SOCIAL METABOLISM and ECOLOGICAL DISTRIBUTION CONFLICTS

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Abstract.- In Ecological Economics, the economy is seen as a system open to the entry of energy and materials, and to the exit of waste. This paper recalls Podolinsky's agricultural energetics, received negatively by Engels in 1882 and positively by Vernadsky in 1924. Marx had used the word "metabolism" to describe the relations between nature and human society but Marxist authors still did not count energy and materials flows, and paid no attention to unequal exosomatic use of energy and materials. The paper also explains Patrick Geddes' 1884 accounting framework for material flows that provides a basis for the theory of ecologically unequal trade. The debate between the ecological and the chrematistic views of the economy continued in the twentieth century, when prominent sociologists and economists (Max Weber, F.A. von Hayek) criticized authors who understood the economy as social metabolism. "Metabolic profiles" of countries or regions are today established by the statistics provided by MEFA (Material and Energy Flow Accounting) and HANPP (Human Appropriation of Net Primary Production). Links are traced between each society's "metabolic profile", and ecological conflicts at different scales, looking thereby at the relations between Ecological Economics and Political Ecology.

Introduction

Authors working on "industrial metabolism" (Ayres, 1989) or on "social metabolism" (Fischer-Kowalski, 1998, Haberl, 2001) look at the economy in terms of flows of energy and materials. This "metabolic" view of the economy has an intellectual foundation in some 19th century natural scientists. Economists did not adopt a socio-metabolic view. Only

much later, in the 1960s, a few dissident economists such as Georgescu-Roegen, Kenneth Boulding, K. W. Kapp, Herman Daly, started to see the economy as a subsystem embedded in a physical system described in terms of flows of materials and energy. Still later, schools of Ecological Economics and Industrial Ecology were established.

Marxist historiography has not done the accounts of material and energy flows, although Marx had shown much interest in the relations between the human economy and the environment, particularly as regards capitalist agriculture. This was expressed in the use in his own drafts after 1857-58 and in *Capital,* of the notion of "metabolism" (*Stoffwechsel*) between the economy and Nature. Marx's use of metabolism became well known with Alfred Schmidt's work that noted Moleschott's and Liebig's influence on Marx's discussion of the cycling of plant nutrients (Schmidt, 1978: 86-9). 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 one generation younger than the agricultural chemists (Liebig, 1803-73, Boussingault, 1802-87) who published from 1840 onwards their research on the cycles of plant nutrients (phosphorous, nitrogen, potassium), in the context of debates on decreasing agricultural yields. The analyses of the composition of guano, and of other manures and fertilizers already known to farmers, laid the foundations for agricultural chemistry. About 11 million tons of guano, an essential bulk commodity, was exported from Peru in four decades (Gootenberg, 1993). Liebig's name was associated by his own wish to a new sector of the economy, the fertilizer industry. He is also seen as a founder of Ecology before the name itself was invented (Kormondy, 1965). 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. Foster (2000), who rediscovered Marx's "metabolism", analyzed in depth Marx's debt to Liebig and other authors, and wrongly dismissed Moleshott's influence, not quoting his books (1850-52) on the "circle of life" and the physiology of metabolism in plants and animals.

So, Marx was a historian and economist, also a student of agricultural chemistry. He noticed that the metabolic flow of materials between human society and Nature was mobilized by human labour except in primitive gathering societies. Tool development by humans was essential for the metabolism. Marx does not seem to have considered the metabolic energy flow, so he could not trace the distinction (as Lotka was to do in 1911) between endosomatic use of energy in nutrition and the exosomatic use of energy by tools. Humans have genetic instructions regarding endosomatic energy use but not exosomatic energy use, very different between rich and poor, and which is explained by history, politics, economics, culture, technology. This difference between biometabolism and technometabolism is basic for human ecology.

Marx wrote to Engels on 13 February 1866 that Liebig's chemistry was more important than all the economists put together in order to dismiss the notion of decreasing returns in agriculture. Marx pointed out in the context of Liebig's analysis of 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. Marx attacked Malthus because Malthus believed in decreasing returns, and also because Malthus said that improving the situation of the poor was counterproductive because they would have more children. There were many debates around 1900 on "how many people could the Earth feed" (Pfaundler, 1902, Cohen, 1995). Some Marxists (Lenin, 1913) not only attacked Malthus, they also attacked the Neo-Malthusians of the late 19th century and early 20th century who were political radicals and feminists (Paul Robin, Emma Goldman) (Gordon, 1976, Ronsin, 1980, Masjuan, 2000).

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 implied changes in the flow of energy and not only in the cycling of plants nutrients (Mayer, 1845, used *Stoffwechsel* for energy flow). Metabolism was used not only for materials but also for energy (Haberl, 2001). Of course, materials could be cycled, energy could not. The theory of the direction of the flow of energy was developed after the Second Law was established in 1850.

Marx and Engels were keen on new sources of energy. One example will suffice: it was 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, it seems that Marx did never refer to the flow of energy as a part of metabolism (though some of his papers are still in course of publication). At a more general level, one intriguing point arises from Engels' unwillingness to accept that the

First and Second Laws could apply together: 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) 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 may sympathize with Engels' dislike for the use to which the Second Law was put. Josef Popper-Lynkeus (1838-1921), who was with Ernst Mach a major influence on the analytical, anti-metaphysical philosophy of the Vienna Circle, complained in 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 not only motivated by its religious use, or abuse. He thought (as other contemporary authors also did) that ways would be found to re-use the heat irradiated into space.

Another interesting point is Engels' negative reaction 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 to convince Marx that this could be brought into the Marxist analysis. Politically he was not a Marxist, he was a Ukrainian federalist narodnik. He complained of Marx's overpowering behaviour at the congress of the International of 1872, praising the anarchist James Guillaume. However, he himself saw his work on agricultural energetics as a contribution to Marxism. Writing to Marx on 8 April 1880, he said: "With particular impatience I wait for your opinion on my attempt to bring surplus labour and the current physical theories into harmony". In his article (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. He did not yet discuss the difference in thermodynamics between open, closed and isolated systems, although he stated explicitly, as the starting point of his analysis, that 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". He certainly realized that the availability of energy was a crucial consideration for the increase (or decrease) of population. However, 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 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.

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,

[1] S.A. Podolinsky, Trud cheloveka i ego otnoshenie k raspredeleniiu energii, *Slovo*, 4/5, 1880, 135-211. That is, Human labour and its relations to the distribution of energy. (A Spanish translation was 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).

