Work" and "entropy" have become in effect mental blockages in renewable energy management and the reasons for this are not hard to find. In a word, we are dealing not with cyclical processes and expensive fuel but with what is in effect a flow, steady or intermittent, from energy sources that are effectively unlimited and free and which must be converted either to heat or electricity, transmitted and stored. The document has emphasized throughout, but it bears repeating, that it is these goals, not fuel efficiency, which constitute the engineering challenge.

Thermodynamics was a late arrival on the scientific scene, emerging nearly two centuries after science had been defined by Galileo and Newton as the study of moving bodies. Influenced by Aristotle's metaphysics, heat was for a long time classified by theoreticians as a substance, a mysterious, aetheric fluid that was given the label of *caloric*, in contrast to cold, which was called *frigoric.* There was lively debate as to whether frigoric actually existed or was simply a lack of caloric. (One can add heat to a room, but can one add cold?) The two giants of the science of thermodynamics are Sadi Carnot and Rudolf Clausius and their seminal insights laid the foundation on which the science of energy was to build, but with effects that are now becoming so contradictory as to warrant a relaying of the foundations by an international body, such as that which was convened to make SI units a global standard. Carnot's ground-breaking work *On the Motive Power of Fire* (1825), which assumed that heat was a caloric fluid, determined the course of thermodynamics by focusing on the efficiency of the steam engine, partly to increase the power-weight ratio but also for the very practical purpose of saving coal. Efficiency is, of course, an essential factor in microgeneration, but calls for a different approach. What can be retained from Carnot is his insight that the absolute limit of efficiency in any engine was determined by the difference in temperature between the heat input and the cold sink into which waste heat was exhausted. At the time this must have seemed like a secondary principle, since attention was focused on extracting more energy from coal, but it is, in fact, a vitally important principle when looking at the wider field of energy management. Its wider significance is obscured by the fact that energy can be said to lie in heat, which distracts attention from the equally important fact that energy is either released or demanded when a temperature or pressure or gravitational differential is either equalized or created.

This principle lies at the heart of renewable energy management and is so fundamental to a universal theory of energy that it calls for an identifying name, for which Return to Equilibrium (RTE) would be appropriate. All that will be noted at this point is that if energy is released by a return to equilibrium, a quite different criterion is established from the conventional and commonsense assumption that heat is energy and lack of heat is lack of energy. This criterion of RTE has long been applied in engineering but its significance goes strangely unnoticed for the main part. Most people, and perhaps even first year engineering students, would be puzzled to see a model Stirling engine running on ice cubes and even faster on solid carbon dioxide. The natural and naïve response is to wonder how an engine can be driven by cold rather than heat.

While commonsense assures us that a hot cup of tea will inevitably become cold, but not vice versa, the RTE principle recognizes that the tea cools as it seeks an equilibrium with the ambient temperature. In a closed system cold becomes hot just as spontaneously as hot becomes cold, as the system seeks equilibrium. Thus a glass of hot water in a perfectly insulated box (i.e., a closed system) will modify the internal temperature until the whole system reaches a point of stasis (or what might be called thermal inertia) but, equally, a glass of cold water will warm up as it finds the same equilibrium point. In line with Newton's third law of motion - that for every force there is an equal and opposite reaction - energy must be applied to create a disequilibrium of temperature *in either direction* in the first place. Once applied, energy is potentiated in the dis-equilibrium state and is released or actualized as the system is allowed to find equilibrium.

Put more concretely, it needs as much energy to turn ice into water as water into ice. This is by no means a trivial statement, since it calls for a rethink of the whole notion of entropic degeneration, which is at the heart of the current energy paradigm, and introduces as an alternative principle that spontaneous change is the effect of equilibrium seeking. It questions the dogmatic statement of Sir Arthur Eddington, earlier quoted, that "the law that entropy always increases … holds the supreme position among the laws of nature," and pushes theory towards a deeper understanding of closed and open systems. From the point of view of energy and human existence, our planet is not a closed system, for it is constantly being fed by solar radiation and radiates heat back into space: it a perfect example of a dynamic system in steady state, now being unbalanced by atmospheric pollution caused by humans. From the point of view of human population, the planet is, alarmingly, a closed system, but closer examination of the problem of catastrophic overpopulation reveals that its solution is inseparable from a sustainable energy policy worldwide.

