

MARXISM, SOCIAL METABOLISM, AND ECOLOGICALLY UNEQUAL EXCHANGE (draft 30/8/03)

Lund University, World Systems Theory and the Environment, 19-22 Sept. 2003

Joan Martinez-Alier

Introduction

Authors working on “industrial metabolism” (Ayres, 1989) or “social metabolism” (Fischer-Kowalski, 1998, Haberl, 2001) look at the economy in terms of flows of energy and materials. Together with the ecological economists, they see the economy as a subsystem of a larger physical system. Is this perspective to be found already in Marx and Engels? Marx (1818-1883) and Engels (1820-1895) were contemporaries of the physicists and physiologists who established the First and Second Laws of Thermodynamics in the 1840s and early 1850s (J.R. Mayer, 1814-78, J.P. Joule, 1818-89, R. Clausius, 1822-88, W. Thomson, later Lord Kelvin, 1824-1907). Marx and Engels followed with a few years’ delay many of the remarkable scientific and technical novelties of their time. Engels wrote in 1888 that the 19th century would be remembered not only as the century of the theory of evolution but also of the theory of the transformation of energy, the century of Darwin, Mayer, Joule and Clausius (letter to Nikolai Danielson, 15 Oct. 1888).

However, Marx and Engels did not consider the relations between their analytical concepts (productive forces, surplus value, exploitation) and the language of energy as they could have done in their mature work after the 1850s. For instance, they never said that the productivity of labour in agriculture and in industry would depend on the energy subsidy to the economic process. Engels’ comments on Podolinsky’s work of 1880 on agricultural energetics was a missed chance for an ecological Marxism. After all, Marx and Engels were not yet environmental historians, ecological economists or industrial ecologists. Increases in productivity depended on the development of the productive forces (*Produktivkräfte*), where “Kraft” (force) was not used with the physical meaning of “energy”. The productive forces could be furthered or could be fettered by the “social relations of production”. Capitalism had meant an enormous development of the productive forces but it provoked economic crises by its very nature, i.e. the exploitation of wage labour. Malthusian crises of subsistances were not relevant. The conflict between capital and labour would lead to a change in the mode of production. These were essential points of their theory.

From the point of view of “social metabolism”, the issue of finding markets for the potential production is less relevant than capitalist advance into commodity frontiers and its use of overflowing sinks for waste. Capital accumulation is based on the exploitation of labour but it can also be described in non-equivalent physical language (Frank, 1959, Hornborg, 1998, a and b). Capital has proven unable to grow by itself, by its own exploitation of labour and technical change. The capitalist economy uses more materials and energy, therefore it produces more waste. It undermines not only its own conditions of production but the conditions

of livelihood and existence of peripheral peoples, who complain accordingly. Such ecological distribution conflicts are more and more visible. They cannot be subsumed under the conflict between capital and labour. They are not seen either (in neoclassical language) as “externalities” arising from “market failure”. On the contrary, to use Kapp’s words, they are “cost-shifting successes”. And, since they are happening with greater intensity, they cannot be seen as consequences of the “original” or “primitive” capital accumulation. What Marx described as “original accumulation” (such as plunder of America after the European conquest, enclosure of the commons in Britain) is going on around the world on an increasing scale. Ecological distribution conflicts (James O’Connor’s “second contradiction of capitalism”, 1988) keep increasing across the world, with a variety of social actors and languages.

Ecological distribution conflicts were not included in Marx’s analysis. They are growing with the increasing demand for energy and materials, and with the geographical displacement of environmental impacts from North to South. Work on social metabolism has advanced to the point where statistics showing the Direct Material Requirements of the economy, and the Total Material Requirements (separating domestic and external effects), are now being published by statistical offices in the European Union (Weisz et al, 2002). They show that in the rich countries the economy is not becoming dematerialized in per capita terms, and that the share of imports is growing. Therefore, issues related to unequal trade and to the “carbon debt” are becoming more relevant. Unequal exchange had already been pointed out in terms of undervaluation of labour and health of the poor and of deterioration of the terms of trade expressed in prices. “Social metabolic” interpretations of ecologically unequal trade will be discussed, such as Hornborg’s view that market prices are the means to increase the flow of energy (exergy) from South to North. The distinction in world systems theory between trade in “preciosities” vs. trade in bulk commodities will be considered. High priced/low volume products may involve large environmental impacts.

Social Metabolism

The first volume of *Capital* was published in 1867. There were certainly precursors of a bio-physical approach to the economy. At least one of them was close to Marxism (S. A. Podolinsky, 1850-91). These proto-ecological economists did not form a school (Cleveland, 1987, Martinez-Alier with Schlüpmann, 1987). One hundred years later, in the 1970s, the study of the human society and economy from a physical point of view (flows of materials and energy) started to be practiced by coherent research groups. Histories of the use of energy in the economy are not connected to Marxism (even when their authors might have Marxist pasts) (Cipolla, 1962, Sieferle, 1982, Debeir, Deléage, Hémery, 1986, Hall, Cleveland, Kaufman, 1986, McNeill, 2000). The notion of energy return on energy input (EROI) was applied in the 1970s to the economy by Charles Hall and other ecologists with no relation to Marxism. Recent explanations of growth in terms of the use of energy in the economy (or rather “physical work output as distinguished from energy (exergy)”), criticize neoclassical production functions and growth theory but draw no inspiration from Marxism (Ayres, Ayres, and Warr, 2002).

Nevertheless, Marx and Engels had a profound interest in the interactions between the human economy and the natural environment, particularly as regards capitalist agriculture. This was expressed in Marx's use in his own drafts after 1857-58 and in *Capital*, of the notion of "metabolism" (*Stoffwechsel*) between humans and Nature. Marxist use of "metabolism" is well known. Alfred Schmidt (1978) was the first author to insist in the role of the concept of *Stoffwechsel* in Marx's work on the development of capitalism, noting Moleschott's and Liebig's influence, noting also its substantive use for the cycling of plant nutrients (Schmidt, 1978: 86-9; Martinez-Alier with Shlupmann, 1987: 220-6). Marx became so keen on the concept of metabolism that in a letter to his wife (21 June 1856), he nicely wrote that what made him feel like a man was his love for her, and not his love for Moleschott's metabolism or for the proletariat.

Marx and Engels were contemporaries of the physiologist Jacob Moleschott (1822-93). To the present day, Marxists call him a "vulgar" materialist (meaning a reductionist materialist, in opposition to (distinguished?) historical materialists who favour dialectics and co-evolution). However "vulgar", Moleschott was a main figure in the introduction of the concept of metabolism in physiology and in what now is called ecology. Materialism was used against the doctrine of vitalism and against religion. Moleschott had been dismissed after 1848 from Heidelberg, he taught in Zurich and in Rome. A well known professor and editor of a scientific journal, he had also been an activist. His book on the theory of human nutrition of 1850 had the subtitle *Für das Volk* (Moleschott, 1850). This was certainly different in intent from the studies by other authors on the cost-effective feeding of soldiers, industrial workers or slaves (in America). In 1851 he published *Physiology of Metabolism in Plants and Animals* (Moleschott, 1851), one year later, *Der Kreislauf des Lebens* (The Cycle, Circuit or Circle of Life) (Moleschott, 1852). Engels, in a letter to Piotr Lavrov of 1875 discussing Darwinism, summarized the idea of the "cycle of life" in "the fact that the vegetable kingdom supplied oxygen and nutriment to the animal kingdom and conversely the animal kingdom supplied plants with carbonic acid and manure". This interplay had been interpreted as cooperation in Nature by that trio of "vulgar" materialists (Vogt, Büchner and Moleschott, who, incidentally, now were talking loudly about "struggle for existence"), and it had been stressed by Liebig.

There is a rediscovery of Marx's "social metabolism" (Foster, 2000). Marx and Engels were one generation younger than the agricultural chemists (Liebig, 1803-73, Boussingault, 1802-87) who published their researches on the cycles of plant nutrients (phosphorous, nitrogen, potassium), influenced by the threat of decreasing agricultural yields and the wholesale imports of guano after 1840 mainly from Peru, an essential bulk commodity for agricultural production. About 11 million tons of guano were exported from Peru (Gootenberg, 1993). The analyses of the composition of guano, and also of other manures and fertilizers well known to farmers (bones, for instance), laid the foundations for agricultural chemistry. Liebig's name was associated by his own wish to a new future leading sector of the economy, the fertilizer industry. It may also be associated to an ecological vision. He is recognized as one of the founders of Ecology before the name itself was invented (Kormondy, 1965). Politically he developed an argument against latifundist agriculture and agricultural exports because the plant nutrients

would not return to the soil. He was in favour of small scale agriculture and dispersed settlements. Marx quoted this opinion favourably on several occasions.

Indeed, Marx's use of *Stoffwechsel* (metabolism) in *Capital* (vol. I) and, before that, in some drafts of the late 1850s was influenced by Liebig, probably by other authors, and certainly by Moleshott. Marx used "metabolism" in two senses. First, as a biological analogy or metaphor to describe the circulation of commodities. Second, more relevantly for the present article, he used the expression "metabolism between man and earth", or "between society and nature" to refer specifically to the cycles of plant nutrients, quoting and praising Liebig. Such metabolism was broken by an agriculture of spoliation.

Marx found Liebig supremely relevant because he described the natural conditions of agricultural fertility and the possibility of development of the productive forces by the fertilizer industry. This was useful for the polemics against Malthus, and for the theory of land rent. Foster (2000) has analyzed in depth Marx's debt to Liebig, and has wrongly denied Moleshott's influence on Marx's use of "metabolism". Foster does not quote Moleshott's books of 1851 and 1852 on the "circle of life" and on the physiology of metabolism in plants and animals.

So, in conclusion, Marx was a historian and an economist, he was also a student of agriculture, and he read on the physiology of plants and animals and on agricultural chemistry, adopting the notion of "metabolism" between humans and Nature. The material flows between humans and Nature were mobilized by human labour, except in very primitive societies that lived from gathering. The development of tools by humans was essential for the metabolism. Marx did not include the metabolic flow of energy in agriculture and in industry in his analysis, so he could not trace a fundamental distinction (as Lotka was to do forty years later) between the use of energy in nutrition (endosomatic) and the use of energy by tools (exosomatic). This difference between bio-metabolism and techno-metabolism is crucial for the understanding of human ecology. We as a species have genetic instructions regarding our endosomatic consumption of energy but not our exosomatic use of energy, which must be explained by history, politics, economics, culture, technology. This is not to be found in Marx. Not only he left energy flow aside, he did not count material flows in detail or even roughly, he was not a proto-industrial ecologist. But on the positive side, he did not see the economy as a closed system, or Nature as an immutable source of free gifts, as the neoclassical economists were to do.

