Global implications of a European environmental tax reform

Stefan Giljum[a], Christian Lutz[b], Christine Polzin[a]

[a] Sustainable Europe Research Institute (SERI), Vienna, Austria

[b] Institute for Economic Structures Research (GWS), Osnabrück, Germany

19 January 2010

PETRE (see http://www.petre.org.uk/papers.htm) is part of the Anglo-German Foundation research policy initiative: *Creating sustainable growth in Europe*
(see http://www.agf.org.uk/currentprogramme/CreatingSustainableGrowthInEurope.php)

1. Abstract

Europe is critically dependent on other countries and regions regarding important resources such as fossil fuels and metal ores. While trade enables Europe to obtain about one third of its used material and energy resources it also extends its responsibility for environmental as well as social impacts associated with the extraction and processing of these resources abroad. Environmental tax reform (ETR) can be used as an instrument to reduce the EU's resource consumption as well as its CO_2 emissions and thus achieve more sustainable and responsible development by taking into account the external costs of consumption and production. So far, however, experiences with ETR have been limited and small in scale. This paper analyses the potential economic and environmental implications of a much more ambitious and far-reaching ETR on the EU and its trading partners. It finds that unilateral action by the EU makes only a small contribution to EU resource security and is insignificant in terms of global environmental sustainability. A larger ETR in the EU in the context of global cooperation produces more substantial results, reducing global material extraction by around 5% and global CO_2 emissions by more than 15%, while reducing world GDP by only 1.4%. The results show that in a cooperative global context, the economic impacts on the rest of the world of a major ETR in Europe are small but that the environmental benefits can be significant.

1. Introduction

European production and consumption activities are increasingly dependent on material and energy resources from abroad and imply significant economic and environmental consequences in other regions around the world. While the overall level of resource use in Europe has stabilised over the past 20 years, the source of these resources has shifted abroad (Schütz el al., 2004; Weisz et al., 2006, Giljum et al., 2008b). Altogether, around one third of material and energy resources used by Europe are imported. This substitution of domestic material extraction through international trade of physical imports has also shifted part of Europe's environmental burden abroad and extends the responsibility for environmental as well as social impacts from the local to the global level (SERI and FOE, 2009). The reserves of the most important resources, especially fossil fuels and metal ores, are located outside of Europe, causing a critical dependence of Europe on other countries and regions. For example, the EU-27 countries only possess 3% of global iron ore reserves, 1% of global oil reserves, and 1% of global uranium reserves (USGS, 2006). Consequently, for many rare metal ores a very high dependency on imports can be observed. For platinum and tantalum the import rate is 100%, for iron ores 83%, and for bauxite 74% (EC, 2006).

In light of Europe's high and growing dependence on resource imports, the European Union has taken a number of policy measures to address resource security and productivity as well as related environmental concerns. Among those are the Raw Materials Initiative (2008), the Sustainable Consumption and Production Action Plan (2008), the trade strategy Global Europe (2006) and the Thematic Strategy on the Sustainable Use of Natural Resources (2005). They all highlight access to resources and resource security as key issues for the future success of the European economy.

Recognising the impacts that the production and consumption activities within the EU have on other world regions, the European Commission has called for a more sustainable management of natural resources along with a de-coupling of resource consumption and related negative environmental impacts from economic growth in Europe. This strategy should diminish the environmental impact the Union has on the rest of the world and thus contribute to global sustainable development (EC, 2005).

In all resource-related policy strategies, resource productivity plays a significant role for future European development – both because of its potential to diminish unsustainable patterns of resource and energy use and because of its importance for future economic development. Given that productivity growth is lacking behind other world regions, in particular North America and Asia, there are growing concerns about the Union's competitiveness on world markets. Europe's economic underperformance coupled with increasing competitive pressures from emerging economies could lead to shifts in national production structures with implications for sustainable development at the global level. In this context of pressing reform needs, eco-efficient innovation and increased resource efficiency could play a key role in increasing European competitiveness on world markets (European Parliament, 2009).

With resource security, efficiency and related environmental concerns high on the EU's agenda, environmental tax reform (ETR) and other market-based instruments to stimulate sustainable and responsible production and consumption have gained widespread interest because they can help address social (mainly employment) and environmental goals.

This paper builds on the results of the project "Resource Productivity, Environmental Tax Reform and Sustainable Growth in Europe" (PETRE, http://www.petre.org.uk), funded by the Anglo-German Foundation. The project aimed at investigating the major economic and environmental implications of improved resource productivity and environmental tax reform (ETR) at different levels, both within the EU and in the global economy. The paper discusses some of the main results of the investigation on the global dimensions of sustainable growth in Europe. The main research questions which guided this analysis included:

- What are the global consequences of the implementation of an ETR (and thus resource productivity increases) in Europe in terms of world-wide patterns of natural resource extraction, production, trade and consumption?
- What are the differences between a business-as-usual scenario, a unilateral EU ETR scenario, and a European ETR in combination with wider commitments to emission reductions in other developed countries and economically more advanced developing countries?
- Which European industries would be most negatively affected in their international competitiveness by the implementation of an ETR in Europe?
- What are the policy implications of the global effects of an ETR?

The relevance of these questions is underlined by the current discussions at international climate conferences about the impacts of unilateral vs. multilateral policy strategies and on the precise interpretation of 'common but differentiated responsibilities', a principle agreed to in the Kyoto Protocol. This paper contributes to the discussion on the roles of the industrialised, emerging and developing countries in dealing with climate change and, more precisely, on the policy impacts of EU vs. international environmental tax reforms (see for example Helm 2008, Whalley and Walsh 2009).

To analyse different policy scenarios from a global perspective and reveal the economic–environmental interdependences, the GINFORS (Global INterindustry FORecasting System) model was used and refined. GINFORS was originally developed as the simulation engine in the EU project MOSUS (Modelling Opportunities and Limits for Restructuring Europe towards Sustainability; www.mosus.net) which analysed the impact of European resource strategies and environmental policy measures on economic development and resource extractions in the world and all European countries. In the course of the PETRE project, the GINFORS model was updated and the material input models extended.

The main policy conclusion from this paper is that strong concerted action from the EU and emerging countries is needed in order to slow the current growth rate of global CO_2 emissions and resource use in order to achieve more environmentally sustainable economic growth.

The paper is structured as follows: Section 2 provides a description of the Global Inter-industry Forecasting System (GINFORS), the integrated simulation model which was used to simulate the scenarios and analyse current and future economic and environmental indicators. Section 3 describes the scenarios. Detailed results are presented and discussed in Section 4. Policy conclusions are derived in the closing Section 5.

2. Model description

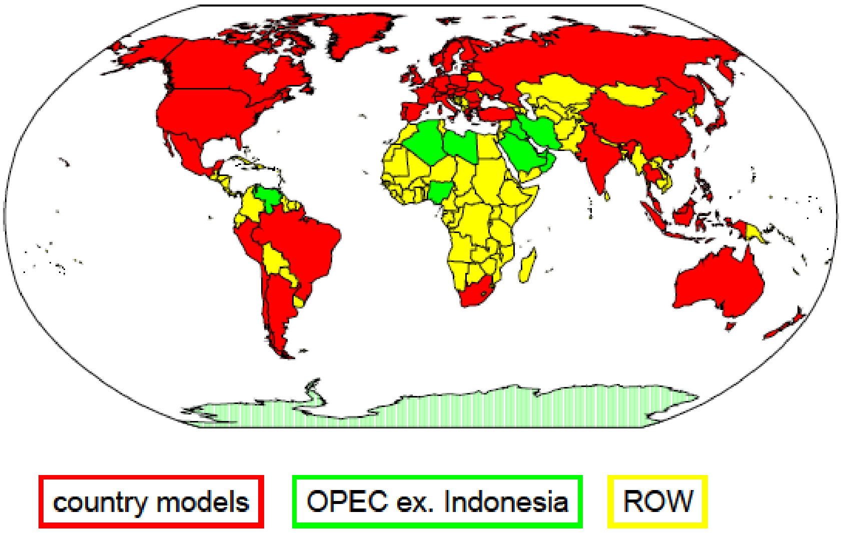
GINFORS is a global economy-energy-environment simulation model which can be used to analyse outcomes of different future (policy) scenarios and to show the interactions and interdependencies of different economic and environmental variables. GINFORS links modules for bilateral trade, macroeconomic behaviour, industrial output from input-output (IO) tables and energy use and prices. GINFORS explicitly covers countries accounting for about 95% of World GDP as well as 95% of global CO_2 emissions. A simplified model for the rest of the world ensures global coverage. It also includes a global dataset on material extraction which allows analysing European and global patterns of resource extraction. In the PETRE project, the GINFORS model was one of the two main simulation models assessing the implications of the implementation of an ETR in Europe and the only one that allowed analysing global implications.[1]

Figure 1 illustrates the country coverage of GINFORS. The countries for which there are individual models are red (dark), those belonging to the OPEC (without Indonesia, which is explicitly modelled) are shaded green (grey). The yellow (white) area represents the Rest of the World (RoW), a group of countries in Central and South America, Asia, Africa and very few in Europe that play a minor role in terms of GDP, trade and environmental pressure.

[1] The model is documented in Meyer et al. (2007), Meyer and Lutz (2007), and Lutz et al. (2010). Current applications of the model can be found in Giljum et al. (2008a), Lutz and Meyer (2009a and b) and Lutz and Giljum (2009).

While GINFORS currently models 50 countries and one region (OPEC) it is open to be extended to further countries.

Figure 1: Country coverage of GINFORS



The database of GINFORS uses five main sources (see Table 1): (1) the Organisation for Economic Co-operation and Development (OECD), (2) the International Monetary Fund (IMF), (3) the COMTRADE database of the UN, (4) the International Energy Agency (IEA) and (5) the Global Material Flows database (http://www.materialflows.net) of the Sustainable Europe Research Institute (SERI). In addition, national statistics are included in the case of China and Taiwan. The trade data result from an integration of OECD and UN trade data. The data for the macro model are based on the "National Accounts of OECD Countries, Detailed Tables" by the OECD and the "International Financial Statistics" by the IMF. In order to ensure a coherent level of data for the model, own calculations are used to fill gaps within the data sets. In most cases, the IO tables were taken from OECD publications and Eurostat. The energy models exclusively correspond to the energy balances published by the IEA. For the material-input models, GINFORS uses world-wide material extraction data from SERI. The population projection stems from United Nations. Purchasing power parities (PPPs) to calculate global GDP figures are taken from the World Bank.

