

Genesis and Development of a Scientific Fact: The Case of Energy¹

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When he asked me to write an article for the February Special, the editor, Michiel Schaeffer commented on some reactions elicited by the editorial of the 1992 issue. To make a point about the ambiguities facing alternative technologists, he had used the example of a little shoemaker. At the beginning of the story, the shoemaker had a bulb hanging from the ceiling of his shop for some light in evening hours and a three-phasic socket to power his sewing and polishing machines. Though the shoemaker did not specially care to investigate where the *energy* distributed to him by the Electric Power Works came from, he somehow knew like everybody else that it came from the aging nuclear plant whose frightening refrigeration towers were sometimes visible on the far horizon.

Here we have a small, “ecologically innocent” craftsman who is plugged, together with the worst industrial sinners, to one of the most hazardous forms of *energy* production. Isn't it as bad as an Amish farmer using no telephone, no car, but struggling against economic competition with pesticides and chemical fertilizers? For the shoemaker, “salvation” came from a committee of concerned citizens who obtained the replacement of the obsolete nuclear plant by a large scale wind *energy* project. The *energy* that fed the shoemaker's bulb and powered his machines could now come from a cleaner source. Happy end? Listen to what has happened to the little shoemaker:

After the replacement of the nuclear plant, he lost control forever. Subsidies and economic profits went to the ‘big shots’ of the electricity cooperative. Prices went up to finance the new necessary (alternative!) technology transfers. Local electricians lost their jobs to Hilton-groomed alternative technologists from abroad.

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This story made me sad: I too had wished a happy ending for the sound political fight in favor of softer *energy* sources. I have read Armory Lovins,¹ I know Lester Brown's efforts² to clean the *energy* landscape from useless gigantism, risk, and the relentless erosion of local ecological and cultural matrices.

By the way, the editor wrote me that the story had the following epilogue:
A month after this publication, we received an angry letter from an American *energy* expert claiming that WISE was opposed to the use of wind *energy*. This was the starting point of a discussion on *energy* and Power.

The editor begged me to frame my article in such a way that it would at least tangentially address that discussion. Though I gladly agreed to try, I am reluctant on embarking on a casuistic of alternative *energy* production, "good" in some cases, "bad" in others. Let's state right away that I find a wind *energy* plant less bad than a nuclear plant, and wind power worth militating for. I would like to say: always. Shall I go on to analyze the cases in which—given that the intention was good—but the unexpected result being such ..., had I known it beforehand..., but if not, then...? Clearly, such casuistic has no place in a general article. Are there perhaps general criteria of judgment? Of course: ecological impact and risks assessments, evaluations of the support capacity of the local ecological or climatic matrix (a term I prefer to the globalizing *neutrum*, "environment"). All that remains politically valid. But isn't there more at stake than pollution and risks? The shoemaker's story obliges me to answer "yes!." Armory Lovins suggests a first decision criterium:
To be valid any alternative *energy* production project should not be content with proposing how to produce a constant quantity of megawatts. It should also contemplate the production of "negawatts."

WISE subscribers know that Lovins uses that charade to stress the urge for any alternative *energy* project to present ways of reducing a community's *energy* needs. Another catchword for the negawatt idea is “conservation” (a word that is indeed associated with “*energy*” since this concept's birth!). Alternatives to hard *energy* paths should not consist in aiming at the same thing through other routes, but in changing the goals too. Conservation is one of these “other” goals.

If there can be ecologically dirtier or cleaner forms of *energy*, there is no form of socially quite innocent *energy*, as, again, the shoemaker's story shows.³ But there is still more to that story. While telling it, I “had” to use the word *energy* 18 times. In less than 2 pages, this is many times. If that had been an exercise in English composition, my teacher would have strewn the margin with red remarks like “repetition!,” “find a synonym!,” “what do you call so, in *this* context?.” It seems that what can be done with any sound common word cannot be done with “*energy*.” Try, and then ask yourself: “what are this strange word's characteristics that make it so resistant to *synonymity*?.” The German linguist Uwe Pörksen has written a whole treatise to try to explain that phenomenon.⁴

Re-reading my own prose makes me realize more acutely than ever, that underlying the debate on alternative *energy* production, beyond or behind the ecological and the social levels, there is the semantic bottom line from which cultural meanings, symbols and social myths all stem. Mainstream ecologists have thus far managed to ignore that ground. It has been a great mistake. It looks as if the first principle of thermodynamics and the word which is its stenographic token (“*energy*”) has been allowed to be the Trojan horse for a contagion not only by ecologically and socially unsound, but also by culturally and symbolically destructive thought habits. Is perhaps the *energy* concept—the intellectual cathedral of 19th Century physics—a cultural equivalent of AIDS when it escapes from the lab and invades concrete life? Is the synonym-less word “*energy*” the vector of an acquired cultural

immunodeficiency syndrome, as soon as it ceases to be strictly a technical term of a well-defined science, thermodynamics⁵?

I pretend to address the question raised by the American reader by inviting him to a tour into the epoch that created the concept *energy*.

Can A Scientific Concept Be An Object of History?

This question has always intrigued me. A decade ago, thanks to a friend's generosity, I spent two winters at the Physics Institute of the University of Marburg in Germany. More exactly, I sat day after day on the unheated veranda of its library. There had run aground, like on the strands on a lonely island, the wrecks of past generations of explorers. On the Institute's shelves, I found what remains of the "forgotten grandfathers": the works of 19th C physicists who are no longer part of the curriculum of standard physics. Half-jokingly, half in a spirit of vicarious revenge of the forgotten, I made a sign that said "Marburger Institut für Papierkorbphysik" (*papierkorb* = wastebin). It hung on the veranda's door until I was politely asked to remove it.

One of the two xerox copiers of the institute stood in "my" veranda. Once in a while, I was interrupted by one "Doctorandus" or the other—often a polite German-speaking Japanese—who needed to use "my" machine. I observed that no one ever copied more than five pages, generally concentrating on a single graph or table from a specialized publication. In contrast, I imagined myself snuffling like a scavenger in the landfills of physics. One day, one of the Ph.D. students remained standing near the door and observed me. He exclaimed, "What? You copy *whole books!*" I confess to that misdemeanor, that disrespect of the modern etiquette! Yet, on behalf of those two winters, I possess the entire conserved corpus of several of the great *haemodynamicists* of the mid-nineteenth century: Hagen, Poiseuille, Hagenbach, part of O.E Meyer and Plateau, the Podolinskys, father and son and some more.⁶

But these were the few ones whose works were “*kopiefähig*.” Most of the items piled up in the veranda’s shelves were under a “*Kopierverbot*.” Not that they contained some top-secret information, on the contrary, physicists considered them discarded stuff (never did I see a student pick up one of “my” authors’ books). These books and booklets were materially so deteriorated, so gnawed by humidity and generations of bookworms that they would have disintegrated in the Xerox-machine. From those, I carefully made hand-notes and copied illustrations. Some of these sketches illustrate this article. I wonder if the dusty works of my friends materially survived the decade that went by since I frequented them.