Men were part of Nature, men used Nature's materials, we could increase its produce by the development of the so-called productive forces but we could also undermine the natural conditions of production. This was the case with capitalist agriculture. Marx wrote: "Capitalist production disturbs the metabolic interaction between man and the earth, i.e. it prevents the return to the soil of its constituent elements consumed by man in the form of food and clothing, hence it hinders the operation of the eternal natural conditions for the lasting fertility of the soil... Moreover, all progress in capitalist agriculture is a progress in the art, not only of robbing the workers, but of robbing the soil..." (*Capital*, I). He added that the separation of town and country, caused by latifundist agriculture and by the concentration of sources of energy in cities, provoked an "irreparable rift" in the

process of social metabolism. The result of this was a squandering of the soil, aggravated by trade, undermining the conditions of agricultural production. Engels wrote: “As the individual capitalists are engaged in production and exchange for the sake of the immediate profit, only the nearest, most immediate results must first be taken into account”. In today’s economic parlance, Engels was saying that individual capitalists discounted the future and did not include externalities in their accounts. He continued: “As long as the individual manufacturer or merchant sells a manufactured or purchased commodity with the usual coveted profit, he is satisfied and does not concern himself with what afterwards becomes of the commodity and its purchasers. The same thing applies to the natural effects of the same actions. What cared the Spanish planters in Cuba, who burned down forests on the slopes of the mountains and obtained from the ashes sufficient fertilizer for one generation of very profitable coffee trees – what cared they that the heavy tropical rainfall afterwards washed away the unprotected upper stratum of the soil, leaving only the bare rock!” (*Dialectics of Nature*). Engels could have mentioned the destruction of forests in western Cuba by the sugar industry after 1830 which was more significant than coffee cultivation, but the main point stays. Luxury items such as sugar and coffee became bulk staples of trade (in the case of sugar as a source of cheap calories), and therefore their environmental “rucksacks” increased.

Such quotations by Marx and Engels could be multiplied, they are not anecdotal, they arose (as Foster, 2000, has shown) from a theory of “metabolic rift”. So, Marx was “greener” than usually thought. However, what Greens can learn in Marx is well known to them, i.e. the cycles of plant nutrients and the damage to soil and forests. Green political thought owes more to the science of ecology than to Marx. Foster (2000) insists with reason that “metabolic rift” was not equivalent to “decreasing returns”. Marx wrote to Engels on 13 February 1866 saying that Liebig’s agricultural chemistry was more important for the discussion on decreasing returns than all the economists put together. This must be interpreted in this sense: the economists talked about decreasing returns in the intensive margin but these could be overcome by fertilizers. Actually, Marx dismissed the notion of decreasing returns in agriculture altogether, pointing out in the context of his praise for Liebig’s agricultural chemistry and its promise of artificial fertilizers, that it did not make sense to assume in Britain that the produce of the land would increase in a diminishing ratio to the increase of the labourers employed, because in practice there was at the time both an increase in production and an absolute decrease (already) in the number of labourers (*Capital*, I, chapter 13). Marx was not worried about crises of subsistence.

Marxists attacked Malthus, which was well deserved because Malthus had made the point that improving the situation of the poor was counterproductive because they would have more children. One hundred years after Malthus, around 1900, there were many debates on “how many people could the Earth feed” (Pfaundler, 1902, Cohen, 1995). Some marxists (Lenin, 1913) not only attacked Malthus, they also attacked in a sectarian way the Neomalthusians of the late 19th century and early 20th century who were often political radicals and feminists (Paul Robin, Emma Goldman) (Ronsin, 1980, Masjuan, 2000, 2003)

Podolinsky's agricultural energetics

The link between material metabolism (*Stoffwechsel*, exchanges of materials) and the flow of energy at the level of cells and organisms was made in the 1840s. It was then also understood that agriculture might be represented in terms of changes in the flow of energy and not only as an intervention in the cycling of plants nutrients (Mayer, 1845, used *Stoffwechsel* for energy flow). Metabolism was therefore used not only for materials but also for energy. Of course, materials could be cycled, energy could not. The theory of the direction of the flow of energy was developed after 1850 and the establishment of the Second Law.

Marx and Engels were interested in energy. For instance, Engels wrote to Marx on 14 July 1858 commenting on Joule's work on the conservation of energy (of 1840) as something well known to them. Marx was interested in new sources of energy. One example will suffice: it was already discussed at the time whether hydrogen could be a net source of energy, depending on the energy requirement for electrolysis. Marx wrote to Engels on 2 April 1866 that a certain M. Rebour had found the means of separating the oxygen from hydrogen in water for very little expense. However, Marx did not refer to the flow of energy as a part of social metabolism throughout his lifetime. At a more general level, one interesting point arises from Engels' unwillingness to understand how the First and Second Laws could apply at the same time: the "dialectics of Nature" failed him there. As Engels became aware of Clausius' concept of entropy, he wrote to Marx (21 March 1869): "In Germany the conversion of the natural forces, for instance, heat into mechanical energy, etc. has given rise to a very absurd theory--- that the world is becoming steadily colder... and that, in the end, a moment will come when all life will be impossible... I am simply waiting for the moment when the clerics seize upon this theory...". Indeed, not only the clerics but also W. Thomson (Lord Kelvin) himself brandished the Second Law in his religious tirades about the "heat death" although he could have no inkling of the source of energy in the sun in nuclear fusion. One understands Engels' dislike for the uses to which the Second Law was put. Josef Popper-Lynkeus (1838-1921), who with Ernst Mach became one source of inspiration for the antimetaphysical philosophy of the Vienna Circle, complained since 1876 about W. Thomson's "theological handling of Carnot's law" (Martinez-Alier with Schlüpmann, 1987: 197). However, Engels' dislike of the Second Law was motivated not only by its religious use or abuse, he believed that it would be shown that the heat irradiated to space was not finally dissipated.

Another interesting point is the reaction by Engels in 1882 (in letters to Marx) regarding Podolinsky's work. Podolinsky had studied, we might say, the entropy law and the economic process, and he tried unsuccessfully to convince Marx that this could be brought into the Marxist analysis. His work has been seen as a first effort to develop ecological economics. Politically he was not a Marxist, he was a Ukrainian federalist narodnik. He had criticized Marx's overpowering behaviour at the congress of the International of 1872, praising the anarchist James Guillaume. However, he himself saw his work on the energetics of agriculture as a contribution to Marxist theory. He wrote to Marx on 8 April 1880: "With particular impatience I wait for your opinion on my attempt to bring surplus labour and the current physical theories into harmony".

In his essay (published in long versions in Russian in 1880 and in German in 1883, and in short French and Italian versions in 1880 and 1881)¹ Podolinsky started by explaining the laws of energetics, quoting from Clausius that although the energy of the Universe was a constant, there was a tendency towards the dissipation of energy or, in Clausius' terminology, there was a tendency for entropy to reach a maximum. Podolinsky considered Rankine's idea, that heat energy dissipated in outer space could be concentrated again, and he accepted Clausius' objections to it. Podolinsky did not discuss explicitly the difference in thermodynamics between open, closed and isolated systems, although he stated as the starting point of his analysis that at the present time the Earth was receiving enormous quantities of energy from the sun, and would do so for a very long time. All physical and biological phenomena were expressions of the transformations of energy. He did not enter into the controversies regarding the creation of the Universe and its "heat-death", nor did he discuss the relations between thermodynamics and the theory of evolution.

He explained that plants assimilated energy, and animals fed on plants and degraded energy. This formed the *Kreislauf des Lebens*: "We have in front of us two parallel processes which together form the so-called circle of life. Plants have the property of accumulating solar energy, but the animals, when they feed on vegetable substances, transform a part of this saved energy and dissipate this energy into space. If the quantity of energy accumulated by plants is greater than that dispersed by animals, then stocks of energy appear, for instance in the period when mineral coal was formed, during which vegetable life was preponderant over animal life. If, on the contrary, animal life were preponderant, the provision of energy would be quickly dispersed and animal life would have to go back to the limits determined by vegetable wealth. So, a certain equilibrium would have to be built between the accumulation and the dissipation of energy".

Not only plants, also human labour had the virtue of retarding the dissipation of energy. Human labour achieved this by agriculture, although the work of tailors, shoemakers or builders would also qualify as productive work, since they afford "protection against the dissipation of energy into space". The energy available for humankind came mainly from the sun. Podolinsky gave figures for the solar constant. He explained how coal and oil, wind energy and water power, were transformations of solar energy. He mentioned tides as another possible source of energy. He then started his analysis of the energetics of agriculture, remarking that only a very small proportion of sun energy was assimilated by plants.

Human work in agriculture, and the work of animals directed by humans, were able to increase the availability of energy. This he showed by comparing the productivity of different types of land use taking statistics from France (he was living at the time in Montpellier). Table 1 summarizes his data (Martinez-Alier with Schlüpmann, 1987: 48). Podolinsky then compared wheat agriculture and sown pastures to natural pastures and forest, concluding that production was

¹ S.A. Podolinsky, Trud cheloveka i ego otnoshenie k raspredeleniiu energii, *Slovo*, 4/5, 1880, p. 135-211. That is, Human labour and its relations to the distribution of energy. (A Spanish translation has been published in Martinez-Alier ed., 1995). The German version with the title Menschliche Arbeit und Einheit der Kraft, appeared in March-April 1883 in *Die Neue Zeit*, the new journal of the Social Democratic Party (i.e. the Marxist party).

higher when there was an input of human and animal work. Thus, comparing wheat agriculture to natural pastures, each kcal put in contributed to an increase of 22 kcal of production. If forests were taken as the terms of comparison, the energy productivity of human and domestic animals work was even higher. Notice that Podolinsky was counting human and animal *work*, that is, not the food intake but the work done. He did not include solar radiation in the input of energy because he was not writing as a biologist but as an ecological economist. Solar radiation is indeed a free gift of Nature (moreover, without an owner so that there is no payment of rent).

TABLE 1

Annual production, and energy input (only work by humans and domestic animals) per hectare, averages for France in 1870, according to Podolinsky

	Production (kg)	Production (kcal)	Energy input (kcal)
Forest	900 (dried wood)	2,295,000	Nil
Natural pastures	2,500 (hay)	6,375,000	Nil
Sown pastures	3,100 (hay, excluding seed)	7,905,000	37,450 (50 horse-hours and 80 man-hours)
Wheat	800 (wheat) and 2,000 (straw) (excluding seed)	8,100,000	77,500 (100 horse-hours and 200 man-hours)

Energy values of wood, hay and straw, 2,550 kcal/kg, of wheat 3,750 kcal/kg. Hours of work converted into kcal: 645 kcal/hour of horse-work, 65 kcal/hour of man-work.

The conclusion was that work could increase the “accumulation of energy on earth”. Although Podolinsky mentioned guano, and although he must have been keenly aware of the war then raging for Peruvian or Chilean saltpetre, he did not subtract from the output, or include in the input, the energy contents and cost of fertilizer. Nor did he consider the energy spent for steam engines for threshing. His methodology is nevertheless basically the same as that used later for establishing the energy balance of particular crops, or for small scale societies, or for the entire agricultural sector of particular countries (Cottrell, 1955, Rappaport, 1967, H.T. Odum, 1971, Pimentel, 1973, 1979, Leach, 1976, Fluck and Baird, 1980).

Podolinsky then went on to explain the capacity of the human organism to do work. Otherwise “it would be difficult to explain the accumulation of energy on the surface of the earth under the influence of labour”. Quoting from Hirn, Helmholtz, Marey, mentioning his own professors Hermann and Haidenhain, and also Fick, he concluded correctly that “man has the capacity to transform one-fifth of the energy gained from food into muscular work”, giving to this ratio the name of “economic coefficient”, remarking that man was a more efficient transformer of energy than a steam engine. Now, for humanity to ensure its elementary conditions of existence, each calorie of human work must then have a productivity of five calories. Taking into account that not everybody is able to work (children, old people), and that there are other energy needs apart from food energy, the necessary minimum productivity would be more like ten or more. If that minimum was not achieved, then of course “scarcity appears and, many times, a reduction of population”. Podolinsky then established the basis for a view of the economy in terms of energetic social metabolism, looking at the energy return to energy input in a framework of reproduction of the social system. He used a steam-engine metaphor to put across a general theoretical principle on the minimum natural conditions of human existence. He wrote that humanity was a “perfect machine” in

Sadi Carnot's sense: "humanity is a machine that not only turns heat and other physical forces into work, but succeeds also in carrying out the inverse cycle, that is, it turns work into heat and other physical forces which are necessary to satisfy our needs, and, so to speak, with its own work turned into heat is able to heat its own boiler". He thought that he had reconciled the Physiocrats with the labour theory of value, although the Physiocrats (in the 18th century) could not have seen the economy in terms of energy flow.