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 a tailor, a shoemaker or a builder would also qualify, in his view, as productive work, since they afforded "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 agricultural energetics, remarking that only a tiny proportion of sun energy was assimilated by plants. Human work together with the work of animals directed by humans, were able to increase the availability of energy by agricultural activity. 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, for information on sources). He compared wheat agriculture and sown pastures with natural pastures and forests, concluding that production was 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. Taking forests 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*, not the food intake but the work done. He did not include solar radiation in the input of energy, because he was writing as an ecological economist. Solar radiation is indeed a free gift of Nature (so far without an owner, therefore without payment of rent). The conclusion was that work could increase the "accumulation of energy on earth".

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.

Although he mentioned guano, and must have been keenly aware of the war then raging for Peruvian or Chilean saltpetre (another early bulk commodity), 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 was nevertheless basically the same as that used later for establishing the energy balance of particular crops, or small scale societies, or the entire agricultural sector of particular countries (Cottrell, 1955, Rappaport, 1967, Odum, 1971, Pimentel, 1973, 1979, Leach, 1975, 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 and Helmholtz, 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. He then used a steam-engine metaphor to put across a general theoretical principle on the minimum natural conditions of human existence, from an energy point of view. 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". 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 other energy needs apart from food energy, the necessary minimum productivity would be more like ten or more. If that minimum is not achieved, then of course "scarcity appears and, many times, a reduction of population". Podolinsky then established the view of the economy in terms of energy metabolism, looking at the energy return to energy input in a framework of reproduction of the social system. 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 emphasized the difference between using the flow of solar energy and the stock of coal energy. 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 primitive farmer could obtain, but this energy surplus from coal was transitory, and moreover (he added in a footnote) there was a theory which linked climatic changes to concentrations of carbon dioxide in the atmosphere, as Sterry Hunt had explained at a meeting of the British Society for the Advancement of Science in the autumn of 1878. Notice here the emphasis, not on capital accumulation in the sense of an increased stock of produced means of production or even less in financial terms, but on increasing the availability of energy (and certainly also its dissipation). This is an early example of "non-equivalent descriptions", in economic and energy terms, of the same economic reality (Giampietro, 2003).

Podolinsky was not, however, pessimistic about the prospects for the economy. 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 relation between the general quantity of energy on earth and the quantity of people who live on it, and this was a more relevant view than the Malthusian prognosis.

Podolinsky's work and life have an entity of their own, apart from his brief encounters with Marx and Engels. He is relevant today for ecological economics because he wrote one of the first studies of the socio-metabolic flow of energy. Trained as a medical doctor and physiologist, he had a short life but left a strong trace in Ukrainian federalist politics (as a friend of Drahomanov) and also in the Narodnik movements against the Russian autocracy (as a young colleague of Piotr Lavrov though with close friends in the Narodnaya Volya group). His work on energy and the economy was praised by Vernadsky in a section of *La Géochimie* (1924). Several authors (Felix Auerbach with his notion of *Ektropismus*, John Joly) had explained life as a process which reversed the dissipation of energy. Vernadsky 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 the development of human culture, in the form of "social energetics" (without historical statistics), became well established and debated in Europe 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 line of Marxist history based on quantitative studies of material and energy flows, emphasizing unequal ecological distribution.

Otto Neurath's Naturalrechnung

In my 1987 book with Klaus Schlüpmann, the relations between Marxism and ecological economics were discussed mainly by looking at Engels' negative reaction to Podolinsky's agricultural energetics. We also called attention to Otto Neurath's ecological contribution to the Socialist Calculation debate of 1919 and following years, already acknowledged by K. W. Kapp. Otto Neurath (1882-1945) was a famous analytical philosopher of the Vienna Circle, he was also an economist or economic historian, and a Marxist in at least two senses. First, in the Socialist Calculation debate he defended a democratically planned economy based on accounting in energy and material terms (*Naturalrechnung*) following Popper-Lynkeus' and Ballod-Atlanticus' quantitative, realistic "utopias". He introduced the idea of incommensurable values in the economy (Martinez-Alier with Schlüpmann, 1987, O'Neill, 1993, Martinez-Alier, Munda and O'Neill, 1998, O'Neill, 2002, 2004, Uebel, 2005). Second, some years later, in the context of the Vienna Circle' project of the Encyclopedia of Unified Science, Neurath defended a dialectical view of history (although he did not like the word "dialectics") as the putting together of 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 findings of another science also present in the Encyclopedia, and leave things at that. Removal of the contradiction should be attempted. To use Edward Wilson's later word, "consilience" should be the rule of the Encyclopedia.

To grasp Otto Neurath's relevance, one must realize that Hayek's strong critique of "social engineering" (Hayek, 1952) was directed, as John O'Neill has put it, not only against past thinkers like Saint-Simon but also against the tradition, now called ecological economics, "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". While Patrick Geddes, Wilhelm Ostwald, Lancelot Hogben, Frederick Soddy and Lewis Mumford were all rudely dismissed by Hayek (because they saw the economy in terms of the metabolic flow), Neurath's *Naturalrechnung* and planning were Hayek's main targets.

One is also reminded of Max Weber's comments against Neurath in *Economy and Society*, and even more of Weber's critique of Wilhelm Ostwald in 1909. Ostwald (a well known chemist) interpreted human history in terms of the use of energy, influencing authors such as Henry Adams (1838-1918) who plausibly believed there was a "law of acceleration" of the use of (final) 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". A hundred years later, research shows the close relation between economic growth and the use of energy (or rather "physical work output as distinguished from energy (exergy))" (Ayres and Warr, 2003).

Ostwald proposed two simple laws that 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 particular technologies and processes. 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. This review was praised by Hayek in the 1940s (Hayek, 1979, 171). Max Weber's basic point (Martinez-Alier with Schlüpmann, 1987, chapter 12) was that entrepreneurs' decisions on new technologies or new products were based on costs and 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. Notice that Max Weber in 1909 did not question energy prices as we do now by taking into account the enhanced greenhouse effect and other externalities, and by questioning the intergenerational allocation of exhaustible resources.

Social Metabolism today

In the 1970s, the economy started to be studied from a physical point of view by coherent research groups. Histories of the use of energy in the economy were written (Cipolla,1962, Sieferle, 1982, Debeir, Deléage, Hémery,1986, Hall, Cleveland, Kaufman, 1986). Other authors later added the use of materials and water, and looked historically at the human influence on the carbon cycle and other biogeochemical cycles (McNeill, 2000). "Metabolic profiles" of countries or regions are today established by the statistics provided by MEFA (Material and Energy Flow Accounting) and HANPP (Human Appropriation of Net Primary Production). The level of economic development, the geography of each country or region, the population density, the external commercial relations, the changing technologies and environmental regulations explain the specific "metabolic profiles". There are links between each society's metabolic profile and the ecological conflicts at different scales (local, regional and national, international).

