Controlling Resource Flows for a Sustainable Society

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Abstract

Resource and material flows are the core of today's environmental and social problems. From extraction of raw material to production of goods, to consumption and disposal they cause environmental and social effects – from soil depletion to global warming, from adverse health effects to social conflict. It is vital for a sustainable society to control these resource and material flows and their effects. Various instruments have been designed to this purpose: Material Flow Cost Accounting, Supply Chain Management, Life Cycle Assessement and others. Target is to integrate these instruments in order to achieve transparency on material flows on a corporate, a national and a global level in terms of costs, weight, time and quality, of environmental and social impacts. Starting point could be to widen present corporate internal and external reporting systems and introduce environmental and social data in addition to the so far predominant monetary fiscal information. This widened information basis is prerequisite for a more sustainability (instead of short-term revenue) oriented corporate decision-making and national taxing system, for a lasting regional and customer relationship. In the end global standards to control resource flows and their economic, environmental and social impacts will be essential.

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Keywords: "Mass Balance", "Material Flow Cost Accounting", "Supply Chain and Lifecycle Assessment", "Internal and External Reporting", "Externalities and International Controlling Standards", "Carbon Footprint".

1. Society in Balance

A sustainable society is a society in balance. "In balance" means equilibrium between the satisfaction of human needs and the consumption of natural resources, between extraction and availability of resources, between harvesting and growth, between disposal and carrying capacities, between input and output of resources .

2. Economic and Physical Balance

An economic or financial balance sheet is in balance if assets and liabilities correspond, if the monetary output matches the monetary input.

In physical terms any system is in or out of balance, if the input of material or energy does or does not equal the output. For this type of input-output- or mass-balance the laws of thermodynamics apply: material and energy can neither be created nor annihilated, just transformed. A change in stocks within the system, the increase or decrease of stocks, has to be considered when balancing in- and outputs. Resources that flow into a system, e.g. raw material and energies flowing into a company, go either to stocks or leave the company again as output in terms of products and solid, fluid, gaseous or heat emissions. [1] These resources, material and energy, thus are not "used up" or "consumed" as in popular perception and thus "disappearing". [2] They are just transformed and can be measured in the case of material in their input-output ratio in exact mass units down to atomic weight. Energy carriers like oil, gas, coal etc. can be balanced as any other (raw) material or mass. The specific energy quality though might distinguish and measure various properties such as exergy, discribing the splitting up of energy into useful work and "lost" heat during a working process (energy efficiency), or entropy, discribing the increase of disorder of matter and energy as a measure for the probability or availability to be used and perform work. [3]

Mass and energy balances are the nucleus for the analysis of human impact on the environment. They quantify the extraction of resources (material and energy input) for human purposes on one side and the corresponding output in terms of products or emissions out of the considered system on the other side. Mass balances extended to the notions of exergy and entropy might be applied to our global system, but also to a production machine in action, a product in use or a plant in operation. [4]

The material output of one system, is the input to a next system, thus creating a (supply) chain of material flows from one input-output-system to the next, e.g. from one production company to the next, starting with a first extraction from the global system and ending with a final disposal in the global system.

Material flows in management science are followed up in-company by Material Flow Cost Accounting (MFCA) from procurement to sales or disposal, by Supply Chain Management (SCM) from supplier to customer, and in environmental sciences by Life Cycle Analysis (LCA) from "cradle to grave".

Input-output-mass-balances for all points of material transformation between material movements can be the common denominator and link between these various approaches. But input-output mass ratios as nucleus of these types of flow analysis only form the basis and starting point of sustainability analysis. The quantitative input-output material and energy account has to be completed by qualitative considerations: Under what human or environmental conditions are raw materials extracted, processed and transported? What impacts at every point of transformation do result in terms of. environmental or social damage? Which entropic or efficiency effects have to be considered? What are the effects of dissipation and

disposal to ground, water or air, to flora and fauna along the flow of material?
The extraction, transformation and transportation of raw materials and materials by human action are the core of our todays environmental problems: depletion of land, water and air, climate change, loss of biodiversity etc. It therefore seems appropriate to gain closer insight in and transparency of material flows on a global, on a regional and on a company level. The above instruments, only developed in the last two decades, might be used to this purpose, also by combining and integrating their specific strengths.[5,6]