Podolinsky also emphasized the difference between using the flow of solar energy and the stock of energy in coal. The task of labour was to increase the accumulation of solar energy on earth rather than the simple transformation into work of energy already accumulated on earth, more so since work done with coal was inevitably accompanied by a great dissipation of heat-energy into space. The energy productivity of a coalminer was much larger than that a farmer could obtain, but this energy surplus from coal was transitory, and moreover (Podolinsky added in a footnote) there was a theory which linked climatic changes to concentrations of carbon dioxide in the atmosphere, as Sterry Hunt explained at a meeting of the British Society for the Advancement of Science in the autumn of 1878. Notice here that the emphasis was not on capital accumulation in financial terms but on increasing the availability of energy and certainly also its dissipation. Podolinsky was not, however, at all pessimistic about the prospects for the economy, and he was hopeful for the direct use of solar energy for industrial purposes, referring to the "solar engine of M. Mouchot" (Mouchot, 1869). One could also envisage that one day solar energy would be used directly to make chemical syntheses of nutritive substances, by-passing agriculture. Thus, a proper discussion of the demographic question had to take into account the relations between the general quantity of energy on earth and the quantity of people who live on it, and this was a more relevant consideration, in his explicit view, than the Malthusian prognosis. In March 1880 he published an article against social-Darwinism. He wrote that the availability of energy was a crucial consideration for the increase (or decrease) of population. However, he thought that the distribution of production was explained by the relations between social classes: "in the countries where capitalism triumphs, a great part of work goes towards the production of luxury goods, that is to say, towards a gratuitous dissipation of energy instead of towards increasing the availability of energy".

He was also hoping (as he had written to Marx on 30 March 1880, sending his work to him) to develop applications of his energy accounts to different forms or modes of production. Marx died in 1883 and apparently never commented on Podolinsky's work, beyond a letter of acknowledgement in the first days of April 1880. He apparently asked Engels to write a comment, which Engels did not do until December 1882. Podolinsky himself became ill in 1881, and never recovered until his death ten years later, back in Kiev.

Engels' reaction to Podolinsky

Engels had some knowledge of the energetics of human physiology, and in a note of 1875 (later included in the *Dialectics of Nature*) he referred to Fick's and Wislicenus' experiment in climbing the Faulhorn in 1865, which became popularized under the name "A day of hunger for science". Fick (1829-1901) had

written in 1857 and 1858 on the amount of kilocalories (2,700) that a man would need and spend per day, when not working, and how different types of work implied different energy expenditures over that rate. An idea being circulated at the time (for instance, in an article in *Das Ausland* in 1877, 50: 298) was that the economic values of different types of work could be established in physical terms. Engels already explicitly rejected this notion in 1875.

On 19 and 22 December 1882, Engels wrote two letters to Marx (about one thousand words) explaining that Podolinsky had “discovered” the following facts, already well known. If the food intake of one person per day were equal, say, to 10,000 kilocalories (literally “heat units”), then the physical work done would be fraction of this energy. This physical work could become economic work if employed in fixing solar energy, for instance through agricultural activity. Podolinsky’s discovery was that human labour employed in agriculture had the power of detaining solar energy on the earth’s surface and permitting its activity longer than would be the case without it. All the economic conclusions he drew from this were wrong. The economic labour which a man working in agriculture performed by the employment of these 10,000 kcal consisted in the fixation for a greater or less time of new energy radiated to him from the sun. Whether, however, the *new* quantity of energy fixated by the application of the original 10,000 kcal of daily nourishment “reaches 5,000, 10,000, 20,000 or 1,000,000 kcal, depends solely on the degree of development attained by the means of production”. Besides, in agriculture, “the energy value of the auxiliary materials, manures, etc. also enters into the calculation” – a perceptive comment that directly makes one think of the agricultural energy balances of the 1970s (Pimentel, 1973, Leach, 1976) which showed that the energy return to energy input of modern agriculture was on the decline. “In industry”, wrote Engels, “all calculation comes to an end: in most cases the work added to the product (he wrote on 19 December 1892) can no longer be expressed in kilocalories”. Engels was certainly right that in industrial production there would not be a net gain of energy – on the contrary, there would be more available energy in the raw materials than in the final product although in economic terms the final product would be more valuable. Actually, also in agriculture the energy in the product does not come from human work, it comes really from photosynthesis, human labour helping and guiding the process by selecting the seeds and performing other tasks. In fact, Engels wrote on 22 December 1882, “storage of energy through work really takes place only in *agriculture*; in cattle raising the energy accumulated in the plants is simply transferred as a whole to the animals, and one can only speak of a storage of energy in the sense that without cattle-raising, nutritious plants wither uselessly, whereas with it they are utilised. In all branches of industry, on the other hand, energy is only *expended*... So that if one chooses one can translate into a physical language (*ins Physikalische übersetzen*) the old economic fact that all industrial producers have to live from the products of agriculture, cattle raising, hunting, and fishing – but there is hardly much to be gained from doing so”. Engels also wrongly wrote that “the energy value of a hammer, a screw or a needle calculated according to the costs of production is an impossible quantity”, concluding: “In my opinion it is absolutely impossible to try and express economic relations in physical magnitudes”. We are here as far away as possible from the “social metabolic” or “ecological economic” perspective.

Engels was most unfair when he wrote: “What Podolinsky has entirely forgotten is that man as a worker is not merely a fixer of *present* solar heat but a still greater squanderer of *past* solar heat. The stores of energy, coal, ores, forests, etc. we succeed in squandering you know better than I”. Podolinsky had not forgotten this at all. Finally, Engels also wrote: “Podolinsky has strayed away from his very valuable discovery into mistaken paths because he was trying to find in natural science a new proof of the truth of socialism, and has therefore confused physics and economics”.

Engels’ negative reaction to Podolinsky’s work, and Marx’s silence from 1880 to the end of his life in 1883 (three years in which he was still intellectually active, much involved in discussions on the Russian peasant commune), may be seen as a missed change for an ecological Marxism. Actually Podolinsky’s work is relevant not only in the Marxist context. His work and life have an entity of its own, apart from his encounters with Marx and Engels. He had a short life but he left a strong trace in Ukrainian federalist thought (as a friend of Drahomanov) and also in the Narodnik movements against the Russian autocracy (as a young colleague of Piotr Lavrov but also connected to the Narodnaya Volya group). He was trained as a medical doctor and physiologist. Forty years later, his work on energy and the economy received Vernadsky’s approval. In a section of *La Géochimie* (1924) Vernadsky wrote about several authors (Felix Auerbach with his notion of *Ektropismus*, John Joly) who explained life as a process which used energy and reversed or slowed down the dissipation of energy. He then added a memorable phrase: Podolinsky had studied the energetics of life and tried to apply his findings to the study of the economy (Vernadsky, 1924: 334-5).

The link between the use of energy and human culture, in the form of “social energetics” (although without historical statistical work) became well established and debated in European culture around 1900. Some marxist authors (Bogdanov, 1873-1928, Bukharin, 1888-1938) adopted this outlook, and their work has been seen (Susiluoto, 1982) as an anticipation of Bertalanffy’s systems theory which grew out of the links between thermodynamics and biology. But, to repeat, there is no Marxist historiography based on quantitative studies of material and energy social metabolism. No clear line of descent from Marxism to ecological economics, agroecology, urban ecology, industrial ecology. Moreover, Lenin wrote a diatribe against Ostwald’s social energetics in the context of his polemics against Bogdanov and against Mach’s “empiriocriticism” (Martinez-Alier with Schlüpman, 1987: 225-8). This was before the October Revolution of 1917. Afterwards, Lenin’s ill-considered remarks became sacred to the faithful. Thus, on the occasion of the publication of Engels’ “book” *Dialectics of Nature* in 1925 (out of drafts and notes he had left behind) on the thirtieth anniversary of his death, Otto Jenssen printed again Engels’ letters to Marx on Podolinsky (which were first published in 1919), and explained that Engels had anticipated a critique of Ostwald’s social energetics even before Ostwald himself appeared on the scene (Jenssen, 1925: 13).

Otto Neurath’s Naturalrechnung

Marx wrote that wealth was undoubtedly created both by human labour and by Nature, quoting William Petty: “Labour is the Father, Nature is the Mother”. Beyond facile jokes on whether fathers or mothers are more important, the

interesting point is the distinction between wealth and use values (on the one hand) and exchange values (on the other hand). Marx quoted Aristotle's distinction between *oikonomia* (dealing with the use values delivered by the material provisioning of the human economy) and *chrematistics* (as the study of market prices). Ecological economists from Soddy to Daly, and economic anthropologists and historians who follow Karl Polanyi, emphasize this distinction. Beyond the analysis of the *oikonomia*, Marx's main objective was to explain in a capitalist wage economy the appropriation of surplus labour. Such exploitation was not so obvious as in a slave economy or a feudal (serf) economy, since wages were apparently freely established in a market. Surplus labour became surplus value.

In my view, an important contribution to the links between Marxism and a biophysical approach to the economy was made later, in the first half of the 20th century, by Otto Neurath (1882-1945). A famous philosopher of the Vienna Circle, he was also an economist or economic historian, and a Marxist in at least two senses. First, in the so-called Socialist Calculation debate of the 1920s, he defended a democratically planned economy based on physical accounting in energy and material terms (*Naturalrechnung*) influenced by Popper-Lynkeus' and Ballod-Atlanticus' quantitative, realistic "utopias". Neurath explained that in order to compare two economic plans, achieving the same objective, a capitalist entrepreneur would use money values. However, in a socialist economy, how would we be able to compare a plan using more human labour and less coal, with a plan using less human labour and more coal? In principle, using less painful human work and more coal would be good, even if it implied using more energy altogether, but a decision would also need appraisals of the uncertain development of future technologies (hydropower, solar energy), and also our moral regard for future generations would play a role in the comparison. Neurath introduced therefore the idea of incommensurable values in the economy. Neurath's idea was also emphasized by K.W. Kapp. Incommensurability of values is seen as a foundation for ecological economics (Martinez-Alier with Schlüpmann, 1987, O'Neill, 1993, Martinez-Alier, Munda and O'Neill, 1998, O'Neill, 2002). Second, some years later, in the context of the Vienna Circle' project of the Encyclopedia of Unified Science of the 1930s and 1940s, Neurath saw himself as a marxist and defended a dialectical view of history (although he did not like the word "dialectics") as the putting together the findings of the different sciences regarding concrete processes or events. The findings of one science, collected in the Encyclopedia, with regard to one particular process or event, should not be contradicted by the assumptions or the findings of another science also present in the Encyclopedia, and leave things at that. "Consilience" (to use today's word by Edward Wilson) should be the rule of the Encyclopedia.

Hayek's strong criticism against "social engineering" (1952) was directed, as John O'Neill has put it, "at the whole tradition which attempts to understand the ways in which economic institutions and relations are embedded within the physical world and have real physical preconditions, and which is consequently critical of economic choices founded upon purely monetary valuation". Translated into Foster's language (Foster, 2000): Hayek criticized those who view the economy in terms of "social metabolism". While Patrick Geddes, Wilhelm Ostwald, Frederick Soddy and Lewis Mumford were all rudely dismissed by Hayek, it was the work of Otto Neurath that was the primary target of Hayek's criticism.