Table 1: Main data sources of the GINFORS model

model type		data sources	Source	global coverage
trade		OECD	www.oecd.org (Bilateral Trade Data)	50 countries,
		UN	http://comtrade.un.org/	2 regions (OPEC, ROW),
country models	input-output / sector	OECD	www.oecd.org (Input Output Tables)	21 countries
		OECD	www.oecd.org (National Accounts: Detailed Tables)	
		national sources	www.oecd.org (STAN)	
	macro	OECD/IMF	www.oecd.org (Detailed Tables), http://www.imfstatistics.org/imf/	52 countries/regions
	energy	IEA	www.iea.org	53 countries/regions
	material	SERI	www.materialflows.net	54 countries/regions
	Population	UN	http://esa.un.org/unpp/	52 countries/regions

The model consists of five main parts: the bilateral trade model, input-output models, macro models, energy-emission models, and material-input models. The trade model, which links the individual country models, is the central part of GINFORS. Bilateral trade matrices are provided for 25 commodities as well as service trade covering all OECD countries, 25 EU countries (EU-25) and 16 further major trade partners. Via this trade context, both quantities and prices are properly allocated to the different countries. The economic core of each country model consists of a macro-economic model and an input-output model providing disaggregated data by sector. The macro models in GINFORS consist of five modules: balance of payments, final demand, money market, labour market and the System of National Accounts (SNA). They are available for all countries. The IO models are available for 21 countries only.

The energy-emission models show the interrelations between economic development, energy consumption (structured by the relevant energy carriers) and CO_2 emissions for all countries and regions. The CO_2 emissions are linked with the fossil energy carriers by constant carbon relations. The variables of the corresponding macro model and of the IO Model – if available – are used as drivers. At the same time, the expenditure for energy consumption has a direct influence on economic variables. The energy models are based on uniform energy balances in physical units published by the IEA (2008a, 2008b) each year since 1960 or 1970. The CO_2 emissions, which are connected to the Total Primary Energy Supply (TPES) via fixed emission factors, are also recorded by the IEA (2008c).

The material-input models reflect the extraction of nine material categories (agriculture, grazing and fish; forestry; coal; crude oil; iron ores; other metal ores; industrial minerals; construction minerals) in the individual countries and the linkages to their global economic drivers, including international trade and domestic production in different economic sectors. The model distinguishes between domestic and export demand for materials and assumes that material extraction follows economic development.

One of the main limitations of the model is that it does not include any restriction in the supply of raw materials and thus puts no physical constraints on future economic development. In reality, two major ecological limits to growth could prevent continued high growth of global resource extraction: resource scarcity and limited biocapacity. Since the peaks of extraction for various commodities have already been reached or are about to be reached (for the case of oil see for example IEA 2008), a future reduction in the extraction of these resources and constricted availability are thus very likely. As demand for material consumption increases, the per capita availability of biocapacity (the supply of biologically productive area and related ecosystem services) declines, leading to overshoot and environmental degradation. While scarce biocapacity could be one of the main limits to future economic development (WWF et al., 2008) it could not yet directly be incorporated in the GINFORS model.

GINFORS is capable of providing scientifically sound, policy relevant insights into the links between economic growth, economic activity at a sector level and environmental pressures including climate change and material consumption. The model has been used for EU policy simulations (Lutz and Meyer 2009a and b) in a global context, including, for example, the projects MOSUS and INDI-LINK (Indicator-based evaluation of interlinkages between different sustainable development objectives). In the MOSUS project (see Giljum et al. 2008a), GINFORS was used to model three scenarios for European development up to the year 2020 to compare different policy interventions. The results suggested that policy instruments aimed at raising eco-efficiency at the micro-level can be conducive to economic growth and lead to the creation of new jobs. However, they must be accompanied by other policies influencing the prices of energy and materials in order to limit rebound effects at the macro level. In the INDI-LINK project, GINFORS was applied to analyse the interlinkages between different economic and environmental sustainable development indicators at the national, EU and global level, and to assess different policy strategies to overcome possible trade-offs (see Lutz and Wiebe, 2009).

3. Scenario assumptions

In the course of PETRE six scenarios were implemented in GINFORS, based on the proposals for energy and climate policy measures which have been discussed at various levels of the EU (EC, 2008), some in different variants, until the year 2020.

The scenario analysis allows for an understanding of different revenue recycling methods and various scales of ETR in order to meet different greenhouse gas emissions targets. The scenarios examined in GINFORS are:

- BL: Baseline with low energy prices,

- BH: Baseline sensitivity with high oil price (reference case),
- Scenario LS1: ETR with revenue recycling designed to meet unilateral EU 2020 greenhouse gas (GHG) target – an overall 20% reduction in GHG emissions by 2020 compared to 1990,
- Scenario HS1: ETR with revenue recycling designed to meet unilateral EU 2020 GHG target (high oil price),
- Scenario HS2: ETR with revenue recycling designed to meet unilateral EU 2020 GHG target (high oil price), 10% of revenues are spent on eco-innovation measures,
- Scenario HS3: ETR with revenue recycling designed to meet cooperation EU 2020 GHG target – an overall 30% reduction in GHG emissions by 2020 compared to 1990 (high oil price)[2].

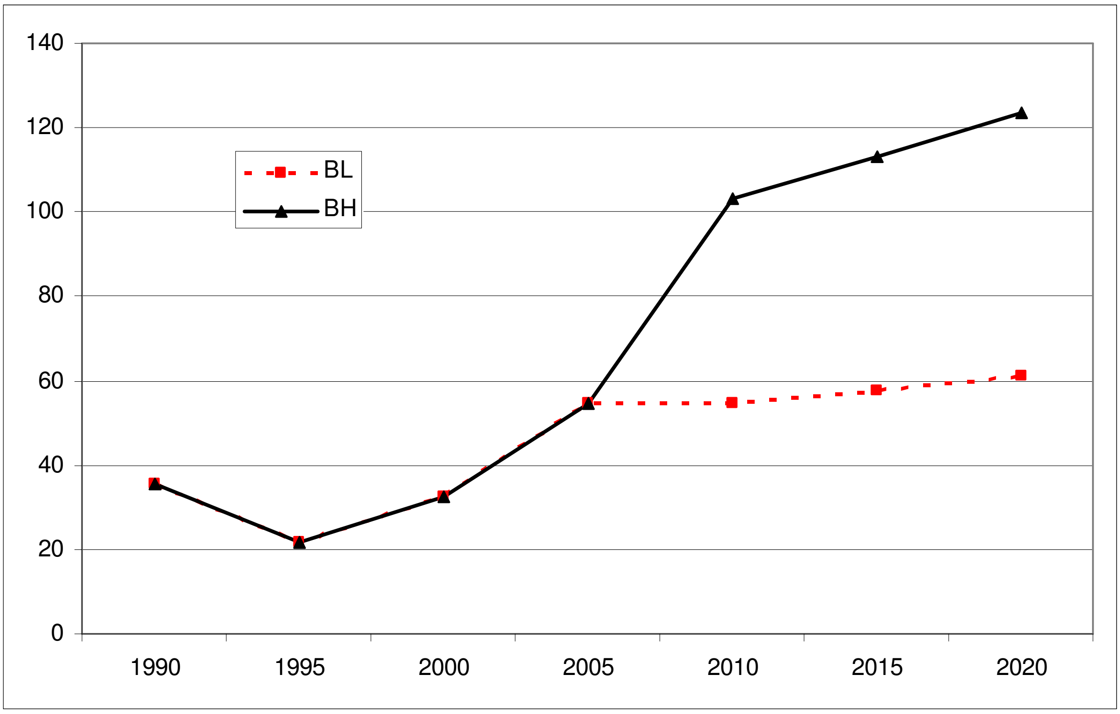
The baseline with low energy prices BL has been calibrated to the 2007 PRIMES baseline to 2030, published by the European Commission (DG TREN 2008). For the high energy price baseline (reference case BH) the effect of a higher oil price, particularly over the period 2008-10 is assumed. Figure 2 shows the different developments of the international oil price in the two scenarios (in USD, 2005). In this scenario coal and gas prices develop in line with the increases to the oil price. In this scenario energy prices are close to the assumptions in the 2008 IEA World Energy Outlook (2008).

Each of the ETR scenarios has the same key taxation components:

- a carbon tax rate is introduced to all non-EU ETS sectors equal to the carbon price in the EU ETS that delivers an overall 20% reduction in greenhouse gas emissions by 2020 compared to 1990, in the international cooperation scenario this is extended to 30%,
- aviation is included in the EU ETS at the end of Phase 2,
- power generation sector EU ETS permits are 100% auctioned in Phase 3 of the EU ETS,
- all other EU ETS permits are 50% auctioned in 2013 increasing to 100% in 2020,
- material taxes are introduced at 5% of total price in 2010 increasing to 15% by 2020.

[2] The term "cooperation" refers to the objective that the 30% reduction in greenhouse gas emissions by 2020 compared to 1990 would be pursued for the period beyond 2012, provided that 'other developed countries commit themselves to comparable emission reductions' and that 'economically more advanced developing countries commit themselves to contributing adequately according to their responsibilities and capabilities' (EC, 2008: 2).

Figure 2: **International oil price in the two scenarios in USD2005/bl**



The scenarios thus distinguish themselves by one or more different input specifications (in this case: energy prices and policy targets on GHG emissions). The outcomes of the scenarios should not be seen as forecasts. They describe different, possible alternatives for future development.

In the baseline scenario population development, economic growth, energy consumption and emission development are based on national and international projections, in particular on the reference scenarios of the PRIMES energy system model of the European Commission (DG TREN 2008) and of the World Energy Outlook (IEA, 2008d) with high energy prices. According to these data, world population will increase to above 8 billion by 2030, and the world economy will grow considerably, driven by the economic development in the developing countries. The baseline scenario assumes that mitigation efforts are not increased worldwide. Note that the consequences of the economic crisis in 2008/2009 are not taken into account in these scenarios. It is thus assumed that long-term economic development is not seriously affected by the crisis.

