Achieving absolute decoupling? Comparing biophysical scenarios and macro-economic modelling results

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Abstract

Most economic models struggle to incorporate biophysical relationships between materials, energy and emissions, in order to appropriately deal with biophysical constraints of supply (and possibly also demand). After the incorporation of biophysical constraints, some functions produced surprising or even highly implausible results. These results have been checked against expert judgement of plausibility, some biophysical assumptions have been refomulated or removed to secure consistency, and some economic functions have been adjusted to take care of adequacy and plausibility of outcomes and model specifications.

A number of efforts were made to check the consistency of economic modelling outcomes with some fundamental functional interdependencies on the biophysical level and against the biophysical scenarios presented in earlier papers (Milestones MS35 - published as WWWforEurope Working Paper no. 25; and MS36 - unpublished). This usually required extensive communication between research teams and the re-formulation of certain parameters, relationships and semi-empirical assumptions. Methodologically, such interdisciplinary cross-checking is a novel and time-consuming exercise. This process highlights the limitations of existing economic models to incorporate certain biophysical functional interdependencies, and vice versa the still very limited ability of biophysical models to explore ranges of flexibility imposed upon changing economic assumptions. Furthermore this ongoing collaboration showed that the specification of the baseline scenario and the semi-empirical assumptions about efficiency gains as well as developments of factor productivity and technical change are highly influential on the results of each scenario. Therefore a 'realistic' specification and critical reflection of the actual feasability of certain baseline trajectories is deemed necessary.

Contribution to the Project

Work package 204 generated plausible biophysical scenarios for resource constraints to economic activity in Europe (mainly supply side) and thus establish the material boundaries within which future welfare, wealth and work for Europe should be generated if environmental sustainability is to be achieved. These scenarios serve as the analytical presuppositions of the macroeconomic models developed in work package 205 and constitute the biophysical frame for the analyses of other work packages. We assess the scenario results of the modelling teams, especially from WIFO, with respect to the biophysical constraints that served as their limiting frames.

Keywords:

Beyond GDP, Biophysical constraints, CGE models, Ecological innovation, Economic growth path, Economic strategy, European economic policy, Full employment growth path, Industrial policy, Innovation policy, Macroeconomic disequilibria, Market economy with adjectives, Socio-ecological transition, Sustainable growth, Wealth

Jel codes:

Q3, Q4, Q5

Content

1. Introduction

This report documents the ongoing cooperation between the Institute of Social Ecology (SEC), which explored biophysical resource use scenarios for Europe until 2050 (Fischer-Kowalski et al. 2013a, 2013b) and WIFO, which uses a macro-econometric new Keynesian model (DYNK) to explore the consequences and requirements of a sustainable development pathway for the European economy (Kratena and Sommer 2014). In this milestone 37 we evaluate the ongoing macro-economic modelling efforts by WIFO against the biophysical resource use scenarios as well as the carbon budgets approach (Raupach et al. 2014).

We strongly focus on the biophysical dimensions and aim for an absolute reduction of resource use in line with proposed potentially sustainable levels of material use (United Nations Environment Programme. et al. 2011; Hoekstra and Wiedmann 2014) as well as greenhouse gas emissions in a carbon budgets approach consistent with a 2°C world (Raupach et al. 2014; IPCC 2014). Early on in the project it has been decided between the two teams that SEC adopts a purely biophysical approach to scenario development, based on observed dynamics of resource use and emissions and potential reductions due to efficiency gains and changes to consumption and production (Fischer-Kowalski et al. 2013a, 2013b). In the next step WIFO then deployed the DYNK model to achieve these kinds of reductions with various policy instruments, taking into account macro-economic feedbacks and endogenous long-run growth paths. In this way it becomes possible to a) evaluate if and with which measures an absolute decoupling and the necessary reductions can be achieved and b) to assess the socio-economic impacts and potential drawbacks of these instruments.

2. Scenarios of European Resource Use and Carbon Budgets for a 2°C World until 2050

In milestones 35 and 36 (Fischer-Kowalski et al. 2013a, 2013b) it was our task to develop purely biophysical resource use scenarios for Europe until 2050. Four scenarios were developed (Figure 1); for a more detailed documentation and discussion, we have to refer to the original milestones. In the following we summarize from the previous milestone 36 (Fischer-Kowalski et al. 2013b) on the discussion of the two scenarios which were chosen for further analysis. We use them as comparison to the WIFO/DYNK results because they propose substantial reductions and are therefore deemed ambitious enough by both teams.

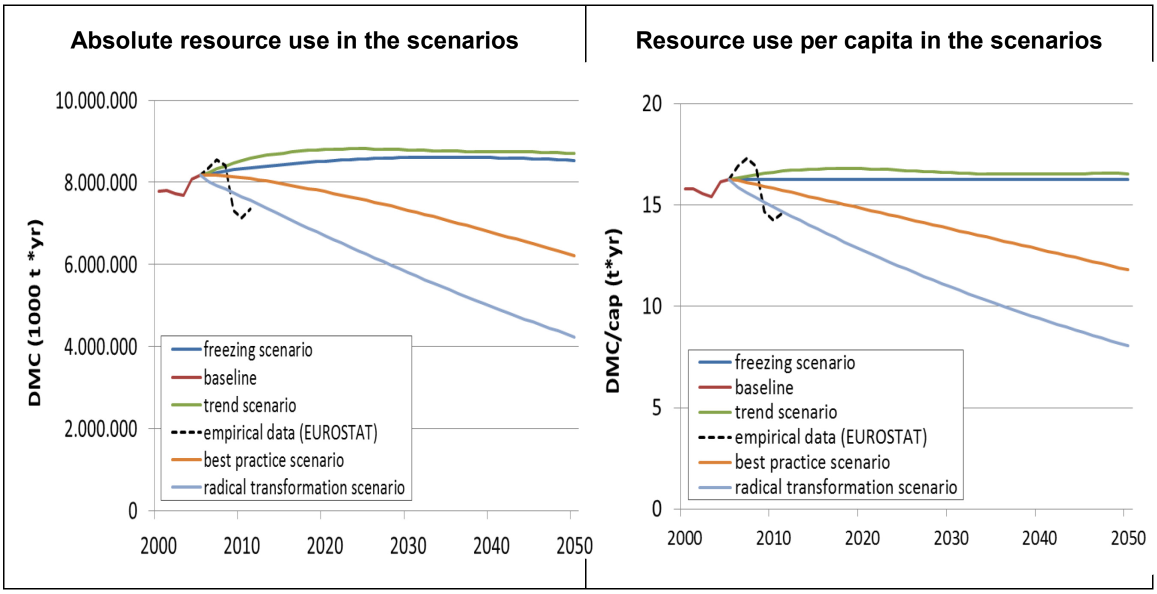


Figure 1: Material consumption in the EU27 from 2000-2050, according to four resource use scenarios (Fischer-Kowalski et al. 2013b)

Best practice scenario: In this scenario, we assume that the DMC/cap decreases in all EU27 countries based on the strongest observed declines of DMC/cap in Europe since 1970. The feasibility of this scenario is justified by best practice of Germany, UK and France, which developed their economies while reducing their per capita material consumption at the same time.

