CREATING AND ADAPTING JOBS IN EUROPE IN THE CONTEXT OF A SOCIO-ECOLOGICAL TRANSITION

CORNERSTONES OF THE MATERIAL DIMENSIONS OF THE EU ECONOMY

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Abstract

This Working Paper presents key parameters (cornerstones) for the material dimensions of the EU27 economy. In 2005, 5.5 billion tonnes of material were extracted from the European environment and net imports amounted to 1.2 billion tonnes. In total, including roughly 1 billion tonnes of recycled material and excluding exports, the EU27 processed 7.7 billion tonnes of material. While 3.3 billion tonnes were used to build and maintain stocks, 4.9 billion tonnes were emitted into nature in 2005. Amongst these flows, biomass (28% of processed material), fossil fuel carriers (26%) and construction minerals (39%) play major roles due to the quantities involved, environmental pressures and interdependencies between flows. In the context of the socio-ecological transition, which is characterised by planetary boundaries and (sooner or later) resource constraints, these flows will have to be reduced significantly. At present, no economic model either currently available or in sight interlinks with environmental models in a two-way manner. To partly deal with this deficiency, we propose to use the simple material-based model presented here to enable discussions on the physical feasibility of economic model outcomes, be it for the past or for scenarios concerned with the socio-ecological transition.

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1. Scope of this report

This paper is a deliverable of Work Package 1 of the NEUJOBS project on "Cornerstones of the material dimensions of the EU economy". The objective of NEUJOBS is "to analyse future possible developments of the European labour market(s) under the main assumption that European societies are now facing or preparing to face four main transitions that will have a major impact on employment" (NEUJOBS, 2013). The so-called socio-ecological transition (SET) is one of these four transitions, and essentially refers to a shift in the material and energetic flows through societies. To this end, the paper provides an appraisal of one specific year.

Specifically, the original Description of Work (DoW) requirements are:

> "Task 5: Calculating cornerstones of the material dimensions of the EU that meet ecological policy targets under different global scenarios (D1.3)
>
> The simple material flow model of EU27 will be used under different global scenarios as framework conditions – especially concerning the areas and level of international trade.
>
> Specifically it will be used for the following purposes:
>
> - The socio-ecological transitions that meet environmental targets will need to stay within certain limits. The model can be used to quantify cornerstones of such a physical economy. Cornerstones might be e.g. energy consumption (level and mix), consumption of construction minerals and efficiency of production in certain areas. Various WPs will develop policy options. With the model, these options can be tested if they hinder or foster the socio-ecological transition.
> - During a socio-ecological transition many processes to a high degree, are uncertain. Therefore specific improbable but possible situations will be identified. For these, one simple relations between environmental, technological and social change will be established. With such an approach insights can be generated and questions for consideration by other Work Packages can be raised."

However, in the course of the NEUJOBS progress report, a change to the DoW requirements was proposed and accepted by the European Commission:

> "Therefore, we propose to modify deliverables:

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- update of D1.2 WP: Scenarios taking into account results of WPs2-8 as well as partial results of WPs11-19;
- a new Working Paper SET and evolving nature of labour, which will be an update of material from D1.2
- correspondingly reduce resources for deliverable D1.3 WP: Cornerstones of the material dimensions of the EU economy. This will be achieved through building on an existing model calculation that combines economic and environmental variables rather than developing a model of the physical economy."

Though resources were reduced, it still was feasible to develop a "simple" model of the physical economy and apply it to the year 2005. Empirical data on domestic extraction (DE) and the physical trade balance (PTB) were taken from the Institute of Social Ecology database (data will be published in Schaffartzik et al., forthcoming). All other data are taken from literature and were used to model the flows through the EU economy.

2. Introduction

Since the notion of sustainability began to gain influence in the environmental discourse, in around 1990, the features of this discourse have changed remarkably. Under the notion of sustainability, the toxicity of some dangerous substances was no longer seen as the main contributor to society's pressure upon the environment. The focus moved from the output side of the production system to a complete understanding of the physical dimension of the economy. From that point on, the economy was conceptualised as an activity – extracting materials from nature, transforming them, keeping them as societal stock for a certain amount of time and, at the end of the production-consumption chain, disposing of them once again in nature. It has been recognised that environmental problems can arise at every step in this process. Furthermore, it has been understood that it is not only problematic substances, but also problematic amounts of matter set in motion by societal activities, that result in environmental problems.

These new insights have prompted new approaches to environmental accounting focusing on the biophysical dimensions of socio-economic activities in a comprehensive and integrative manner. In the early days of methodological developments, the decision was taken to develop an accounting framework analogous to national accounts. While national accounts describe economies in terms of monetary units, a physical or material perspective uses physical units like tonnes or joules. Both accounting frameworks are consistent in themselves. In the case of material accounts, the accounting applies the same understanding of system boundaries as national accounts and follows the physical law of conservation of mass.

When discussing socio-ecological transitions, it is useful to consider changes in both the monetary and the physical economy. The physical economy will have to obey the same physical laws throughout all phases of the transition. Since the economic system is not only embedded in the larger environmental system but is also completely dependent on it, both as a source of inputs and as a sink for the matter or energy transformations required by economic activity (Pollitt, 2010), economic models should only allow for developments that are feasible in physical terms. The discourse on such a comprehensive integration of the environment into economic modelling has just begun. Since no economic models are available yet that interlink with environmental models in a two-way manner, we present a simple material-based model that enables a discussion of the physical feasibility of economic model outcomes.