In scenarios LS1 and HS1 the 20% GHG target translates into a 15% reduction of energy-related carbon emissions against 1990 as other emissions such as methane and nitrous oxide have already been reduced above average. The target is reached by a tightened EU Emission Trading Scheme (ETS) cap and by the introduction of a carbon tax on the non-ETS sector. The tax rate applied will be equal to the carbon price in the EU ETS that will deliver 20% reduction in GHG by 2020. Auctioning and tax revenues are recycled back via reductions in employers' social security contributions and income tax cuts. 50% of the EU ETS permits will be auctioned at the start of phase 3 (2013) and will increase to 100% by the end of Phase 3 (2020). In the power generation sector permits will be 100% auctioned from 2013 onwards.

Taxes on materials will be introduced so that a 5% tax will be introduced in 2010 on each of the materials that the GINFORS model is able to account for. This tax rate will rise to 15% in 2020, i.e. an annual increase of 1%.

The modelled ETR also includes a tax on energy outputs, i.e. on the final use of energy, based on the carbon content of each fuel. Carbon prices are assumed to be fully passed on to consumers. All carbon taxes will be in addition to any existing unilateral carbon taxes. The carbon reductions in the different EU Member States depend on the single EU carbon price and do not correspond to a fixed burden sharing as in the starting allocation determined by the EC (2008).[3]

All revenues, including EU ETS auctioning revenues, carbon tax revenues and material tax revenues will be recycled. The proportion of tax raised from industry will be recycled into a reduction in employers' social security contributions and thus reduce the cost of hiring labour. Recycling will be additional to the existing ETRs in some EU member states. Revenues raised from households will be recycled through standard rate income tax reductions.

In scenario HS2 only 90% (90% from industry and 90% from households) of revenue will be recycled through either employers' social security contributions or standard rate income tax reductions. The remaining 10% will be invested in low carbon technologies. The additional revenue is invested in measures which increase the share of renewables in electricity production. Additional investment is allocated to increase household energy efficiency which is considered to have considerable potential for improvement (Boardman, 2004).

HS3 is leaned on scenario HS1 but with higher targets in line with the EU's stated policy objective of a 30% GHG reduction against 1990 until 2020 (EC, 2008). In GINFORS ETS and ETR are modelled in the major OECD countries. CO_2 prices in these countries will be set to EU prices. It is further assumed that emerging economies will introduce a CO_2 tax which is recycled via income tax reductions. CO_2 tax rates will be 25% of EU (OECD) prices in 2020. Restricted participation of emerging economies takes into account common but differentiated responsibilities (lower historic burden, lower GDP per capita), based on a post-Kyoto project for the German Ministry of Economy in 2007 (Lutz and Meyer, 2009a). The 30% reduction will be in European emissions, without trying to take account of Joint Implementation (JI) and Clean Development Mechanism (CDM) transactions that could be

[3] For a comparison with the EU policy targets see Speck and Jilkova (forthcoming).

on top of the extra EU carbon reduction. Finally, the emerging economies are not assumed to implement material taxes.

The following analysis will only compare the baseline scenario BH with the policy scenarios HS1 and HS3. The global impacts of HS2 will be very close to HS1 as the additional investment in renewables and efficiency in the scenario is not supposed to have any impacts on the costs of low carbon technologies in other parts of the world.

4. Scenario results and discussion

4.1 Global economic implications

To analyse the global economic implications of an ETR in Europe, model calculations were compared on economic growth and trade (particularly the developments of imports and exports) and on the performance of different industries. The following analysis will largely focus on the EU-27[4], OECD (non-EU), emerging economies[5], and the rest of the world (RoW). Impacts of the economic crisis of 2008/09 have not been taken into account in this set of scenarios.

4.1.1 Impacts on economic growth

In the baseline, annual average GDP growth in the EU-27 is expected to remain positive and to fluctuate between 2.2% and 2.5% until 2020 (see Table 2). In the non-EU OECD group, growth rates range between 2.0% and 3.0%. Given that the population of emerging and developing countries is projected to increase significantly over the next four decades and that industrialisation is expected to continue and broaden, average annual GDP growth rates in the group of emerging economies are between two and three times higher than in the EU and other OECD countries. Economic growth in the rest of the world largely depends on energy and resource prices which are not supposed to be above average after 2010, in line with expectations of International Energy Agency (IEA, 2008).

This catch-up trend also leads to a shift of global economic weight in terms of output away from the old industrialised nations. While the EU and OECD countries together accounted for almost 62% of world GDP in 2000, this share is expected to shrink to around 46% in 2020 in the baseline scenario, while emerging and developing countries together will produce around 54% of global GDP. These figures are calculated based on GDP expressed in

---

[4] Due to a lack of data from Romania and Bulgaria, resource extraction is only analysed for the remaining EU-25. All other data in this paper refers to the EU-27.

[5] The group of emerging economies in the GINFORS model comprises the following countries: Argentina, Brazil, China, India, Indonesia, Philippines, Russia, South Africa, and Thailand.

purchasing-power parity (PPP) terms. When calculating them in market exchange rates the shares of the OECD (non-EU) countries are higher.

Table 2 – GDP development in the baseline scenario BL (average annual growth rates)

Average annual growth rates	1995-2000	2000-2005	2005-2010	2010-2015	2015-2020
	In % (based on USD PPP, 2004)				
EU-27	3.1	1.9	2.2	2.5	2.2
OECD (non-EU)	3.8	2.6	2.0	3.0	2.9
Emerging economies	6.2	8.0	8.7	8.3	6.8
RoW	3.8	4.9	5.1	3.7	2.9
World	4.2	4.8	4.4	4.9	4.4

Shares in world GDP (PPP 2004)	2000	2005	2010	2015	2020
	In % (based on USD PPP, 2004)				
EU-27	25.4	22.4	20.4	18.4	16.8
OECD (non-EU)	41.3	37.5	33.8	31.2	29.3
Emerging economies	27.9	31.4	37.0	42.0	46.0
RoW	5.9	9.2	9.5	9.0	8.5
World	100.0	100.0	100.0	100.0	100.0

Note: The regional aggregate economic growth rates are calculated based on GDP expressed in purchasing-power parity (PPP) terms.

Table 3 illustrates the impacts of the implementation of the policy measures in scenarios HS1 and HS3 on GDP in the different regions and in the world as whole.

Table 3 – GDP impacts in different world regions, three scenarios (in billion USD 2000, PPP)

GDP in 2020	Total value of GDP, baseline BH	Absolute deviation of HS1 from BH in 2020	Percentage deviation of HS1 from BH in 2020	Absolute deviation of HS3 from BH in 2020	Percentage deviation of HS3 from BH in 2020
EU-27	15,931	-92	-0.6	-297	-1.9
OECD (non-EU)	27,840	28	0.1	-78	-0.3
Emerging economies	43,699	53	0.1	-688	-1.6
RoW	8,033	6	0.1	-266	-3.3
World total	94,926	-3	0.0	-1,313	-1.4

The impacts of the policy measures on world GDP are limited. As could be expected, the introduction of the policy measures in Europe alone (HS1) reduces world GDP by only USD 3 billion compared to the baseline in 2020, mainly due to declines in the EU (- USD 92 billion) which would be bigger than the relative gains in the non-EU OECD countries (USD 28 billion), the emerging economies (USD 53 billion), and the rest of the world (USD 6 billion). A more substantial decline can be observed for HS3 with a reduction of USD 1.3 trillion. However, this is still only 1.4% lower than in the baseline BH.

It should be noted that HS3 also has positive impacts on some countries' GDP in comparison to BH in 2020 - in the EU-27 notably Latvia (+ 8.6%) and the Slovak Republic (+4%), in the other OECD countries notably Korea (+6.9%) and Australia (+1.3%), in the Emerging Economies mainly the Philippines (+2.7%) and Argentina (+1.4%), and in the RoW Singapore (+5.9%) and Malaysia (+1.5%). The size of the worldwide reduction in GDP must be compared to the enormous negative externalities related to global warming and environmental degradation. Stern (2007) estimates that in the absence of policy interventions, the long-term costs of global warming to the environment, society and the economy may add up to 5 to 20% of global GDP.

The regions' relative positions (shares) in the total value of global GDP do not vary significantly between the different scenarios. All scenarios predict a shrinking of the EU-27 and OECD (non-EU) groups' shares in global GDP in the period from 2000 to 2020: from 66.6% in 2000 to 46.1% (BH), 46% (HS1) and 46.4% (HS3). In contrast, the positions of the emerging economies and of the rest of the world will be stronger. The emerging countries' share of global GDP will increase from 28% to 46% in all scenarios between 2000 and 2020, and the rest of the world will gain between 2.6% (BH and HS1) and 2.4% (HS3).

4.1.2 Impacts on international trade and sectoral competitiveness

Increasing international trade and deeper integration of different world regions in global markets have been central characteristics of globalisation. Between 2000 and 2007, world export volumes grew by 5.5% annually while production only increased by 3.0% a year. Growth in trade was highest for manufactured products (6.5%), followed by agricultural products (4.0%), and fuels and mineral products (3.5%) (WTO, 2008).

In the baseline scenario BH, the GINFORS results show continuous growth of both exports (Table 4) and imports (Table 5) in monetary terms across all regions from 2000 to 2020.

Table 4 – Export developments in different world regions, baseline scenario BH

Average annual growth rates	2000-2005	2005-2010	2010-2015	2015-2020
	In % (based on USD, 2000)			
EU-27	3.7	3.1	2.6	2.9
OECD (non-EU)	7.7	5.1	3.1	2.5
Emerging economies	5.1	9.3	5.4	6.1
RoW	8.7	8.3	5.3	5.8

Table 5 - Import developments in different world regions, baseline scenario BH

Average annual growth rates	2000-2005	2005-2010	2010-2015	2015-2020
	In % (based on USD, 2000)			
EU-27	1.7	2.8	3.6	3.7
OECD (non-EU)	1.6	2.7	4.0	3.9
Emerging economies	14.2	7.6	7.0	6.3
RoW	7.1	7.6	5.2	5.7

The lowest growth of export values in the baseline scenario BH is expected in the non-EU OECD region while the highest growth would occur in the group of emerging economies. For the periods 2010-2015 and 2015-2020 the growth of imports in the emerging economies can be expected to be twice as high as that in the EU-27 in the baseline scenario.