One is also reminded of Max Weber's comments against Otto Neurath in *Economy and Society* but even more of his critique of Wilhelm Ostwald in 1909. Ostwald (a well known chemist) was trying to interpret human history in terms of the use of energy. He proposed two simple laws, which are not untrue, and which might act or not in opposite directions. First, the growth of the economy implied the use of more energy, and the substitution of human energy by other forms of energy. Second, this came together with a trend towards higher efficiency in the transformation of energy inside each technology. Max Weber (1909) wrote a famous, ironic review of Ostwald's views, where he insisted on the separation between the sciences. Chemists should not write on the economy. The review was much praised by Hayek in the 1940s. Max Weber's basic point (Martinez-Alier with Schlüpmann, 1987, chapter 12) was that decisions by entrepreneurs on new industrial processes or new products were based on prices. It could so happen that a production process was less efficient in energy terms and nevertheless it would be adopted because it was cheaper. Energy accounting was irrelevant for the economy. Max Weber did not question energy prices.

Ostwald influenced many authors, among them Henry Adams (1838-1918) who proposed a "law of acceleration" in the use of energy: "the coal output of the world, speaking roughly, doubled every ten years between 1840 and 1900, in the form of utilized power, for the ton of coal yielded three or four times as much power in 1900 as in 1840". Since Marxism is in this article under critical review, it is worthwhile pointing out that from the opposite camp, Karl Popper in *The Poverty of Historicism* which is directed against Marxist laws of history, thought it worthwhile to attack also Henry Adams in a footnote (without ever mentioning the word "energy") because Henry Adams dared propose a historical law. Henry Adams quoted Marx as a remote source for his law of acceleration in the use of energy (in terms of used power, not of primary energy). However he was certainly not a Marxist, on the contrary he was a Bostonian aristocrat who thought the world would probably come to a bad end socially and technologically.²

When the anthropologist Leslie White (1943) wrote on energy and the evolution of culture, he realized that Ostwald and Soddy were precursors of his views but he did not quote Podolinsky although he also looked for stages of evolution in terms of harnessing energy in increasing magnitudes and in various forms, in a dialectical interplay between the technological level (defined by the availability and the efficiency in the transformation of energy), the social system (in terms of Marxist "relations of production") and the cultural-symbolic system.

Marx' doubts on the benefits of economic growth expressed in his ecological critique of capitalist agriculture, were not forgotten within Marxism (think of Walter Benjamin and Raymond Williams). However, the technological optimists who believed in the development of the productive forces, predominated. One most influential in mid-20th century was the historian of science J.D. Bernal. He was in the 1950s totally in favour of the "civil" use of nuclear energy, which Lewis Mumford was strongly criticizing already at the time (Thomas, 1956: 1147). Mumford, described by Ramachandra Guha as the "forgotten American environmentalist" (in comparison to G.P. Marsh, John Muir, Gifford Pinchot,

² Martinez-Alier with Schlüpmann, 1987, chapter 8: Henry Adams' "Law of Acceleration" in the Use of Energy.

Aldo Leopold, Rachel Carson) was a heir to John Ruskin, William Morris and Patrick Geddes, he does not belong in the Marxist tradition.³

Mumford's mentor, Patrick Geddes (1854-1932), a biologist and urban planner, early on attacked neoclassical economists such as Walras because they did not count flows of energy, materials and waste (Martinez-Alier with Schlüpmann, 1987, chapter 6) but he did not discuss Marx. Geddes (1884) proposed the construction of a sort of input-output table inspired by the *Tableau Economique* of the Physiocrat François Quesnay. The first column would contain the sources of energy as well as the sources of the materials which were used, not for their potential energy, but for their other properties. Energy and materials were transformed into products through three stages, extraction, manufacture, and transport and exchange. Estimates were needed of the losses (dissipation and disintegration) at each stage. The quantity of the final product (or "net" product, in Physiocratic terms) might seem surprisingly small in proportion to the gross quantity of potential product. Now, however, the losses at each stage were not accounted for in economic terms. The final product was not added value at all. It was the value remaining from the energy and materials available at the beginning once they had been through all three stages. In today's language we say, the exergy in the raw materials is larger than in the final products.

The languages of unequal trade

Geddes' scheme is relevant to the attempt by several authors today to develop a theory of ecologically unequal exchange between the metropolitan centres and the world peripheries. Recent work on Material Flow Accounting by ecological economists and industrial ecologists shows that the European Union imports almost four times as many tons as it exports, while Latin America exports six times more tons than it imports (Giljum and Eisenmenger, in press). Material flow accounts are a good approximation to exergy accounts. Historical statistics on such currents of trade (including also the "ecological rucksacks") would be most relevant to world systems theory. (Carpintero, 2002, has published the material flows for the last forty years of the Spanish economy, it would be interesting to have Spanish figures for the last 500 years). A precise accounting of the "ecological rucksacks" today requires research on the "carbon dioxide" terms of trade. In the past and today, it requires research on the embodied pollution terms of trade (for other polluting substances). This is being done (Muradian et al., 2002). One may argue therefore that the existence of ecologically unequal trade is an empirically proven fact based on research on "social metabolism" (Muradian and Martinez-Alier 2001, Hubacek and Giljum, 2001, Giljum and Hubacek, 2003, Giljum in press). In an ecological economics theory of unequal exchange, one could say that the more of the original exergy [available energy or "productive potential" in the exported raw materials] has been dissipated in producing the final products or services (in the metropolis), the higher the prices of these products or services will be (Hornborg, 1998a, Naredo and Valero, 1999). Thus, Hornborg concludes, "market prices are the means by which world system centres extract exergy from the peripheries", sometimes helped, one must say, by military power.

³ Foster, 2000, classifies the socialist William Morris as a marxist. This is wrong.

However, neoclassical economists will argue that unequal trade in terms of exergy (or in terms of tons) is not evidence of economic exploitation. In neoclassical economics, provided that markets are competitive and ruled by supply and demand, there cannot be unequal exchange. This can only arise from monopoly or monopsony conditions, or because of non-internalized externalities (or excessive discounting of the future). In neoclassical economics, the theory of incomplete markets tries to provide explanations of why externalities might arise and what problems they might bring to known welfare propositions. A substantial part of the recent application of this framework to study trade and environmental issues focuses on the presence of incomplete property rights over natural resources and services to explain why trade might not be necessarily welfare improving for the exporting country. Shrimp farming destroys mangroves - never mind, this naïf body of theory says that such losses could be monetarized through appropriate property rights and appropriate markets on the livelihood and ecological functions of mangroves, and then we could know exactly what the balance is. Another way of putting this point across: negative environmental externalities derived from the export activity can be introduced in the standard trade theory approach by bringing the distinction between private and social marginal cost of production or extraction. However, the applicability of standard economic reasoning necessarily implies aggregating the externalities, at present values, under a unique numeraire. Economic valuation will depend on relative incomes and on power relations. Moreover, many of the negative effects derived from economic activities cannot be translated into a unique monetary measure. The problem becomes only harder when we consider that the externalities might reach the future as well as the present. In that case, the problem is not only to translate the externalities of the present period into money value but also of the future periods, something that forces us to choose a discount rate, and therefore to choose an intertemporal distributional pattern of costs and benefits. Today neoclassical economists have learnt to talk of Pigouvian taxes and “natural capital depletion taxes” because of local or global externalities (such as the enhanced greenhouse effect), and because the intergenerational allocation of natural resources discounts too much the future. However, the inability to bring all externalities and the deterioration of natural resources into the measuring rod of money, and the issue of choosing a particular discount rate, make it hard to produce a chrematistic measure of ecologically unequal exchange.

Standard economic theory points to the need to internalize externalities, something that to the extent possible, is desirable in order to bring the costs of extraction and exporting of natural resources closer to the “real” social costs. The point is that, it is precisely the limitations in achieving this goal, what pushes the analysis outside the neoclassical sphere, towards incommensurability of values (which means the absence of a common unit of measurement across plural values) (Cabeza and Martinez-Alier, 2001). Poor people are well advised to defend their interests in languages different from that of compensation for externalities, because in the economic sphere “Lawrence Summers’ principle” (“the poor sell cheap”) is operative.

There are other languages in which the main lines of a theory of ecologically unequal exchanged may be expressed. The Ricardian theory of comparative advantage showed that if all countries specialized in the production which was

internally cheaper to produce in relative terms, all could win by trade. Subsequent elaborations of the theory showed that if countries specialized in productions which relied on the internally most abundant factors (say, natural resources as opposed to skilled labor or manufactured capital), all could win by trading freely. Critics pointed out that relying on comparative advantage would mean, in some cases, to remain locked-in in a pattern of production which excluded gains in productivity from economies of scale (i.e. the infant industry argument for protectionism). Moreover, the recognition that production involves also destruction and degradation of the environment (pointed out by Henry Carey in the United States already in the early 19th century) brings a new argument against free trade between regions and countries. There is no need to argue for autarky, or for a strict “bioregional” position. From a purely ecological point of view, there is an argument for importing imports the lack of which would limit production, in the sense of Liebig’s law of the minimum (Pfaundler, 1902).

Marx showed that the exploitation of labour (the appropriation of its surplus labour) would cause crises in capitalism. The money value of the products could not be realized because of lack of purchasing power from the exploited proletariat. Imperialism, it was argued later, arose from the competition between states to get new markets for their own capitalists. Imperialism also was useful for the appropriation of new sources of labour (not necessarily wage labour, also slaves or indebted labour) and new raw materials. Imperialism came together with *Raubwirtschaft*. The process of destruction of Nature that lies behind ecologically unequal trade was already described by some geographers in the 19th century as *Raubwirtschaft* (Raumoulin, 1984). Jean Brunhes explained this term in his well known *Geographie humaine*. Carl Sauer also mentioned it. There have been three main lines in the links between geography and history. First, the “determinist” line (which in a Marxist context would be associated with the so-called Wittfogel’s thesis). Second, the “conditioning” line, shown in Braudel’s idea of the *longue durée*: the geography does not determine but it helps to explain historical economic and political phenomena. Economy and politics change more rapidly than the geography. Third, the line of *Raubwirtschaft* or “the human role in changing the face of the Earth”. Thus, in America and Oceania, human depopulation and species invasion after the European contact and conquest took place quickly. No *longue durée* in the ecology of America under Philippe II (Crosby, 1986, Melville, 1994) (Today, climate change is perhaps quicker than political change).

Combining ecological economics and political ecology in the study of the state-sponsored large projects in the 1970s in the Northern Amazonian region of Brazil (mainly iron and aluminum exports), two pioneering authors (Bunker, 1985, Altvater, 1987, 1993) reached the idea of ecologically unequal exchange. We move out of a purely economic language, because the concept focusses *on the poverty and the lack of political power of the exporting region* (Bunker, 1985) to emphasize the idea of lack of alternative options, in terms of exporting other renewable goods with lower local impacts, or in terms of internalizing the externalities in the price of exports. Bunker emphasized then the lack of local political power in the exporting region. Differing “production times” together with the valorization (*mise-en-valeur*) of new territories are the notions that Altvater brought into play in an ecological elaboration of Rosa Luxemburg’s theory of imperialism and

capital accumulation. Capitalism necessarily incorporates new spaces by means of new transport systems in order to extract natural resources. Spatial relations being modified, temporal relations are altered as well because production in the newly incorporated spaces can no longer be governed by the time of reproduction of nature. Capitalism needs new territories and accelerates the production times. The antagonism (noticed long ago by Frederick Soddy) between economic time, which proceeds according to the quick rhythm imposed by capital circulation and the interest rate, and geo-chemical-biological time controlled by the rhythms of nature, is expressed in the irreparable destruction of nature and of local cultures which valued its resources differently. Nature is an open system, and some of its organisms grow sustainably at very rapid rates, but this is not the case of the raw materials and products exported by the South. By placing a market value on new spaces we change also the production times, and economic time triumphs, at least apparently, over ecological time.

