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# Human Labour and Unity of Force

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## I. The doctrine of energy

If we acknowledge the correctness of the theory of the unity of force, of the constancy of energy,[1] we are also obliged to accept that nothing can be created by labour and that its goal and its utility consists only in a conversion of certain quantities of forces. In what way do these conversions come about? What are the best means of employing human labour in order to draw upon a greater fraction of natural forces for the satisfaction of human needs? We want to try to give an answer to this question in the present essay.

We know that human labour can accumulate greater quantities of energy in its results than was necessary to produce the labour-power of the worker. Why and in what way does this accumulation of energy arise?

In order to answer this question we have to pay closer attention to the general diffusion of energy in space.

The total energy, the whole sum of physical forces of the universe, is a constant quantity. It is entirely otherwise, however, with the quantities of energy in the different parts of the universe. Some celestial bodies send significant quantities of different physical forces through the universe to other celestial bodies. This fact allows us to say that the first bodies, the suns, have energy in a greater quantity than the second, the planets and their satellites. The latter celestial bodies receive their energy from their closest suns in the form of illuminating, heating and chemically potent rays. Such an exchange of force between the bodies that have more energy and those that are endowed with less must lead, after a more or less long time, to a universal equilibrium of energy.

This equilibrium, however, cannot be accomplished other than by means of a whole series of transformations of physical forces. Observation teaches us that all such transformations of physical forces are accompanied by a tendency of those physical forces to assume a determinate form, namely that of the heat uniformly distributed throughout space. This last form of energy is the enduring form which is transformed with the most difficulty, while all other forms of energy – light, electricity, chemical affinity, etc. – are transformed frequently into heat, at least partially, in the course of their transformations.

In this way, a conversion of the energy of the universe constantly occurs through energy losing its less enduring forms and other more immutable forms taking their

1. The capacity of the development of force is called energy.


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place. Thus further transformations of energy gradually become more difficult. After a long series of millions of years, therefore, all energy has to take on an enduring form, namely, that of heat uniformly diffused throughout the universe. If the universe endures for long enough, every type of mechanical movement perceptible to our senses and thus also every type of the phenomena of life will be completely absent, for a difference in temperature is absolutely necessary in order to transform heat into any other force. This tendency of energy towards a general equilibrium is called dispersion [*Zerstreuung*] of energy or, following the terminology of Clausius, entropy.[2] This latter expression signifies the quantity of transformed energy that is no longer capable of any reverse cycle transformations. From this follow the two laws of Clausius: *the energy of the universe is constant. The entropy of the universe has a tendency to reach a maximum*.

Thus, in the strict mechanical sense of the word, the energy of the universe is an always and absolutely constant quantity. However, this energy, brought completely into equilibrium, would be incapable of generating all those phenomena in the inorganic and organic world that we now observe, and which represent, fundamentally, nothing more than an expression of the different transformations of energy. That part of physical force that has now already been transformed into uniformly diffused heat constitutes, in a manner of speaking, a leftover of the world's activity, a leftover that gradually grows more and more.

Presently, however, we still receive on our earth enormous quantities of physical forces that are capable of experiencing the most varied transformations, as whose expression all the physical and biological phenomena appear.[3] According to Secchi, each square metre of the sun's surface delivers 5,770,540 kilogrammometres or 79,642 horsepower of labour.[4] A few square metres of the sun's surface would suffice to set all the machines on the earth into motion. The total labour-power of the sun is estimated at 470 quintillion horsepower. If we accept the widespread theory that establishes the source of the sun's heat as its own condensation [*Verdichtung*], we find that 18,257 years would be necessary for the reduction of the apparent diameter of the sun by a single second and 3820 years would need to pass before the temperature of the sun would fall by a single degree. The last figure will in no way appear to be exaggerated if we consider that the sun's substance is probably almost constantly in that state of chemical indifference, caused by the high temperature, which is known by the name of *dissociation*.[5]

We thus see that the danger of one day suffering a lack of transformable forces on the surface of the earth is still a long way off; at the same time, however, we note upon closer inspection that the distribution

2. Clausius, *Théorie mécanique de la chaleur*. T.I., p. 411. Paris, 1868. [R. Clausius, *The Mechanical Theory of Heat*, translated by Walter R. Browne. London: Macmillan, 1879, pp. 106–7, 195–7 (editorial note).]

3. Biology is the doctrine of living animals.

4. Secchi, *Le Soleil*, II. p. 258. Paris, 1875. [Angelo Secchi, *Le Soleil*, Second Edition. Paris: Gauthier-Villars, 1875–7, two volumes (editorial note).]

5. H. Saint-Claire Deville, *Leçons sur la dissociation*. Paris, 1862. [Henri Sainte-Claire Deveille, *Leçons sur la dissociation: professées devant la Société Chimique le 18 Mars et le 1 er Avril 1864*. Paris: Lahure, 1864 (editorial note).]

of these forces is not always the most advantageous for the satisfaction of the needs of the organic world in general and of the human species in particular. We believe, however, that it is in the power of humanity, to a certain extent, to effect changes in this distribution that will enable us to use a greater part of the world's energy for the benefit of humanity.

In reality, the greater part of the physical forces on the earth's surface is far from being in the most advantageous condition for the satisfaction of human needs.

Humans above all need significant quantities of food, combustible material and mechanical work forces; the most advantageous forms of physical forces would thus be: 1) the more or less free chemical affinity in the form of nutritious substances deriving from plants and animals or in the form of combustible material, and 2) any mechanical movement which could serve as a driving force for the machines working for the benefit of humanity.

We see, though, that our globe in itself provides very few physical forces shaped into such advantageous forms for humanity. If the interior of the earth is really still in a state of incandescence and thereat are found large quantities of dissociated elements which, thanks to the high temperature, contain significant quantities of potential work, we nevertheless do not use these. Rather, we experience only their destructive effects at the time of earthquakes and volcanic explosions. Incidentally, we are nevertheless partially recompensed by the exceptional fertility of volcanic earth and by the increase in temperature in the vicinity of volcanoes. 'On the slopes of Etna', E. Reclus says, 'the earth is so fertile that its products are able to suffice for a population three or four times more dense than that of the other counties of Sicily and of Italy. More than three hundred thousand inhabitants are clustered on the slopes of this mountain, which from a distance is considered a place of terror and imminent danger, and from time to time this proves to be the case as it is uncovered to flood its countryside with a deluge of fire. At the base of the volcano the cities touch and follow one another like pearls in a necklace'.[6]

In general, however, the surface strata of the earth's crust are made up of chemical compounds, which contain almost no free chemical affinity and consequently have very little potential (possible) force of movement. We find the same thing in relation to the bodies of water and atmosphere that surround the surface of our globe, and with which we continually come in contact. All movements of air and water, ebb and flow, the movement of the waves caused by the wind, the currents of the rivers, the force of falling rain, even the wind, borrow their forces from the sun's energy or are caused by the gravity of the moon and the sun. The chemical affinity that is accumulated in the form of coal inside the earth is likewise an effect of solar heat, a product of the sun's rays over the course of many thousands of years. Even the free oxygen of the atmosphere, according to new geological hypotheses, was previously

6. E. Reclus, *Géographie universelle*. I. 538. Paris, 1875. Kilometric population of Italy 94, of the Etna region 550. [Elisée Reclus, *Nouvelle géographie universelle: La Terre et les hommes* (19 volumes). Paris: Hachette, 1876–94; Elisée Reclus, *The Earth and Its Inhabitants* (19 volumes), edited by E.G. Ravenstein and A.H. Keane. New York: D. Appleton & Co., 1882–95, Volume I, p. 315 (editorial note).]

combined with the carbon that now constitutes coal – and was freed from it only through the influence of the sun's rays by means of a very rich growth of plants.[7]

All these examples show us very clearly that the radiant energy of the sun is almost the only source of all the forces on the earth's surface useful to humans.

