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Labour, Energy, and Information as Historical Configurations

Notes for a Political Metrology of the Anthropocene

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Notes for a Political Metrology of the Anthropocene

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The essay contributes to the debate on the role of metrics in geoanthropology. It argues that the use of the energy metric in the study of the Anthropocene among other phenomena should be seen in its relation to the metrology of labour and productivity that originated in the industrial age. In order to clarify this genealogical question, the essay extends the method of 'historical metrology' (Kula) to the notion of energy and, in addition, to the notion of information, that can be understood in its own as a metric of knowledge, mental labour, communication and co-operation. In illuminating the nexus between the abstractions of political economy and technoscience, the essay stresses specifically the role of machines (such as the steam engine and telegraph) as 'epistemic mediators' (Wise). The essay concludes by advocating for the inclusion of political metrology in the necessary toolbox and 'geopraxis' (Omodeo) of the Anthropocene.

Every measure as a social institution is an expression of a particular configuration of human relations and may well throw light upon these relations.
Witold Kula, *Measures and Men* [1970] (1986, 101).

One King, One Law, One Weight, One Measure!
Cahiers de doleances, [1789] (Kula 1986, 498).

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1. The measuring units of the planetary factory

What is the political role that systems of measurement play in the Anthropocene debate, and more generally in environmental science? If one takes the crucial measurement of climate change according to an average temperature differential and the mediation of an international institution such as the Intergovernmental Panel on Climate Change (IPCC) in defining such an average, it is clear that systems of measurement play a big political role in the current predicament. The present essay, however, is not concerned with recording the *political impact* of the metrics of the Anthropocene (climate statistics such global temperature, carbon dioxide emissions, etc.), but rather with tracing the *political genealogy* of metrics, in particular the metric of energy and, in addition, information as a type of metric on its own. Tracing the genealogy of the energy and information metrics since the industrial age will hopefully help to illuminate the political economy of metrics also in the post-industrial age and in the Anthropocene debate.

The definition of the Anthropocene has been developed through the cooperation of many disciplines, which have contributed to the identification of numerous *markers* of anthropogenic phenomena at an unprecedented geological scale (Rosol and Rispoli 2022). There is by now agreement that anthropogenic effects such as the concentration of carbon dioxide in the atmosphere are mostly due to the acceleration and excesses of the processes of industrialisation that began at least as early as the nineteenth century. This burden on industrialisation has shifted the focus to the *technosphere* as a central actor of the world system. The technosphere is the global infrastructure for the extraction, transformation, and distribution of energy, materials, and goods—a true planetary factory with a vast environmental footprint. The technosphere, however, does not operate autonomously and requires, as an organ of control and government, the parallel infrastructure of the *infosphere*. Entangled with the technosphere, the infosphere is itself a global system of communication networks, data centres, and distributed computing networks whose principle of operation is *information*. Incidentally, in the same way the infosphere controls the technosphere, it is has been also used to collect data about the world's ecosystem and its energy metabolism. As the historian of science Paul Edwards has shown, even the calculation of climate change relies upon a "vast machine" of sensors, networks, data centres, and institutions that interpret environmental data through mathematical models (Edwards 2010). No definition and political perception of nature would exist today without the global infrastructure of the infosphere.

Yet the perspective of the world system as an interplay of geosphere, biosphere, atmosphere, technosphere, and infosphere remains incomplete. This picture clearly omits the role of social and economic dynamics, and the very responsibility of the *anthropos*, which forms the problematic core of the Anthropocene question. To remedy such a shortcoming, the historian of science Jürgen Renn has recently suggested adding a further sphere, the *ergosphere*: "a sphere of human work—characterized by the transformative power of human labor both with regard to the global environment and humanity itself".[1] The ergosphere would take into account the role of human labour, cooperation, and knowledge production in the transformation of the world against positions that fatalistically depict the autonomy of the technosphere from the will of humankind.[2] The concept of the ergosphere also highlights the power asymmetries and social conflicts that have long shaped world dynamics. The *anthropos* of the Anthropocene is not, it should be added, a universal subjectivity, but one crossed by class, race and gender divisions.

The ergosphere concept should not invite us to overlook the immense heterogeneity of humanity, its striking inability to act collectively, the basic tensions and conflicts of in-

[1] The Greek word *ergon* means 'work' in the transformative material sense, referring not primarily to effort and suffering like the word *ponos*, but also not primarily to the procedural, goal-oriented capability captured by the word *techne*. The ergosphere is, by definition, still open in its evolutionary logic to different ways of shaping the relationship between humanity and its planetary home in terms of the cumulative effects of human interventions embodied in their 'works.' See Renn 2020, 382.

[2] For a critique of the idea of the autonomy of the technosphere in Peter K. Haff, see Renn 2020, 383.

terest tearing it apart, and its asymmetries of power (e.g., between those who are driving the interventions in Earth system cycles and those suffering their consequences). These asymmetries of power also concern the generation of knowledge and science on a global scale (Renn 2020, 382).

It is in order to contribute to a more consistent perspective of the relation between the technosphere, infosphere, and ergosphere, that this essay concentrates on two notions, energy and information, and the role they play in technoscience and the paradigm of the Anthropocene.[1] In particular, this essay investigates energy and information as *metrics*, that is systems for quantifying nature, labour, productivity, and social praxis, and analyses the way such metrics have been historically spaces for the negotiation of social conflicts prior to the making of their scientific objectivity.