Hence the renewed relevance of the Latin American theory of deteriorating terms of trade, as proposed in the later 1940s by the Argentinian economist Raul Prebisch. This theory was the backbone for the CEPAL's proposals from the 1950s to 1973 on "import substitution" - 1973 saw the fall of Allende in Chile, and the inauguration of economic neo-liberalism under Pinochet. The theory, which has precedents in eastern Europe in the period between the world wars, explains that increases in productivity in the primary export sectors (that is, larger production per worker thanks to technological progress) are translated into lower prices, because of three reasons. First, despite attempts at forming cartels, there are many international competitors. Second, the income-elasticity of demand for such products is low. Third, the workers are poor, often non-unionized, and there is an ample supply of unemployed labour - this was so in Central American banana plantations, and in Bolivian mines, not so much in the Argentina of Peron. In the meantime, the prices of imported manufactured goods and services do not drop in proportion to the increases in productivity, because the market structure is more oligopolistic, and the workers, unionised and already well paid, are in a strong bargaining position which allows them to raise salaries at least in proportion to the increase in productivity. Hence, the trend towards worsening terms of trade for primary producers. The theory is open to objections. For example, in some periods economies can grow on the basis of primary exports, and these open economies can create significant urban and industrial bases. This has been called the staple theory of economic growth, after the work of the Canadian historian Harold Innis, himself critical of this mode of development. It applies to some periods of the economic history of Canada, New Zealand, Australia, the Scandinavian countries, also to regions such as Buenos Aires and Sao Paulo. Another objection is that industrial products and services are also subject to competitive commercial pressures which lower their prices, as it has occurred with cars and with information technology. However, the theory of the deterioration of the terms of trade is again relevant. There is a real deterioration in the terms of trade, and also (as Marxist economists such as Emmanuel (1972) had explained) many hours of badly paid work are "exported" in exchange for a few well paid hours. Such theories now are complemented by adding to them the environmental component.

Attempts at counting in physical units the use of the environment attached to trade have been present in the literature for some time, before the recent flourishing of

Material Flow Accounting. H.T.Odum's theory of unequal exchange in terms of "emergy" is an example (Odum and Arding, 1991). Emergy is defined as embodied energy. Odum was concerned with exposing unequal exchange of emergy between regions or nations, and he discussed trade in terms of their emergy exchange ratio. The periphery is underpaid for the emergy content of its natural resources because they are not properly valued in the market. The problem, as Hornborg points out (Hornborg, 1998a), is whether Odum intended to give us a normative or a positive approach. That is, whether the emergy content is something that should be used to determine how exports should be paid for, and thus we should aim at an emergy-equity trade, or is just something to be used descriptively, an indicator about unbalances in trade along with measurements in tons of materials, in "ghost acreage" or "ecological footprints", in hours of work, and in money. Trade policy should then take into account several indicators which perhaps show different trends. (The emergy values have moreover specific problems in calculation which are not discussed here).

Finally, as mentioned before, Hornborg proposes the use of the concept of exergy to provide a foundation for a theory of unequal trade. Exergy stands for available energy. Hornborg argues that market prices are the specific mechanism by which world centres extract exergy from, and export entropy to, their peripheries (Hornborg, 1998a). The disposal of waste, like carbon dioxide emissions, with zero money cost, is another key factor to understand economic growth in the North. Hornborg's point is a crucial one because it stresses the importance of understanding the mechanism by which unequal exchange take place. Still, the use of exergy would only account for one aspect of the link between extraction of resources and the environment. The important point is not the difficulty of calculation. In any case the values obtained would be less arbitrary than the money-values given (for instance) to externalities such as the loss of biodiversity. The essential point is that incommensurability applies not only to money value but also to physical reductionism. Can "biopiracy" be reduced to energy calculations?

Ecological dumping?

The recent attempts to organise "Fair Trade" networks by means of cooperation of the North with the South (consumers who, for example, are willing to pay a higher price for imported "organic" coffee) stem from the awareness that consumption drives the economy and from a willingness to incorporate certain social and environmental costs in the price. Conversely, those costs are not internalised in the prices which apply in normal production and marketing. There is no "fair trade" in oil or copper. The "Fair Trade" movements shows in practice that in order to allow exported products to be produced in ecologically and socially sustainable processes, importers must be ready to pay a premium.

Selling at prices which do not include compensation for environmental externalities and for the exhaustion of resources can be described as "ecological dumping". This happens not only in the trade of natural resources from South to North but also sometimes from North to South, such as agricultural exports from the United States or Europe to the rest of the world which are directly subsidized, and also indirectly because of cheap energy, no deductions from water and soil pollution and use of pesticides, no deductions for the simplification of biodiversity.

We describe the first kind of ecological dumping (from South to North) as ecologically unequal exchange to emphasize the fact that most extractive economies are often poor, powerless, and therefore unable to slow down the rate of resource exploitation or to charge “natural capital depletion taxes”, unable to internalize externalities into prices, and unable to diversify their exports. Thus, contrary to the view that environmental non-tariff trade restrictions are a manifestation of “Northern” protectionism at the cost of “Southern” producers, there are “Southern” demands for “Northern” consumers to boycott “Southern” exports because of their social and environmental effects. Such voices are largely unheeded, but they perhaps announce a different world where consumers will have information on the processes of production of the products they consume.

“Dumping” implies a voluntary decision to export at a price lower than costs. When oil is exported from the Niger Delta, power and market relations are such that there is no possibility of including the social, cultural and environmental costs of oil extraction in the price. When a country like Peru exports gold and copper, and much environmental and human damage is suffered internally, it is not appropriate to say that the social values of the Peruvians are such that they care little for health and the environment. Rather, we should say that they are unable to defend their interests for a better environment and a better health because they are relatively poor and powerless. In an economic model, whatever the causes, the result will be the same. The externalities (insofar as they are known) are not factored into the prices, it does not matter if this is a free choice or an imposed decision, whether they are inscrutable preferences or unjust social structures.

Memories of guano and quebracho

Oversupply of primary commodities, forced by a doctrine of export-led growth and by the obligation of servicing the external debt, leads to low prices. This must not be confused with a trend towards the material and energy “delinking” in the importing economies. The point needs some emphasis. Thus, an authoritative African view is that: “Current difficulties of such countries as Cote d’Ivoire and my own country, Cameroon, which until recently, were considered development models in Africa, can largely be explained by ... the fall of prices of African commodities in the international market”. Agreed, but why should this be so? “The main reason is that the quantity of raw materials now required for an industrial production unit represents only two fifths of what was needed in 1990, and this decline in demand for raw materials is accelerating. In this respect, the Japanese experience is particularly striking. In 1984, for each industrial production unit, Japan used only 60 percent of the raw materials it had used eleven years earlier, in 1973, for the same volume of industrial production. The example of some industries is also significant. Thus, it is possible to send as many telephone messages with a glass fiber of 50 to 100 pounds as with a ton of copper wire. However, the production of the 100 pounds of glass fiber does not require more than five percent of the energy needs for the production of the ton of copper wire. Similarly, plastic that is more and more replacing steel in automobile bodies is only half the cost of steel, energy and raw materials included. Reliance on raw materials as sources of income for exports cannot therefore be a wise long-term policy for African governments; to the contrary”. (Doo Kingue, 1996:41).

One agrees with the conclusion, that reliance on exports of raw materials is bad economic policy, without fully agreeing with the premise of “dematerialization”. Witness in that region the new Chad-Cameroon pipeline to ship oil for exports. The volume of materials exported from South to North which is far higher than the volume imported, is not decreasing in absolute terms. True, some bulk raw materials may become technologically obsolete, as it happened to the exports of Chilean saltpetre, which were substituted by nitrogen obtained through the Birkeland-Eyde process and later the Haber process (during the First World War) In other cases, exhaustion or at least substantial depletion occurred before substitution arrived, even though the resources themselves were renewable, like the *chinchona officinalis*.

Sometimes there are products which in principle would be ecologically sustainable but are not, like extraction of guano in Peru between 1840 and 1880. Guano is a word in Quechua meaning “excrement” which has made it not only into Spanish but also into English. Certainly not a luxury good or “preciosity”. It is a substance that consists of the dried excrements of sea birds, and is used as a fertiliser. It was not a commodity that had to be produced, its deposits already existed on small islands and promontories accesible to cargo ships. As remarked above, the large scale commercial exploitation of guano was contemporaneous to the birth of agricultural chemistry with Liebig’s and Boussingault’s publications. A chemical analysis of its contents had been made by Fourcroy and Vauquelin, as the science of plant nutrients was being born. A few Peruvians already thought of “turning guano into railroads”, like the chemist Mariano de Rivero, born in Arequipa and trained in Paris, he was a colleague of Boussingault. About eleven million tons of guano were exported in four decades from Peru (Gootenberg, 1993; Martinez-Alier with Schlüpmann, 1987). Guano is the same resource as fishmeal (even though at a later stage of the trophic chain), which was also exported from Peru at a non-sustainable rate in the 1960s and early 1970s. Periodically, the warm waters of El Niño appear around Christmas (hence its name), provoking intense rains on the coast of Ecuador and the Piura dessert in northern Peru, also displacing or destroying the fisheries of anchovy (*Engraulis ringens*) and other species, many birds dying of hunger. This natural phenomenon, locally well known (Lavalle, 1913:97), is today world famous because its global reach has been understood particularly after El Niño event of 1972-73. El Niño helps to explain the foretold collapse of the anchovy fishery in the early 1970s but not the near-exhaustion of guano in 1880. Thinking of exports of Peruvian fishmeal, Borgstrom (1967) developed the notion of “ghost acreage” (which the South “exports” to the North), an ancestor of today’s well-known “ecological footprint” (Rees and Wackernagel, 1994).

Good monographs have been written on Peruvian guano (Maiguashca,1967, Bonilla, 1994, Matthew, 1981), from the financial and political more than ecological viewpoints. A.J. Duffield, towards the end of the Peruvian Guano Age of 1840-80, reflected on the money that the guano deposits had aproduced and the uses to which it had been applied (in a “weak sustainability” framework, if one may use the words). He estimated the guano deposits still existing in Peru. He transcribed an optimistic dispatch sent by Juan Ignacio Elguera, the Peruvian Minister of Finance, for the benefit of overseas bondholders a few years before the start of the war of 1879: “However long the guano deposits may last, Peru always

possesses the nitrate deposits of Tarapacá to replace them. Foreseeing the possibility of the former becoming exhausted, the Government has adopted measures by which it may secure a new source of income, in order that on the termination of the guano, the Republic may be able to continue to meet the obligations it is under to its foreign creditors” (Duffield, 1877: 102). This was indeed extremely “weak” sustainability on the verge of the Chilean takeover.