Table 6 shows that exports will not change significantly in countries outside the EU (less than 2%) in response to the introduction of HS1 and HS3 policy measures, compared to the baseline situation in 2020. In scenario HS3, exports in non-EU OECD countries would be 0.5% lower than in the baseline, 1.4% lower in the group of emerging countries and 1.5% lower in the rest of the world. In the EU itself, exports would slightly decline by 0.8% in HS1 and by 3.3% if HS3 policies were to be adopted. Countries within the groups are affected differently. Resource exporters will have to reduce exports such as fossil fuels. Thus, the largest export reductions in 2020, compared to the baseline scenario, would be experienced by OPEC (-12.7%), Spain (-8.9%), Italy (-8.2%), and Canada (-6.3%). In the emerging economies, exports would decline in China (-3.4%), South Africa (-2.7%), and Russia (-1.7%). Yet some Asian countries can increase their trade shares and export more than in the baseline scenario by 2020, especially in scenario HS3, notably Korea (+8.7%), Singapore (+5.5%), the Philippines (+2.8%), Malaysia (+2.5%), and India (+2.3%).

Table 6 - Export impacts in different world regions, three scenarios

Country group	Total value of exports, 2010 (PPP bn USD)	Total value of exports, BH, 2020 (PPP bn USD)	Absolute deviation of HS1 from BH in 2020 (PPP bn USD)	Percentage deviation of HS1 from BH in 2020	Absolute deviation of HS3 from BH in 2020 (PPP bn USD)	Percentage deviation of HS3 from BH in 2020
EU-27	5144.4	7972.0	-60.1	-0.8%	-264.2	-3.3%
OECD (non-EU)	4044.7	5505.1	14.1	0.3%	-29.5	-0.5%
Emerging economies	6651.4	11036.0	19.8	0.2%	-159.2	-1.4%
RoW	3166.5	4913.9	7.4	0.2%	-73.2	-1.5%

The ETR does not only affect the international competitiveness of different countries but also that of different sectors. ETS and ETR will increase transport costs, which will partly reduce the ongoing globalization process in terms of international trade volumes. Exports and imports will therefore be lower than in the baseline. Economic production processes may partly be regionalised again.

Comparing EU export growth rates of the different policy scenarios to the baseline in 2020, all sectors under investigation would experience stronger declines in HS3 than in HS1 (see Figure 3 and Figure 4). Since the higher costs of fossil fuels lead to a loss in sectoral price competitiveness, especially in energy-intensive industries in the short run, the strongest decline rates would be experienced in the utilities and heavy industries, notably Electricity, Gas and Water Supply (HS1: -10.9%, HS3: -27.1%), Coke and Refined Petroleum Products (HS1: -9.0%; HS3: -10.4%), and Iron and Steel (HS1: -6.1%; HS3: -16.8%). Interestingly, export values of the Mining and Quarrying sector would increase by 0.2% in HS1 but decline by 17.0% in HS3 compared to the baseline in 2020. This may be explained by the fact that the exports of Mining and Quarrying depend entirely on the demand of the world market, which GINFORS reflects by fixed supply structures. As the use of coal declines significantly in scenario HS3 the exports of Mining and Quarrying reduce accordingly. Apart from Mining and Quarrying, Office Machinery as well as Medical, Precision and Optical Instruments would be least negatively affected in HS1 (experiencing growth rates of 0.05 and -0.2% respectively compared to the baseline in 2020).

The relatively weak negative effects on exports in the emerging economies in HS3 may be due to the fact that many of them have a diversified export market in which the industrialised countries of the EU and OECD are not always the main destination. For example, only 10% of all Chinese exports will be delivered to the EU in 2020 if HS3 policies are implemented, while 67% will go to the rest of the world, 10% to OPEC, and 13% to other emerging countries. In the case of India, 58% of all exports are expected to go the rest of the world, 25% to the EU, 14% to other emerging countries, and 3% to OPEC by the year 2020 in scenario HS3.

The strongest declines in terms of absolute monetary values would be experienced in EU exports of Chemicals (excluding pharmaceuticals) (HS1: -4.4 bn USD, HS3: -17.0 bn USD), followed by Machinery and Equipment (HS1: -2.8 bn USD, HS3: -14.7 bn USD), and Motor Vehicles (HS1: -2.8 bn USD, HS3: -7.7 bn USD).

Figure 3: EU Exports to non-EU countries – percentage deviation of HS1 from baseline BH in 2020

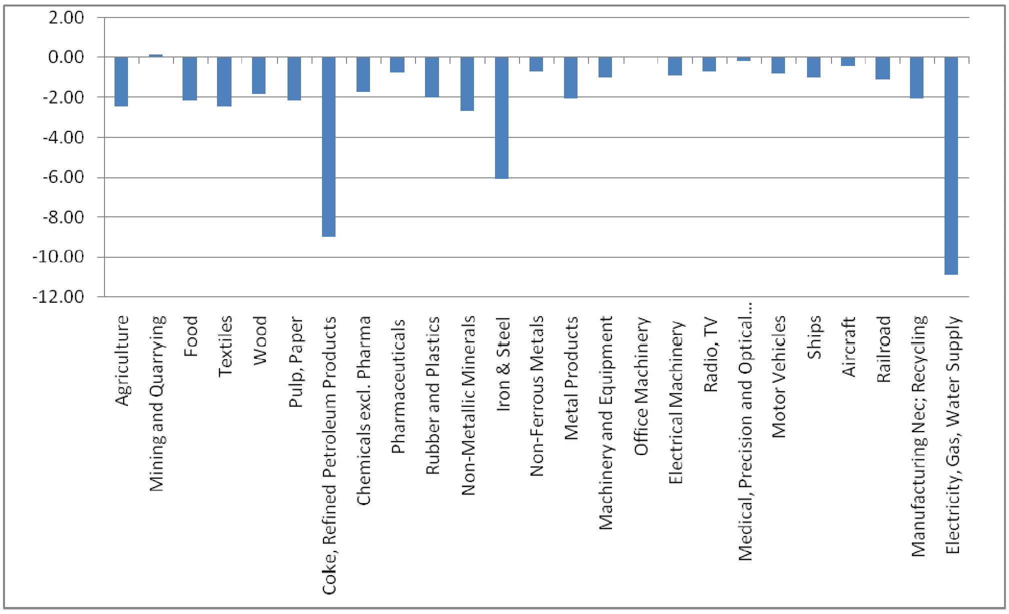
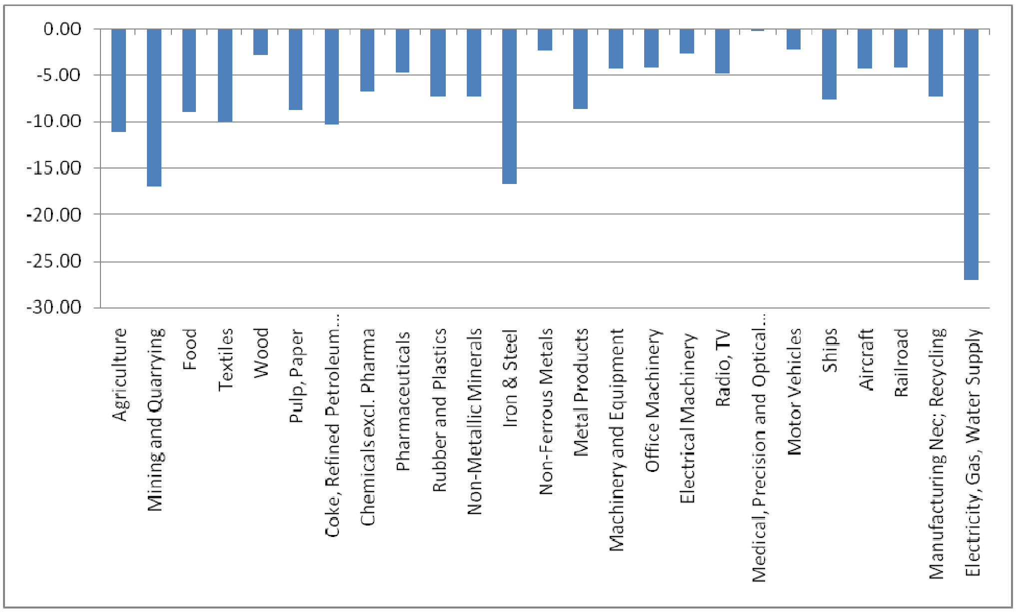


Figure 4: EU Exports to non-EU countries – percentage deviation of HS3 from baseline BH in 2020



In total, the EU's export markets would not suffer notably by the unilateral introduction of an ETR in scenario HS1. A more significant impact on trade for all country groups can be expected from scenario HS3 with its larger reduction in CO_2 emissions in the EU and international cooperation to reduce emissions in other countries.