3. Material Flow Cost Accounting (MFCA) to Integrated Material Flow Analysis

MFCA has been developed in its first stage (s. ISO 14051 [7]) to trace material flows primarily within a company. MFCA monitors material flows within a company in order to increase material efficiency in physical as well as in monetary terms. By assessing material flows in physical and monetary units MFCA is qualified to be linked to customary economic company reporting and enterprise resource planning (ERP, e.g. by SAP) systems. ERP-Systems as MFCA also are based on the basic structure of cost centers (= input-output-centers, = centers of cost and mass balance, in MFCA terms: quantity centers) and movements between these centers of transformation.[8] MFCA thus can bridge the gap between an economic view (of present ERP-systems in monetary units) and an environmental view (in physical units) of corporate processes. Today in corporate reality these two views are separated. The Sustainability Department depends largely on physical data to insure compliance with e.g. emissions regulations. Corporate strategic decision making on the other hand is determined mainly by the economic view in monetary terms. As monetary effects of environmental impacts are not consequently followed up and transparent, the links between the two generally are not evident. MFCA can show these links, e.g. MFCA accounts for the physical amount of waste fractions and flows as well as for the total costs of these fractions and flows.
But MFCA can also be extended across the company limits along the supply chain. While Supply Chain Management (SMC) traditionally focuses on the number of delivered quality parts, and on time and price (cost), with a tendency to neglect material efficiency or environmental and social effects, MFCA concentrates at first on physical amounts (weight delivered and lost) and price/cost (delivered and lost). MFCA in a further step after the pure quantitative assessment of physical and monetary amounts is designed though to enlarge its view to qualitative environmental or social effects of material flows, but in practice quite often concentrates on material and energy efficiency, neglecting the sustainability aspect. Life Cycle Assessment (LCA) on the other hand is mainly concerned with environmental and social effects along the flow of material from the very beginning (cradle, meaning extraction of resources) to the very end (grave, meaning final disposal), with a tendency to neglect economic aspects in financial or monetary terms. LCA as applied today such covers the widest range. SCM faces the range between close suppliers and customers and MFCA in practice mostly is restricted to an in-company view. After a separate elaboration of the above approaches in the past first combinations emerge. Next steps will be the integration of MFCA, SCM and LCA by integrating the economic, the social and the environmental viewpoint targeting sustainable material flows for a sustainable society. This means more transparency of material flows simultaneously in terms of cost, weight, quality, time, environmental and social effects from source to sink.
The predominant quantitative economic approaches (SCM) have to be accompanied by qualitative environmental and social appraisals from LCA and vice versa. MFCA, composed of input-output-mass balances for centres of material transformation (quantity centers) and material movements between these centers can be the link between the two.

4. From Integrated Material Flow Analysis to Internal Reporting

The purpose of these integrated appraisals of material flows is to prepare a comprehensive basis for reporting and decision making. This firstly applies to in-company decision making. Presently corporate information systems, like ERP-systems, in general do rarely include sustainability relevant information, even if related to costs or risks. They are treated, if at all, in separate sustainability reports and as such are mainly used to ensure compliance or for PR-intentions. They generally do not appropriately reach top decision making. If internal reporting systems do not contain appropriate sustainability information the corresponding strategic decisions of top management can not appropriately reflect environmental or social matters. If for example management information systems do not contain information on carbon footprints along the life cycle of products corporate management necessarily neglects carbon footprint considerations in policy or operative decisions. The information basis for decision making on all corporate levels, derived from material flow analysis, suitably condensed, should contain essential data on material or energy efficiency, on emissions, on environmental or social effects and risks, on criticality of substances, on carbon or water footprint and biodiversity impacts etc.

5. From Material Flow Analysis to Specific Reports: The Example Carbon Footprint

According to the specific situation of a company in-depth assessmets and reports will be required in respect to the companies specific impacts. In the case of e.g. renewable energy plants corporate manangement might be advised, considering competition to fossil energy plants, to control and demonstrate emission advantages. Management also might be interested to further reduce emissions along the chain of command. To this purpuse it uses MFCA for a first assessement of material flows. The following example in Fig. 1 shows the simplified material flow of a Biomass Combined Heat and Power (CHP) Plant in Germany and its Carbon Footprint derived from MFCA. The analysis started with the breakdown of all input-output-materials, their physical amounts and costs, for the various quantitiy centers (points of material processing) along the material flow from the forest to the disposal of ashes. On the basis of the GHG Protocol and GEMIS [9] considering the relevant inputs, fossile energies, the corresponding emissions were calculated. In order to determine the overall Carbon