Against this background, the paper provides a rough estimate of the material dimensions of the EU27 for the year 2005. Aside from discussing economic model results for the recent past, the simple model underlying the calculation of key parameters[1] (cornerstones) allows for the calculation of consistent sustainability-oriented scenarios. The key parameters of such a material scenario can be used to discuss economic model results for similar sustainability-oriented scenarios.

The paper demarcates the geographic area that was investigated and describes relevant methods, datasets and assumptions. It presents the results for the key parameters of the material dimensions of the EU economy, and finally formulates key conclusions that can be derived from the results.

3. Territorial coverage

The EU27 is a political and economic union that started with six countries (Belgium, France, West Germany, Italy, Luxembourg and the Netherlands) and experienced five enlargement phases up to 2005, in 1973 (Denmark, Ireland and the United Kingdom), 1981 (Greece), 1986 (Portugal, Spain), 1995 (Austria, Finland, Sweden) and 2004 (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania and Malta). The calculations presented in this paper are based on country data of the EU27 countries as listed in Table 1.

Table 1. EU27 countries and their average population in 2005

Country	Average population in 2005
Belgium	10,478,617
Bulgaria	7,739,900
Czech Republic	10,211,216
Denmark	5,419,432
Germany (including former GDR)	82,469,422
Estonia	1,351,231
Ireland	4,159,914
Greece	11,103,965
Spain	43,653,155
France	63,001,253
Italy	58,607,043
Cyprus	738,540

[1] The word "cornerstone" is associated with something static. In contrast, the term we are looking for should hint at something that changes over time, i.e. that has a more dynamic characteristic. For this reason, the word "cornerstone" in this paper is replaced by "key parameter".

Latvia	2,238,799
Lithuania	3,322,528
Luxembourg	465,158
Hungary	10,087,065
Malta	403,834
Netherlands	16,319,868
Austria	8,227,829
Poland	38,165,445
Portugal	10,503,330
Romania	21,319,685
Slovenia	2,000,474
Slovakia	5,372,807
Finland	5,246,096
Sweden	9,029,572
European Union (27 countries)	492,024,171

Source: Eurostat (2013).

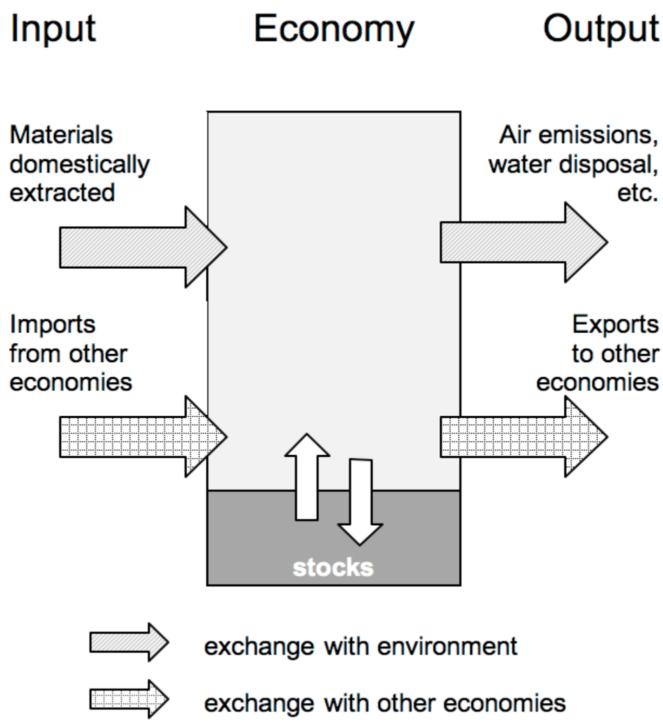
4. Concepts, methods and data sources

4.1 Material flow accounts

The most important source of data on material consumption in the European Union are material flow accounts. During the last years, material flow accounting (MFA) has emerged as an important tool in monitoring socio-economic resource use.

Economy-wide material flow accounts provide consistent information on the overall material inputs into national economies, changes in material stocks within the economic system, and material outputs to other economies and to the domestic environment of the respective economy (Figure 2). Economy-wide MFAs cover all solid, gaseous, and liquid materials, except for bulk water and air; the unit of measurement is tonnes (i.e. metric tonnes) per year. Similar to the system of national accounts, material flow accounts serve two major purposes. The economy-wide material flow accounts (EW-MFA) describe the interaction of the domestic economy with the natural environment and other economies in terms of flows of materials. Such detailed accounts provide a rich empirical database for numerous analytical studies. The aggregate accounts are also used to compile different extensive and intensive material flow indicators for national economies at various levels of aggregation. Economy-wide MFA can therefore be seen as a satellite system to the system of national accounts (Eurostat, 2009; OECD, 2008; Weisz et al., 2007). Thus the economy is demarcated by the same conventions that national accounting systems use (resident units). In material accounting, inputs to the economy cover extractions of materials (excluding water and air) from the natural environment and imports of material products (goods) from other economies. Material outputs are disposals of materials in the natural environment and exports of material products and waste to other economies. Except for net additions to stocks in the accounting system, flows within the economic system are not considered.

Figure 1. Scope of economy-wide material flow accounting (MFA)



Source: Eurostat (2012).

