European Commission

Technical report 2014-2478

Study on modelling of the economic and environmental impacts of raw material consumption

Final report, March 2014

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EXECUTIVE SUMMARY

This report provides a quantitative analysis of different resource productivity (RP) targets for the EU. Resource productivity in this study is defined as GDP per unit of raw material consumption (RMC), instead of the usual GDP per unit of domestic material consumption (DMC). The RMC-based indicator adjusts the weight of materials recorded at border crossings so that they are counted as if they were produced domestically.

The analysis was carried out using the macro-econometric E3ME model (www.e3me.com). The model is used for analysing the detailed linkages between the economy, materials, environment and energy. E3ME is commonly used to quantify the impacts of environmental and energy policies on the EU economy.

The past trends for RMC in the EU28 were analysed using raw material equivalent (RME) estimates from Eurostat. Resource productivity based on RMC has been continuously increasing during the period 2001 to 2011 at +1.9% per year on average. The economic crisis boosted resource productivity as RMC decreased drastically. If the years before the economic crisis are an indication of how resource productivity will develop, we can expect that resource productivity will continue to increase with economic growth at approximately half the rate of GDP growth.

The main drivers of RMC are economic development, population, industry structure and, particularly for energy resources, policy intervention. However, it is not always clear to what extent past changes in RMC are due to changes in resource productivity, demand factors or industry structure. The demand for construction materials, which represents about half of RMC, is mainly driven by economic factors and to a lesser extent population growth. Metal RMC is linked to the economic activity in manufacturing and construction sectors as well as import dependency in the EU's mining sector. Biomass RMC has been fairly stable in the period 2001-2011.

Since 2001 the overall consumption of fossil energy resources has been decreasing, and at the same time there has been a shift in the shares of fuels, e.g. from coal to lower carbon fuels such as natural gas. In terms of RME, imports have been gradually increasing over the time period observed, but so too have exports. The EU remains highly dependent on imports such as oil crops, mineral fertilisers, metals and most fossil fuels but, in terms of RME, the EU exports as much or more biomass and minerals as it imports.

Based on a mixture of past trends and a literature review of future projections, a 'business as usual' baseline for RMC and resource productivity was constructed. The main drivers for material resource consumption were used as variables to determine RMC for individual material categories. While the baseline scenario builds upon the European Commission's projections for population and economic growth, many broad assumptions were used to estimate how RMC would evolve until 2030.

The baseline scenario takes into account the adopted climate and energy targets in the EU, which results in an increase in bioenergy (+80%) and a decrease in fossil fuels (-22%). Metal and mineral RMC is expected to continue to grow until 2030 (39% and 26%, respectively) as these are still closely coupled to economic activity and we assume that these materials are needed for future renewable energy installations and developing infrastructure. In total, RMC is expected to increase by 0.7% pa on average until 2030. With the GDP projections, this entails that the baseline scenario assumes relative decoupling with resource productivity increasing by an average 0.9% per year until 2030.

The scenarios in this report are based around different resource productivity targets for the EU28, ranging from a modest improvement in RP (1% pa) to ambitious improvements (3% pa). In the period to 2030 this translates to an RP improvement of around 15% for the modest scenario and 50% for the ambitious scenario. Policies to improve RP are assumed to fall under three categories: market-based instruments such as taxation, private-funded measures such as recycling and public-funded capital investment to improve efficiency. Revenues from the market-based instruments are assumed to be used to fund the investment, with the remainder used to lower labour taxes.

Prior to the scenario analysis, the E3ME model was set up to provide marginal cost information for the different abatement options. The scenarios are based on the results from this analysis, expressed as a set of cost curves. It should be noted that these cost curves are for the most part top down in nature as there is little bottom-up information on economy-wide reductions in material consumption.

Given these assumptions, the modelling results suggest that resource productivity improvements of around 2% to 2.5% pa can be achieved with net positive impacts on EU28 GDP. This is because the benefits of higher efficiency levels outweigh the costs of making the improvements to efficiency. Beyond a rate of 2.5% pa, however, further improvements in RP are associated with net costs to GDP as the abatement options become more expensive.

The use of revenues from MBIs to reduce labour costs can have very important effects on employment levels. There are around two million additional jobs in the scenario with 2% pa RP improvement in 2030.

At sectoral level, the sectors that sell raw materials, such as agriculture and mining are likely to see lower demand for their products. Sectors that are intensive consumers of raw materials may be affected adversely from the costs associated with RP improvement but at the same time may benefit from material input savings. In some cases these sectors also produce the investment goods that are required to improve efficiency in other sectors. Labour intensive sectors such as retail and consumer services benefit the most from lower labour taxes.

Sensitivity analysis shows that the EU target to have a 20% manufacturing share in EU GDP can also be achieved without compromising the RP targets.

The study also considered a case where there is no recycling of the revenues from MBIs. In this case, the net positive GDP impacts are much smaller and become negative over time.

The interactions between materials consumption and greenhouse gas emissions are complex, but the model results suggest that the overall impact on CO_2 emissions is small. This means that RP targets can be viewed as complementary to the existing EU targets for reducing greenhouse gas emissions.

Despite the uncertainty around the potential RP improvements within each EU sector, the outcome of the study suggests that it could be possible to meet RP targets through policies that lead to slightly higher rates of growth and employment across the EU.

1 Introduction

1.1 Study overview

The objective of this study is to assess the economic, social and environmental impacts of alternative policy packages to improve European resource productivity, as measured by GDP per unit of Raw Material Consumption (RMC). The analysis is quantitative in nature and a modelling approach is applied so that indirect effects (including interlinkages between different resource types) are taken into account.

Why use RMC instead of DMC?

Using Domestic Material Consumption (DMC) in the calculation of a resource productivity measure has the shortcoming that it does not adjust for raw material weight when materials are traded across borders. Consequently DMC risks overstating the resource efficiency of an imports-intensive European economy.

Measuring resource productivity using GDP/DMC, as proposed in the Roadmap to a Resource Efficient Europe[1], therefore has some shortcomings. The RMC indicator adjusts traded materials to be in raw material equivalent units, and provides a better representation of material consumption. Throughout this study we use resource productivity measured by GDP/RMC.

The study was carried out by Cambridge Econometrics and BIO Intelligence Service.

1.2 Structure of this report

This report has six chapters. The next chapter discusses briefly the E3ME macroeconomic model that was used in this study with a reference to the full model manual. Chapter 3 presents historical trends of RMC, drivers and our baseline projections. Scenario descriptions and modelling methodology are given in Chapter 4 and modelling results are presented in Chapter 5. Chapter 6 concludes with our main findings from the analysis.

The appendices include further information about the data used and the modelling results.

[1] European Commission, http://ec.europa.eu/environment/resource_efficiency/index_en.htm

2 Material Modelling in E3ME

2.1 The E3ME model

This chapter describes briefly the macroeconomic E3ME model and its material sub-model. Further information, including the full model manual, is available online at www.e3me.com.

Introduction to E3ME

E3ME is a computer-based model of Europe's economies, linked to their energy systems and the environment. The model was originally developed through the European Commission's research framework programmes in the 1990s and is now widely used in collaboration with a range of European institutions for policy assessment, for forecasting and for research purposes.

Economic structure

The economic structure of E3ME is based on the system of national accounts, as defined by ESA95 (European Commission, 1996)[2], with further linkages to materials, energy and environmental emissions. The labour market is also covered in detail, with sets of equations for labour demand, supply, wages and working hours. International trade is modelled at sectoral level.

Relationships in the E3ME model are estimated empirically. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, and international trade), prices, energy and material demands. Each equation set is disaggregated by country and by sector.

The main dimensions of the model are:

- 33 countries[3] (the EU28 Member States, Norway and Switzerland and three candidate countries)
- 69 economic sectors, defined at the NACE (rev2) 2-digit level, linked by input-output relationships
- 43 categories of household expenditure
- 13 types of household, including income quintiles and socio-economic groups such as the unemployed, inactive and retired, plus an urban/rural split
- 14 users of 7 different material types
- 22 different users of 12 different fuel types

Energy and emission linkages

The scenarios presented in this report focus on reducing material consumption, but energy products are an important component of this. The economy and energy demand are closely linked; economic activity creates the demand for energy, but energy consumption also affects the economy through output in the energy production and distribution sectors (e.g. electricity sector, oil and gas sector). Most environmental emissions are caused by fuel combustion (modelled as a fixed coefficient) but there are also direct economy-emission linkages through process emissions.

[2] Eurostat (1996), "European System of Accounts (ESA95)", Eurostat, European Commission.
[3] The new version of E3ME has a global coverage.

Energy consumption is measured in tonnes of oil equivalent. Physical consumption of fossil fuels is estimated by applying a fixed ratio of energy content per tonne to each fuel type. These ratios are based on the available historical data.

2.2 The material sub-model

Overview

Although static environmentally extended input-output (EEIO) analysis of material consumption is well established, very few macroeconomic models currently include physical measures of material demands. The E3ME model is an exception to this; E3ME's material model was originally developed for the European Matisse research project[4] and documented in Pollitt (2008)[5]. It has since further been applied in the petrE project (Ekins et al, 2012[6]) and in previous studies for DG Environment[7]. The advantage that E3ME offers over the input-output approach is its dynamic nature, with rates of material intensity allowed to change over time and in response to price and other economic factors, rather than following a fixed input-output structure. This allows the model to assess *ex ante* policies for reducing material consumption within a full macroeconomic framework.

Material types

E3ME models material consumption at Member State level. At present the following material types are included:

- Food
- Animal feed
- Forestry
- Construction minerals
- Industrial minerals
- Ferrous ores
- Non-ferrous ores

These match the aggregate categories that feature in Eurostat's MFA data set. In future they could be expanded further for specific analysis such assessing bio fuels demand and its economic impact.

Data

Data for material consumption are in general not disaggregated by sector. However, in E3ME consumption is split into a set of material users, and so sectoral consumption must be estimated. This is done largely by combining two different data sets: the Eurostat material flows data (MFA), disaggregated by country and material (Eurostat),

[4] http://www.matisse-project.net/

[5] Pollitt, H. (2008), "Combining Economic and Material Flows Analysis at the Sectoral level: Development of the E3ME Model and Application in the MATISSE Case Studies", Deliverable 8.6.1, Work Package 8, MATISSE, European Commission project No 004059 (GOCE), Brussels: European Commission.

[6] Ekins, P., Pollitt, H., Summerton, P. and Chewpreecha, U. (2012), "Increasing Carbon and Material Productivity through Environmental Tax Reform", Energy Policy, 42 (3): 365-376.

[7] 'Macroeconomic modelling of sustainable development and the links between the economy and the environment' 2011, DG Environment, European Commission.

and the regional time-series of supply and use tables (Eurostat) to disaggregate material users. Some additional assumptions are made, for example that only the agriculture sector consumes animal feed.

Time series are constructed on this basis and used to estimate the model parameters.

Material demand equations

The basic structure of the material demand equations is similar to that of the equations for energy demand in the model. Material consumption intensity (DMI per unit of output[8]) is a function of economic activity (+/-)[9], material prices (-) and measures of technology (-).

It should be noted that the long-run price elasticities for material intensity are estimated at EU level. The reason for this is that attempts to estimate elasticities at the national/sectoral level did not produce robust results. The EU price elasticity results are imposed on the long-run price parameters for each region while short-run price elasticities and estimates for other explanatory variables are made at sectoral/country level. The functional form of the equations allows for the estimated coefficients to be interpreted as elasticities. Table 1 summarises the price elasticities and R&D elasticities from material intensity equations.

Table 1: EU28 long-run material price and R&D elasticities

Material	Price elasticity	R&D elasticity
Food	-0.04	-0.20
Animal Feed	0.00	0.00
Forestry	-0.41	-0.22
Construction Minerals	-0.38	-0.06
Industrial Minerals	-0.05	-0.13
Ferrous Ores	-0.40	-0.27
Non-Ferrous Ores	-0.49	-0.19

Source(s): E3ME, Cambridge Econometrics.

The elasticities give the percentage change in material consumption for a 1% increase in price or R&D spending. The EU price elasticities are imposed at national and sectoral level, but R&D elasticities are estimated freely for each sector.

The results above suggest that both price increases and higher R&D spending could lead to reductions in material consumption. The price elasticities are highest for ores, forestry and construction minerals but (as one would intuitively expect) lower for food[10]

Material variables

E3ME principally uses Domestic Material Input (DMI) as its measure of material consumption, although exports can be separated to get Domestic Material Consumption (DMC), and imports removed to get Domestic Extraction (DE). The basic model structure does not include rucksack measures or estimates of unused materials,

8 DMI is Domestic Material Input, see next chapter.

9 Expected relationship.

10 It is not possible to estimate an elasticity for animal feed as the production and purchasing sector are the same (i.e. agriculture)

but Total Material Requirement (TMR) is estimated by using a coefficient method that fixes the ratio of TMR to DMI.