The growth of the 'planetary factory' has extended, as a matter of fact, the specific *energy metric* of industrialism to a global scale. The measurement and judgement of the planet's condition according to an energy cost assessment is surely extending the political economy of energy that gave impetus to the industrial age. This time, however, the principle of such a political economy seems to be reversed: it is no more the precise calculation and modulation of productivity, but the management of its collateral costs (e.g. environmental costs) that expresses a model of the reverse valorisation of energy resources and assets. Whereas in the industrial age the metric of energy was a measure of the factory's productivity (workers' performance, steam engine output, fuel costs, etc.), today it is used in fact for the calculus of the energetic impact of all sectors and members of society (Fischer-Kowalski and Haberl 2015).[2] The productivist interest of industrialism is replaced by an ethical perspective, a generalised ethics that is less concerned with the productivity of workers. Instead it aims at measuring the energy impact of any individual in society regardless of their standpoint, background, or class. In this sense the political economy of energy in the Anthropocene seems to follow the passage from industrialism to post-industrialism in which the whole social production is considered central to the process of valorisation (yet often obliterating class divides and global inequalities in this view). For instance, the *social metabolism* energy metric has

[1] For a genealogy of the world system thinking, see: Rispoli 2020, 2023; Grinevald and Rispoli 2018.
[2] For a history of ecological economics, see Franco 2018.

recently been introduced in ecological economics to assess the energy budget of large national infrastructures and small societal entities such as households. Eventually, the metric of industrial metabolism appears to be the complimentary principle to the energy metric of social metabolism: where the former still avows a productivist worldview which strives for resource and labour exploitation irrespective of environmental costs, the latter expresses concerns for the limits of the system and the need for sustainable growth or degrowth. Although these two perspectives appear to be opposed, they demonstrate that the energy metric of the Anthropocene remains a key field of political negotiation just as it was in the industrial age.

In addition, this essay explores also the hypothesis that the notion of information is a metric of productivity, in the way it encodes knowledge, mental labour, communication and cooperation.[1] Information is not simply a techno-scientific notion, but one that has played an underrecognized role in political economy and labour automation since the nineteenth century. The numerous conceptions of 'information society', 'knowledge economy', and 'data capitalism' that have emerged, for example, since the 1960s recognize the role that information came to play in the economy.[2] Yet that information measures the productivity of the social body has become evident only in the last two decades, in the age of big data analytics, the quantified self, and "surveillance capitalism" (Zuboff 2019). Eventually, a metrology of information—a conception of information as a metric of productivity—remains still fragmentary.[3]

2. Quantification as conflict: political metrology after Witold Kula

The international standards and measuring units that are used in everyday life, such as the meter and kilogram, are defined in laboratories of materials

[1] This essay aims at extending and amending previous reflections on the entangled history of energy and information. See Pasquinelli 2017.

[2] For a detailed list of post-industrial paradigms, see: Beniger 1986, 4-5.

[3] David Beer has studied the use of metrics in contemporary society as a form of "power, governance, and control" (Beer 2016, 6). For a quick historical overview of metrics see Muller 2019. Mau (2019) has clarified the economic rationale and class composition of current techniques of quantification and data analytics.

physics following complex procedures. Common trust in science regards these units of measurement as objective, unbiased, a-historical, and universal principles.[1] Yet beyond their appearance of exactitude, all systems and instruments of measurement conceal a complex genealogy. As the Polish economist Witold Kula made clear in his influential book *Measures and Men* (Kula 1986), the metric system is a recently-established convention and specifically a fruit of the universalist and emancipatory aspirations of the French Revolution: measures such as the meter and kilogram have emerged from a long history of strenuous negotiations since the time of feudal power and even earlier. Specifically, Kula defined the mission and method of historical metrology in this way:

> Historical metrology is concerned with past systems of measurement. This definition, in which the emphasis is on the term 'system', postulates that in our investigations we take into account all the elements associated with measuring: systems of counting, instruments of counting, methods of using these instruments (...), the different methods of measuring in different social situations, and finally, the entire associated complex of interlinked, varied, and often conflicting social interests. (Kula 1986, 94)

"Who invented measures?"— Kula provocatively asks at the beginning of his book: "Cain! This wicked son of Adam and Eve, having killed his brother Abel, went on to commit many other sins" such as the invention of weights and measures. Kula goes on to highlight that "in the simple reasoning of the Biblical tradition, the notion of measure is associated with cheating" and the corruption of human values (ibid., 3). This Biblical reference already indicated "that old measures bearing the same names can signify vastly different magnitudes, depending on the time, the place, and the substance measured (*ratione loci*, *ratione temporis*, and *ratione materiae*)" (ibid.). Yet the recognition of the instability and contingency of measures is not really what matters: according to Kula what is necessary to understand is the "hidden, social content" of measuring systems and their relation to power, sovereignty, and the substrate of politics (ibid.).

> It is indeed amazing that, beginning with the Bible, the authorization of measures had everywhere been an attribute of sovereignty, and changes in it over time had corre-

[1] The seven International System of Units are: length: meter (m); time: second (s); amount of substance: mole (mole); electric current: ampere (A); temperature: kelvin (K); luminous intensity: candela (cd); mass: kilogram (kg).

sponded to the changing concept of sovereignty. Amazing, too, that among all imaginable ways for the noble to exploit the peasant, and the town to exploit the country, metrological privileges were never absent; and no less amazing that in various countries, quite independently of one another, the same issues bound up with measures and measuring played the same part in social relations. (Kula 1986, 226)

In which way did systems of measure evolve from the subjective and heuristic methods of antiquity into the 'objective' standards of modern science? To explain this, Kula proposed an evolutionary reading of metrics that, similar to other cultural techniques of humankind, developed in close relation to social and economic factors. Kula stressed that "the earliest stage in the development of man's metrological concepts is the anthropomorphic, in which the most important measures correspond to parts of the human body", such as a *foot*, an *arm*, etc., but "in a later stage that reference is made to units of measure derived from the conditions, objectives, and outcomes of human labor" (ibid., 5). Labour became a unit of measure in its own under the form, for example, of the necessary time taken to complete a task: the expressions *Morgenland* in German, *giornata* in Italian, and *journée* in French still refer to the amount of land that can be ploughed in one day. The emergence of the perspective of labour as a measuring unit is key. It would go on to have, of course, great influence on the consolidation of 'abstract labour' in the industrial age, that is the equalised measure of the labour power of the average worker. Importantly, in measuring labour productivity, machines and means of transportation also played a role and established their own metrics. Charcoal, sand, and other materials were measured in *baskets*, *wagonloads*, and *boatloads* (ibid., 6). The length of one full operation on the mechanical loom was used to measure textiles. After replacing workers, machines implicitly became a measure for the productivity of labour. This is another key aspect yet to be properly analysed: machines are invented by the organisation of labour and, thereafter, it happens that they impose back on labour their own metrics. Labour metric and labour automation appear to be closely entangled.