Rationale and assumptions: Germany, UK and France are the biggest economies in Europe and experienced a decrease of their joint DMC/cap of 28% over the period from 1970 to 2004. This decrease was then applied to the baseline values of all EU27 countries as an annual percentage for the period 2006 to 2050. The assumption is that all European countries can emulate these large economies with respect to shrinking material demands, while these forerunners continue on their declining pathway. These reductions in all European countries between 2005 and 2050 would lead to an average metabolic rate of 12t/cap year in 2050. The reductions observed in the past where mostly due to very specific circumstances, such as a far-reaching de-industrialization in the UK and the German reunion where inefficient production sites in Eastern Germany where closed on a large scale. These are circumstances that cannot simply be “emulated” by other countries, nor do they necessarily remain the same for the forerunners. Nevertheless, this scenario teaches an important lesson: shrinking material use is not necessarily associated with economic decline.

Fossil fuels: For this scenario, we furthermore assume a 30% dematerialization of the energy supply, due to reductions of fossil fuels use. Because the transport infrastructure requires large amounts of non-metallic minerals (Wiedenhofer et al. 2015), these reductions of fossil fuel use in turn reduce the stress on transport infrastructure, thereby requiring less metallic and non-metallic minerals[1].

Biomass: Somewhat less than a quarter of material use consists of biomass (food, feed, timber, textiles…), the large majority of which relates to human nutrition. Reducing the animal share in human nutrition, and reducing food waste moderately, could account for 30% less biomass use. Again, there are co-implications for transport and transport infrastructure.

Non-metallic minerals, ores and metals: Half of the materials used consist of construction minerals (cement, sand, gravel) usually extracted domestically, and a significant proportion is used for constructing and maintaining public infrastructure (roads, harbours, dams and the like). Some of this is a one-time investment in the course of modernization processes, as can be seen from comparing the construction materials use of EU15 and new member states in the last decade. The projection for 2050 assumes a saturation of infrastructure and improved recycling. Consequently additional construction activities can be minimized and the main use of construction minerals is to maintain and transform already existing infrastructure and buildings. We assume a 15% reduction of construction minerals compared to 2005. Since about 70% of metals are used for infrastructure (Wang et al. 2007), the same 15% reduction as for construction minerals is assumed for the share of ores used for construction.

Radical transformation scenario: The EU27 halves its per capita domestic material consumption until 2050. We apply a simple geometric function applied to per capita material consumption rates of the EU27 as a whole.

Rationale and assumptions: This is a simple application of the "contraction" rule used in the UNEP moderate contraction and convergence scenario above, where high income industrial countries halve their metabolic rates, while the rest of the world catches up to these rates. In its "Roadmap to a Resource Efficient Europe", the European Commission considers such a strategy, among others.

Fossil fuels: If Europe takes its climate policies seriously, fossil fuels should be drastically reduced. The use of most renewable energy sources, as soon as investments are taken, is associated with a substantially lower amount of materials. In our projection we assume that achieving 80% GHG emissions by 2050 entails a 70% dematerialization of the energy supply. This also has major implications for reducing the demand for transport infrastructure[1].

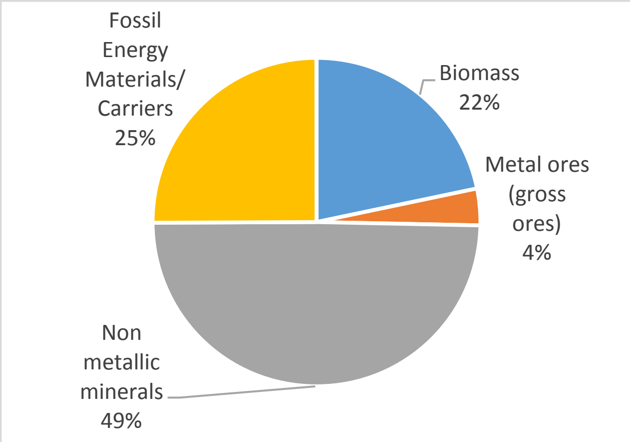
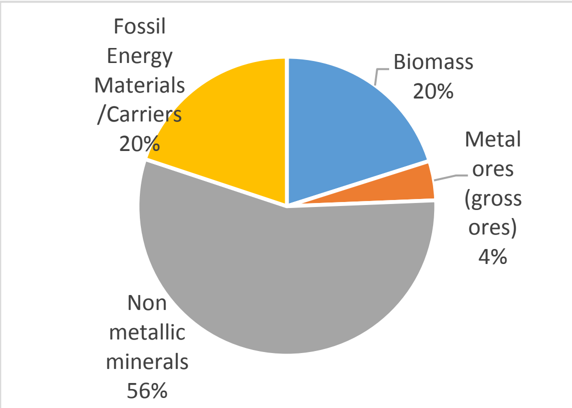
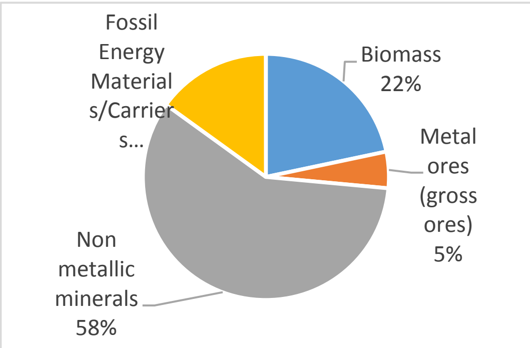
Biomass: Somewhat less than a quarter consists of biomass (food, feed, timber, textiles…), the large majority of which relates to human nutrition. Reducing the animal share in human nutrition, and reducing food waste, could account for halving biomass use in a way co-beneficial for human health and the environment. Again, there are co-implications for transport and transport infrastructure.

Non-metallic minerals, ores and metals: In our projection for 2050, we assume a saturation of infrastructure. Consequently, additional construction activities can be minimized and the main use of construction minerals is to maintain already existing infrastructure and adapt them to changing functions. We assume a 40% reduction of construction minerals compared to 2005. Since about 70%[2] of metals are used for infrastructure, the same 40% reduction as for construction minerals is assumed

[1] Fossil fuels, in terms of tons, amount to 50% of world transport (according to trade flows as presented by (Krausmann et al. 2008).This is distributed between ships, pipes and road transport. Reducing fossil fuel use would have major consequences in reducing transport volumes and the need for transport infrastructure.

for ores. Additional substantially increased recycling activities reduce the virgin material needed for the metallic content of short-lived products by 20%.

Table 1: The projected amounts and composition of material consumption in EU27+2 (Norway and Switzerland) for 2050 (Fischer-Kowalski et al. 2013b)

Scenario	2050
Freezing per capita: DMC = 8,5 billion tons Material composition stays the same **Trend: DMC = 8,7 billion tons** - High income countries maintain their per capita material consumption - Low density transitional economies converge with the level of EU15 low density countries - High density transitional economies still grow for a short period and then they reduce their per capita consumption to the level of EU15 high density countries (between the two scenarios there is no difference in share of material categories)	
Best practice: DMC = 6,2 billion tons - Domestic material consumption per capita decreases in all EU 27 countries as in the countries with the strongest observed decline since 1970: Germany, UK and France - These countries experienced a decrease of their joint per capita domestic material consumption of about 28% over the period from 1970 to 2004. - This is achieved by 30% dematerialization of energy supply, 30% less biomass, 15% reduction in non-metallic minerals and in metallic minerals used for construction	
Radical transformation: DMC = 4,2 billion tons - Halving European per capita material consumption by 2050 - This is achieved by 70% dematerialization of energy supply, 50% less biomass, 40% reduction in non-metallic minerals and in metallic minerals used for construction, increased recycling reduces consumption of virgin materials by 20% for metal share in short lived products	

These biophysical resource use scenarios already include assumptions on the use of fossil fuels until 2050. In the light of the importance of climate change as one of the major environmental crises we also explicitly evaluate the model results for their greenhouse gas emission trajectories. Currently only emissions from fossil fuels are modelled, while emissions from land-use change, agriculture and other gases are disregarded (Kratena and Sommer 2014).