We know, however, that the quantity of the energy that is radiated by the sun towards the earth would be thrown back into space in the same amount if this energy did not undergo certain transformations, which allow it a longer stay and even to become an accumulation of solar energy on the earth's surface. This actually occurs whenever the sun's rays that arrive to us, warm, illuminating and chemically effective, are so received by matter that they are transformed into free chemical affinity or into mechanical movement. In this last case, a part of the radiating solar energy is no longer, according to the well-known Kirchhoff's Law,[8] simply thrown back into space. Rather, it can then be accumulated for a longer time on the earth's surface, taking on forms that temporarily guard it against dispersion. 'Energy rises by degrees', says the famous English physicist William Thomson about this process.[9] The following words of Secchi illustrate the point well: 'The sun's rays that fall on the plants are not reflected by them to the same degree as would be found for the desert or mountainous rock. They are held back in a greater measure and the mechanical force of their vibration is used for the decomposition of compounds of oxygen with carbon and with hydrogen, of saturated and enduring compounds, which are known by the names of carbon dioxide and water'.[10]

What occurs during this process? A part of the sun's heat perishes as such. It is held by the earth's surface without raising its temperature, that is, without increasing its losses [into space]. With the same loss [into space], the earth's surface obtains more energy, or receiving the same [quantity of

7. Sterry Hunt, *Congress of the British Society*, 1878. [See Thomas Sterry Hunt, *Chemical and Geological Essays*, Third Edition. New York: Scientific Publishing Company, 1891, pp. ix–xi, 40–7 (editorial note).]

8. Kirchhoff's Law can be expressed as: the quantity of radiated heart is directly related to the difference between the temperature of the heat-source and the environment that surrounds it. [Gustav Kirchhoff, *Researches on the Solar Spectrum, and the Spectra of the Chemical Elements*, Part 1, translated by Henry E. Roscoe. Cambridge and London: Macmillan, 1862–3, p. 17; Gustav Kirchhoff, 'On the Relation Between the Emissive and the Absorptive Power of Bodies for Heat and Light', in *The Laws of Radiation and Absorption: Memoirs by Prévost, Stewart, Kirchhoff, and Kirchhoff and Bunsen*, translated and edited by D.B. Brace. New York: American Book Company, 1901, pp. 75–6 (editorial note).]

9. [William Thomson (Lord Kelvin, 1824–1907), Irish-Scottish mathematical physicist and engineer, one of the founders of the science of thermodynamics, who also supported the controversial interpretation of the entropy law as implying the eventual 'heat death' of the universe. The quotation in the present text may be a reference to William Thomson, 'On an Absolute Thermometric Scale founded on Carnot's Theory of the Motive Power of Heat, and Calculated from Regnault's Observations', *Proceedings of the Cambridge Philosophical Society*, Vol. 1, 1848, pp. 66–71, republished in William Thomson, *Mathematical and Physical Papers*, Vol. 1. Cambridge, England: Cambridge University Press, 1882, pp. 100–6 (editorial note).]

10. Secchi, *Le Soleil.* T. II, p. 300.

energy], it loses less of it. However we may look at this process, we obtain under the influence of plants an accumulation of energy – and not radiated energy, like, for example, heat, electricity and light, but energy of a higher degree – which can be kept for hundreds of years and still retains the capacity for further transformations. Thus the plants on the earth's surface are the worst enemy of the dispersion of energy into space.

## II. The transformable energy on the earth's surface

We thus see that the radiating energy of the sun has not yet completely lost the ability of taking on further higher forms on the earth's surface. Nevertheless, the way in which this process happens ranges within relatively narrow limits. More specifically, this transformation happens in the following ways:

1) The generation of winds, that is, through the impetus which the air gains from changes in temperature.
2) The elevation of water by means of evaporation.
3) The dissociation of enduring compounds, for example, of water, of carbon dioxide, of ammonia during the growth of plants.
4) The muscular and nervous labour of animals and humans.
5) The work of the machines made by humans, which have the sun's heat as their only driving force, in either a mediated or an immediate way, as in the case of the now widely known solar machine of Mouchot.[11]

Of course, there are also enormous quantities of transformable energy on our earth, outside of this list of processes we have compiled. These, however, have been left unused by humanity up until now.

First place, according to its size, is taken by the energy of the movement of the earth around the sun and around its own axis. Both movements are forms of energy that are still very transformable or, according to Thomson, high-grade energy, as are in fact all mechanical movements. There is a well-known calculation according to which the immediate stop of the earth in its cycle around the sun would be expressed in the development of a quantity of heat, for whose generation it would be necessary to burn a quantity of coal exceeding the mass of the earth fourteen times. The energy of rotation [*Umdrehung*] around the earth's axis is likewise of a very significant amount. However, the influence of both movements on the distribution of energy on the earth's surface has not been precisely determined. Concerning the energy of rotation around the axis, however, this conclusion is perhaps not completely correct because it is known that a part of this energy is transformed into heat under the influence of friction against the mass of water remaining behind in the change from low to high tide. This increases

11. [A reference to the work of the French mathematics teacher and engineer/inventor Augustin Mouchot (1825–1912). Mouchot was awarded a Gold Medal at the Worlds Fair of 1878 for his research relating to the use of solar heat. In 1861 he had patented the first machine capable of producing electricity by exposure to the sun. His device used glass-enclosed water to evaporate water in an iron bucket, with the resulting steam providing a motive force for a simple engine. See Frank Kryza, *The Power of Light: The Epic Story of Man's Quest to Harness the Sun*. New York: McGraw-Hill, 2003, Chapter 6 (editorial note).]

the temperature of the water, while the movement of the earth, even if very insignificantly, is slowed down.[12] By using the tide as a moving force for machines, for example, mills, we hold water up during its highest point at the time of the high tide and use the receding water during the low tide. On the whole, however, the tides are still relatively rarely used as motors.

We have already seen that the inner heat of the globe likewise does not play a very significant role in the economy of energy on the earth's surface. If we view magnetism as an expression of the energy found in the earth's interior, it of course represents a relatively significant quantity of force that is not to be scorned because it is used during navigation and for the fabrication of many scientific apparatuses. At any rate, the absolute size of the earth's magnetic force is not very noticeable in comparison to the solar energy effective on the earth's surface.

Thermal springs furnish us with a not large but nevertheless advantageously applicable quantity of transformable energy. Their heat can be used for various technical ends, for example, for the heating of houses, for the preparation of mortar, etc. We still do not know how to apply the heat of the thermal springs as motor power; to a small degree, such an application is of course entirely conceivable.