In summary, one can discern four stages in the history of metrology. First, in the *anthropometric* stage, the human body is taken up as a unit of measure (e.g. the foot, the arm, sight of distance). Second, in the *ergometric* stage, human labour is taken up as a unit of measure (e.g. land ploughed in a day). Third, in the *technometric* stage, tools and machines are used to measure resources and products (e.g. quantity of fabric measured in one loom cycle). Finally, in the *scientific* stage, physical properties of nature are adopted as a standard (e.g. the meter calibrated on the earth's meridian arc or the wavelength of the atom krypton-86).

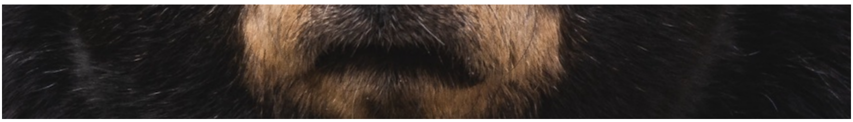
This process of standardisation, of continuous refining and redefining of measures, is a process of abstraction which should be studied alongside other processes of political abstraction. According to Kula, it is clear that the standardisation of each unit of the International System of Units happened alongside the processes of globalisation that have defined capitalist modernity: "That the standardization of measures is a historical process, parallel to the widening of the marketplace, goes without saying" (1986, 121). Kula specifically remarked that

> For a society to be able to adopt measures of pure convention, two important conditions have first to be satisfied: there must prevail a *de facto* equality of men before the law, and there must be accomplished the process of alienation of the commodity'. (122)

The makings of abstract measures, abstract rights, and abstract value (i.e. the money form) are combined in the historical process, that although with different temporalities, unfold in parallel. Moishe Postone, for example, has explained the consolidation of abstract time (the exactitude of the labour discipline as measured by mechanical clocks) together with the rise of abstract labour in industrial capitalism (see Postone 1993, ch. 5).

The process of political abstraction that metrics drive remains, however, ambivalent. Kula regarded the birth of modern metrology as a confrontation between social actors and a space of class struggle, taking the relationship between the French Revolution and the establishment of the metric system as the example *par excellence* (Kula 1986, 127). The French Revolution promoted the metric system as a more objective alternative to the inequal measurements of the feudal society that had preceded it. At the same time, peasants and workers often refused to have their produce and labour measured, as a way of resisting exploitation and resource extraction. Kula reported that nineteenth-century Russian peasants protested: "He who calculates the yield of the harvest from our fields, sins. We gain nothing by counting" (ibid., 13). The tension between the revolutionary ideal of equal measure and the refusal to be measured exemplifies a political polarity that has continued through to the technological composition of the present. It is within this polarity—the refusal to be measured and the demand for an equal metrology—that any system of measurement should be studied.

That the quantification of resources implies a social hierarchy, that the quantification of labour plays a role in the modulation of social conflict, are aspects that should also be investigated in other forms of scientific quantification such as energy and information. As Anna Echterhölter observes: "Kula investigates measurement as a medium of political conflict, where generations of historians have [instead] focused on factual values. His metrology may thus serve as an example of how to politicise a previously neutral field of study" (Echterhölter 2019, 118). After reviewing the more familiar case of how the notion of energy was born out of the measure of manual labour in the industrial age, this essay will go on to consider whether information should also be understood as a metric of productivity, in particular as a measure of knowledge, mental labour, communication, and cooperation, and if such information metric could also operate as a modulation of the coefficient of social conflict in the Anthropocene.



3. Energy as a scientific notion and metric of labour

In his influential book, *The Human Motor*, the historian Anson Rabinbach highlights how the notion of energy in physics units emerged through the direct engagement (and confrontation) with the *measure of labour* in the industrial milieu (Rabinbach 1992). In the nineteenth century, industrial capitalism demanded the improvement of production through better standards and measurements: the scientific conceptualisation of energy and its measuring units served this purpose. Industrialism brutally put the work of animals, humans, and machines on the same level and framed them from the same productivist perspective. As Rabinbach has pointed out, the physicist Hermann von Helmholtz originally defined energy as *Arbeitskraft*, a universal 'labour force' that rendered commensurable the outputs of sources as varied as the sun, steam engines, workers and even horses (from which, for instance, the unit of *horsepower* emerged). Even today one can easily perceive the ghostly traces of workers' movements in the definition of the universal measuring unit *work*:

> In physics, *work* is the energy transferred to or from an object via the application of force along a displacement. In its simplest form, it is often represented as the product of force and displacement. (…) The unit of work is the joule (J), the same unit as for energy.[1]

It is no historical exaggeration to affirm that the need to control the 'energy' of industrial labour consolidated the study of the 'energy' of the universe.[2] A related process happened in the political economy of the nineteenth century which also placed labour at its centre, shaping what has been known, since Ricardo, as the *labour theory of value.* The labour theory of value states that labour is the only source of the collective wealth and origin of the processes of valorisation. In a similar way in which the *labour theory of value* contributed to the making of political economy in the nineteenth century, the *labour theory of energy* grounded modern thermodynamics, as both emerged from the measure of labour as their keystone. The circulation of these ideas was notable at the time and trafficked in both directions between political economy and physics: for instance, according to Rabinbach, Marx's notion of *Arbeitskraft*, labour power, was also fashioned after Helmholtz's original definition and specifically as a contestation of its energetic reductionism of labour and ideological influence on science (Rabinbach 1992, 72). Marx aimed to show that labour power, *Arbeitskraft*, was not a universal notion, but a political and partisan one, which structured the confrontation between classes in the industrial age.

[1] From Wikipedia: `https://en.wikipedia.org/wiki/Work_(physics)`.

[2] Wise has noticed that at a certain point even natural systems were framed as engines: "Between 1845 and 1862 Thomson developed his work-centered perspective on dynamics. In 1845, well before he subscribed publicly to energy conservation, he had begun to regard the idea of natural agency—electric, magnetic, thermal, etc.—as an expression of the capacity to produce work, and thus to regard natural systems as engines" (Wise 1988, 80).