In contrast to many other resources and emissions, where limits and constraints cannot easily be quantified, the sink capacities of the climate system are much better understood. Therefore, it becomes possible to quantify the amount of carbon emissions, which can still be emitted while staying below 2°C (or 2.5°C or 3°C) of global warming. These remaining emissions have been termed the carbon budget (IPCC 2014; Alexander 2013; Raupach et al. 2014). Recently a mechanism has been proposed with which it becomes possible to share this globally remaining carbon budget (Figure 2a) among the countries/regions of the world (Raupach et al. 2014). This mechanism either focuses purely on equitable share for each person on the planet or starts with current emission levels as weighting factor for the remaining carbon budget. Finally, one can have blended version of both approaches. Depending on the weighting mechanism applied the remaining European share of the carbon budget ranges from 90-159 Gigatons of CO_2 that can still be emitted while staying below 2°C of warming (Figure 2b). Using these European carbon budgets allows to evaluate the outcomes of all modelling scenarios if they are compatible with the 2°C target.

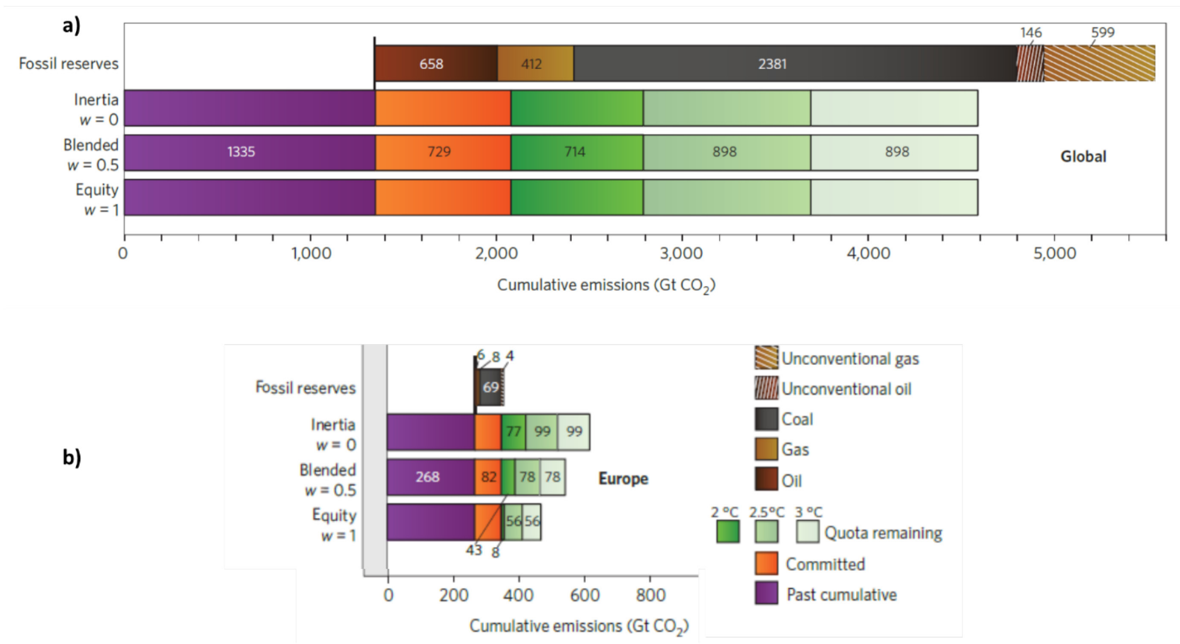


Figure 2: Global and European Carbon Budgets in 2012 (Raupach et al. 2014)

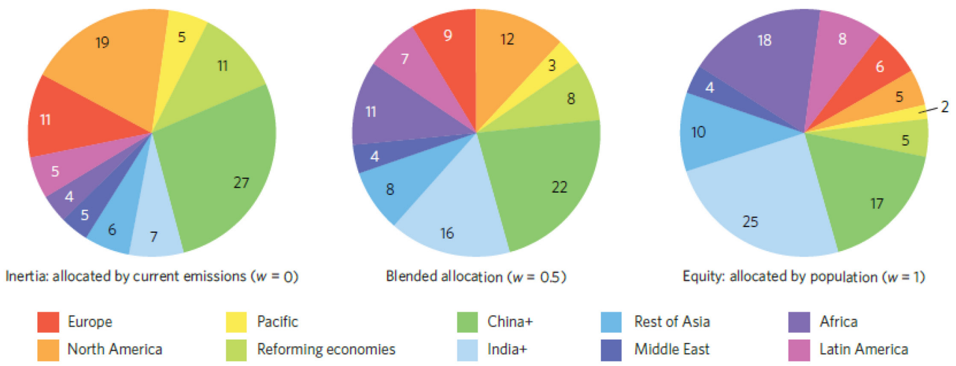


Figure 1 | Sharing the carbon-quota pie. The share of an available carbon quota allocated to 10 regions (Europe, North America, Pacific Organisation for Economic Co-operation and Development countries, reforming economies, China+, India+, Rest of Asia, Middle East, Africa, Latin America) under three sharing principles based on equation (2), with sharing index w = 0, 0.5 and 1. Numbers give the percentage share of the global quota allocated to each region, summing to 100 for each chart. Shares are calculated using equation (2) with emissions (f_i) averaged over last five years of data, and population (p_i) averaged over a five-year period centred on the time at which world population reaches nine billion. See Supplementary Text 1 for details.

Figure 2: Global Carbon Budgets for three allocation mechanisms (Raupach et al. 2014)

3. Biophysical Constraints for the Economy, Policy Simulations and Model Implementation

In Milestone 35 we discussed more extensively the challenge of formulating biophysical constraints for the economy and developed the following conceptualization (Figure 2). In this approach there are three pathways for biophysical constraints and global environmental change to affect the European economies. Firstly, policy and regulation can, based on scientific evidence and other factors, aim to improve environmental conditions and pre-emptively reduce certain pressures and impacts, thereby constraining certain economic activities. Secondly there can be direct biophysical effects, which includes floods, droughts, sea level rise and changing seasons (e.g. winter tourism). These are mostly local or regional and very complex to quantify, while potentially becoming major issues in the coming decades. At the moment no such effects are included in the modelling exercise. Thirdly there are effects which are mediated via the market, mostly via rising prices and increased price volatility.

