Increasing Resource Use Efficiency without Problem Shifting

Issues of resource use, resource scarcity and resource efficiency are currently gaining renewed economic and political momentum both at the national and the international level. Human-caused material and energy flows are one of the key causes of both social and environmental problems today, and can serve as an indirect indicator of pressure exerted on the environment by humans.[1 2 3 4] For a more sustainable use of natural resources in Europe, it is vital to understand current as well as past patterns of resource use within as well as across countries. This is especially true with regard to the European enlargement, as levels of material and resource use of the new member states might undergo changes following their accession. The notion of industrial or socio-industrial metabolism has been introduced as a concept to describe the use and transformation of resources and the flows of materials induced by economic activities. A rapidly expanding field of research has emerged that serves to measure and analyze the socio-industrial metabolism of national economies using Material Flow Analyses (MFA) and related indicators.[5] Material flows cross the functional boundary between the environment and the economy and can be regarded as indirect pressure indicators for environmental degradation.

For example, the extraction of primary material, which is at the start of the production-consumption chain, is associated with environmental pressures such as landscape disruption and subsequent impacts on the water cycle and biodiversity. In addition, since matter can neither be created nor destroyed, the higher the amount of material input into the economy, the higher will be the ultimate output in the form of emissions and waste as both materials and energy.

What was done?

This case study explored potential options to decouple overall levels of resource use from economic growth by analysing economy-wide material flows and driving forces and by using models to examine technological and institutional potentials for minimizing resource use and waste generation for selected products. The work aimed to derive insights into the driving forces of resource use for specific countries, as

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well as addressed the question of what sort of development one might expect with regard to the further technological and socio-economic convergence of the Czech Republic (chosen for study as one of the new member states of the EU) and the EU-15.

This was done using ISA methods and tools that also support the detection and assessment of environmental problem shifting (for instance moving production outside the EU) associated with increased materials and resource productivity. The case study developed a multi-level analytical framework for the analysis and assessment of the socio-industrial metabolism, which incorporated the elements of the ISA-cycle.

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The analysis and the assessment of the economy-wide material flows were done on three levels: the macro-, the meso- and the micro-level. The purpose of this analysis was to provide a complete description of the situation of the material and resource use as well as the productivity. The macro-level refers to the economy-wide or regional scale, the meso-level applies to the sectoral scale, while the micro-level relates to the product and/or producer level. On the macro-level, the focus was on:

- Germany, as a representative of an old member state of the EU;
- the Czech Republic (CZ), as a representative of a new member state; and
- the EU-25, while distinguishing between EU-15, as a benchmark representing the established Western European part of the EU, and the new member states.

The analysis across these three levels (macro, meso, micro) was undertaken in order to

a) capture the drivers for resource use at and across the different levels and
b) explore technological and institutional potentials for minimizing resource use at these levels and how these measures feed into and interact with the next higher levels.

In order to capture the essentials of the system, different sub-case studies were developed at each level, focusing on relevant resource and product groups. The scope of the study was discussed with expert groups and stakeholders.

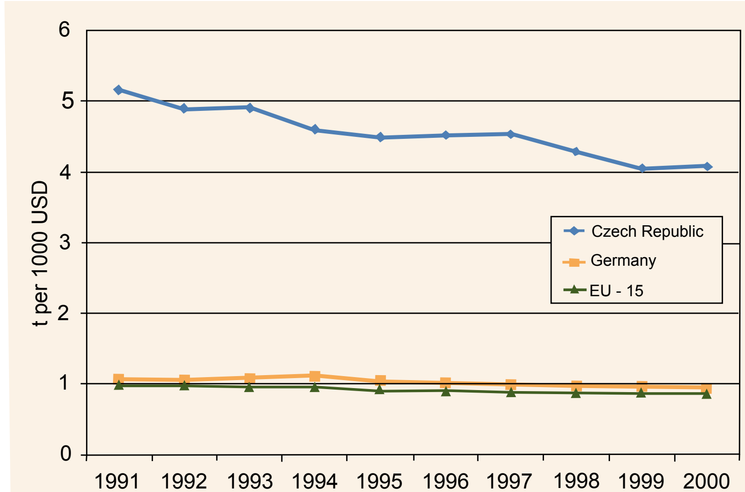
The main methodology used on the macro-level was a comparative analysis of the aggregated indicators *Direct Material Input (DMI)* and *Total Material Requirement (TMR)* and their components over time. The DMI measures the direct input of materials for use into the economy, i.e. all materials that are of economic value and are used in production and consumption activities. DMI equals domestic extraction used plus imports. The TMR measures the total 'material base' of an economy in terms of primary materials. TMR equals domestic extraction used plus unused domestic extraction plus imports plus indirect flows associated with imports.