The quantification of human labour into a magnitude of energy is not a neutral act but a *political translation* with deep social implications. The quantification of human labour in this way, however, can hardly be distinguished from early experiments with mechanisation. What instruments have been used to measure labour? The clock is one of, if not *the*, key measuring instrument to have historically established the standard metric of labour power in time units for many centuries (Rabinbach 1992, 31-33; see also Postone 1993). The clock is therefore a good example of a technology that operates in between a system of measurement and a means of social discipline. The clock, however, has not been the only instrument to measure labour. Machines also implicitly played the role of measuring instruments of labour. To clarify this point at the intersection of labour, technology, and science, Norton Wise has proposed seeing technologies such as the steam engine and the telegraph, as "mediating machines". Wise has proposed, in particular, seeing industrial technologies as *epistemic mediators* in between the domains of political economy and natural philosophy, between labour and capital, and has highlighted the twofold role of the steam engine in the measurement of labour and the making of the notions of physics.[1]

> The steam engine illustrates *conceptual mediation.* It simultaneously instantiates 'labour value' in political economy and 'work' in engineering mechanics, thereby identifying the two concepts in the region of their common reference. The partial identification carries with it a structural analogy between a network of concepts from political economy and a similar network in natural philosophy, providing a potent heuristic for the reformulation and further development of dynamics (Wise 1988, 77).

Wise's analysis is an example of a 'technological reading' of scientific notions that is commonly found in the historical epistemology of science, but conversely it can also be seen as a 'technological reading' of political notions such as labour, since the instruments of modern science clearly also played a role in the

[1] A dialectical understanding of the relation between labour, technology, and science existed already in Soviet Marxism. Both Alexander Bogdanov in *Philosophy of Living Experience* (1913) and Boris Hessen in the paper "The Economic and Social Roots of Newton's *Principia*" (1931) argued that the principle of the conservation of energy emerges in physics from problems relating to the industrial use of steam engines. Bogdanov further argued that only the working class can detect the labour element while a bourgeois perspective only sees the universal laws.

definition, measurement, valorisation, and management of labour.[1] Wise goes on to provide an intriguing description of the function of technology in between societal and scientist forms—a relation that he depicts through the analogy of the lens diffracting lights in between two visual fields.

> A machine functioning within a societal context carries with it, simultaneously, a set of ideas (as both concepts and values) which explain its physical operation and a set of ideas which explain its societal function. These sets of ideas are part of what the machine is, for us. Through them we interact with the machine, in effect carrying on a dialogue with it. I shall therefore say that it 'embeds' our ideas. The simultaneous embedding of physical and societal ideas requires, for consistency alone, a mutual adaptation of the one set to the other. In this adaptation exists the potential for the mediating role of machines. But such adaptation is not passive, nor simply an adaptation for the sake of consistency. It is also purposive, aimed at effective practice and problem solution. If we concern ourselves with scientific problems, therefore, the notion of embedding will yield a fairly strong form of social construction of scientific knowledge in which the categories of a local scientific community are interdefined with political and economic categories (Wise 1988, 79).

The valorisation of labour according to a *metric of energy* happens, however, because another much more important metric, the *metric of capital* requires it. As Wise has noticed: "From a steam engine one cannot read off a theory of measurement, unless the engine already is taken to represent something worth measuring, something valuable" (ibid., 89). Wise continued his reasoning hinting to a closer relation between use value and exchange value.

> As conceived through the classical theory of political economy, the wealth of the nation was measured in labor value, the quantity of labor bound up in the agricultural and industrial commodities that the nation produced, or for which they could be sold. Engines replaced labor; their value was labor value. Engineers, however, between 1820 and 1840, learned to conceive the labor value of engines as work, defined as a unit weight lifted to a unit height, or as a force multiplied by the distance over which it acted. (…) The engine therefore embedded both the natural philosophers' 'energy' and the political economists' 'labor value' as work. (ibid., 80)

[1] "Technological reading" of science is a definition from Peter Galison 2000.

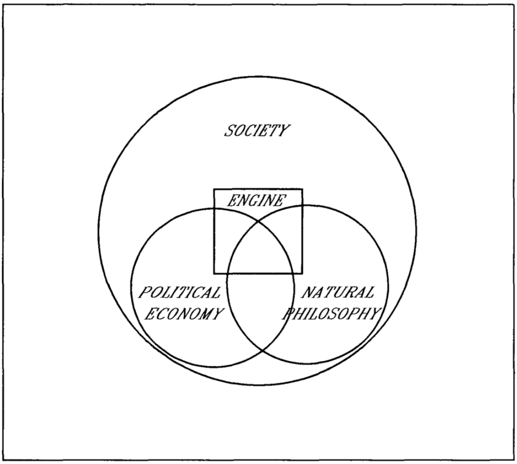


Figure 1. The engine is embedded in society and in the intellectual subcultures of political economy and natural philosophy.

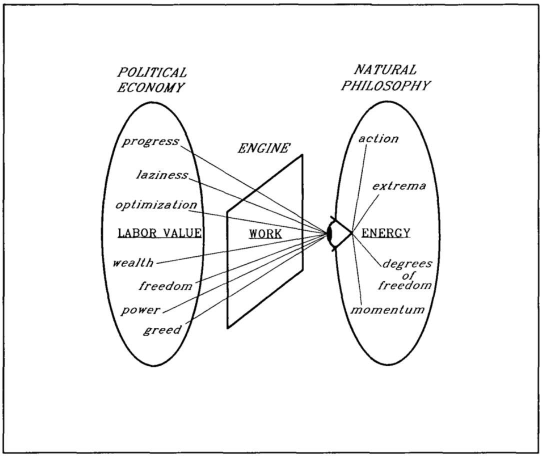


Figure 2. Conceptual mediation. Thomson's eye of energy looks at political economy through the engine, which projects concepts of political economy into concepts of natural philosophy.

Figure 1: Figures from Wise 1988.

In summary, the genealogy of the notion of energy should be read according to stages of techno-scientific development that are grounded on the political economy of industrial labour and productivity. According to this reading: first, *metrics of labour* are introduced to control and negotiate the value of labour (e.g. workers' manual performance is measured in time units); second, manual labour is replaced by *machines* that embody the same metric of productivity (e.g. steam engines are measured in terms of performance per time units); third, machines inspire and consolidate new *scientific notions* (e.g. the notion of energy is defined in physics as *work*: displacement of a mass per units of space and time); fourth, scientific notions are then used to improve machines and their initial measuring units. Ultimately, scientific 'revolutions' were not conceptually distant from workers' struggles and their social revolutions; both formed part of similar processes of economic and social abstraction.