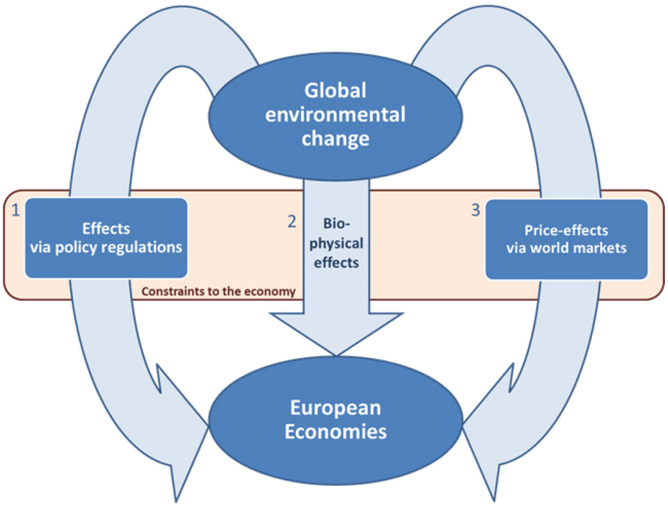


Figure 3: Conceptualizing general pathways how potential biophysical constraints may affect economies (Fischer-Kowalski et al. 2013a)

During the ongoing exchange and cooperation between SEC and WIFO several potential ways to model biophysical constraints have been discussed. While there are many ways in which European economies could be affected by global environmental change, the goal of this exchange process was to develop some specific ideas and measures which are a) actually implementable in the DYNK model and b) have the potential for impacts in order to actually achieve the reductions of material use and emissions foreseen in the SEC scenarios.

Utilizing the above conceptualization (Figure 2), we formulated several approaches on how policy could intervene and constrain the economy in order to shift the pathway of the European economy in the light of global environmental change (sections below). We discussed direct biophysical effects as well, but they are very hard to quantify and require an extensive amount of regionalized model details as well as potentially coupled economic-ecological integrated assessment approaches. These could, for example, simulate the damages of climate change over time or quantify the impacts of environmental change on production patterns, health and other factors. This was beyond the scope of this project. Finally the changing global conditions (Fischer-Kowalski et al. 2012) have been taken into account insofar as we put special emphasis on a critical evaluation of the world market price forecasts of energy carriers and import prices for all other commodities.

3.1 Pricing Materials Extraction for Metals and Non-Metallic Minerals

In analogy to carbon pricing certain areas of resource use are also potential candidates for implementing upstream environmental taxes on extraction activities. Currently construction minerals such as sand, gravel and stones can be extracted ‘for free’, apart from capital investments required. This favours the extraction of virgin materials and negatively skews the market against recycled construction materials. As the EU proposes a strong increase of it’s recycling of construction and demolition waste until 2020 (European Parliament, Council 2008), an additional support for improving resource efficiency and strengthening the re-use and recycling of materials could be achieved via the introduction of a tax on the extraction of construction minerals (Bahn-Walkowiak et al. 2012; Meyer et al. 2012). This tax could start at 2.- Euro / Tonne, increase by 5% each year until a price of 4.80- Euro / Tonne is reached in 2030.

3.2 Pricing of Domestic Carbon Emissions and the Use of Fossil Fuels

Carbon pricing is a well-established instrument at the European level. Although implementation, coverage and market-dynamics have to be improved, especially when it comes to the EU-Emissions Trading Scheme, for this model steadily increasing carbon prices are seen as a major policy instrument. This is implemented in line with the EU2050 roadmap approach of a carbon price of 25.- Euro / Tonne, which rises to 250.- Euro / ton.

3.3 Differentiated VAT and Green Sales Taxes

Often more efficient and environmentally friendlier products are more expensive and therefore require higher upfront capital investments. This is a major issue in sustainable consumption, because many customers are not adept at full cost accounting over the entire lifecycle of a product and therefore are easily influenced by upfront costs. Also for lower income households, buying more expensive but more efficient goods might not be possible because of liquidity constraints. Therefore, differentiated consumption taxes based on ecological criteria might be an interesting avenue. Currently value added taxes on consumption are usually differentiated into a higher and lower tax rate. Usually the lower tax rate is used for basic goods such as food or books. In the literature there are proposals to apply these differentiated VAT rates based on ecological criteria (Bleischwitz 2012).

- For so-called white goods (dishwashers, vacuum cleaners, etc) the highest efficiency class could receive the lower VAT rate, in order to decrease the usually higher up-front investment requirements for households.
- Now all food receives the lower VAT rate. From an ecological viewpoint rampant consumption of large amounts of food products from ruminants (cows) and especially (read) meat as well as (conventional) dairy products are not sustainable (Girod et al. 2014). Therefore, these could receive the higher VAT rate to induce shifts towards more vegetarian diets or white meat.
- Potentially organic production could also receive lower VAT rates due to its numerous environmental benefits.
- Mobility is another important driver of emissions and resource use (Girod et al. 2014; Tukker and Jansen 2006). Especially fossil-fuelled cars are not sustainable at all and vehicle specific sales taxes should be directly linked to their CO2 / km ratings. Specifically the, for example, the top 10% range of cars based on their CO2 / km ratings could then also receive lower VAT or vehicle sales taxes to lessen the burden of often higher up-front investments for more efficient cars.
- Similar measures could be implemented for electricity, where green electricity (from renewables such as sustainable biomass, wind, solar and hydro) receives the lower VAT, all fossil fuelled electricity receives the higher sales tax.

Despite the interesting potentials of such an approach, the level of detail required in the modelling is not supported by the available data and therefore has to be left for more focused research.

3.4 Taxing Embodied Emissions and Materials

Reoccurring concerns are voiced over the effect of domestic or European efforts on international competitiveness as well as the potential undermining of national level environmental policy efforts by the outsourcing of production (Kanemoto et al. 2014; Hertwich and Peters 2009). So called border tax adjustments have been discussed to counteract the differential environmental standards between European economies and potentially less stringent standards in developing economies, especially in regards to carbon taxes and the European Emissions trading scheme (Jakob and Marschinski 2013; Ismer and Neuhoff 2007).

In the wider context of sustainable resource use and the necessity for an absolute decoupling it becomes interesting to model the economy-wide effects of an implementation of 1) comprehensive border tax adjustments for carbon emissions or potentially even a 2) consumption-based tax of ‘embodied’ materials and emissions in final goods.

4. Comparative Evaluation of Modelling Results and Biophysical Resource Use Scenarios – what can be learnt for improved modelling and scenario evaluation?

For the macro-economic modelling exercise it has been decided to focus on the more ambitious scenarios presented by the Institute of Social Ecology (Fischer-Kowalski et al. 2013a, 2013b). We first use the trend scenario of a European stabilization of resource use to calibrate the baseline scenario of the DYNK model.

Second, we use the DYNK model to simulate a classical Green Tax Reform, including a steadily increasing carbon price from 25 Euro (constant 2005 Euros) in 2012 up to 250 Euro in 2050 (constant 2005 Euros) and a resource extraction tax of 2 Euro per Ton, which increases by 5% p.a. (Bahn-Walkowiak et al. 2012) and which is also levied on metals and industrial minerals. Revenues from these taxes are used to lower social security contributions of employers and employees.

