

International Experience in Establishing Indicators for the Circular Economy and Considerations for China

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Circular Economy in China: Moving from Rhetoric to Implementation

This report has been prepared in support of the work commissioned by China's National Development and Reform Commission (NDRC) to establish an indicator system that helps monitor progress towards the objectives of the circular economy (CE). For the purposes of this paper I adopt the working definition of CE referenced on NDRC's Cleaner Production site:

“CE may be interlinked manufacturing and service businesses seeking the enhancement of economy and environmental performance through collaboration in managing environmental and resource issues. The theme of the CE concept is the exchange of materials where one facility's waste, including energy, water, materials - as well as information - is another facility's input. By working together, the community of businesses seeks a collective benefit that is larger than the sum of the individual benefits each enterprise, industry and community would realize if it intended to optimize its performance on an individual basis (i.e. industrial symbiosis).” (NDRC 2006)

CE in many ways resonates with the concept of industrial metabolism, rooted in a systems perspective on the interaction of the natural environment and the anthroposphere. It focuses on the input-output analysis of material flows transformed by production and consumption (e.g., Ayres 1989; Fisher-Kowalski 2003).

CE has received growing political prominence in China since the late 1990s as a mechanism to help balance China's runaway economic development that is increasingly seen as producing unsustainable social and environmental costs and consequences (Zhu 1998, Heymann 2006). Finding effective ways to tackle China's growing environmental sustainability problem is increasingly urgent. As Premier Wen Jiabao noted in his April 18, 2006 address at a national conference on environment protection in Beijing, major environmental targets of the recently ended tenth 5-year plan were not achieved, and additional problems emerged. Besides urging continuing pollution control efforts, he pressed for increased emphasis on adjusting economic structure and developing environmental technologies. CE has relevance for many if not all of these areas.

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The rising prominence of CE was indicated by the transfer of primary responsibility for its implementation in 2004 from the State Environment Protection Administration (SEPA) to NDRC in charge of national development programs. Support for the CE concept in China's political establishment is broad. In 2005 the State Council published a document called *Suggestions on Accelerating the Development of Circular Economy* that provided guidelines to help integrate CE into the 11th 5-Year Program of China (Task Force on Circular Economy and Cleaner Production 2005). Emphasis is shifting from considering CE as primarily a tool for environmental protection towards considering it in a broader socio-economic context. Objectives and goals for the CE were outlined at the 16th National Congress of the Communist Party of China (CPC). The Congress has projected a quadrupling of GDP by 2020 and set a goal of achieving a 20% reduction in pollution, outlining a decoupling trajectory for the country.

More recently the central government initiated a large series of pilots across the country on at least three levels (Yuan et al. 2006; Task Force on Circular Economy and Cleaner Production 2005). At the *micro* or firm level participating companies are required or encouraged to carry out CP audits, disclose results and be rated on a performance scale. At the *meso* level, the emphasis is on developing eco-industrial networks (EINs) and eco-industrial parks (EIPs). At the *macro* level the focus is on city, municipality or province-scale programs and coordination of both production and consumption related material and energy flows. Ideally, initiatives across these three levels would be coordinated to achieve maximum eco-efficiency and impact.

The push to move beyond CE rhetoric increases the need for management tools that can help create a policy environment and incentive structure conducive to systemic implementation. Indicators and underlying accounting systems are such tools, already receiving prominence through emphasis on the 'scientific concept of development'. The Circular Economy and Cleaner Production Task Force of the China Council for International Cooperation on Environmental and Development (CCICED) has called for the establishment of an integrated evaluation and indicator system and a supporting database. The system would monitor progress towards CE and sustainable development objectives and would be supported by databases of material and energy flows (CCICED 2003).

Recognizing the need for new ways of measuring progress has preceded CE and is the subject of intensive discussion in many international and sub-global processes (Pintér et al. 2005). It is expected that many of the CE indicators would also be found in indicator sets developed for other policy purposes and around other concepts. This view is supported by existing indicators developed for various CE initiatives. For China, in particular, the ongoing intensive work on green and material flow accounting (MFA) and *xiaokang* indicators provide rich opportunities for synergies and cooperation.

This paper will start with a very brief review of some key criteria for indicator development that would by definition also apply to indicators for the CE. I will then review the conceptual foundations of the CE that can serve as a starting point for

developing or identifying performance indicators aligned with its key aspects. The paper will also discuss selected international, national or sub-national CE initiatives that may be of particular relevance for the work commissioned by NDRC. Finally, I will offer my opinion on the way CE indicator development could unfold in parallel with other indicator and green accounting initiatives in China.

In support of this report, a non-comprehensive review of the more recent literature on CE, material flow accounting and related concepts has been prepared and is attached in Annex 1.

Indicators and Indicator Development

The purpose of indicators is to provide objective, credible information on the status of a system to decision-makers and thus help clarify and reach desired outcomes. If certain conditions are met, indicators can help meet goals and outcomes. This section mentions three general conditions that may be of specific importance to indicators related to the measurement of material and energy flows that are at the heart of the CE concept.

One of the most widely referenced set of principles focused on sustainability measurement and assessment is the Bellagio Principles, developed in 1997 by a group of internationally noted experts (IISD 1997). While thorough review of these principles in the context of indicator systems for the CE is beyond the scope of this paper, there are a couple of points worth emphasizing. First, the effectiveness and eventual usefulness of indicators is influenced not only by the issues indicators address and their scientific or technical validity, but also the process used to develop them. Second, strategic development of indicators requires integration into mainstream policy mechanisms. This is critically important if they are to have major influence on policymaking and practice by local government, municipalities, industry and others.

The strategic importance of indicators has been recognized in China at the political level and has resulted in several parallel initiatives that focus on various aspects of measurement. Of particular importance for CE is the work focused on environmental or green accounting, given the importance of connecting indicators to underlying monitoring and information systems. In this regard, it is preferable to follow the accounting conventions underlying the System of National Accounts (SNA) and the more recently developed System of Integrated Environmental and Economic Accounts (SEEA). The roles and functions of accounting systems and indicators are complementary and represent two sides of the same coin (Bartelmus, Anielski and Pintér 2005; OECD 2000). Once fully established, material flow accounts (MFAs) would enable the systematic collection of data, thus providing the raw material for CE indicators.

The third general point related to the design of indicators is the importance of linking indicators as much as possible to specific policy targets and objectives. China's 5-year Plan (more recently 5-year *program*) includes desired outcomes and targets as a standard feature, and thus creates a reference base against which actual performance can be evaluated. Beyond integrating key CE indicators into a core set of measures, based on

endorsement from central government and adoption by the provinces, it would be important to identify specific performance objectives. This would not only help clarify further quantitative, time bound details of what is meant on the CE, but also enable indicators to be used as a measuring stick of actual versus expected performance. This has particular relevance at a time when better aligning the performance evaluation system of local government officials is seen as a priority (IQTE 2005).

The Conceptual Basis for CE Indicators

CE refers to the material aspects of integrated socio-economic and environmental systems, where the economy is embedded in a planetary biogeophysical system and depends on it both for securing the necessary raw materials and absorbing or processing waste (e.g. Ayres and Simonis 1994; Robèrt and Eriksson 1991). More fundamentally, CE is rooted in the first law of thermodynamics on mass conservation according to which material inputs into a system equal material outputs plus net accumulation. A sustainable system is characterized, among others, by a much reduced use of renewable and non-renewable inputs and closed loop reuse and recycling of material outputs, thus drastically reducing or eliminating waste and dissipative loss. These concepts and strategies have been captured by the Factor 4/10 and dematerialisation ideas (e.g. Weizsäcker et al. 1995; Schmidt-Bleek 1998).