It is through these friends (“*durch sie hindurch*,” a Heideggerian philosopher would say) that I will now try to find an answer to the angry question of Michiel Schaeffer’s correspondent. Physics is not a ukase of nature, not a monologue. At its best, it is a dialogue between man’s imagination and nature’s intimations. At its worst, it is an arrogant axiomatic construction warded by bureaucratic Cerberes. Ernst Mach (1838-1916), a forerunner of relativity “*malgré lui*” wrote once that scientific concepts are the machinery behind the stage of physics.⁷ As different playwrights require different offstage arrangements, the type of concepts that a physicist needs depends on the kind of empirical facts that he wants to manifest. For Mach, the facts of physics had their origin both “in the world out there” and in man’s sensorium. Consequently, all physical analysis had to be *impirio-critical*, that means that it had to consider the way in which nervous sensations are construed as perceptions of physical facts. As a consequence, not the abstract atom, but elementary sensations were the conceptual building blocks of physics.⁸

The energy concept is part of the conceptual machinery depicted by Mach. It did not become a cornerstone of the building before the 1840’s, when the “law of conservation of the ‘force’ (energy)” was simultaneously discovered,⁹ or invented,¹⁰ by at least three scientists (Mayer, Joule and Helmholtz) who spent part of the rest of their life claiming their “priority

rights.” I will first concentrate on the ten years (1842-1852) during which the concept of “force”¹¹ crystallized into what we now call energy. This is also the decade when what we know as the first and the second principle of thermodynamics (the energy conservation law and the entropy maximization law) coalesced. These principles were no pure edicts of nature but rather the result of a *chassé-croisé* between the epoch’s preoccupations, interests, representations, and nature’s “*resistance avisos*.” Neither is it irrelevant that the energy conservation law was discovered, or invented, a few years after England opened history’s first national market for the labor force (1834)¹², Ricardo formulated a theory of value potentially disembedded from concrete costs, or when Liebig made the soil, once “the plant’s stomach,” virtually obsolete in agriculture by showing that chemicals could substitute for it¹³, when the first railroads and the first electric telegraphic lines were built¹⁴, photography invented, and when Marx wrote “Das Kapital”! Nature’s intimations entered of course the constitution of the concept, for instance her refusal to be tricked by those who attempted to build machines producing both work and the cause of this work. In fact, the impossibility of the perpetual mobile is a perfect example of nature’s avisos of resistance: in itself, it was not a concept, but a physico-logical constraint acting on the formation of the concept to come. The law of energy conservation was that concept. In relation to the impossibility of the perpetuum mobile, the concept, energy, as all works of the imagination, is “overdetermined,” redundant of societal and cultural meanings. It is, for instance, the product of a time that considered *scarcity*, the fundamental axiom of formal economics, to be *the* law governing social order, much as the gravity law governs the Newtonian universe.¹⁵

So, the first question I would like to ask the questioner is this: Do you not consider plausible that the industrial enthusiasm that characterized the time of the railroad mania and of the “energy mania” will *volens nolens* taint every social and cultural reality where the concept energy is imported, today? In other words, since it is a constitutive theme—or an

active connection—of its genesis, will not *scarcity* be transferred together with the *energy* concept? And is this not the bottom line of the debate on “Energy and Power” courageously initiated by WISE?

The editor recalled to me the title of a pamphlet I once wrote, “Cow-dung Is Not Energy.” I was thinking then of the Indian villagers who have no other fuel than dry cow-dung. Imagine that a do-gooder from abroad comes to the village with the blueprints of a marvelous bio-digester, importing with them a pop science version of the concept *energy* where people had one hundred words for nature’s forces and gifts. If our alternative technologist succeeds in building his contraption, the villagers who can afford to pay for it will have gas in their kitchen. The poor will have no biogas and no cow-dung left. This can rightly be seen as a result of the transmogrification of cow-dung, a gift of a domestic goddess into an input for alternative industrial production: energy. Though it is scientifically correct inasmuch as it confirms the impossibility of tricking nature, the energy concept is more than a correct scientific statement. It is also a conceptual device that transforms all that it touches into gold for the industrial process. If you don’t want gold, but cow-dung for everyone, you have to let cow-dung remain a free gift and, among ten dozens, use the appropriate word for it. If you aim at protecting the concrete living matrix of real women and men, “energy” is perhaps not an appropriate word.

It is no hairsplitting to insist that, underlying the debate on the appropriateness of technologies, there is the need of another debate on the appropriateness of the alternative technologists’ semantics. In blunders like the one mentioned by the editor or the one just recalled, women are the first victims. So it is not idle either, to ask what the word “energy,” when it evades from the lab and invades social reality, says *about* and does *to* the vernacular gender¹⁶ of the ones exposed to the semantic and technological innovations imported from abroad. And here comes my second question to Michiel Schaeffer’s correspondent: Don’t

you realize that “energy,” the concept underlying most alternative technologies, can be the vector of an industrial bias destructive of forms of local self-reliance founded in a place’s perception of gender? In an attempt to address that question, I will delve again into the “waste basket of physics” in which I scavenged ten years ago. For, if “energy” imports unwanted industrial assumptions, they must be traced back to the epoch that shaped the concept.

“Energy” and Gender

Before Marie Curie’s time, physics was an exclusively and jealously guarded male’s realm¹⁷. Yet, I do not share the opinion of the American feminist physicist Evelyn Fox Keller. Following her, physics is *therefore* tainted with a “gender bias”¹⁸ and she claims that it is the female physicists’ duty to cleanse their science from it. I see things differently. Physics, like modern science in general has on the contrary the eminently dis-gendered character of those realms of activity that do not stem from a living interplay between feminine and masculine, masculine and feminine spaces, times and tools. No matter how “macho” an individual physicist may be, the lab is a dis-gendered space because men and women alike are asked to leave their gendered body in the wardrobe in order to become physicists. The history of physics from 1840 to our days does not speak of a more intense dialogue of the genders, but on the contrary, of a steady increase of its dis-gendered characteristics. Yet, be sure that if traces of gendered perceptions are to be found in my old friends’ works, they are imports of their inborn decency, that is of their cultural context or matrix, and not the effect of more feminine presences in physics, since the contrary was true.

Motion, its nature, has always been one of the fundamental concerns of physics. In the history of this science since Antiquity, there are broadly two concepts of motion:

1. the Aristotelian concept, that contemplated all kinds of change and always

- viewed motion as an affection of the medium, with this medium actively participating, as in Aristotle's example of the arrow, and
2. the Galilean concept of the motion of an individual body in a thought void, obtained by "peeling away" the motion's medium.