Thirdly, the DYNK model is also used to model an Environmental Fiscal Devaluation or Tax on embodied resources and emissions. It uses the same price levels and revenue recycling mechanisms but is entirely imposed on consumption and thereby affects output prices, imports and domestic industries similarly as well as generally consumption patterns.

For more detailed descriptions of the DYNK model and the scenarios we have to refer the interested reader to the specific deliverable (Kratena and Sommer 2014).

4.1 Global Framework Conditions: World Market Prices

One important aspect of any macro-economic long-term modelling concerns the use of specific world-market energy price forecasts. For the task at hand these have been sourced from several forecasts (Table 2). Specifically these world-market fossil fuel prices start at 78 US$ (constant 2010) per barrel of crude oil (boe), 8 US$ (constant 2010) per million British thermal units (Mbtu) of natural gas and 99 US$ (constant 2010) per ton of coal. Until 2050, these prices are projected to increase by 66% in real terms for crude oil and 166% in nominal terms, by 74% for natural gas in real terms and by 179% in nominal terms and by 11% for coal in real terms and by 77% in nominal terms (Figure 4). Also for all other imports real commodity prices are increasing in the long-term, by on average 60% (+/-30%) between 2005 and 2050 (Figure 4).

Table 2: Sources for world market prices and forecasts for fossil energy carriers 2000 - 2050

Price Forecasts 2011-2050 on the basis of :	
Crude Oil	PRIMES, 2012
Natural Gas	Commodity Markets Outlook, April 2014 (World Bank 2014)
Coal	World Bank: Australian Coal Price Forecast
Price Levels 2000 - 2010 were based on	
Crude Oil	World Energy Outlook (International Energy Agency 2010)
Natural Gas	World Energy Outlook (International Energy Agency 2010)
Coal	World Energy Outlook (International Energy Agency 2010)

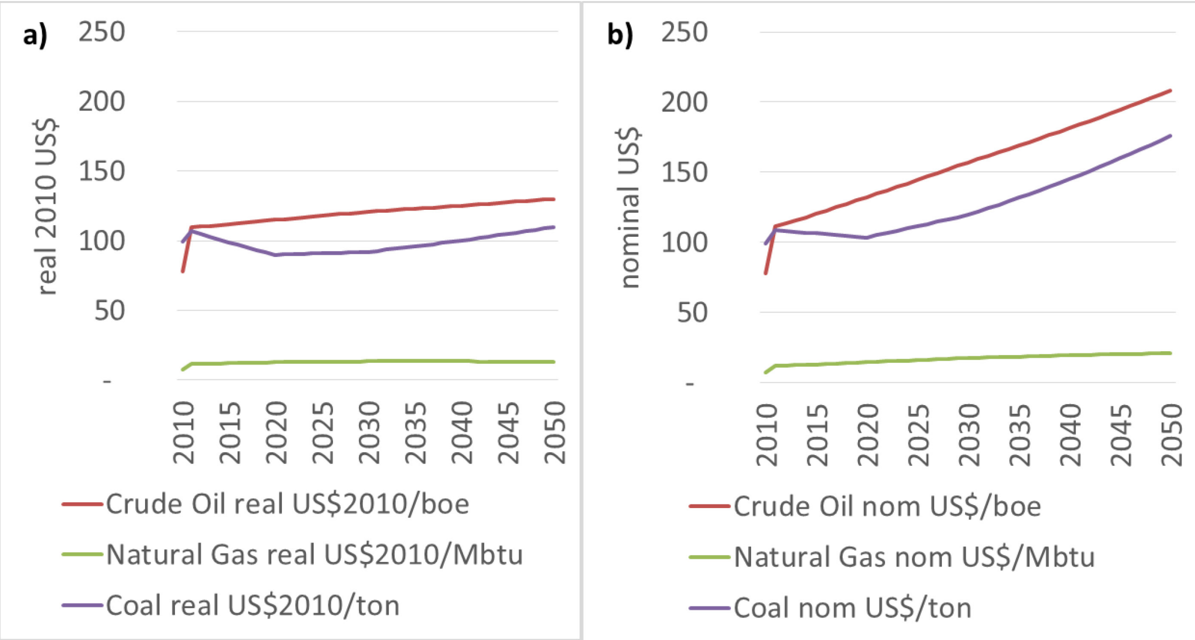


Figure 4: Forecasts of world market prices as used in the macro-economic modelling. Real 2010 US$ in a) and nominal US$ in b). (Sources see Table 2)

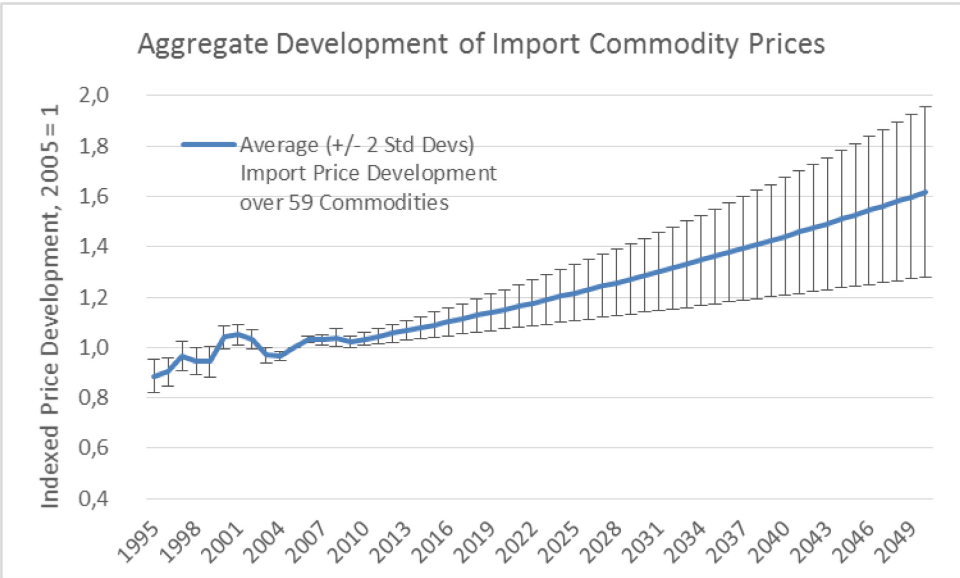


Figure 3: Aggregate Development of Import Commodity Prices used in the modelling until 2050

4.2 Biophysical Evaluation of Model Outcomes and Scenario Results: European Carbon Budgets and Climate Mitigation

From a purely biophysical ecological sustainability perspective, the scale of resource use and emissions is the main factor of interest for any serious evaluation of model outcomes and the 'success' of scenarios. For this purpose, we compare the equitable, blended and inertia carbon budgets for Europe (section 2) against the carbon emissions modelled in the two DYNK scenarios Green Tax Reform and Environmental Fiscal Devaluation (Figure 3). For additional reference we also include the EU2050 Roadmap goals on climate mitigation, on which the initial carbon pricing scheme in the DYNK scenarios is based. The EU2050 roadmap additionally to carbon pricing also explicitly includes carbon capture and storage as well as specific subsidization of renewable energy sources, which add the mid-term mitigation effects of additionally reducing emissions from the mid 2030s on (Figure 3).

