

Chapter 11

Materials Flow Analysis in Latin America



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11.1 Introduction

Ecological economics (EE) incorporates the biophysical perspective into economic analysis through the concept of social metabolism, a term adopted from biology, extending the idea of the metabolic profile of living organisms to the functioning of economies and society (Ayres & Kneese, 1969; Ayres & Simonis, 1994; Fisher-Kowalski & Haberl, 2015; Infante-Amate et al., 2017). Material Flow Analysis (MFA) is one of the principal methods to study social metabolism by quantifying the economy in tons (Hák et al., 2012; Martínez-Alier, 2003). MFA is part of the satellite systems of natural resource accounts. It is used by industrial ecology and ecological economics to quantify the natural processes of extraction, exchange, and consumption of natural resources (Vallejo, 2015). In Europe, this method has been used academically and has also been included in official government statistics.

In Latin America and the Caribbean (LAC), material flow studies have been developed by researchers and academics without yet being incorporated into national statistical institutions. Some of the research has focused on the study of individual countries and others have made comparisons between countries in the region. However, a detailed inventory and evaluation of MFA-related academic production for LAC have not yet been carried out to identify its progress, scope, and limitations. This chapter has that purpose. Not only to learn about research

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developments in the region but also to see the influence of the “*Barcelona School*”¹ and that of Professor Joan Martínez-Alier in this field of work.

To achieve these objectives, a systematic and organized literature review was carried out using two search engines: *Google Scholar* and *Scopus*. Literature was searched for in Spanish, Portuguese, and English, using as search words Material Flow Analysis and Material Flow Accounting. These were filtered with the word Latin America and the Caribbean (LAC) and the names of the countries in the region. After excluding unpublished papers and articles where there was little mention of LAC or were more focused on the field of Industrial Ecology or Urban Ecology, the universe of publications analyzed was 47.

The results of the analysis of this inventory of publications are organized in four parts: first, a historical analysis of social metabolism as a pillar concept of MFA is made; then, the articles analyzed are characterized along three lines: the role of the “*Barcelona School*” in the dynamics of publications; the most studied countries and sub-regions; and the most frequent time periods analyzed and their implications for metabolic studies. Subsequently, we show the main findings on the dynamics of the flow of materials from Latin American economies, extracted from the publications evaluated. We conclude with some reflections on the important legacy of the “*Barcelona School*” and of our honored professor Joan Martínez-Alier on the work on MFA in LAC.

11.2 Social Metabolism: A Short History

After the emergence of the concept of “metabolism” associated with the biochemical behavior of cells, it was extended to organs, organisms, and even ecosystems, studying their exchanges of matter and energy (Fisher-Kowalski, 1998; Fisher-Kowalski & Hüttler, 1998). From there it is taken up by Marx, who knew the writings of the Dutch physiologist Jacob Möleschot (1822–1893) on the “*The Cycle of Life*”, extrapolating it to society (Martinez-Alier, 1987; Fischer-Kowalski, 1998).

Social Metabolism (SM) is defined as the way societies organize their exchange of matter and energy with their environment (Fischer-Kowalski, 1998, 2002). As in Marx, this concept is not a metaphor; it is an analogy, as it extends cellular and living organism behavior to society. Human beings, articulated by social relationships and institutions that are organized to guarantee our subsistence and reproduction, extract matter and energy from nature through collective structures and artifacts, and excrete a whole range of wastes or residues (González de Molina & Toledo, 2007).

Robert Ayres and Allen Kneese (1968), recover the notion of the economy as an open system and present a clear idea of the metabolism of nations. However, the author who is key to the development of the concept is Marina Fisher-Kowalski who

¹It refers to the Doctorate of Environmental Sciences in its option of Ecological Economics of the Instituto de Ciencia y Tecnología Ambientales (ICTA) of the Universidad Autónoma de Barcelona (UAB) (Spain).

publishes one of the pioneering texts in SM: “*Society’s Metabolism: On the Childhood and Adolescence of a Rising Conceptual Star*” (Fischer-Kowalski, 1997). From these years onwards, their work together with other colleagues (Fischer-Kowalski, 1998; Fisher-Kowalski & Huttler, 1998; Fischer-Kowalski & Haberl, 1997) are the starting point of one of the most robust tools for understanding the complex interactions between society and nature (Infante-Amate et al., 2017). Since the nineties of the last century, SM has grown in terms of followers, methodologies, and fields of action and application, with detailed evidence that allows us to better understand the biophysical functioning of societies (Toledo, 2013).