What do my friends have to say about that? Was perhaps a less dis-gendered concept of motion at home in physics before this was reshaped as "the science of energy"? I will show that around 1840, two contrasting concepts of motion, both *analytically correct* were at odds. One was thematically, if not mathematically, Aristotelian since it started by considering the medium's affections and changes. The other, inherited from Galileo, saw motion as a sheer *displacement* of individual bodies in a thought void. It only conceived motion disembedding it from its medium and finally succeeded in reducing even this to the individual displacements of "atoms" (till the mid-19th century, physicists called the molecules "atoms").

The Skinning of Nature

In the construction of the energy concept, a broad movement analogous to that of the social construction of the *public fetus*¹⁹ occurred. Barbara Duden has convincingly shown how the fetus, now a dominant public emblem, was progressively arrived at by a process of elimination of the motherly body.²⁰ From the drawings of early 18th century midwifery books showing the correct position of the midwife's hands and the right delivery gestures that emphasized with all detail the concreteness of the motherly body, to William Hunter's pictures at the end of the same century, half the way to that disembedding was laid down (Figs. 1 and 2). The other half of the road leads to *Life Magazine*'s famous picture of the fetus as a small cosmonaut floating freely in amniotic liquid and culminates with our days'

sonographic images (“Hello, I’m Jimmie, I’ll be born in 4 months from now.”). Hunter pictured the dead fruit in a dead motherly body whose fabrics were surgically removed layer by layer to lay bare the dead fruit *as* fetus. It will take the masculinization of midwifery into obstetrics, X-rays and the sonogram to socially construct the public fetus that we “have” nowadays and that often seems to be the common object emerging from the confrontation between the “reproductive rights” and the “pro-life” movements.

Something very similar to this scanning or skinning process can be observed—at least by the “epistemological eye”—in the genesis and development of the energy concept between 1842 and 1852. One question was of paramount importance in the first sketches of the concept that we now call energy: it was the question of the origin of bodily heat. That is to say that the matter was more a concern of physicians than of what we now call physicists. In fact, the very first known formulation of the “law of conservation of the ‘force’” was due to a modest doctor of the poor, Robert Julius Mayer from Heilbronn in Bad Wurthemberg.

Around 1840, most of the “compound” of German physicists thought that bodily heat was mainly caused by the friction of the blood with itself (internal friction layer upon layer) and with the inner surface of the blood vessels (external friction). The generally accepted explanation was that the mutual friction of neighboring layers affected with different speeds “ground,” so to speak, the body’s heat. The branch of physics associated with this concept was called *haemodynamics*, which was an “internal kinetics” of the blood and, by extension, of every fluid that happened to be affected by internal, also called *molar*-motion. There was, for instance, a “haemodynamical” meteorology in search for some ordered patterns in the majestic, but seemingly haphazard celestial landscapes of towering cumulus, whirling nimbus or raveling out stratus clouds.²¹ *Haemodynamics* was the branch of physics in which, before 1845, a young physicist had more chances to illustrate himself and gather the laurels of academic awards. (Besides speculating about the origin of bodily heat, haemodynamicists

also gave the first precise mathematical formulations of a liquid's viscosity coefficient and of the dependence of this on temperature²²).

In contrast, by 1850 all the odds were in favor of the opposing school, which postulated that an oxidation of the food's juices taking place in the blood was the cause of bodily heat as it was of muscular "force." This new physico-physiological doctrine was called "*die Wärmelehre*" (the "doctrine" of heat). Its adoption of the steam engine metaphor and of the mechanics' technical terms—viz. the kilogrammeter²³—as well as its reconceptualization of internal motion as occurring in a thought void was to originate the postulates of what we now call thermodynamics.

On the subject of bodily heat, haemodynamics was partially wrong and thermodynamics was right in part, by default. The last haemodynamicists had to retire or to convert to the tenets of the new doctrine. The "thermodynamical truth" had won over the "haemodynamical error." Was it really so? Though it of course corresponds to the victors' perception, this is a naive view of the "progress of science." In fact, a complex change occurred that an observer, Ferdinand Rosenberger has expressed in the following terms: At the beginning, almost every experimental physicist followed on the path that was his (before the invention of the *energy* concept), dedicating himself for some more years to the same tasks. However, these tasks were subtly inflected by the new theory, often without close notice of the concerned worker himself (sic)²⁴

This particularly applies to experimental haemodynamics. After an eclipse around 1845, it flourished again in the 1850, as if the "late haemodynamicists" had wanted their theory to usher in an ultimate thematic protest against the growing grasp of atomicism on physics.

The rise of the thermodynamical view of the body, and of the world, was an epistemological landslide that gave the Young Turks the occasion for breaking off with old

authorities. Along with the haemodynamic conception of bodily heat, the “vital force”²⁵, the separation between a “translunar” world of ideal realities expressed in pure concepts (see Lagrange’s mechanics) and a “sublunar” realm of birth, growth, corruption and friction as well as the concept of the soil as the plant’s stomach succumbed. Since its very beginning, “*die Wärmelehre*”—soon to be rechristened “*mechanische Wärmetheorie*”—was much more than a way to “correctly” explain the origin of bodily heat. Not unlike heliocentrism in Galileo’s time, it was part of a worldview for which some, new Brunos and Galileos, suffered a true martyrdom and, more often, vilified their adversaries²⁶.

We have seen that thermodynamicists conceive first motion as *motion in a void* “peeling away” its concrete earthly matrices (e.g. the atmosphere) and then eventually ask the lubrication and the hydro- or aero-dynamical lab to re-introduce “the medium’s constraints”²⁷. Haemodynamics had sustained itself on a contrasting worldview for which everything was *embedded in concrete, terrestrial matrices*, rejecting explicitly Galileo’s abstract view of motion along with atomicism.

Such an opposition between two worldviews embodying thematic bundles is what Gerald Holton has called a Q-Q confrontation.²⁸ Such confrontations use to end up with the victory of one theta or thematic bundle, with the “valid tenets” of the loser—e.g. the superior analytical skills of the haemodynamicists—being subordinated to the victor’s paradigm. Exactly that happened with haemodynamics, whose “valid tenets,” rechristened “fluid mechanics” are still an important but accessory branch of industrial physics (like research in the lubrication department of the transportation industry is today subordinated to R.& D. on engines and fuels). Haemodynamics lost first its short-lived hegemony on physics and then its epistemological autonomy to its victor. Since the epoch was imbued with the notion that the “law of scarcity,” the founding axiom of formal economics, was the cause of all social order,

energy, the concept that arose from the confrontation, was a reformulation of the forces of nature under the assumption of scarcity.²⁹

The victor's interest in economic rentability—translating into the concept of a machine's duty!—became an implicit tenet of 19th Century physics. Concomitant with the emergence of the energy concept occurred the mathematization of the language of physics³⁰ and what Ferdinand Rosenberger already described as a specialization that did no longer allow inter- and intra-disciplinary conversations. Some of the most dangerous tendencies of 20th century physics (its blind specialization, its thorough surrender to industry and the military, its lack of recognized meta-physical authorities, its disdain for concrete matrices like the atmosphere) can already be detected, as if it were “in the egg” in that change.