4. Information as a metric of knowledge labour, communication, and cooperation.

The French philosopher Gilbert Simondon once observed that the industrial machine was already an *infomechanical relay*, as it separated, for the first time, the traditional form of labour as a source of *energy* (propelled by a natural resource such as water or coal) and a source of *information* (the conscious movements and instructions of a worker supervising the machine) (Simondon 2009, 20). This may sound like a retroactive application of a later notion, but it should be noted that informational devices already existed in the industrial age. As is well known, the Jacquard loom (which set the standard of the punched card as a data storage), for instance, was widely used in the era of steam engines around 1800. The information technologies of this era may have been relatively quiet compared to their noisy thermodynamic counterparts, but they were nevertheless imposing: the transatlantic telegraph cable that was laid in 1866, for instance, was ca. 3200 km long and weighted ca. 5000 tons.

Wise expounded on the case of the steam engine as a *conceptual mediator*, but he also proposed to see the electric telegraph, in a similar way, as a *methodological mediator*. "Picturing the telegraph, like the steam engine, as a lens, one can project science into industry or industry into science", in particular Wise adds, "the interests of engineering and industry into the interests of electromagnetic theory and vice versa" (Wise 1988, 94, 77). Expanding Wise's intuition, one could also see the electric telegraph as a *mediating machine* that played a key role in the definition and metric of another kind labour: mental labour, also understood as the labour of communication and cooperation that was taking shape and emerging through the media of the time.[1] Whereas the steam engine contributed to consolidating the notion of energy, the telegraph instigated the conceptualisation of information and the theory of its transmission. The genealogy *labour-engine-energy*, which sees energy as a metric of manual labour mediated by thermodynamic machines, can be envisioned also for the genealogy *labour-telegraph-information* to comprehend information as a metric of knowledge, mental labour, communication and cooperation.[2]

The telegraph is no secondary device in the history of ideas. It has played an important role as a *model machine* for paradigms of sensation, cognition, and automation. In the nineteenth century, the German scientists Emil DuBois-Reymond and Helmholtz took the telegraph network as a model for the physiology of the nervous system.[3] In the twentieth century, US cyberneticians Warren McCulloch and Walter Pitts implicitly adopted it as the model for neural networks. At the 1948 Hixon Symposium on cerebral mechanisms at the California Institute of Technology, McCulloch urged his colleagues to "conceive neurons as telegraphic relays".[4] Last but not least, the British mathematician Alan Turing adopted the telegraph as the speculative structure for the so-called Turing machine.

A quintessentially social technology, the telegraph exerted a lasting influence on the disciplines of the mind and the automation of mental labour and

1 The invention of the telegraph is based on the definition of the measuring unit of resistance *ohm*, which was by the way a measuring unit of energy (*ampere*). The exact definition of *ohm* was key in the design of a vast infrastructure such as the transatlantic cable in the nineteenth century. See Schaffer (1992). See also Gooday (2004).

2 The measure of electrical impulses in the body of animals and humans, it should be noted, was a primordial measure of 'mental work' understood as the brain's response (either conscious or unconscious) to an external stimulus. On the history of psychophysics, see: Schmidgen (2015; 2002). On early 'metrology' of the nervous system in relation to the technical and cultural milieu of the nineteenth century, see Schmidgen (2014).

3 See Otis (2001; 2002). See also Hoffmann (2003).

4 Jeffress, ed. (1951), 45.

communication. Recognising the telegraph as a *mediating machine* may help us illuminate a historical relation between labour automation and information theory. The theory of information was born, in fact, in close relation to the architecture of the telegraph before being generalised as a measuring unit across different media. In 1948, US mathematician Claude Shannon published his paper "A Mathematical Theory of Communication" in which he sketched the basic design of a "system" for transmitting any kind of message focusing on the problem of encoding a sequence of discrete symbols through a noisy channel regardless of its meaning:

> Frequently the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one *selected from a set* of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is unknown at the time of design (Shannon 1948, 379).

Interestingly, information came to replace what in telegraphy was called the 'intelligence' or interpretation of a signal (see Geoghegan 2016; Shannon 1948).[1] The term 'information' was chosen to remove the 'human factor' and anthropomorphic skills from the act of interpreting a message. This aspect demonstrates once again the interest of information theory in the automation of mental labour. Shannon and Warren Weaver, for instance, insisted on explaining 'communication' as an intellectual faculty:

> The word *communication* will be used here in a very broad sense to include all of the procedures by which one mind may affect another. This, of course, involves not only written and oral speech, but also music, the pictorial arts, the theatre, the ballet, and in fact all human behavior. (Shannon and Weaver 1949, introductory note)

In what ways was the 'intelligence' of messages replaced by the quantification of the new 'information'? The calculus of information was a way to automate the labour of interpretation and communication after reducing these activities to a sequence of quantifiable signs. The measure of information involves

[1] The origin of the 1948 paper was actually Shannon's research on cryptoanalysis for the military. See Shannon (1945).

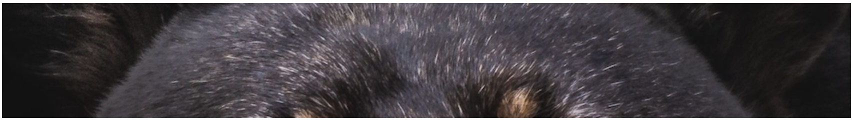
a process of simplification typical for any cultural technique: Shannon's theory, like telegraphy, reduces a message to the number of its symbols and compares its readability against all the possible permutations within a given alphabet or code. Primarily, then, Shannon's information is not the measurement of a continuous magnitude but of the combinatorial capacity of a sequence of symbols. Information is the *number of decisions* to be taken in encoding a message or a sequence of instructions, evidently not a measure of a phenomenon existing in nature, but only in human society.