Several state-of-the-art papers on Anglo-Saxon contributions have appeared (Pauliuk & Hertwich, 2015; Gerber & Scheidel, 2018). In 2017, an article was published that inventories work on SM in several languages and since the late nineteenth century (“*Social metabolism. History, methods and main contributions*”, Infante-Amate et al., 2017). This inventory shows that the concept had been used on 10,038 occasions, mostly in the period 2001–2016 (Idem, p. 132). English was until 2005 the main vehicle of dissemination, but from that year onwards, articles and publications in Spanish and Portuguese (both languages combined) were the preferred ones (Idem, p. 132).

Growing academic output has included methodological and instrumental developments to measure a society’s metabolism. These try to quantify the flows of energy and materials used, transformed, and produced as pollutants or wastes to and from the environment. For added large-scale studies the methodology used is Economy-Wide MFA (EW-MFA or simply MFA). This provides indicators of extraction, consumption, and trade of materials in a territory (generally a country). There is now a standardized and recognized MFA methodology that has allowed its consolidation and dissemination (Eurostat, 2001, updated 2018). This chapter is aimed at reviewing the state of the art of the academic production on MFA for LAC (MFA-LAC).

11.3 Characterization of the Literature Analyzed²

11.3.1 Role of the “Barcelona School” in the Dynamics of MFA-LAC Publications

Chart 11.1 presents the academic production on MFA-LAC according to 3-year periods. It shows a trend with two growing cycles between 2004 and 2012 and with a great dynamic for the period 2016–2018. Of the 47 publications inventoried, 28 are written in English, 15 in Spanish, and 4 in Portuguese.

Academic production began in 2001 with two classic articles analyzing the environmental implications of North-South trade relations from an ecological

²Support for these results can be found in Annexures A and B.

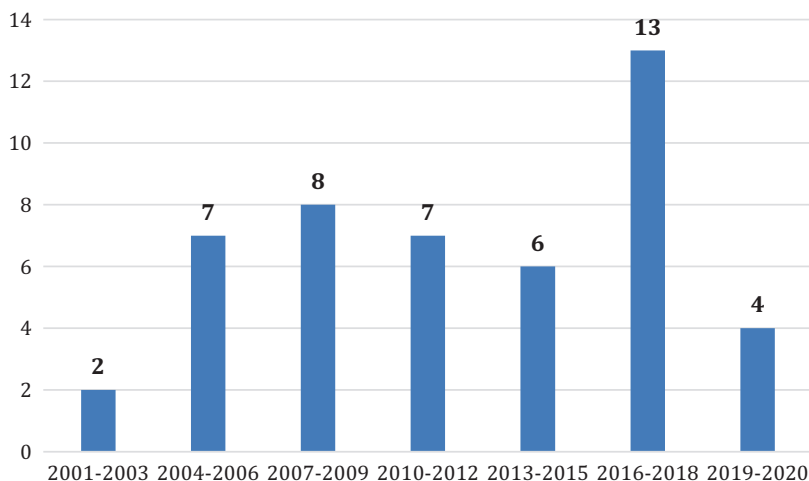


Chart 11.1 MFA-LAC: Number of publications by periods (2001–2020). (Source: MFA-LAC Inventory Database (Scopus-Google Scholar))

economics (EE) perspective.³ These two articles are a reference for many of the following works identified in the framework of this research for LAC (Muradian & Martinez-Alier, 2001a, b).

Both are produced within the framework of the ICTA-UAB Doctorate in Environmental Sciences created in 1997, under the direction of Martínez-Alier. This fact begins to highlight the importance of the “Barcelona School” in the field of EE and specifically in the area of MFA. This influence will be much greater in the Latin American scenario, as will be shown below.

The following period of academic production on MFA-LAC marks a significant increase between 2004 and 2012. In these 8 years, 22 articles were produced (47% of the total). The influence in this period of the “Barcelona School”, is overwhelming. Academics or students linked to ICTA published, alone or in partnership, 77% (17) of the 22 articles. There are two additional facts that accentuate the influence of “Barcelona School”: (i) 11 of these articles (55%) are part of doctoral theses carried out at ICTA-UAB, many of them directed by Professor Joan Martínez-Alier; (ii) 32% (7) of the articles are published in the journal *REVIBEC* (Ibero-American Journal of Ecological Economy).