The “Gender of Physics”

The German haemodynamicists of the 1830's called the internal motion of the medium “*molare Bewegung*” (molar motion), using an adjective that is very appropriate on three different grounds:

1. until the end of the 19th century, molar *denotes* physical processes “relating to a mass of matter as distinguished from the properties or motions of molecules and atoms” (Webster, vol. II, p. 1454): the haemodynamicists were convinced continuists, which means that they did not ignore, but actively rejected the atomistic hypothesis on the ground of their belief that matter was continuous until the infinitely small³¹;
2. “molar” *connotes* a sense of grinding inherent to its Latin origin: let me recall that molar motion was described analytically as the mutual “grinding” of the medium's layers through which internal friction converted mechanical motion into heat (fig. 3);

3. from its (casual?) homonymity with molar as “related to a uterine mole” (Webster, *ibid.*), the term seems besides to have been endowed with an implicit uterine *connotation*.

Insofar “Galilean” motion is disembedded from concerns for the medium that it affects and derives its themes from ballistics, it can be termed “phallic.” Here is the core of the thematic difference between the Galilean and the molar sense of motion: molar motion is “uterine,” if this means that it is completely *embedded* in the *terrestrial* medium of which it is an affection and describes concrete “matrices of physical existence” rather than their raping, transformation or annihilation.

Beyond these gender metaphors, I ask the reader to make the effort of imagining this alternative as a line of radical epistemological rupture: around 1840, a physicist could still either *choose* to consider motion in the Galilean, disembedded way, or he could stick to a molar sense of motion that starts with the consideration of how it affects its terrestrial medium. Though physics in the broad “modern” (= post scholastic) sense was born with Galileo’s decision to disembed motion from its medium and ignore secondary qualities,³² the other path remained theoretically walkable and analytically describable *in the sublunar world*. It was the path—*thematically* if not analytically more akin to Aristotle’s, against which Galileo built his kinetics—that haemodynamicists chose to go.

The emergence of the energy concept is contemporary and concomitant with the closing of that path, as if the thermodynamicists had re-written Galileo’s *Dialogues Concerning the Two New Sciences* (1638)³³ taking the haemodynamicists for their Simplicios (Simplicio, the Aristotelian physicist, was the laughing stock of the *Dialogues*). Only that the haemodynamicists of 1840 were extremely well skilled experimenters and that their analytical descriptions (their math) were highly sophisticated and generally flawless. An

epistemological gulf separates these “two new sciences.” As Gerald Holton would say, the thematic origins of both scientific approaches are heterogenous. The first is “trans-lunar” in the sense that it is fit for the description of frictionless motion occurring in the thought void of outer space. Applied to terrestrial, “sub-lunar” motion, it first has to reduce it to an equivalent of the motion of the ethereal spheres, reintroducing stochastically certain terrestrial factors like friction as constraints (as in Stokes’ and Langevin’s versions of Newton’s equation of friction and of the stationary speed of fall of a body of given dimensional characteristics in a homogenous viscous medium at constant temperature).

The second method is *physical* in the original sense: it takes terrestrial motion for what it is: a relation between a moving mass or mole—which can be part of the medium itself—and a medium *affected* by it.

Epistemological Reflections

Did haemodynamics contain the seed of an alternative *understanding* of energy and entropy? Such a question can of course not be answered, all what can be granted is that the haemodynamicists’ concept of motion, their “active connections” in general, were distinct from those of the thermodynamicists. As to the obtention of the viscosity coefficient, and of the analysis of the average stationary speed of fall in a viscous medium, it can be said that it makes them *retrospectively* forerunners of Stokes, Langevin or Painlevé,³⁴ but again, that would miss the point of their epistemological specificity.

Haemodynamics could have reached an independent formulation of the law of energy conservation—and even more, of entropy—if it had given a full analytical description of *Joule’s experiment*³⁵ of 1845 (fig. 4). It failed to do so. What happened in reality is that, once agreement was reached about the “exchange rate” of the “bank of nature,” this rate (confirmed analytically and experimentally in one sense and only experimentally in the other)

was simply used both ways in all the physicists', and physiologists', equations and experiments to come. Clausius elaborated the entropy concept in order to deal with the experimental fact that friction can convert all the mechanical work (energy) imparted to a medium into heat,³⁶ while a thermic engine can only convert a relatively small part of the caldron's or cylinder's heat into useful mechanical work.³⁷

The controversy was closed by the victory of a "*mechanische Wärmetheorie*" that associated atomicism and the Galilean disembedding of motion with an insistence on economically useful energy conversions (viz. the "useful" conversion of thermic into mechanical energy) and considered the opposed conversions as nuisances to be minimized (friction, residual, "useless" heat, "entropy"). This economic bias has become such a built in thematic part of the energy concept that many physicists pretend not to notice it. I suspect that it is because their whole worldview is imbued with the notion that the cosmos is ... a scarce place (in that respect, the whole "heat-death" ideology of the late 19th Century, its echo in a physiological theory of fatigue and of social degeneration that became the subject of novels, and the speculations motivated by the ambiguities of the entropy concept would deserve a psychoanalysis). As the conversion of heat into mechanical work (the economy of the steam engine) became the stereotype of all conversion processes, in organisms as well as in machines, it metaphorically transformed nature into a giant "*arbeitende Maschine*" (economically working machine).³⁸

Instead of the expression of nature's "idleness," that is of "cosmic" scarcity justifying economic assumptions, the haemodynamists of the mid 19th Century, a time when the energy concept was still "in flux,"³⁹ discovered that the conversion of mechanical work into heat in a viscous fluid generates patterns of molar motion of which many of Plateau's experiments in the 1850's expressed the visual aesthetics.⁴⁰ In other words, a concept that has been taken as a paradigm of chaos (entropy) would have found a complement in an order-manifesting

principle (fig. 5). The crucial difference between both schools is beyond error or correctness. Its essence lies in a radical difference in *intellectual interests* (Fleck's active connections) concerning nature.