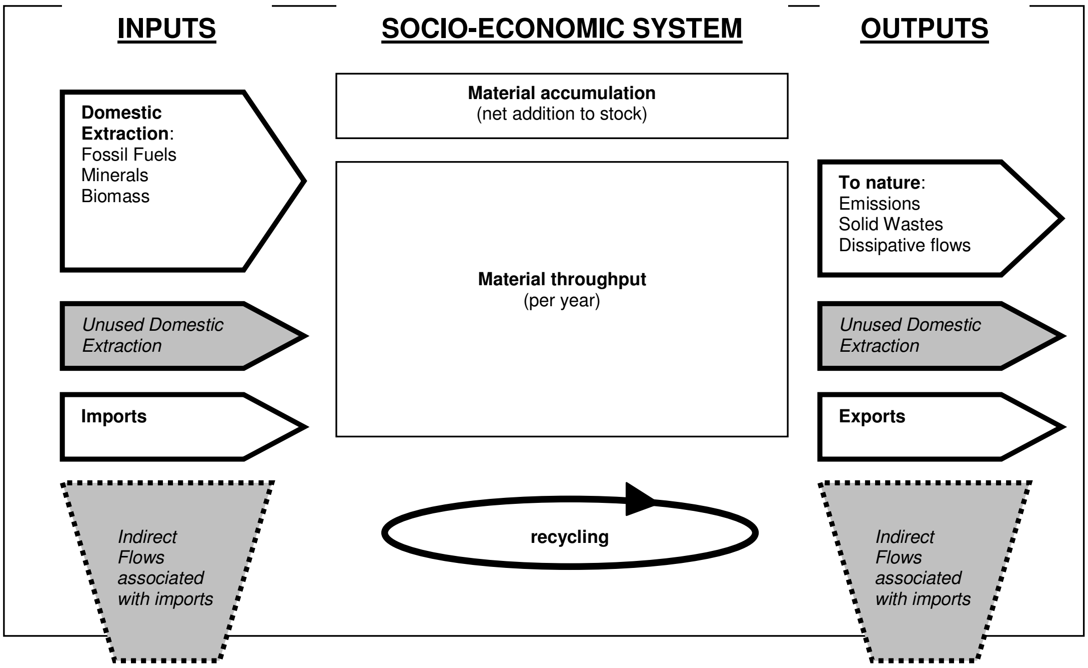
The relations between energy and the economy have been much discussed, and they are more relevant than ever as we anticipate the patterns of economic growth of India, China and other countries, their effects on the prices of oil and gas, the increased use of biomass as fuel by humans to the detriment of other species, the immediacy of "peak oil" and the increased use of coal and its effects on the greenhouse effect, the growth of nuclear power. At world level there has *not* been a breakthrough in energy systems, all

sources go up (Mc Neill, 2000). Biomass energy (as food and feedstuffs, fuelwood), must have increased over four times in the 20th century, coal increased six times, oil increased many times more. The notion of energy return on energy input (EROI) was applied in the 1970s to the economy by Charles Hall and other ecologists (Odum, 1971), that is, the energy costs of obtaining energy (in different systems: wind energy, tar sands ...), asking about its implications for the economy. Thus, one may question the use of biomass as fuel when it comes from agricultural systems increasingly inefficient in terms of energy.

Research on Material Flows has made much progress. Eurostat statistics for European countries follow an agreed methodology developed through discussions between the Wuppertal Institut and the Sozial Oekologie group at the IFF, Vienna (Brigenzu and Schütz, 2001, EUROSTAT, 2001, Adriansee et al. 1997, Matthews et al, 2000). In this framework, a complete balance of an economy can be carried out by taking into account what crosses the system's boundaries. The net accumulation of materials in a system can be calculated as the difference between what enters (inputs) the system and what goes out (outputs). According to the Eurostat classification, material flows can be domestic, if extracted from the system, or RoW, if coming from the Rest of the World. RoW material flows can be direct or indirect. The former enter directly into the system while the latter are linked to the production of goods, even though not exchanged in the market. Both direct domestic and RoW material flows can be used and unused. The latter represent materials extracted or discarded during the production of a good, i.e. mining overburden, while the term "used" refers to an input for use in the economy. Indirect flows increase the comprehensiveness of the analysis but they also increase its arbitrariness. This is because indirect flows are calculated by multiplying direct flows by standard coefficients. However, in reality they vary considerably.

In the Eurostat methodology, material flows are classified into three main material groups (minerals, energy and biomass) and into three main categories (imports, exports and domestic extraction), which are used to structure the indicators calculated. (Fig. 1). Part of the waste produced by economies is recycled outside markets by natural cycles. A small part is recycled by markets (some paper, metals).

Figure 1. Economy-wide material balance (excluding air and water)