As Shannon remarked, information has nothing to do with the semantics of a message but rather with the number of symbols that can be transmitted through a channel and potentially encode any message. The measuring units of information (such as: *bit*, *Shannon*, *nat*, *Hartley*) changes according to the number of symbols used in a given code (two for bits and *Shannons*, ten for *digits*, twenty-six for the English alphabet, etc.). The Morse code of telegraphy (made of two symbols only, the perfect dichotomy) constituted originally the simplest and most economical case of this problem of encoding, shaping all the subsequent technologies of information and computation. Before Shannon's theory, communication had never been mathematically defined, whereas after Shannon's theory, communication became a measurable entity of computable signs (Stone 2015).[1] In this view, information operates as a basic metric of mental labour because it quantifies the series of small acts of decision and logical steps that constitute operations of different kinds, such as composing a message or operating a machine. The definition of information as a measure of decisions is interestingly cognate to the semiotic model of the Danish linguist Louis Hjelmslev who defined language as a system of dichotomies (Hjelmslev [1943] 1953). Seen under the lens of semiotics, numerical information does not ultimately impose a reduction on language. Grounded on the inner logic of language, information rather reveals components of the language's deep constitution.

Whereas energy was a key notion for the political economy of the nineteenth and twentieth centuries, information has played a similar role in the twentieth century, although the conceptualisation of the latter is less advanced and still struggling to find its place in the history of science and technology. The critical

[1] For a more systematic overview of the history of information, see Geoghegan (2008); Aspray (1985); Cherry (1953); Peters (1988).

literature on energy as a metric of labour, for instance, has not been paralleled by an equivalent one on information as a metric of labour, because today it is still not clear what information measures and what is its 'value'. Expressions such as 'information is the new currency' or 'data is the new oil' betray a misunderstanding: information has less to do with the money form than with the metric form.[1] Information is not value; information measures value in its capacity as a metric of labour and productivity.



5. Information as a metric of the ergosphere.

'Mediating machines' such as steam engines and telegraphs did not only mediate definitions, standards, and metrics in between political economy and natural science: they also mediated conflict between workers and capital. Machines and metrics did not only operate as *epistemic mediators*, as mediators of scientific abstractions, but also as *social mediators*, as mediators of economic abstractions such as wage relations. Machines have always exercised a role of control and, specifically, of the control of social productivity. Already during the nineteenth century's 'Machinery Question' in England, it was debated how machines had not only came to automate labour and replace workers, but also to suppress strikes, playing an important role of political deterrence and social negotiation (Marx 1990, 526; Berg 1980). In the last decades, this has become evident for information technologies as well, however this aspect often fades away in favour of instrumentalist and depoliticised readings of information.

Stressing the role of information in the making of abstract representations of the world, anthropologist and cybernetician Gregory Bateson upheld that "the

[1] 'Data is the new oil' is an expression by Clive Humby.

elementary unit of information is a difference that makes a difference" (Bateson 1972, 459). But which kind of difference? The founder of cybernetics, Norbert Wiener, hinted at an ethico-logical definition, when he stated that each piece of information is a "decision".[1] Italian sociologist Romano Alquati (1963) added that any bit of information as much as any gesture of a worker is a "micro-decision", that can control a machine or give shape to a product, for example. Following Syed Mustafa Ali, the media scholar Jonathan Beller has encapsulated this logic saying that "information is (…) a difference that makes a *social* difference", meaning that information plays an increasing role in class, race, and gender discrimination (Beller 2021; see also Ali 2013). In fact, recently, a growing number of authors have begun to frame digitality and its *cultural logic* as a continuation of the old apparatuses of discipline, discrimination, and oppression (see Golumbia 2009; Franklin 2015). It has become apparent that information technologies do not only channel the drive for communication and cooperation, but also serve as vectors of social control, in what has been defined (sometimes through questionable analogies) as "data colonialism" and "surveillance capitalism" (Zuboff 2019).

What these positions often overlook, however, is that the infosphere has not only a role of surveillance and discrimination according to old and new power structures but also of measure and the management of labour and social productivity in general. Historian James Beniger has argued that the information revolution was actually a "control revolution" that had the function of governing the economic boom and commodity surplus of the Global North since the end of the nineteenth century. Although Beniger recognised that "the impact of the Information Society is perhaps best captured by trends in labor force composition", his analysis regards mostly the spheres of circulation and consumption, rather than that of labour and production (Beniger 1986, 22).[2] Beniger nevertheless acknowledged a dialectical relation between the infosphere and economic sphere: an aspect that is missing from many critical theories of digitality that

[1] "What is this information, and how is it measured? One of the simplest, most unitary forms of information is the recording of a choice between two equally probable simple alternatives, one or the other of which is bound to happen—a choice, for example, between heads and tails in the tossing of a coin. We shall call a single choice of this sort a *decision*". Wiener (1948), 61.

[2] Beniger endorsed a typically cyberneticist point of view according to which information is not a historical artefact but a feature of biological life since its origin.

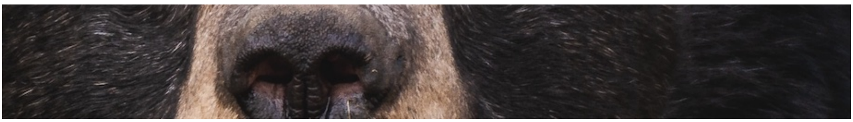
only perceive information's role in surveillance, discipline and domination. This issue, in fact, can be illuminated from quite different angles. In the late 1960s, for instance, the political philosopher Mario Tronti proposed the reversal of a thesis which was then also mainstream in Marxism: capitalist development had often been considered as substantially autonomous from society as well as from labour organisation. To the contrary, Tronti claimed that capitalist development, including technological innovation, was always triggered by, and subsequent to workers' struggles: "Every technological change in the mechanisms of industry thus turns out to be determined by the specific moments of the class struggle". According to Tronti, "the working-class struggle reached its highest level of development between 1933 and 1947, and specifically in the United States" (Tronti [1971] 2019, 243). This localisation and periodisation appears unusual (also for a Marxist perspective that primarily focused on social transformations in Europe and Asia), but it matches interestingly the period that witnessed the rise of information theory, cybernetics and automated computation in North America (ibid., 294; see also Panzieri 1961).

Information technology helped, for the first time, an accurate analysis and management of the division of labour in the factory, as Taylorism intended. This already boosted productivity in the first half of the twentieth century according to Beniger and the scholars of the 'information society'. Yet what was the source of the power of information? In his research into labour composition at the Olivetti computer factory in Ivrea, Italy, around 1960, Alquati started to read information theory through the lens of political economy (rather than the other way around). He declared, probably for the first time, that information is a key component of labour, which had hitherto been considered mostly a manual activity rather than a mental one:

> Information is essential to labour-force, it is what the worker—by the means of constant capital—transmits to the means of production on the basis of evaluations, measurements, and elaborations in order to operate on the object of work all those modifications of its form that give it the requested use value (Alquati 1963, 121).[1]

[1] "L'informazione è l'essenziale della forza-lavoro, è ciò che l'operaio attraverso il capitale costante trasmette ai mezzi di produzione sulla base di valutazioni, misurazioni, elaborazioni per operare nell'oggetto di lavoro tutti quei mutamenti della sua forma che gli danno il valore d'uso richiesto"; translation mine.