Entropy Revisited

Building on Carnot's work, Clausius published in 1875 *The Mechanical Theory of Heat* and, still equating energy with heat for practical purposes, invented the term *entropy* to indicate the concept of wasted heat. This key idea of degraded and unusable heat, along with the emphasis on useful energy as work, have had the most far-reaching consequences for thermodynamics, so much so that Ostwald could state without fear of contradiction, "Energy is anything that comes from or can be converted back to work." It would, in fact, be hard to find a dictionary of science today that does not repeat this in different words. Theory therefore became inseparable from fuel efficiency, although, as the quotation from Percy Bridgman at the head of this chapter makes clear, the laws of nature are surely not determined by what is useful to the human species. With the search for renewable energy theory takes a new direction, since the three main sources, namely sun, wind and falling water are not fuels in the normal sense and are all "free". Furthermore, since most of the energy requirement of a house is for heat – space heating, hot water, cooking, ironing - the concept of "unusable heat" becomes ambiguous. Waste heat is not what is left over from work but concerns periodic over-production and the need for dump-load technology. With microgeneration the quest for efficiency shifts from entropic to parasitic and standing loss – that is, to reducing losses from friction and heat dissipation in the process of collecting and storing energy.

The search for maximum work and minimum entropy was right for its time: it not only focused attention on the efficient use of fuel, but led to great advances in engineering in many fields, from bearing and lubrication technology to the double condensing boiler. Understanding entropy became the driving force of the science of thermodynamics. Gibbs extended the concept of entropy from engines into chemical reactions, Boltzman into the atomic microstructure of heat systems, [2] and Shannon and Brillouin carried it over into communications theory, using Gibbs' equations to explain signal decay.[3] This only served, however, to add to the confusion about the nature of energy, since entropy of information has an inescapably subjective dimension, and this line of thought was pursued by the physicist E. T. Jaynes, who proposed in a wide-ranging historical review paper [4] that modelling entropic decay is a particular example of Bayesian logic. What began as hardly more than a rule of thumb for steam engineers slowly morphed into what the science writer Denis Overbye could call "one of the most fabled and mystical principles in science."[5]

Despite its now almost religious, and unquestionable, status, one can hardly escape the conclusion that the protean idea of entropy, which drove thermodynamics through its formative years has become too elastic to be of much further use, certainly in microgeneration. Percy Bridgman, made this point in different words (and rather ungrammatically), "There's as many formulations of the second law as there have been discussions of it."[6] Ironically, Jaynes' magisterial paper argues exactly the opposite, that it is the very generality of the concept of entropy which makes it so scientifically significant. Against that it must be said that life, and thus biology, the science of life, depend upon the law of entropy apparently being suspended, since living organisms create order and complexity "spontaneously", a word which will call for closer examination below. So looking at science as a whole, it can be said that the law of entropy is anything but universal, and a few mavericks, notably perhaps the mathematician Luigi Fantappie, the all-round futurist Buckminster Fuller and the pioneering physiologist Albert Szent-Georgy have tried to find a more balanced view, each independently inventing an opposite term *syntropy* to replace the standard term *negentropy*. This is the familiar contraction of the term *negative entropy* coined by Erwin Schroedinger in his famous book *What is Life?* to retain the centrality in science of the law of entropy, and is as logical as referring to life as "non-death". The mental contortions to which he was reduced by classical energy theory are well illustrated in his description of life as the amount of order that an organism "sucks from its environment."[7] Notwithstanding Schroedinger's eminence and his contributions to physics, such a bizarre statement is not only non-scientific but anti-scientific, and is an indicator of a paradigm in terminal crisis.

The strangely energetic nature of entropic decay is well exemplified in Clausius's explanation, "the entropy of the universe strives [*strebt*] to find a maximum value." We may be uncomfortable with his anthropomorphic term, but it is difficult to find a clinically scientific replacement. In another place, he stated the principle as, "Heat does not pass from a body at low temperature to one at high temperature without an accompanying change elsewhere" and it is the inspired vagueness of the underlined phrase which now needs to be clarified. Clausius's "accompanying change" is a tacit qualification "in a closed system", but the concept of closed system has an illusory clarity, and the reality is very tricky to find or create in real life. Alternatively, his phrase can be taken to mean "without applying energy to take a system from or return it to its ground state." Microgeneration tends naturally to see the world of energy as an open system, not as a closed system running down to uselessness.