I hope to have encouraged the reader to recover a sense of the fluidity of the energy concept in the decades in which it coalesced. However, our reflection must now concentrate again on the transfer of the energy metaphor as a Trojan horse for pre-, trans- or meta-scientific themes. If I am right, it will export scarcity together with thermodynamical rationality to cultural contexts in which it was not a dominant perception.⁴¹ It will besides contribute to break the asymmetric complementarity of the genders.

Podolinsky: A “Molar,” Matricial ... or Easteuropean View On Energy

Would a concept of motion (and hence of “energy”) genuinely respectful of living matrices because it shares their embeddedness have more benign social consequences when it evades from the lab than the thermodynamicists’ motion in a void and its conceptual aftermath? The question is concretely whether the energy concept—and in this case: which energy concept?—can be used in a judo-like fashion to limit the destruction of *self-reliant communities* by the industrial package of which “energy” is always a part. *This* is in my opinion the intellectual project that Sergej Sergejevichtch Podolinsky succeeded in formulating if not in realizing.⁴² In his attempt to enroll the energy concept for the protection of communities embedded in a cultural tradition, rather than for their exploitation or transformation, I found many fundamental *molar* intuitions. It is no wonder if one knows that Podolinsky’s interests were haemodynamical and that he learned thermodynamics relatively late.⁴³

Yet, Podolinsky has been thus far depicted as a pioneer of “ecological economics,⁴⁴ of “social energetics” or of “energy accounting.” I think that more can be read in his work.

Social energetics has regained actuality in the 1960's, since it was seen as a possible antidote to a destruction of nature not quite wrongly ascribed to monetary economics. The concept of "energy accounting" was then presented as the truly ecological way of bargaining with nature, reckoning its forces and assessing the ecological costs of economic development. For a reading of Podolinsky *in that light*, I recommend Juan Martinez-Alier's seminal paper, which introduced the "green academia" to Podolinsky as a forerunner of Lotka, Cottrell, Leslie White or even Georgescu-Roegen.⁴⁵

I will not repeat here what Martinez-Alier has so competently said. I will rather focus on one aspect that has thus far not been sufficiently highlighted: it is Podolinsky's use of the energy concept as a scale to evaluate and measure human labor and to limit it when it becomes industrial.

It is nowadays trivial to recall that: Every square meter of land receives daily between 2000 and 5000 kilocalories of solar energy. Some of it is *conserved* by the plants in the form of "affinity energy" (chemical energy), which constitutes the first circle of biological energy conservation, of which coal—Podolinsky does not speak of oil yet—*must be considered an integral part*. Animal life can be visualized as a smaller cycle "feeding" on the first and conserving energy as carbohydrates and proteins. Man contributes to conservation in both cycles, not only in agriculture and the raising of life stock, but also through the making of clothes, shoes and heated and well-insulated houses. Within this circle, man needs 1500-2500 Cal a day to keep himself alive and can transform one tenth of it into useful work. Yet, unless one tolerates the death of the soil—and Dutch-style industrial hydropony on dead soil—he has to remember that man ultimately derives his alimentary energy from the soil. So, as economics is scaled by the measure of a man's work output (some 200 Cal/day), social geography must be scaled by the amount of cultivated land required to feed one person (about one acre in intensive agriculture). No wonder that Podolinsky pretended to have unified the

views of the Physiocrats, of the Marxists and of the thermodynamicists! Yet, man's labor can contribute either to the conservation or to the dissipation of energy. It will inevitably do the latter if his industry is based on the exploitation of fossil energy. But the evaluation of his work as conservative or dissipative depends also on the knowledge of his immediate or mediate relation to the soil that feeds him. Following Podolinsky, man's activity only deserves the name labor if it is conservative.⁴⁶ Dissipative activities do not deserve that name and must be sanctioned as undue withdrawal of a common good from a community's existential matrix. Heavy industry, which rely on conserved solar energy in the form of fossil organic compounds exhausts a common good and is not sustainable in the long run. As the over-exploitation of the soil, it is not legitimate labor and must therefore be sanctioned.

The question that Podolinsky did not address directly is how illegitimate work must be sanctioned. Ulrich von Weizsäcker has recently suggested that all forms of tax raising ought to be replaced by a single tax on energy conversions. In other words, all "labor" that involves an industrial conversion of energy must be taxed in proportion to that conversion's intensity. I think that it is a practical complement to Podolinsky's embedded view of energy and the use of it as a *factor of proportionality* to evaluate man's productive activities.⁴⁷ Under the shield of this radical protection of self-reliant communities, their commons and their ecological-climatic matrices, an economy in the true sense of "administration of one's own house" could flourish again. A sustainable world of austere hedonistic activities, freed from the energy-entropy form of the obsession with scarcity, in which the soil would be the generator of plant life, wheat would again be allowed to be the substance of our daily bread, and cow-dung to be a goddess' gift.