RMC

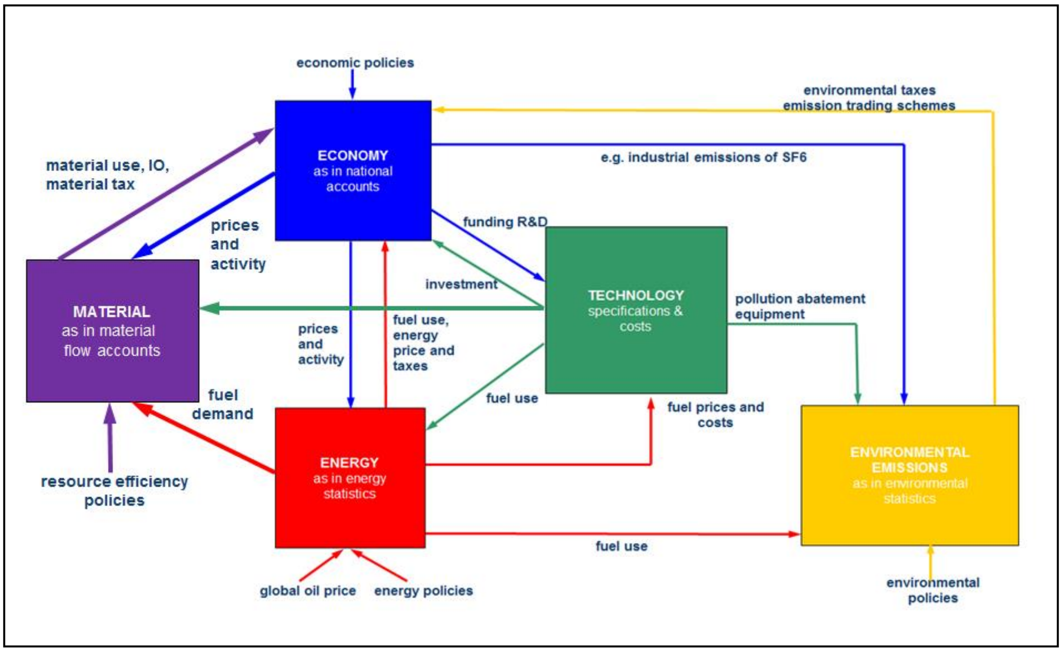
The data and necessary processing are described in the next chapter. The following steps were taken to estimate RMC in E3ME:

- convert Eurostat RME EU27 export and import (in raw material equivalent unit) and Eurostat MFA EU27 export and import (in physical unit) to the E3ME material classification
- calculate the RME coefficients for EU27 imports and exports for each material
- apply the RME coefficients to the model estimated imports and exports in physical units for each Member State (including Croatia)
- calculate RMC with the new import and export figures, RMC = DE (used) + Import (RME) – Export (RME)

Feedback to the economic model

It is assumed that all material consumption meets intermediate demands (i.e. materials are used as part of the production process and not bought by households directly). A relatively small number of sectors produce the materials: agriculture and fishing produce food and feed; the forestry sector produces forestry; and other mining produces all mineral categories. The feedback is through adjustments to economic input-output coefficients at the Member State level.

Figure 1: Energy-Environment-Material-Economy linkages in E3ME



3 RMC Baseline to 2030

3.1 Methodology and data

Introduction

Eurostat publishes annual data from their Economy-wide Material Flow Accounts (EW-MFA[11]) for all Member States (EU28) for the years 2001 to 2011[12]. The dataset consists of:

- Domestic Extraction Used (DEU)
- Imports (total and extra-EU)
- Exports (total and extra-EU)
- Domestic Material Consumption (DMC) = *Domestic Extraction Used (DEU) + Imports – Exports*
- Domestic Material Input (DMI) = *Domestic Extraction Used (DEU) + Imports*

The annually reported EW-MFA do not include the raw material equivalents of imports and exports. However based on an expanded hybrid input-output model, Eurostat has recently released estimates for raw material equivalents (RME) for the EU27 for the period 2000 to 2011[13] . The estimates include data for the following four indicators:

- Imports in Raw Material Equivalents (IMP_RME)
- Raw Material Input (RMI) = *DEU + IMP_RME*
- Exports in Raw Material Equivalents (EXP_RME)
- Raw Material Consumption (RMC) = *DEU + IMP_RME – EXP_RME*

Together with the RMC estimates Eurostat has also established a set of coefficients for the conversion of EU ‘simple’ imports (IMP) and exports (EXP) into raw material equivalents (IMP_RME and EXP_RME). Eurostat does not provide RMC estimates for individual Member States, but proposes that two principal approaches could be used to calculate RME of the imports and exports of individual Member States[14]:

- Coefficient approach for imports and exports
- Input-Output Table (IOT) approach for exports combined with coefficient approach for imports

As the scope of this study did not allow the IOT approach to be applied, the simpler but cruder approach using EU average coefficients was chosen. The coefficient approach assumes that the RME coefficients for imports and exports at Member State level are similar to the average EU level coefficients. Furthermore it was assumed that

11 Eurostat (online data code: env_ac_mfa)

12 EW-MFA data for Croatia only exists for 2001-2011. Data for EU27 is also available for 2000.

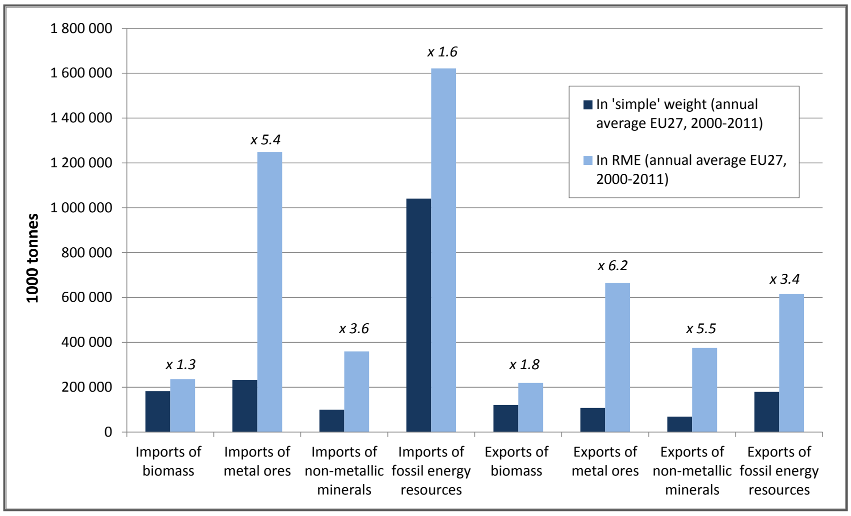
13 Ifeu, SSG & CUEC (2012) Conversion of European product flows into raw material equivalents. Institut für Energie- und Umweltforschung (ifeu), Sustainable Solutions Germany – Consultants (SSG) and Charles University in Prague, Environment Centre (CUEC) for Eurostat.

14 Eurostat (2012) RME estimations & coefficients – explanatory notes.

intra-EU imports are more similar across the EU than with countries outside of the EU. Following from this, we distinguished between intra-EU and extra-EU imports. To calculate the extra-EU imports of individual Member States in RME, we used the average EU27 coefficients for imports. For the RME of intra-EU imports of individual Member States, we used the average EU27 coefficients for exports. The RME of exports of individual Member States was calculated using the EU27 average coefficient for exports (regardless of whether the exports were exported within or outside the EU).

The EU27 average RME coefficients was calculated by dividing the estimated RME of EU27 imports / exports (taken from the Eurostat pilot study on RME) with the 'simple' amount of extra-EU imports / exports (taken from Eurostat's EW-MFA database). This was done for each year and for each of the four main material categories (i.e. biomass, metal ores, non-metallic minerals and fossil energy resources)[15]. Figure 2 shows the difference between EU27 imports and exports measured in 'simple' weight and in RME. The RME coefficients for exports are higher than the corresponding coefficients for imports as EU exports are generally more material intensive that the imports (e.g. the EU imports basic metals, which it then exports as vehicles or equipment).

Figure 2: The ratio between EU imports and exports measured in 'simple' weight and in RME (based on an annual average 2000-2011)



Limitations

It should be noted that the relationship between 'simple' imports/exports and RME is not as straightforward as the simplified coefficient approach suggests. The RME of imports and exports includes all the raw material used in their production including the fossil fuel energy. For example, for metals, the RME covers not just metal ores, but also the fossil fuels and non-metallic minerals used to produce one unit of metal imports.

In order to calculate RMC for the EU28, we first calculated the RMC for Croatia using the EU27 average RME coefficients for imports and exports as described above. Eurostat only provides EW-MFA data for Croatia for 2001-2011, therefore EU28 RMC

15 It was not possible to perform the calculations at a more disaggregated material category level as the small quantities of imports/exports of some individual materials (e.g. straw, grazed grass, etc.) resulted in aberrant RME coefficients.

could only be calculated for 2001-2011. Furthermore, Eurostat does not provide specific data for extra-EU imports and exports, so no distinction was made for the use of RME coefficients for Croatia. Despite these assumptions and the simplified approach used to calculate RME for Croatian imports and exports, this does not influence the overall results significantly – Croatian RMC is less than 1% of the EU's total.

Raw material categories and main final use product groups

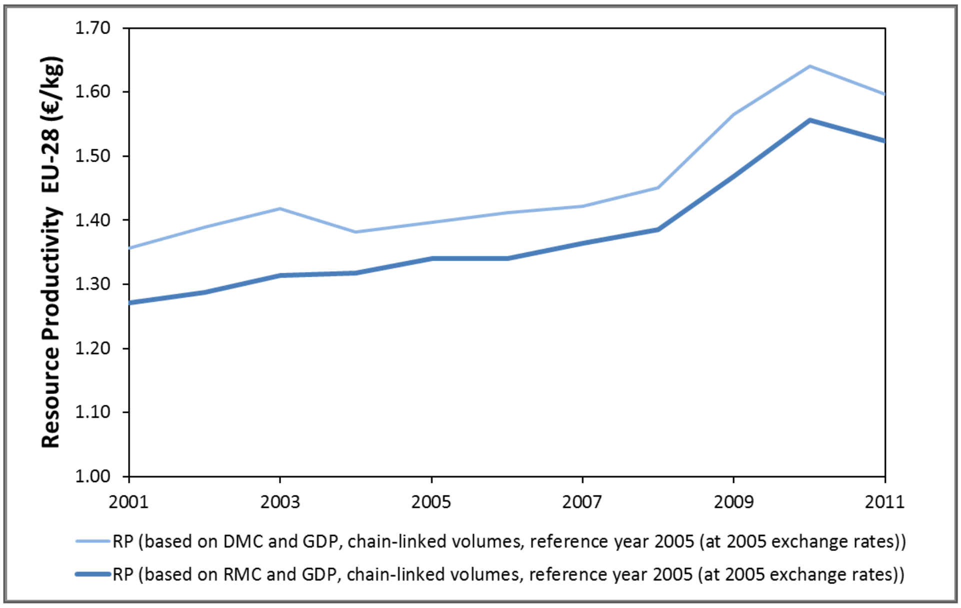
In this study, the four main material categories (i.e. biomass, metals, minerals and fossil energy resources) used in Eurostat's economy-wide Material Flow Accounts (EW-MFA) were disaggregated into sub-groups to be better suited for macro-economic modelling in the next phase of the study, using the E3ME model[16]. The material categories used in this study, as well as the corresponding codes in EW-MFA, are presented in Appendix A.

3.2 Historical trends

Past trends of resource productivity in the EU28

This section presents the historical trend of resource productivity (GDP/RMC) between 2001 and 2011 in the EU28. Figure 3 shows the evolution of resource productivity (RP) based on DMC and RMC in the EU28 between 2001 and 2011. As RMC includes the raw material equivalents of imports and exports, resource productivity is lower when measured in RMC instead of DMC. Resource productivity based on RMC has been continuously increasing since 2001 (with a sudden increase in 2008-2009 during the economic crisis and a drop between 2010 and 2011), with a total increase of +19.6% over the ten year period from 1.27 to 1.52 €/kg, or a +1.9% increase per year on average.

Figure 3: Evolution of Resource Productivity (RP) of EU28 between 2001 and 2011



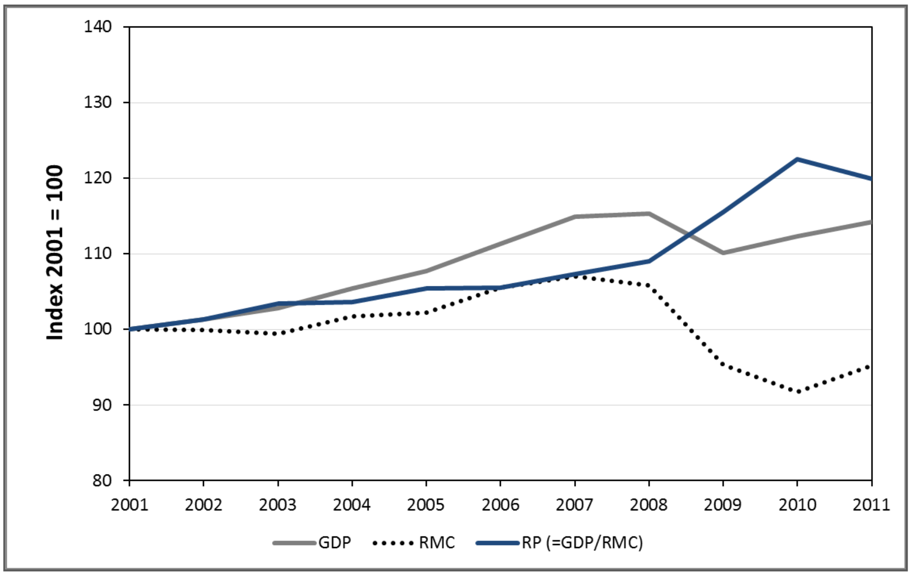
Resource productivity has increased by less than GDP in the period before the economic crisis that started in 2007 (see Figure 4), meaning an overall increase in

16 www.e3me.com

material consumption. The sudden rise in resource productivity from 2008 to 2010 is due to a drastic decrease in RMC rather than changes in GDP. It would seem that material resource consumption has remained relatively coupled with economic growth in the period 2001 to 2011.