From this perspective, it is natural see energy flow not as a spontaneous transition from hot to cold or ordered to disordered, but as a process in which the energetic system seeks (or strives, to use Clausius's term) toward an equilibrium or ground state, releasing energy in so doing. A metastable system in a far from equilibrium state has an excess of energy and is nearing its limits to contain it. Metastability is a concept never far from E-plus theory, for it is a condition that requires a minimum of trigger energy to release an excess. This may be quickly illustrated in the way that a container of supersaturated brine will transition almost instantaneously to a new ground state (of water and crystalline salt) by dropping in a grain of sand or even by giving a slight tap to the container. The energy required to trigger a phase change is far less than the energy which is released when it transitions.

The principle of Return to Equilibrium is not new and is essentially a clarification of the principle of least action, first stated by Maupertuis, as early as 1740. It is clearly implicit in Tesla's proposal for what he called a "self-acting engine" where he explicitly denies the universality of the law of entropy.[8] It appears again in Le Chatelier's principle about 1900. Max Planck dedicated one of his Columbia lectures to it, asserting that in "a unified system of theoretical physics … it is self evident that the principle of least action will be called upon to play the principal role" and is "the foundation for general dynamics."[9] The common element in all these versions lies in the dynamic nature of the least energy configuration, which is a rather mysterious fact of nature. To take a very simple example, a globule of water will always tend towards the spherical, absent other forces that would distort it. This may seem at first obvious, but its obviousness is akin to that of the falling apple which inspired Newton to wonder why it always fell downward and never sideways. [10]

Problems with the Four Laws of Thermodynamics

The four laws of thermodynamics begin not with the first but with the so-called zeroth law. This odd nomenclature is a perfect example of the way in which the laws have been cobbled together in an *ad hoc* way. Every one of them is now open to radical questioning as regards their universality and internal coherence.

Very briefly, the four laws are as follows:

<u>The Zeroth Law</u>

> **if A is in thermal equilibrium with B, and B is in thermal equilibrium with C, then C will be in thermal equilibrium with A.**

Otherwise expressed, the total system will not necessarily go from hot to cold but will seek temperature equilibrium in either direction. Note that this statement of a law of static and logical equilibrium is a shuffling move in the direction of the dynamic law of RTE.

<u>The First Law</u>

> **Energy can neither be created nor destroyed, only transformed.**

Obvious as this may seem, energy does exist, and therefore in its present state must either have been created or transformed from some other state or existed from eternity, whatever "eternity" might mean in a scientific context. Although the energy of consciousness is a concept without relevance to energy management, a comprehensive science of energy must eventually give an account of it, as Schroedinger spectacularly failed to do in *What is Life?* [11]

<u>The Second Law</u>

has been expressed in several quite confusing ways, as the quotation from Bridgman above notes. Kelvin's version is probably the most neutral and does not mention entropy:

> **No cyclic process is possible in which heat is taken from a hot source and converted completely into work.**

This explicitly relates the law to "work", a concept of which nature knows nothing, but ignores the critical factor which Carnot recognized, that "heat" is a relative term and "hot source" is never separable in engineering from "cold sink". In his *Four Laws that Drive the Universe* Peter Atkins defines entropy in one place as "a measure of the 'quality' of the stored energy" of a fuel or system, and makes the seemingly innocuous assertion that:

> **The entropy of the universe increases in the course of any spontaneous change.**

Leave aside the unscientific measure of "quality", even when in quotes, the devil is in the innocent word "spontaneous", for on reflection it is seen to mean "without cause" or perhaps "without known cause", just as once scientists puzzled over the spontaneous combustion of oily rags. At issue is a metascientific issue of the first order, namely, can any change happen without prior cause? A science in which things really do happen spontaneously would be a science where the law of cause and effect was optional, where magic ruled and, in a word, anti-science. In cosmological physics this sad state of affairs is concealed in various ways, notably by positing an uncaused quantum fluctuation as the trigger which set our expanding universe in motion, by statistical sleight of hand in which random events give a new definition to causality and, of course, in renormalisation when required, which Feynman, the inventor, called "dippy" and which has been called more bluntly a "dirty business". [12]

The Third Law

Sometimes called the Nernst theorem, is of a different kind from the others and Atkins notes that "some have argued that it is not a law of thermodynamics at all." [13]. To the contrary, it could be argued that it is the most significant law of all, for it tells both theorist and practising engineer a non-obvious fact that is of the utmost importance both in understanding energy and inventing energy-amplifying machines.