The Peruvian guano economy, today a staple of ecological-economic history, provided in the 1960s the model for the theorization by Levin (1960) of the “enclave” economy, defined as an economy where economic linkages were lacking between the export sector and the internal economy. Peruvian guano was extracted by some local labor, and by Chinese imported indentured laborers. It was not produced but quickly extracted and then “commoditized” or merchandised by European merchants from London and Paris. The U.S. arrived late to the great guano rush, no Monroe doctrine applying here. The U.S. Congress tried to make up for the delay by passing an Act in 1856 (which apparently is still in the current statutes) “to authorize protection to be given to citizens of the United States who may discover deposits of guano” in small islands, rocks or keys off the coast of Africa, the Caribbean, or the Pacific, or wherever they might be, provided they did not belong to other states or were not occupied by citizens of other states. Nothing of much commercial value came out of this attempt at enjoying the pleasures of open access to guano through newly well-defined property rights (Skaggs, 1994).

The trade in quebracho (*Schinopsis balansae*) from Argentina is a story of the 20th century.⁴ It was used for railway sleepers, for posts, and for tannin extract for export, at a non-sustainable rate. There are two types of quebracho, white and red. The extract from red one was used since the end of the 19th century for tanning. It is a hard wood, which grows in isolated strips. The regions containing these slowly growing trees were the Chaco and Santa Fe, in Argentina. After some initial attempts by local entrepreneurs at developing an export industry of extracts, Baron Emile Beaumont d’Erlanger of London set up a company in 1906 known as La Forestal for the purpose of acquiring and further developing the business of the Compañía Forestal del Chaco. By 1911 the new company owned 1.5 million acres, and leased 0.5 million acres, by 1913 it grew to 5 million acres freehold, and 0.6 leased (Hicks, 1956:7, 16). In 1920-21 there was much labour unrest, and the tannin factories in Argentina were locked-out. The 1920s became a period of expansion, the productive capacity of quebracho extract reaching 430,000 tons yearly in 1928 (for La Forestal and other minor companies) (Hicks, 1956:45). The company sold land cleared of quebracho for cattle raising, and for settlers. The official history of the company remarks that “of the vegetable tanning materials in common use at the end of the First World War -oak, chestnut, spruce, quebracho, etc- quebracho was not only by far the cheapest, it was, and it is still today, the tanning agent which most rapidly penetrates the hide” (Hicks, 1956:22). Despite such advantages, La Forestal company diversified its sources, developing black wattle and mimosa tree plantations in Eastern and South Africa as a source of tannin. Argentina forbade the export of roundwood quebracho in 1928, to foment the production of tannin extract in its own territory. Later, during the Peron government from 1946 onwards, the regulation of export of quebracho extracts (through state control), and its taxation (as on agricultural exports in general)

⁴ I am grateful to Marcela Guerrero for references.

were introduced. According to the official history of La Forestal, this attempt to increase export prices initially made Argentinian quebracho extract not competitive internationally but by the early 1950s a successful accommodation had temporarily been reached. More than 200,000 tons of extract were sold annually during the Korean war years. Many of La Forestal's factories were in Santa Fe, where, in contrast with the Chaco, "supplies of quebracho trees round the factories were becoming exhausted" (Hicks, 1956:68). These factories had to be closed down. For the local populations, the abandoned settlements were to be regarded as the equivalent to mining ghost-towns. Large reserves of quebracho still existed in the Chaco, owned by the state, and new factories could be opened, though there was the threat from African plantations, and also a new threat: "the full impact of leather substitutes [such as artificial rubber] on the sale of leather, which in its turn may influence the demand for tanning materials, has not yet made itself fully felt" (Hicks, 1956:70).

Here I shall use such cases in order to establish a typology regarding both *renewable* and *exhaustible* natural commodities or resources:

- a) resources which are exploited at particular locations and exported at such a rate which they became (almost) exhausted, whether they are renewable or not (guano, oil, and certainly many metals the costs of extraction of which grow too much as the concentration diminishes).
- b) resources which are exported at such a relatively slow rate that substitution intervenes and they become economically obsolete much before they are exhausted (Chilean saltpetre). They become non-essential commodities, in a material sense.
- c) resources which are exploited at a rate quicker than renovation, whose stocks are depleted locally (such as the *quebracho colorado*), but of which it can be argued that a slower rate of exploitation would have been unwise, because of the threat of substitution.

From the reality of many instances of substitution of particular raw materials which became non-essential, we cannot argue that growth of the economy will always endogenously make available "backstop" technologies. Against this view, economic growth achieves sometimes the remarkable feat of exhausting not only exhaustible resources but also renewable resources. Thus, depletion is quicker than production today in fishing grounds around the world.

Preciosities, staples, and environmental "rucksacks"

There is today a renewed interest in the old-fashioned *Warenkunde* from the ranks of industrial ecologists who evaluate the "life-cycles" of products from "cradle to grave" and indeed from "grave to cradle" as waste is recycled. For example, in order to export one ton of aluminum, major inputs of bauxite are necessary, and in order to extract and move the bauxite a great deal of material and vegetation is destroyed. Then the large input of electricity for the smelting of the aluminum has also its own material rucksack. In order to export a luxury good such as cocaine, a lot of soil is eroded (growing coca leaf on slopes under precarious conditions) and rivers are polluted by its production inputs (kerosene, sulfuric acid). Consider trade in ivory or rhino's horns, diamonds, mahogany, or other "preciosities" such

as gold (with enormous ecological rucksacks in open cast mining, Muradian et al, 2003) or shrimp (a large industry around the Tropics of over 10 billion US\$ per year, grown at the expense of mangroves and human livelihoods). In the exporting coastal regions, people do not care whether shrimp are consumed in the metropolis as a luxury good or as a source of protein. “Preciosities” with high economic value/ low weight ratios may have bulky environmental impacts on ecosystems and human livelihoods.

World systems theory traced a contested distinction between essential commodities and “preciosities”, and one may wonder whether the “social metabolic” perspective may help clarify it. I am not sure. Market prices and trade figures in money are crucial in capitalism but they are also deceptive, we have to look to the flows of energy and materials. There are also the ecological linkages. Anthropologists objected to the view that exchanges of “preciosities”, as distinct from trade in bulk, are not essential to the constitution of world systems (Schneider, 1977). They rightly argued that pure “prestige goods”, far from being superfluous, are on the contrary crucial in a social sense (as dowry for instance, or for the accumulation of political power in clientelistic systems). But there is more to be said. Some “preciosities” become staples. Sugar, as Sidney Mintz showed, was a luxury good and became a source of cheap calories for industrial workers in the metropolis. This is indeed a “social metabolic” view of the issue. However, some “preciosities” remain preciosities. They are not essential inputs to production processes and they do not become cheap wage-goods. They are genuine luxury goods: perhaps their consumption drives the economy and destroys the environment. One is reminded of the large impact of Potosi in the Andean demography and social structure (including pollution from mercury).

Clearly, the chrematistic point of view is still relevant (as argued by Max Weber against Ostwald) in order to explain the decisions of capitalist entrepreneurs regarding production and trade. The physical point of view is also relevant, in at least two senses. First, it allows us to signal different trends between two non-equivalent descriptions of economic reality, the economic and the physical. Thus, Africa and Latin America seem increasingly irrelevant continents in world trade in money terms (non-essential continents?), while in material terms their share of exports (and ecological rucksacks) is increasing. The United States now imports almost half of the increasing amount of oil it consumes. Second, behind the physical realities there are social issues of pollution and environmental degradation, from which social movements arise. Ecologically unequal exchange is one main cause of the local movements and the networks around the world against oil and gas wells and pipelines, against eucalyptus plantations, against gold and copper mining, against “biopiracy”, against shrimp farming or the abuse of fisheries.

Such movements are in the vanguard on the issue of “corporate accountability” and try to bring foreign firms to court in their own countries of origin (under the ATCA legislation in the United States). Examples are Texaco in Ecuador (an oil company), Freeport McMoRan in West Papua (Irian Jaya, Indonesia) (a gold and copper mining company), and many others. The concept of “environmental liabilities” arising from concrete instances of pollution in mining or oil extraction is significant in this respect. The CERCLA-Superfund legislation in the United

States is not applicable internationally. After listing a number of cases in the United States in which indemnities have been paid by corporations such as the Exxon Valdez, a Venezuelan journalist asked himself: “Being Venezuela a country dominated by the oil and mining industries, the question is, which is the *pasivo ambiental* (i.e. environmental liability) of all this oil and mining activity in our country?”⁵ It is fascinating to watch the diffusion of the term *pasivo ambiental* (equivalent to *deuda ecológica*) in Latin America.

The ecological debt

In this section, the notion of the “ecological debt” will be considered. It brings together many international ecological distribution conflicts, and it also puts on the table the question of the languages in which such conflicts are represented. The ecological debt is in principle an economic concept. The first discussions took place around 1992, largely because of the inputs from Latin American NGO. Fidel Castro was persuaded by Latin American activists to use this concept in his own speech at the official conference in Rio de Janeiro in 1992.⁶ Also Virgilio Barco, the president of Colombia at the time, had used the expression in a speech in the United States at the M.I.T. commencement ceremony on 4 June 1990. Almost one decade later, Friends of the Earth at its general assembly of 1999 made of the Ecological Debt one of its campaigns for the following years. The notion of an ecological debt is not particularly radical. Think of the environmental liabilities incurred by firms (under the United States Superfund legislation), or of the engineering field called “restoration ecology”, or the proposals by the Swedish government in the early 1990s to calculate the country’s environmental debt.⁷

Ecologically unequal exchange is one of the reason for the claim of the Ecological Debt. The second reason for this claim is the disproportionate use of environmental space by the rich countries. Putting both reasons together, and expressing the Ecological Debt in money terms, these would be the main components:

Regarding Ecologically Unequal Exchange:

- **The (unpaid) costs of reproduction or maintenance or sustainable management of the renewable resources which have been exported. For instance, the nutrients in the agricultural exports of Argentina (Pengue, 2002).**
- **The actualized costs of the future lack of availability of destroyed natural resources. For instance, the oil and minerals no longer**

⁵ Orlando Ochoa Teran, *Quinto Dia*, 18 January 2000, relayed by J.C.Centeno through the Environment in Latin America discussion list (ELAN at CSF).

⁶ Personal communication from Manuel Baquedano, the head of the Instituto de Ecología Política, Chile.

⁷ See www.deudaecologica.org. For Sweden, the reports of Arne Jernelov issued by the Swedish Environmental Advisory Council.

available, the biodiversity destroyed. This is a difficult figure to compute, for several reasons. Figures on the reserves, estimation of the technological obsolescence because of substitution, and a decision on the rate of discount are needed in the case of minerals or oil. For biodiversity, knowledge of what is being destroyed would be needed.

- The compensation for, or the costs of reparation (unpaid) of the local damages produced by exports (for example, the sulfur dioxide of copper smelters, the mine tailings, the harms to health from flower exports, the pollution of water by mining), or the actualized value of irreversible damage.
- The (unpaid) amount corresponding to the commercial use of information and knowledge on genetic resources, when they have been appropriated gratis (“biopiracy”). For agricultural genetic resources, the basis for such a claim already exists under the FAO’s Farmers’ Rights.

Regarding lack of payment for environmental services or for the disproportionate use of Environmental Space:

- The (unpaid) reparation costs or compensation for the impacts caused by imports of solid or liquid toxic waste.
- The (unpaid) costs of free disposal of gas residues (carbon dioxide, CFC...), assuming equal rights to sinks and reservoirs (see below).