4.2 Global environmental implications

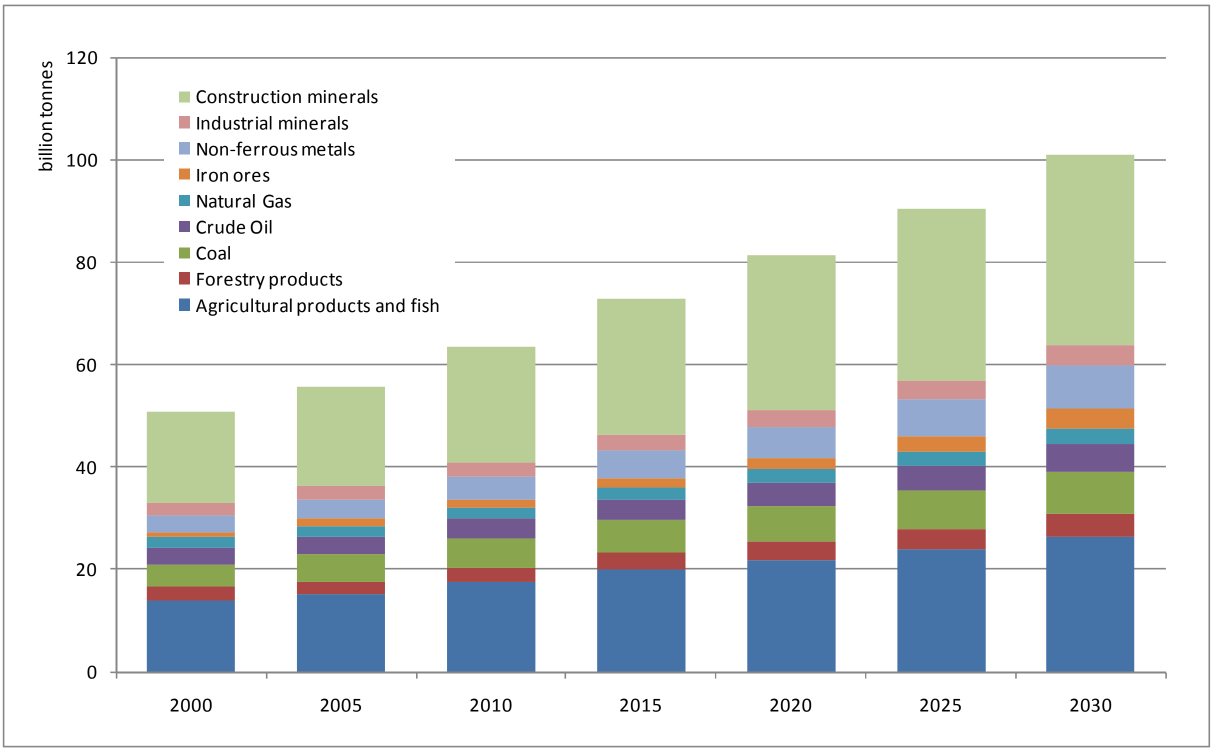
Two core indicators were chosen for the analysis of the environmental impacts of the scenarios - material extraction and CO_2 emissions. The first indicator, material extraction of natural resources, is strongly related to various environmental impacts. The extraction of mining metals and ores, for example, influences the environment in various ways, including structural changes to the landscape which reduce the value of important ecosystem services, diminished aesthetic values, the loss of biodiversity, increased local demand for water and electricity, the contamination of surface and ground waters, the release of hazardous elements from soil and rocks or from the minerals themselves to the environment (e.g. of sulphur-containing substances in brown-coal mining, causing acidification of ground water) (Giljum et al., 2005). Although the GINFORS model does not deliver data on environmental impacts related to material extraction and use, an indirect link between the overall levels of resource extraction and environmental consequences can be established. CO_2 emissions, the second indicator, are widely regarded as the major cause of global warming and thus play a central role in the current climate policy negotiations. Moreover, CO_2 emissions are closely linked to the use of materials (in particular fossil fuels).

Both indicators are production-oriented indicators, in other words, they account environmental pressures in those countries where they occur. Additional models are needed to analyse consumption-oriented indicators which illustrate the environmental pressures associated with the final consumption of goods and services in a particular country. GINFORS cannot allocate environmental data (such as material extraction) to specific economic variables, such as domestic final consumption or exports, in the country models. This impedes the assessment of all direct and indirect (up-stream) materials needed for producing specific imported and exported goods. Consequently, a complementary model, called GRAM (Global Resource Accounting Model) was constructed in the course of the PETRE project, which allows calculating comprehensive consumption indicators (for different environmental categories, such as material extraction and CO_2 emissions). GRAM complements GINFORS in terms of determining the resource base of the European economy in a comprehensive manner, fully including the international trade dimension (Giljum et al., 2008b). This paper will only present and discuss the results of the GINFORS model. The GRAM results of the PETRE modelling can be found in Giljum et al., 2008.

4.2.1 Impacts on material extraction in different scenarios

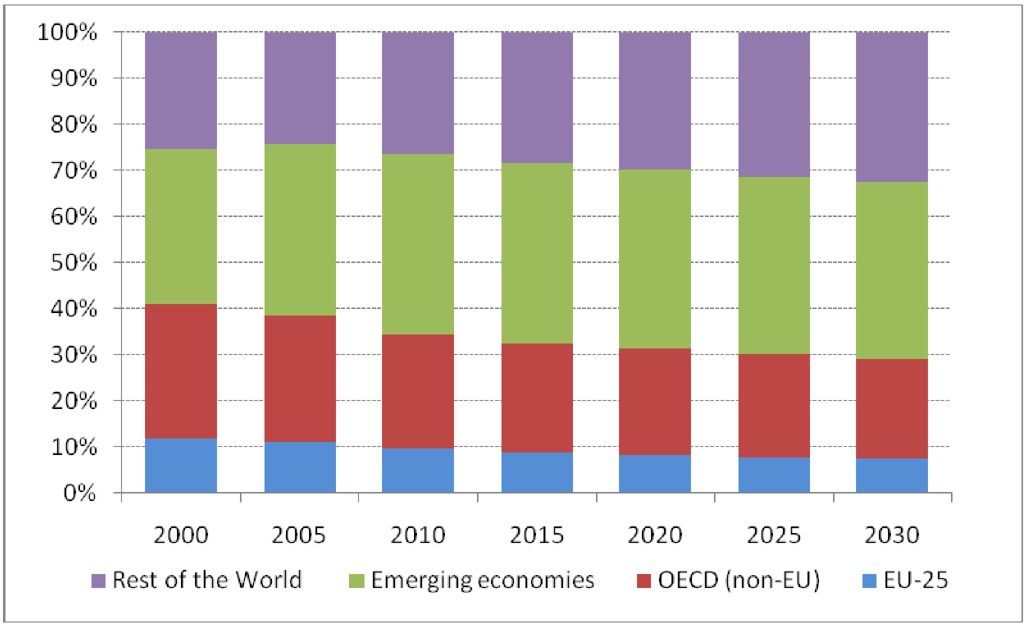
Figure 5 presents global used material extraction disaggregated into nine material categories in the baseline scenario. Historical data shows that global used extraction grew at around 1.5% p.a. from 40 billion tonnes in 1980 to 57 billion tonnes in 2005. This trend of increasing extraction continues in the baseline scenario, with total used extraction reaching more than 80 billion tonnes in 2020 and more than 100 billion tonnes in 2030. The numbers for extraction in 2020 are thus close to earlier baseline scenario calculations (Giljum et al., 2008b). Growth rates are unevenly distributed among the main material categories. Figure 5 clearly illustrates that construction minerals, non-ferrous metals and iron ores will experience the highest growth rates. By 2030, the extraction of construction minerals will be more than twice as high as in 2000, an indication of the importance of this category of materials for resource-intensive industrial development, especially in emerging markets such as China.

Figure 5: Global used material extraction of different material categories, baseline scenario BH



The shift in global material extraction and production patterns is underpinned by Figure 6, which shows that the shares of EU-25 and other OECD countries will decrease continuously to less than 30% in 2030. At the same time, the emerging economies and the rest of the world will raise their share in global extraction.

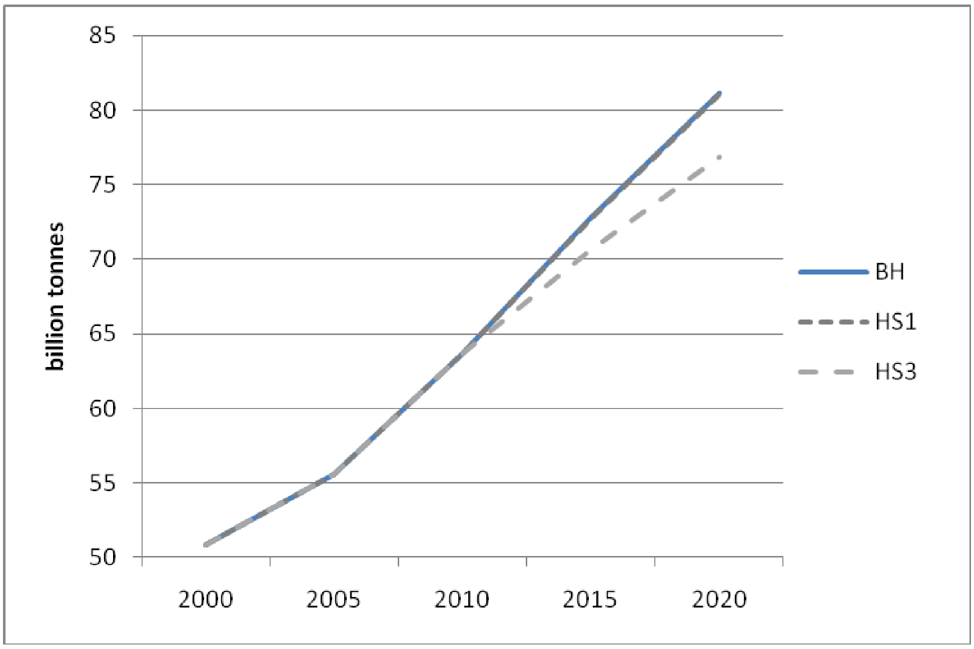
Figure 6: Global shares of used material extraction for country groups, baseline scenario BH



Together, Figure 5 and Figure 6 confirm that a significant reduction of the material throughput of the world economy and the related negative environmental impacts can only be tackled on a global scale. While material extraction is comparatively low in the EU-25, it is important to note that the European Union has larger net imports of resources than any other single country in the world economy (see Giljum at al., 2008b). From a consumption perspective, which includes indirect (or embodied) natural resources of traded products, the shares of both the EU-25 and the rest of the OECD countries would thus be bigger than Figure 5 suggests. This implies that production of products for final consumption in industrialised countries uses more resources than those extracted within these countries.

Figure 7 illustrates the global development of material extraction in the three scenarios.