Over the last decades, several schools and approaches have developed analytic tools to describe the physical (material and energy) basis of CE and corresponding interactions of the economy. These approaches have been reviewed in detail by several authors, comparing their strengths, weaknesses and potential for practical application (e.g., Uno and Bertelmus 1998; Eurostat 2001; Daniels 2002; Bringezu and Moriguchi 2003). Drawing from these reviews, the approach with most direct relevance for CE indicators is material flow analysis and accounting (MFA), based on the principles and methods of mass balancing and input-output analysis.

Bringezu (2001) defined MFA as “the analysis of the throughput of process chains, comprising the extraction or harvest, chemical transformation, manufacturing, consumption, recycling and disposal of materials”. MFA provides a diagnostic tool to monitor material flows in physical units, typically in tons throughout the entire supply chain. MFA is also increasingly used as a diagnostic tool to understand the material use related impacts of entire economies, as will be illustrated by examples in the next section of this paper.

The conceptual details and terminology of MFA is well established and provides a starting point for the development of highly aggregate indices at the level of national economies or regions. However, there are other associated tools that help diagnose material flow related details at the *meso* (e.g., municipal) or *micro* (e.g. firm or even household) level. A categorization of material flow types and units of analysis is shown in Table 1. The regional perspective is emphasized in this paper.

MFA also has of course its limitations. Using the weight of materials without consideration of material quality masks major potential differences in terms of environment or human health impact and liability. The impact and relevance of material flows also depends on the status and type of the impacted ecosystem. Calibrating material flows according to material quality and ecosystem or human system sensitivity is not always a straightforward exercise and needs careful consideration of context.

Table 1: Types of material flow analysis on different scales (modified after Bringezu et al. 1997)

		Specific environmental problems related to certain impacts per unit flow of:		
		Substances	Materials	Products
Problems of environmental concern related to the throughput of:	Firms – e.g. plants, single companies etc.	e.g. Cd, Pb, Hg, CO ₂ , N, P etc.	e.g. pulp and paper, energy carriers, metals etc.	e.g. cars, diapers, batteries, computers
	Sectors – e.g. construction, agriculture, mining etc.	e.g. Cd, Pb, Hg, CO ₂ , N, P etc.	e.g. pulp and paper, energy carriers, metals etc.	e.g. cars, diapers, batteries, computers
	Regions – total or main throughput, mass flow balance, total material requirement	e.g. Cd, Pb, Hg, CO ₂ , N, P etc.	e.g. pulp and paper, energy carriers, metals etc.	e.g. cars, diapers, batteries, computers

Figure 1 shows a general diagram of the metabolism of an economic system with the key input-output components of MFA as measured *by weight*. The domestic economy is shown as an open system that relies on material inputs from domestic extraction and imports, and releases materials to the domestic environment and by export. Note that air, water, and possibly other factors such as migratory species, synthetic chemicals circulated in the global atmosphere or chemicals transported through ocean currents may also transit and influence the system.

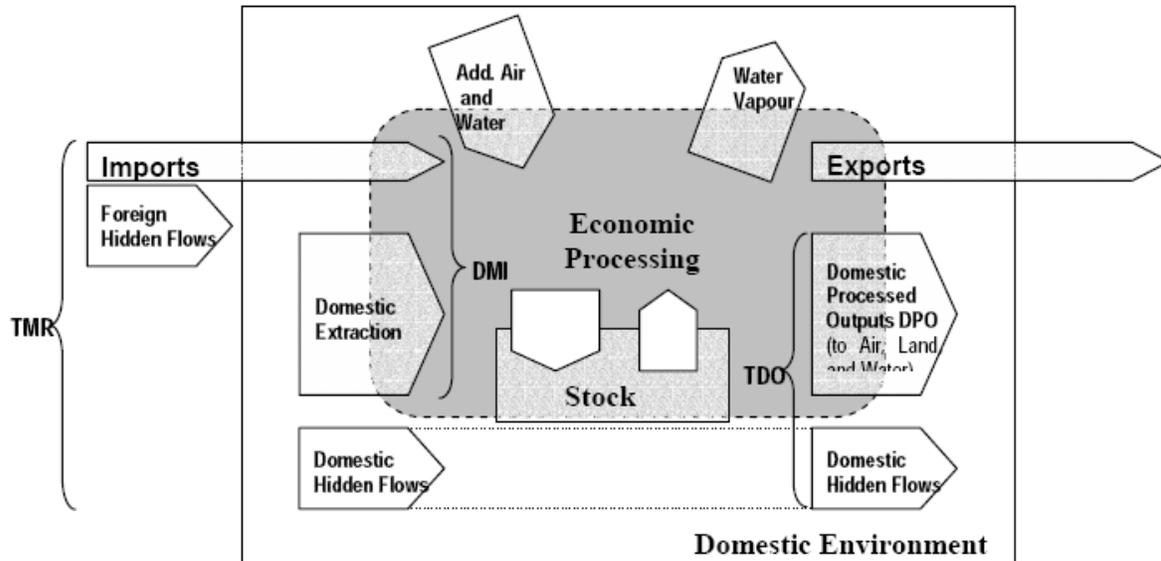


Figure 1: Conceptual diagram of material flows in an economy (Matthews et al. 2000).

Hidden flows (also referred to as ‘ecological rucksack’), are imported and exported material flows that never enter the economy. Ancillary flows are a type of hidden flow created when non-economically useful materials are extracted along with desired materials and are separated and discarded. Excavated or disturbed materials such as mineral overburden that are removed to provide access to economically valuable raw materials are another form of ancillary flow (Adriaanse et al. 1997). Hidden flows have no direct economic value, and can be classified as positive or more often negative externalities.

The treatment of water from the MFA perspective requires special attention. Water represents both direct material inputs and hidden flows, and from the sustainability point of view has both human system and ecosystem uses. However, aggregating water by its weight drowns out other material flows (P. Bartelmus, pers. comm.), thus producing a potentially misleading result. Therefore, most MFA accounts omit water, although they usually consider emission of pollutants to water.

Water use is usually captured in separate water resource accounts, as part of a country’s overall environmental accounts. A general input-output based conceptual model of water resource accounts is shown on Figure 2. The framework assumes the account to be calculated for a geographic area that exchanges water with adjacent areas and the global hydrologic cycle. The system is composed of two main parts – the hydrologic system and the water use system with an exchange of water between the two. Water accounts include (a) water uses by sectors and exchange between sectors; (b) the account of the hydrologic system; and (c) a synthesis balance sheet (OECD 2000).

In China water accounts are being developed by the National Bureau of Statistics (NBS) in the context of a collaborative project with Statistics Canada that started in 2004. Work is ongoing and besides developing physical accounts for water resources, wastewater treatment and discharge etc. it also includes a regional pilot for the Haihe River (Xu n.d.).