One objection to the notion of an Ecological Debt is that debts are obligations arising from contracts, such as a sale or a mortgage. A non-recognised debt does not exist, according to this view. However, there are cases in which debts have arisen without a contract. Witness for instance the obligation to pay reparations by the German state or companies after the Second World War (with the agreement of most citizens of the country). Another objection to the notion of the Ecological Debt is that it implies monetization of Nature’s services. I confess, *mea culpa*. One excuse: the chrematistic language is well understood in the North.

The idiom of Environmental Justice against “environmental racism” has been employed in the United States in the struggle against the disproportionate amount of pollution in areas occupied by minority and low income people. Anti-racism is a powerful language in the United States. The disproportionate emissions of carbon dioxide are an international example of environmental injustice. Another idiom is that of Environmental Security, similarly to how we speak of food security as an agricultural policy which would assure local availability of food through use of local human and land resources. The AOSIS countries could argue that the North is producing a disproportionate amount of greenhouse gases which is not only counter to environmental justice, and it does not only give rise to environmental liabilities. It also puts the environmental security of the South (or at least parts of the South) at risk.⁸

⁸ Authors who have written on environmental security include Thomas Homer-Dixon, Peter Gleick, Norman Myers. See Deudney and Matthew, 1999.

Consider then the case of the environmental service provided by the permanent carbon sinks (oceans, new vegetation, soils), and by the atmosphere as a temporary reservoir where the carbon dioxide accumulates while waiting for a permanent sink. Thus, the concentration of carbon dioxide in the atmosphere has increased from 280 ppm to 360 ppm. The decision of the European Union at Kyoto in December 1997 was to allow the concentration to increase to 550 ppm which would possibly involve a two degree centigrade rise in temperature, with much uncertainty on the range, and even more regarding local effects. That this is a “safe” limit has been strongly disputed (Azar and Rhode, 1997). The emissions per person per year are in the United States of the order of 6 tons of carbon, in Europe half of this, in India 0.4 tons. We all breath in and out more or less the same, and it would be impracticable to reduce carbon dioxide emissions by slow respiration. There are livelihood emissions, and luxury emissions. We are dealing here with one characteristic feature of human ecology, extreme intraspecific difference in the exosomatic use of fuels, differences which are much larger than such national per capita figures reveal. The global average is about one ton of carbon per person/year (global emissions, 6000 M tons of carbon), already excessive, though it will normally increase because of population growth and economic growth. In Kyoto in 1997 and afterwards, the European Union, playing the “leadership game”, got “grandfathered rights” in exchange for a slight reduction in emissions. The United States found difficult to accept any reduction (partly because population is growing in the U.S.) until President Bush’s final refusal of the Kyoto Protocol in early 2001. Kyoto gave rights to the U.S., Europe and Japan equal to their 1990 emissions, on the promise of a reduction of 5.2 per cent for the year 2010. The required reduction in order to avoid further increase in concentration in the atmosphere, is much larger, of the order of half the present emissions, that is some 3000 M tons of carbon per year.

There are many instances in which through a change of industrial technology, or through conservation of forests under threat, or through new vegetation, there is a genuine gain in jointly implementing the objectives of carbon emissions reduction. How will such gain be shared? What will be the price of reduction of carbon emissions, or the price of the extra absorption? When the commitment to reduce emissions is small, as at present, then, in principle, the price of a ton of carbon in joint implementation projects will be low because the demand for sinks will be small. The price will be low if local negative externalities from the projects themselves are not factored into the price. The price will also be low when the supply of projects in the South (whether as additional sinks, especially when conservation of threatened primary forests is also accepted, or as changes in techniques which diminish carbon emissions such as substituting natural gas for coal) is large, compared to the demand. However, should the commitment to reduce be of the order of 3000 M tons of carbon per year, as it should be, then the price would increase enormously. In other words, the stronger and quicker the commitment to reduce, the higher the marginal cost of the reduction. Perhaps, if the owners of carbon sinks are poor, the local selling price of carbon absorption will still be low - then intermediaries would come into play, perhaps southern governments, perhaps northern financial institutions. Instead, if there is not reduction, this implies the persistent and disproportionate use of the sinks (oceans, new vegetations and the soils), and the atmosphere, as de facto property of the

rich, and therefore a continuous increase year after year of the ecological debt, at the tune, say of, US\$ 60 billion per year (3000 M tons of carbon which should be reduced at the cost of US\$ 20 per ton). The ecological debt arises on this count because, by not doing the necessary reduction, the rich countries save themselves a quantity which would be roughly of this order of magnitude. One could easily argue that the appropriate average cost to use should be US\$ 100 per ton or even higher. In any case, as a term of comparison, the present accumulated Latin American external debt is in 1999 of US\$ 700 billion (equivalent to only 12 years of “carbon debt” at US\$ 60 billion per year).

A similar calculation was published already in 1995 by Jyoti Parikh (a member of the IPCC), making in substance the same argument. If we take the present human-made emissions of carbon, the average is about 1 ton per person and per year. Industrialized countries produce three-fourths of these emissions, instead of the one-fourth which would correspond to them on the basis of population. The difference is 50 per cent of total emissions, some 3000 M tons. Here the increasing marginal cost of reduction is again contemplated: the first 1000 M tons could be reduced at a cost of, say, US\$15 per ton, but then the cost increases very much. Let us take an average of US\$25, then a total annual subsidy of US\$ 75 billion is forthcoming from South to North (Parikh, 1995).

Such calculations are now being taken up and elaborated upon by NGOs concerned with the social and environmental burdens imposed on poor countries by the service and repayment of the external debt. Thus, Christian Aid made available in 1999 a document on climate change, debt, equity and survival (with the title *Who owes who?*, and pictures of Bangladesh children with water up to their necks) that argues that to mitigate the effects of climate change “we will all have to live within our environmental budget. The atmosphere can only absorb a certain amount of greenhouse gases before disruption begins. So, their emission needs controlling. As, each day, industrialized countries delay action on the 60-80 per cent cuts that are needed, they go over-budget and are running up an environmental or “carbon” debt. Ironically those same countries today stand in judgement over much poorer countries who have comparatively insignificant conventional, financial debts”. Christian Aid’s calculation of the “carbon debt” is done in this way: the carbon intensity of GNP is taken as constant, a reduction of carbon emissions in rich countries of 60-80 per cent is assumed, the corresponding decrease in GNP is calculated. The enormous decrease in GNP does not occur because the reduction in emissions does not take place: this is the avoided cost, i.e. the debt. Christian Aid’s figures are far too high because small reductions of carbon emissions can be achieved with small marginal costs (perhaps even with win-win opportunities), the marginal cost increasing with the volume and urgency of the reductions. One has to allow for changing in techniques and in the composition of output.

Other Christian groups such as the Canadian Ecumenical Council for Economic Justice have also in 2000 estimated the “carbon debt” in the context of the increasing discussion on the ecological debt (www.ecej.org). There are many uncertainties as to how the future energy systems will develop. Methods for injecting the carbon dioxide into the earth or in aquifers might become practicable and widespread. Photovoltaic energy might become cheaper. The number of

windmills is increasing in many places. If we look at the past century, we see that new energy systems are added on top of the existing ones, without substituting for them. The world economy, and especially the rich countries' economy, will be based on fossil fuels at least for thirty or forty years. Afterwards, we do not know. Hydrogen, to be used in fuel cells, should be seen as an energy carrier not as an energy source, because much energy is needed to obtain the hydrogen. Meanwhile, the carbon debt accumulates.

To sum up, countries which are in a creditor position in the ecological debt could give a sense of urgency to the negotiations on climate change (and also on other issues, such as Farmers' Rights), by claiming the ecological debt, which is admittedly hard to quantify in money terms. They could join in a greenhouse politics based on Contraction of emissions, Convergence to about 0.5 tons of carbon per capita and per year, and in the meantime Compensation, at the same time deploying also the language of their threatened environmental security.

Conclusion

In conclusion, a social metabolic view of the world capitalist system leads to doctrines of ecologically unequal trade and ecological debt. It also helps to see history in wider terms than merely the economic, and it might help therefore to change the international political agenda by giving intellectual support to the many resistance movements grown out of ecological distribution conflicts. Such "environmentalisms of the poor" (Martinez-Alier, 2002) might choose to express their grievances in economic language because the capitalists and their institutions appreciate it (i.e. the carbon debt in money terms, a chrematistically quantified estimation of unequal trade because of unaccounted externalities and exhaustion of resources, a proposal for "natural capital depletion taxes"). They might quote again with reason Prebisch's thesis. Normally however, except in contexts where claims for environmental liabilities are being adjudicated, they might prefer to argue not in the hegemonic economic language but in physical or social languages. Why? Because of "Lawrence Summers' principle" - "the poor sell cheap" both in actual markets and in fictitious markets where willingness-to-accept compensation is assessed. Also, because money valuation is unable to cope convincingly with future damages, and with losses of biodiversity and other unknown or uncertain effects.

Environmental movements of the poor might choose instead a Marxist economic language (in terms of unequal exchanges of labour). They might move outside economics altogether, and argue in terms of environmental justice against environmental racism. They could emphasize their threatened livelihoods (the *oikonomia*) and environmental security. Or they could also argue in physical terms, pointing at the widely different "ecological footprints" per capita, and refer back to "social metabolism" accounting showing trade balances so favourable to the North in terms of tonnage (and in terms of pollution and other "ecological rucksacks"), and correspondingly the uncompensated current of exergy from South to North. They might list other cruelties and profanations that take place in their countries because of international trade and capital accumulation, using different idioms. There are many languages of valuation. This diversity is here not a cause for post-modern celebration, rather we are looking again at the history of

systemic exploitation of the South by the North. Some of these languages may be used concurrently.

REFERENCES

Altvater, E., *Sachzwang Weltmarkt: Verschuldungskrise, blockierte Industrialisierung, ökologische Gefährdung*, VSA, Hamburg, 1987.

Altvater, E., Ecological and economic modalities of space and time, in M. O'Connor ed., *Is capitalism sustainable? Political economy and the politics of ecology*, Guildford, New York, 1994.

Ayres, R.U., *Industrial metabolism*, in J. Ausubel ed., *Technology and Environment*, National Academy Press, Washington DC, 1989.

Ayres, R.U., Ayres, L., Warr. B., *Exergy, power and work in the US economy, 1900-1998*, CMER-INSEAD, working paper, 2002.

Bonilla, H., *Guano y burguesía en el Perú*, 3rd ed., Flacso, Quito, 1994.

Borgstrom, G., *The hungry planet*, Collier-Macmillan, London, 1967.

Bunker, S., *Underdeveloping the Amazon: extraction, unequal exchange, and the failure of the modern state*, Univ. of Illinois Press, 1985.

Cabeza Gutes, M. and Martinez-Alier, J., *L'échange écologiquement inégal*, in M. Damian and J.C. Graz eds., *Commerce international et développement soutenable*, Economica, Paris, 2001.

Carpintero, O., *La economía española: el "dragón europeo" en flujos de energía, materiales y huella ecológica, 1955-95*, *Ecología Política*, 23, 2002.

Cipolla, C., *The economic history of world population*, Penguin, London, (1962), 6th ed., 1974.

Cleveland, C. J., *Biophysical economics: historical perspectives and current recent trends*, *Ecological Modelling*, 1987.

Cohen, J., *How many people can the Earth support?*, Norton, New York, 1995.

Cottrell, F., *Energy and society: the relations between energy, social change and economic development*, McGraw Hill, New York, 1955.

Crosby, A., *Ecological imperialism: the biological expansion of Europe, 900-1900*, Cambridge U.P., Cambridge, 1986.