4.2 Classification of material categories

Aggregated economy-wide material flow indicators allow monitoring of the material use of national economies in a comparable, transparent and comprehensive way. To identify the driving forces of national material use patterns and to further evaluate progress concerning dematerialisation and sustainable use of resources, however, detailed material flows, rather than highly aggregated indictors, should be examined (Commission of the European Communities, 2003; Ayres et al., 2002; Femia et al., 1999). Such a detailed analysis in turn needs to be based on a consistent classification.

The classification of material categories and the level of detail according to which we carry out our analysis follow specific guiding principles. First, the level of detail must be justified by the data quality (Weisz et al., 2004). Second, the level of detail should not impair the strength of material flow analysis in providing an overall picture of economy-wide material flows. Third, the classification should be consistent and meaningful in terms of physical and chemical properties, economic use, and environmental pressures associated with the primary production of the materials.

According to these guiding principles, the following classification of material flows was developed and is presented here for the main material categories and the sub-categories used for the physical model of this paper.

Table 2. Classification of material flows

Main material category	Sub-categories
Biomass	Primary crops Crop residues Fodder crops incl. grassland harvest Grazed biomass Wood Fish capture, crustaceans, molluscs and aquatic invertebrates
Fossil energy carriers	Hard coal Brown coal / lignite Peat Crude petroleum (incl. NGL) Natural gas
Metals (content)	Iron ore Copper Nickel Bauxite Zinc Lead Tin Chromite Manganese ore Silver Gold Tungsten Palladium Platinum Other PGM Ilmenite and titaniferous slag Rutile
Waste rock	Total waste rock
Industrial minerals (gross ore)	Asbestos Gypsum Fluorspar Salt Phosphate Potash Feldspar Barite Boron Graphite Quicklime Soda ash Industrial sands Kaolin Bentonite Fullers earth
Construction minerals	Limestone for cement production Sand and gravel

4.3 Key parameters of the European economy

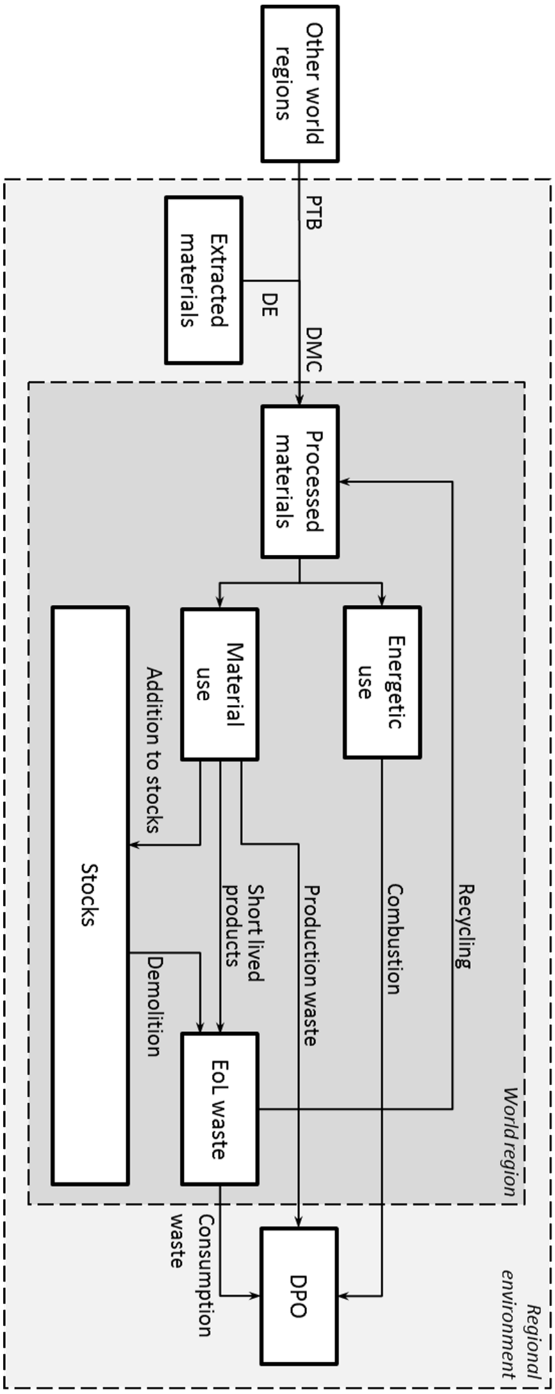
To identify the key parameters of the EU economy, we developed a simple model that calculates various steps from the input to the output side of the material flow accounting framework. On the input side, we use quantitative information on the extraction of materials by type (sub-categories). Data on material extraction for all EU27 countries are available by 40 different material groups in tonnes/year and for the year 2005 (the most recent year when several data quality checks were performed). At an aggregate level, we distinguish six main material groups: biomass, fossil energy carriers, metals, waste rock, industrial and construction minerals. The simplified socio-metabolic flow chart in Figure 2 shows the flow of these materials through the global economy. We start with the extraction and the physical trade balance with other world regions (in the case of Europe, these are net imports). These flows, together with the recovered and recycled material, add up to the sum of processed materials. For the following use phase, two distinctions need to be made which are of high relevance for the flows through the economy.