This journal is published in Spanish and Portuguese, which facilitates access to academic publications for Latin Americans. It was created in 2004 at the initiative of the first graduates of the PhD in Environmental Sciences (Fander Falconí, Roldán Muradian, and Jesús Ramos), who also promoted the creation of the *Ibero-American Network of Ecological Economics*. This network helped to promote the founding of

³ Although these two articles do not strictly use MFA, they are pioneers in identifying the socio-environmental implications of North-South trade relations. They are also among the first papers to address *Ecologically Unequal Trade* by analyzing its effects in the region.

2 of the 4 regional societies of ecological economics that are part of the ISEE: the *Mesoamerican and Caribbean Society* (SMEE) founded in 2008 and the *Andean Society* (SAEE) created in 2013.

During 2013–2015, there was a small decrease in the production of articles on the subject, but the influence of the “*Barcelona School*” is maintained. Of the 6 publications made, 3 (50%) are linked to ICTA-UAB”. Most important in this period is the beginning of the MFA methodology’s institutionalization at the regional level through UNEP and the *Commonwealth Scientific and Industrial Research Organization* (CSIRO). The latter is strongly influenced by the “*Interdisciplinary Institute of Research and Continuing Education*” (IFF) in Vienna, Austria, where Marina Fischer-Kowalski works. Through this cooperation, a database for LAC covering the period 1970–2005 is produced. It also produced the Working Document “*Trends in Material Flows and Resource Productivity in Latin America*” (UNEP-CSIRO, 2013), which is an important reference for this topic in the region.

In the following period (2016–2018), there is a significant increase in the number of publications on the subject, reaching 13 (28% of the total analyzed). During this period, the influence of the “*Barcelona School*” is somewhat reduced, contributing with 4 articles (31% of the total for the period). At the same time, other academic origins gain weight (9), and a thematic shift towards other areas of work closer to industrial ecology can also be observed. These include specific economic sectors (construction, soya, nickel) or smaller territorial units (e.g. Galapagos Islands). The spectrum of publication sources is also diversifying.

In the last period, 2019–2020, 4 articles are published. One linked to the “*Barcelona School*” on social metabolism and environmental conflicts in the Andean countries (Pérez-Rincón et al., 2019); another, which addresses the analysis of the most extended available time series in the flow of International Trade materials for the region: “*Latin America’s Open Veins in the Anthropocene Era: A Biophysical Study of Foreign Trade (1900–2016)*” (Infante-Amate et al., 2020). And the final two work conceptually on metabolism (Araújo et al., 2019) and the quantification of potassium stocks and fluxes for Brazil (Sipert et al., 2020).

11.3.2 Countries and Sub-regions Most Studied in the Studies Reviewed

Among the 47 articles evaluated on MFA-LAC, we find the following: 5 analyze LAC as an aggregate whole; 7 select the largest countries; 4 investigate the Andean countries; 1 compares the metabolic patterns of this group of countries with those of Central America (Crespo & Pérez-Rincón, 2017); 4 analyze the material dynamics of the world economy and its influence on LAC. The most studied countries are: Colombia (19), Brazil (16), and Ecuador (15) (Chart 11.2).

The inventory also finds that 17 of the 20 countries in the continental region have some study of MFA, with only Belize, Guyana, and Suriname missing. In contrast,