There is very little free chemical affinity on the earth's surface, except for that (already mentioned) of the oxygen in the atmosphere. Inside the earth there are certainly significant masses of metals and sulphur in a free state, but we feel little of the efficacy of their chemical energy on the earth's surface.

Turning now to the forms of transformable energy already enumerated at the beginning of this section, we see that the movement of the air or the wind is a very high-grade and, in the human sense of the word, useful form of energy that can furnish a large quantity of mechanical work. Nonetheless, it is not very difficult for us to show that the movement of air is nothing other than a part of solar energy, comprehended as in retrogressive transformation. In order to generate the active force of the wind, the sun must deliver a many times greater amount of energy, of which a significant part is dispersed into space. It cannot happen otherwise, however, because the sun's heat, a low-grade energy, according to the general laws of dispersion, cannot ever be completely transformed into the mechanical movement of air, a higher-grade energy. Even that part of energy that is transformed into movement passes over into dispersion, for the wind is nothing other than a result of the tendency towards equalisation of temperatures.

What has been said about the force of movement of the wind is likewise applicable to the forces of the water currents and in general of falling water. By falling on the millwheels, water gives a higher fraction of useful work than either the steam engine or electromagnetic machine or the more advantageously equipped organisms of pack animals or of humans can deliver. We should not forget here, however, the enormous mass of solar energy that has served to raise the water by means of evaporation.

12. The credit for the first thought of such an influence of the tide goes to Kant. See his *Theory of the Heavens*. Königsberg, 1785. [The correct reference is Immanuel Kant, 'Examination of the Question Whether the Earth Has Undergone an Alteration of its Axial Rotation', in *Kant's Cosmogony*, translated and edited by W. Hastie. Glasgow: James Maclehose and Sons, 1900, pp. 1–11. See the discussion in Frederick Engels, *Dialectics of Nature*. Moscow: Progress Publishers, 1964, p. 106. (editorial note).]

We see from all this that regardless of the significant quantity of solar energy retained by the earth's surface, it is nevertheless in no way rich in transformable energy such as, for example, mechanical movement or free chemical affinity. Even heat is not in abundance. We find free chemical affinity accumulated in large quantities only in combustible materials of organic derivation. This mass as such is of course significant. According to approximate calculations, the English coalfields amount to 190,000,000,000 tonnes of coal and the North-American even 4,000,000,000,000.[13] This whole quantity, however, just as with all the other organic combustible materials, e.g. peat, petrol etc., is formed by the influence of solar energy, i.e., from the plants on the earth's surface from different epochs. We believe, that is, that plants, with the help of solar rays, have in the course of centuries transformed a saturated substance deprived of free chemical affinity, carbon dioxide, into coal, which contains a large quantity of such energy. At the same time, the oxygen of the atmosphere was freed from the carbon dioxide to which it was previously bound, and its energy of chemical affinity thereby freed up to nourish the life of the higher organisms, of animals and humans.

## III. Energy accumulation

We can begin our investigation from the moment when the earth's land surface was formed to such an extent that the earth's crust frustrated a significant influence of the earth's inner heat on its surface temperature. As this filling up was already so advanced that the temporarily dissociated water could be transformed into steam and a large part of the steam could be transformed into fluid water (which, dissolving the salt that had been condensed up until then, formed the oceans in the depressions of the earth's crust), most of the chemical processes in the inorganic substance of the earth's crust were already finished. Chemical affinity was already saturated to approximately the same degree as today, if we leave out of consideration the processes of plant life. We even believe that thanks to its influence the saturation of chemical affinity is not as extensive now, for, according to the above mentioned hypothesis, the whole quantity of coal now found in the earth's layers was then in compound with the oxygen of the atmosphere. We know, that is, that the plants draw their carbon from the carbon dioxide of the atmosphere. We have no reason to suppose that they would have done differently during the coal period. Therefore, we have every right to believe that at the beginning of organic life the quantity of unsaturated chemical energy on the earth's surface was insignificant. The influence of the transformable energy inside the earth was constantly diminished by the gradual swelling of the earth's crust. Of course, back then the earth received somewhat more energy from the sun than it does now. However, the dispersion of the same was also much more significant, for the earth was then hotter than it is today and radiated more energy into icy space. The large quantities of energy obtained from the sun increased only insignificantly

13. *Edinburgh Review* 1860. Coal Fields of North America and Great-Britain, pp. 88–9. ['Review of Henry Darwin Rogers, *Essays on the Coal Formation and its Fossils, and a Description of the Coal Fields of North America and Great Britain, annexed to the Government Survey of the Geology of Pennsylvania*. Edinburgh and Philadelphia, 1858', *Edinburgh Review*, Vol. CXI, January 1860, p. 88 (editorial note).]

the energy of the earth, because the chemical solar rays then found no such substances upon which they would have been able to exercise an influence, as now occurs, for example, with the help of plants, that is, through the dispersion of unsaturated compounds. The same thing occurred with heat and light rays. Heat rays were merely absorbed in the same way as its dispersion and did not increase the amount of transformable energy on the earth's surface. With the exception of the movement of heated air and the water, solar energy was not transformed into any other form on the earth's surface, as still now occurs on the plantless sand area of the Sahara desert or on the ice sheets of the polar regions. If one does not consider the heat contained inside the globe, the quantity of transformable energy contained by the sun back then and the preservable solar energy on the earth's surface appear to have been less significant than at the present time. For if we reckon the coal beds within the earth's surface (to which we are completely entitled, given the organic derivation of the coal deposits), we find ourselves today in possession of very significant quantities of transformable energy. This supply consists, on the one hand, in the unsaturated affinity of enormous quantities of carbon, and on the other, in the free affinity of the oxygen of the atmosphere.

If we examine the course of development of this process, we find that energy contained inside the earth plays an ever-smaller role in the course of time in the formation of the energy budget of the earth's surface. The quantity of energy obtained from the sun decreases, slowly, but regularly. In order for an accumulation of energy to be formed on the earth's surface despite the diminished supply of it, it is essential that a process come about that works against the dispersion. This process must be such that a part of the heat obtained from the sun is transformed into other forms of energy, into chemical affinity, mechanical labour, etc., and, indeed, into ever greater masses.

At the moment, the earth's surface has in a higher degree than formerly the quality of converting lower forms of solar energy (heat) into higher forms (chemical affinity, movement). One must have a correct idea of such a conversion working against the process of dispersion, in order to recognise its significant complexity. This is especially the case with regard to the transformation of heat into mechanical activity. The ways and means in which solar energy is transformed into mechanical movement are also certainly not numerous.

It is easy to prove that the quantity of solar energy that is transformed into free chemical affinity or into mechanical work is not always the same and that, among other causes, it can also be influenced by the activity of humans.