The first distinction is whether a specific material is used as an energy carrier for energetic use or as raw material for other processes (material use). Energy-rich materials like wood, coal or oil are converted into technically useful energy by combustion. This applies to the largest fraction of all fossil materials (only about 5% of fossil energy carriers are used in material applications such as plastics) and some biomass (e.g. wood fuel). But agricultural biomass, which is used to feed humans or livestock, also has to be considered as an energy carrier as it is converted into metabolic energy through katabolic processes in the bodies of humans and livestock. All fossil and biomass materials used as energy carriers are converted into gaseous emissions (mainly CO2) and other residues (combustion residues, excrements). None of these residues can be recycled in the sense that they can be used again for the original purpose.

The second distinction applies only to the non-energy share of material inputs and concerns the duration of life. We need to distinguish between materials which are used within one year and materials which remain in the socio-economic system for a longer period of time and thus add to global stocks of artefacts. Products consumed within a year directly become end-of-life (EoL) waste and are potentially available for recycling after use. Typically, these are consumer goods like packing, hygiene products, newspapers, batteries, etc. In contrast to these consumables, a large amount of durable goods remain in the socio-economic system for more than a year. These durable goods range from books, household appliances, furniture, machinery and cars to buildings and infrastructures. This share of materials is not immediately available for recycling, since they may remain in the economy for several decades. While economies are still increasing their physical stocks, there is also a considerable amount of stocks which reach their end-of-life point every year and are discarded or demolished.

For all materials coming to end-of-life within an economy there are essentially two possible pathways: they might be recycled, or they might leave the economy as processed output (consumption waste).

Figure 2. Simplified model for calculating key parameters of the material dimensions of the EU economy



The identified key parameters for the EU's physical economy are presented in Figure 2 and Table 3. They are organised along the flow through the economy and by the main material categories. Some are single flows (named arrows) and some are sums of flows (white boxes).

Table 3. Overview of key parameters of the material dimensions of the EU economy

	Domestic material extraction	Physical trade balance	Processed materials	Energetic use	Material use	Addition to stocks	Demolition	Short lived products	EoL waste	Recycling	Domestic processed output
Biomass											
Fossil energy carriers											
Metals											
Waste rock											
Industrial minerals											
Construction minerals											

4.4 Assumptions

In order to model the flows through the economy, each step according to Figure 2 was calculated at the level of the material sub-categories. For each step, it was necessary to use data, to formulate assumptions and to use methods; these were done on the basis of literature (see Table 4).

Table 4. Sources for both data and assumptions

Main material category	Domestic extraction	Physical trade balance	Split in material to energetic use	Addition to stocks	Demolition	Recycling rates
Biomass			Primary crops and crop residues: assumptions based on FAO commodity balances and Krausmann et al. (2008)	According to use	Estimates based on assumption of life time (delay model; see van der Voet et al., 2009)	n.a.
			Wood: FAOSTAT (2013)		Estimates based on assumption of life time	FAOSTAT (2013)
Fossil energy carriers			Crude petroleum: Plastics Europe (2012) Natural gas: Wood and Cowie (2004)	According to use	Estimates based on assumption of life time	Estimates based on Plastics Europe 2012
	Schaffartzik et al. (forthcoming)			Assumption: Deliberate dispersal in the year of production	n.a.	n.a.
Metalls (content)			n.a.	Iron: Wang et al. (2007)		
			n.a.	Aluminium: Cullen and Allwood (2013); Bertram et al. (2009)		
			n.a.	Other metals: Allwood et al. (2010)	Estimates based on assumption of life time	Hislop and Hill (2011); UNEP (2011b)
Waste rock			n.a.	n.a.	n.a.	n.a.
Industrial minerals (gross ore)			n.a.	Own assumptions	Own assumptions	Own assumptions
Con-struction minerals			n.a.	Estimates based on Wiedenhofer et al. (forthcoming)		Monier et al. (2011)

While for most material categories the level of uncertainty is quite satisfactory, in the categories of construction minerals the uncertainty is quite high. However, the data represent the best available estimates. Here, the biggest data quality problems stem from unreliable and diverging information concerning existing stocks. Together with weaknesses in waste statistics, uncertainties over the amount of construction and demolition waste and over recycling remain. In a review of the literature, Monier et al. (2011: 15) conclude that the construction and demolition waste for the EU27 varies by a factor of two. Also, present day recycling rates are quite uncertain since a larger share of construction and demolition waste is not used for the same original purpose or a similar purpose, as required by the definition of recycling. Thus, e.g. concrete waste is not used to produce concrete again, but for purposes with reduced demand for quality of the material, such as backfilling (downcycling).

The data presented here represent a rather optimistic view of the EU27's material efficiency. We think it is more likely that a higher amount of minerals remain in the economies' stocks and that the construction and demolition waste is lower than assumed here. Also, the net effects of recycling (saving of virgin material) might be lower than assumed here. This could mean that less material would be available for recycling.

5. Results

5.1 Results for the EU27

In 2005, the EU27 economies extracted 5.5 billion tonnes of materials, of which about 50% were industrial and construction minerals. The EU27 is a net importer and imports 1.2 billion tonnes of materials, of which 85% are fossil energy carriers. This, together with roughly 1 billion tonnes of recycled materials, amounts to 7.7 billion tonnes of processed material, i.e. materials that the EU27 processes. Of this material, about 46% is used energetically and 54% is used as materials. Of the flows used as materials, about 80% are additions to stocks. The equivalent of around half of the amounts added to stocks are demolished. Together with short-lived products, about 30% of the processed materials become end-of-life waste. This EoL waste is comprised of about 65% construction minerals. Since about 46% of construction minerals are recycled (using a very inclusive understanding of recycling), the overall recycling rate (recycled materials to EoL waste) amounts to 41%. Altogether the EU27 emits 4.9 billion tonnes into nature, as gaseous emissions or as liquid and solid waste.