Figure 7: Global used material extraction, three scenarios



The figure illustrates that global material extraction continues to grow in all three scenarios. With less than 0.1% reduction, the world-wide effects of the measures implemented in scenario HS1 are negligible (and cannot be discerned in Figure 10.5). HS3 measures lead to a global decrease in material extraction of 5.3% compared to the baseline BH in 2020, but overall levels of extraction still continue to grow. In HS3, the highest growth rates of material extraction between 2000 and 2020 occur in Portugal (+175% compared to 178% in BH), Brazil (+146% compared to 156% in BH), Japan (+110% in both HS3 and BH), and Malaysia (+109% compared to 107% in BH). Throughout the scenarios, the group of emerging countries largely determines the overall growth trend. Brazil is expected to experience the strongest growth in material extraction, especially iron ore, due to large amounts of available resources, agricultural and forestry products and construction materials (overall growth in material extraction between 2000 and 2020: 156% in BH and HS1, 146% in HS3).

Comparing the effects of policy measures in scenarios HS1 and HS3 with the baseline in terms of material extraction in the year 2020, HS1 policy measures lead to a decrease in material extraction in the EU-25 by 1.47% and in the rest of the world by 0.08% (see Table 10.6). In the OECD (non-EU) and emerging countries, by contrast, material extraction increases slightly by 0.1% and 0.03% respectively. Globally, HS1 policy measures thus lead to a very low decrease of material extraction compared to the baseline (-0.11% or 90 million tonnes). HS3 policies on the other hand are expected to reduce global material extraction by 4.3 billion tonnes (-5.3%) in 2020. In this scenario, material extraction declines most significantly in the emerging countries (-7.1%), followed by the OECD (non-EU) group (-5.5%), the EU-25 (-3.6%) and the rest of the world (-3.3%). It is remarkable that in scenario HS3 material extraction impacts in emerging countries are so much higher than in the EU. This clearly indicates the importance of a global perspective.

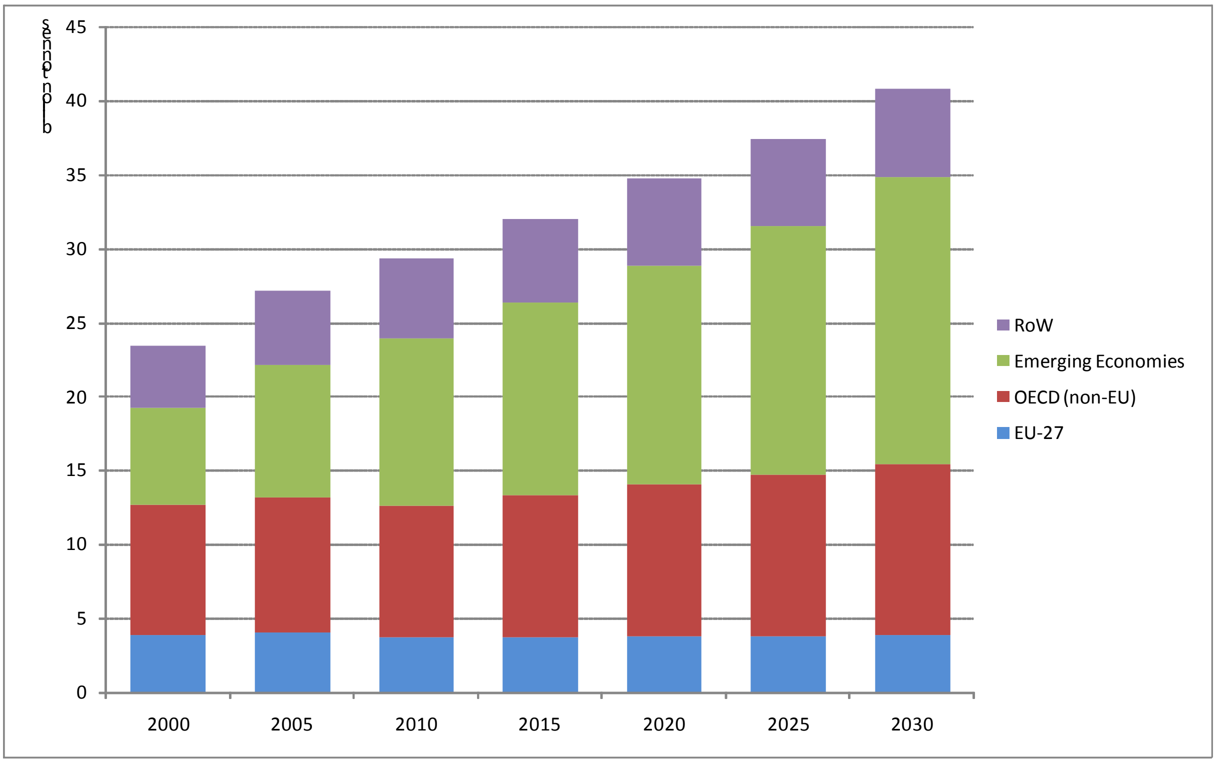
Table 7: Impacts of an ETR on material extraction in HS1 and HS3

Country group	Total extraction, BH, 2020 (in billion tonnes)	Absolute deviation of HS1 from BH in 2020 (in billion tonnes)	Percentage deviation of HS1 from BH in 2020	Absolute deviation of HS3 from BH in 2020 (in billion tonnes)	Percentage deviation of HS3 from BH in 2020
EU-25	6.8	-0.10	-1.47 %	-0.24	-3.6 %
OECD (non-EU)	18.7	0.02	0.10 %	-1.03	-5.5 %
Emerging economies	31.5	0.01	0.03 %	-2.23	-7.1 %
RoW	24.2	-0.02	-0.08 %	-0.79	-3.3 %
Global total	81.2	-0.09	-0.11 %	-4.30	-5.3 %

4.2.2 Impacts on energy-related CO_2 emissions

Figure 8 shows the energy-related CO_2 emissions in the baseline scenario for the four regions.

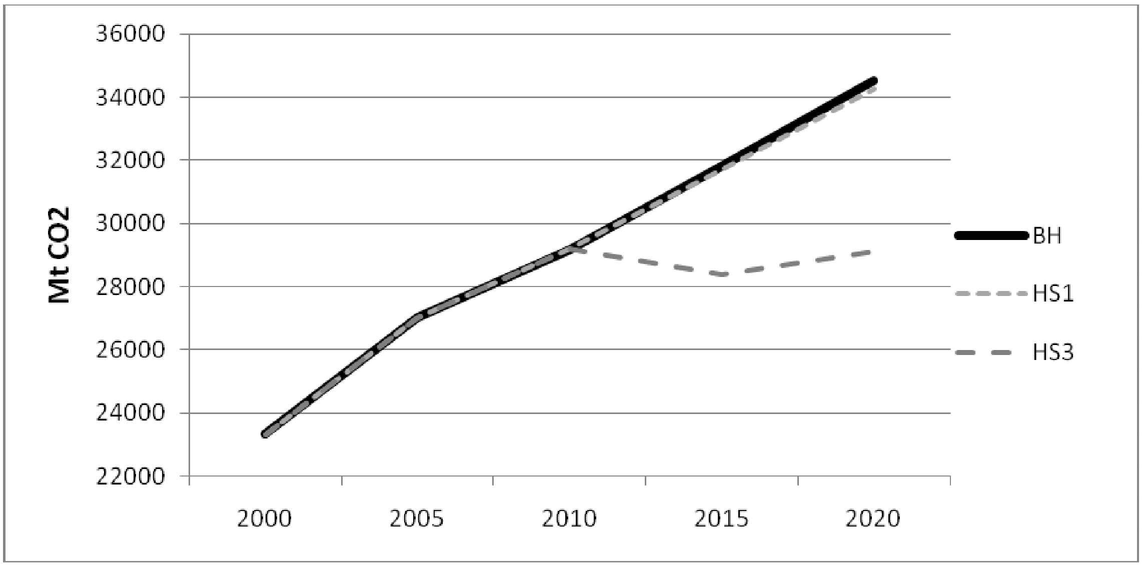
Figure 8: Energy-related CO_2 emissions in the baseline BH (billion tonnes)



The figure shows that the expected future emissions of the EU remain almost constant, while those of the other three country groups will grow continuously until 2030. The most notable increase will happen in the emerging economies. In the G5 group (China, India, Brazil, South Africa and Mexico), for example, energy-related CO_2 emissions will increase by almost 9 billion tonnes, of which more than half will be emitted by China. At the global level, these figures are in line with the Reference Scenario of the 2008 World Energy Outlook (IEA 2008d) in which global energy-related CO_2 emissions are expected to rise from 28 gigatonnes in 2006 to 41 gigatonnes in 2030 - an increase of 45%. According to the IEA, three quarters of the increase in projected annual emissions comes from China, India and the Middle East, and 97% from non-OECD countries as a whole. Note again that these emissions are territorial, that is, production-oriented.

Figure 9 compares the absolute values of energy-related CO_2 emissions in the different policy scenarios.

Figure 9: Global energy-related CO_2 emissions, three scenarios (Mt CO_2)



As with material extraction, the global impact of scenario HS1 is very limited; global reduction only equals -0.8%. In scenario HS3, however, the reductions of CO_2 emissions are substantial, with 15.6% less emissions worldwide than in the baseline BH. The measures implemented in HS3 thus achieve the stabilisation of CO_2 emissions between 2010 and 2020 in absolute terms. Table 8 presents the detailed numbers for CO_2 emissions in the four world regions.

Table 8 - Impacts of an ETR on energy-related CO_2 emissions in HS1 and HS3

Country group	Total energy-related CO_2 emissions in BH, 2020 (in Mt)	Total change in HS1 from BH in 2020 (in Mt)	Relative change in HS1, % against BH in 2020	Total change in HS3 from BH in 2020 (in Mt)	Relative change in HS3, % against BH in 2020
EU-27	3776.3	-318.8	-8.4 %	-722.4	-19.1 %
OECD (non-EU)	10244.6	10.4	0.1 %	-1829.1	-17.9 %
Emerging economies	14835.5	2.3	0.02 %	-2741.9	-18.5 %
RoW	5854.9	0.4	0.01 %	-141.4	-2.4 %
Global	34526.7	-272.8	-0.8 %	-5398.6	-15.6 %

While the CO_2 reduction in the EU is already substantial in HS1 (-8.4%) all other regions are not affected and show slight increases in CO_2 emissions. On the contrary, the measures implemented in scenario HS3 lead to a substantial reduction in CO_2 emissions in all world regions compared to the baseline in 2020, with similar reductions in the EU, the OECD and the emerging economies. Among the group of emerging countries, the largest CO_2 reductions would result in South Africa (-48%), India (-27.5%) and China (-20.8%). The reduction in the rest of the world is smaller, as the policy measures have not been implemented in these countries. In these countries, emission reductions would only be experienced in the OPEC countries (-9.5%) and Chile (-2.5%), while the other countries may see small increases in CO_2 emissions of between 0.2% (in Hong Kong) and 2.3% (in Singapore).