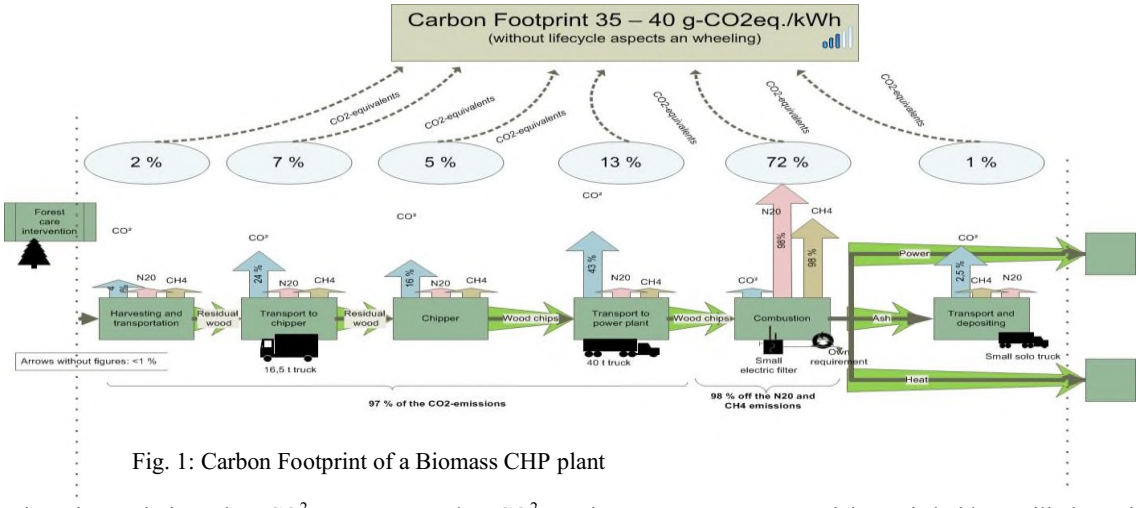
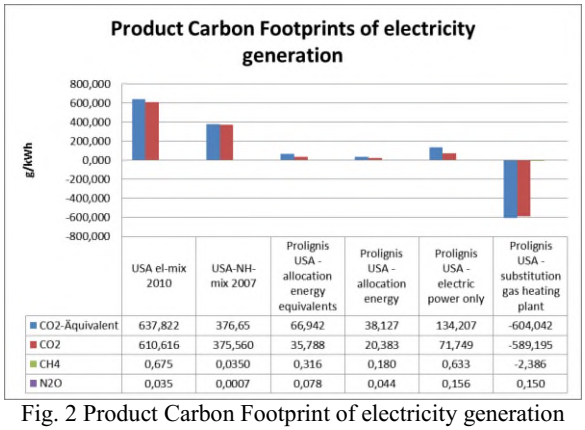


Fig. 1: Carbon Footprint of a Biomass CHP plant

Footprint other emissions than CO^2 were converted to CO^2 equivalents. Results show that 97% of pure CO^2 emissions are produced before combustion of forest wood residues in the power plant. But 72% of the overall Carbon Footprint come from combustion in the power plant mainly caused by CO^2 equivalents from N2O and CH4. Fig. 1 shows the main drivers of Cabon Footprint and as such the main levers for emissions reduction (Carbon Management). As a further result it was shown that, using the Substitution Method for the Carbon Footprint calculation, the analysed Prolignis biomass technology was able to reduce GHG emissions compared to a the typical US electricity mix in 2010 (s. Fig. 2).[11] As the CHP energy generation makes use not only of exergy but also of anergy (s. [3]), the latter use of "waste" heat can substitute e.g. a former gas heating system and gets credits for this additional emissions reduction, -CO^2-neutrality of biomass energy assumed.