Of the processed materials, about 12% are generated from recycling activities, 88% are from virgin materials. About 40% of the outputs and about 30% of the inputs are from renewable resources.

Figure 3. Key parameters of the material dimensions of the EU27 economies

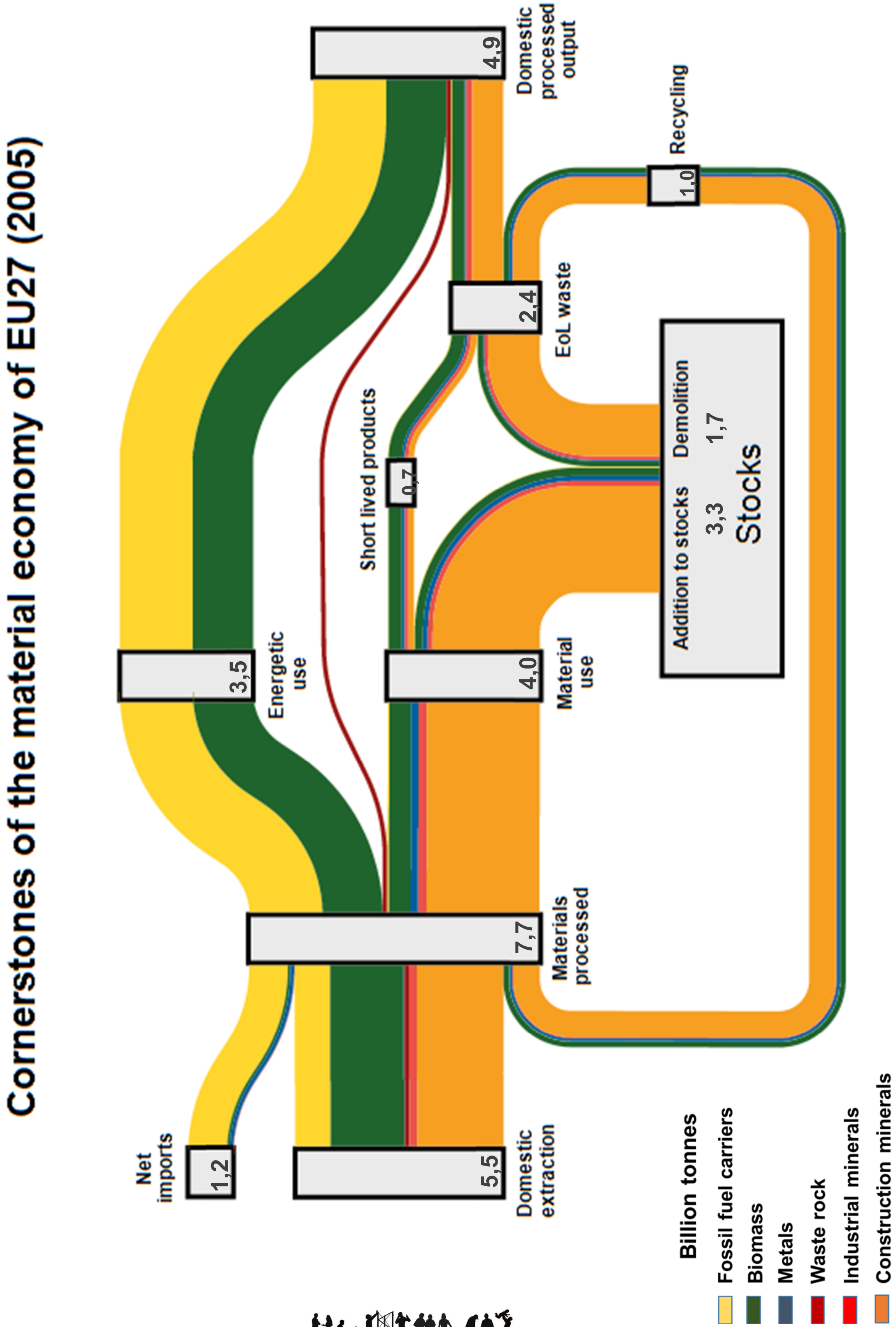


Table 5. Key parameters of the EU economy in billion tonnes (109 tonnes)

	Domestic Extraction	Physical trade balance	Processed materials	Energetic use	Material use	Addition to stocks	Demolition	Short lived products	EoL waste	Recycling	Domestic processed output
Biomass	1.94	0.07	2.16	1.59	0.57	0.21	0.14	0.36	0.50	0.15	1.94
Fossil energy carriers	0.94	1.03	1.97	1.93	0.05	0.02	0.02	0.02	0.04	0.01	1.96
Metals	0.02	0.10	0.20	0.00	0.20	0.13	0.03	0.07	0.10	0.08	0.02
Waste rock	0.12	0.00	0.12	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Industrial minerals	0.21	0.01	0.23	0.00	0.23	0.13	0.10	0.10	0.19	0.03	0.17
Construction minerals	2.28	0.00	2.98	0.00	2.98	2.83	1.37	0.15	1.52	0.70	0.82
Sum	5.51	1.21	7.66	3.52	4.14	3.33	1.66	0.70	2.35	0.97	4.91

Source: own calculations.