The fact that the impact on material extraction (Table 7) is much lower than on carbon emissions (Table 8) is due to the fact that no material taxes are implemented in the major emerging economies in scenario HS3. Coordinated action in the major economies could reduce material extraction much further.

5. Policy implications

The results from the modelling exercise support four main policy conclusions.

From a global perspective, the first conclusion to be derived from this study is that combating climate change can only be successful through global cooperation and global climate treaties. As the large emerging economies will increase their share in global CO_2 emissions (Fig. 8), ensuring their contribution to a post-Kyoto agreement on climate change must be one of the key objectives in future international climate treaties. As the impacts of scenario HS1 have shown, unilateral action by the EU is insignificant in terms of global environmental sustainability. EU environmental policy objectives, such as the 2°C target for the maximum global temperature increase above pre-industrial levels, can by far not be achieved through measures in the EU alone. All other OECD countries and the major emerging economies have to join to keep the carbon concentration below 450 ppm (IEA (2008d). Coordinated multilateral policies are also necessary in order to avoid carbon leakage (Bruvoll and Fæhn, 2006; IEA, 2008e). If only the EU-27 members participate, the emissions of non-participating countries could further increase by the migration of emission-intensive industries.

Second, targets in the range of 20-30% reductions of CO_2 emissions are not sufficient in order to lessen the environmental impacts of our economic activities. Targets are also needed on overall resource use. The scenarios have confirmed that overall resource use will grow steeply on the global level if no measures are taken to further increase resource productivity and to limit resource consumption. Similar to the Kyoto goals on CO_2 reductions it is thus strongly recommended that goals are set aimed at reducing overall resource use. The results of the scenario analyses suggest that a reduction of the overall level of resources used would be most effective if done in concerted action between the EU and emerging economies. The changes expected in response to the introduction of in ETR in Europe alone (HS1) but also in collaboration with the OECD and emerging economies (HS3) are in line with the results from other studies (see for example IPCC 2008). The focus on CO_2 reductions in most international climate policy negotiations, including the Copenhagen Climate Conference, is too narrow. As the case of biofuels has shown, it is important to consider not just CO_2 but also other greenhouse gases, such as nitrous oxide (Howarth and Bringezu, 2009). Otherwise, expensive policy instruments aimed at climate change mitigation by cutting CO_2 emissions, such as biofuel targets, Carbon Capture and Storage (CSS) and nuclear energy, may in fact increase overall levels of resource use and thus indirectly aggravate climate change. As most greenhouse gas emissions are directly caused by resource extraction and use it is crucial to address one of the most important contributors to climate change – the unsustainable use of resources such as raw materials, land and water. This is not only a root cause of climate change but also a serious environmental threat in a finite world and one which ultimately impacts people's livelihoods.

Third, given the increasing importance of embodied emissions in exports, the integration of environmental aspects into trade policies must be a key part in the implementation of a pathway towards sustainable growth in Europe and globally. So-called multi-regional input-output models of CO_2 emissions have shown that CO_2 emissions would be significantly higher in the industrialised world if indicators were based on consumption-oriented indicators (e.g. Shui and Harriss, 2006; Nakano et al., 2009). The consumption-based CO_2 emissions of the OECD overall, for example, were 16.1% higher in 2000 than the conventional measurement of production-based emissions suggests. Those differences even exceed 30% in seven OECD countries (Austria, France, Luxembourg, Portugal, Sweden, Switzerland, and the United Kingdom) (ibid.).

Table 9: Production versus consumption-based CO_2 emissions in different world regions

	Production-based emissions (Mt CO_2)		Consumption-base emissions (Mt CO_2)		CO_2 trade balance (Mt CO_2)	
	1995	2000	1995	2000	1995	2000
OECD	11,229	12,088	12,487	14,037	-1,259	-1,949

Non-OECD	6,469	6,821	5,498	5,687	971	1,134
World Total	19,138	21,757	19,272	22,171	-134	-414

Source: Nakano et al. (2009: 7)

Effective and globally responsible environmental policies should take a life-cycle perspective in assessing and addressing current challenges, in other words, address the environmental effects of production independent from whether the negative impact occurs within national borders or beyond (see for example OECD 2001, Peters 2008). Therefore, shared responsibility of producers and consumers is likely to remain a prominent topic at international climate negotiations (see for example Lenzen et al., 2007; Wiedman et al., 2007; Rodrigues and Domingos, 2008), especially for developing countries which produce a large share of GHG emissions on behalf of industrialised countries ("outsourced emissions"). As recent studies reveal (e.g. Bruckner et al. 2010) a significant amount of all CO_2 emissions embodied in trade consumed in Annex B countries[6] originates from non-Annex B countries (carbon leakage). In 2005, the highest carbon leakage occurred in the United States where 1.25 billion tonnes of CO_2 emissions from consumption originated from non-Annex B countries. The G77 countries consume 22.8% less CO_2 emissions than they produce while the OECD countries consume 28.5% more CO_2 emissions than they produce. Whereas most existing accounting frameworks (including the Kyoto Protocol) follow a production or territory accounting principle, it should be debated whether a consumption-oriented accounting approach may also be useful in analysing sustainability-oriented concepts such as the allocation of "fair shares" of the world's resources to all inhabitants of the planet. An agreement on the distribution of costs to reduce GHG emissions between the producers and the consumers of products in the world economy is a possible step towards the realisation of an effective post-Kyoto regime. Alternatively, a global carbon tax could be a solution in sharing the common responsibility of all countries. A carbon tax in China, for example, would decrease their embodied emissions and, by raising their prices to consuming countries, reduce exports. This, in turn, again feeds into the topic of producer versus consumer responsibility.

Finally, the results support an OECD proposal of a joint reform of fiscal and environmental measures which may protect the environment as well as raise revenue and free up resources which can be allocated to poverty reduction efforts (OECD 2005). The trends in all scenarios

[6] Annex B countries are industrialised countries and countries in transition to a market economy with greenhouse gas emissions limitations or a reduction commitment under the Kyoto Protocol.

show a dramatic increase in natural resource extraction which is already beyond sustainable levels in many resource-rich countries and causes substantial social and environmental impacts (see EEA 2005, UNEP 2007). If policies do not tackle these problems they may exacerbate them. Many of the external EU policy documents, such as the trade strategy "Global Europe" (2006) and the "Raw Materials Strategy" (2008), have been criticised because the goals of *access* to and *supply* of raw materials and natural resources prevail over the objective of their *sustainable* and *equitable* use (FoE 2008). Such criticism along with the long-term trends in resource use and environmental impacts suggest that Europe should more actively address the potential conflict between economic goals (ensuring access to resources around the globe) and development goals (raising the material standard of living in developing countries). The European Commission is in a strong position to ensure that the causal link between environmental and wider social and economic development goals is better recognized and articulated in development cooperation and that adequate response systems will be developed. In the UN Millennium Development Goals (MDGs), environmental issues do not receive much attention outside of MDG 7 on environmental sustainability. According to the UNDP (2005), the lack of quantifiable targets for MDG 7 has been one reason for its relatively low profile on the global agenda. Apart from ETR, a frequently expressed policy suggestion for developed countries is an increase in technical and financial assistance for measures to reduce emissions and implement adaptation measures in developing countries (Stern 2007). Supporting developing countries in mitigation and adaptation efforts may also be achieved by placing access to resource efficient technologies outside the purview of International Property Rights restrictions into the public domain or with international public buyouts of patents on such technologies.

6. Conclusions

This paper has presented and discussed some of the global economic and environmental implications of the introduction of an ETR in Europe, based on scenario simulations using the GINFORS model.

The results show that the implementation of an environmental tax reform could reduce the EU's resource consumption as well as CO_2 emissions. The unilateral ETR described in scenario HS1 reduces resource extraction in the EU by around 1.5% (100 million tonnes), and global CO_2 emissions by less than 1%. Such unilateral action therefore makes only a small contribution to EU resource security and is insignificant in terms of global environmental sustainability. The scenario HS3, however, with a larger ETR in the EU in the context of global cooperation, produces more substantial results, reducing global material extraction by more than 5% and global CO_2 emissions by more than 15%, while reducing world GDP by only

1.4%. The results show that the economic impacts on the rest of the world of a major ETR in Europe in a cooperative global context are small but that the environmental benefits can be quite significant.

The results show that the implementation of an ETR could reduce the EU's resource consumption as well as its CO_2 emissions. The worldwide effects of the unilateral ETR scenario (HS1) on the growth trend of used material extraction and energy-related CO_2 emissions are negligible. Resource extraction in the EU would only be reduced by around 1.5% (100 million tonnes) and global CO_2 emissions by less than 1%. Without international cooperation, global material extraction and energy-related CO_2 emissions will continue to grow. This trend is largely led by the group of emerging countries. In an internationally cooperative context, however, the economic impacts of a major ETR in Europe on the rest of the world are small, while the environmental benefits can be quite significant. In scenario HS3, the larger ETR (than HS1) in the EU in the context of global cooperation, reduces global material extraction by more than 5% and global CO_2 emissions by more than 15%, while reducing world GDP by only 1.4% compared to the baseline scenario in 2020. Thus, an ETR in Europe would be more effective in terms of reducing global CO_2 emissions and material extraction in a context of international cooperation on emission reduction targets.