One can, that is to say, assume as undoubted that the existence of plants has the quality of effecting an accumulation of solar energy on the earth's surface to a higher degree than that of animals. The coal deposits are a smoking gun in this regard. One should even recognise that despite the new theories (Bernard, et al.) about the unity of life in both kingdoms,[14] animals lose a large quantity of their heat through

14. [Podolinsky refers parenthetically to the work of the French physiologist Claude Bernard (1813–78), who in 1870 gave a series of lectures at the Paris Museum of Natural History that were later published as *Leçons sur les phénomènes de la vie, communs aux animaux et au végétaux*. Paris: J.-B. Ballière, 1878–1879. For the English edition see *Lessons on the Phenomena of Life Common to Animals and Plants*, translated by Hebbel E. Hoff, Roger Guillemin and Lucienne Guillemin. Springfield, IL: Thomas, 1974 (editorial note).]

respiration and movement, that is, they disperse much solar energy into space that had been accumulated by plants. It is of course very difficult to ascertain the precise relation of the two quantities; it is certain, however, that *humans, though certain activities dependent upon their wills, can increase the quantity of accumulated energy of plant life and reduce the quantity of energy dispersed by animals*.

By cultivating plants in places where they either do not yet exist, or exist only in a small amount, by draining marshes, irrigating the deserts, applying perfected cultivation systems, using machines for agriculture and, finally, by protecting the cultivated plants against their natural enemies, we reach the first of the two indicated goals.

Through the displacement or extermination of animals that are damaging to the plant kingdom, we work at the same time for the second goal. In both cases, we obtain as a result an absolute or relative enlargement of the solar energy retained on the earth's surface.

We are thus presented with two parallel processes which, taken together, form the so-called life cycle. Plants have the quality of accumulating solar energy; animals, however, by nourishing themselves from plant stuffs, transform a part of this saved energy into mechanical labour and disperse it afterwards into space. If the amount of energy accumulated by plants remains larger than that of the energy dispersed by animals, there arises a build up of energy stores, e.g. in the period of the formation of coal during which it seems plant life had a preponderance over animal life. If, on the other hand, animal life obtained the upper hand, the accumulated energy store would soon be dispersed and animal life would have to return to the mass determined by the plant kingdom. In this way a certain state of equilibrium between the accumulation and the dispersion of energy would develop. The energy budget of the earth's surface would then be of a more or less stable size; the accumulation of energy, however, would fall to nothing or at any rate much lower than at the time of the preponderance of plant life.

Factually, however, we see no such stagnation of the energy budget on the earth's surface. The quantity of accumulated energy is even now generally understood to be growing. The quantity of plants, of animals and of humans is now undoubtedly more significant than in previous times. Many previously infertile strips of land are now cropped and covered with luxurious plant growth. In almost all civilised lands the harvests have increased. The number of domestic animals and especially of humans has substantially increased. If some countries have lost their earlier fertility and number of inhabitants, that depends on far too gross and self-evident business mistakes; otherwise, however, the opposite is the rule, and on the whole a general increase of the amount of nutritious material and of transformable energy on the earth's surface can no longer be denied.

*The most important cause of this general increase is the labour performed by humans and the domesticated animals used by them*.

Some examples from the agricultural statistics of France will illustrate for us the correctness of this proposition:

At the moment France possesses nine million hectares of forest, which deliver a yearly yield of 35,000,000 cubic metres, or nearly 81 million metric quintals, of dry wood. Thus, each hectare delivers a yearly yield of nine metric quintals or 900 kilograms. Each kilogram of dry cellulose contains 2550 calories, so consequently the yearly accumulation of energy on each hectare of forest constitutes the quantity of 900 × 2,550 = 2,295,000 calories.

The natural pastures in France cover an area of 4,200,000 hectares and produce each year on average 105,000,000 metric quintals of hay, that is, 2,500 kilograms on each hectare. The accumulation of solar energy thus represents 2,500 × 2,550 = 6,375,000 calories per hectare.

We therefore see that without the contribution of labour, plant growth yields an accumulation of solar energy that does not exceed the amount of 2,295,000 to 6,375,000 calories per hectare, even in the most favourable conditions (as they are encountered in the forest or on the pastures).

Where, however, labour is applied, we immediately see a significant increase. France currently possesses 1,500,000 hectares of artificial pastures that, after deducting the value of the sown seeds, yield in an average year 46,500,000 metric quintals of hay, that is, 3,100 kilograms for each hectare. Consequently the yearly energy accumulation is 3,100 × 2,550 = 7,905,000 calories per hectare. The excess in comparison with the natural pastures thus equals 1,530,000 calories per hectare, and this surplus is due only to the labour used in the creation of the artificial pastures. The quantity of this labour for a hectare of artificial pasture is approximately the following: 50 hours of labour of a horse and 80 hours of labour of a human. The whole labour expressed in terms of thermal units is 37,450 calories. We thus see that each calorie of labour applied in the creation of artificial pastures effects a net energy accumulation of 1,530,000 : 37,450 = 41 calories.

We observe the same thing also in the cultivation of grain. France grows something over 6,000,000 hectares of wheat, which, deducting the seed, gives 60,000,000 hectolitres of grain and a further 120,000,000 metric quintals of straw. Each hectare thus gives 10 hectolitres or 800 kilograms of grain and 2,000 kilograms of straw. The 800 kilograms of grain contain – according to a special calculation of the composition of starch, bran, etc. – approximately 3,000,000 calories, which, together with the 2,000 × 2,550 = 5,100,000 calories found in the straw, make up the sum of 8,100,000 calories.

The surplus in comparison with the natural pastures is 8,100,000 – 6,375,000 = 1,725,000 calories. In order to obtain this, approximately one hundred hours of horse labour and 200 hours of human labour are used, which together have the value of 77,500 calories. Consequently each calorie in the form of labour for cultivation of the pastures generates a terrestrial accumulation of solar energy equivalent to 1,725,000: 77,500 = 22 calories.

Where does this surplus of energy come from, which is indispensable for the elaboration of this mass of nutritious and combustible materials? We can give only one answer: *from the labour of humans and domesticated animals*. What, then, in this connection, is labour? *Labour is such a use of the mechanical and intellectual energy accumulated in the organism, which has as a consequence an increase of the general energy budget of the earth's surface*.[15]

15. See 1. *Statistique de la France* 1874, 1875 and 1878. 2. *Dictionnaire des arts et de l'agriculture* de Ch. Laboulaye, 4. édition 1877. *Articles agriculture* par Hervé Mangon, et *Carbonisation*. 3. Pelonze et Frémy, *Traité de Chimie*. 4. Hermann, *Grundzüge der Physiologie*, 5. Auflage, 1877. [Charles Laboulaye, *Dictionnaire des Arts et de l'Agriculture*, Fourth Edition. Paris: Librairie du Dictionnaire des Arts et Manufactures, 1874; Théophile Jules Pelouze and Edmond Fremy, *Traité de chimie générale*, Third Edition. Paris: V. Masson, 1865–1866; Ludimar Hermann, *Grundriss der Physiologie des Menschen*, Fifth Edition. Berlin: Hirschwald, 1874; Ludimar Hermann, *Elements of Human Physiology*, Fifth Edition, translated and edited by Arthur Gamgee, M.D. London: Smith, Elder, & Co., 1875 (Editorial note).]

This increase can come about either directly, through the transformation of new quantities of solar energy into more transformable forms, or also in a mediated way, through protection against that dispersion into space, which would have occurred inevitably without the involvement of labour. To this last category belongs, for example, the labour of the tailor, the shoemaker, construction workers and such.