Debeir, J.C., Deléage, J.P., Hémerly, D., *Les servitudes de la puissance. Une histoire de l'énergie*, Flammarion, Paris, 1986.

Deudney, D.H. and Mathew, R.H., eds., *Contested grounds: security and conflict in the new environmental politics*, SUNY Press, Albany, 1999.

Doo Kingue, M., Prospects for Africa's economic recovery and development, in A.Y. Yasane, ed., Prospects for recovery and sustainable development in Africa, Greenwood Press, Westport CT and London, 1996.

Duffield, A.J., Peru in the Guano Age. Being a short account of a recent visit to the guano deposits, with some reflections on the money they have produced and the uses to which it has been applied, R. Bentley & Son, London, 1877.

Emanuel, A., Unequal exchange: a study in the imperialism of free trade, Monthly Review Press, New York, 1972.

Engels, F., Dialektik der Natur (1925), MEW, vol. 20, Dietz Verlag, Berlin, 1972.

Fluck, R.C., Baird, D.C. , Agricultural energetics, Avi Publishing Co., Westport, 1980.

Fischer-Kowalski, M., Society's metabolism: the intellectual history of materials flow analysis, Part I: 1860-1970, Part II (with W. Huettler): 1970-98, *Journal of Industrial Ecology*, 2(1) and 2(4), 1998.

Foster, J. B. , Marx's ecology. Materialism and nature, Monthly Review Press, New York, 2000.

Frank, A.G., Industrial capital stocks and energy consumption, *Economic Journal*, LXIX: 170-4, 1959.

Geddes, P., An analysis of the principles of economics, Proceedings of the Royal Society of Edinburgh, 17 March, 7 April, 16 June, 7 July 1884, repr. Williard and Norgate, London, 1885.

Giljum, S., Hubacek, K., International trade, material flows and land use: developing a physical trade balance for the European Union, IR-01-059, IAASA, Laxenburg, 2001.

Giljum, S., Eisenmenger, N. (forthcoming): International trade and the distribution of environmental goods and burdens: a biophysical perspective. *Journal of Environment and Development*.

Giljum, S. (forthcoming): Trade, material flows and economic development in the South: the example of Chile. *Journal of Industrial Ecology*.

Gootenberg, P., Imagining development: economic ideas in Peru's "fictitious prosperity" of guano, 1840-80, Univ. of California Press, Berkeley, 1993.

Haberl, H., The energetic metabolism of societies, Parts I and II, *Journal of Industrial Ecology*, 5(1): 11-33, 5(2):71-88, 2001.

Hall, Ch., Cleveland, C. J., Kaufman, R., Energy and resources quality: the ecology of the economic process, Wiley, New York, 1986.

Hicks, A.H., The story of the Forestal, published by The Forestal Land, Timber and Railway Company Ltd, Shell-Mex House, Strand, London, produced by Newman Neame, London, 1956.

Hornborg, A., Toward an ecological theory of unequal exchange: articulating world system theory and ecological economics, *Ecological Economics*, 25 (1): 127-36, 1998a.

Hornborg, A. , Ecosystems and World Systems: accumulation as an ecological process, *Journal of World-System Research*, IV(2): 169-177, 1998b

Hubacek, K. , Giljum, S., Applying physical input-output analysis to estimate land appropriation of international trade activities. *Ecological Economics* 44 (1):137-151. 2003.

Jenssen, Otto, ed., *Marxismus und Naturwissenschaft: Gedenschrifts zum 30. Todestage des Naturwissenschaftlers Friedrich Engels, mit Beiträgen von F. Engels, Gustav Eckstein und Friedrich Adler*, Verlagges. des Allgemeinen Deutschen Gewerkschaftsbundes, Berlin, 1925.

Kormondy, E.J., *Readings in ecology*, Prentice-Hall, Englewoods Cliffs, NJ, 1965.

Lavalle y García, J.A. de, *El guano y la agricultura nacional*, Lima, 1913.

Leach, G., *Energy and food production*, IPC Science and Technology Press, Guildford, 1975.

Lenin, V.I., The working class and Neomalthusianism, *Pravda*, 137, 16 June 1913 (trans. in *Collected Works*, vol. 19).

Levin, J.V., *The export economies*, Harvard U.P., Cambridge MA, 1960.

Maignushca, J., *A reinterpretation of the Guano Age 1840-80*, D.Phil. thesis, Oxford University, 1967.

Martinez-Alier, J. with K. Schlüpmann, *Ecological economics. Energy, environment and society*, Blackwell, Oxford, 1987.

Martinez-Alier, J., ed. *Los principios de la economía ecológica (Textos de Podolinsky, Geddes y Soddy)*, Argentaria-Visor, Madrid, 1995.

Martinez-Alier, J., Munda. G. and O'Neill, J., Weak comparability of values as a foundation for ecological economics, *Ecological Economics*, 26: 277-86, 1998.

Martinez-Alier, J., *The environmentalism of the poor. A study of ecological conflicts and valuation*, Edward Elgar, Cheltenham UK, Northampton MA, 2002.

Marx, K., *Das Kapital*, vol. I 1867, vol. III, 1894, Ullstein Verlag, Frankfurt-Vienna-Berlin, 1969.

Marx, K., Engels, F., *Lettres sur les sciences de la nature et les mathematiques*, Mercure de France, Paris, 1976.

Masjuan, E., *La ecología humana y el anarquismo ibérico: el urbanismo "orgánico" o ecológico, el neo-malthusianismo y el naturismo social*, Icaria, Barcelona, 2000.

Masjuan, E. *Neomalthusianesimo e anarchismo in Italia: un capitolo della storia del pensiero ecologico dei poveri?*, *Meridiana* (Rome), 2003 (in press)

- Matthew, W.M., *The House of Gibbs and the Peruvian Guano Monopoly*, Royal Historical Society, London, 1981.
- Mayer. J.R., *Die organische Bewegung in ihrem Zusammenhang mit dem Stoffwechsel*, Heilbronn, published also in *Die Mechanik der Wärme: gesammelte Schriften*, Stuttgart, 1893, and in W. Ostwald, *Klassiker der exacten Naturwissenschaften*, Akademische Verlag, Leipzig, 1911.
- McNeill, J. R., *Something new under the sun. An environmental history of the twentieth-century world*, Norton, New York, 2000.
- Melville, E., *A plague of sheep: environmental consequences of the conquest of Mexico*, Cambridge U.P., Cambridge, 1994.
- Moleschott, J., *Lehre der Nahrungsmittel. Für das Volk*, Enke, Erlangen, 1850.
- Moleschott, J., *Physiologie des Stoffwechsels in Pflanzen und Thieren*, Erlangen, 1851.
- Moleschott, J., *Der Kreislauf des Lebens*, Von Zabern, Mainz, 1852.
- Mouchot, A., *La chaleur solaire et ses applications industrielles*, Gauthier-Villars, Paris (1869), 2nd ed. 1879.
- Muradian, R. and Martinez-Alier, J., Trade and the environment from a “southern” perspective, *Ecological Economics*, 36: 281-97, 2001.
- Muradian, R., O’Connor, M. and J. Martinez-Alier. Embodied Pollution in Trade: Estimating the 'Environmental Load Displacement' of Industrialised Countries. *Ecological Economics* 41(1): 41-57, 2002.
- Muradian, R. , *Nepad and the environment: Envisioning the ecological consequences of outward-oriented development in Africa*. In: Anyang'Nyong'o, P., Ghirmazion, A. and D. Lamba (Editors). *New Partnership for Africa's Development: A New Path?*. Heinrich Boell Foundation. Nairobi, 2002.
- Muradian, R., Martinez-Alier, J. and H. Correa. *International capital vs. local population: the environmental conflict of the Tambogrande mining project, Peru*. *Society and Natural Resources* Vol. 16 (in press, 2003).
- Muradian, R. and J. Martinez-Alier, *Economic specialization and the international distribution of environmental burdens*. In: Serfati, C. (Ed.). *Enjeux de la mondialisation: un regard critique*. Octares Editions. Toulouse, 2003.
- Naredo, J.M. and Valero, A., *Desarrollo económico y deterioro ecológico*, Argantaria-Visor, Madrid, 1999.
- O’Connor, J., *Introduction, Capitalism, Naure, Socialism*, 1, 1988.
- O’Neill, J., *Ecology, policy and politics*, Routledge, London, 1993.
- O’Neill, J. *Socialist calculation and environmental valuation: money, markets and ecology*, *Science and Society*, Spring 2002.
- Odum, H.T., *Environment, power and society*, Wiley, New York, 1971.

- Odum H.T. and Arding, J.E., Energy analysis of shrimp mariculture in Ecuador, working paper, Coastal Resources Center, University of Rhode Island, 1991.
- Parikh, J.K., Joint implementation and the north and south cooperation for climate change, *International Environmental Affairs*, 7(1): 22-41, 1995.
- Pengue, W., Lo que el Norte le debe al Sur. Comercio desigual y deuda ecológica, *Le Monde Diplomatique* (Buenos Aires), April 2002.
- Pfaundler, L., Die Weltwirtschaft im Lichte der Physik, *Deutsche Revue*, 22, April-June, 29-38, 171-82, 1902.
- Pimentel, D. et al., Food production and the energy crisis, *Science*, 182: 443-9, 1973.
- Pimentel, D. and M., Food, energy and society, Arnold, London, 1979.
- Rappaport, R. Pigs for the ancestors: ritual in the ecology of a New Guinea people, Yale U.P., New Haven, 1967.
- Rees, W. and Wackernagel, M., Ecological footprints and appropriated carrying capacity, in A.M. Jansson et al, eds., Investing in natural capital: the ecological economics approach to sustainability, ISEE, Island Press, Washington DC, 1994.
- Ronsin, F., La grève des ventres. Propagande néo-malthusienne et baisse de la natalité en France, 19-20 siècles, Aubier-Montagne, Paris, 1980.
- Schmidt, A., Der Begriff der Natur in der Lehre von Marx, 3rd ed., EVA, Frankfurt-Cologne, 1978.
- Schneider, J., Was there a pre-capitalist world system? *Peasant Studies* VI(1): 20-29, June 1977.
- Sieferle, R. P., Der unterirdische Wald. Energiekrise und industrielle Revolution, Beck, Munich, 1982 (English trans., White Horse Press, Cambridge, U.K., 2001).
- Skaggs, J.K., The great guano rush: entrepreneurs and American overseas expansion, St. Martin's Press, New York, 1994.
- Susiluoto, I., The origins and development of systems thinking in the Soviet Union. Political and philosophical controversies from Bogdanov and Bukharin to present-day reevaluations, Suomalainen Tiedeakatemia, Helsinki, 1982.
- Vernadsky, V., La Géochimie, Alcan, Paris, 1924.
- Weber, M., Energetische Kulturtheorien, *Archiv für Sozialwissenschaft und Sozialpolitik*, 29, 1909, repr. in Max Weber, Gessamelte Aufsätze zur Wissenschaftslehre, 3rd ed., J.C.B. Mohr (Paul Siebeck), Tübingen, 1968.
- Weisz, H., et al., Economy-wide Material Flow Accounts and Indicators of Resource Use for the EU. Eurostat Tender 2001/S125 – 084782/ EN. Final Report, Luxemburg, 2002.
- White, L., Energy and the evolution of culture, *American Anthropologist*, 45(3), 1943.

**White, L., The energy theory of cultural development, in Morton H. Fried ed.,
Readings in Anthropology, Thomas Y. Cromwell, New York, vol. II 139-46, 1959.**