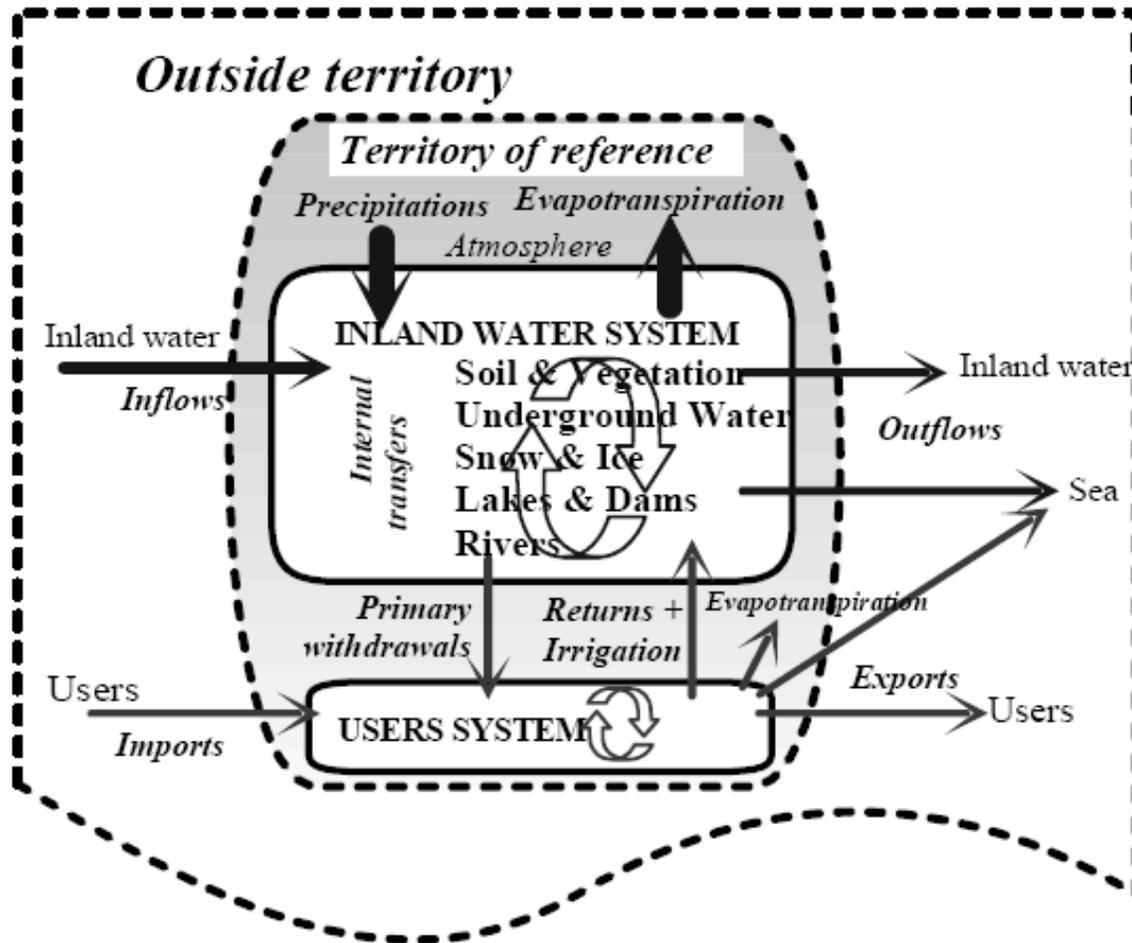


Figure 2: General conceptual framework for water resource accounts as developed in France (OECD 2000).

Based on the general model of economy-wide material flows, several authors have derived and applied indicators to the analysis or comparative assessment of the industrial metabolism of various national or sub-national entities. These indicators are useful in analyzing a number of aspects of material use that are central to understanding (a) changes in the absolute volume of material stocks and flows, which are important for understanding their aggregate environmental impact of material production and consumption and (b) the physical efficiency of an economy to transform raw materials into useful products with minimum waste.

Based on the theoretical and applied work carried out on MFA over the last decade or two, there is now common terminology and key indicators that can be derived from the accounts. Referring back to the acronyms shown Figure 1 and building on the classifications reported by Bringezu (2001) and Giljum (2006), some of the key indicators are as follows.

Main input indicators

- **Direct material input (DMI)** – combined weight of all materials having economic value and directly used in production and consumption; equals domestic extraction of materials and imports; does *not* include hidden flows;
- **Total material requirement (TMR)** – measures the total primary resource requirements of an economy and in addition to DMI includes domestic hidden flows plus hidden flows associated with imports in their place of extraction;

Main output indicator

- **Domestic processed output (DPO)** – includes all outflows of used materials, whether domestic origin or imports to air, water, landfills and dissipative flows; materials that are recycled are *not* included;

Main consumption indicators

- **Domestic material consumption (DMC)** - total quantity of materials with economic value that is used within a system, excluding hidden flows associated with domestic extraction of resources or imports; calculated by extracting subtracting exports from DMI;
- **Total material consumption (TMC)** – includes the total material requirement of domestic consumption; equals TMR minus exports and their indirect flows;

Balance indicators

- **Physical trade balance (PTB)** – physical trade surplus or deficit of an economy, calculated by imports minus exports; may also be calculated to include hidden flows;
- **Net addition to stock (NAS)** – measures the physical growth rate of the economy, a balance between new materials and products added each year minus old materials removed and disposed of;

Indicators derived from MFA can be converted into measures to calculate the efficiency or material use. Efficiency can be physical i.e., the amount of physical waste or hidden flows generated per unit of useful output, or economic. Eco-efficiency indicators measure environmental performance related to economic (financial) performance. In the context of the CE and material flow accounts, environmental performance may concern both input and output variables listed. The resulting eco-efficiency indicators or indices measure the performance of an economy in improving the *physical* efficiency of its material use. Eco-efficiency measures can be applied at various levels, including national, sub-national or organizational, including corporate (e.g., UNCTAD 2004). Some

commonly used eco-efficiency indicators are related to water use, energy use and waste production (NRTEE 2001).

While efficiency measures can be useful in determining e.g., whether China is successful in decoupling its GDP growth from material use and, by proxy, the environmental impacts of material use, they also have limitations. The most significant limitation is that eco-efficiency measures alone do not indicate increases or decreases in environmental impact. Particularly in a fast growing economy like China, the rate of growth may outstrip the rate of improvement in eco-efficiency, leading to an overall continuing increase of environmental pressures. Therefore, both eco-efficiency and absolute material use measures need to be used, the latter preferably tied to specific performance targets. Progress towards de-coupling is achieved only if the rate of improvement in resource use intensity is higher than the rate of growth of the *physical economy* (after Spangenberg et al. 2002).

Following the logic of the driving force-pressure-state-impact-response (DPSIR) framework, commonly used for analyzing environment-development interactions, the input and output indicators derived from MFA would typically fall in the *pressure* category, and can be shown to influence environmental state, or lead to impact on ecosystem or human well-being (EEA 1999; OECD 1998). Main input and output indicators such as TMR or TMC are direct sources of pressure, driven by economy-wide processes such as population growth. These pressures directly influence the state of the environment, such as water quality or land degradation. While the DPSIR framework has some limitations, in the context of material flow related measures, it helps establish causal linkages at least at the conceptual level between total or disaggregated material production and consumption and related impacts on the state of the environment and human well-being. Recognizing and quantifying these linkages, while not always simple, is necessary for designing effective policy responses.

MFA related high level indicators are most applicable and applied at the *macro* national level and thus most useful in the context of developing macro level policy measures. In order to diagnose material production and consumption dynamics in more detail at the *meso* or *micro* levels shown in Table 1, other diagnostic tools and indicators such as substance flow, life cycle or commodity chain analysis are required. Cross-scale linkages have been analyzed in a few contexts, but methodological challenges and data limitations make the construction of multi-scale and comprehensive MFA analytic systems challenging (see e.g. Kytzia 2004).