NOTES

1. *Soft Energy Paths*. Cambridge, Ma: Ballinger, 1977.
2. For a list of the Worldwatch papers edited by L. Brown, write to Worldwatch Institute, 1776 Massachusetts Ave., NW. Washington, D.C. 20036, USA.
3. Illich, Ivan, *Energy and Equity*. New York, Harper & Row, 1974 (or: London: Calder & Boyars, 1974).
4. Pörksen, Uwe, *Plastikwörter: Die Sprache einer internationalen Diktatur*. Stuttgart: Klett-Cotta, 1988 (an English abstract can be obtained by the author).
5. Rahnama, Majid, "De l'homo oeconomicus au développement et à l'aide: l'histoire d'un autre SIDA," in Gilbert Rist, Majid Rahnama et Gustavo Esteva, *Le Nord Perdu. Repères Pour L'après-Développement*. Lausanne: Editions d'en bas, 1992, p. 115-166.
6. See for instance: Hagen, G., "Ueber die Bewegung des Wassers in engen cylindrischen Röhren," in *Poggendorff's Annalen der Physik und Chemie*, 46, 1839, p.423-442. Poiseuille, Dr, "Experimentelle Untersuchungen über die Bewegung der Flüssigkeiten in Röhren von sehr kleinen Durchmessern," in *Poggendorff's Annalen der Physik und Chemie*, 58, 1843, p. 424-448. Hagenbach, Ed. "Ueber die Bestimmung der Zähigkeit einer Flüssigkeit durch den Ausfluß aus Röhren," in *Poggendorff's Annalen der Physik und Chemie*, 109, p. 385-426.
7. Mach, Ernst, *The Analysis of Sensations and the Relation of the Physical To the Psychical*. (English by Sydney Waterlaw, with an introduction by Thomas Szasz), New York: Dover, 1959.
8. This position was violently attacked by Lenin, V.I., *Materialism and Empiriocriticism*. Saint-Petersburg, 1908.
9. Kuhn, Thomas, "Energy Conservation as an Example of Simultaneous Discovery," in M. Clagett, ed., *Critical Problems in the History of Science*. Madison: University of Wisconsin Press, 1955, p. 321-356. Simultaneous discovery is the rule, single discovery the exception (or, in Merton's phrasing: multiples, not singletons are the rule). The search for the pioneer and the resulting "priority struggles" are part of 19th Century's naive theory of science.
10. Merleau Ponty, Jacques, "La découverte des principes de l'énergie: l'itinéraire de Joule," in *Revue d'Histoire des Sciences* 32. 1979, p. 315-333. Insists on the invention character of Joule's itinerary. Truesdell, C., *The Tragicomical History of Thermodynamics 1822-1854*. Heidelberg: Springer, 1980. Einstein, in a letter of January 6 1948 to Besso: "I see [Mach's] weakness in this, that he more or less believed science to consist in a mere ordering of empirical material; that is to say, he did not recognize the freely constructive element in the formation of concepts. In a way, he thought that theories arise through discoveries and not through inventions (quoted in Holton, Gerald, *Thematic Origins of Scientific Thought. Kepler to Einstein*. Cambridge, Ma: Harvard University Press, 1973, p. 231). Thaddeus J. Trenn, in his preface to the reprint of Fleck's *Genesis and Development of a Scientific Fact*. op. cit.: "The conceptual creation of science, like other works of the mind, become accepted through a complex process of social consolidation. These thought products, and the thought style under which they arise, are never finalized but can undergo transformation through intra-collective or even inter-collective interaction whereby symmetry is democratically preserved between the esoteric circle of the experts and the exoteric circle of the wider society, and marginal men participating in diverse thought collective can create something new from the conflict." (p. xiii) Not long ago, Michaela and Augusto Odone, the inventors of "Lorenzo's oil" gave a striking demonstration of the truth of this last sentence.
11. I know that strictly speaking, the unity of force corresponds (now) to the dimensional expression $C^1 G S^{-2}$ while the unity energy has the dimensional expression $C^2 G S^{-2}$. But this distinction was not clearly admitted before 1887, after the Beneck Foundation of the

Göttinger Fakultät had invited, in 1884, to a competition whose program was phrased in the following words: “Since Thomas Young (Lectures on Natural Philosophy, London 1807, Lecture VIII) many physicists ascribe to the physical bodies a property called energy. Since William Thomson (Philosophical Magazine and Journal of Science, IVth Series, London, 1855, p. 523), the notion of a principle of the conservation of energy valid for all physical bodies has gained acceptance, which **seems** (emph. mine) to correspond to what Helmholtz had understood under the name “Principle of Conservation of the Force.” The Beneck Foundation asked to answer the question whether Young’s and Thomson’s concept of “energy” was equivalent to what Helmholtz called “force.” There were two entries, but no first praemium was awarded. The young Max Planck won the second praemium with a book-length essay entitled “Das Prinzip der Erhaltung der Energie,” Leipzig: Teubner Verlag, 1908 (1887).

12. Polanyi, Karl, “*The Great Transformation: The Political and Economic Origins of Our Time*. Boston: Beacon, 1957 (1944), p. 102.

13. Dubiel, Ivo, “Cambios de relevancia social en el transplante de teorías. Los ejemplos de la teoría económica y agronómica,” manuscript, 1984.

14. Postman, Neil, *Amusing Ourselves to Death*. New York: Methuen, 1988.

15. Polanyi, op. cit., on Edmund Burke’s and Jeremy Bentham’s belief in a “law of scarcity” governing society more efficiently than any political law, p. 117: “To the question ‘What can the law do relative to subsistence’ Bentham answered ‘Nothing directly’.”

16. Illich, Ivan, *Gender*. New York: Pantheon Books, 1982.

17. This is true for the 19th Century, the century during which physics became a profession. It is not quite true for the 18th Century, when enlightened aristocratic ladies performed physical experiments in their salons.

18. Keller, Evelyn Fox, *Reflections on Gender and Science*. Yale: University of Yale Press, 1985.

19. An expression coined in Pollack Petchesky, Rosalind, “Fetal images: the power of visual cultures in the politics of reproduction” in *Feminist Studies* 13, no 2, Summer 1987.

20. Duden, Barbara, “*Disembodying Women: Perspectives on Pregnancy and the Unborn*. Cambridge, Ma: Harvard University Press, 1993.

21. Babinet, “Ueber einen neuen Neutralpunkt in der Atmosphäre, in J.C. Poggendorf, *Annalen der Physik*, Vol. 51, 1840, S. 562, p. 618.

22. This was the feat of Meyer, Oskar Emil, “Ueber die Reibung der Flüssigkeiten,” in J.C. Poggendorf, *Annalen der Physik*, Vol. 113, Leipzig, 1861, p. 55 ff., 193 ff and 383 ff (experimental results). Meyer (with e!) is a “late haemodynamicist,” long reluctant to convert to the tenets of the opposing school. He however did so around 1875 and was as successful as in his haemodynamical studies, since, as a precursor of Perrin, he gave the first sketch of what is now known as the “Avogadro Number”: Meyer, Oskar Emil, *Kinetische Theorie der Gase*, Beslau, 1877, p. 232. His brother underwent a similar “late conversion” and, before Mendeleiev, gave the first blueprint of what had to become the periodic table of the elements. About the Meyer brothers and their dramatic change of “philosophy of matter,” see Rosenberger, Ferdinand, *Die Geschichte der Physik*, 3rd part, Braunschweig: Vieweg, 1887-1890. Notice that the passage from haemodynamical to thermodynamical views generally implied a shift of interest from the internal kinetic of liquids—with the mutual dependence of neighboring infinitesimal layers—to the kinetic of gas molecules conceived as individual Galilean bodies on a kind of 3-D “billiard board.” I suspect that the motif for such changes of “matter philosophy” lies in the lack of a “scaling element” in continuistic considerations, probable reason of the haemodynamicists’ failure to give a full mathematical analysis of the caloric equivalent of mechanical work.