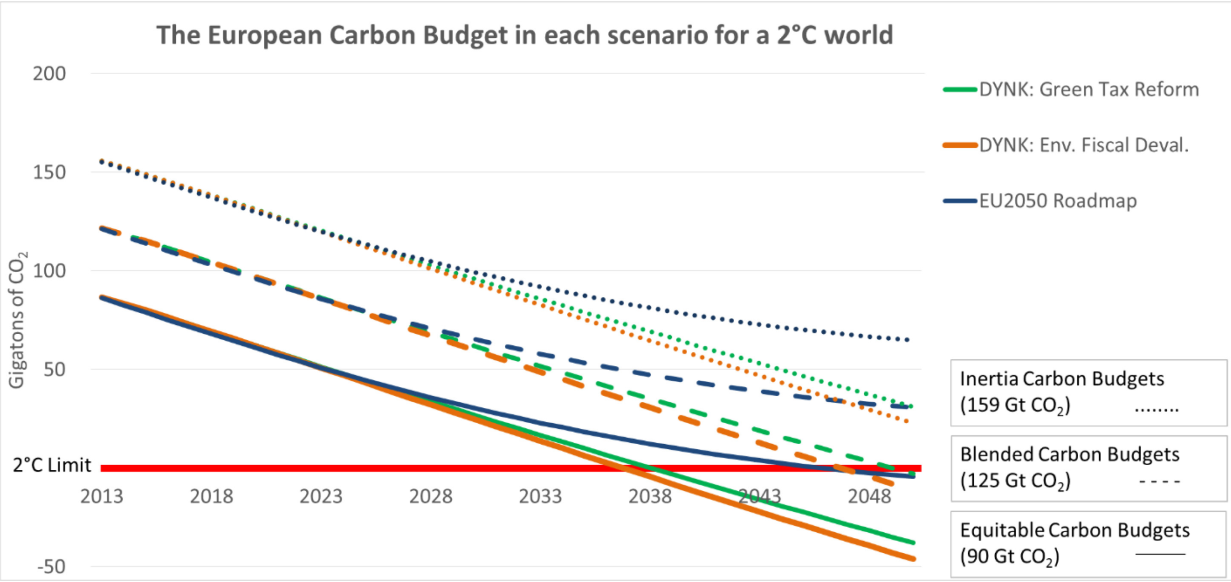


Figure 4: European Carbon Budgets in each scenario until 2050 (own calculations and (Raupach et al. 2014; Kratena and Sommer 2014))

The results of the DYNK scenarios exhaust the entire equitable and blended European carbon budget during the period modelled (ether around 2040 or 2050). After 2050, no more additional carbon emissions would be 'allowed' if Europe sticks to its equitable/blended share of the global carbon budget (Figure 3). However, in both scenarios significant annual emissions continue to 2050 and beyond (3 and 3.3 Gigatons of CO_2 per annum). The EU2050 roadmap goals would, given equitable carbon budgets, exhaust the entire carbon budget by 2050, but would only have annual emissions of 0.9 Gt of CO_2 in 2050. Given blended carbon budgets, the EU2050 roadmap trajectory would leave 31 Gt of CO_2 to be emitted in Europe in the second half of the 21st century, which would easily suffice, given the very low projected annual emissions remaining at that point (0.9 Gt CO_2 p.a. in 2050). It has to be noted that the EU2050 roadmap projections are based on optimistic technological assumptions about the feasibility and scalability of carbon capture and storage to decarbonize electricity supply. The DYNK scenarios, using only the carbon pricing instrument, are on the same trajectory as the EU2050 roadmap up until 2030, where CCS and a rapid rollout of renewable low-carbon energy supply additionally affects aggregate carbon emissions.

Only for the inertia based carbon budgets both DYNK scenarios comply with the 2°C target in 2050, with remaining inertia carbon budgets of 31 Gt for the Green Tax Reform, 23 Gt for the Env. Fiscal

Devaluation and 65 Gt for the EU2050 Roadmap. This inertia based allocation only takes into account current emissions and therefore leaves hardly any "environmental space" for the developing countries to achieve certain levels of material welfare and to substantially alleviate poverty.

4.3 Biophysical Evaluation of Model Outcomes and Scenario Results: Scale, Composition and Patterns of European Resource Use

Regarding material and resource use the definition of specific limits is not as straightforward and therefore the debate surrounding sustainable levels of material use are not yet entirely conclusive. Currently approximately 8 tons per capita are seen as potentially viable goal for global per capita resource use. Given the scenario definitions already presented by SEC (Fischer-Kowalski et al. 2013a, 2013b), we can evaluate if the DYNK modelling can achieve the deep reductions in European resource use that were aimed for in the purely biophysical approaches.

In absolute terms, the two DYNK scenarios produce steadily increasing material use across the entire period modelled, while both biophysical SEC scenarios propose absolutely decreasing resource use (Figure 5). While the DYNK scenarios result in an absolute scale of annual resource use of 8.8 Gigatons in the Green Tax Reform scenario, the Environmental Fiscal Devaluation approach even results in 9.9 Gt of annual material use in 2050. In contrast, the SEC scenario of best practice lowers resource use to 6.2 Gt p.a., and in the radical transformation scenario, it is even lowered to 4.2 Gt p.a.

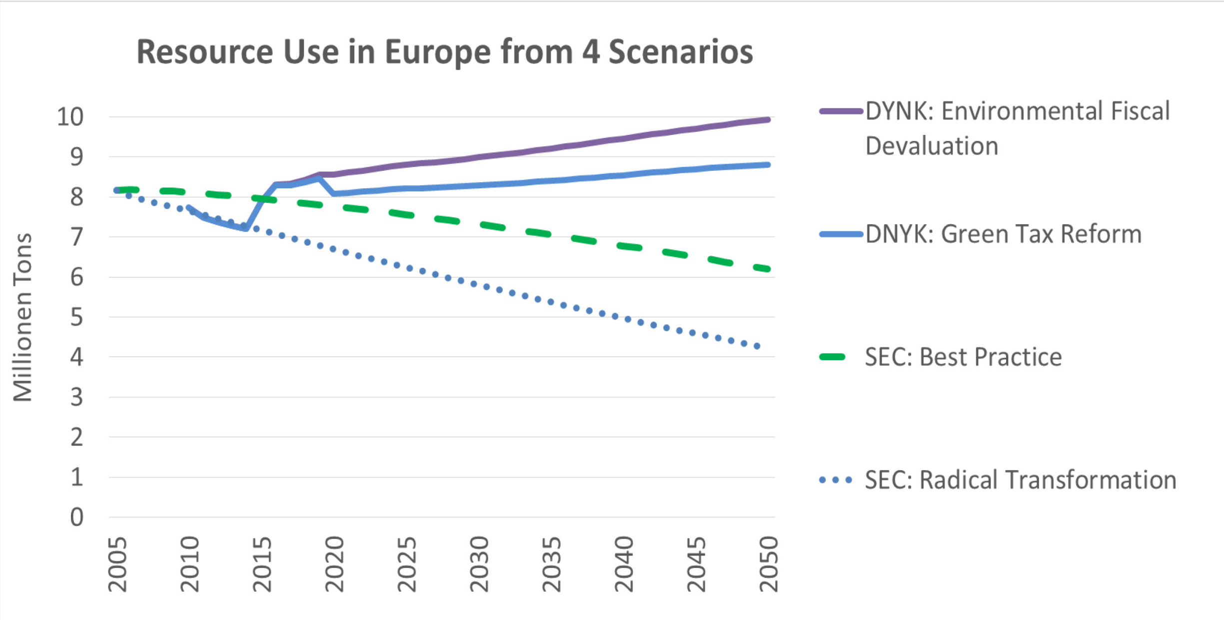


Figure 5: Resource Use in Europe for two DYNK and two SEC scenarios (own calculations), from (Kratena and Sommer 2014; Fischer-Kowalski et al. 2013a, 2013b)

Interestingly the composition of total material use also differs strongly between the two SEC and the two DYNK scenarios (Figure 6). In the DYNK results, 29% of total resource use is biomass and 9-12% (Green Tax Reform vs Env. Fiscal. Deval.) are metals (and ores). In the SEC scenarios, the share of biomass (22 and 20%) and metals (5 and 4%) are substantially lower. In turn the relative importance of non-metallic construction minerals is much higher in the SEC scenarios (59 and 56%) than in the DYNK scenarios (40 and 46%).