No finite sequence of cyclic processes can succeed in cooling a body to absolute zero.

Given that only cryogenic specialists are likely to have any professional interest in trying to approach absolute zero, it may hardly seem to be of relevance in the context of energy management, but within it lies the wider implication that if, as Nernst argued, the last step in using energy to force down temperature to absolute zero cannot be made, there is plausibly the need for increasing expenditure of energy as the temperature of any system is pushed further from equilibrium. This is of practical value in telling the engineer that there will come a point where heating a hot source or cooling a cold sink (or vice versa) in the cause of energy generation will become counter-productive, as more and more input energy will be required for each incremental increase in output. As a concrete example, a highly efficient Stirling engine could be imagined where the difference in temperature between heat source and cold sink (or cold source and heat sink) is maximized by using refrigeration technology, but at some point more energy would be expended in cooling the cold side than would be obtainable from the engine.

Once absolute zero is brought into the picture, a fourth law of thermodynamics should logically be added, which would deal with absolute maximum temperature. This law already exists in the form of the Sakharov limit but has never captured the imagination in the way that the quest for absolute zero has done. Sakharov's work on nuclear fusion led him to estimate an absolute maximum temperature of about 10^{32} degrees K. The logic underlying his conclusion derives from the temperature of photons with a wavelength at the Planck limit of 10^{-35} metres. At this point space-time breaks down, and physical theory descends into vague notions about quantum foam. Other theorists using different criteria have placed the upper limit at between 10^{11} and 10^{12} ° K. [14] The point here is simply that confronting the problem of absolute maximum temperature would make a start on tidying up the laws of energy science and, hopefully, initiate a long overdue debate. That such a tidying up is becoming urgent may be gauged from the fact that there are a dozen other proposals for a fourth law of thermodynamics, most of which are implicitly seeking to crack the problem of life and entropy that eluded Schroedinger, some taking half a step towards a general theory based on energy equilibrium, rather than, or as well as, entropy. Typical is the following, which claims to subsume the zeroth, first and second laws of thermodynamics: "When an isolated system performs a process, after the removal of a series of internal constraints, it will always reach a unique state of equilibrium … characterized by a maximum value of entropy."[15]

The relevance of these brief historical notes and speculations to the E-plus house concept lies in two overarching perceptions that open up a creative new approach to microgeneration, in that the engineering challenge is now seen to be not how to extract work from heat but (1) how to harness differentials of various kinds most efficiently – in temperature, wind, barometric pressure and gravitational head – and (2) how to harness the potential of phase change, as in heat pump and heat storage technology. A large part of the design engineer's work would thus be to identify, and indeed to artificially create, these sources of differential and phase change energy release. This kind of research is at the heart of the E-plus project. It is not an add-on to conventional engineering but a revolution in the whole concept of energy management that will need time to appreciate and will doubtless be resisted because of its novelty. Initial resistance may be lessened perhaps by observing the classical "Atmos" clock, which runs with the appearance of perpetual motion by utilizing minute changes in temperature differential or, as earlier noted, pondering on how a Stirling engine can run on an ice cube, so long as the ambient temperature is greater or less than zero Celsius.