Before the economic crisis, the average annual change in resource productivity was only +1.2% (see Figure 4). GDP growth was on average 2.3% per year in the period 2001 to 2007. If the years before the economic crisis are an indication of how resource productivity will develop in the future, we can expect that resource productivity will continue to increase with economic growth at approximately half the rate of GDP growth.

Figure 4: Evolution of GDP, RMC and Resource Productivity (RP) in the EU28 between 2001 and 2011

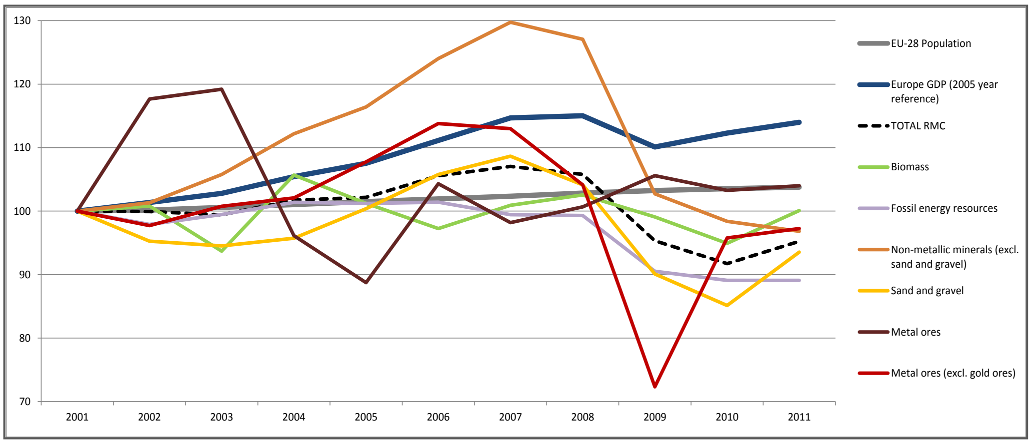


Past trends of Raw Material Consumption (RMC) of EU28

This section presents the historical trends of RMC between 2001 and 2011 in the EU28.

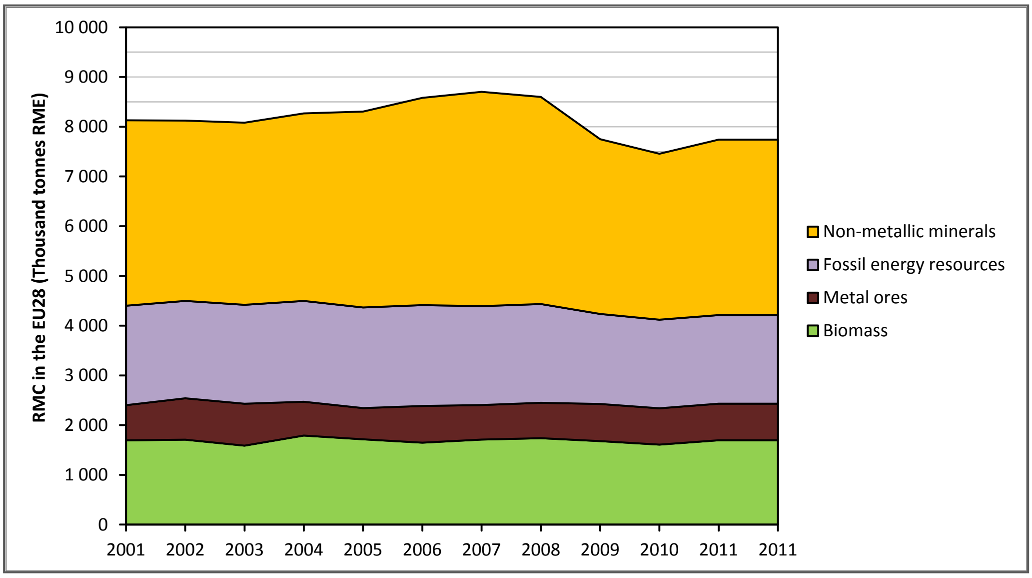
Figure 5 shows how total RMC in the EU28 has evolved between 2001 and 2011. On average almost half of total RMC is non-metallic minerals with sand and gravel by far the single largest material category (representing 30% of total RMC). Fossil fuel resources constitute almost a quarter of total RMC, while biomass is just over 20% and metal ores just under 10%. When looking at the evolution of total RMC, we can note a first stable trend with a steady increase of 7% of total RMC between 2001 and 2007. This upward trend ended once the recession hit as total RMC dropped by -11% from 2007 to 2012. In 2010 there were signs of a recovery as total RMC began to increase again.

Figure 5: Evolution of EU28 RMC (billions of tonnes RME) between 2001 and 2011



This general trend was mainly driven by the evolution of RMC of non-metallic minerals (mainly construction materials), which showed a significant increase until 2007, followed by a sharp drop between 2008 and 2010 during the economic crisis (see Figure 6). RMC of biomass has remained relatively stable over the entire period, whilst metal ores has fluctuated a lot (mainly due to gold ores) until 2007. Besides gold ores, RMC of all the other metal ores generally increased until 2007, then dropped sharply and then increased again in 2010. RMC of fossil energy resources has shown a decreasing trend throughout the entire period, and particularly after 2007.

Figure 6: The evolution of RMC of the main material categories in relation to GDP and population



It is not completely clear to what extent changes in RMC are due to changes in resource productivity, demand factors or industry structure. The following observations may however provide a clue.

Biomass

Biomass consumption is mainly linked to agricultural and forestry activities and the production of food, wood products and bioenergy. In agriculture, biomass is used for food and animal feed, but also for biofuel and natural fibre production[17]. In forestry, wood is harvested for wood products (e.g. construction materials, furniture and packaging), paper and pulp products and bioenergy[18]. Consequently, the main drivers of biomass consumption are associated with food and feed demand, but also demand for renewable energy and construction materials[19.] All these drivers are linked to[20,21]:

- population growth:
  - increase of food and, indirectly, animal feed to produce meat;
  - increase of energy demand for electricity, heating and transport;
  - increase of paper products, housing and infrastructure demand for furniture and construction materials.
- consumption behaviour related to rising incomes:
  - diet with increasing meat proportion, less vegetables, increasing food intake;
  - increasing demand for larger living areas and single person households.
- EU policy incentives to increase the share of renewable energies.

The EU is a net producer of biomass. Thanks to its highly productive land and agricultural support, most of its biomass is produced domestically, with the exception of some crops such as oil crops, nuts and fibres, where the EU is very dependent on imports. Cereals and animal feed (fodder crops and grazed grass) account for the largest share of biomass domestic extraction. Trade in biomass (both imports and exports) seems to have increased throughout the entire period studied.

Besides the material category 'Other food' (i.e. potatoes, vegetables, fruits, sugar, fish, etc.), which has experienced a steady, gradual decrease of RMC over the period, the other material categories have seen some annual variation but their long-term trends have been largely constant. More precisely:

- Cereals: the RMC trend was stable over the period 2001-2011 (+0.3%), with significant annual variations (from -16% to +34%);
- Other food: gradual decrease (-7%) between 2001 and 2011;
- Animal feed: RMC was stable over the period 2001-2011 (+0.6%) with moderate annual variations (from -8% to +10%);

17 BIO Intelligence Service, Ecologic Institute, IVL Swedish Environmental Research Institute & Policy Studies Institute (2013) DYNAMIX (Decoupling growth from resource use and environmental impacts) – The underlying reasons for resources (in)efficiencies, 208 pp.

18 Wuppertal Report (2005) Resource use in European Countries – An estimate of materials and waste streams in the Community, including imports and exports using the instruments of material flow analysis, 105pp.

19 ETC/SCP (2011) Key messages on material resource use and efficiency in Europe - Insights from environmentally extended input-output analysis and material flow accounts, 31pp.

20BIO Intelligence Service (2012) Update of analyses of DMC accounts - Environmental Data Centres on Natural Resources and Products, 29pp.

21 Kearney J. (2010) Food consumption trends and drivers. Phil. Trans. R. Soc. B 2010 365, 2793–2807.

- Bioenergy in the form of wood fuel and oil bearing crops [22]: has shown gradual growth over the period;
- Wood (industrial round wood): has experienced only a slight change between the level in 2001 and 2011 (+2.4%). However, this masks a gradual increase until 2007, followed by a drop and recovery, probably linked with economic activity in the construction sector;
- Other biomass (e.g. fibres, straw): RMC was stable between 2001 and 2011 with moderate annual variations (from -9% to +24%).

As the EU28 population has increased by 4% between 2000 and 2011, the stable trend of cereals and feed RMC can be explained by a compensation between increasing exports and changes in diets (for example the share of cereals in calories for food use has gradually been declining since 1960, while the negative trend of the 'other food' material category can be explained by a decrease in fruits, vegetables, roots and tubers in European)[21].

The domestic extraction for bioenergy materials has significantly increased during this period of time (wood fuel increased by over 40%) – resulting from EU climate and energy policies, which aim to increase the share of renewables in the EU energy mix[23], but also increased exports. The domestic production and imports of oil crops has increased significantly, but so has the exports of oil crops. Domestic production of fruits and vegetables have not changed much, but both imports and exports have seen significant increases over the past decade.

Metal ores

Metal ores (gold, copper, aluminium, ferrous and non-ferrous ores) consumption is mainly linked to industrial and construction activities[24], whose trends are reflected in the evolution of GDP (economic growth). Except for gold ores for which trade data are inconsistent, the trends of copper, aluminium, ferrous and other non-ferrous ores were increasing until the economic crisis and then suffered significant drops followed by a gradual recovery.

The import dependency measured in RME is very high (90%) in the EU. The EU mainly extracts copper and iron ores, but also zinc, gold and silver. However, the extracted quantities (in raw material equivalents) are much lower than the imported or exported RME. Domestic extraction (mining) of iron, copper, nickel and gold ores in the EU has increased over the period, whereas domestic extraction of bauxite and lead ores has decreased.

The imports of most metal ores seem to be increasing throughout the period, although many experienced a sharp drop between 2007 and 2008 due to the economic crisis. Lead is the only metal that has seen a significant decrease throughout the period due to decreasing demand following the Directive on the restriction of hazardous substances in products (RoHS). Although the imports in RME are significantly higher

22 Bioenergy includes more than wood fuel and oil crops. In this study it was however not possible to directly relate the amount of other biomass raw material used for energy purposes. Bioenergy from waste is not included here.

23 Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC COM(2008) 772 - Communication from the Commission of 13 November 2008 - Energy efficiency: delivering the 20% target

24 ETC/SCP (2011) Key messages on material resource use and efficiency in Europe - Insights from environmentally extended input-output analysis and material flow accounts, 31pp.

than the exports for all metal ores, exports of metal ores have also experienced significant growth in the past 10 years. A drop in exports could be observed when the economic crisis hit Europe, but this has since increased and reached pre-crisis levels or higher in 2011. The fact that the absolute decline of metal ore RMC only occurred during very short periods linked to the economic crisis shows that absolute decoupling of metal consumption and economic growth has not been achieved in the EU. The following points summarise the evolution of RMC of metal ores between 2001 and 2011:

- Consumption of ferrous ores increased by 3.1% on average pa between 2001 and 2007 and then experienced a steep drop during the economic crisis, but has since recovered.
- Similarly copper ores experienced an average annual increase in consumption of 1.8% pa until 2007 but consumption decreased during the economic crisis before recovering by 7.0% between 2009 and 2010.
- Bauxite and other aluminium ores: RMC increased by 2.8% pa on average between 2001 and 2007; it then decreased drastically but grew significantly after 2009;
- Consumption of the other non-ferrous ores has overall been stable with fairly large fluctuations – particularly between 2008 and 2010.
- Gold-gross ore: *significant fluctuations due to unreliable data.*

Non-metallic minerals

Non-metallic minerals consumption is mainly related to construction and industry activities[25]. In the construction sector, sand and gravel as well as other construction minerals (such as marble, granite, sandstone, chalk and dolomite, etc.) are used as raw materials to produce construction materials such as concrete. In industry, non-metallic minerals are used in the production of paper (notably kaolin)[26], in the production of fertilizers[27] or in the chemical industry. Hence, the consumption of non-metallic minerals is mainly driven by the demand and economic activity in these sectors. Another important driver for this category is population growth, which influences the demand for products, housing and infrastructure[28].