It is clear, from this perspective, that useful labour can only be ascribed to humans and some animals, which are either managed by humans, as with domesticated animals, or which, like ants, partially work on their own, and partially devote themselves to the breeding and raising of domesticated animals, driven by their own instincts.

The movement of air, i.e., the wind, cannot ever be regarded in and for itself as useful labour, for, left to itself, the wind, through the dispersion of its energy, generates no new accumulation of energy on the earth's surface. The same is also the case for water currents as a moving force.

Although plants accumulate energy in the substance of their own bodies, they cannot, in the majority of cases, set such energy into movement independently; they cannot usefully employ it in the sense of a general increase of the quantity of force on the earth's surface.

Man-made machines may, if left to themselves, remain in operation for a long time; but they would nevertheless not yield any useful work, for we still cannot imagine an artificial mechanism that would have the ability to progressively augment the solar energy accumulated on the earth without the participation of the muscle-power of humans.

Finally, even the nervous labour of humans only becomes really useful labour for humanity when it leads to some type of muscular effort. For we do not know any other way of achieving through nervous labour an immediately useful goal, i.e., an absolute or relative increase of the energy available in the human kingdom.[16]

In passing over to the muscular labour of animals and humans, it is similarly difficult to determine with certainty the boundaries of useful labour. If we subject a lowly member of the animal kingdom to observation, we will find out only with great difficulty which of its functions should have the name of labour attached to it. Often labour is confused with mechanical movement; hence, the question becomes: are the fluttering of a butterfly and the crawling of a snail also labour?

From our point of view, we can confidently answer: no. The crawling of a snail and the fluttering of a butterfly are not labour, for they are accompanied merely by a dispersion of energy, but not by an accumulation of energy. But, one could reply, the snail crawls around in order to find food, the butterfly flutters about in order to find a good place for the development of its larvae. We, however, reply in turn: nature knows no goals and reckons its account merely from the results. The entire life of the snail, all of its crawling, seeking for food, digestion of the found means of existence and the ability gained from this for new movements, do not transform the slightest quantity of solar energy into such higher forms which by their further deployment could increase the store of energy on the earth's surface. A snail is incapable of dedicating itself to

16. Cf. M. Marey, *Du mouvement dans les fonctions de la vie*. p. 205. Paris, 1868. [Etienne-Jules Marey, *Du mouvement dans les fonctions de la vie*. Paris: G. Baillière, 1868. (editorial note).]

agriculture, thus it also cannot increase the accumulation of solar energy through plants. One might perhaps respond to us that the snail, even if not through its life, then at least through its death, could advance the growth of plants. For a snail can, given good conditions and rich nutrition, destroy a large mass of plant material. If, on the contrary, it is forced to suffer hunger and die in the case of a failed crop of the types of plants most beneficial to it, it thereby gives the plants the possibility of developing in greater numbers, thus increasing the accumulation of energy. This is certainly a curious objection, the answer to which is not difficult. If the luxuriousness of the growth of plants of any particular locality really increases through the loss of the snail, it is then very probable that also the number of enemies of this plant growth will increase. After its death, the snail is no longer in a condition to keep the plants it formerly exploited from their new enemies and therefore the energy conversion remains presumably the same as it was before.

For we should keep in mind that by the word 'labour' must be understood a 'positive act' of the organism, which has as a necessary consequence an accumulation of energy. Therefore the 'passive fact' of death in the struggle for life can never belong to the category of labour.

We have introduced this example – which admittedly may seem peculiar to many – in order to assign the question of the conservation of energy its correct place from the beginning. It could, for example, appear that the death of the snail or the caterpillar actually encourages plant growth simply due to the fact that they no longer destroy any plant material. After all, one says that a capitalist saves when he does not consume all of his income. We have just sought to show, however, that a snail can never perform useful labour because it never increases the accumulation of energy through its activity. The same is the case regarding those conscientiously saving humans [the capitalists].

We hope that we have thus managed to bury the doctrine of saving or, as it were, of negative labour. For labour is always a positive concept, which consists in such an expenditure of mechanical or physical labour that has its end result an increase of energy accumulation.

Viewed from this perspective, we can conclude that the different movements of animals that are self-evidently goal-less or have as a goal merely the seeking out of means of nutrition, etc., cannot be counted as labour, precisely because they leave behind no increase of energy accumulation. Thus, for example, the activity of the spider that goes to great pains spinning its web and that of the doodlebug, despite all of the engineering knowledge involved, are still not by a long way useful labour.

In the strict sense of the word, it is only with the agriculture of humans that the correctness of our definition of labour becomes clear. For it is evident that a hectare on a wild steppe or in a virgin forest, without the involvement of humans, produces each year merely a determinant quantity of nutritious material, but the application of human labour can raise this amount ten or twenty fold. Of course, the human creates neither material nor energy. The material was already contained in its totality in the ground, in the seed and in the atmosphere; all of the energy was furnished by the sun. Thanks to the involvement of humans, however, a hectare of land covered with cultivated plants can accumulate perhaps ten times the quantity of energy it would have without their involvement. One should not believe that all of this energy was already aggregated in the soil and merely dispersed in a greater amount by human labour. That would not be correct, for agriculture exhausts the soil only if it is conducted irrationally, that is, wastefully. On the contrary, a perfected agricultural science gives the best harvests precisely in the lands where agriculture has flourished already for a longer time, e.g. in England, France, Belgium, in Lombardy, in Egypt, China, Japan, etc. Therefore we believe we are correct to say that scientifically organised agriculture can be counted as one of the best examples of really useful labour, that is, such labour which increases the amount of solar energy upon the earth's surface.

## IV. The labour of the human organism

Beginning with the distribution of energy in space, we have arrived at human labour, an important factor in the distribution of energy upon the earth's surface. We have not said anything until now, however, about the emergence of that capacity for labour in the human organism, without which the accumulation of energy on the earth's surface under the influence of labour would be difficult to explain. From where in the organism does the energy necessary for labour derive? Which mechanisms does this activity use? What phenomena accompany it?

We can answer the first question by saying that the whole mechanical labour of animal organisms has its source in nutrition. The free chemical affinity of nutritious material is saturated within the organism by the inhaled oxygen, and thereby converted into heat. A part of the latter passes over into mechanical labour.

Hirn conducted one of the first and most important experiments on the conversion of the heat of the human organism into labour.[17]

He used a large wooden hermetically (airtight) sealed box, but which was furnished with glass openings in order to be able to observe its interior. In the box a human who served as the object of the experiment could find enough free space in order not to touch its walls. The air necessary for breathing was admitted through a pipe and the exhaled gases were removed in the same way. At the beginning of the experiment, the human remained in a state of rest. In the further course of the experiment, however, he performed a determinant sum of labour in the box, climbing up or down a ladder. The mechanism for this was arranged in the following way:

In the lower part of the box was mounted a wheel that turned around an axis, being set into movement by a belt outside the box. During the movement of the wheel, the human who served as the object of the experiment had to imitate the movement with his feet while holding himself up on a handrail mounted in the upper part of the box, just as if he were climbing stairs. Accordingly, rungs were also mounted on the wheel at certain intervals. When the wheel was moved in the opposite direction, the human had to descend onto the wheel and, after an hour, for example, his centre of gravity had covered the same distance as the circumference of the wheel in the opposite direction.