Reviving Energetics

There have been three historical attempts to create a science of energetics, as distinct from thermodynamics. Although they differ in many ways, the critical similarity is that all saw a challenge to understand and systematize the transformation and storage of energy in its various forms. In 1853 William Rankine (who also proposed a science of engineering) delivered a paper to the Glasgow Philosophical Society with the very specific title "The Science of Energetics", the principles of which had grown out of his pioneering work in external combustion engines. Although energy was clearly in some sense related to work, Rankine was the first to notice the anomalous nature of potential energy, and, in fact, invented the term. Coming from a quite different direction, George Helm, a physicist, published in Germany *The Doctrine of Energy* in 1887 and Wilhelm Ostwald (a founding father of physical chemistry and creator of the Ostwald colour chart) carried on the campaign to replace what Helm had called "classical thermodynamics" with a whole new science, to be called energetics. Although largely forgotten today, there was a ferment of debate during this period about the whole nature of science, as it struggled to incorporate radical new concepts into the natural philosophy in which it was rooted. The very word "scientist", invented by William Whewell in 1834,[16] to replace "natural philosopher", was at first resisted, and a flavour of the opposition to it may be caught in the fact that James Maxwell said he preferred to be called an "electrician". While Maxwell, saw the future of natural philosophy in electromagnetism and field theory physics, Rankine, Helm and Ostwald saw it in deeper understanding of the significance of energy. Energetics was to be, in Helm's words, "a great reorientation in the human understanding of natural events" and Ostwald saw in it a unifying and organizing principle for natural philosophy, a new system of measurement and, significantly, a new interpretation of entropy. Ostwald believed that science should be centred not on matter in motion but on energy in transformation. Unfortunately, as noted earlier, he did not believe that atoms really existed, let alone subatomic particles, so it is obvious today that his dream of a new kind of science would prove abortive. He did come to accept atomism before he died, in 1932, but long before then the growing wave of enthusiasm for energetics had been overtaken by exciting new discoveries about matter through particle physics, by the radical (and now hypertrophied) development of mathematical modelling, by Einsteinian relativity and the new scientific continent of an expanding cosmos. With the exception of the last mentioned, all these new waves have run their course, and there is a general feeling of crisis in science, assuaged only by the wistful hope of finding the ultimate particle in the Higgs boson. [17]

Now, surely, is the time for a science of energetics to be re-examined and for the best metascientific brains to engage on constructing it. In one sense history would then be repeating itself, since the theory will have grown out of practical engineering, or at least be symbiotic with it. For just as classical thermodynamics grew out of the reality of the steam engine and an understanding of energy as contained in fossil fuels and converted into work, energetics is envisaged as a new understanding of energy as revealed in the effectively unlimited resources of "natural", renewable energy, plus a growing new role for chemical engineering. It seems worthwhile to present some initial suggestions as to the laws and hypotheses that a new science of energetics might embrace, and the following suggestions are presented as starting points for discussion. The RTE principle on which all hinges is in direct contradiction to the principle of entropy as enshrined in the current laws of energy and will thus come up against kneejerk rejection by most professionals, who cannot imagine change at this fundamental level of understanding. The history of science, like religion, is replete with examples of the most violent resistance to ideas which call for abandonment of long held assumptions and dispassionate examination of the new on its own merits is an ideal rarely found in practice. In this situation, it is worth repeating the words of Louis de Broglie in his ground-breaking thesis about the nature of the electron, "My hypothesis is worth what every hypothesis is worth and that is as much as the consequences that can be deduced from it."

Proposed Draft Framework of Principles for a Science of Energetics

Laws

- A closed energetic system spontaneously seeks equilibrium.
- Energy is needed to drive a system from an equilibrium or ground state.
- As a system departs from equilibrium, increasing amounts of energy are required to drive the process to the limits.
- State change either requires or releases energy.
- The cosmos is a system in process of adiabatic expansion.
- The lower and upper limits of the cosmos as a thermal energy system are zero degrees Kelvin and 10^{-36} degrees Kelvin.
- The increase in energy required to take an energetic system from its ground state to its limits is an exponential function.

Taxonomy

- The two most fundamental categories of energy are time-free and time-functional.
- Potential energy is time-free
- Planck's quantum is time-free.
- Planck's quantum of action [h bar] is time-bound.

Axioms

- The cosmos is an open system.
- Consciousness is a form of energy.

It should be emphasized that this is a primitive sorting of some initial facts and conjectures, merely to give a broad picture of the task involved. That the cosmos is an adiabatic system is really a perspective, rather than a law, and the first of the two items listed as axioms is at this point an act of faith. The second axiom would be hotly contested by many scientists, even though it is empirically clear that a state of consciousness creates chemicals in the brain and an act of will is required to trigger the electro-chemical sequence that result in my lifting a mug of coffee. There is a wider issue regarding the nature of scientific proof, particularly as regards predictiveness, vulnerability and systemic coherence. While such matters may be of no relevance to the practical engineer, they are a necessary framework of understanding for a genuine science of engineering such as Rankine envisaged. A wrong understanding at this level must necessarily inhibit insight.