The trends for non-metallic minerals show an increase between 2001 and 2008, followed by a drop in 2008-2009 (due to the economic crisis) and growth since 2009-2010. The strong link between consumption of non-metallic minerals and economic growth is further illustrated by the decrease of all sub-categories during the economic crisis.

Sand and gravel, and construction minerals both grew in the pre-recession period (+1.5% and 5.2% pa, respectively) with a fall during the recession. Sand and gravel has shown signs of post-recession recovery but is still -6.3% below its 2001 value. Whilst construction materials has ended up 6.7% higher than in 2001, this is largely due to the strong growth in the early part of the decade as this material had not yet begun to recover from its decline by 2011. Industrial minerals and other non-metallic

25 BIO Intelligence Service, Ecologic Institute, IVL Swedish Environmental Research Institute & Policy Studies Institute (2013) DYNAMIX (Decoupling growth from resource use and environmental impacts) – The underlying reasons for resources (in)efficiencies, 208 pp.

26 Bundy WM & Ishley JN (1991) Kaolin in paper filling and coating. Applied Clay Science, 5:397-420.

27 USGS (2008) The Global Flows of Metals and Minerals, 15pp.

28Wuppertal Institute for Climate, Environment and Energy (2007) The relation between resource productivity and competitiveness, 155pp.

minerals' RMC trend has followed the pattern described above with steady growth followed by a fall during the recession period (-24% and -42%, respectively). Overall both of these sub-categories have been stable relative to the larger non-metallic minerals, but both have experienced a general fall over the entire period (-19.2% and -24.5%, respectively).

Except for chemical and fertilizer minerals, most non-metallic minerals (particularly construction minerals and sand & gravel) consumed in the EU are also extracted in the EU. Even if domestic extraction of non-metallic minerals has declined slightly over the 10 year period (-4%) and imports have risen by +13.5% in the same time, the non-metallic minerals import dependency remains low (10%) – except for chemical and fertilizer minerals. Moreover, exports have increased by almost +20%. The trade flows of non-metallic minerals have intensified in the past ten years, especially for industrial and construction minerals (+20-30% for both imports and exports). Sand & gravel trade has also been quite dynamic between 2001 and 2011 (+13% for imports and +16% for exports).

One aspect which may explain why construction minerals have decreased their RMC over 2001 – 2011 is the increasing importance of recycling. For instance, sand and gravel have been increasingly recycled in aggregates during this period, either for the production of concrete or for road applications (up to 6% of tonnage is recycled aggregates)[29]. This last point is also true for the chemical industry, where more and more recycling processes have been implemented[30], leading to a reduction in raw materials consumption. The reduction in chemical and fertilizer minerals with stable biomass production over the same period indicates that this might be due to productivity increases in agriculture.

Fossil energy resources

Fossil energy resources consumption is mainly driven by energy demand and the efficiency of energy production systems, but also includes the embedded energy of imports. The demand for chemicals and materials such as plastics made from fossil fuels is a minor driver (about 4%)[31] of fossil energy consumption in the EU. Energy demand is closely related to economic and population growth, but it is increasingly also determined by EU climate and energy policy. Fossil fuel combustion is an important source of anthropogenic greenhouse gases (GHG). At the EU level, targets have been set to mitigate climate change and notably:

- The energy and climate '20-20-20' targets (implemented in 2009) aiming at:
    - Reducing GHG emissions by 20% in 2020 in comparison to 1990 levels
    - Raising the share of EU energy consumption produced from renewable resources to 20%
    - Improving the EU's energy efficiency by 20% (i.e. reducing the EU's energy consumption by 20% compared to a baseline projection)

Crude oil and hard coal, two high-carbon energy resources, have seen their RMC significantly reduced over the 2001 – 2011 period (-16.2% and -22.8%, respectively). On the contrary, the consumption of other 'low-carbon' fossil energy resources such as

29 UEPG (2012) A sustainable industry for a sustainable Europe, 40pp.

UEPG (2006) Aggregates from Construction and Demolition Waste in Europe, 4pp.

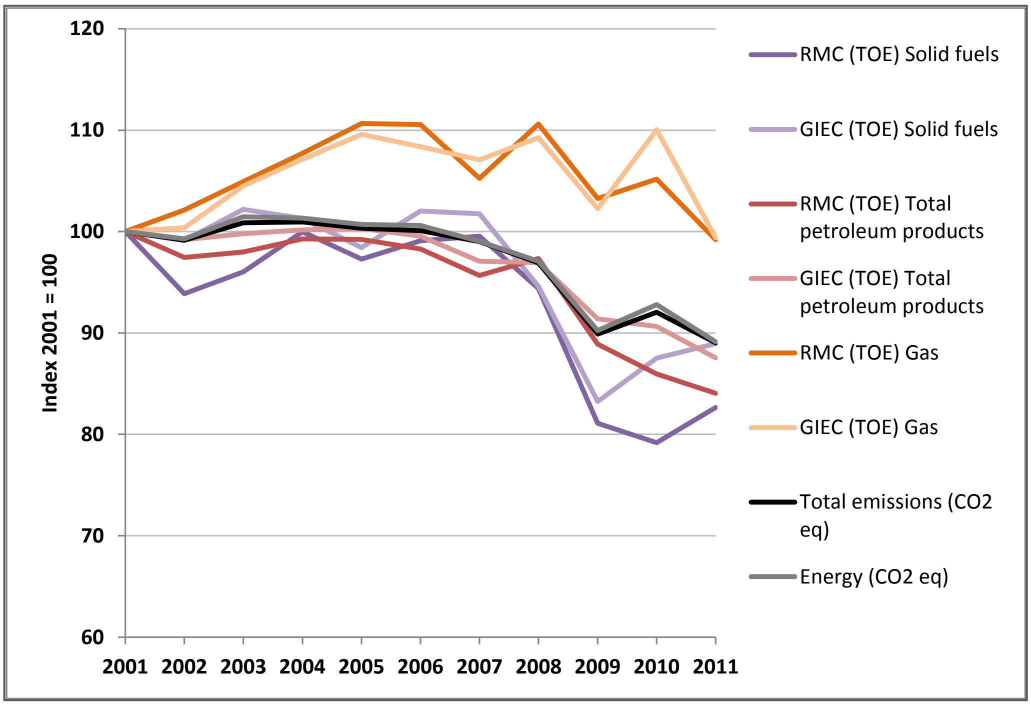
30 IHS (2009) Recycling and the Chemical Industry, Safe & Sustainable Chemicals Series.

31 DG ENER (2009) EU 27 energy trends to 2030 — UPDATE 2009.

natural gas, have been constant over this period. This reflects the shift that has been made in order to replace high-carbon energy resources with low-carbon fossil energy technologies or even renewable energy technologies, as illustrated by the growing consumption of biomass for bioenergy production. This shift from 'high-carbon' fossil energy resources to 'low-carbon' fossil energy resources has led to reduced GHG emissions from the energy sector and the EU28 as a whole, as illustrated in Figure 7.

Although being closely related, RMC of fossil fuel resources and Gross Inland Energy Consumption (GIEC) differ by the fact that the energy embodied in products consumed in Europe is accounted for in RMC, while it is not taken into account in GIEC. Hence, RMC of fossil fuel resources should typically be higher than GIEC, but as the figure below shows, RMC of fossil fuel resources is closely correlated to GIEC as energy use in the EU is the main driver of fossil fuel RMC.

Figure 7: Evolution of EU28 RMC (expressed in TOE), Gross Inland Energy Consumption (in TOE[32]) and GHG emissions (in thousands of tonnes CO2 eq.) (2001 = 100)



Finally, although being quite negligible in comparison to crude oil, condensate and natural gas liquids consumption, oil shale and tar sands have seen their consumption increase by 76% over the 2001 – 2011 period. This atypical trend can be explained by domestic extraction in Estonia. Estonia – which has about 90% of EU oil shale and tar sands extraction in the EU - has made significant investments in extraction techniques, resulting in higher extraction volumes.

The EU does not have enough fossil energy resources in its soil to meet its demand. The EU28 is an overall net importer of crude oil, condensate and liquid natural gas (LNG), and to a lesser extent hard coal and natural gas. Domestic extraction has significantly decreased for hard coal, crude oil & LNG and natural gas (−30-50%) between 2001 and 2011. Lignite and peat extraction have remained stable.

The imports and exports showed an overall increase in the 2001-2011 period (with a change in growth during the economic crisis), while domestic extraction decreased.

32 Tonnes of Oil Equivalent.

However, the overall fossil energy resources import dependency is high (67%). Imports of fossil fuel RME has increased for all types of fossil fuels throughout the entire period. The highest increase is the import of natural gas RME, which has increased by +32% between 2001 and 2011. Exports of fossil energy resources have also grown for every material category, from +8% (hard coal and peat) to +20-30% (lignite, crude oil & NGL and natural gas). In terms of RME, the EU imports almost three times more hard coal, crude oil & NGL and natural gas than it exports.

The following points summarise the evolution of RMC of fossil energy resources in the EU28 between 2001 and 2011:

- Hard coal, and crude oil, condensate and natural gas liquids have had similar trends over this period. Their RMC have decreased between 2001 and 2011 (-22.8% and -16.2%, respectively).
- Lignite and natural gas have both declined slightly over this period (-3.1% and 0.8% respectively), with lignite experiencing a subtle recovery in 2010.
- Oil shale and tar sands: RMC has grown strongly between 2001 and 2011 (+76.3%), mainly due to domestic extraction in Estonia.
- Peat: RMC was stable between 2001 and 2011 (+1.5%) but is subject to very large annual variations (from -50% to +35%).

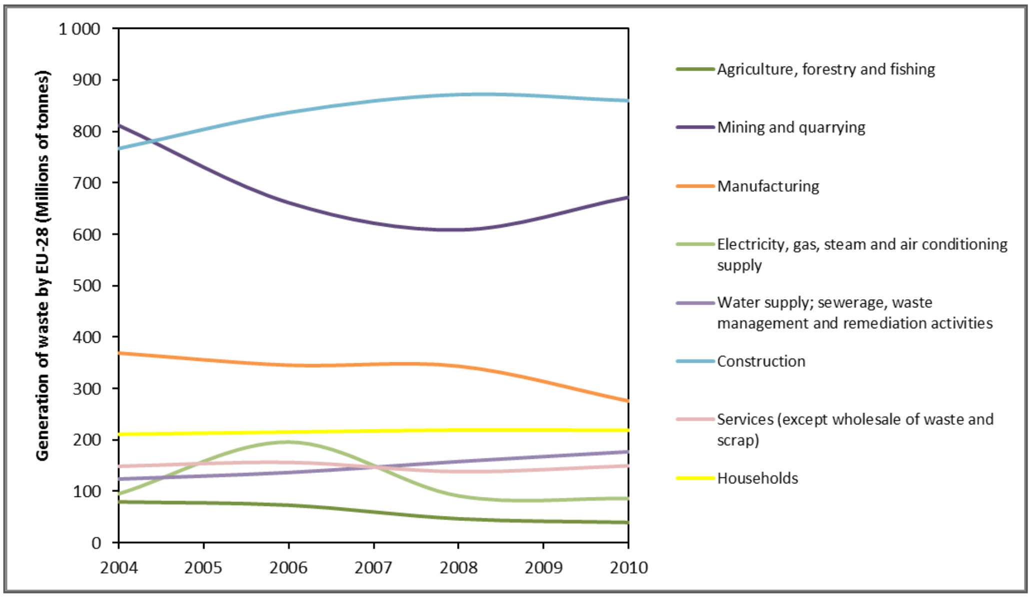
Waste

To assess if the slight reduction of RMC observed in the EU is due to increasing use of waste materials (use of recycled waste as secondary materials), the evolution of waste generation and waste treatment has been investigated between 2004 and 2010 in the EU. Since 2004, Eurostat compiles complete waste data in the EU every two years[33] for all NACE sectors and activities aggregated, plus waste from households. The overall generation of waste in EU28 decreased by -5% between 2004 and 2010 (from 2.6 to 2.5 billion tonnes). Figure 8 shows the evolution of EU28 waste generation per sector/activity between 2004 and 2010. Construction and mining & quarrying are the activities that generate the most waste (about 750-900 and 600-800 million tonnes, respectively). Construction waste generation increased between 2004 and 2008 (+12%) but has decreased since. Conversely, waste generation from mining & quarrying exhibited the opposite trend with a decrease between 2004 and 2008 (-25%) followed by a +10% increase of waste generation. Manufacturing and households are the sectors that generate a large amount of waste in the EU28 (275-375 and 215 million tonnes, respectively), with opposite trends between 2004 and 2010: wastes from households rose by +3.6% whereas the ones from manufactured were reduced by -25%. The different activities contained in the manufacture sector will be detailed in the next section.