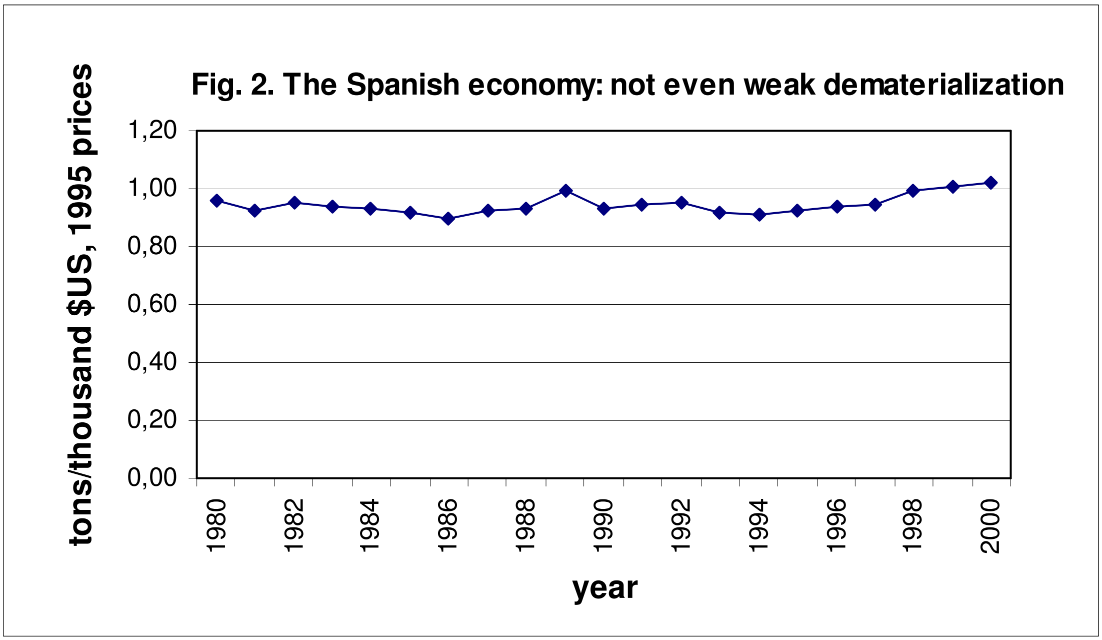


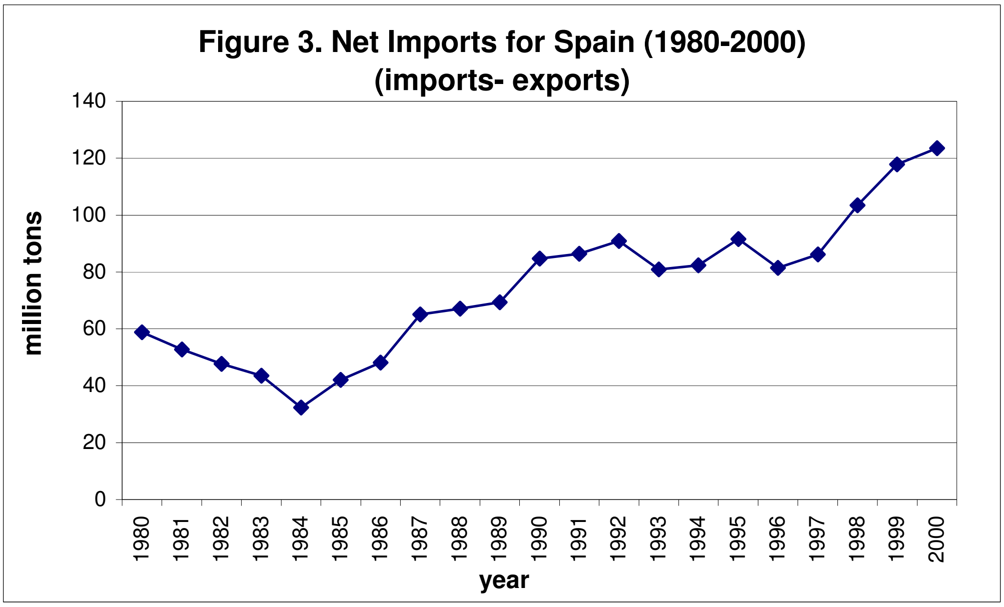
These are accounting definitions:

- Domestic Extraction: materials extracted in the national territory per year.
- Direct Material Input (DMI): Domestic Extraction (DE) plus Direct Material Imports (I) (DMI=DE+I).
- Domestic Material Consumption (DMC*):* DMI minus Direct Material Exports (E) (DMC=DMI-E=DE+I-E).

Further disaggregation of the metabolic flows (fossil fuels, biomass, metal ores, building materials) could be done, and try to link them up to concrete ecological conflicts and remedial measures. Material flow accounting can be also used to test different aspects of the Environmental Kuznets Curve hypothesis. Does the EKC apply to biomass, does it apply to different fossil fuels, and therefore to different sources of carbon emissions? In fact, the dematerialization hypothesis can be seen as a different formulation of the EKC.

Taking, for instance, the MFA of Spain between 1980 and 2000 (Cañellas et al, 2000), the conclusion is reached that Spain's nice trend towards convergence of per capita income within the European Union is matched by its "race to the top" in terms of materials (Fig. 2 and 3). The materials moved by the Spanish economy (i.e. DMI = domestic extraction plus direct material imports) increased by 85% from 1980 to 2000, whereas GDP increased by 74%. While in other European countries there has been relative dematerialization (i.e. increased resource productivity), Spain followed still a trend typical of developing economies. Second, in Spain domestic extraction (DE), domestic consumption (DMC) and domestic material input (DMI) have evolved in line with the economic cycles. Again, there is no evidence of a decoupling trend. The growth of building materials is remarkable as also the increase in energy-carrying materials (despite the decline of domestic coal extraction). The importance of the building sector is also reflected in the very rapid rates of *soil sealing* in some regions of Spain. (Soil sealing is also relevant for the calculation of HANPP). Third, the Spanish economy has become increasingly dependent on international trade. Imports double exports in terms of weight. In other words, Spain is displacing environmental loads to poorer countries. Imports of biomass and particularly of energy-carriers have increased. Also, metals that were domestically produced are now imported.





The increase in internal and external material flows is likely to cause environmental impacts during extraction, transport, or waste disposal. Thus, in Spain conflicts arise on quarrying or on transport infrastructures, while in other countries there are conflicts on oil extraction (Ecuador), coal mining (China) or hydroelectricity exports (Laos). Some regions of China are getting locked into technological and consumption patterns (based on fossil fuels) similar those of the rich countries. Many developing economies are primary exporters, European metabolic profiles cannot be understood apart from our relations with them. This also applies to Japan whose metabolic profile is very different from Indonesia or other primary exporting countries. The United States reached in the 1970s the Hubbert curve domestic peak. Oil imports are now over 10 mbd, i.e. 500 million tons or 2 tons per person per year, more than half the oil it consumes. Hence, geopolitical worries on the security of oil sources, and military interventions. For comparison, DMI in very poor countries (biomass and all other materials) is only 3 tons per person/year.

Metabolic profiles must be characterized both in terms of material flows and in terms of energy flows. Both are needed, fossil fuels and biomass will show up in the material and energy statistics, but nuclear energy and hydroelectricity are not included in the material flows. The HANPP, on its side, uses biomass statistics (which can be counted also as energy or materials). HANPP also incorporates land-use data on soil sealed that does not produce biomass. In contrast to Material Flows, the HANPP is not yet an official statistic. It is calculated in three steps. First, the potential net primary production (in the natural ecosystems of a given region or country), NPP, is calculated. Then we calculate the actual net primary production (normally, less than potential NPP, because of agricultural simplification, soil sealing), and then we calculate which part of actual NPP is used by humans and associate beings (cattle, etc.): this is the HANPP. In terrestrial ecosystems, the ratio between HANPP and potential NPP seems to be around 40% worldwide, but of course this is indeed a rough figure. The HANPP is meant to be an index of loss of biodiversity (because the higher the HANPP, less biomass available for "wild" species). This assumed relation is itself a topic for research. Results for Austria are presented in Kraussman et al, 2003, and Haberl et al, 2003. The EKC for HANPP could also be researched. Another research objective should be the modelling of the relations between such variables (Haberl et al, 2004, Krausmann et al 2004). For instance, an increase in the use in India of fossil fuels for cooking (kerosene or LPG) might lead to a slight decrease in HANPP, and therefore, to less pressure on wild biodiversity (so that kerosene and LPG would be good for the tigers). On the contrary, use of more biomass instead of fossil fuels, reduces net emissions of carbon dioxide, but increases HANPP. This would happen even more with the use of biomass for bio-diesel or ethanol.

