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Energy

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I. E and Energy: a necessary distinction

The afterglow from the death cloud over Hiroshima on August 6, 1945 remains a frightful reminder of the link between modern science and technology. Nevertheless, the distinction between scientific abstractions and their popularizations remains obscure. For instance, what the physicist scribbles as E on his chalkboard has little in common with "energy" when mouthed by economists, politicians or athletes. Energy has a precise denotation as a scientific term. For example, in the formula $E=MC^2$, E denotes the quantity released by the disintegration of a quantity of matter multiplied by the square of the velocity of light. Although this statement is scientifically correct, it is also perplexing. Modern science is characterized by theories formulated in mathematics and tested through experiments. But neither mathematical constructs nor controlled experiments are the stuff of everyday experience (Dear 1995). After all, who ordinarily experiences the velocity of light! To avoid perplexity, we have had to distinguish E from "energy." This distinction is necessary to grasp how the popularization of E as "energy," confounds what is scientifically certain about things with what is good for people. It is this confusion that contributes, for example, to the transmogrification of a formula from physics into a recipe for extermination.

II. E: a brief history

The history of modern science has been marked by a controversy over whether mathematics or experiments is more decisive to scientific knowledge. This conflict between "mathematical constructivism" and "experimenticism" was central to the development of E as a scientific fact and particularly spirited among German scientists (Holton 1973, pp. 275-280). Therefore, we trace the history of E in the footsteps of German thinkers, despite the important contributions of both French and English scientists (see, Smith 1990).

Since the late 18th century, the practical concern with steam engines, voltaic cells and other technical devices had prompted engineers and scientists to experiment with a variety of conversion processes. In 1842, **Julius Robert Mayer** calculated the caloric equivalent of mechanical work. Though his result was purely theoretical, he pretended to have obtained it from experiments (Mayer, 1842). According to Mayer, nature converted mechanical work into heat and vice versa at an exchange rate of 365 (modern value 423,8) kilogram-meters for one kilocalorie. By this he meant that lifting a weight of one kilogram to a height of 365 meters required the same Kraft or "force" as raising the temperature of one liter of water by 1^0C. This Kraft was the conceptual precursor of E that, therefore, in its first appearance as a scientific term denoted the quantitative equivalence between physiological heat and mechanical work (Hiebert, 1962; Elkana, 1974).

By the mid 19th century, it was experimentally well established that such physical phenomena as electricity, heat, electromagnetism, and even light were inter-convertible at determinate rates of exchange (Kuhn, 1955). Through experiments and calculations, scientists had established the commensurability of previously incomparable phenomena. To German scientists in particular, the fixed rates of exchange governing the conversion of diverse phenomena suggested the existence of a single underlying substance. They postulated a meta-physical quantity behind physical manifestations in nature and named this quantity Arbeitskraft, literally, "workforce." **Hermann von Helmholtz** (1847) offered a succinct formulation of this "capacity for work" that scientists imputed to nature. In what came to be known as the first law of thermodynamics, he announced that Arbeitskraft can neither be created nor destroyed. The "workforce" of Helmholtz was none other than what William Thompson called "energy" in 1849 when he wrote, "Nothing can be lost in the operations of nature—no energy can be destroyed." So enshrined in the "law of energy conservation," E denoted an unknowable substance manifest in the transformations of matter and measurable in units of work. It is no wonder that at least one philosopher would refer to the law of energy conservation as the exemplar of the "transcendental materialism" that seems to have beset most 19th century scientific thought (Bachelard 1984).

Rudolf Clausius (1850) complemented the first law of thermodynamics with a second law founded on the notion of entropy. Without violating the law of energy conservation, Clausius noted a distinction between the quantity and "quality" of E. The "quality" of E referred to the reduction in the usefulness of E through successive conversions. For example, less then 30% of heat can be converted to work in a motor, and friction exacts besides a net loss that cannot be recouped. Clausius therefore argued that though E remains constant, entropy always increases. That is, while the quantity of E remains fixed in total, nature's "capacity to do work" constantly decreases. The steady and irrecoverable increase in entropy implied that E would finally, at the end of time, take the form of undifferentiated heat. Accordingly, in the years after Clausius, the scientific notion of heat shed every remaining bond with the commonly experienced primal element "fire." Instead, heat was reduced to the kinetic energy of theoretically postulated particles. By classifying populations of these particles — gases-- by a distribution curve of their speed, physics introduced statistics into the scientific description of phenomena. The kinetic theory of heat and the ensuing rise of statistical mechanics thereby widened the gap between physics and everyday experience into a chasm.