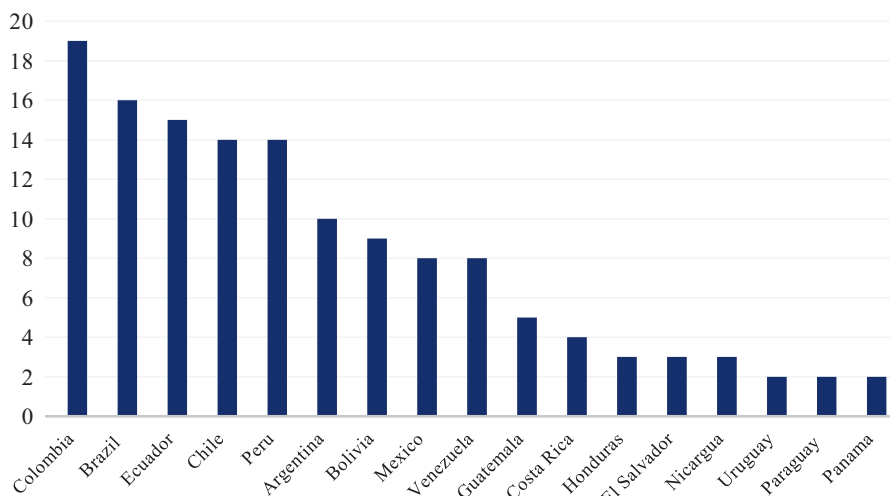


Chart 11.2 Publication of MFA-LAC by country analyzed. (Source: MFA-LAC Inventory Database (Scopus-Google Scholar))

the Caribbean region does not have any studies, although we are aware of an unpublished doctoral thesis on MFA for Cuba (Eisenhut, 2009).

11.3.3 *Periodization and Analytical Implications for Social Metabolism Studies*

The time period most used in this inventory is the medium term (between 20 and 40 years). Eighteen (38%) of the 47 publications deal with this period and 6 (13%) with a period between 10 and 20 years. The longest term is covered by 6 publications (13%), highlighting Infante et al. (2020) covering a period of 118 years. The sum of publications dealing with the medium and long term gives 30 articles (64% of the total). The preponderance of this time range is understood by the greater explanatory capacity to find trends, patterns, and aggregate metabolic transitions of economies.

Publications covering short periods of time are also identified: 4 that make temporal analyses between 1 and up to 10 years and 10 articles (21% of the total) that use a base year. These last 10 articles are characterized by the fact that they seek to overcome the limitations generated by the high level of aggregation of the MFA methodology. To do so, they complement MFA with other methodologies: *Life Cycle Analysis* (LCA), *Input-Output Analysis* (IOA), *Embodied Energy Analysis* (EEA), *Land-use change* (LUC), *Global Supply Chain* (GSC) and *Exergy Replacement Cost* (ERC). This allows them to better understand the black box of the material and energy processes of the economic sectors analyzed and their environmental impacts.

The analysis of the temporality of these publications shows that there is an exclusion threshold between achievable targets for the MFA. If we want to understand metabolic trends and material transition processes of economies, long-term time series analyses are essential. But these have limitations for understanding in detail the environmental impacts and metabolic processes within economies and their sectors. To go deeper into these two aspects, a combination of short-term studies with a wide range of methodologies complementing MFA is needed.

11.4 Main Findings on Material Flow Dynamics in Latin American Economies

11.4.1 On the Aggregate Dynamics of Material Resource Consumption

In all the works related to the aggregate material dynamics of the countries studied, there is evidence of a continuous and strong absolute materialization of the region's economies. This materialization is growing and permanent, but there is a significant upward break that becomes more pronounced in the 1990s. This change relates to what has been called in LAC, the extractivist model. This model corresponds to the action of massively extracting large quantities of raw materials from the soil, sub-soil, or water in order to subsequently commercialize them without much transformation, mainly aimed at the global market (Gudynas, 2013). The renewed impetus that extractivism has taken on has made it a fundamental concept for understanding the contemporary reality of the region, with significant economic, social, and environmental impacts.

The evaluated publications also show that this new material impulse since the 1990s has generated a socio-metabolic transition of the region's economies towards the abiotic. In the 1970s and until the mid-1990s, extraction focused on the appropriation of biotic material (mainly biomass for export). This pattern, although maintained in some countries, has shifted in the last two decades towards economies with a greater emphasis on abiotic extraction (minerals and fossil fuels). However, this specialization bias is not homogeneous throughout the region. It is not true in Central America (Crespo & Pérez-Rincón, 2017) and is less intensive in Mexico.

11.4.2 On International Trade and Unequal Ecological Exchange

Historically, the region has been a net global exporter of natural resources and raw materials to the rest of the world. The longest-term study carried out for LAC (1900–2016) demonstrates this (Infante et al., 2020, p. 187), noting that the “great

acceleration” of this biophysical deficit is due to the growth of LAC exports from the 1980s onwards. Neoliberal policies imposed by international financial institutions contributed to this. Total exports of materials increased from 7 to 115 Mt between 1900 and 1980. The jump starts in 1980 and accelerates in the 1990s. In 2016, they amounted to 1035 Mt. (Infante et al., 2020: 188).