Finally, water is a topic by itself. Water enters in social metabolism in large quantities (100 times more in terms of weight than the MF). Consider for instance the dumping of waste into water, the exhaustion or pollution of aquifers, the energy and environmental impacts of new large desalination projects. There is also a new discussion on "virtual water" (i.e. the water "cost" of different products). In the present article, water is left aside. [2] In Material Flow Accounting water and air are excluded.

Metabolic profiles and Environmental conflicts

Political Ecology has been defined as the study of ecological distribution conflicts, i.e. conflicts on the access to natural resources and services and on the burdens of pollution. Externalities are not so much market failures as cost-shifting successes. The names of conflicts come from authors who study them, or have arisen from the NGO world. Take a name like "biopiracy" - the fact is old; a new insulting name reveals now a sense of injustice. By looking at the metabolic view of the economy, ecological conflicts may be

[2] **Hoekstra, A.Y. and P.Q. Hung (2002),** ***Virtual water trade: a quantification of virtual water flows between nations in relation to international crop trade*****. Value of Water Research Report Series n. 11, UNESCO-IHE, Delft. See: www.waterfootprint.org**

classified according to the different points in the "commodity chains" where they occur, whether at the point of materials and energy extraction, or in manufacture and transport, or finally in waste disposal. Given space limits, only a few cases can be mentioned here.

Conflicts on the extraction of materials and energy

1.- Mining and Oil extraction conflicts. Complaints over mines and smelters because of water and air pollution, and land occupation by open-cast mining and slag. (Many such conflicts are historical, e.g. Ashio in Japan or Rio Tinto in Southern Spain c. 1900). Also, conflicts on oil and gas extraction. (Networks active in 2004: Mines and Communities / Oilwatch). For instance, in the growing economy of India, there are conflicts on the mining of coal, iron ore, uranium, bauxite located mainly in Orissa and Jharkhand (*Down to Earth,* 15 April 2005, 26-35) by national public or private companies but also by transnational companies (e.g. the Alcan and Vedanta current projects in Orissa). There are also conflicts on the extraction of building materials (including killing of revenue officials who try to stop the quarrying of sand by "sand mafias" in Tamil Nadu, *The Hindu*, 17 Dec. 2004).

2.- Biopiracy. The appropriation of genetic resources ("wild" or agricultural) without adequate payment or recognition of peasant or indigenous ownership over them (including the extreme case of the Human Genome project). This word was introduced by Pat Mooney, of RAFI, c. 1993.

3.- Land Degradation. Soil erosion caused by unequal land distribution, or by pressure of export production. Blaikie and Brookfield (1987) introduced the crucial distinction between pressure of population and pressure of production on the sustainable use of land.

4.- Plantations are not Forests (Carrere and Lohman, 1996). All around the world, some social groups complain against eucalyptus, pine, acacia plantations for wood or paper pulp or cellulose production (often exported). (www.wrm.org.uy). There is a link between the uses of the biomass material flows and the growth of such conflicts (like the conflict on the Spanish ENCE cellulose plants in Uruguay in 2005).

5.- Mangroves vs shrimp. The movement to preserve the mangroves for livelihood, against the shrimp export industry, in Thailand, Honduras, Ecuador, Brazil, India, Philippines, Bangladesh, Sri Lanka, Indonesia... (See the Environmental Justice Foundation's reports, London, www.ejfoundation.org).

6.- National / local fishing rights. Other forms of use of biomass give rise to other conflicts. Thus, there are national and local fishing conflicts. Hence the attempts to stop open access depredation by imposing (since the 1940s in Peru, Ecuador, Chile) exclusive fishing areas. The language here is international public law. Another conflict is that of the defence (or introduction) of local communitarian fishing rights against industrial fishing (as in coastal India, or the lower Amazon).

7.- Water conflicts (Mc Cully, 1996, Khagram, 2005). For instance, in India the movements against large dams for hydroelectricity or irrigation, such as the Narmada Bachao Andolan, also new conflicts, as in Pulichintala (Andhra Pradesh) or in the North-East, and complaints against the project of "interlinking of the rivers". Also, conflicts on the use and pollution of aquifers (of which the Plachimada conflict in Kerala between farmers and the Coca-Cola company became world famous). In Brazil there is an organized movement of

atingidos por barragens. In 2005 a successful civic resistance movement stopped water transfer from the Sao Francisco river. (See www.irn.org).

Conflicts on transport

8.- Complaints over oil spills from tankers or pipelines, over new motorways, harbours and airports, also over "hidrovías" (such as Paraguay-Paraná). E.g., the Sethusamundram Ship Canal Project between Tamil Nadu and Sri Lanka that will shorten navigation time between the east and west coasts of India, but constitutes a threat to the local fisheries because of dredging. Physical indicators for transport (tons-km) grow faster than GDP, and than the material and energy throughput in the economy. New conflicts arise all the time such as that in Val di Susa in late 2005 against a new train line from Turin to Lyon (part of a wider European network) that would destroy a beautiful mountain landscape.

Conflicts on waste and pollution

9.- Toxic struggles. A name given in the U.S. to fights against risks from heavy metals, dioxins (Gibbs, 1981, Hofrichter, 1993). It describes also older cases in other countries, such as Minamata mercury poisoning in Kumamoto Prefecture in Japan caused by the chemical manufacturer Chisso Corporation in the 1950s and 1960s; complaints continue to be put forward still today.

10.- Waste dumping. In an international context, *Toxic imperialism* was used by Greenpeace in 1988 to describe the dumping of waste in poorer countries. For instance, the ship breaking yards at Alang in Gujarat have a devastating environmental impact, a situation highlighted by the debate in 2005 on a toxic Danish ship sent there. The Danish authorities themselves tried to call her back (*Down to Earth*, 31 May 2005, 16-17). Or, for instance, "thousands of tonnes of electronic and electrical waste (e-waste) are being illegally exported every year from Britain to developing Asian countries, including India, Pakistan, and China" ("The trade is absolutely illegal and against the spirit of the Basel Convention, said Kishore Wanhade of Toxics Link in Delhi". *The Hindu*, 18 Dec. 2004).

11.- Transboundary pollution. Applied in the 1970s and 1980s mainly to sulphur dioxide crossing borders in Europe, and producing acid rain. Also between areas in the U.S. A. (New England polluted by western winds), and from China to Japan.

12.- Equal rights to carbon sinks. The proposal for equal per capita use of oceans, new vegetation, soils and atmosphere as sinks or temporary reservoirs for carbon dioxide (Agarwal and Narain, 1991). The disproportionate emissions of carbon dioxide have given rise to a "carbon debt" (www.deudaecologica.org), as Andrew Simms calls it.