The quantity of heat energy generated by the worker is different in these three cases, according to whether the man was at rest or descended onto or dismounted the wheel. These differences agree completely with the postulations of the mechanical theory of

17. [Gustave Adolphe Hirn (1815–90), French industrialist and thermodynamic theorist/engineer. He tried to apply to human muscular labour the concepts and measurement methods developed in his experiments involving steam engines (editorial note).]

heat. It was the case, namely, that during the pause each gram of oxygen inhaled delivered 5.18 to 5.80 calories, while during labour it only delivered 2.17 to 3.45 calories. This experiment yields very important results. For it gives us the possibility, even if only approximately, of determining the size of the economic coefficient of the human machine, that is, the percentage yield of the heat transformed during labour.[18] Helmholtz managed on the basis of Hirn's experiment and with the help of some hypotheses commonly acknowledged in physiology to quantify this coefficient.[19]

At complete rest, an adult human delivers a quantity of heat in the course of an hour, which carried over into labour, could raise the body of this human to a height of 540 metres. This height is precisely that at which one arrives when mountain climbing without particular effort in the course of an hour, that is, under the same conditions as in Hirn's experiment. However, during this experiment the respiratory activity of the worker was intensified fivefold. It follows immediately that the economic coefficient of the human machine represents 20% or 1/5 of the total heat generated by the organism or, what is the same thing, that the human possesses the ability to transform 1/5 of the total energy added by nutrition into muscular labour. As is generally known, even the most advanced steam engines do not reach this quantity. This extraordinary capacity to convert lower forms of energy into mechanical labour is found to an even higher degree in some of the inner organs of the human body, e.g. in the heart. Helmholtz has found that the heart, by means of its own force, could raise itself up to a height of 6,670 metres in the course of an hour. The strongest locomotives, which e.g. are used on the Tyrol railways, could not raise their own weight up over 825 metres in an hour. Consequently, these locomotives, considered as machines, are eight times weaker than a muscular apparatus similar to the heart.[20]

The causes of this disproportionately significant strength of the muscular apparatus have been partially explained by the latest researches in the field of muscle physiology. In part, however, they still remain shrouded in darkness. Here is not the place to enter into further discussion of this matter. In general, however, we can apply most of the laws of the steam machine or any other thermal machine (set into movement by heat) also to the labouring human.

In this comparison we should not forget that the human organism is much more complicated than any other thermal machine. All artificial machines obtain their sources of movement in one or a few ways, e.g. through the burning of combustible material, through chemical processes in galvanic elements, etc. Similarly, the work of machines proceeds only in one or a few directions. We observe something completely different when it comes to humans. Even though nutrition together with the inhaled gases are likewise almost its only sources of force, the human

18. The economic coefficient of a machine is that number which gives the relation of its efficiency to the heat used by it.

19. [Hermann von Helmholtz (1821–94), German physicist and physician, and one of the co-discoverers of the first law of thermodynamics, which he termed the 'Law of Conservation of Force' (editorial note).]

20. Verdet, *Theorie mécanique de la chaleur*. II., 246. [*Oeuvres de Émile Verdet*, Volumes VII–VIII. Paris: Imprimerie Impériale, 1868–72 (editorial note).]

organism possesses, on the other hand, certain abilities to prevent the energy from dispersing. These are partially applied instinctively, as satisfaction of needs, and also partially deliberately, in the form of education, learning, and improvement. For instance, houses and walls, which merely satisfy our immediate needs and protect us from the excessive lack of warmth, also lead to a saving and advantageous distribution of energy in the human body just as much as does, for example, instruction in a useful employment of energy during labour.

A second and even more significant difference between the human organism and any other thermal machine consists in the diversity of human labour. Without taking the intellectual activity of humans into account, the mechanical achievements of humans are already so rich and diverse that they are overtaken by a mechanical apparatus only with difficulty. It is precisely this diversity of movements that gives human labour the ability to cause simultaneously all those transformations in the environment, which in their end results make possible an accumulation of energy. Such is the case, for example, with the long series of various kinds of cultivation. This diversity of movements of the human machine is the most important cause of the higher productivity of the labour of humans.

On the other hand, we must also mention those causes that apparently result in a significant decrease in the high economic coefficient of the human machine. Foremost is the necessity of satisfying some purely intellectual needs, which meanwhile cause a great addition to the general energy budget of humanity. Naturally, the higher the development of humanity rises, the greater the role these intellectual needs play in its life.

However, there are not a few purely material needs in addition to the need for nutrition and for air to breath, and it is not easy to determine the quantity of necessary labour for these. Since we still do not have a close measure of this, we hold ourselves to the following calculation, which is certainly inexact but nevertheless is provisionally adequate for our purposes.

In most civilised lands food expenditure represents approximately half of the budget of the middle classes. Housing, clothing and the satisfaction of intellectual needs claim the second half. We should conclude from this that if the economic coefficient, calculated according to the quantity of nutrition and the inhaled oxygen, equals the fraction of 1/5, and if the whole quantity of energy that is claimed by humanity for the satisfaction of its material and intellectual needs is properly brought into consideration, this coefficient must be decreased to the fraction of 1/10, and then even more so in light of the fact that a human passes a significant part of its life, during childhood, old age and sickness, as unproductive.

Thus, if we consider the human organism as a thermal machine with an economic coefficient of 1/10, it becomes possible to define a little more closely the preconditions of human life on earth. In earlier times of its presence on this planet, humanity did not yet have the means to increase the earth's energy store. We should thus believe that humanity lived exclusively from materials drawn from already existing stores. Actually, humanity did nothing more than hunt wild game, catch fish, gather fruits and consume all of these foodstuffs, without furnishing any type of useful labour; that is, humanity simply dispersed energy into space. If humanity had reached no higher development than the wild animals, it would probably have been made extinct by other animals, or at any rate its number would have been one corresponding merely to the general conditions of the struggle for life. But under the influence of very special conditions, particularly of an advantageous organisation of the brain and the upper extremities, humanity began to employ its mechanical energy in a direction that enabled a general accumulation of energy on the earth's surface. With that, the existence, increase and development of humanity were also made possible. Humanity is no longer bound by the quantity of the energy store; on the contrary, it can independently increase this store. Whether or not it really did this from the beginning, whether or not it currently does this in all cases, is an altogether different question. The possibility, however, is already at hand. Of course, at the beginning of civilisation, the dispersion of energy, due to destruction of forests, unregulated hunting etc., exceeded by a long way the accumulation of energy through agriculture and animal husbandry. With time, however, both influences came into equilibrium and finally the accumulation of energy by means of agriculture began to gain the upper hand over the dispersion of energy. Actually, of 1,300–1,400 million humans, barely 100 million are fed with the products of hunting, fishing or solely of animal husbandry, i.e., with foodstuffs that are not a product of human labour. All the remaining humans, 1,200–1,300 million in number, are obliged to feed themselves at the cost of agriculture, that is, at the cost of an energy accumulation that is the immediate result of human labour. If all present cultivation together with the more than 1,000 million tillers of the soil should ever disappear, the remaining humans would have great difficulties in feeding themselves with natural products, and would certainly not manage without also resorting themselves to tilling the soil. It immediately follows from this that no less than 1,000 million humans must now regularly be occupied in working on the accumulation of solar energy on the earth's surface in order to satisfy the needs of the entire population.