Alquati's quote is a historical record of how much the perception and definition of labour changed in between the age of industrial thermodynamics and that of mass media and computation (and how critical Marxism detected this shift before others). Alquati distinguished specifically two types of information: "valorising information" and "control information". Workers are the source of valorising information within the factory, while the factory's management and bureaucracy monopolise control information to govern the production process as a whole and ultimately labour power. It is in between the two flows of 'valorisation' and 'control' that one can envision information technologies, once again, as *mediating machines* within capitalism. What information measures and mediates here between workers and capital is clearly intelligence, knowledge, the know-how of the production process. This kind of intelligence belongs to both manual and mental work, to explicit and tacit knowledge; it is the know-how that also emerges from the unconscious movements and 'micro-decisions' that workers continuously make during the production process. Information is an ambivalent technique of both analysis and synthesis. Information technologies have atomized workers and simultaneously recomposed them into a new artificial sociality. Alquati's aphorisms on cybernetics still ring true for describing today's global infosphere and its organic relation to the ergosphere: "Cybernetics recomposes globally and organically the functions of the general worker that are pulverized into individual microdecisions: the *bit* links up the atomized worker to the *figures* of the *Plan*".[1]



6. Labour metric and the value form

[1] "La cibernetica ricompone globalmente e organicamente le funzioni dell'operaio complessivo polverizzate nelle microdecisioni individuali: il 'bit' salda l'atomo operaio alle 'cifre' del 'Piano' ". Alquati (1963), 134, my translation.

Kula's research on metrology shows how the general process of valorisation, the dominion of the money form and ultimately of capital, cannot be established without the ground of a formal or informal system of metrics. Labour power and productivity can be measured, monetised, and sold, only if a metrological convention is established together with a monetary convention. To make the abstraction of the money form effective, other abstractions are necessary, such as the metrics of resources, labour, and productivity. The comprehension of this double game of abstraction, the coupling of two semiotic operators—the money form and the labour metric—is also key to understanding the economic dynamics between the ergosphere, technosphere, and infosphere; the way the notions of energy and information have been instrumental to processes of valorisation and capital accumulation. Regarding information, this entanglement has been recently described through ideas such as the 'digital economy', 'data capitalism', and so on, which rarely specify, however, what the 'value' of information would be.[1]

In an attempt to understand the 'value' of information, some authors have recently proposed reading information as a value form or price signal, sometimes even speculating that the *monetary form is the origin of information.*[2] Media scholar Sebastian Franklin, for instance, has investigated the "striking similarities between value and digitality" arguing that that: "Digitality is not an allegory of value. Rather, value is (or appears) informatic *avant la lettre*, and this is why it so precisely furnishes digital imaginaries with their form and conceptual efficacy" (Franklin 2021, 15-16). The argumentation about the rise of information

[1] A survey of all the theories on the role of information and knowledge in the economy is not possible in the space of this essay. For an overview of these theories in the first part of the twentieth century, see Beniger 1986.

[2] From a different perspective, also Renn has suggested a comparison between data and money: "Data may be considered as the monetary form of information—a specific but universally applicable external representation (encoded in symbolic language and typically housed and transmitted today in an electronic medium) that can serve as its universal standard and measure. Big Data is thus the capital form of information; it is data whose accumulation has become a purpose in itself, transitioning from the cycle information-data-information to the cycle data-information-more data. (…) 'Data' is an abstract category in an Internet-based circulation sphere similar to the concept of 'exchange value' in the traditional material economy. The relationship between the two concepts is established by the cost of data generation, acquisition, storage, and transfer, as well as the production processes of the knowledge represented by the data" (Renn 2020, 157-402).

from the value form follows Alfred Sohn-Rethel's thesis on the origin of abstract thinking from the "real abstraction" of money and commodity exchange. Sohn-Rethel argued that philosophy, the first recognised and institutionalised form of abstract thinking in the West, emerged in Ancient Greece as a consequence of the introduction of the first currencies which embodied abstract value into a material substrate for the first time. Money exchange represented the first instance of "real abstraction", "an abstraction other than that of thought", which nevertheless had an effect on the forms of thinking themselves (Sohn-Rethel 1978). Along this line of reasoning, Franklin concludes in support of Sohn-Rethel's reductionism of mental models to the abstract models of the money form: "This convergence seems to support Sohn-Rethel's suggestion that the relationship between the exchange abstraction and "the formal constituents of cognition" is one of identity, not mere analogy" (Franklin 2021, 46).[1]

In the recent years, Sohn-Rethel's thesis has exerted an enduring fascination on critical theory, but it has also been challenged by a large number of historians and archaeologists who have questioned the evidence for the first 'real abstraction' also within Marx's own historical epistemology. Joachim Schaper has noted that "real abstraction was generated much earlier than Sohn-Rethel thought: not in seventh-century Greece, but in late third-millennium Mesopotamia", and that "while he was right in drawing attention to real abstraction, he mistakenly traced it back to the realm of circulation instead of that of production" (Schaper 2019, 73-74). Peter McLaughlin and Oliver Schlaudt have similarly argued that "the exchange of commodities, from which Sohn-Rethel derived the real abstraction, [is] just one special case of a more general process of real abstraction" and that "there are multifarious examples of real abstraction in technological practice" (McLaughlin and Schlaudt 2020, 309-311). The conflation of the rise of abstract thinking with the rise of the value form, under the influence of commodity exchange and later money, is an over-simplification. Ancestral metrological techniques sure predated and were independent from the abstraction of value and already represented a consistent process of abstraction as 'social thinking'. As Kula aptly remarked:

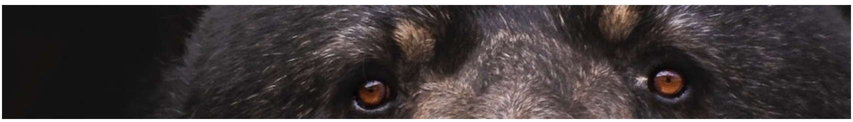
In every metrological system, the measure abstracts just one of the properties of the

[1] On the relation between information and price see also: Beller (2021), 7.

objects measured—be it length, weight, or volume. This enables us to compare various objects in one particular respect, while ignoring all others. The 'invention' of measures marks a significant step forward for civilization, testifying to a significant advance in social thinking (Kula 1986, 69).