Results

At the *macro-level* the modelling focused on material and resource use of the EU-25 with a special focus on the Czech Republic. The driving forces of material and resource use of the Czech Republic were analysed by looking at the past and current trends of resource use in the Czech Republic as compared to Germany and the EU-15. This analysis served as a basis for developing alternative scenarios in conjunction with the case study on environmental technological change (see pages 35 - 38).

Altogether, the analysis revealed that the material and resource basis of the Czech Republic underwent significant changes in the 1990s (see graph on the right). Most of the dynamics tend towards a higher similarity in terms of material use, resource requirements and related productivity to the old member states of the EU, probably due to a convergence of production technologies and use patterns in industry and households. At the same time, the volume and structure of the material and resource input of the Czech Republic resembles the German pattern to a higher degree than the EU-15 average, despite the fact that the German GDP is much higher. This implies that the physical structure of both economies is rather similar; for instance, with regard to overall material and resource use per capita, but also with respect to the direct use of biomass, the disproportionate use of brown coal, a comparable level of construction mineral use, and a high dependence on metal resources for manufacturing. The degree to which future development of the Czech economy will continue towards lower material and resource use and further increase of resource efficiency will critically depend on whether the major trends will follow the historical German path or orientate more towards the average EU-15 performance.

At the *meso-level* the focus was on the PGM (platinum group metals) system, with a link to the work done within the hydrogen case study (see pages 31 - 34). In the scoping stage PGM flows to Europe from the rest of the world, as well as within Europe were analysed. This included the identification of the major industries and product groups driving the use of PGM in Europe, as well as the environmental pressures associated with the production and use of PGM. Among the different industries the automotive industry was identified as the single largest user of primary PGM as well as the source of the largest losses of PGM in the system (due to exports of cars). In addition the issue of problem shifting was highlighted, as the introduction of automobile catalytic converters led to a reduction of diffuse air pollution in Europe on the one hand, but at the same time the increased demand for primary PGM is linked to increased environmental pressures (e.g. mining wastes and atmospheric emissions) at the production sites in Russia and South Africa in particular. The experimenting phase thus focused on the automotive industry in particular, modelling the future development of the European passenger car fleet as well as conducting an *ex-ante* assessment of introducing fuel cell vehicles based on PGMs. In addition technological and institutional potentials were explored to minimise the environmental pressures associated with the production and use of PGM. In the case of passenger cars, increasing the recycling rate of catalytic converters was found to be an effective measure to minimie losses and reduce the dependency on primary PGM. At the same time, the demand for cars also has a decisive influence, as potentials for recycling are limited in the case of a physically growing stock of products when demand exceeds the generation of waste. For the *ex-ante* assessment of fuel cell vehicles, it was shown that the widespread introduction of fuel cell vehicles requires important technological improvements to reduce the PGM content of the fuel cell stack and in order to reduce pressures on reserves