As we have seen, the economic coefficient of this labouring human machine, that is, of the entirety of humanity, equals approximately the fraction of 1/10. Although humanity can transform only 1/10 of its energy into mechanical labour, this quantity already suffices for it to support a more or less steady growth of the human population. Even though humanity's intellectual needs grow with its development and the economic coefficient thereby naturally becomes smaller, the total labour of humanity in general is nevertheless progressing. What are the causes of this apparent contradiction?

Since the development of the mechanical theory of heat, any process that leads to the production of mechanical movement can be compared to the activity of a thermal machine, i.e. a machine that transforms heat into labour. Incidentally, such views were enunciated in the past by Sadi-Carnot in his famous work that appeared in 1824. 'In order to consider in the most general way the principle of the production of motion by heat, it must be considered independently of any mechanism of any particular agent. It is necessary to establish principles applicable not only to steam-engines but to all imaginable heat-engines, whatever the working substance and whatever the method by which it is operated'. Sadi-Carnot says further: 'Whenever there exists a difference of temperature,... it is possible to have also the production of impelling power'.[21]

21. Sadi-Carnot, *Réflexions sur la puissance motrice du feu*. Paris, 1824. See p. 8 et sqq. [Sadi Carnot, *Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette*

We know, however, that the entirety of the heat can never be transformed into work, and that in the most advantageous of cases hardly 20% of useful work is obtained. All remaining heat is for the most part dispersed. In order to come to an accurate conception of the quantity of work obtained, we must move on to consider the machine's opposed transformation of work into heat, so that we can determine the quantity of heat contained in our work. Following Sadi-Carnot, this would be a reverse cycle or circular process. In his opinion, we can speak of a relation between the contained work and the employed heat only when the cycle is completed. Sadi-Carnot names a machine that carries out this circular process of the transformation of heat into work, and work again into heat (existing only in the imagination, for it has not yet been constructed), the *perfect machine*. Such a machine cannot yet be mechanically made, for it would have to apply the heat itself, by means of its own labour, to its own steam boilers.

When we observe the labour of humanity, however, we have before our very eyes an example of what Sadi-Carnot called a perfect machine. For from this perspective, the human organism would be a machine that not only transforms heat and other physical forces into labour, but which also brings about the operational reverse cycle, i.e. it transforms labour into heat and into the other physical forces which are necessary for the satisfaction of our needs, heating with its own labour converted into heat, its own steam boilers, so to speak. A steam engine, for example, even if it could function for a longer time without the involvement of human muscular power, does not possess the ability to produce the elements necessary to undertake its own work the following year. The human machine, on the other hand, creates new harvests, raises the young generations of domesticated animals, invents and builds new machines etc. In a word: humanity regularly creates the material and the elements for the future continuation of its labour. Thus, humanity fulfills Sadi-Carnot's requirement of perfection much better than any artificial machine.

The degree of perfection of the human machine is not however always the same and changes not only depending upon its economic coefficient but also particularly with respect to its ability to bring about the operational reverse cycle, i.e. to convert its labour into an accumulation of physical forces necessary for the satisfaction of our needs. Of course, the needs of savages are much easier to satisfy than those of civilised people, and therefore its economic coefficient is significantly greater, perhaps 1/6 instead of 1/10. However, the labour of the savage is much less productive in its end results than that of the civilised human, because the savage lives for the most part from natural produce that he finds already at hand, while the civilised human satisfies his needs with the products of his labour and in this way creates an accumulation of energy on the earth's surface, whose quantity exceeds the force of his muscles by at least ten times.

The necessary conditions for the continuation of the work of an inanimate machine are not immediately dependent upon the work of this machine, upon its

*puissance*. Paris: Chez Bachelier, 1824. Sadi Carnot, *Reflections on the Motive Power of Fire*, translated by R.H. Thurston, edited by E. Mendoza. Gloucester, Mass.: Peter Smith, 1977, pp. 6, 8 (editorial note).]

qualities. All artificial machines on the contrary are immediately dependent upon the muscular labour of the human who governs it, and supplies it with the heat engendering substance. The conditions of labour or, if we will, of the existence of the human machine, can on the other hand be rigorously established:

> *So long as the labour of the human machine can be transformed into such an accumulation of energy, capable of satisfying our needs, which exceeds the entire force of humanity by so many times as the denominator of the economic coefficient is greater than its numerator, the existence and the possibility of working is guaranteed for the human machine.*

Every time the productivity of human labour falls below the size of the inverse economic coefficient, poverty and often a decrease of population arises. Conversely, when the utility of labour exceeds this size, we have to expect an increase of prosperity and an increase of population.

## V. Labour as means for the satisfaction of our needs

The degree in which our needs can be satisfied by the accumulation of an energy supply is dependent on a whole series of factors that we will now subject to our attention. The most important of these are: the energy supply on the earth's surface, the number of humans, the extent of their needs, and the productivity of their labour, i.e. their ability to increase the energy accumulation.

The availability of a sizeable store of energy in the plant kingdom alleviated significantly the struggle of prehistoric man against the wild animals, despite the latters' greater force and ability to procure food for themselves. The use of fire, i.e. the solar energy accumulated by plants, was a powerful ally of humanity during its earliest and most difficult victories.

If humanity achieved all these victories while it was still in a lower stage of development, this occurred mostly because even then the energy store which it knew how to use was greater than that available to all of the stronger animals. The wildest predators could only set the force of their own body against humans, but humans, naturally much more weak, met them with a whole arsenal of offensive and defensive weapons, whose comparatively colossal store of energy only they knew how to use. In the beginning they used their victory in the most wasteful way without thinking about a renewal of the dispersed energy accumulation. Naturally, the energy store in the hands of humanity in such an inefficient economy remained a very insignificant one. Further, since the numerical population is dependent on the size of this store, it will not surprise us if we only rarely encounter a dense population during the hunting and animal husbandry periods. This situation changes only with the general spread of agriculture, which, through the application of the mechanical labour of humanity on energy accumulation, enables a more rapid increase of population.

In order to understand fully the influence of useful labour on the accumulation of energy and consequently also on the increase of population, we must deal a bit more closely with the special character of labour as a means for the satisfaction of our needs.

We can see from the following passages on labour of three famous economists how difficult it is to come to a correct understanding of it without using the methods of contemporary science. Quesnay said:

'Labour is unproductive'. Adam Smith: 'Only labour is productive'. Say: 'Labour is productive, natural forces are productive and capital is productive'.[22]

Is it possible to reconcile such contradictions? Apparently, this is only a semantical dispute. Adam Smith said, for example: 'The yearly labour of a nation is the base fund [*Urfond*] which produces all objects that are necessary or comfortable for life; all of these objects are either the immediate product of labour or they are bought for the value of this product'. Sismondi added: 'We believe with Adam Smith that labour is the sole source of wealth,… however, we add that utility is the only goal of the accumulation (of products) and that the national wealth only grows with national usage'.[23]

For his part, Quesnay says the following: 'We are not concerned with the formal side of production, how, for example, the hand workers who work any type of material perform their labours, but rather with the real production of wealth. I say real production because I will not deny that the labour of the worker gives the raw material an allowance of value, but one should not confuse a simple addition of commodities with their real production'.[24]

Today we can ascribe this contradiction to the fact that labour of course creates no material, so that the productivity of labour can only consist in adding something to the object that was not created by labour. This 'something' is in our opinion energy. On the other hand, we know that the only means through which humanity is in a position to increase in any situation the quantity of energy is the use of his labour-power. Therefore, Quesnay was correct when he said that labour does not create any real commodity precisely because labour cannot create any material. However, Smith was equally correct, because that which we need in any commodity, that which satisfies our needs, can only be attained with the help of labour.