	USA el-mix 2010	USA-NH-mix 2007	Prolignis USA - allocation energy equivalents	Prolignis USA - allocation energy	Prolignis USA - electric power only	Prolignis USA - substitution gas heating plant
CO2-Äquivalent	637,822	376,65	66,942	38,127	134,207	-604,042
CO2	610,616	375,560	35,788	20,383	71,749	-589,195
CH4	0,675	0,0350	0,316	0,180	0,633	-2,386
N2O	0,035	0,0007	0,078	0,044	0,156	0,150

Fig. 2 Product Carbon Footprint of electricity generation

As for the above example of CFP, MFCA also can be the starting point for other in-depth analysis assessing water footprint, heat or noise emission, biodiversity impacts, criticality of product material etc.

6. From internal to external reporting

An adequate internal information and reporting system not only is basis and prerequisite for internal decision making but also for external reporting addressing various external stakeholders according to their specific interest: customers, communities, local residents, investors, taxing authorities etc. A long-term sustainable relationship between a company and its stakeholders will depend on mutual acceptance and transparency. Investors have learned to calculate environmental and social risk and benefit data and will increasingly ask for these data in reports. Taxing authorities are only able to direct fiscal steering towards sustainable development if their decision process is based on sound sustainability information in corporate reporting. So far worldwide fiscal steering primarily reflects pure financial reporting data.

Standards for financial reporting concerning price, cost and revenue have been developed and internationally accepted (IAS, US-GAAP, IFRS) for many decades. Corresponding standards and methodologies for the definition and reporting of external costs ("externalities") are not yet established and acknowledged. To agree on standards of external "integrated" reporting including the accounting for external environmental and social cost, analogous to accepted and applied internal accounting standards, will an vital challenge of the future. [12]

Without the proper reporting and assessment of financial, social and environmental costs and benefits of material flows caused by human activity there will be no sustainable resource management, no control of regarding or disregarding carrying capacities, there will be no sustainable society. These costs and benefits have to be expressed as well in monetary terms as in non-financial terms. Non-financial information though is much less likely to play a major role in corporate decision making as monetary information. The logic of perception and decision-making, the language, rewards and sanctions in corporate management, they all depend on and are linked by a common denominator: the expression in monetary units. In order to reach management awareness it therefore is essential to express sustainability matters as far as possible in monetary terms. This also applies to the afore mentioned externalities or "social costs". As long as there exist no standards or agreements on how to price externalities (as in the case of internal prices and costs) external effects, damages or benefits, will not be priced, will not be internalized, will not be taxed - positively or negatively. The external effects and their often latent social costs will be socialized. Market forces will have no grip.

The pricing of emissions by the instrument of emission trading might be a major breakthrough in order to start valuing externalities, social costs or global "commons", such as air (atmosphere), water (ice) and soil in monetary units. Again: as long as sustainabilty arguments are not

expressed in monetary terms they will hardly affect corporate and neither political decision making. [13] But in order to valuate and price external effects, costs as well as benefits, a proper standardized corporate external reporting system on in- and outputs of material will be necessary.

As mentioned before endeavors are on their way to promote an integrated corporate reporting including externalities and their monetary valuation. But these undertakings are far from global agreement, standardization or acceptance. [14,15]

In sum: Transparency of material flows and their side effects including their monetary valuation on a corporate, on a national and a global level therefore seems to be a precondition of sustainable development.

7. From Reporting to Controlling

Transparency -with the help of reporting systems- again is only the first requirement for the governance of material flows. Transparency is meaningless if not followed up by steering or corrective action. In management terms corrective action is introduced by controlling cycles: Setting targets, planning and implementation of programs and measures, evaluation of results, corrective action (Plan-Do-Check-Act- or PDCA-cycle). This means that insuring a sustainable future demands much more then transparency of past and present developments. It means that targets have to be accepted and clear, people involved have to be motivated to take action, progress and setbacks have to be observed and corrective action has to be introduced and in in time. [16] Today the first step, to agree on targets of sustainability is not yet achieved, not on a global level, seldom on national or corporate levels.

As resources today flow globally, an international, global controlling system or PDCA-cycle quantifying and monetizing man-made material flows will be necessary, including international controlling bodies established with sufficient power of sanction in the interest of global sustainability. International accepted principles and standards (e.g. Global Compact, GRI, ISO norms) can be and are an important step in this direction.

Local regulations might mitigate the depletion of sources and sinks locally. But in todays global markets as soon as corporate economic competitivness is effected companies and investors drift globally to low cost areas with less regulation. In the end global regulation and control therefore will be indispensable. But as this end is not in sight uni- or bilateral agreements by major players, - EU, USA, China etc. - might convince others to join.

8. References

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