5.2 Comparison of some EU27 results with USA and Japan

Europe has significant imports of fossil energy carriers and metals. To compare this with USA and Japan for 2005, a key indicator from material flow accounting (MFA) is introduced as a reference: domestic material consumption (DMC), which is the sum of domestic extraction (DE) and imports (Im) minus exports (Ex).

$$DMC = DE + Im - Ex$$

Table 6. Domestic extraction, imports and exports as a percentage of domestic material consumption

	Extraction	Import	Export	DMC
		Fossil fuels		
EU27	48%	75%	23%	100%
USA	72%	35%	7%	100%
Japan	1%	106%	6%	100%
		Metals		
EU27	17%	85%	3%	100%
USA	35%	136%	71%	100%
Japan	0%	194%	94%	100%

Source: SEC database; Schaffartzik et al. (forthcoming).

In terms of fossil energy carriers and metals, the USA has the highest level of extraction as a percentage of domestic consumption, followed by the EU27. Japan has the lowest extraction level. The picture for imports is the inverse to that for extraction: Japan has the highest level of imports compared to its domestic consumption. In terms of exports, there is a significant difference between fossil fuels and metals. Japan and the USA export quite substantial amounts of metals but a comparatively small amount of fossil energy carriers. In contrast, the EU27's exports of fossil fuels add up to a quarter of the amount that it consumes domestically, whereas only a comparatively small amount of metals was exported in 2005.

6. Conclusions

The key parameters for the physical economy sketch the overall flows through the EU27 economies. Several insights can be gained for further discussion of this set of data:

- The socio-ecological transition Europe will have to face sooner or later will not allow it to maintain its high level of per capita consumption of roughly 16 tonnes (see also Fischer-Kowalski et al., 2012). To stay within planetary boundaries, per capita consumption levels of roughly half those of 2005 amounts have been discussed under the assumption of a "tough contraction and convergence scenario" (see UNEP, 2011a; Appendix 1 for a brief summary of the UNEP decoupling report; Fischer-Kowalski et al., 2013).
- Fossil energy carriers are a very large mass flow, accounting for 26% of processed materials. Future scenarios to model a socio-ecological transition need to opt for less material- and emission-intensive renewable energy forms like solar energy, wind power and geothermal heat to substantially reduce the current material flows.
- Biomass accounts for 28% of processed materials and is a flow with different and competing uses, including as food, feed, paper, construction material and energy sources. While the physical trade balance (PTB) for biomass appears quite small compared with its extraction, both import and export levels are around a quarter of European extraction levels, resulting in a relatively low net import. Due to the specific trade pattern, the actual land required abroad for imports is proportionally much higher than the land required in Europe for exports (Kastner et al., submitted). In other words, Europe is a net importer of land. During a socio-ecological transition this might become critical, since biomass is to a large extent limited by the area available. Global food and feed is likely to increase with the world's population until its peak; biomass as construction material and paper might continue to increase with economic growth, especially in emerging economies. Finally, use of biomass as a renewable energy source might also increase due to source limitations of fossil fuels and/or to global climate mitigation policy. Therefore, biomass could become a challenging policy issue in the light of the socio-ecological transition.
- One of the most crucial issues is large and still growing physical stocks; about 39% of processed materials are added to stocks. In particular, the road network, with the

relatively short service lifetimes of materials involved, plays a major role as a driver of material flows. Here, a stock and flow model for the EU25 shows that present infrastructures entail a significant commitment of annual resources to maintaining existing stock alone. To illustrate this with a few figures: construction minerals for roads, rails and buildings accounted for roughly 50% of the additions to stocks in 2009. Of these flows, roughly 40% are for maintenance and 12% for expansion of the road network. A further 10% are for maintenance, and 30% for the expansion of buildings. Rail networks play a minor role (Wiedenhofer et al., forthcoming).

- Additionally, net expansion of estimated stocks amounted to approximately 28% of the DMC of non-metallic construction minerals in the EU25 in 2009, with the majority going into new residential buildings. But even if these buildings are extremely energy efficient and long-lived, their impact on overall resource use patterns would only be visible in the long term due to the large existing stocks. Stock-related flows are highly interlinked with energy flows. Without a radical shift in infrastructural policy, flow reductions will be quite limited since infrastructures determine future flows to a large extent (due to maintenance, and since they foster certain uses and impede other uses).
- At present levels of material inputs into the EU27, recycling alone cannot contribute enough to reduce the material throughput to the required levels (a hypothetical increase in the recycling rate to 100% would reduce present day requirements for virgin material by only 14%).
- When applying energy content factors to the flows, the material-based model can be transformed in an energy flow model (material and energy flow accounting, MEFA). When using prices for certain flows as represented by the key parameters of the EU27, the results can be used to discuss the results of economic models (e.g. energy, metals, food and feed or construction minerals).
    - Illustration of the conversion to energy flows: The simple model contains five categories of fossil fuels, one of these is natural gas. Of the 0.94 billion tonnes (see Table 5) extracted within the EU27, about 0.18 billion tonnes[2] are extracted as natural gas. The default value to convert it into calorific units is 50 MJ/kilogram (Eurostat, 2012: 55). Consequently, 0.18 billion tonnes equals 9 exajoules. Therefore, if demand for natural gas is reduced, the material demand can be reduced proportionally.
    - Illustration of how economic results can be discussed: If a scenario used for an economic model assumes a certain price increase for iron in the future, the model of the physical economy in combination with the economic model can be used to find out how this could affect recycling rates (costs of recycling compared to costs for pig iron) and, consequently, how this would affect imports.