These differences mainly result from the very different modelling approaches applied in DYNK and by SEC, where DYNK relies on a dynamic econometric input-output structure and its empirical interdependencies, while the SEC scenarios are only based on literature and expert judgments.

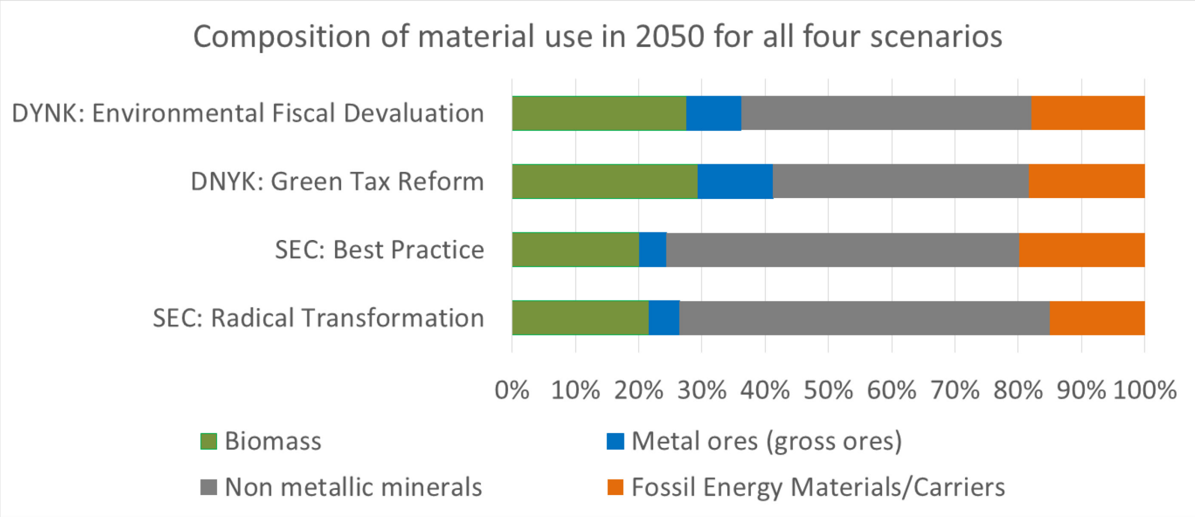


Figure 6: Projected Composition of Resource Use in 2050 (own calculations, from (Kratena and Sommer 2014; Fischer-Kowalski et al. 2013a, 2013b)

On a per capita level substantial differences also persist between the resource use implications of the four scenarios and the potentially sustainable level of about 8 tons per capita (Figure 7). The SEC radical transformation scenario reaches this level of per capita resource use by definition, while the best practice estimates only arrives at 12 tons per capita. Both DYNK scenarios have higher resource use per capita than the current level in 2012 (14 tons), with 19 and 17 tons per capita. Again, it becomes quite clear that the DYNK and SEC scenarios are mainly differing in the amounts of biomass and metals used. This has to be investigated further.

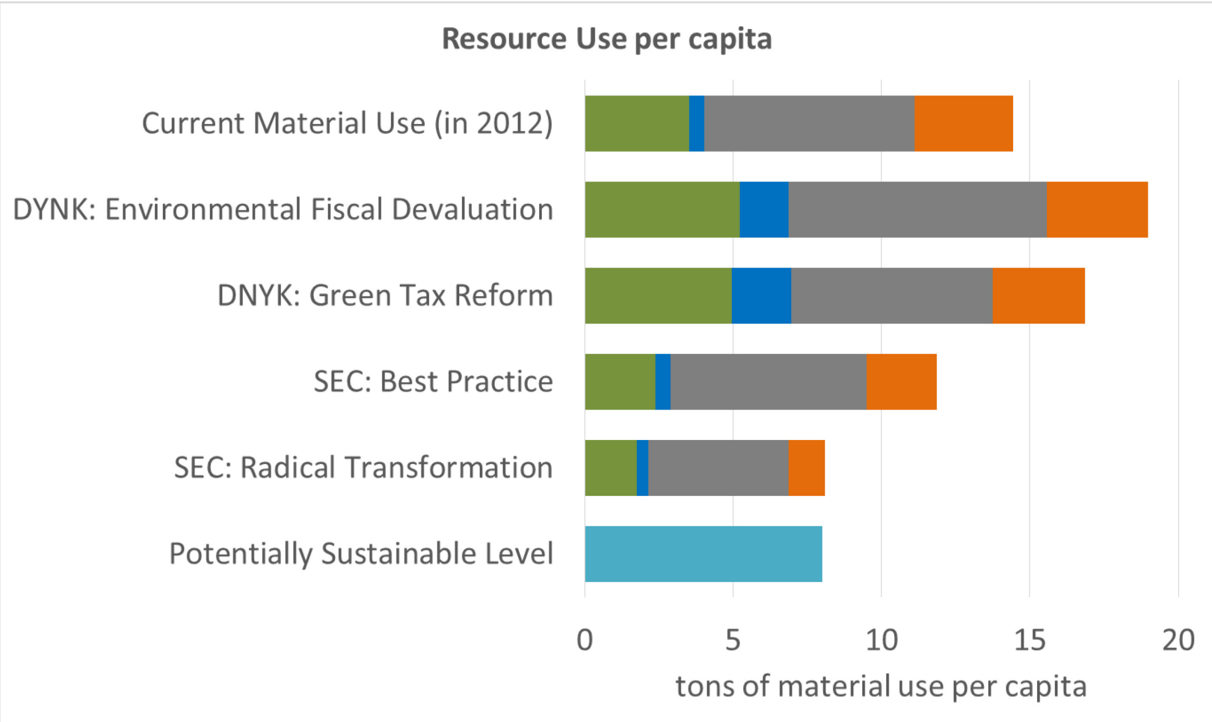


Figure 7: Projected Resource Use Per capita in Europe for two DYNK and two SEC scenarios (own calculations, (Kratena and Sommer 2014; Fischer-Kowalski et al. 2013a, 2013b); for the potentially sustainable level we refer to (United Nations Environment Programme. et al. 2011; Hoekstra and Wiedmann 2014). Current material use has been sourced from Eurostat Material Flow Accounts.