References

1. Peter Atkins, *Four Laws that Drive the Universe.* OUP, 2007. p. 50.

2. The danger of using statistical models, such as Boltzmann proposed, is that they ultimately destroy the directionality of entropy, and thus the concept itself. Poincaré's recurrence theorem was to reveal mathematically the paradox that an ideal heat system (like a box of gas) will sooner or later find a no-entropy state, however improbably, as it transitions through all possibilities, just as a perfect hand at bridge will eventually turn up if the cards are dealt often enough.

3. John von Neumann advised Claude Shannon to use the term *entropy* for signal decay, because "nobody knows what entropy really is, so in a debate you will always have the advantage." The deliberate obfuscation was to deflect attention from the impossibility of defining information with scientific rigour.

4. E. T. Jaynes, "The Evolution of Carnot's Principle". Paper delivered at EMBO (European Molecular Biology Organisation) 1988. Available in PDF on the Internet. Jaynes' enthusiasm for entropy as a universal type of explanation is seen also in his 1991 paper "How Should We Use Entropy in Economics" (modestly subtitled "Some half-baked ideas in need of criticism") also in PDF. His ideas had actually been largely anticipated twenty years earlier by Nicholas Georgescu-Roegen, in *The Entropy Law and the Economic Process* (Harvard UP, 1971).

5. Denis Overybye, *Einstein in Love*. London: Bloomsbury, 2001. p.8.

6. Percy Bridgman, *The Nature of Thermodynamics*. NY: Torchbooks, 1961 [1941] p. 20.

7. Erwin Schroedinger, *What is Life*? Cambridge:CUP, 1944. Chap 6, pp. 67-75.

8. Nikola Tesla, "The Problems of Increasing Human Energy", *The Century Illustrated Monthly Magazine*, June 1900.

9. Max Planck, *Eight Lectures on Theoretical Physics.* (trans. A.P. Wills) Mineola, NY:Dover Publications, 1998. p.99. First published by Columbia University Press in 1909.

10. What force brings about a least energy configuration is puzzling, but it would seem at least possible that nature seeks return to a ground state of less than three dimensions, and from that premise one may deduce that the force of gravity (and the cosmological constant) may ultimately be found to be an equal and opposite force seeking return to an original equilibrium point from which it was disturbed in the Big Bang. If so, that would spell an end to Einsteinian orthodoxy.

11. It is a measure of the confusion surrounding the principle of entropy that Schroedinger's "negative entropy" can be dismissed by a competent judge as "suspiciously like a kind of vitalism dressed up as thermodynamics." (Philip Ball, a consultant editor of 'Nature', in *Molecules: A Short Introduction*. OUP, 2003. p. 74.) Yet in the same breath he offers his own explanation of life as "pumping out entropy into your environment." It is impossible to deal rationally with this kind of handwaving in lieu of reasoned explanation. It is the latter day equivalent of the emperor's new clothes.

12. Timothy Ferris, *The Whole Shebang: A State of the Universe Report*. NY: Simon & Schuster, 1997. p.15.

13. Atkins, *op. cit*., pp. 99 & 111.

14. See, e.g., D. C. Kelly, Y. Rocard, in P. Perrot, *A to Z of Thermodynamics* (Dictionary). OUP, 1998.

15. G. Hatsopoulos and J. Keenan, *Principles of General Thermodynamics*. NY: Wiley, 1965.

16. The Oxford English Dictionary dates the invention of "scientist" to 1834 and of "physicist", another of Whewell's neologisms, to 1840. Whewell's two great works in metascience, *History of the Inductive Sciences* (3 vols.) and *The Philosophy of the Inductive Sciences* appeared in 1837 and 1840.

17. These sweeping generalisations call for extensive justification. There is a growing literature on the need for a revolution in the way that science, and particularly physics, is defined and practised. Three of a score or more of books opening up the debate are David Lindley's *The End of Physics: The Myth of a Unified Theory* (London: Basic Books, 1994), Lee Smolin's *The Trouble with Physics* (NY: Houghton Mifflin, 2006) and Peter Woit's *Not Even Wrong* (London: Vintage, 2007).