National level experience with applying MFA indicators relevant for the circular economy

Methodological advances in indicators and MFA and an increased recognition of the importance of a stronger evidence base for policy has resulted in growth in national indicator calculations and economy-wide material flow accounts (e.g., Hinterberger et al. 2003). In what is becoming an increasingly busy field, the seminal work of a number of organizations, particularly the Wuppertal Institute in Germany, the National Institute for

the Environment and Health in Japan, the European Environment Agency and Eurostat in the EU, RIVM in the Netherlands and the World Resources Institute in the United States tend to stand out. Coordination of national level initiatives in industrialized countries is provided through the Working Group on Environmental Information and Outlooks (WGEIO) of the OECD, with particular emphasis on measuring the efficiency of material use and monitoring the decoupling of environmental pressures from economic growth (OECD 2004).

Material flow accounts and indicators with relevance for the CE have been calculated for a wide range of mostly industrialized countries. Three prominent cases are discussed here, but references to others are also provided in the attached literature review (Annex 1).

European Union

Material flow accounts are now regularly calculated for member states of the European Union and detailed national calculations have been available for several years for countries such as Germany, Austria, Denmark, Finland and the UK. Eurostat, the EU's statistical organization published both a detailed methodological guide on MFA and a retrospective analysis of key material use indicators (Eurostat 2001; Bringezu and Schütz 2001). Some countries, such as Germany, have established and regularly publish physical input-output tables (PIOTs) alongside with economic input-output tables as part of regular statistical reporting. The European Environment Agency's (EEA 2005) comprehensive and regular state of the environment reports now also include an analysis of key material flow trends and assessment of linkages to policy (EEA 2003).

The growing policy relevance of material flow indicators was emphasized in a detailed study commissioned under the EU's 6th Environmental Action Programme (EAP). The study set out to review resource use patterns across the EU 25 and to provide information that could be used in priority setting (Moll, Bringezu and Schütz 2005). Absolute levels of material use and changes in material use efficiency in member states are also provided.

The main economy-wide indicators calculated in this initiative included domestic material input (DMI), domestic material consumption (DMC), total material requirement (TMR), physical trade balance (PTB) plus domestic processed output (DPO) to land, air and water. Sub-accounts are provided for fossil fuels, metals and industrial minerals, construction minerals, and biomass. Estimates have been calculated for per capital economy-wide material flows as shown on Figure 3.

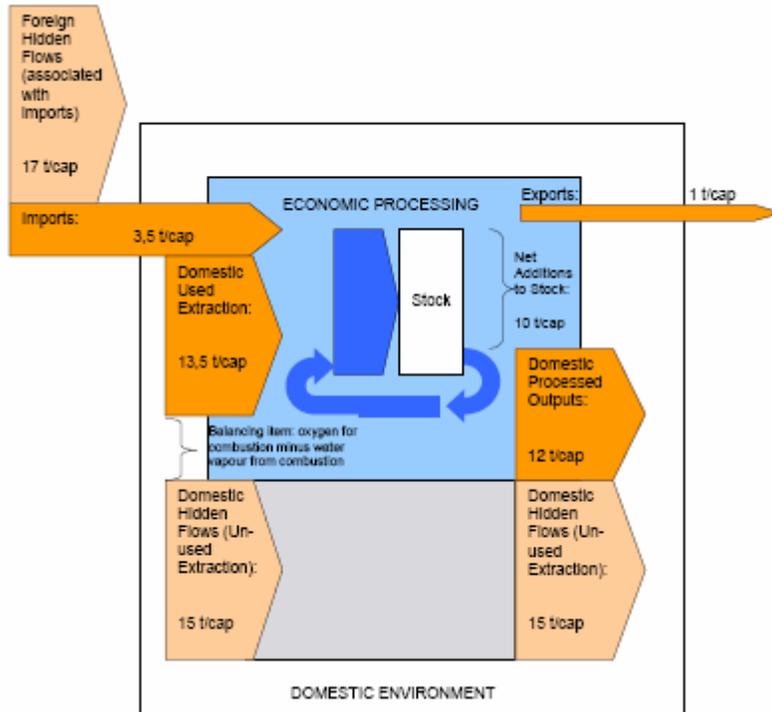


Figure 3: Estimated per-capita economy wide material flows in the European Union (Moll et al. 2005).

Moll et al. (2005) also provide estimates of de-coupling and resource productivity, with emphasis on the following indices:

- relative decoupling of GDP growth and resource requirements (GDP/TMR)
- resource productivity (GDP/DMI)
- direct resource productivity (GDP per tonne DMI)
- resource productivity from the consumption point of view (GDP/DMC)

The study for the 6th EAP is notable for its attempt to draw policy relevant conclusions from MFA indicator analyses on decoupling, resource use, differences in countries and burden shifting thought changes in structural changes in trade patterns. It also calls attention to the potential (in)sensitivity of overall material flows to policy measures and calls for a long-term strategy. Even though EU countries have arguably some of the most advanced statistical data collection and monitoring systems, data gaps and uncertainties continue to limit analytical capabilities. Detailed assessment of linkages between policy measures and changes overall material use patterns as well as specific sub-accounts is therefore lacking.

United States

In comparison with efforts in the EU, efforts to establish comprehensive material flow accounts for the United States are more recent and to date less institutionalized. This has resulted in a call by the U.S. National Academy of Sciences in 2003 for the establishment

of a consistent material flow accounting framework that integrates existing and future data (National Research Council 2003). In a broader context, these needs are also echoed by a recent report by the US Government Accountability Office (GAO) calling for better coordination in developing environmental indicators that can inform policy decisions (GAO 2004).

Initial, but already quite detailed calculations for material flow indicators in the US have been included in a series of seminal reports by the World Resources Institute (Adriaanse et al. 1997; Matthews et al. 2000). These reports include not only some economy-wide aggregate measures but also sub-accounts for specific materials both on the input and output side.

US reports to date emphasize the importance of providing information on material flows throughout their lifecycle, from extraction through manufacturing, use and disposal or dispersion. Eco-efficiency is emphasized and several indicators are calculated, including decoupling of material flow intensity measured as DPO per unit of GDP or per capita. Using these measures, Matthews et al. (2000) conclude that dematerialization has not progressed and small or temporary improvements are often offset by increases in absolute volumes of pollutants or resource consumption.

While detailed information on a large number of materials is already available, there appears to be a lack of data on some synthetic chemicals (Wernick and Irvin 2005). In response to a call for improved information and accounting framework and in recognition of data gaps, WRI established a pilot MFA database, available at < <http://materials.wri.org/> >, for over 160 primary material inputs and hundreds of outputs.

Work is currently under way at WRI to analyze material flows by economic sector, to identify environmental implications of some material flow trends, and to provide policy recommendations for responding to changes and improving the basis for existing material flow accounts.

Japan

In the Asia-Pacific region Japan has been a pioneer in developing its environmental indicator and MFA system. This presumably arises from the combined effects of Japan's heavy reliance on imported raw materials, very limited physical space for the disposal of waste and strict regulatory regime. The MFA work also received an early boost through the early application of input-output matrices to analyze Japan's production and consumption cycle (Leontief and Ford 1970).