An increase in international carbon prices will reduce overall exports and impact the international competitiveness of emission-intensive industries. Measured in terms of export growth rates, the negative effects on international competitiveness are especially pronounced in European emission-intensive industries and are smaller in the unilateral ETR policy scenario than in the scenario with multilateral cooperation. The strongest declines in export rates would emerge in the EU's Utilities and Heavy Industries (Electricity, Gas and Water Supply; Coke and Refined Petroleum Products; Iron and Steel). In terms of absolute monetary values, the strongest declines would be experienced in EU exports of Chemicals (excluding Pharmaceuticals), Machinery and Equipment, and Motor Vehicles. The negative effects on the export growth rates of emerging countries would be relatively weak.

Four major policy conclusions can be drawn from this investigation. First, combating climate change is significantly more successful in a context of international cooperation and through strong global climate treaties. Secondly, targets on CO_2 emissions alone are not sufficient in order to lessen the environmental impacts of our economic activities but should also be envisaged for other resource use with damaging environmental effects. Thirdly, given the importance of embodied emissions in imports and exports, environmental aspects must be integrated into international trade policies in order to achieve sustainable development. Possible approaches for sharing the common responsibility of all countries may include a fair distribution of costs to reduce GHG emissions between the producers and the consumers of products in the world economy, or a global carbon tax. Finally, the results call for a stronger recognition of the intricate linkages between economic and environmental objectives in international development cooperation policies, and for adequate responses such as increased technical and financial assistance for mitigation and adaptation, or international public buyouts of patents on expensive resource efficient technologies.

Future research should first of all further improve the models. This holds for the integration of additional data, and a better representation of the energy supply and upcoming technologies. More and more internationally comparable data becomes available. The underlying assumptions of bounded rationality have to be cross-checked and combined with new agent-based approaches that are increasingly able to overcome the simplified assumptions of the homo oeconomicus on which most energy models are based. Supply side developments like crude oil stocks and supply constraints and their medium-term price implications should be taken into account. The understanding of the role of technology has to be further improved, either by soft linking the models with technology based bottom-up models or by better incorporation of technology data. This can include such stock data as the power generation mix with its age structure, or the vehicle fleet, which limit substitution possibilities in the medium-term. Future technology options such as renewable energy sources, efficiency potentials, or Carbon Capture and Storage (CCS) should also be analysed. Models should also be expanded to cover additional greenhouse gases and material extraction categories, other environmental impacts and scarce biocapacity. Otherwise, complex impacts of, for example, an international CCS strategy on energy efficiency, energy consumption, material extraction, and economic conditions and effects will not be fully covered. Combining the results presented in this paper with environmentally extended multi-regional input-output models, such as GRAM, can substantially improve the understanding of consumer and producer responsibility in the context of international negotiations.

References

Boardman, B. (2004) New directions for household energy efficiency: evidence from the UK. *Energy Policy*, 32(17), 1921-1933.

Bruckner, M., Polzin, C., Giljum, S. (2010) Embodied CO2 emissions in trade and the global responsibility of consumption. German Development Institute, Bonn.

Bruvoll, A. & Fæhn, T. (2006) Transboundary effects of environmental policy: Markets and emission leakages. *Ecological Economics,* 59**,** 499-510.

DG TREN (2008) European energy and transport trends to 2030 – update 2007, Directorate-General Transport and Energy (DG TREN), European Commission, Brussels.

EC (European Commission) (2008) *Decision on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020* (COM(2008)17 final). Available from http://ec.europa.eu/environment/climat/pdf/draft_proposal_effort_sharing.pdf

EC (2006) *Global Europe Competing in the World. A Contribution to the EU's Growth and Jobs Strategy.* COM(2006) 567 final, European Commission, DG External Trade: Brussels.

EC (2005) Thematic Strategy on the sustainable use of natural resources. Brussels, European Commission.

EEA (2005) *The European Environment. State and Outlook 2005*. Copenhagen: European Environment Agency.

European Parliament (2009) *Eco-innovation - putting the EU on the path to a resource and energy efficient economy*. Brussels, European Parliament's Committee on Industry, Research and Energy.

FoE (Friends of the Earth) (2008) *Living beyond its resources: impacts of 'Global Europe' on sustainable development: Background and Issues*. Available from http://www.global-europe.org/docs/GlobalEurope_Conference_Background_Issues_241108.pdf

Giljum, S., Behrens, A., Hinterberger, F., Stocker, A. (2005) Scenario Evaluation Component Material Extraction. MOSUS Work Package 5.2 (Environmental Evaluation), SERI, Vienna. Available at http://www.mosus.net/documents/Evaluation%20report_Material%20flows_final.pdf.

Giljum S., Behrens A., Hinterberger F., Lutz C., Meyer B. (2008a) Modelling scenarios towards a sustainable use of natural resources in Europe. *Environmental Science and Policy*, 11, 204-216.

Giljum, S., Lutz, C., Jungnitz, A., Bruckner, M., Hinterberger, F. (2008b) Global dimensions of European natural resource use. First results from the Global Resource Accounting Model (GRAM). *SERI Working Paper* 7, Sustainable Europe Research Institute, Vienna.

Howarth, R.W. & Bringezu, S. (eds.) (2009) Biofuels: Environmental Consequences and

Interactions with Changing Land Use. Proceedings of the Scientific Committee on Problems of the Environment (SCOPE) International Biofuels Project Rapid Assessment, 22-25 September 2008, Gummersbach, Germany.

IEA (International Energy Agency) (2008a) Energy Balances of OECD countries: 2005/2006, IEA, Paris.

IEA (2008b) Energy Balances of Non-OECD countries: 2005/2006, IEA, Paris.

IEA (2008c) CO2 Emissions from Fuel Combustion, 2008 Edition, IEA, Paris.

IEA (2008d) World Energy Outlook 2008, IEA, Paris.

IEA (2008e) Issues behind Competitiveness and Carbon Leakage. Focus on Heavy Industry. *IEA Information Paper*, October 2008, IEA, Paris. Available at http://www.iea.org/Textbase/papers/2008/Competitiveness_and_Carbon_Leakage.pdf.

IPCC (2008) Further Work on Scenarios Report from The IPCC Expert Meeting Towards New Scenarios For Analysis Of Emissions, Climate Change, Impacts, And Response Strategies, 19–21 September, 2007, IPCC-XXVIII/Doc.8 (19.III.2008), Noordwijkerhout, The Netherlands. Available at http://www.ipcc.ch/meetings/session28/doc8.pdf.

Lenzen, M., Murray, J., Sack, F., & Wiedmann, T. (2007) Shared producer and consumer responsibility—Theory and practice. *Ecological Economics*, 61(1), 27-42.

Lutz, C. & Meyer, B. (2009a) Environmental and Economic Effects of Post-Kyoto Carbon Regimes. Results of Simulations with the Global Model GINFORS. *Energy Policy*, 37, 1758-1766, DOI: 10.1016/j.enpol.2009.01.015

Lutz, C. & Meyer, B. (2009b) Economic impacts of higher oil and gas prices. The role of international trade for Germany. Energy Economics, 31. 10.1016/j.eneco.2009.05.009

Lutz, C., Meyer, B. & Wolter, M. I. (2010) The Global Multisector/Multicountry 3-E Model GINFORS. A Description of the Model and a Baseline Forecast for Global Energy Demand and CO_2 Emissions. *Journal of Sustainable Development*, special issue on global models, 10, 25-45.

Lutz, C. & Giljum, S. 2009. Global resource use in a business-as-usual world until 2030. Updated results from the GINFORS model. In: Bleischwitz, R., Welfens, P.J.J., Zhang, Z.X. (Eds.), Sustainable Growth and Resource Productivity. Economic and Global Policy Issues, Greenleaf Publishing. 30-41.

Lutz, C. & Wiebe, K. (2009): GINFORS. In: Van Drunen et al. (Eds), Modelling future linkages, Deliverable number D2.5 of INDI-LINK Indicator-based evaluation of interlinkages between different sustainable development objectives, Vienna.

Meyer, B. & Lutz, C. (2007) The GINFORS model. Model Overview and Evaluation. PETRE Working Paper, Osnabrueck. http://www.petre.org.uk/papers.htm

Meyer, B., Lutz, C., Schnur, P. & Zika, G., (2007) Economic Policy Simulations with Global Interdependencies: A Sensitivity Analysis for Germany. Economic Systems Research, 19, 37-55.

Nakano, S., Okamura, A., Sakurai, N., Suzuki, M., Tojo, Y. & Yamano, N. (2009) The measurement of CO2 embodiments in international trade: evidence from the harmonised input-output and bilateral trade database. STI Working Paper 2009/3, DSTI/DOC(2009)3.

OECD (2005) Environmental Fiscal Reform for Poverty Reduction. DAC Guidelines and Reference Series. OECD, Paris.

Rodrigues, J., & Domingos, T. (2008). Consumer and producer environmental responsibility: Comparing two approaches. *Ecological Economics*, 66(2-3), 533-546.

Schütz, H., Bringezu, S. & Moll, S. (2004) Globalisation and the shifting environmental burden. Material trade flows of the European Union. Wuppertal, Wuppertal Institute.

Shui, B. & Harriss, R. C. (2006) The role of CO2 embodiment in US-China trade. *Energy Policy*, 34, 4063.

Speck S. & Jilkova, J. 'Design of environmental tax reforms in Europe' in Andersen, M.S. & Ekins, P. (eds.) *Carbon-Energy Taxation: Lessons from Europe*, Oxford University Press, Oxford (forthcoming).

Stern, N. H. (2007) The Economics of Climate Change: The Stern Review, Cambridge, Cambridge University Press.

UNDP (2005) Environmental Sustainability in 100 Millennium Development Goals Country Reports.
http://www.unep.org/dec/docs/UNDP_review_of_Environmental_Sustainability.doc (accessed 14 April 2009)

UNEP. (2007) Global Environmental Outlook - 4. Malta: Progress Press Ltd.

USGS (United States Geological Survey) (2006) Minerals Yearbook 2006. Washington, D.C.: USGS.

Weisz, H., Krausmann, F., Amann, C., Eisenmenger, N., Erb, K. H., Hubacek, K. & Fischer-Kowalski, M. (2006) The physical economy of the European Union: Cross-country comparison and determinants of material consumption. Ecological Economics, 58, 676-698.