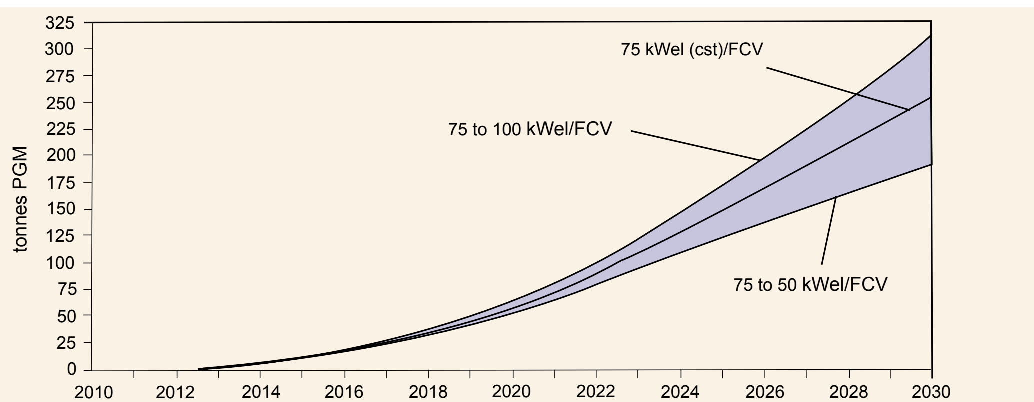
Material intensity (DMI per 1000 US $) Czech Republic, Germany, EU 15, 1991-2000 and the environment (see figure below). In addition, independently from technological progress, the basic design of future fuel cell vehicles will have a large influence on the total PGM requirements. As the power of the vehicle seemed to be a key driver influencing the PGM content of the fuel cell, developments towards lighter vehicles could present a viable option to reduce environmental pressures.

The dematerialisation of the car was thus a further case study that was taken up at the *micro-level*. Here the trade-off between different substitution strategies was shown (e.g. aluminium vs. steel) and different potentials for minimizing resource use associated with the production of cars were explored. Among these, radical changes in product design (e.g., towards lightweight cars) were shown to have the greatest potential for minimizing overall resource use.

Increasing resource productivity and life-cycle-wide dematerialisation of products and services is a key strategy to sustain the environmental basis of economy and society. The example of cars shows that synergies between materials reduction and climate protection can be combined – a happy outcome, which is probably also beneficial for innovation and competitiveness.

Lessons learned

ISA by definition allows for a more integrative, multidisciplinary and system-wide approach and therefore elements and links can be captured that traditional mono-disciplinary assessments fail to incorporate. Such a system-wide and multi-level perspective is especially important for detecting problem shifting and for *ex-ante* assessment, for example when new technologies are being pushed (e.g., fuel cells, biofuels) and the consequences of such a development cannot yet be observed from past developments. The experience from the work conducted has shown that it is not only possible but necessary to repeat this type of case study for other product groups/materials in order to get a better understanding of the complexities of the socio-industrial metabolism. ISAs of this type would also bring invaluable insights for other emerging technologies.



Platinum cumulative primary input for a given FCV introduction scenario and for different evolutions of the fuel cell stack power

[1] Schmidt-Bleek, F., 1993. *Wieviel Umwelt braucht der Mensch? MIPS – Das Maß für ökologisches Wirtschaften*. Birkhäuser Verlag, Berlin, Boston, Basel.

[2] Ayres, R.U., Simonis, U.E. (eds.), 1994. *Industrial Metabolism: Restructuring for sustainable development*. UNU Press, Tokio.

[3] Weizsäcker, E.U. and Lovins, A., (1997). Factor Four: doubling wealth – halving resource use. Earthscan, London.

[4] Bringezu, S., (2002). Towards Sustainable Resource Management in the European Union, Wuppertal Papers 121, Wuppertal.

[5] Bringezu, S., Schütz, H. and Moll, S., (2003). Rationale for and Interpretation of Economy-Wide Material Flow Analysis and Derived Indicators. *Journal of Industrial Ecology* 7 (2): 43 - 67.

Further Reading

van de Sand, I., Markosova, K., Kovanda, J., Schütz, H. and Bringezu, S. (2007): Comparison of material use and resource intensity of the Czech Republic, Germany, EU-15. Analysis of the input structure and major trends of the physical economy between 1991 and 2000. MATISSE Working Paper 13. Available at: www.matisse-project. net