The policy context for Japan's MFA work includes the country's Basic Environmental Law, first enacted in 1993 and the Basic Environmental Plan. Out of the 2000 Basic Environmental Plan's four policy goals, the goal related to the "sound material cycle" captures the concerns related to the CE, and aims to tackle the problems associated with mass resource consumption and mass production of waste (Moriguchi 2000).

In order to measure progress towards the ‘sound material cycle’ objective, the government reports three sets of indicators as follows, with further detail available in Moriguchi (2000):

- Indicator set for material and energy flows
 - Material flows
 - Direct material input (total)
 - Total waste generation
 - Recycle ratio of waste generated
 - Recycle ratio of specific materials
 - Energy flows
 - Total Primary Energy Requirement (TPER)
 - Total Final Energy Consumption (TFEC)
 - TPER per GDP
 - TFEC per GDP
 - Ration of renewable energy to TPER
- Indicators for sound water cycle
 - Natural water cycle indicator
 - Anthropogenic water cycle indicator
- Driving force – State – Response (DSR) indicators for issues associated with material and energy flows
 - DSR indicators for 15 priority environmental themes

While Japan has made significant progress in MFA indicators, it also faces some of the same challenges noted by others. There are continuing data problems, particularly associated with imported hidden flows, which are very important given the country’s reliance on imported materials. A second problem relates to defining a commonly accepted and transparent indicator for recycling rate. And, thirdly, dis-aggregation by industrial sectors and type of materials requires further work in the future.

Conclusions and considerations for China

China’s important role in international trade and its impact on the environment makes understanding and aligning China’s industrial metabolism with the principle of the circular economy is of primary importance. While the development of CE indicators continues to have challenges, significant progress during the last decade has made the integration of CE-focused material and energy flow measures feasible.

Based on this brief study, the following are provided for consideration as NDRC proceeds with the establishment of a CE indicator system:

- Build on the accepted concept, terminology and methods of MFA, successfully applied by a range of countries;
- Ensure the indicators have a stable institutional home and the program is well resourced and has the required capacity

- In order to ensure the availability (or development) of sufficient data into the future, CE and MFA indicators should be closely integrated with the system of national accounts, following particularly the conventions established by the System of Integrated Economic and Environmental Accounts;
- The work on economy-wide metabolism and indicators should be accompanied by *meso* and *micro* level work on sub-accounts and indicators on the municipal and firm level, recognizing that in many cases this will require the integration of CE-relevant indicators into broader *xiaokang* or sustainability indicator sets;
- Explore ways of communicating and using CE and MFA indicators to analyze some of China's most pressing domestic sustainability problems and its impact on the rest of the world, and develop policy or technical scenarios to address highest priority issues in the future; and
- Pursue a vigorous program of exchange and collaboration with the international MFA practitioner community to facilitate mutual learning.

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< <http://www.oecd.org/dataoecd/2/20/4425421.pdf> >

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<http://www.unctad.org/en/docs//iteipc20037_en.pdf>

United States Government Accountability Office (GAO). 2004. *Environmental Indicators. Better Coordination is Needed to Develop Environmental Indicator Sets that Inform Decisions*. GAO Report GAO-05-52. Washington D.C.: United States Government Accountability Office. < <http://www.gao.gov/new.items/d0552.pdf> >

Uno, K. and P. Bartelmus. 1998. *Environmental Accounting in Theory and Practice*. Kluwer: Dordrecht, the Netherlands.

Weizsäcker, E.U. von, A.B. Lovins and L. H. Lovins. 1995. *Factor Four: Doubling Wealth, Halving Resource Use*. London: Earthscan.

Wernick, I.K. and F.H. Irwin. 2005. *Material Flows Accounts: A Tool for Making Environmental Policy*. Washington, D.C.: World Resources Institute.
< http://pdf.wri.org/WRI_MFA_Policy.pdf>

Xu, X. n.d. *Current International Cooperation on National Accounts in China*. Paris: OECD <<https://www.oecd.org/dataoecd/33/38/36570458.pdf>>.

Yuan, Z. J. Bi and Y. Moriguchi. (2006) 'The circular economy. A new development strategy in China.' *Journal of Industrial Ecology* 10(1-2): 4-8.

Zhu, D. 1998. 'Circular economy and sustainable development in Shanghai.' *Shanghai Environmental Sciences*. 17(10): 1-4.

ANNEX 1

Circular Economy Indicators Study in China

Literature Search

Last updated: April 4, 2006

Prepare a summary note (around 10 pages) on international experience in establishing indicator systems relevant to the circular economy concept

Scope note:

- description of circular economic concept and its parameters
 - identification of indicator systems relevant to the circular economy concept
 - identification and description of international experience
 - keywords: circular economy, material flow analysis, dematerialization, closed-loop, industrial ecology, ecological industrial parks, eco-efficiency, life cycle assessment
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Adriaanse, Albert et al. *Resource flows: the material basis of industrial economies*. Washington, DC: World Resources Institute, 1997, vi, 66 p.

Abstract: This report proposes a way to enlarge our understanding of what sustainable economies require. It constructs a parallel set of national accounts in physical terms using material flow analysis and proposes new summary measures or indicators that can be used with economic indicators to give a more accurate sense of the scale and consequences of industrial activity. The analysis in this report derives from a study of the physical basis of four high-income industrial economies - Germany, Japan, United States, and the Netherlands. The report includes a discussion of the methodology that is used by the authors.

Contents: Executive summary; 1 - Introduction; 2 - Accounting for material flows; 3 - Results, implications, and conclusions; 4 - Next steps; Notes; Data summary; Appendix: German material requirements, Japanese material requirements, Netherlands material requirements, United States material requirements.

Location: 03.01.02, WRI, 1997 **Barcode:** 000644 **Status** (AVAIL)

Ayres, Robert U. and van den Bergh, Jeroen C. J. M. The role of material/energy resources and dematerialization in economic growth theories. Amsterdam, NL : Tinbergen Institute, 2000. Tinbergen Institute discussion paper /TI 2000-068/3.

Abstract: "The nature of energy and material resources in an endogenous growth theory framework is clarified. This involves three modifications of the conventional theory. Firstly, multiple feedback mechanisms or "growth engines" are identified. Secondly, a production function distinguishes between resource use, technical efficiency and value creation. Thirdly, the impact of the cost of production through demand on growth is accounted for. A formal model is analytically solved under a condition of a constant growth rate. Given model complexity, numerical experiments are performed as well, providing relevant insights to the academic and political debates on 'environmental Kuznets curves' and 'dematerialization'."—Abstract

Location: S - Economics /AYR **Status** (AVAIL)

Bartelmus, Peter and Andre Vesper. 2000. Green accounting and material flow analysis: alternatives or complements? Wuppertal: Wuppertal Institute. 28 p.

<http://www.wupperinst.org/Publikationen/WP/WP106.pdf>

Bouman, Mathijs, Heijungs, Reinout and van der Voet, Ester. "Material flows and economic models : an analytical comparison of SFA, LCA and partial equilibrium models." *Ecological Economics* v. 32, no. 2; Feb. 2000; p.195-216

Bringezu, Stefan. (2002) "Material flow analysis—unveiling the physical basis of economies." IN *Unveiling wealth: on money, quality of life and sustainability*, edited by Peter Bartelmus. Dordrecht: Kluwer Academic Publishers, 2002, xiv, 225 p.