It is important to recognize that other forms of abstraction existed before the cult of the 'Golden calf' of the money form took over epistemology. Metrics, specifically, operated as early instances of 'real abstraction'. Probably, metrics were even the origin of the process of valorisation before value happened to be 'realised' into commodity exchange and into money. In the past, metrics surely took the form of a *particular equivalent* that predated the general equivalent of money. In this respect, money could actually be defined as the autonomisation of the metrological praxis into more abstract sphere of social relations. It should finally be acknowledged that the generalisation of scientific and technical standards of measurement contributed not only to the consolidation of power apparatuses but also to the expansion of capital as a general equivalent at a planetary scale.

As mentioned earlier, the depiction of information as a surrogate of money misunderstands its functions, which seem to originate from the abstraction of the metrics of labour and productivity. That information may transmit a price signal (as Friedrich Hayek once suggested and as automated stock markets do today) should not be taken as evidence that value and information are very similar or indeed the same entities. The controversy surrounding information can be better explained by taking into consideration the ground of human labour and social praxis in the making of metrics. Information is neither value nor capital, it is a measure of language reduced to dichotomic signals. Information is a metric of knowledge, labour, communication, and cooperation, and it is in relation to these entities that it has evolved into further forms of numeration and computation.



7. Metrology as geopraxis.

In conclusion, we should ask: How is the Anthropocene debate addressing the political role played by the metrics of labour and social production at different level of its research? How can we better contextualise the role of metrics in the sciences of the Anthropocene, which have been more influenced by the categories and methodology of the natural sciences than of political economy? Conversely, we should also ask: what is the role of metrics of resources, labour, and productivity in the political economy of the present, namely the critique of neoliberalism and extractivism (including the idea of Capitalocene), which have highlighted processes of financialisation, speculation, and accumulation, often postulating the autonomy of capital from nature and labour itself?[1] The previous excursus on the history of energy and information qua the metrics of labour and productivity had the purpose of illuminating the *social substrate of the abstractions* that are used both in the natural sciences and in political economy. This essay concludes by advocating a 'practice turn' in the study of the metrics technoscience, a renewed focus on its operative 'real abstractions', in order to see also metrics and metrology as spaces of political intervention and negotiation; a part of a novel praxis.[2]

The 'real abstraction' that this essay has attempted to illuminate is the humble practice of measurement that nevertheless has carried great consequences for the development of labour automation, scientific research, government by numbers through modernity, and today for the calculus of the variables of the global ecosystem. The substrate of metrics, I have argued, also carried crucial consequences also for the processes of valorisation and capitalisation, for the making of the money form itself. The attention to the metrological substrate in this text, however, has not just been the attempt to reconcile the positions of technoscience and political economy, but especially to recognize a more important *substrate*, the position of the working classes in the global economy, i.e. the political subjectivity of the ergosphere. Historical geoanthropology, the theme of this volume, must take the centrality of the ergosphere into account in order to illuminate the mechanisms of the planetary factory, but it should

[1] See Malm 2016; Moore 2017; Demos 2017.
[2] On the role of practice in the history of knowledge see Renn 2016.

also recognise the *epistemic potentiality* of the ergosphere, its historical role in knowledge making and in the making of technoscientific notions.

As this essay has attempted to show, energy and information cannot be considered as independent and a-historical magnitudes that impose an uprooted point of view 'from above' on the planet, because they have always played a role in the governance of labour, productivity, and social relations. When energy and information are used as metrics of the ecosystem, they must be reconciled with their political genealogy, with their origin in the ergosphere and the metrics of resources, labour and productivity. As Kula has well illustrated, any gesture of quantification of nature, labour, and social praxis is twofold. Quantification is the attempt at establishing a general equivalent among the most diverse materials and resources and this has been pursued in late modernity with the help of the scientific method and technologies of computation. These *just measures* are supposed to be valid everywhere and for everyone, but obviously are often complicit with the control and exploitation of an underlying productive surplus. As Kula specified, the establishment of a metric of resources, labour, and productivity has been a moment of contestation and confrontation in between classes from time immemorial. The perception of the problem of metric power, by the way, remains extremely different in different parts of the world and it would be naive to reduce it to the same analysis. As the anthropologist and urbanist Sanjeev Routray has stressed in the analysis of the displacement of the urban poor in Delhi, India, there also exists "the right to be counted" which local communities express in their struggle against blind spots of governmental policies that try to invisibilise them (Routray 2022). But how can this right to be counted by the public sphere be reconciled with the right *not* to be counted by corporate data monopolies? The contradiction of quantification as a social practice lies in between the right to measure and be measured and the refusal to measure and be measured.

Measurements have been fundamental to the political equilibria of every epoch, as they are today in the measurement of the Anthropocene's different variables. Metrics are an originary praxis that have generated key coordinates of the political constitution, and likewise a new metrological praxis is necessary for the politics of the present. A new metrological theory and practice should be included in the field of tools, techniques and knowledges that compose the Anthropocene disciplines, as a part of what Pietro Daniel Omodeo has recently defined as *geopraxis*. Omodeo has suggested geopraxis as a method of inhabiting and changing the world in the face of globalisation and anthropogenic transformations, moving from the material, social, and ideological structures of historical subjectivities, while also engaging with the transformative power of science and technology (see Omodeo's paper in this volume). In this regard, promoting a new metrological praxis in the Anthropocene means, for example, that the new metrics of the world ecosystem should not overwrite and obliterate the current metrics of labour and social production but should rather address and question them directly. Ultimately (appropriating a felicitous dictum by Donna Haraway), the metrology of the Anthropocene should "stay with the trouble" and become a space of political experimentation in itself (Haraway 2016). If geopraxis is a method of changing the world, it should also contest old and new systems of measurement and valorisation, and reinvent them anew.

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