13.- Consumers' and citizens' safety. Struggles over the definition and the burden of uncertain risks from new technologies (nuclear, GMO, etc.). They also affect producers (agro-toxics). Some conflicts are new (BSE), others are old when regulatory authorities failed to apply what is now called the "precautionary principle". [3] Ulrich Beck (1992) focused on surprises (such as Chernobyl) more than on old technological conflicts (asbestos, DDT, CFC...) or on trends of metabolic flows (e.g. increased fossil fuels use). In China and India, the debate on nuclear safety will perhaps grow given the growth of nuclear power. (There is mistrust of breeder reactors both in Europe, where Creys-Malville

[3] See the report by the European Environment Agency, *Late lessons from early warnings*, 2003 (available in the web, published also by Earthscan, London).

was closed, and in Japan, where the Monju project in Fukui Prefecture was stopped by the courts. Meanwhile, the building start of the Kalpakkam breeder reactor near Pondicherry in 2005 was celebrated with such fanfare that it seems the main temple of modern India).

All such conflicts use different vocabularies. Thus, resource extraction fights often deploy the language of *indigenous environmentalism*, that it, the use of territorial rights and ethnic resistance against external exploitation. Convention 169 of ILO might be used in such cases (as in June 2005 against gold mining in Sipacapa, Guatemala), or in India the protection of adivasi peoples by the Constitution and by court decisions (Samata, 2003, Das, 2003). The language of *human rights* is also used since livelihoods might be threatened. Waste disposal and pollution threats have given rise to the language of *Environmental racism* in the United States, meaning the disproportionate environmental burden in areas mainly inhabited by African Americans, Latinos, Native Americans. *Environmental Justice* is the movement against environmental racism. Uncertainties on the causes of illness have given rise to *popular epidemiology.* Environmental "blackmail" has been used in situations where either LULU (locally unacceptable land use) is finally accepted, or the local population stays without jobs. The notion of Environmental Justice is also used in South Africa and in Brazil (and in Scotland where poor communities are adversely affected by open cast coal mining or by waste dumps, like in Greengairs). (Bullard, 1993, Bond, 2002, Dunion, 2003, Acselrad et al, 2004). Movements for environmental justice may become a strong force for sustainability.

The metabolic perspective makes visible the ecological contents in social conflicts which were "disguised" under different headings, e.g. *workers' actions for occupational health and safety* are struggles (in the framework of collective bargaining or outside it) to prevent damages to workers in mines, plantations or factories (they are, so to speak, "red" outside and "green" inside). Also, *urban activism for clean air and water, green spaces, cyclists and pedestrian rights* has inspired old or new struggles outside the market in order to improve environmental conditions of livelihood or to gain access to recreational amenities in urban contexts. Such actions have long expressed ecological conflicts even though the actors (and their analysts) did not yet use an explicitly environmental vocabulary.

Ecological conflicts also give rise to what Bina Agarwal (1992) called *social ecofeminism* or *environmental feminism*, meaning the environmental activism of women, motivated by their social situation. The idiom of such struggles is not necessarily that of feminism and/or environmentalism. Finally, the *Environmentalism of the Poor* describes social conflicts with an ecological content, today and in history, of the poor against the relatively rich, not only but mainly in rural contexts. (Guha, 1989, Guha and Martinez-Alier, 1997).

Politics of Identity or Structural Conflicts?

The defence of indigenous groups against oil extraction or mining, or against large dams or logging, and the Environmental Justice movement in the United States insofar as it fights against "environmental racism", could be interpreted in terms of a *politics of identity*. This is mistaken, as will be argued here. There are cross-cultural similarities in resistance movements. In the fights around the world for biomass and against the private appropriation of common property lands, the eucalyptus or other undesired plantation trees are pulled out, and other locally useful trees are put it. Another instance (Martinez-Alier, 2005): in July 1998 I took part as a sympathetic observer in an action by Greenpeace together with Fundecol (a local grassroots group of about 300 people in Muisne, Ecuador), in destroying at sunrise one crop of shrimps from an illegal pond by opening a hole in one wall, letting the water flow out, and replanting mangrove seedlings. The presence of the Rainbow Warrior's motley crew gave moral strength to the local group but both the destruction of that particular pond, and the replanting, were ideas proposed earlier by Fundecol. In December 2003 I travelled in Orissa and Tamil Nadu. I got an update on the conflict on shrimp farming in Chilika Lake when I read that the traditional fishermen (200,000) opposed a bill that would give rights to other groups practicing "improved traditional" methods of fishing. Under those adjectives, "improved traditional" (taken from the Supreme Court's decision of 11 December 1996), they feared prawn culture was lurking. The Orissa government withdrew the bill holding it for public consultation, after 10,000 fishermen of the Chilika Matysajivi Mahasangh camped for some days in Bhubaneswar (Debrata Mohanty, "Chilika bill in troubled waters", *The Telegraph*, 22/12/03). Further south, in Killai (Cuddalore District) in Tamil Nadu, where about 8000 families made a living by fishing and agriculture, and where there were about 60 shrimp farms in 750 acres of cultivable *patta* and *poramboke* land, there was water pollution from the shrimp farms. As in Ecuador, so in Tamil Nadu. The proposal arose of breaking open the bunds of the shrimp farms. On 18 September 2003 at midnight, the shutters were opened. The following morning the police arrested 92 fishermen including 32 women, and charged them with criminal offences. The Campaign against the Shrimp Industries (CASI) declared that since "all the arrested persons are victims of destructive shrimp industries, and the enforcement authorities [foreseen in the Supreme Court's decision of 1996] have failed to protect the resources of the people… it is the duty of the state to withdraw all the criminal proceedings" (CASI, 2004, pp. 41, 52-64). Table 2 offers a tentative classification of ecological conflicts, depending on their geographical location and the stage of the commodity chains when they occur. Local movements reinforce the regional or global networks, and in turn they profit by adding the language and the strength of global environmentalism to their own local resistance.

Table 2. A tentative classification of some ecological distribution conflicts

Geographical scope ---------------- *Stage*	Local	National and Regional	Global
Extraction	E.g. resource conflicts in tribal areas, such as bauxite mining in Kashipur, Orissa	Mangrove uprooting. Tree planting for export. Collapses of fisheries.	Worldwide search for minerals and fossil fuels, and bio-piracy by TNCs. Regulation of "corporate accountability".
Transport and Trade	Complaints on urban motorways because of noise, pollution, landscape loss.	Inter-basin water transport. Oil/gas pipelines (e.g. Burma to Thailand)	Oil spills at sea. Also, "ecologically unequal exchange" because of large South to North material flows.
Waste and pollution, post-consumption	Conflicts on incinerators (dioxins) in urban areas.	Acid rain from sulphur dioxide. Nuclear waste, at Yucca Mountain, Nevada, USA.	CO_2, CFC as causes of climate change/ ozone layer destruction. POPs even in remote pristine areas. Claims for a "carbon debt".