Abstract: Does money blur perspectives for a better life? Lifting the money veil from our yardsticks of progress, income and wealth, reveals the trade-offs of economic growth. The book presents new indicators of the social, economic and ecological impacts of our lifestyles and production techniques. The indicators help to identify those responsible for these impacts and account for their accountability in terms of environmental and other ("social") costs. Sustainable development is to bring about long-term prosperity without undermining its natural foundation. For the assessment of the opaque concept we need both, physical impact measures and environmentally modified ("green") indicators of income, capital and output. Peter Bartelmus opens the dialogue between frequently hostile camps of economists and environmentalists, data producers and users, and scientists and policy makers. Together, they may steer us towards a sustainable future.

Location: 18.08.01, BAR, 2001 **Barcode:** 007126 **Status** (AVAIL)

Bringezu, Stefan. *Towards sustainable resource management in the European Union.*

Wuppertal: Wuppertal Institute, 2002. 50p.

<http://www.wuppertal.org/Publikationen/WP/WP121.pdf>

Bringezu, Stefan, Hinterberger, Friedrich and Schutz, Helmut. Integrating sustainability into the system of national accounts: the case of interregional material flows. [s.l.]: The Authors, 1994.

Abstract: Reprint of a paper presented at the International afcet Symposium Models of Sustainable Development. Exclusive or Complementary Approaches to Sustainability; Paris, March 1994 pp. 669-680.

Location: S - Public Policy - Economic Instruments /BRI **Status** (AVAIL)

Bringezu, Stefan and Yuichi Morigushi. (2003) "Material flow analysis." IN *Green accounting*, edited by Peter Bartelmus and Eberhard Seifert. Aldershot, GB : Ashgate Publishing, 2003, xxxviii, 448 p

Abstract: Our cherished economic indicators of income, product, consumption and capital fail in taking a long-term view of social progress. They do not account for environmental deterioration, which impairs the quality of life of present and future generations, and hence the sustainability of development. 'Greening' the conventional national (and corporate) accounts introduces environmental impacts and costs into these accounts and balances. The result is a new compass for steering the economy towards sustainability, which may change not only our main measures of economic performance but also the basic tenets of environmental and resource policies. The book presents path breaking methodological advances and case studies of environmental accounting, and discusses their use in environmental management and policies. In their introduction, the editors provide a critical perspective of historical developments and current debates. For them, green accounting is the best available tool for defining and assessing the environmental dimension of sustainable development. The sustainability of the paradigm may depend on it.

Bringezu, Stefan, Schutz, Helmut. Total material requirement of the European Union. Copenhagen, DK: European Environment Agency, 2001. Technical report /No. 55

Abstract: This report contains the results of the first calculation of the Total Material Requirement (TMR) of the European Union comprising both extraction from domestic sources and imports along with their hidden flows.

Contents: Foreword; Summary; 1. The policy context; 2. Monitoring total material requirement; 3. Data availability for the EU; 4. Total material requirement of the EU; A closer look at the major flows; Comparing TMR in the EU with Japan and the United States; 5. Domestic resource extraction; 6. Resource requirements of the EU in foreign countries; 7. Direct material inputs; 8. Material productivity; 9. Conclusions.

URL: http://reports.eea.eu.int/Technical_report_No_55/en/tech55.pdf

Location: S - Economics /BRI **Status** (AVAIL)

Bringezu, Stefan et al. "International comparison of resource use and its relation to economic growth: the development of total material requirement, direct material inputs and hidden flows and the structure of TMR." *Ecological economics* 51 (1-2, 2004): 97-124.

Abstract: Resource flows constitute the materials basis of the economy. At the same time, they carry and induce an environmental burden associated with resource extraction and the subsequent material flows and stocks, which finally end up as waste and emissions. A reduction of this material throughput and the related impacts would require a reduction of resource inputs. And breaking the link between resource consumption and economic growth would require an increase in resource productivity. Material flow analysis (MFA) can be used to quantify resource flows and indicate resource productivity. In this article, we study the available empirical evidence on the actual (de-)linkage of material resource use and economic growth. We compare resource use with respect to total material requirement (TMR) and direct material input (DMI) for 11 and 26 countries, respectively, and the European Union (EU-15).

Canellas, Silvia et al. "Material flow accounting of Spain." *International journal of global environmental issues* 4 (4, 2004): 229-241.

Abstract: Material throughput is a means of measuring the so-called social metabolism, or physical dimensions of a society's consumption, and can be taken as an indirect and approximate indicator of sustainability. Material flow accounting can be used to test the dematerialization hypothesis, the idea that technological progress causes a decrease in total material used (strong dematerialization) or material used per monetary unit of output (weak dematerialization). This paper sets out the results of a material flow analysis for Spain for the period from 1980 to 2000. The analysis reveals that neither strong nor weak dematerialization took place during the period analysed. Although the population did not increase considerably, materials mobilized by the Spanish economy (DMI) increased by 85% in absolute terms, surpassing GDP growth. In addition, Spain became more dependent on external trade in physical terms. In fact, its imports are more than twice the amount of its exports in terms of weight.

WJR

ConAccount. *Workshop "Quo vadis MFA?" Material Flow Analysis - where do we go? Issues, trends and perspectives of research for sustainable resource use 8.-10. October 2003, Wuppertal: proceedings [various html and pdf].*
<http://www.wupperinst.org/Sites/Projects/material-flow-analysis/u43.html#summary>

Daniels, Peter L. "Approaches for quantifying the metabolism of physical economies: a comparative survey Part II: review of individual approaches." *Journal of industrial ecology* 6 (1, 2002): 65-88.

Abstract: This article is the second of a two-part series that describes and compares the essential features of nine "physical economy" approaches for mapping and quantifying the material demands of the human economy upon the natural environment. These approaches are critical tools in the design and implementation of industrial ecology strategies for greater ecoefficiency and reduced environmental impacts of human economic activity. Part I of the series provided an overview, methodological classification, and comparison of a selected set of major materials flow analysis (MFA) and related techniques. This sequel includes a convenient reference and overview of the major metabolism measurement approaches in the form of a more detailed summary of the key specific analytical and other features of the approaches introduced in part I. The surveyed physical economy related environmental analysis approaches include total material requirement and output models, bulk MFA (IFF (Department of Social Ecology, Institute for Interdisciplinary Studies of Austrian Universities) material flow balance model variant), physical input-output tables, substance flow analysis, ecological footprint analysis, environmental space, material intensity per unit service, life-cycle assessment (LCA), the sustainable process index, and company-level MFA.

Daniels, Peter L. and Stephen Moore. "Approaches for quantifying the metabolism of physical economies: Part 1: methodological overview." *Journal of industrial ecology* 5 (4, 2002): 69-93.

Abstract: This article is the first of a two-part series that describes and compares the essential features of nine existing "physical economy" approaches for quantifying the material demands of the human economy upon the natural environment. A range of material flow analysis (MFA) and related techniques is assessed and compared in terms of several major dimensions. These include the system boundary identification for material flow sources, extents, and the key socioinstitutional entities containing relevant driving forces, as well as the nature and detailing of system components and flow interconnections, and the comprehensiveness and types of flows and materials covered. Shared conceptual themes of a new wave of physical economy approaches are described with a brief overview of the potential applications of this broad family of methodologies. The evolving and somewhat controversial nature of the characteristics and role that define MFA is examined. This review suggests the need to specify whether MFA is a general metabolic flow measurement procedure that can be applied from micro- to macrolevels of economic activity, or a more specific methodology aimed primarily at economy-wide analyses that "map" the material relations between society and nature. Some alternative options for classifying MFA are introduced for discussion before a more detailed comparative summary of the key methodological features of each approach in the second part of this two-part article. The review is presented (1) as a reference and resource for the increasing number of policy makers and practitioners involved in industrial ecology and the evaluation of the material basis of economies and the formulation of eco-efficiency strategies, and (2) to provoke discussion and ongoing dialogue to clarify the many existing areas of discordance in environmental accounting related to material flows, and help consolidate the methodological basis and application of MFA.