Agriculture, services, electricity and water supply are sectors that generate less than 150 million of tonnes of waste per year in EU28. Waste generation from services has remained stable whereas waste from agriculture & forestry was significantly reduced between 2004 and 2010 (-50%). Waste from the electricity supply sector was also reduced but at a more moderate level (-10%). On the contrary, the water supply & management sector generated increasingly more waste in the EU28 (+43%).

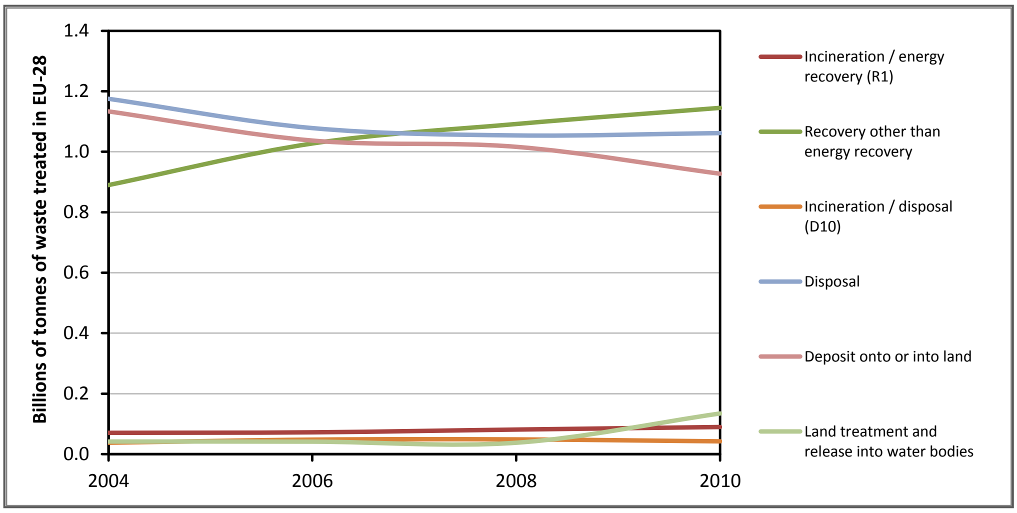
33 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wasgen&lang=en

Figure 8: Evolution of waste generation of EU28 by activity categories



Increased recycling can lead to increased resource productivity. Figure 9 shows the evolution of EU28 waste treatment between 2004 and 2010 following the treatment process. Deposit, disposal and recovery other than energy recovery are the treatment processes that manage the most waste (between 900 and 1200 million tonnes). Increasing quantities of waste have been treated by recovery other than energy recovery (i.e. recycling) in the period 2004 to 2010 (+28.7%).

Figure 9: Evolution of waste treatment in EU28 by treatment process



The evolution of the generation and recycling of waste in the EU28 during the 2004-2010 period contributes to resource productivity but it cannot totally account for all the observed variations in RMC.

3.3 RMC Baseline to 2030

Methodology

The baseline scenario describes the expected development of the EU28 Raw Material Consumption (RMC) under current trends and policies. It encompasses current trends on population and economic development. This baseline scenario has thus been constructed on the basis of 2001-2011 past trends and a literature review, and analysis on how the main drivers of each product categories are expected to affect their evolution in the future. The main underlying macro-economic and demographic assumptions have been based on the European Commission's population and energy projections, published by DG ECFIN(The 2012 Ageing Report[34]) and DG Energy (energy, transport and GHG emissions projections[35] based on the PRIMES model). These have been supplemented with Cambridge Econometrics' estimates for economic activity in individual sectors in the economy (largely based on the Commission's projections). The assumptions on economic development are driven by market forces and technological progress in the framework of national and EU policies and measures implemented until December 2013, including the recent economic downturn. They also take into account the volatility of global commodity prices in recent years, for example in the energy sector. The baseline scenario is a conservative projection that assumes that no further resource productivity policy measures are put in place. When no information is available, demand is assumed to follow the same trends observed in the period 2001 to 2030.

Baseline population and GDP trends until 2030

GDP and population assumptions are taken from the DG ECFIN 2012 Ageing Report and Eurostat, respectively. The GDP projection for the period 2012–2030 indicates a quite stable trend for GDP with an annual growth between 1.6% and 1.9% resulting in a 33.2% increase of GDP between 2012 and 2030.

The Croatian population has been added based on projections performed by Cambridge Econometrics using the EU12 average. The resulting trend shows an increase in the EU28 population of 3.7% during this period.

Baseline biomass trends until 2030

The main drivers of biomass consumption are linked with demographic growth (that increases demand for food, energy and construction) and economic growth (triggering rising incomes that induce changes in consumption behaviour and life style).

Figure 10 presents the expected development of total biomass and biomass product categories trends until 2030. Table 2 summarises the growth rates from 2012 to 2030. The baseline average growth per annum for biomass consumption in EU28 between 2012 and 2030 is calculated at +0.7% pa, which is higher than its historical trend on 2001-2011 of +0.2% pa. This is mainly due to the assumptions that meat (represented by animal feed in RMC) and bioenergy demand will increase.

34 European Commission – DG for Economic and Financial Affairs of the European Commission (2012) The 2012 Ageing Report, Economic and budgetary projections for the 27 EU Member State (2010 – 2060), Table A8, p. 297.

35 European Commission – DG Energy (2013) EU Energy, Transport and GHG Emissions. Trends to 2050. Reference Scenario 2013.

Figure 10: Projections of total biomass and biomass material categories for the baseline scenario

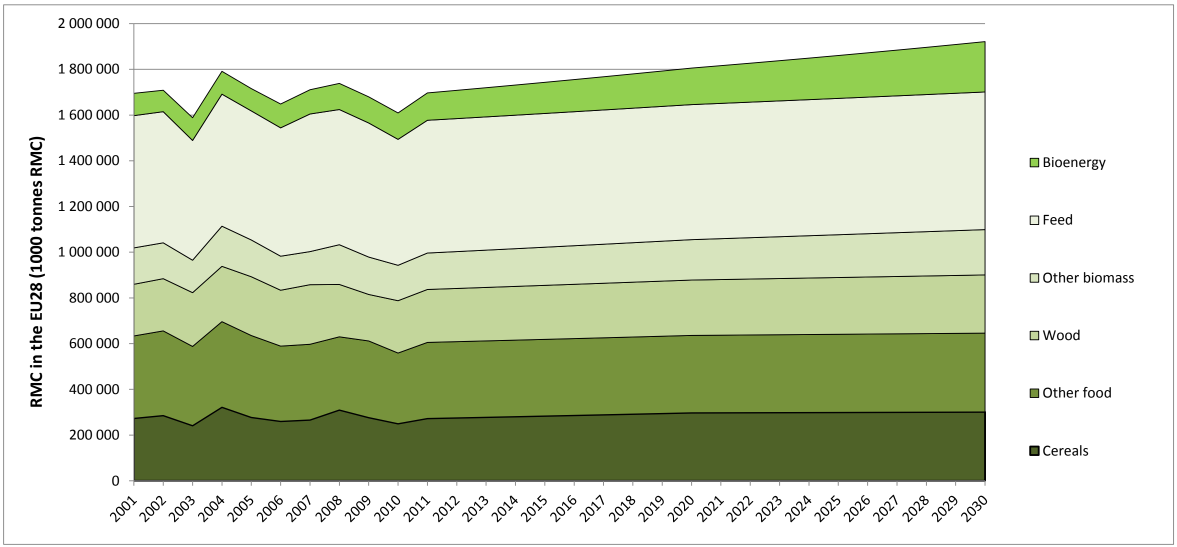


Table 2: Summary of biomass future trends in RME

	Average growth per annum		
Material categories	**2012-2030**	**2012-2020**	**2021-2030**
Biomass	***0.6%***	***0.7%***	***0.6%***
Cereals	0.5%	1.0%	0.1%
Other food	0.2%	0.2%	0.2%
Feed	0.2%	0.2%	0.2%
Wood	0.5%	0.5%	0.5%
Bioenergy	3.3%	3.3%	3.3%
Other biomass	1.2%	1.2%	1.2%

The following sections detail the assumptions made for the 2010-2030 trends of each biomass product category.

Cereals

The evolution of cereals consumption in the EU28 was modelled on the basis of the 2009-2022 projection of the total cereals balance sheet in the EU performed by DG AGRI[36], with the assumption that between 2022 and 2030 the annual trend will be same as the one of the 'plateau' observed between 2020 and 2022, i.e. about 0.1% per year. The projected overall trend for 2012-2030 is +9% growth, which is equal to +1.0% per year between 2012 and 2022 and 0.1% per year between 2021 and 2030. This annual trend for 2010-2022 is aligned with the 2001-2011 historical average annual trend of 1%. The population assumptions of the DG AGRI study are consistent with the assumptions with this study (i.e. +0.2% pa for EU28 population between 2015 and 2022), whilst GDP growth is estimated to be higher (i.e. +2% pa).

36 DG Agriculture and Rural Development (2012) Prospects for Agricultural Markets and Income in the EU 2012-2020. European Commission.

Other food

The evolution of food consumption (vegetables, roots, potatoes, pulses, fruits, etc.) provided by Kearney (2010)[37] forecasts a 33% increase between 1983 and 2050 in Europe (see Table 3). Kearney provides an annual trend between 2003 and 2025 of +0.2% per year. The GDP and population assumptions of the Kearney study were not mentioned explicitly, so it is unclear whether they are aligned with this study.

Table 3: European consumption of food, extracted from Kearney, 2010

g/hab/day	2003	2025	2050
Vegetables	539.7	541.1	571.8
Roots and Tubers	49.3	38.2	34.7
Potatoes	254.8	225.0	210.5
Pulses	5.5	14.5	13.3
Fruits	241.1	252.3	270.8
Total (g/hab/day)	***1090***	***1071***	***1101***
Total in tonnes	***193 431 378***	***201 717 790***	***208 975 494***

The baseline trend of the category 'other food' consumption between 2012 and 2030 was then modelled at about +0.2% per year (extrapolation of the linear growth between 2003 and 2025), accounting for an overall growth in consumption of +3% between 2012 and 2030. This annual trend is higher than the historical average trend over 2001-2011 (i.e. -0.6% pa).

Feed

The development of feed consumption (that is driven by meat and dairy consumption essentially) between 2009 and 2022 provided by DG AGRI forecasts a +0.2% per year increase between 2012 and 2022. The baseline trend of the category 'feed' was then modelled by extrapolating the +0.2% pa trend from 2022 to 2030, exactly in line with the historical average annual trend of +0.2% pa during the period 2001-2011. The overall increase in feed consumption between 2012 and 2030 is estimated to be +3%.

Wood

The baseline evolution of wood consumption (which is mainly driven by the construction and paper industry) was taken from the FAO (2011)[38] forecast of +0.5% pa increase for wood used for products consumption in Europe between 2012 and 2030, i.e. an overall growth of 9% between 2011 and 2030. This trend is aligned with the historical average annual trend of +0.5% pa between 2001 and 2011. The 2030 assumptions made for GDP and population growth in the European Forest Sector Outlook Study are based on the IPCC scenario B2.

Bioenergy

The development of biomass for bioenergy consumption (which is driven by energy policies that promote the increase of renewable energy) was provided by the EC's (2014)[39] forecast: 123% increase between 2005 and 2030, i.e. 3.3% per year. The

37 Kearney (2010) Food consumption trends and drivers, Phil. Trans. R. Soc. B 2010 365 supplementary data.

38 The European Forest Sector Outlook Study II, 2010-2030, United Nations Economic Commission for Europe & FAO.

39 European Commission (2014) Impact Assessment - A policy framework for climate and energy in the period from 2020 up to 2030 (PRIMES)

assumption for the baseline trend of the 'bioenergy'[40] category is that the same annual trend (i.e. +3.3% pa) will apply between 2012 and 2030. This value is higher than the historical average annual trend of +2.1% between 2001 and 2011. The GDP and population assumptions of the EC study are consistent with this study's assumptions (based on PRIMES).