Thus, in the Pacific Coast of South America movements in favour of mangroves insist on their role as coastline defence confronted with recurrent Niños plus the risk of greenhouse sea level rise. The same environmental service (coastal protection not against El Niño here, but against cycloons) is mentioned in Bangladesh, Thailand, India, Sri Lanka, particularly after the 2004 Tsunami. Other conflicts seem to arise in the first instance because of the external global influence - witness the use of the language of biopiracy in conflicts over property rights on *ayahuasca, uña de gato, sangre de drago, quinua*, and also basmati rice, neem, turmeric, in Latin America and in India. On the other hand, Oilwatch groups complain against local impacts of oil extraction (in Amazonian Ecuador or Peru, in the Niger Delta), they also point out that more oil extraction means more carbon dioxide emissions. Stopping oil production is some wells (as they have sometimes done), and a moratorium on oil extraction in fragile areas, would make a global contribution against climate change, deserving "carbon credits". Thus, Oilwatch, born from local conflicts between oil companies and local populations, has learnt to use global "greenhouse" arguments against oil extraction. Therefore, to see ecological conflicts as a manifestation of the politics of identity is not convincing. It is rather the other way around, identity politics being one idiom in which ecological distribution conflicts are expressed.

Ecologically unequal exchange

The trade pattern consisting in specialization in the export of raw materials has given rise to the notion of *Ecologically Unequal Exchange*, one of the global conflicts in Table 2. This is defined as importing products from poor countries or regions, at prices which do not take into account resource exhaustion and the local externalities. Attempts to set up "fair trade" chains for some commodities (such as coffee) signal a growing awareness that trade is often unfair. Such plunder economy was called *Raubwirtschaft* by German and French geographers one hundred years ago, denoting an environmental conflict.[4]

Patrick Geddes (1854-1932), a biologist and urban planner, attacked neoclassical economists such as Walras because they did not count flows of energy, materials and waste (Martinez-Alier with Schlüpmann, 1987, chapter 6). Geddes (1884) built a sort of input-output table inspired by the *Tableau Economique* of the Physiocrat François Quesnay, which is relevant to the attempt today to develop a theory of ecologically unequal exchange between the metropolitan centres and the world peripheries. The first column would contain the sources of energy as well as the sources of materials which are used, not for their potential energy, but for their other properties. Energy and materials were transformed into products through three stages, extraction, manufacture, 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 neoclassical economics, provided that markets are competitive, there cannot be unequal exchange. This could only arise from monopoly or monopsony conditions, or because of non-internalized externalities (or excessive discounting of the future). 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

[4] Geographers have long worried about the human role in changing the face of the Earth, Thomas et al. 1956.

higher the prices of these products or services will have to be (Hornborg, 1998, Naredo and Valero, 1999, Naredo, 2001). This was indeed implied by Geddes with different words. Thus, Hornborg concludes, "market prices are the means by which world system centres extract exergy from the peripheries".

At the beginning of European colonization, the goods imported were what Immanuel Wallerstein called "preciosities". For instance, silver and pepper. The means of transport at the time made bulky trade impossible. Indeed, preciosities (high chrematistic value per kilogram) are still traded: gold, diamonds. The effects on the ecology and livelihoods in the exporting countries might be terrible (as in Sierra Leone) but such trade is marginal to the metabolism of the importing countries. Consider the heavy local ecological impacts of exports of ivory or tiger body parts, compared to the irrelevance of such trade for the importing countries' metabolism. Preciosities may be crucial for the relations and social rituals of some groups, as gold is in India. However, the impacts of gold extraction will be felt in distant localities, not in the importing countries or regions. Gold is like shrimp, in this regard. Sugar was initially a preciosity, based on the slave trade. It became a bulk commodity playing a great role (as Sidney Mintz showed) in the biometabolism of the English working class. Other bulk commodities (such as guano) became decisive in the techno-metabolism of the importing countries. In this sense, Europe is now far more colonial than it ever was. Gas stations in central Europe could have signs reading "Kolonialwaren". In the 19th and early 20th centuries, the countries of today's European Union largely depended on their own coal and biomass as energy sources, now the European Union is a large net importer of oil and gas. Taking all materials together (energy carriers, minerals, metals, biomass), the European Union is importing about four times more tons than it is exporting. Meanwhile, Latin America appears to be exporting six times more tons than it imports (Giljum and Eisenmenger, 2004). Moreover, Southern exports carry heavier "ecological rucksacks" than the imports. This is shown by research on the energy and carbon-intensity of Brazil's trade, i.e. the energy dissipated and the carbon dioxide produced by each dollar of exports and of imports (Machado et al, 2001), and by research on the "environmental pollution terms of trade" for several metals (Muradian et al, 2002). Pengue (2005) has computed the hidden flows in the soybean trade of Argentina in the form of loss of nutrients (this would have pleased Liebig and Marx), the soil erosion, and the "virtual water". Will Argentina and Brazil become not only soybean exporters but also large fuel-biomass exporters?

Pérez-Rincón (in press) gives figures for Colombia of 70 million tons of exports per year compared to 10 million tons of imports. Prebisch's approach in the 1950s and 1960s (at the UN Economic Commission for Latin America) was based on the notion that there was an international historical division between *peripheral* countries specialized in exporting primary goods and *centre* countries that exported industrial goods. This specialization fixed the role that peripheral regions fulfill in terms of the resources they extract to satisfy the requirements of the centre. The theory on the deterioration of terms of trade in developing countries was formulated in parallel by Prebisch (1949) and Singer (1950). Now, the Centre-Periphery division does not only involve the monetary exchange of goods, it also involves the physical exchange in which Southern regions provide materials and energy so that the North can maintain and develop its socioeconomic metabolism. The metabolic aspects were not yet considered by Prebisch. An "ecological Prebisch" would propose new economic instruments such as "natural capital depletion taxes". However, some developing countries are not net physical exporters: India and China are probably net importers (because of oil imports). Internally, some regions in India and

China provide coal and other minerals. India exports much iron but also exports outsourced services. Also, some rich countries are net resource-exporters (Canada, Australia), they have low populations and high material flows and energy use per capita. So far they have successfully followed the path of Harold Innis' "staple theory of growth". This is not the case of Latin America, Africa, Indonesia. Whatever the historically changing positions of different countries, the metabolic processes that maintain the world system centres are guaranteed by ecologically unequal exchange, deteriorating terms of trade for natural resources, and sometimes by military power. The deterioration of terms of trade means that an increasing quantity of primary exports is needed to obtain the same amount of imported goods. Marxists pointed out that exports from poor countries were often more intensive in human labour than imports, so that there was an unequal exchange in terms of labour (Emmanuel, 1972). Environmental aspects must also be considered.