The study of the “*Terms of Trade*” from an ecological perspective has been an important research topic of the “*Barcelona School*” and Professor Joan Martínez-Alier. This School, together with Professor Alf Hornborg of Lund University (Sweden), has put forward the hypothesis of “*Ecologically Unequal Terms of Trade*”, an environmental extension of Prebisch’s thinking. ECLAC’s approach pointed to a historical trend for commodity prices to lose value to imported capital goods. As southern countries specialize in exporting goods rich in natural resources, getting imported goods requires increasing exports. In doing so, they increase pressures on nature, thereby increasing environmental liabilities (Hornborg, 1998; Pérez-Rincón, 2006; Hornborg & Martínez-Alier, 2016).

The works analyzed that address this issue find that this trend cannot be generalized for all countries and that it becomes more relevant for certain periods of time. However, the growth of environmental impacts seems to be decoupled from the behavior of the “*terms of trade*”. For example, during the commodity boom (late 1990s–2009), “*terms of trade*” recovered (Muradian et al., 2012), but environmental pressures did not decrease; on the contrary, they increased. This was facilitated in two ways: (i) regulatory flexibilization of extractive concessions, environmental requirements, and capital inflows policies. This enhanced comparative advantages related to the abundance of natural resources; and (ii) high international prices incentivized the extraction of resources for export, further impacting the environment and fostering environmental conflicts (Pérez-Rincón et al., 2018). In the next phase of the post-boom cycle with declining prices (2010–2018), the terms of trade of exports declined. Despite this, the region’s economies increased extraction to compensate for the price reduction, producing a double trade deficit: monetary and biophysical (Samaniego et al., 2017).

11.4.3 On Distributive Ecological Conflicts

One of the frequent themes addressed in several of the articles in this MFA-LAC inventory is that of environmental conflicts generated by increasing metabolic dynamics. This approach is clearly influenced by the “*Barcelona School*”, especially Professor Martínez-Alier. With the strengthening of extractivism in LAC since the 1990s and the increased environmental awareness of the population, environmental conflicts have become more dynamic throughout the region.

The Global Atlas of Environmental Justice (www.ejatlas.org), initiated in 2011 and led by Joan Martínez-Alier, currently (Jan/11/2023) reports 3795 cases of environmental conflicts in the world. Of these, 1041 correspond to LAC (27,4%), when the region's population only represents 8.3% of the world's inhabitants. Almost all of these conflicts in the subcontinent are related to extractive dynamics, generating an over-representation of the region. Several of the articles analyzed address this issue, pointing to a close relationship between the growing dynamics of different metabolic variables and the growth in the number of environmental conflicts (Manrique et al., 2013; Samaniego et al., 2017; Infante-Amate et al., 2017; Pérez-Rincón et al., 2018; Pérez-Rincón et al., 2019).

11.5 Final Reflections

This review of academic literature on MFA in LAC identified 47 papers. The overall balance shows the important influence of the “*Barcelona School*” on the region. Of the 47 articles published, 27 (57% of the total) have its mark; 17 (36%) are part of doctoral theses linked to the PhD in Environmental Sciences at ICTA-UAB; 30% of the papers (14) were published in journals generated within the “*Barcelona School*”: *REVIBEC* and *Political Ecology*, the latter created and directed by Joan Martínez Alier since 1991.

Besides, the main topics addressed in a good part of the articles and their main reflections have the stamp of the “*Barcelona School*”: absolute materialization of the region's economies, deficit biophysical trade balance, unequal exchange relationships in environmental terms, increasing ecological debts and liabilities, environmental conflicts associated with the growth of social metabolism, and several others. These characteristics adequately describe LAC's economies.

And the “*Barcelona School*”, with Professor Martínez Alier at its head, has been pointing this out since the first articles produced in 2001. All this shows the relevance of this School for the region, but specifically, the influence of an academic who has promoted a joint perspective between ecological economics and the political ecology in the world. In this work, there is evidence that much of the intellectual output in these fields in the subcontinent bears the imprint of his thinking. These results are the best tribute to a master who has sown seeds that have germinated favorably in our region: Professor Joan Martínez-Alier.