Other biomass

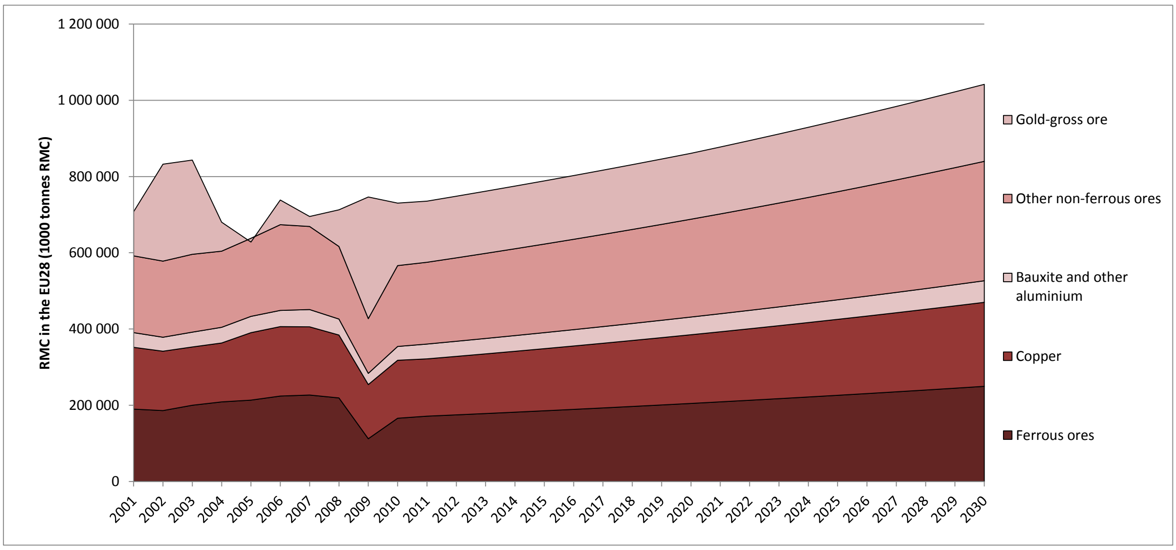
The evolution of the product category 'other biomass' was modelled on the EU28 straw potential evolution. The development of straw potential was provided by IEEP's (2012)[41] forecast of a 26% increase between 2000 and 2020, i.e. +1.2% per year. This value is higher than the historical average annual trend of +0.6% between 2001 and 2011. The GDP and population assumptions of the IEEP study were not mentioned. The assumption for the baseline trend of the 'other biomass' category is that the annual same trend will apply between 2012 and 2030 (i.e. +1.2% pa).

Baseline metal ore trends until 2030

The main drivers of metal ores consumption are linked with economic growth in industry and construction, indirectly linked with population growth and demand (triggering rising incomes that induce changes in consumption behaviour and life styles). Figure 11 presents the overall development of total metal ores and metal ores product categories trends until 2030.

Table 4 summarises the growth rates from 2012 to 2030. The baseline average annual growth for metal ores consumption in the EU28 between 2012 and 2030 is calculated at +1.8% pa, which is higher than its historical trend (2001-2011) of +1.0% pa. We expect that there will be an increase in metals consumption up to 2030 to build up the planned renewable energy installations and renewal of infrastructure.

Figure 11: Projection of total metal ores and metal ores material categories for the baseline scenario



40 In this study, the bioenergy RMC material category includes only wood fuel and oil crops.

41 IEEP (2012) Mobilising cereal straw in the EU to feed advanced biofuel production

http://www.biocore-europe.org/page.php?optim=agricultural-residues13

Table 4: Summary of the future trends of metal ore RMC

	Average growth per annum		
Material categories	**2012-2030**	**2012-2020**	**2021-2030**
Metal ores	1.8%	1.8%	1.9%
Ferrous ores	2.0%	2.0%	2.0%
Copper ores	2.0%	2.0%	2.0%
Bauxite and other aluminium ores	2.0%	2.0%	2.0%
Gold gross ores	1.0%	0.8%	1.6%
Other non-ferrous ores	2.0%	2.0%	2.0%

The following sections details the assumptions made for the 2012-2030 trends of each of the metal ores.

Ferrous metal ores

The baseline evolution of ferrous metal ores consumption until 2030 has been modelled on the assumption of the JRC Report[42] that 'between 2009 and 2030, the finished steel consumption is expected to grow by a Compound Annual Growth Rate of 2% per year for the EU27'. The overall 2012-2030 baseline trend of ferrous ores consumption is then expected to be +43%, i.e. about +2.0% per year, slightly higher than its historic average annual change of +1.7% between 2001 and 2011, but lower than the pre-crisis annual growth rate of +3.1% pa. The GDP assumptions of the JRC study are consistent with this study (i.e. +1.2% pa between 2010 and 2030). Trends of population until 2030 are however not mentioned.

Copper

The evolution of copper was based on the assumption of the European Copper Institute[43] that 'one of the best indicators of copper consumption per capita is income per capita'. Based on the projections until 2030 of population (+0.3% over 2010-2020 and +0.2% over 2020-2030) and GDP (+1.4% over 2010-2020 and +1.6% over 2020-2030), the baseline overall 2012-2030 trend of copper consumption has been calculated as +44%, i.e. +2.0% per year, consistent with its 2001-2007 historical annual trend (+1.8%).

Bauxite and other aluminium

The development of bauxite and aluminium RMC baseline consumption (which is driven by construction and industry) was provided by JRC's (2008)[44] forecast of 2% per annum increase in Europe until 2030 ('*The European consumption of aluminium will grow by 2% annually until 2030*'), i.e. 49% growth from 2010 to 2030. This baseline trend of +2.0% per year is less than the pre-crisis (2001-2007) annual trend (+2.8%).The GDP assumptions for 2030 of the JRC report were +2.1% per year. The population projections for 2030 were not detailed.

Gold gross ores

The future evolution of gold gross ores consumption was based on the evolution of GDP as provided in the EU 2012 Ageing Report [45], i.e. 1.2% per year between 2012 and 2015, 1.5% per year between 2015 and 2020 and then +1.7% per year between

42 JRC (2012) Prospective Scenarios on Energy Efficiency and CO2 Emissions in the EU Iron & Steel Industry.

43 European Copper Institute http://www.copperalliance.eu/industry/economy

44 Luo Z & Soria A (2008) Prospective Study of the World Aluminium Industry, 22951 EN.

45 EC (2012) The 2012 Ageing Report Economic and budgetary projections for the 27 EU Member States (2010-2060).

2020 and 2030. The overall increase of gold gross ores consumption is expected to be 25% from 2012 to 2030.

Other non-ferrous metal ores

The assumption for the baseline evolution of other non-ferrous metal ores consumption until 2030 in the EU28 is that, as demonstrated with various material categories, the baseline annual trend between 2010 and 2030 will be aligned with the historic average annual trend. The overall baseline trend of other non-ferrous ores consumption is then expected to be +43% between 2012 and 2030, i.e. about +2.0% per year.

Baseline non-metallic minerals trends until 2030

The main drivers of non-metallic minerals consumption are linked with economic growth in industry and construction. The results for the 2030 baseline RMC for non-metallic minerals are indicated in Figure 12 and summarised in Table 5.

Figure 12: Projection of total non-metallic minerals and non-metallic minerals material categories for the baseline scenario

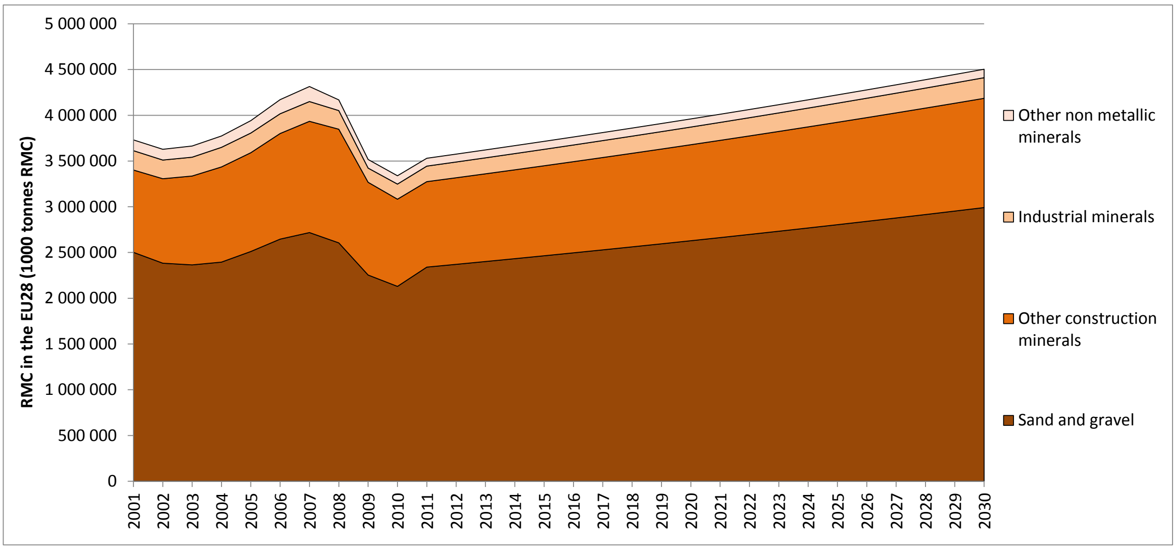


Table 5: Summary of future trends of non-metallic minerals RMC

	Average growth per annum		
Material categories	**2012-2030**	**2012-2020**	**2021-2030**
Non-metallic minerals	1.3%	1.3%	1.3%
Sand and gravel	1.3%	1.3%	1.3%
Other construction minerals	1.3%	1.3%	1.3%
Industrial minerals	1.5%	1.4%	1.6%
Other non-metallic minerals	0.4%	0.4%	0.4%

Sand and gravel

Industry estimates[46] project an annual increase of +2.0% for sand demand until 2020 in Europe. This is higher than the 2001-2007 historical annual trend (+1.5%). Instead the baseline evolution of sand & gravel consumption until 2030 has been modelled on the projected economic activity of the construction sector (+1.2% between 2021 and 2030). The baseline annual trend of sand and gravel consumption was then assumed to be slightly higher that the GVA growth of the construction sector: +1.3% pa until 2030 for an overall increase between 2010 and 2030 of +26%.

Other construction minerals

The baseline evolution of other construction mineral consumption in the EU28 until 2030 was modelled on the evolution of sand and gravel because the consumption of both material categories are strongly linked, as they are both intensively used in the same sector of activity, i.e. the construction sector. The baseline annual trend of other construction minerals consumption is then also +1.3% pa until 2030.

Industrial minerals

The baseline evolution of industrial mineral consumption in the EU28 until 2030 was modelled on the evolution of GDP, i.e. +1.4% per year between 2012 and 2020, then +1.6% between 2020 and 2030.

Other non-metallic minerals

The assumption for the baseline evolution of other non-metallic minerals consumption until 2030 in the EU28 is that, as demonstrated with various material categories, the baseline annual trend between 2012 and 2030 will be aligned with the historic average annual trend. The overall baseline trend of other non-ferrous ores consumption is then expected to be +7% between 2012 and 2030, i.e. about +0.4% per year.

Baseline fossil energy resources trends until 2030

The 2030 baseline RMC for fossil energy resources has been estimated using the EU energy trends to 2050 (2013 update)[47]. Based on PRIMES, the reference scenario for Gross Inland Energy Consumption has been used to estimate the future trends of fossil energy RMC[48]. The reference scenario includes only policies that have been adopted and reflects the agreed legally binding targets on greenhouses gas reduction and renewable energy. As mentioned, the GDP and population assumptions of the EU energy trends are the same as this study.

Data for gross inland energy consumption in the EU28 by fuel were used to estimate future trends of fossil energy resource consumption. These data are presented in Table 6. In order to use the data for the raw materials categories for this study, the following ‘mapping’ was performed:

- Solids = Lignite (brown coal), Hard coal, Peat
- Oil = Crude oil, condensate and natural gas liquids
- Gas = Natural gas

46 IHC (2011) Update of sand and gravel resources and extraction worldwide

47 Based on DG ENER, EU Energy, Transport and GHG emissions trends to 2050 - Reference Scenario 2013.

48 RMC does not correspond entirely to Gross Inland Energy Consumption (it also includes plastics and the energy embedded in imports and exports), but the use of fossil fuels is by far the main driver for fossil energy resources.

It has been assumed that oil shale and tar sand extraction (mainly Estonia) will remain the same until 2030[49].