[2] Production is measured after purification and extraction of NGL and sulphur, and excludes re-injected gas and quantities vented or flared (so-called total dry production) (see Eurostat, 2012: 53).

References

Allwood, J.M., J.M. Cullen and R.L. Milford (2010), "Options for Achieving a 50% Cut in Industrial Carbon Emissions by 2050", *Environmental Science & Technology*, Vol. 44, No. 6, pp. 1888-1894.

Ayres, R.U. and L.W. Ayres (eds) (2002), *A Handbook of Industrial Ecology*, Cheltenham, UK and Northampton, MA: Edward Elgar Publishing.

Bertram, M., K.J. Martchek and G. Rombach (2009), "Material Flow Analysis in the Aluminum Industry", *Journal of Industrial Ecology*, Vol. 13, No. 5, p. 650-654.

Commission of the European Communities (2003), "Integrated Product Policy - Building on Environmental Life-Cycle Thinking", communication from the Commission to the Council and the European Parliament.

Cullen, J.M. J.M. and Allwood (2013), "Mapping the Global Flow of Aluminum: From Liquid Aluminum to End-Use Goods", *Environmental Science and Technology*, Vol. 47, p 3057−3064.

Eurostat (2009), "Economy Wide Material Flow Accounts: Compilation Guidelines for reporting to the 2009 Eurostat questionnaire" (http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/documents/Economy-wide%20material%20flow%20accounts%20compilation%20guide%20%20-.pdf).

Eurostat (2012), "Economy-wide Material Flow Accounts (EW-MFA) - Compilation Guide 2012" (http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/documents/Economy-wide%20material%20flow%20accounts%20compilation%20guide%20%20-.pdf).

Eurostat (2013), Population statistics (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_pjan&lang=en), extracted 18 October 2013

FAOSTAT (2013), Forest statistics (http://faostat3.fao.org/faostat-gateway/go/to/download/F/*/E), extracted 18 October 2013.

Femia, A., F. Hinterberger and F. Luks (1999), "Ecological economic policy for sustainable development - Potentials and domains for intervention for delinking approaches", Working Paper No. 1, Seri, Vienna.

Fischer-Kowalski, M., W. Haas, D. Wiedenhofer, U. Weisz, I. Pallua, N. Possanner, A. Behrens, G. Serio, M. Alessi and E. Weis (2012), *Socio-ecological Transitions: Definitions, Dynamics And related Global Scenarios*, NEUJOBS Report (http://www.neujobs.eu/sites/default/files/publication/2012/05/wp1_Socio-ecological%20transitions%20and%20global%20scenarios.pdf).

Fischer-Kowalski, M., D. Wiedenhofer, W. Haas, I. Pallua and D. Hausknost (2013), "Developing Resource use Scenarios for Europe", Work Package 204, WWWforEurope, Vienna.

Hislop, H. and J. Hill (2011), *Reinventing the wheel: a circular economy for resource security*, London: Green Alliance.

Kastner, T., K.-H. Erb and H. Haberl (submitted), "Rapid growth in agricultural trade: effects on global area-efficiency and the role of management", *Environmental Research Letters.*

Krausmann, F., K.-H. Erb, S. Gingrich, C. Lauk and H. Haberl (2008), "Global patterns of socioeconomic biomass flows in the year 2000: A comprehensive assessment of supply, consumption and constraints", *Ecological Economics*, Vol. 65, No. 3, pp. 471-487.

Monier, V., M. Hestin, M. Trarieux, S. Mimid, L. Domrose, M. van Acoleyen, P. Hjerp and S. Mudgal (2011), *Study on the Management of Construction and Demolition Waste in the EU*, Contract 07.0307/2009/540863/SER/G2, Final Report for the European Commission DG Environment, Paris, France: Bio Intelligence Service S.A.S.

NEUJOBS (2013), Summary info about the project (http://www.neujobs.eu/).

OECD (2008), *Measuring Material Flows and Resource Productivity*, Synthesis Report, OECD Paris (http://www.oecd.org/dataoecd/55/12/40464014.pdf).

Plastics Europe (2012*), Plastics – the Facts 2012; an analysis of European plastics production, demand and waste data for 2011*, Brussels: Plastics Europe.

Pollitt, H., A. Barker, J. Barton, E. Pirgmaier, C. Polzin, S. Lutter, F. Hinterberger and A. Stocker (2010), *A Scoping Study on the Macroeconomic View of Sustainability*, Final report for the European Commission DG Environment, Cambridge: Cambridge Econometrics, Sustainable Europe Research Institute (http://seri.at/wp-content/uploads/2009/12/SERICE-2010_Macroeconomic-view-of-sustainability.pdf).

Schaffartzik, A., A. Mayer, S. Gingrich, N. Eisenmenger and F. Krausmann (forthcoming*): The Global Metabolic Transition. Regional Patterns and Trends of Global Material Use, 1950-2010.*

UNEP (2011a), *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth*. A Report of the Working Group on Decoupling to the International Resource Use Panel, Nairobi: United Nations Environment Programme (UNEP).

UNEP (2011b), *Recycling Rates of Metals - A Status Report*. A Report of the Working Group on the Global Metal Flows to the International Resource Use Panel, Nairobi: United Nations Environment Programme (UNEP).

Van der Voet, E., L. Van Oers, S. De Bruyn, F. De Jong and A. Tukker (2009), *Environmental Impact of the use of Natural Resources and Products*, Report for Eurostat, Contract no. 71401.2007.011-2008.065.