Of course, one should not forget that the earth's surface has the ability, apart from the influence of human labour, to accumulate a certain quantity of energy that can be used by humans. But the older economists already knew that these stores were insufficient in comparison to those furnished by labour. Thus, for example, James Stuart said: 'The natural products of the earth which are presented independently from the will of the humans and always in a merely inadequate quantity resemble the

22. *Dict. Encycl. du XIX S.* Article Travail. [*Le Grand Dictionnaire Universel du XIX Siècle*, supervised and edited by Pierre Larousse. Paris: Administration du Grand Dictionnaire Universel, 1865–90, Vol. 15, pp. 435–6. For Quesnay's view, see the quotations in *The Economics of Physiocracy*, Ronald L. Meek, editor. Cambridge, Mass.: Harvard University Press, 1963, pp. 72–4, 207, 227–9. For Adam Smith, see *An Inquiry Into the Nature and Causes of the Wealth of Nations*. New York: Modern Library, 1937, pp. lvii–ix, 314–32. For Say, see Jean-Baptiste Say, *A Treatise on Political Economy*, Fifth American Edition, translated by C.R. Prinsep. Philadelphia: Grigg & Elliott, 1832, pp. 26–32 (editorial note).]

23. *Collection des principaux économiste*s. T.V., p. 1. [Smith, *Wealth of Nations*, p. lvii; J.-C.-L. Simonde de Sismondi, *New Principles of Political Economy: Of Wealth in its Relation to Population*, translated and annotated by Richard Hyse. New Brunswick, NJ: Transaction Publishers, 1991, p. 53 (editorial note).]

24. Quesnay. *Collection des principaux économistes. Physiocrates II.* pp. 187–8. [*Economics of Physiocracy*, R. Meek, editor, pp. 205, 207 (editorial note).]

small sum of money that one gives to a young man in order to give him the possibility of beginning his career and of establishing a business venture, with whose help he is supposed to seize his luck himself'.[25]

From all sides, therefore, we obtain evidence that the natural products of the earth are in no position to satisfy all of our needs and that we are obliged to increase the quantity of products artificially. Useful labour serves as a means to this end.

According to everything that has been said, we can arrive at the following conclusions as an answer to the question posed at the beginning of our work:

1) The total quantity of energy that the earth's surface receives from its interior and from the sun is gradually being reduced. Despite this, the accumulation of energy on the earth's surface is growing.
2) This increase takes place under the influence of the labour of humans and domesticated animals. By the word 'labour' we understand any use of mechanical or physical force of humans or animals that leads to an increase of the energy budget on the earth's surface.
3) The human, considered as a thermal machine, possesses a certain economic coefficient that becomes ever smaller with the growth of human needs.
4) At the same time, however, the productivity of labour rises as the economic coefficient sinks, and in this way needs are satisfied more easily and in a greater number.
5) So long as the average human has at his disposal a quantity of chemical affinity and available mechanical labour which exceeds his own force as many times as the denominator of the economic coefficient is larger than its nominator, the existence of humanity is materially assured.

## VI. Unity of force and political economy

Here we have arrived at the point where we should give an answer to the second question we posed: 'What are the best means of employing human labour in order to draw upon a larger fraction of natural forces for the satisfaction of human needs?'

In general terms, we have already given this answer: *the best means are those that cause the largest accumulation of energy on the earth*. Primitive cultivation – which is not yet actually a cultivation, because it is not based upon useful labour, upon an accumulation of energy, but merely on the use of force amassed already through the earlier life processes – cannot be reckoned among these means. The savage, by nourishing himself with fruits or roots, hunting game or catching fish, merely disperses the previously accumulated energy into space.

The slave economy is already an advance; but even it is still very imperfect, for this form of society, which has its foundation in perpetual wars, excludes a large part of the workers from participation in the accumulation of energy, in the labour that is really useful for the satisfaction of human needs. Without speaking of the immense number of workers killed or wounded in the continual wars, we mention only *the standing regular armies, the owners of slaves*

25. James Steuart. *Principles of Political Economy*. Dublin. I. p. 116. [Sir James Steuart, *An Inquiry into the Principles of Political Economy*, Volume One, edited by Andrew S. Skinner. Chicago: University of Chicago Press, 1966, p. 118 (editorial note).]

*and their cohorts of overseers* in order to show how many unuseful and unproductive elements are contained in the society founded upon slavery.

Feudalism already contains more elements of progress. At least the serf possesses a parcel of land that he is allowed to work without being overseen by the eyes of the lord and without feeling the whip of the overseer.

But how evanescently small is this progress still! How tiny are the parcels of the serf in comparison to the incalculable goods of the lord. For the serf, free labour-time is merely a short repose after the long days of compulsory labour for the lord. One should therefore not wonder that the productivity of labour under feudalism did not reach even the median of today's productivity.

Thus we come to the capitalist mode of production. This form of production knows how to use the division of labour and, as this no longer sufficed for it, it began to employ machines for industry and for agriculture on a large scale. It achieved magnificent results that exceeded its own expectations. But capitalism also has its dark side.

Instead of increasing the accumulation of energy on the earth, the machines often intensify the useless dispersion of the already available labour powers. They do this by excluding a part of the proletariat from production following upon inevitable overproduction. Under socialism, by contrast, any mechanical or any other improvement would directly reduce the labour time of all workers, giving them the leisure for new production, for intellectual and artistic culture, etc.

A higher level and a more equitable division of the quality and quantity of foodstuffs would inevitably bring about an increase in the muscular and nervous force of humanity. From that would spring a new growth of production and a greater accumulation of energy on the earth's surface.

An exact and precise system of accounting, which neither hides nor falsifies the numbers, would conserve much superfluous labour that is lost in the current anarchy.

Rational public health care and the possibility of accommodating all of the demands of science in one's personal hygiene would necessarily raise the life-expectancy of humanity and simultaneously also the productivity of the human organism to such a height which today is only found in exceptional cases.

Such are, in our opinion, in the form of a very short and perhaps overly general sketch, the relations between the accumulation of energy and the different forms of production. We hope to return to this question in a more extensive work in the near future.[26]

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*Translated by Peter Thomas*
*Edited and Annotated by Paul Burkett and John Bellamy Foster*

26. This hope of the gifted writer could unfortunately not be fulfilled. It was not granted to him to explicate further his fruitful idea of applying the results of the physical sciences to political economy, for soon after completing the sketch published here he fell victim to an incurable neuropathy. The Editor. [This footnote was inserted by the editor of *Die Neue Zeit*, Karl Kautsky.]