Since the 17th century, physicists have dreamt of a unified theory of everything instead of accepting the existence of incommensurable domains of experience (Weinberg 1997). Theoretical unity requires consistency, or the absence of contradictions among the different branches of physics. The drive towards a unified scientific theory of nature relies on the mutual provocation of mathematically formulated theories and controlled experiments, both of which deny or denigrate ordinary experience. The development of E is testimony to this scientific dream. The first formulations of E had not only erased conceptual distinctions, such as between "force" and "mechanical work." They also desiccated common experience by, for example, extricating the hotness from heat. By the mid 19th century, E did serve to theoretically, if temporarily, unify physics. To overcome every inconsistency since then, the unity of physics was re-established by replacing conceptual distinctions rooted in common sense with uncommon assumptions. In the next phase of the development of E as a scientific fact, this aspect would become particularly pronounced.

In 1854, the mathematician and amateur physicist **Bernhard Riemann** demanded that scientific theories be established on new mathematical foundations: on "a new frame for the known natural laws." Such a framework, he argued, would comprise interconnected concepts including "...some (that) would be deprived of any force of representation" (Riemann, 1876). Accordingly, Riemann constructed a non-Euclidean ("curved") four-dimensional manifold wherein space and time were axiomatically fused into an insensible "here-now"; a key to the future twists of E (Riemann 1854). Historically moreover, Riemann was the first to recommend misplaced concreteness as a goal of scientific theorizing in stating that his hypothetical geometry would "...make future perceptions necessary and even allow us to predict them and determine their probability" (Riemann 1876, p. 488). He thus foresaw the "synthetic perceptions" that would mushroom in the wake of scientific constructs uprooted from daily experience. And indeed, E has leaked outside the laboratory as "energy," conferring a misplaced concreteness to quasi-scientific abstractions. From "energy bars" to "energy taxes," the word "energy" seems to beget all manner of synthetic or pseudo-perceptions. It is as if the proliferation of "energy" compensates for the sensual vacuity of E.

Riemann's claims and proposals did not go unchallenged. The physicist **Ernst Mach** insisted a contrario that physics ought to be grounded in sensations; the real "elements" of experience (Mach, 1959). Countering Riemann's essay on "the hypotheses that are at the base of Geometry" (Riemann, 1854), the "Bismarck of Physics," Helmholtz, emphasized "the facts that are at the base of Geometry" (Helmholtz, 1876). **Heinrich Hertz**, Helmholtz's pupil, proposed to recover the primacy of experimentation over abstract theorization in physics by purging it of all "metaphysical assumptions," starting with E (Hertz, 1894). Yet, none of these attempts to discipline theoretical speculations by controlled experiments could solve the growing antinomy within physics.

By 1900, physics was split between the classical mechanics of macroscopic bodies and the new mechanics of sub-microscopic particles and waves, particularly optics, understood as a branch of electrodynamics. The two domains obeyed different laws. For instance, the classical additivity of speeds did not apply to optics: whereas the speed of a bullet shot from a train in the direction of its motion is increased by the speed of the train, the speed of a beam of light similarly thrown is unaffected by it. **Albert Einstein** (1905) saved the appearances by invoking Galileo's relativity principle, which states that motion can never be detected by intrinsic measurements; that is, from within the moving body. However, in order to restore the unity of the laws of physics, he had to abandon the classical notions of universal simultaneity (everything that occurs now from my perspective, occurs now everywhere); of the invariance of the mass in motion (the mass of a moving body remains the same at every speed); and of the geometric congruence of bodies in relative motions (the distance between any two points of a solid body in motion measured from any other body, and hence its shape, is constant). To escape these "intuitive" postulates of classical physics that were contradicted by electrodynamics, he required a frame in which simultaneity was relative to a particular observer's position, and in which mass, length and time were dependent on velocity. Riemann's mathematically constructed curved "space-time" fit the bill precisely. With it, Einstein was able to formulate an "energy-momentum tensor" according to which mass and energy were inter-convertible. To state that $E= MC^2$, implies that E and mass have an exchange rate. Yet, the E of Mayer is not the E of Einstein. For Mayer, E was a measurable principle of the equivalence between heat and work. For Einstein, E and mass were equivalent by construction. If Riemann's space-time were a looking glass, then Einstein's E was its lens. It is in this sense that mathematical constructs "are free creations of the human mind, and are not, however it may seem, uniquely determined by the external world" (Einstein and Infeld, 1938, p.33). Yet, "the external world" can and has been reshaped by such "freely created" constructs. It remains an intriguing chapter in the history of physics that it was partly the conflict between mathematical constructivism and experimenticism that spurred the Americans on to building the first atom-bomb (see, Beyerchen, 1977, p. 159; Jungk 1970; Frayn 2000).