Wang, T., D. Müller and D.E. Graedel (2007), "Forging the Anthropogenic Iron Cycle", *Environmental Science and Technology*, Vol. 41, pp. 5120-5129.

Weisz H., C. Amann, N. Eisenmenger, F. Krausmann and K. Hubacek (2004), *Economy-wide Material Flow Accounts and Indicators of Resource Use for the EU: 1970-2001*, Final report to Eurostat, Vienna: IFF Social Ecology.

Weisz, H., F. Krausmann, N. Eisenmenger, H. Schütz, W. Haas and A. Schaffartzig (2007), *Economy-wide Material Flow Accounting. A Compilation Guide*, Luxembourg: EUROSTAT

Wiedenhofer, D., W. Haas, M. Neundlinger and N. Eisenmenger (forthcoming), "The role of material stocks for sustainable development", in M. Fischer-Kowalski, H. Haberl, F. Krausmann and V. Winiwarter (eds), *Society-Nature Interaction and its History*, Springer Netherlands, Human-Environment Interactions.

Wood, S. and A. Cowie (2004), *A review of Greenhouse Gas Emission Factors for Fertiliser Production*, Report to Bioenergy Task 38, Paris: International Energy Agency.

Appendix 1: Decoupling natural resource use from economic growth

UNEP's International Resource Panel published a report in 2011 assessing the potential of decoupling resource use and environmental impacts from economic growth. On a global level, this report presents a similar picture of the dynamics of resource use during the 20th century as we have shown in Section 2.6 of the WP1 report (D1.1. "Socio-ecological transitions: Definition, dynamics and related global scenarios"). The main conclusion offered was that although a decoupling of resource use from GDP could be observed, this did not prevent global annual resource extraction from skyrocketing (materials: an eightfold increase, energy: a tenfold increase in the course of this one century). A more detailed analysis by groups of countries according to their development status revealed that it was the increasing per capita resource use that mainly drove the rising resource consumption of high-income countries, while it was population growth driving resource use of developing countries. In the last two decades though, a substantial catching-up of developing countries in terms of per-capita consumption took place – a convergence process of socio-metabolic patterns towards the level of high-income industrial countries. This triggered a new acceleration in annual global resource extraction that would, if convergence to this level continued (i.e. a continuation of observed trends), imply a tripling of global annual extraction of material resources, with the severest environmental consequences. They find that this scenario "probably represents an unsustainable future in terms of both resource use and emissions, exceeding all measures of available resources and assessments of limits to the capacity to absorb impacts." (UNEP, 2011a: 29). On the other hand, a global convergence of socio-metabolic rates is considered welcome from the standpoint of international equity.

In response to this dilemma, the decoupling report developed three scenarios for global material consumption:

1. The above *trend scenario*, assuming that high-income industrial countries maintain their per capita resource consumption, and developing countries increase their consumption rates to the same level until 2050. This would lead to a tripling of global annual resource extraction by 2050.
2. *Moderate contraction and convergence*, in which high-income industrial countries halve their per capita resource consumption by 2050, and developing countries increase their metabolic rates to the same level. This would lead to a 40% increase in global annual resource extraction by 2050.
3. *Tough contraction and convergence*, in which total global resource consumption is maintained at the 2000 level, and all countries converge to the same per capita resource consumption. This by definition would keep global annual resource extraction at its current levels, but allow for an average metabolic rate of no more than 5.5 tonnes per capita and year.

About NEUJOBS

"Creating and adapting jobs in Europe in the context of a socio-ecological transition"

NEUJOBS is a research project financed by the European Commission under the 7th Framework Programme. Its objective is to analyse likely future developments in the European labour market(s), in view of four major transitions that will impact employment - particularly certain sectors of the labour force and the economy - and European societies in general. What are these transitions? The first is the **socio-ecological transition:** a comprehensive change in the patterns of social organisation and culture, production and consumption that will drive humanity beyond the current industrial model towards a more sustainable future. The second is the **societal transition,** produced by a combination of population ageing, low fertility rates, changing family structures, urbanisation and growing female employment. The third transition concerns **new territorial dynamics** and the balance between agglomeration and dispersion forces. The fourth is **a skills (upgrading)** transition and and its likely consequences for employment and (in)equality.

Research Areas

NEUJOBS consists of 23 work packages organised in six groups:

- **Group 1** provides a conceptualisation of the **socio-ecological transition** that constitutes the basis for the other work-packages.
- **Group 2** considers in detail the main drivers for change and the resulting relevant policies. Regarding the drivers we analyse the discourse on **job quality**, **education**al needs, changes in the organisation of production and in the employment structure. Regarding relevant policies, research in this group assesses the impact of changes in **family composition**, the effect of **labour relations** and the issue of financing transition in an era of budget constraints. The regional dimension is taken into account, also in relation to **migration** flows.
- **Group 3** models economic and employment development on the basis of the inputs provided in the previous work packages.
- **Group 4** examines possible employment trends in key sectors of the economy in the light of the transition processes: energy, health care and goods/services for the **ageing** population, **care services**, housing and transport.
- **Group 5** focuses on impact groups, namely those vital for employment growth in the EU: **women**, the **elderly**, immigrants and **Roma**.
- **Group 6** is composed of transversal work packages: implications NEUJOBS findings for EU policy-making, dissemination, management and coordination.

For more information, visit: www.neujobs.eu

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