23. The following, incredible statement by Mayer must be quoted in the original: “Den unproduktiven Druck haben wir umsonst, die Kraft aber, oder das sogenannte Kilogrammometer kostet immer Geld. In noch höherem Grade, womöglich, als für die Physik, ist für die Physiologie, welche bekanntlich in der Wärmelehre ihre wissenschaftliche Grundlage erst gefunden hat, das Kilogrammometer ein notwendiger Lebensbedürfnis” (Mayer, R. J., *Kleinere Schriften und Briefe*. Edited by Weyrauch, Stuttgart, 1893, p. 419.
24. Rosenberger, Ferdinand, “Die Geschichte der Physik in Grundzügen mit synchronistischen Tabellen,” Braunschweig: Vieweg, 1887-1890, 3rd vol., p. 386.
25. Dubois-Reymond, Emil, “Die Lebenskraft” in *Reden von Emil Du Bois-Reymond*. Leipzig: Veit Verlag, 1887, p. 1-28. This article is a historical summary of the decline of the concept of the vital force after energetism substituted mechanical metaphors for it.
26. See in this respect the incredible performance of Dühring, when he passionately took side with Mayer, “the true German physicist”—not like Joule, a stranger, and unlike Helmholtz, (the “Bismark of physics”), free of “English ideas”! The old German-English “Prioritätsstreit” became three-national in the 1880’s, as France entered the arena with Hippolyte Carnot brandishing an old sheet of paper meant to prove that his brother Sadi had already calculated the mechanical equivalent of heat before 1824. Dühring, Eugen, “Robert Mayer, der Galilei des neunzehnten Jahrhunderts,” Chemnitz: Ernst Schmeitzer Verlag, 1880.
27. Applied to social matters, the thermodynamicists’ Galilean recipe reads: “Disembed from the context. Make abstraction of its reality. Re-introduce it as controllable abstract constraints.” No wonder that outside the lab, such practices could only lead to the A-bomb and to the climatological catastrophe, which in the strong sense is a negation of the atmosphere and its climatic horizons. For an ambiguous attempt to take the atmosphere and a place’s climate at face value and as the starting point of all ecological discussion, see Murota, Takeshi, “Heat economy of the water planet earth: an entropic analysis and the water-soil matrix theory” in *Hitotsubashi Journal of Economics*, vol. 25, no 2, Tokyo: Hitotsubashi University, December 1984. The strong part of the Japanese theory of the soil-water-air matrix is its repeated reference to the historical climatic concept of *fudo* as scaling element of geography.
28. Holton, Gerald, *Thematic Origins of Scientific thought: Kepler to Einstein*. Cambridge: Harvard University Press, 1973.
29. See Illich, Ivan, *The Social Construction of Energy*. op. cit. “I am interested in the history of ‘energy’ because I discover in the emergence of this notion the means by which ‘nature’ has been interpreted as a domain governed by the assumption of scarcity, and human beings have been redefined as nature’s ever needy children. Once the universe itself is placed under the regime of scarcity, **homo** is no more born under the stars but under the axioms of economics.”
30. Schickel, Joachim, “Die Sprache der Physik,” in *B.P. Kurier*, 3.4.1982, p. 26-28. Robert, Jean, “Der Verlust der Erläuterungssprache der Physik von 1840 bis 1900,” in Stephan H. Pfürtner, “Wider den Turmbau zu Babel. Disput mit Ivan Illich,” Reinbek bei Hamburg: Rowohlt, 1985, p. 116-130, 152-153. The commented bibliography of this disarmingly naive essay is still interesting.
31. This is not so extraordinary, if one thinks that as late as in 1913, Mach wrote: “I gather from the publications which have reached me, and especially from my correspondence, that I am gradually becoming regarded as the forerunner of relativity. (...) I must, however, as assuredly disclaim to be a forerunner of the relativists as I personally reject the atomistic doctrine of the present-day school or church” (quoted by Holton, Gerald, op. cit., p. 230).
32. Quoting Alexandre Koyré, Gerald Holton writes: “... Galileo’s work was an experimental proof of Platonism as a methodology of science (‘La découverte galiléenne transforme l’échec du platonisme en victoire. Sa science est une revanche de Platon’). The scholastics had

always been able to point to the two main failures of Platonism: on the one hand there was no good theory of **terrestrial motion** (...) and on the other hand there was no successful mathematization of quality.(...) What of the second challenge? The mathematization of quality had proved possible for such qualities as motion and size, but not for others, such as taste, the sensation of heat, color (though most of these subsequently were indeed also found to have quantifiable aspects). Galileo’s decision was simple: to **banish** (emphasis mine) the unquantifiable qualities from science—or more properly, to withdraw the attention of science from the realm of the unquantifiables” (Holton, op. cit., p. 439).

33. In Robert M. Hutchins, ed, “Great Books of the Western World,” Chicago, *Encyclopaedia Britannica*, 1952, Vol. 28, p. 129-260.

34. One of the humidity and worm-gnawed documents I could save during my “trip to the grandfathers’ country” was a handwritten version of Painlevé, Paul, *Leçons sur le Frottement*. Paris, 1895.

35. It has not been sufficiently noticed that Haller’s haemodynamics, as exposed in his *Physiology* was the main source of inspiration of Joule’s first experiments. The young Joule quoted Haller in the following terms: “... the hypothesis that blood is heated by friction in veins and arteries would account for that part of animal heat which Crawford’s theory had left unexplained.” See: Wobmann, Peter, “Albrecht von Haller, der Begründer der modernen Haemodynamik,” in *Archiv für Kreislaufforschung*, Vol. 52, Fasc. 1-2, 1967, p. 96-128. Haller, Albrecht, *Physiology*, vol.ii, p. 304. In 1845, Joule built a machine in which the conversion of a liquid’s molar motion could occur practically without heat losses, what allowed an experimental measurement of the *caloric equivalent of mechanical work*: Joule, James Prescott, “On the caloric equivalent of mechanical work” (communicated by Michael Faraday, Foreign Associate of the Academy of Sciences, Paris, &c. &c. &c.) in *Philosophical Transactions* 1850, Part 1, p. 298 ff. “In 1843, I announced the fact that ‘heat is evolved by the passage of water through narrow tubes’ and that each degree of heat per lb. of water required for its evolution in this way a mechanical force represented by 770 foot-pounds. Subsequently, in 1845 and 1847, I employed a paddle-wheel to produce the fluid friction, and obtained the equivalents 781.5, 782.1 and 787.6 respectively from the agitation of water, sperm-oil, and mercury.” A question that historians of science have thus far not answered with due precision is this: why did the haemodynamicists repeatedly fail to formulate **analytically the caloric equivalent of mechanical work** (= to describe Joule’s experiment mathematically without starting a priori from the inverse of the mechanical equivalent of heat), while Mayer, who was by no means a skilled mathematician succeeded in giving a conceptually—if not numerically—flawless analytical formulation of the **mechanical equivalent of heat**? The reason is this: nature is “scaled,” which means that every creature is morphologically related to its size. The haemodynamicists failed to identify the scale at which a “mole” of liquid will necessarily cease to grind heat between its layers. Some still thought, like Leibnitz, that “the ‘force’ can disappear from particular bodies (falling into the ‘abysses of the infinitely small’) without being lost for the universe”: “*Etsi enim pars potentiae ab impedimentis absorbeatur, non destructa tamen, sed in impedimenta translata est, quae in effectum integrum computantur.*” In other words, Leibnitz thought that friction can occur ad infinitum between smaller and smaller moles, the “force” not disappearing, but being unlimitedly fractalized, as if we would change good money for cents and these cents for hundredths of cents and so forth, until, without having “less” we would no longer have anything that means something in monetary terms. Wouldn’t it be interesting to open a forum for those who will attempt to do what the haemodynamicists were impeded to complete by the victory of the opposing school? The epistemological wager of the exercise is this: While it is impossible, within one school or “theta” to disentangle the active from the passive connections, it is possible, knowing nature’s resistance avisos, to compare the active and the

passive connections of two schools engaged in a ?-? controversy. Wise could provide the mail-box. Please, don't try alone!