EUROSTAT. 2001. *Economy-wide material flow accounts and derived indicators - A methodological guide.* 2000 edition. 85p.

"This guide provides a framework and practical recommendations for establishing material flow accounts and balances and for deriving a set of physical indicators for a whole economy. It offers harmonized terminology, concepts and a set of accounts and tables for implementation. The guide also offers help to compilers on the types of accounts to be implemented first, on data sources and methods and on the interpretation of the derived indicators."

http://epp.eurostat.cec.eu.int/cache/ITY_OFFPUB/KS-34-00-536/EN/KS-34-00-536-EN.PDF

Finland -Ministry of the Environment. Material flow accounting as a measure of the total consumption of natural resources. Helsinki: Ministry of the Environment, 1999, 53 p.

Contents: Principal concepts; 1. Introduction; 2. Consumption of materials in global economy; 3. Monitoring materials consumption; 4. Materials consumption in Finland; 5. Reducing consumption of materials in Finland; 6. Conclusions.

Location: S- Sustainable Development - Indicators /FIN **Status** (AVAIL)

Geiser, Kenneth. Materials matter: toward a sustainable materials policy. Cambridge, MA: MIT Press, 2001, xvi, 479 p.

Abstract: This book argues that the safest and least costly point at which to avoid environmental damage is when materials are first designed and selected for use in industrial production.

Contents: 1. Material incompatibilities; I: Developing Industrial Materials; 2. Developing industrial materials; 3. The economy of industrial materials; 4. Industrial materials and the environment; 5. Industrial materials and public health; II: Reconsidering Industrial Materials Policy; 6. The federal policy response; 7. The performance of industrial materials policies; 8. Reconsidering materials policies; III: Alternative Materials Strategies; 9. Recycling and reuse of materials; 10. Advanced and engineered materials; 11. Renewable materials; 12. Biobased materials; IV: Toward a Sustainable Materials Policy; 13. Dematerialization; 14. Detoxification; 15. A sustainable materials economy.

Location: 09.01.03, GEI, 2001 **Barcode:** 003494 **Status** (AVAIL)

Giljum, Stefan. 2006. "Material flow-based indicators for evaluation of eco-efficiency and dematerialization policies." IN *Sustainable development indicators in ecological economics*, edited by Philip Lawn. Cheltenham, UK: Edward Elgar. Pp. 376-396.

Hinterberger, Friedrich and Luks, Fred. Material flows vs. "Natural Capital": what makes an economy sustainable? Wuppertal, DE : Wuppertal Institute, 1996, 22 p.

Abstract: In the discourse about sustainable development, "constant natural capital" is frequently referred to as a criterion for ecological sustainability. But what is "natural capital"? The concept will be analyzed by presenting arguments in favor of using the term and different versions of sustainability (strong and weak). Subsequently, a critique of the "natural capital" concept is brought forward, from an ecological as well as an economic perspective. Following this critique, the use of material inputs and the material input per unit of service (MIPS) as a measure for the environmental impact potential is suggested. Dematerialisation is understood to be an alternative management rule for sustainability. In conclusion, a change of perspective is proposed. Due to the conceptual and measurement problems associated with the "constant natural capital" criterion (which refers to a stock), it seems more reasonable from a scientific as well from a practical perspective to add flows (i.e. material inputs) to a decision criterion for whether development is sustainable or not.

Location: S - Economics /HIN **Barcode:** 002069 **Status** (AVAIL)

Hobbes, Marieke. "Material flow accounting of rural communities: principles and outcomes in South East Asia." *International journal of global environmental issues* 5 (3/4, 2005): 194-224.

Abstract: The paper develops a system of local Material Flow Analysis that links material flows to issues of land use transition, globalisation and food security. This system (rMFA) is then applied to villages in Vietnam, the Philippines and Laos. The rMFA shows that these villages greatly differ in terms of these indicators, and with that, in terms of risks and future-oriented policies, issues that remain hidden in standard MFA indicators, as illustrated by an MFA application in India. The methodological conclusion is that rMFA offers a good tool for theory-connected insights and cross-country comparisons.

Japan -Environment Agency. Quality of the environment in Japan: 1992. Tokyo: Global Environment Department, Environment Agency, 1992, 658 p.

Contents: State of the environment; Our experiences toward a sustainable society; Recent socioeconomic trends and sustainability; New approaches for increased sustainability; Comprehensive promotion of environmental administration; Air pollution, noise, vibration and offensive odors - present state and measures; Water pollution - present situation and measures; Other pollution - present state and measures; Promotion of environmental health measures; Settlement of pollution disputed and handling or pollution offences; Conservation of natural environment; Global environment and international environmental cooperation; Surveys and research on environment protection; Other environmental administration.

Location: 20.01.00, 4JP, JAP, Qua, 1992 **Status (AVAIL)**

Kandelaars, Patricia P. A. A. H. and van den Bergh, Jeroen C. J. M. “A survey of material flows in economic models.” *International Journal of Sustainable Development* 4 (3, 2001) : 282-303.

Abstract: Various types of economic models address environmental problems. This article examines whether these can be applied to the analysis of material flows. The approaches and research issues relating to the economic analysis of material flows are discussed for each model type, and some examples illustrate how material flows can be integrated in the models at hand.

Korhonen, Jouni, Wihersaari, Margareta and Savolainen, Ilkka. “Industrial ecosystem in the Finnish forest industry : using the material and energy flow model of a forest ecosystem in a forest industry system.” *Ecological Economics* 39 (1, 2001) : 145-161.

Abstract: Industrial Ecology is an industrial environmental management concept with an analogy in the natural ecosystem. In an ecosystem, materials are recycled between organisms, and energy is embedded in the matter of the food chain, while the only external input to the system as a whole is the solar energy. An Industrial Ecosystem is a system where the industrial actors use this natural recycling model and co-operate by using each other's waste material and waste energy flows to minimize the system virgin material and energy input as well as the waste and emission output from the system as a whole. In theory, the economic environment win-win can be achieved as raw material, emission control and waste management costs are reduced through using waste as a resource of production. In this paper, the material and energy flows of the forest ecosystem are considered, and this natural recycling model is used to construct an industrial ecosystem in the forest industry of Finland. Recycling of matter including nutrients and carbon constitutes the basis in the operation of the forest ecosystem as well as in the operation of the forest industry system. The forest industry will use the cycle in these flows as a source of raw materials and energy. An industrial ecosystem is constructed with the flows of matter, nutrients, energy and carbon.

Korhonen, Jouni and Niutanen, Ville. “Material and energy flows of a local forest industry system in Finland.” *Sustainable development* 11 (3, 2003) : 121-132.