In summary, E started as a principle of equivalence between the phenomena of physiological heat and mechanical work. First forged as a bridge between incommensurable domains, E slowly but steadily shed any reference to everyday experience. The scientific elaboration of an insensible E occurred through the interplay of mathematically formulated theories and controlled experiments. Both mathematics and experiments are alien to everyday experience. The racist denigration of mathematical constructivism in the name of an experimental "Aryan physics," only cemented the confusion between experiments and experience. E escaped the laboratory and chalkboard as "energy;" itself an incitement to the pseudo-perceptions generated by scientific constructs. It is the resulting blindness to the distinction between E and "energy" that has also maimed moral judgments on the atomic bomb.

III. The Politics of Energy and Equity

It is ironic that William Rankine popularized "energy" as a scientific term in 1853 in the belief that energeia meant "work" in Greek. E was measured in units of work. Energeia designated a quality of action incomparable to any quantity. The ancient Greeks distinguished between three kinds of human activity: the repetitive labor of daily sustenance done by slaves; the endeavor of the craftsman oriented by an end distinct from the activity itself; and finally, action which is exemplified by the citizen's courage to actualize himself before others. Aristotle called this last class of human action, energeia -- pure actuality. Unlike slave work and the artist's craft, energeia exhausts itself in its performance. It referred to the always surprising intertwining of the living deed and spoken word expressed, for example, in song and dance (Arendt, 1958, p. 206-7). For Aristotle, politics was the supreme instance of energeia, since it reflected the feats of man qua man. As such, politics lay outside the category of means and ends and not only because the dispositions necessary to achieve it - the virtues- were themselves actualities. Thus, energeia referred to gratuitous and virtuous action beyond any calculus of exchange.

In contrast, both E and "energy" radically threaten the possibility of politics. Both carry the scientific disdain for conceptual distinctions rooted in everyday experience. For instance, Helmholtz asserted that E was the imponderable prime mover -- whether of invisible molecules under the bell curve, blood in the veins, or stars in the sky. Others indiscriminately applied the words "work," "duty" and "force" to steam-engines, pumps, workers and thunder. By such characteristic scientific disregard for sensible differences, Helmholtz and other scientists prepared the ground for "energy."

"Energy" is neither a concept nor an experience. Instead it functions as a fog that blurs the distinctions between nature and machines, living organisms and persons, mechanical work and human action. It was the misplaced concreteness generated by "energy" that: led Karl Marx to impute the capacity for labor to people (1887); fooled neo-classical economists into conserving utility as if it could neither be created nor destroyed (Mirowski 1989); seduced Sergei Podolinsky and his contemporary students to imagine nature as a primordial economy (see, Georgescu-Roegen 1971); prompted Stanley Jevons to think of coal as a scarce natural resource (1865); encouraged the chronometry of physical activities by Entienne-Jules Marey (1874), the scientific management of industrial work by Frederick Taylor (1911), and the time and motion studies of the homemaker by Lillian Gilbreth (1927). "Energy" fed fantasies of reorganizing society and reshaping individuals into efficient and productive things. Both capitalist and socialist regimes fell under the spell cast by "energy": neither denied that the unending growth in "energy slaves" was the road to freedom. Both ignored the fact people are reflected as mere "human motors" in the mirror of an energy slave (Rabinbach 1990).

By now this is taken-for-granted. That people have "energy needs" goes unquestioned, partly because "energy" has almost transformed society into a laboratory. Professionals of every stripe now offer competing ways to optimize the relation between "energy resources" and "energy needs." Such "energy policies" are blind to the truth that neither cars nor human motors can act politically. They perpetuate the scientific disregard for sensible differences and thereby deepen man's enslavement to his "energy" slaves. Man is no less enslaved whether the car runs on coal or hydrogen; whether the light bulb shines because of water or wind. Neither the technocrat nor the ecocrat can lessen man's slavishness as long as both cannot see the commonsense distinctions erased by "energy." It would a political act to stop looking at the wonderland that appears through "energy" glasses. To recover such a clear-eyed vision, one cannot do much better than to reread Illich (1973).

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