36. It was only stated much later that, in the conversion of a liquid's internal mechanical work into heat, there **must always be** a remnant of macroscopically observable mechanical motions, named—after the Scottish botanist who observed them around 1840—Brownian motions. These are explained by stating that, for a very small body floating on a liquid's surface or in suspension within it, the resultant of the pressures on the body's immersed surface at any moment due to the shocks of the liquid's molecules' haphazard thermokinetic motions, is generally not zero and greater than the resultant of the resistance factors like inertia and friction. As a body of increasing dimensions is considered, these shocks tend to statistically equate themselves, leaving at any moment a resultant that can be neglected in relation to the body's inertia and the surface interactions (capillary adherence, friction).

Einstein, Albert, "Ueber die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen," in *Drudes Annalen der Physik*, Vol. 17, May 1905, p. 549.

37. Clausius, Rudolf, *Abhandlungen über die mechanische Wärmetheorie*, Braunschweig: Vieweg, 1864.

38. Breger, Herbert, *Die Natur als arbeitende Maschine. Zur Entstehung des Energiebegriffs in der Physik, 1840-1850*. Frankfurt: Campus Verlag, 1982.

39. Elkana, Yehuda, *The Discovery of the Conservation of Energy*. Cambridge: Harvard University Press, 1974. "I consider this case as an illustration of that general aspect of scientific change which, to make it thought-provoking by the image it creates ... I will call concepts in flux" (p. 12 ff).

40. Plateau, Joseph, "Recherches expérimentales et théoriques sur les figures d'équilibre d'une masse liquide sans pesanteur" in *Mémoires de l'Académie des Sciences*, Vol. XXXI, Paris, Brusell, 1857.

41. Dumouchel, Paul, "L'ambivalence de la rareté" in Paul Dumouchel and Jean-Pierre Dupuy, *L'Enfer des Choses. René Girard et la Logique de l'Economie*. Paris: Seuil, 1979.

42. His son's commitment with the idea of protecting the Russian *mir*—peasant commune with its commons—by defining its horizon and legally limiting what could cross it both ways can be seen as a striking application of his father's ideas. A member of the Ministry of Agriculture led by his cousin Pyotr Stolypin, Podolinsky jr was the intellectual author of the tsar's last agrarian reforms. Podolinsky, Sergej S., *Rußland vor der Revolution: Die Agrarsoziale Lage und Reformen*. Berlin: Berlin Verlag, 1971.

43. While in Marburg, I have found Podolinsky's doctoral thesis: Podolinsky, Serge, "Beitrag zur Kenntniss des pancreatischen Eisweissfermentes," in E.F. W. Pflüger's, *Archiv für die gesammte Physiologie des Menschen und der Thiere*. Bonn: Cohen Verlag, 1876, p. 422-443.

44. Diwan, Romesh, "Ecological Economics: A Dangerous Myth or a Noble Vision? Notes on Gandhian Perspective," State College, 1968: Penn State Seminar October 14-16, 1988, manuscript.

45. Martinez-Alier, Juan, "Energy accounting and the notion of 'productive force'," Barcelona, Berlin, 1984, manuscript. Isn't it symptomatic that this work about a thinker from a region of the industrializing world that was despised as "marginal" was first published in Catalan? See also: Martinez-Alier, Naredo, J.M. and Schinepmenn. K., "Research Project: Energy Analysis and Economics - Studies on Neglected Interdisciplinary Currents of Thought," Berlin, 1984, manuscript.

46. Podolinsky, Serge, "Menschliche Arbeit und Einheit der Kraft" in *Die Neue Zeit*. Stuttgart, 1883, p. 413 ff.. The most important passage for my interpretation is: "We hope to have succeeded in burying the so-called doctrine of abstinence or 'negative labor' [of the

capitalists]. For labor is always a positive concept denoting the expanse of mechanical or psychical energy for the sake of energy conservation” (p. 423).

47. Another modern complement to Podolinsky’s alternative “social energetics” comes from Bettina Corves, who has recently written a thesis in which she shows the clash between East-European and West-European ideas in the formation of the energy concept. The victory of the utilitarian-thermodynamical paradigm attests the predominance of West-European, pro-heavy industry conceptions. Corves, Bettina, “Energie in der westlichen Industriegesellschaft. Geschichtliche Entwicklung des Begriffes und die Bedeutung in der Umweltdiskussion,” Nürnberg: Wirtschafts- und sozialwissenschaftliche Fakultät der Friedrich-Alexander Universität, 1986.

In an old essay, Georgescu-Roegen, who had been himself an agrarian activist in his native Romania, deplored this catastrophic Western predominance and saw it as a threat for socialism: Georgescu-Roegen, Nicholas, “Economic Theory and Agrarian Economics” in *Oxford Economic Papers*, 1960, 12: 1-40 (on this theme there is an older, more interesting paper by G.-R., a statement of the “agrarian specificity” of East-European socialism which I was unable to retrieve in my files).

Clausius’ response to Podolinsky is a striking illustration of the rightness of Georgescu-Roegen’s point over the Western despise for East-European agrarian practices and theories: Clausius, Rudolf, *Ueber die Energievorräte in der Natur und ihre Verwertung zum Nutzen der Menschheit*. Bonn, 1885. “We now live in a marvelous period with respect to the consumption of mechanical energy. In economic relations, it is usually taken as a rule that of anything, only as much is consumed as can be produced in the same period (...). In reality, we go about in a totally different manner, having at our disposal under the earth stocks (...) formed in periods compared to which all historical times vanish. These we are now using and we behave just as the happy heir eating up a rich legacy.” The tone of the several references to Podolinsky to be found in the Marx-Engels correspondence is in tune with Clausius’: there are no reasons for limiting industrial progress in its tapping of nature’s forces: “What Podolinsky has completely forgotten is that the laboring man is not as much a conserver of present sun energy as he is a waster of past sun energy.” Marx, Engels, *Lettres sur les Sciences de la Nature*. Paris: Editions sociales, 1972, p. 109. The book contains 4 pages of comments on Podolinsky, the largest from Engels, dated Dec. 1882.