Abstract: Forestry, forest, pulp and paper industries provide important cases for environmental and ecological economics and for corporate environmental management, because of the large quantities of flows of material and energy that are derived from the natural ecosystem. Because of the natural capital intensive nature of its activity, the forest industry also offers a fruitful case study for industrial ecology (IE), the practical concern of which is the comparison of material and energy flows of nature to these same flows in economic and industrial systems. In this paper, the concept of an industrial ecosystem is reflected in a typical local forest industry system in Finland, known as a local forest industry integrate. We present a material and energy flow model that can

be used to study forest industry environmental management and for the planning of environmental policies directed to forest industry. Flows of matter (biomass), nutrients, energy and carbon are described, and the waste utilization possibilities are considered. A local forest industry system can be a fruitful case for IE development as the cuttings of forests in Finland are below the renewal rate, material cycles, nutrient cycles and energy cascades are developed and the carbon dioxide (CO₂) binding capacity of the forest ecosystem is maintained. The difficulties and barriers in light of the industrial ecosystem vision of a materially closed local system include the high export rates of paper, energy intensive production and problem displacement in waste utilization efforts. The presented material and energy flow model of forest industry environmental management is compared with a case of a local agricultural and food industry system. For agro-food sector applications, a different emphasis on the flows may have to be adopted than in a forest industry application.

Kytzia, Susanne and Nathani, Carsten. "Bridging the gap to economic analysis : economic tools for industrial ecology." *Progress in industrial ecology* 1 (1/2/3, 2004) : 143-164.

Abstract: A number of approaches have been suggested to combine MFA or LCA with economic analyses in order to build integrated models for development and evaluation of industrial ecology related strategies. This paper provides a systematic review in vision of a comprehensive modelling framework. It is focused on models using Process-based MFA either as modelling framework to integrate economic models or as sub-model within an economic modelling framework. In addition, the possible role of alternative physical models (LCA, SFA and Industry-based MFA) within an integrated modelling framework is discussed. The authors conclude that integrated models should generally include: (i) physical models, (ii) economic input-output analysis and (iii) microeconomic models of behaviour. Future development should aim at developing a "common language" in mathematical formulation as well as underlying theoretical concepts eventually resulting in a tool box of well defined models with clearly specified interfaces.

Location: S - Economics /KYT **Barcode:** 014620 **Status** (AVAIL

Maepaa, Ilmo and Juutinen, Artti. "Materials flows in Finland : resource use in a small open economy." *Journal of industrial ecology* 5 (3, 2002) : 33-48.

Abstract: In this article, the development of natural resource use in Finland during the period 1970-1997 is analyzed. In measuring natural resource use, the concept of total material requirement (TMR) is applied. The focus is on the linkages of resource use with the changing structures of the economy. The linkages are studied using input-output analysis. Using input-output analysis, the TMR is further partitioned into resources used for domestic final use or for total material consumption (TMC) and total material requirement of exports (TME). The analysis shows that TMR has the problem of double accounting: if the TMRs of all countries of the world are summed, then international trade would be accounted for twice in the world TMR, once in imports and once in exports of each country. The TMC concept does not have this kind of defect. In a small, open economy like that of Finland, where the share of foreign trade is large, the difference between the TMR and the TMC is also large. We show that by 1997, the TME comprised about half of Finland's TMR and that the growth of the TMR over the study period has been due to the TME only as the TMC has stayed rather constant.

Matthews, Emily et al. *The weight of nations: material outflows from industrial economies.* Washington, DC: World Resources Institute, 2000, xii, 125 p.

Abstract: This is the second report seeking to document the materials that flow through industrial economies and develop sets of national physical accounts that can be used alongside national monetary accounts. Includes indicators of material flows that complements such economic indicators as gross domestic product (GDP).

Contents: Preface; Acknowledgments; Key Findings; 1. Introduction; 2. Approach and Methodology; The material cycle; Accounting for output flows; What's in and what's out; Characterizing material flows; Data access and quality; The importance of physical accounts in understanding material flows; 3. Study Findings; Total domestic output (TDO); Domestic processed output (DPO); Sector indicators: where do material outflows go?; Dissipative flows; Net additions to stock (NAS); 4. Policy Applications; 5. Next Steps; Notes; Annex 1: Data Summary: National Comparisons; Annex 2: Country Reports.

Location: 03.01.02, WRI, 1999 **Barcode:** 002212 **Status** (AVAIL)

Moll, Stephan, Bringezu, Stefan and Schutz, Helmut. Zero study : resource use in European countries : an estimate of materials and waste streams in the community, including imports and exports using the instrument of material flow analysis. Copenhagen, DK : European Topic Centre on Waste and Material Flows, 2003, 91 p.

Abstract: Objective of this study is to support the development of a Thematic Strategy for Sustainable Use and Management of Resources through the provision of background information, in particular "an estimate of materials and waste streams in the Community, including imports and exports" (Article 8 a 6th EAP) using the method of material flow accounting. It further presents first ideas on how the resource use pattern of the EU can be assessed with regards to priority setting for possible policy measures.

URL: http://europa.eu.int/comm/environment/natres/zero_study_final.pdf

Location: S - Waste Management - Europe /MOL **Barcode:** 010076 **Status** (AVAIL)

Scasny, Milan, Kovanda, Jan and Hak, Tomas. "Material flow accounts, balances and derived indicators for the Czech Republic during the 1990s : results and recommendations for methodological improvements." *Ecological economics* 45 (1, 2003) : 41-57.

Abstract: The economy and the environment are connected through material and energy flows. These flows are the key cause of environmental problems (together with land use and other biological and social factors) and can serve as an indirect indicator of pressure on the environment. The leading method for assessing material flows and dematerialisation at a macroeconomic level was developed during the 1990s by a number of research institutes and organisations. The result of this effort was the guide [Eurostat (2001) 92]. This is a guide for the analysis of the total mass of annual material inputs and outputs for the whole economic system, using accounts, balances and derived indicators of material flows. The manual touches only briefly on the flows between various sectors of the economy. This article describes the application of material flow analysis (MFA) to the economy of the Czech Republic. Relevant indicators were derived on the basis of accounts and balances of material flows compiled for the Czech Republic for 1990-2000. The indicators and analysis of material flows presented here are the first results covering a long time period and a comprehensive set of material flow accounts in a transition economy. The results show that indicators of material flows decreased during the 10-year-period analysed by approximately 30-40%. Material intensity also dropped by 30% (i.e. material efficiency increased by 30%) while the material intensity of other countries such as Germany dropped by 30% in the 15-year-period. Finally it has been possible to demonstrate that economic growth as expressed by GDP has been decoupled from environmental pressure as expressed by material flow indicators. The article proposes further work that should be undertaken in MFA at macroeconomic level in the Czech Republic. In conclusion, recommendations are made on how to improve the methodology used.

Weisz, Helga. Material flow analysis and environmental indicators: the positioning of MFA in the European discussion about environmental indicators. Vienna, AT : Federal Ministry of Agriculture and Forestry, Environment and Water Management, 2001, 15 p.

Location: S - Sustainable Development - Indicators /WEI **Barcode:** 005269 **Status** (AVAIL)

Yuan, Zengwei; Bi, Jun; Moriguchi, Yuichi “The Circular Economy: A New Development Strategy in China.” [Journal of Industrial Ecology](#), Volume 10, Numbers 1-2, Winter/Spring 2006, pp. 4-8(5)

Young, John E. and Sachs, Aaron. The next efficiency revolution : creating a sustainable materials economy. Washington, D.C., : WWI, 1994, 58 p.
Worldwatch paper. 121

Location: 12.07.02, YOUN, 1994 **Status** (AVAIL)

Links:

http://www.chinacp.com/eng/cplinks/ce_links.html