Table 6: Projected trends for Gross Inland Energy Consumption in the EU28 (in ktoe) (based on PRIMES)

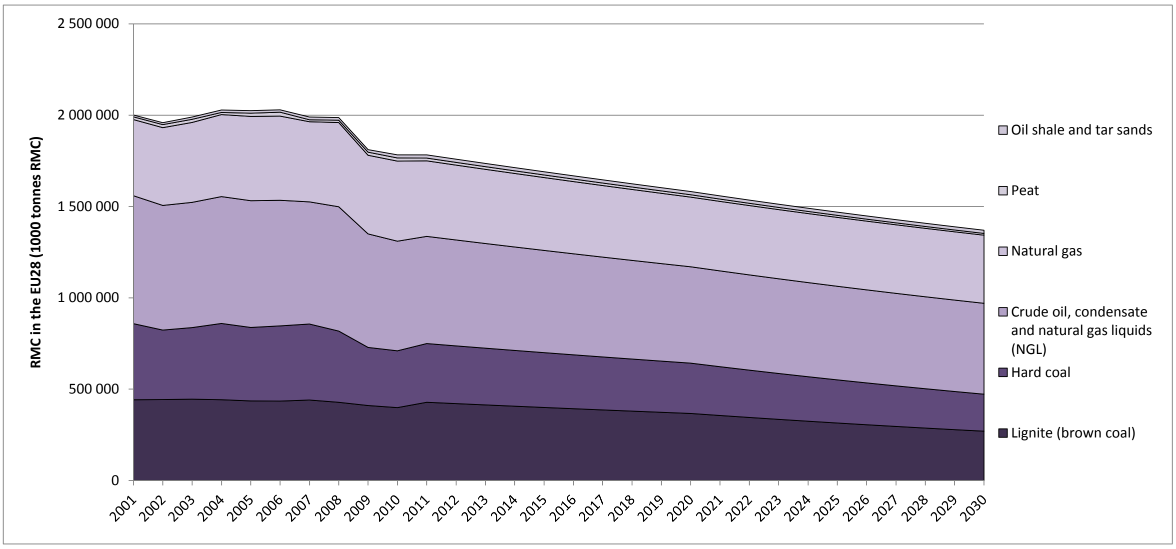
	2000	2005	2010	2015	2020	2025	2030
Solids	321 277	317 986	280 653	266 262	236 423	215 659	173 864
Index 2010 = 100	*114*	*113*	*100*	*95*	*84*	*77*	*62*
Oil	665 142	683 909	620 735	589 584	551 528	530 942	520 209
Index 2010 = 100	*107*	*110*	*100*	*95*	*89*	*86*	*84*
Gas	396 145	448 380	444 428	435 221	406 259	406 923	397 218
Index 2010 = 100	*89*	*101*	*100*	*98*	*91*	*92*	*89*

Table 7: Summary of fossil energy resources future trends

	Average growth per annum		
Material categories	2012-2030	2012-2020	2020-2030
Fossil energy resources	-1.4%	-1.3%	-1.4%
Lignite (brown coal)	-2.4%	-1.7%	-3.0%
Hard coal	-2.4%	-1.7%	-3.0%
Oil shale and tar sands	0.0%	0.0%	0.0%
Peat	-2.4%	-1.7%	-3.0%
Crude oil, condensate and natural gas liquids (NGL)	-0.9%	-1.2%	-0.6%
Natural gas	-0.5%	-0.9%	-0.2%

Results of these calculations are provided in Figure 13.

Figure 13: Evolution 2001-2030 of total fossil energy resources and fossil energy resources material categories for the baseline scenario

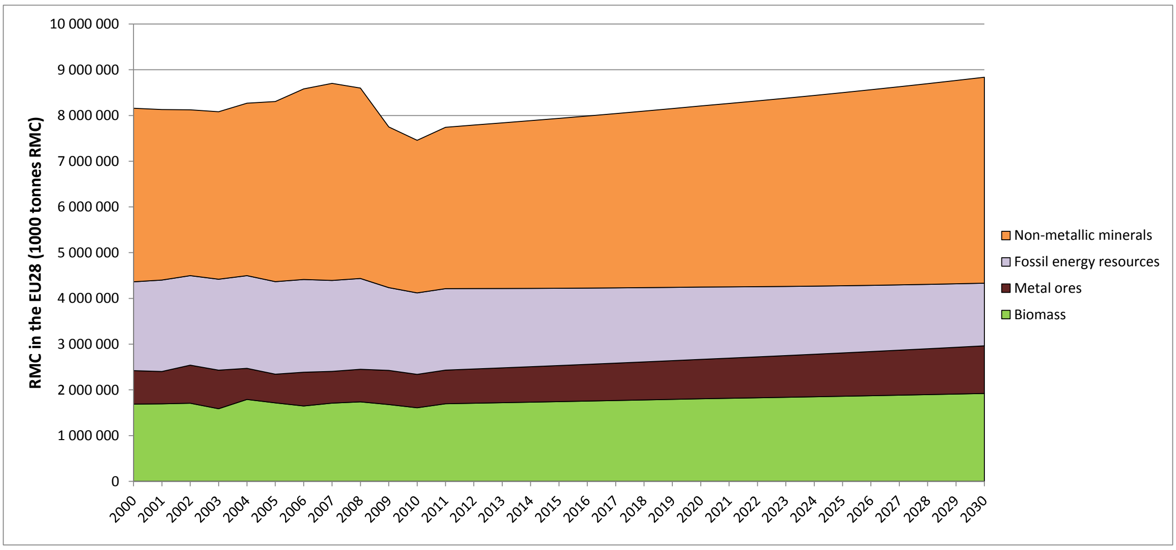


49 Tammeoja, T. & Reinsalu, E. (2008) Forecast of Estonian oil shale usage for power generation. Oil shale, 2008, Vol. 25, No. 2.

Overall RMC baseline projection

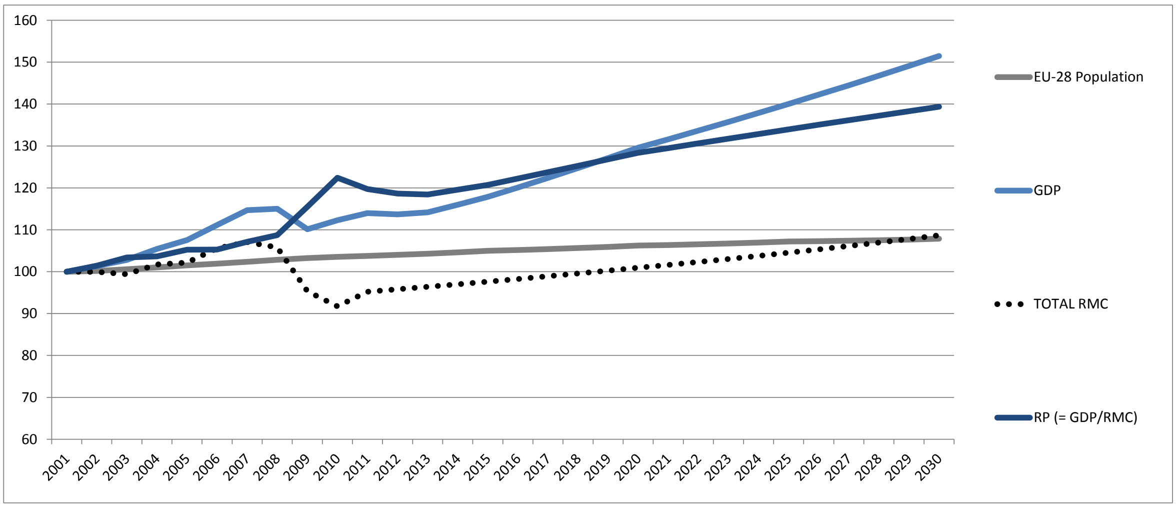
Based on the above assumptions of how RMC will develop for each of the material categories, we estimate that total RMC will increase by 0.7% per year until 2030 (13% increased from 2012 to 2030). Figure 14 shows the projections by main material category. Biomass RMC is expected to increase with higher demand for meat and bioenergy. Metal ore and non-metallic mineral RMC will continue to increase following past trends and strong projections for the sectors that use these materials. RMC of fossil energy resources is the only main material category that is expected to decrease until 2030 following climate and energy policies in the EU.

Figure 14: Baseline scenario projection of RMC until 2030 in EU28



In terms of decoupling, the baseline scenario assumes relative decoupling with resource productivity increasing by an average 0.8% per year until 2030 (Figure 15).

Figure 15: Baseline projections for Resource Productivity (RP) of the EU28 between 2001 and 2030 (2001=100)



4 RMC Scenario Descriptions

4.1 RMC scenario descriptions

This chapter provides a summary of the scenario descriptions and key assumptions for the E3ME modelling.

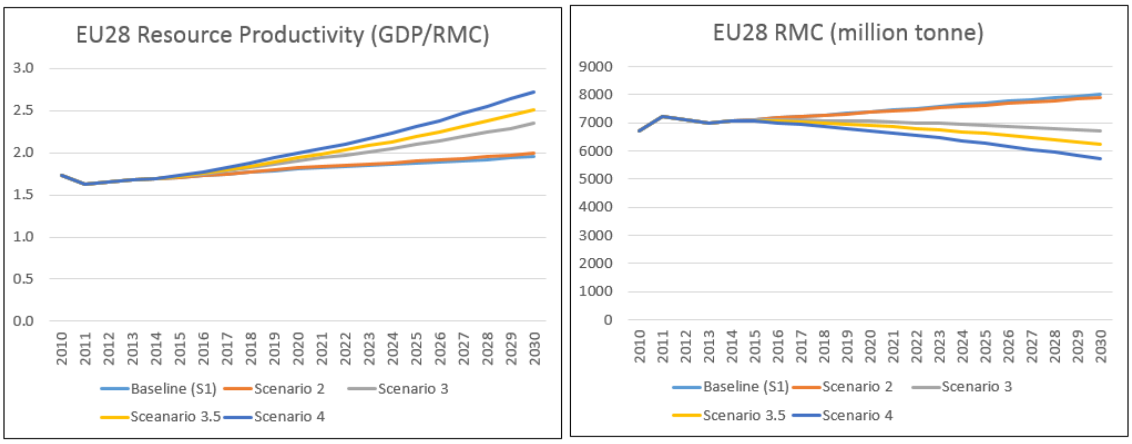
Table 8: Summary of the scenarios

Scenario	Description	RP	Feature
Scenario 1	Baseline	0.85% pa	Single EU28 target
Scenario 2	Modest and flexible Improvement	1% pa	Single EU28 target
Scenario 3	Enhanced and flexible Improvement	2% pa	Single EU28 target
Scenario 3.5	Further enhanced and flexible Improvement	2.5% pa	Single EU28 target
Scenario 4	Ambitious and flexible Improvement	3% pa	Single EU28 target
Scenario 5	Resource Constrained Enhanced Improvement	2% pa	EU28 target for every material group
Scenario 6	Effort Constrained Enhanced Improvement	2% pa	Target for every Member State
Sensitivity 3a	S3 under better economic conditions	2%pa	Single EU28 target
Sensitivity 3b	S3 under worse economic conditions	2%pa	Single EU28 target
Sensitivity 4NR	S4 with no revenue recycling	3%pa	Single EU28 target

Resource productivity targets

The scenarios are based on EU resource productivity (RP) targets, defined as GDP per unit of RMC. The baseline (or business as usual) is referred to as Scenario 1. Four scenarios (2, 3, 3.5 and 4) are set up to investigate the impacts of different levels of EU28 resource productivity targets: modest (1% pa) improvement, enhanced (2% pa), further enhanced (2.5% pa) and ambitious (3% pa). These scenarios are flexible in that RP can increase where there is potential (by material and country) and the target is for the EU28 as a whole. Scenarios 5 and 6 are set up to test this flexibility assumption. In Scenario 5 the RP target of 2% pa is met for all materials. In other words, consumption of each material group must fall to meet the 2% pa RP target in this scenario. In Scenario 6 the target must be met by all Member States.

Figure 16: Resource productivity targets in the scenario



RMC targets

Figure 16 shows how RP targets translate to absolute RMC consumption. Since the GDP growth rate for Europe is estimated at 1.7% pa between 2014 and 2030 (European Commission, 2012[50]), absolute material decoupling takes place in the scenarios where RP targets are 2% pa and above (Scenarios 3-6).

Table 9 shows how RP improvement each year accumulates to an overall improvement over the period 2014 to 2030. In the ambitious scenario, the 3% pa RP improvement amounts to almost 50% RP improvement over the whole period.

Table 9 Overall RP improvement between 2014 and 2030

Scenario	Description	Approximate Improvement (2014-30)
Scenario 1	Baseline	14 %
Scenario 2	Modest and flexible improvement	15%
Scenario 3	Enhanced and flexible improvement	30%
Scenario 3.5	Further enhanced and flexible improvement	40%
Scenario 4	Ambitious and flexible improvement	50%

Sensitivity testing

In addition to the main scenarios, three sensitivity scenarios are set up to test the RP target in Scenario 3. The first two of these are under different economic conditions, with manufacturing driving these changes. Output in manufacturing is adjusted by making exogenous changes to international trade.

Another sensitivity scenario is set up to test the revenue recycling assumption in the main scenarios.

4.2 RMC policies in the scenario

Policy Assumptions

The policy assumptions in the scenarios are designed to be transparent and simple. For each scenario, improvement in resource productivity comes from:

- 1/3 publicly funded investments in the capital stock to improve resource efficiency
- 1/3 privately funded business measures (such as recycling systems)
- 1/3 market-based instruments (MBI) (such as tax)

The policy assumptions apply to all the materials groups (and the three fossil fuels groups) and start from 2014. For these scenarios our analysis goes up to 2030.

Fossil fuels RMC

Fossil fuels are assumed to contribute to the RMC RP targets in the scenarios in line with the improvement in other materials. However, since fossil fuels in the baseline

50 European Commission, DG Economic and Financial Affairs (2012): "The 2012 Aging Report", available online

http://ec.europa.eu/economy_finance/publications/european_economy/2012/pdf/ee-2012-2_en.pdf already see RP improvement of around 2.5% pa (DG Energy 2010)[51], we only included further improvement in Scenario 4 where the overall RMC RP target is 3% pa.

Revenue recycling

For the MBI share, we have introduced a tax on the consumption of raw materials (biomass, minerals, metals and energy where applicable). Tax revenues are collected by national governments and recycled back at Member State level through lower income taxes and employers' social security contributions (i.e. labour taxes) in order to achieve revenue neutrality.