Annexures

Annex (part 1): Triannual Synthesis of the Main Characteristics Found in the 47 Inventoried Articles on MFA-LAC

Period	Total number of publications	Influence, trajectory or institutional link					Work field			Main topic addressed					Methodologies used (Part 1)											
		ICTA-UAB	IFF	ICTA-UAB & IFF	ICTA-UAB & Others	Remaining	Is part of doctoral thesis	EE	IE	EE/IE	EE/PE	General economy	International trade	Economic sector/product	Small or regional scale	Conceptual	MFA ^a	MFA/LCA	MFA/IOA	MFA/MU/SIASSEM	MFA/SDA/IOA	MFA/WF	MFA/IOA/RME	MFA/TRM/HMF/PERF	MFA/I=PAT	
2001–2003	2	4,3%	2				0	2	2				2													
2004–2012	22	46,8%	12	1	2	3	4	12	16	4		8	8	5		1	10	3	2	1	2	1	1	1		
2013–2015	6	12,8%	3	2	0	0	1	2	6	0		4	1			1	2								2	
2016–2018	13	27,7%	4	0	0	0	9	1	7	0	5	1	4	3	4	1	5	1								
2019–2020	4	8,5%	1	0	0	0	3	0	2	0	1	1	2	0	1	1	2									
TOTAL	47		22	3	2	3	17	16	33	4	6	2	18	14	10	1	19	4	2	1	2	1	1	1	2	
Participation (%)	100%	47,8%	6,4%	4,3%	6,4%	36,2%	34,0%	70,2%	8,5%	12,8%	4,3%	38,3%	29,8%	21,3%	2,1%	8,5%	40,4%	8,5%	4,3%	2,1%	4,3%	2,1%	2,1%	2,1%	4,3%	

Annex (part 2): Triannual Synthesis of the Main Characteristics Found in the 47 Inventoried Articles on MFA-LAC

Period	Total number of publications	%	Methodologies used (Part 2)								Type of flow analyzed		Temporality of the analysis				Name of the journals where the article has been published and other types of publications								
			MFA/DS	MFA/EEA	MFA/LUC/GSC	MFA/DEC	MFA/LUC	MFA/ERC	MFA/Other tools	Theoretical	Inputs	Inputs and outputs	1 year	<10 years	>10 <20 years	>20 <40 years	>40 years	Ecological Economics	Industrial Ecology	Revibec	Ecologia Politica	Resources, Conservation and Recycling	Other journals	Book or book chapter	Institutional document
2001–2003	2	4,3%					2		2		2				1		1					1			
2004–2012	22	46,8%						11	1	18	4	5	1	5	10	1	4	5	6	1	3	2	1		
2013–2015	6	12,8%						3	1	5	0				5		1	1	2	1	0	0		1	
2016–2018	13	27,7%	1	1	1	1	1	10	1	11	2	4	2	1	2	3	1	0	3	0	0	8	1		
2019–2020	4	8,5%	0	0	0	1	0	0	1	2	1	1	0	0	0	2	1	0	1	0	0	2	0	0	
TOTAL	47		1	1	1	2	3	1	27	4	38	7	10	4	6	18	6	8	6	12	2	3	13	2	1
Participation (%)		100%	2,1%	2,1%	2,1%	4,3%	6,4%	2,1%	57,4%	8,5%	80,9%	14,9%	21,3%	8,5%	12,8%	38,3%	12,8%	17,0%	12,8%	25,5%	4,3%	6,4%	27,7%	4,3%	2,1%

Source: MFA-LAC database (Scholar Google and Scopus)
ACRONYM: *ICTA-UAB* Instituto de Ciencias y Tecnologías Ambientales – Universidad Autònoma de Barcelona, *IFF* Interdisciplinary Institute of Research and Continuing Education, *EE* ecological economics, *IE* industrial ecology, *PE* political ecology, *MFA* material flow analysis, *IOA* input-output analysis, *MUSIASEM* multi-scale integrated analysis of societal and ecosystem metabolism, *SDA* structural decomposition analysis, *WF* water footprint, *RME* raw material equivalents, *TRM* total material requirement, *HMF* hidden material flow, *PERF* potentially environmentally relevant flows, *I=PAT* impact = population, affluency, technology, *DS* dynamic of systems, *EEA* embodied energy analysis, *LUC* land-use change, *GSC* global supply chain, *DEC* database of environmental conflicts, *ERC* exergy replacement cost

^aMoney flows are also regularly included

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