When exports of raw materials are produced by Transnational Corporations, there is often a demand for *Corporate Accountability*. This desire to make companies pay for their socio-environmental liabilities is shown by the court cases over the last twenty years under the ATCA legislation (Alien Tort Claims Act), against Chevron-Texaco, Freeport McMoRan, Southern Peru Copper Corporation, Dow Chemical and other companies, claiming compensation for damages caused in poor countries. For instance, Indonesian authorities were reported to be going ahead with a criminal law suit (in Indonesian courts) against the world's biggest gold producer, the Newmont Mining Corporation, for purposely disposing of poisonous material into the water in Buyat Bay on Sulawesi island, damaging the health of the inhabitants (*International Herald Tribune*, 3 Dec. 2004). One such case was settled out of court in 2004, when Unocal agreed to pay compensation in a human rights court case in California brought by Myanmar (Burma) villagers and Earth Rights International against the oil company concerning the Yadana gas pipeline to Thailand. Lack of corporate accountability also exists in the case of Bhopal from 1984 to today.

There is also a claim for repayment of the so-called *Ecological Debt* from North to South, bringing together the "carbon debt", i.e. damages from rich countries on account of past and present excessive emissions of carbon dioxide, and claims because of biopiracy and ecologically unequal exchange. Another term used in the context of international inequalities is that of *Environmental space* meaning the geographical space really occupied by an economy, taking into account imports of natural resources and disposal of emissions. *Ecological footprint* is a similar notion. It thrives as a political instrument. The *ecological footprint* adds up the per capita use of food and other biomass, plus fossil fuels, plus the built environment, translating everything into space). It has much merit as a communication device, but it will not make it to the level of official statistics because the "ecological footprint" contains information that largely duplicates the energy (food, biomass and fossil fuels) statistics. It is presented in attractive spatial terms that explain its success (Wackernagel and Rees, 1995). Finally, the opposition between *Ecological trespassers* and *Ecosystem peoples* signals the contrast between people living from their own resources, and people living from the resources of other territories and peoples. This idea from Dasman was applied in India by M. Gadgil and R. Guha (1995) to three categories of people: "omnivorous", "ecosystem peoples" and "ecological refugees".

Conclusions: Linking Political Economy and Ecological Economics

The environment is not one more sector of the economy, in the sense that we talk about the economics of agriculture or the economics of transport. The economy is embedded in the environment, it is a system open to the entry of energy and materials, and to the exit of waste (e.g. carbon dioxide). The metabolic perspective implies that capital accumulation does not take place by itself, and it is not only based on the exploitation of labour and technical change. Capitalism (or, in general, the industrial system) advances into commodity frontiers because it uses more materials and energy, therefore it produces more waste, it undermines the conditions of livelihood and existence of peripheral peoples, who complain accordingly. Ecological distribution conflicts are more intense and visible, and they cannot be subsumed under the conflict between capital and labour. Economic growth, and population growth, lead towards increased use of materials and energy, and therefore towards larger production of waste. Because of unequal property rights, and social inequalities of power and income among humans (both international and internal to each state), the pollution burdens and the access to natural resources are unequally distributed.

The economy may be described in terms of economic indicators such as growth of GDP, savings ratio, budget deficit as percentage of GDP, current account balance in the external sector… Social factors may be taken into account, as in the Human Development Index (countries' ranking by the HDI is much the same as the ranking by GDP per capita). The economy may also be described in terms of physical indicators. Economic, social, and physical indicators are non-equivalent descriptions. An economy may be described in the following non-equivalent terms: it provides 260 GJ of energy per person/year, its HANPP is 35%, material flow amounts to 21 tons per person/year of which fossil fuels account for 6 tons. Of the material flows, 5 tons are imported, 1 ton is exported. Income per capita is 25,000 US$. Of another economy, we may say that it provides only 20 GJ person/year, its materials flow amounts to only 4 tons person/year, its HANPP is 70% (a heavily populated country, relying on biomass, with little external trade). Income per capita is 1,700 US$.

Different classes of people in such countries could be classified according to their metabolic profiles. We could study the different trends in the various components of the metabolic flows as the economy grows, and also discuss the influence of rural-urban migration, urbanization and globalization on the trends. The study of trends in metabolic flows will become a staple of environmental-economic history (Martinez-Alier and Schandl, 2002). What we cannot do, however, is to anticipate "surprises", whether good or bad (availability of fusion energy or the next large nuclear accident…).

If the economy was "dematerializing" in an absolute sense (and not only, as in some countries, relative to GDP), then many of the conflicts listed above would be less pervasive and intense. One example of the link between metabolic flows and socio-environmental conflicts, is the appropriation of the biomass of mangroves by the shrimp industry. Another instance: the amount of carbon dioxide produced by a country (and its use of the carbon sinks, and of the atmosphere as a temporary reservoir) is directly related to the inputs of different fossil fuels. Ecological Economics studies the relations between the economy and the use of materials and energy. Ecological Economics is relevant for Political Ecology for a second reason, namely, the conflicts regarding the use of the environment may be expressed in different languages of valuation. For instance, some social actors might say that mangrove destruction or climate change is after all an "externality" which can be made good and compensated by the economic value established in a fictitious market. Other actors will appeal instead to the livelihood and rights of local peoples, or to the sacredness of nature, or to ecological and landscape values measured in their own units, or to the equal dignity of all humans when confronted by "environmental racism". People who are poor and whose health and lives are cheap, often appeal to non-chrematistic languages of valuation. Who has then the power to simplify complexity by imposing a single language of valuation?

An Ecological Economics which is not money-reductionist but is open instead to value pluralism (perhaps operationalized through social multi-criteria evaluation) will therefore be able to cooperate with Political Ecology in the analysis of ecological distribution conflicts. The question is not whether economic value can only be determined in existing markets, inasmuch as economists have developed methods for the monetary valuation of environmental goods and services or of negative externalities outside the market. Rather, the question is: must all evaluations in a given conflict (e.g. on extraction of gold in Peru or bauxite in Orissa, on a hydel dam in the North-East of India, on the destruction of a mangrove in Bangladesh or Honduras to the benefit of shrimp exports, on the determination of the suitable level of carbon dioxide emissions by the European Union), be reduced to a single dimension? (Funtowicz and Ravetz, 1994). Ecological Economics in fact rejects such a simplification of complexity, favouring instead the acceptance of a plurality of incommensurable values.

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