4.4 Transforming capital and infrastructure stocks to enable a sustainable metabolism – modelling challenges and current treatment

One major aspect of any long-term transformation of the socio-metabolic system is a deep structural change in the scale, composition, functions and types of stocks used and accumulated in a society (Pauliuk and Müller 2014; Fischer-Kowalski and Haberl 2007; Fischer-Kowalski et al. 1997; Müller et al. 2013). A transformation towards a more sustainable energy system also requires structural change of the entire capital stocks bound up in the energy sector (Hertwich et al. 2014). For example, the current energy system of the European Union has co-evolved into a complex infrastructure network of power stations, power lines, transformation stations, distribution networks to households and industries as well as appliances, machines and various electrical equipment as well as legal systems, user behaviour, industry standards and so forth. The prospect of potentially re-building large infrastructure networks in order to enable a sustainable metabolism has led to concerns about the material and energy implications of such a large scale endeavour, where only recently systematic energy/material/emissions linked efforts have been published (Hertwich et al. 2014). Usually the environmental consequences of a transformation of stocks are only simplistically modelled, because of large requirements for detailed data and work-time involved (Pauliuk et al. 2014; Turner et al. 2011). In the SEC scenarios stock dynamics are not explicitly modelled but based on the literature we assumed relative stock stabilization and increased recycling, thereby freeing up certain amounts of virgin and recycled resources for the transformation of existing stocks.

Expanding these considerations towards macro-economic models and the specific representation of capital stocks used in production highlights several interesting points. Firstly, in macro-economic models capital is usually only represented via its monetary value on capital costs, depreciation and relative prices, without much technical or biophysical information on the stocks of capital and infrastructure themselves. Secondly, modelling substitution and complementarity of capital, labor, energy and materials depends on statistical relationships between the monetary values of these four integral parts of production, without much consideration of functional biophysical relationships, for example between the transformation of materials into products requiring certain energy use. A change in the composition and types of capital are therefore represented only very simplistically. To properly model change towards substantially more efficient physical capital would therefore require an explicit module integrated into a macro-economic model which tracks the cohorts of capital stocks, their specific efficiencies and energy as well as material requirements and material contents (Pauliuk et al. 2014; Turner et al. 2011). While the DYNK model is very detailed in its sectoral level treatment of production functions and sectoral interdependencies, via the use of a KLEMS production function (Kapital, Labour, Energy, Materials, Services), these issues are only represented at the level of monetary relationships.

Because of the significant commitments which would be required to develop the SEC and the WIFO approaches into this direction, and due to data constraints, this avenue has not been followed in the WWWforEurope project and remains to be resolved by further research.

5. Preliminary Conclusions and Potential Next Steps

The results presented above have to be treated as preliminary. In this collaboration, the SEC scenarios are supposed to define potentially sustainable resource use trajectories, which are then to be reached by the macro-economic modelling exercises. The SEC Scenarios have been defined top-down, based on literature reviews and expert judgments; they constitute more of a goal setting in environmental terms than a formal modelling exercise based upon explicit system dynamics. The DYNK results on the other hand are strongly driven by the baseline trajectories derived from the conceptual layout and the econometric parametrization of the DYNK model itself. The ability of such models to simulate deep structural change is constrained by the empirical relationships in the data as well as by the level of detail achievable with existing datasets.

One of the key issues for further collaboration between the two teams is improving estimates and conceptualizations for a ‘realistic’ baseline scenario. The comparison and evaluation of each further scenario and policy instrument has to counteract the built-in relationships of the baseline, thus implicitly assuming that this baseline is actually feasible and realistic in itself. Judging the merit of certain policy interventions in terms of relative change against the baseline, as seems to be common practice in macro-economics, thus ignores the potential pitfalls and negative non-linear feedbacks of a continued and unabated growth path, including the probably mounting damages and interruptions due to global environmental change and climate change to be expected in the 21st century, if no substantial mitigation happens (Moore and Diaz 2015; Friedlingstein et al. 2014; Alexander 2013; IPCC 2014). Semi-empirical assumptions about endogenous technical change, factor productivity developments and autonomous efficiency gains therefore also require a critical evaluation in order to not overestimate endogenous dynamics and underestimate the impact of certain interventions, especially when absolute reductions in resource use and emissions are the goal. Therefore, updates of the DYNK baseline and scenario results would be desirable in 2015.

In this exercise the carbon budgets approach has proved to be a highly useful metric for an evaluation of the impacts of the scenarios for climate mitigation, because these budgets represent credible and scientifically founded absolute limits, if climate change is to be contained within the 2°C target. Because newest estimates and credible sharing mechanisms of a global budget were just published in September 2014, SEC could not use them in the scenario definition and the formulation of biophysical constraints at the beginning of the project. It is also clear that the DYNK model is not designed to specifically simulate detailed climate mitigation scenarios but focuses on interlinkages between materials, energy and emissions as well as socio-economic impacts. Therefore, staying approximately within these budgets would suffice as a criterion. Currently the two DYNK scenarios do not stay within the equitable and blended carbon budgets; only the inertia based carbon budget suffices. We consider the simulation of additional policy interventions, as well as the re-calibration of the baseline scenario as necessary to arrive at results that are more satisfactory. This would also be highly desirable for 2015.

With regard to material and resource use, the current results of the modelling exercise are not satisfactory. In both DYNK scenarios, absolute resource use is increasing, while a strong reduction of overall material use is deemed necessary in the SEC scenarios and the literature. The definition and parametrization of the baseline trajectory, as well as semi-endogenous efficiency gains need to be critically evaluated by the WIFO and SEC team. This is another area for improvements in 2015.

Finally, these steps allow for a more detailed investigation and understanding of the potential interactions or trade-offs between reducing both emissions and material use (Barrett and Scott 2012). At this stage, it seems that while carbon emissions decline in the DYNK scenarios, overall material use is still growing slightly. This is surprising, because high carbon prices and a certain taxation of resource use should actually reduce both, as has been assumed in the SEC scenarios. Furthermore, on a biophysical level, one would expect reduced energy use (via emissions) to causally lead to decreasing material use as well. Therefore, we need to check if the econometric substitution elasticities actually represent these fundamental relationships in a realistic manner and to specify the mechanisms under which the DYNK model can represent the interdependencies between energy, materials and emissions.

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Project Information

Welfare, Wealth and Work for Europe

A European research consortium is working on the analytical foundations for a socio-ecological transition

Abstract

Europe needs change. The financial crisis has exposed long-neglected deficiencies in the present growth path, most visibly in the areas of unemployment and public debt. At the same time, Europe has to cope with new challenges, ranging from globalisation and demographic shifts to new technologies and ecological challenges. Under the title of Welfare, Wealth and Work for Europe – WWWforEurope – a European research consortium is laying the analytical foundation for a new development strategy that will enable a socio-ecological transition to high levels of employment, social inclusion, gender equity and environmental sustainability. The four-year research project within the 7th Framework Programme funded by the European Commission was launched in April 2012. The consortium brings together researchers from 34 scientific institutions in 12 European countries and is coordinated by the Austrian Institute of Economic Research (WIFO). The project coordinator is Karl Aiginger, director of WIFO.

For details on WWWforEurope see: www.foreurope.eu

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