Funding for investment

One third of the reductions in material consumption are met by improvements in the capital stock, e.g. investment in machinery to cut down raw material consumption per unit of production. This requires estimates for the amount of investment required per tonne of material saved; although figures are available for energy consumption[52], little is available for materials. For example, the UNEP (2011)[53] report estimates that around 10% of global annual global capital investment is needed for making the world economy more resource efficient. However, there is no clear description of what this means in terms of actual reductions in resource consumption.

To simplify our scenarios, we have taken an estimate that is in line with the figure quoted for reduction in energy consumption: €31.4bn annual investment is required in the EU for each 1% reduction in energy consumption (IEA, 2010)[54]. This investment figure is assumed to be the same for other non-fossil fuel materials.

In the scenarios we assume that material taxes collected by government are used to pay for investment in resource efficiency, the remaining revenues are available for recycling.

Commodity price assumptions

In all scenarios we assume no change to world raw material prices because reduction in raw material demand in the EU alone is unlikely to have significant impacts on the global material and energy markets. In the baseline and all scenarios, our raw material price assumptions come from the World Bank's commodity price forecast[55] and energy price assumption from the IEA's World Energy Outlook (current policy scenario) publication[56].

4.3 RMC reductions in the scenarios

Least-cost options

In order to determine the most cost-effective ways of reducing RMC in the scenarios, a pre-analysis was set up to calculate the abatement cost for each user of each

51 European Commission, DG Energy (2010): "EU Energy Trends to 2030", available online http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf

52 World Energy Outlook, IEA (2010).

53 UNEP (2011), "Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication", available online www.unep.org/greeneconomy

54 International Energy Agency (2010), "World Energy Outlook 2010", IEA.

55 Commodity Price Forecast Update, World Bank (January 2013).

56 World Energy Outlook, IEA (2013).

material, using each of the three policy types: MBIs, regulation, and investment. In this analysis, the model worked out a level of cost or investment in order to achieve a one percent reduction of RMC for each material/user/policy from the baseline in 2030. The GDP outcomes are calculated as difference from baseline and the euro per tonne costs of RMC reduction are obtained. The euro/tonne results are ranked, per policy, to indicate the least-cost (or most beneficial) options to be included in each scenarios. The outcome of this analysis is given in Appendix B: Marginal Abatement Analysis.

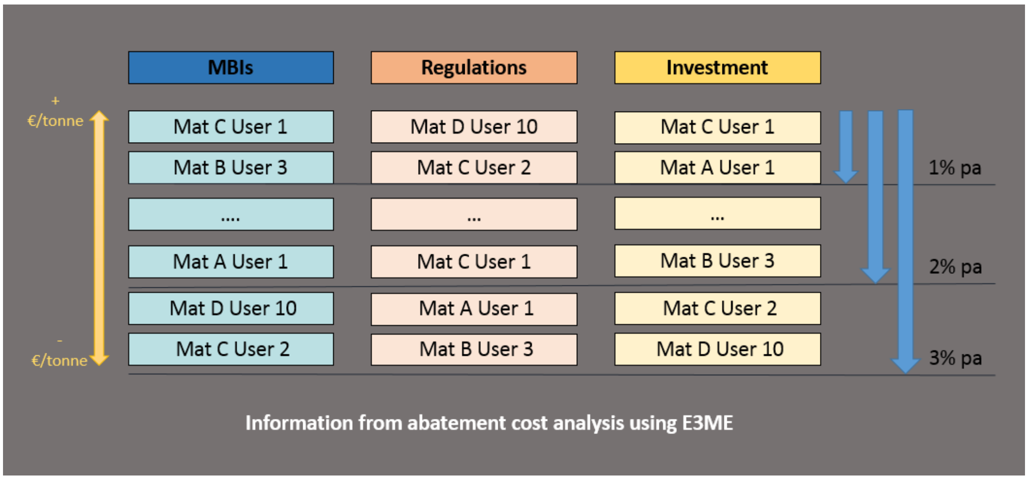
Estimating RMC reductions in the scenario

In summary the main stages are:

- Calculate the absolute reduction in RMC in each scenario (converting % pa to absolute figure in thousands of tonnes).
- Estimate the potential reductions in material consumption for each material and user group:
    - for each material and user group we assume that there is an X% reduction possible, where X is such that when summing across all materials we meet the same total reduction in consumption as in the 3% pa improvement scenario (i.e. so this scenario must include all the options by definition)
    - divide the potential reductions three ways equally, to give the possible reductions from MBIs, regulation and investment for each material and user group
- Estimate the cost of the reduction from each option – using information from the cost curve pre-analysis for MBIs, regulations and investment.
- Rank the options for each policy as in the cost curve analysis to give a menu of possibilities starting with the most cost optimal and ending with the most expensive.
- Set up the modelling scenarios so that the specified reductions in RMC include take up of the lowest cost options first. This should mean that the scenarios with the lower targets have the largest relative benefits.

Figure 17 provides a summary of the process described above.

Figure 17: Summary of process to select least cost options in the scenario



Bottom-up studies

We have also used the results from various bottom up studies to provide additional potential material savings from policies that are not captured in the analysis above. These savings are done at very small or no costs but nevertheless can deliver a significant level of RMC savings. Based on these findings we have simplified three further RMC reduction inputs to the scenarios:

- food industries and hospitality services can save around 15% of RMC from reducing food waste (middle estimates)
- the built environment can save around 15% from a selection of policies
- information programmes can save around 2% of total RMC

A third of these RMC savings are entered exogenously to the scenarios as regulation options and are assumed to have zero costs. We assumed only a third of the savings to reflect our three-way split of policy assumptions; i.e. the other two thirds could be met be investment or MBIs, which may or may not have net macroeconomic costs.

5 Results

5.1 Summary of expected key impacts

This chapter provides results from the E3ME modelling. It starts with a summary of the expected main impacts in the scenarios, in order to aid understanding of the modelling results.

Material consumption

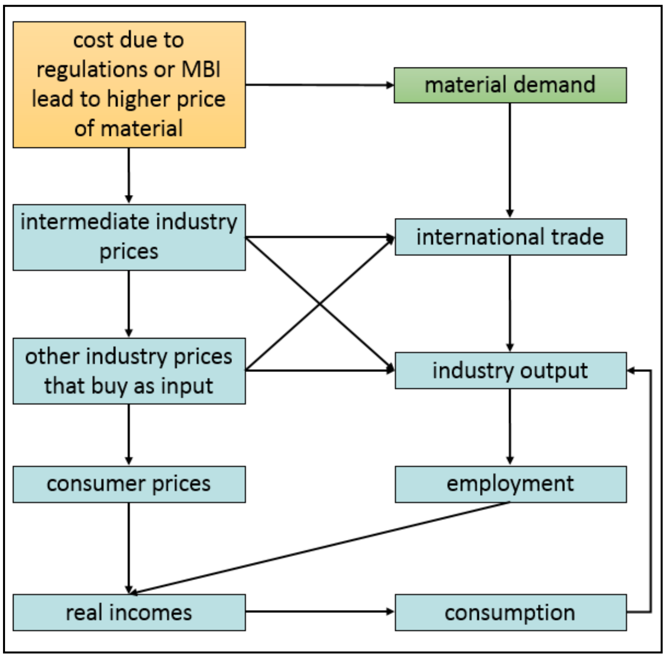
Material consumption decreases in line with the targets in each scenario. In the flexible scenarios, reductions take place where costs are lowest, i.e. effort sharing between materials and regions with one EU cost. In the more constrained scenarios, these targets are applied to all materials (or countries) and consequently different costs are applied accordingly.

Economic impacts from price-based policies

Price-based policies (MBIs) and regulations result in additional costs to consumers of raw materials (see Figure 18). These cost increases may be passed through to the product prices of these industries. The extent to which costs get passed on to final product prices are estimated from historical time series. An industry may choose not to pass on cost increases if it operates in a highly competitive international market. Generally, however, at least some of the costs will get passed through to final product prices.

Price increases have two main impacts: a) on industry competitiveness and b) on household real disposable income. Products of industries that consume materials may be substituted by cheaper imports as a result of higher prices. Imports of raw materials, however, should reduce in line with reduction in material demand. On the income side, price increases lower real disposable income and lead to lower household spending. The scenarios are designed to reduce these negative impacts on the economy through the recycling of material tax revenues.

Figure 18: Main economic impacts from MBIs and regulation



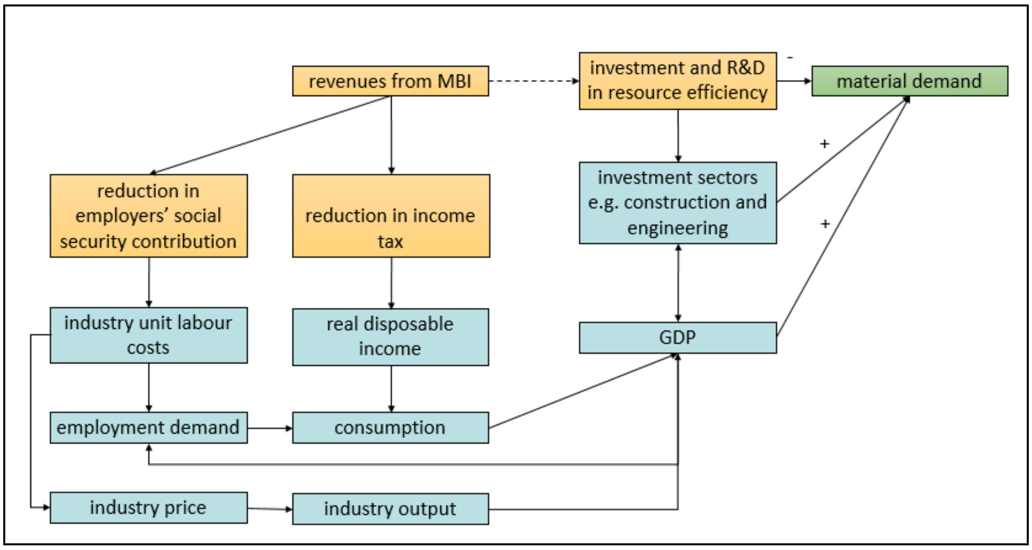
Economic impacts from revenue recycling

Revenues from MBIs in the scenarios are used in three ways:

- funding for resource efficiency investment - so that industries do not have to cover the cost of additional investment
- reducing income tax – to help offset any reduction in real incomes due to higher prices
- reducing employers' social security contributions and therefore labour costs – to help offset cost increases to industries from higher material costs

The main (first-round) economic impacts of these revenue recycling measures are given in Figure 19. Everything else being equal, reductions in income tax increase household real disposable income, leading to higher consumption. Reductions in employers' social security contributions lower labour input costs to industries and generate demand for employment. Overall an increase in revenue recycling leads to a better GDP outcome and this could in turn lead to an increase in material demand, i.e. a rebound effect. The E3ME model captures these secondary effects and the policies that were modelled have been adjusted accordingly in the scenarios so that the targets are met. The rebound effect is most evident when looking at investment in resource efficiency (see below).

Figure 19: Main economic impacts from revenue recycling and investment, including the rebound effects



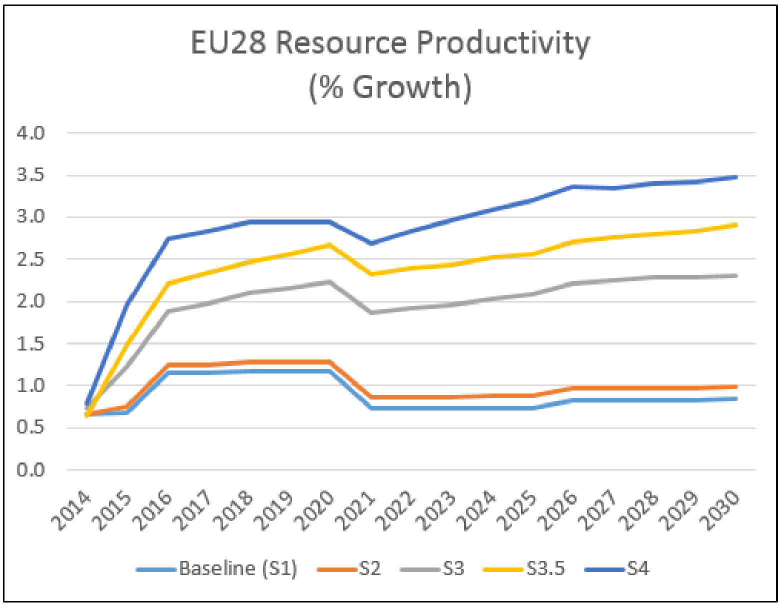
Resource efficiency investment and material demand

The link between investment and GDP is a straightforward one and can generate positive multipliers in an economy. However, a less obvious but rather important link between investment in resource efficiency and material demand should also be considered. Resource efficiency investment requires raw materials. For example, construction minerals are needed for buildings and metals are needed to produce more efficient machinery. Any cost increase for minerals could therefore make investment in resource efficiency more expensive.

5.2 E3ME resource productivity results

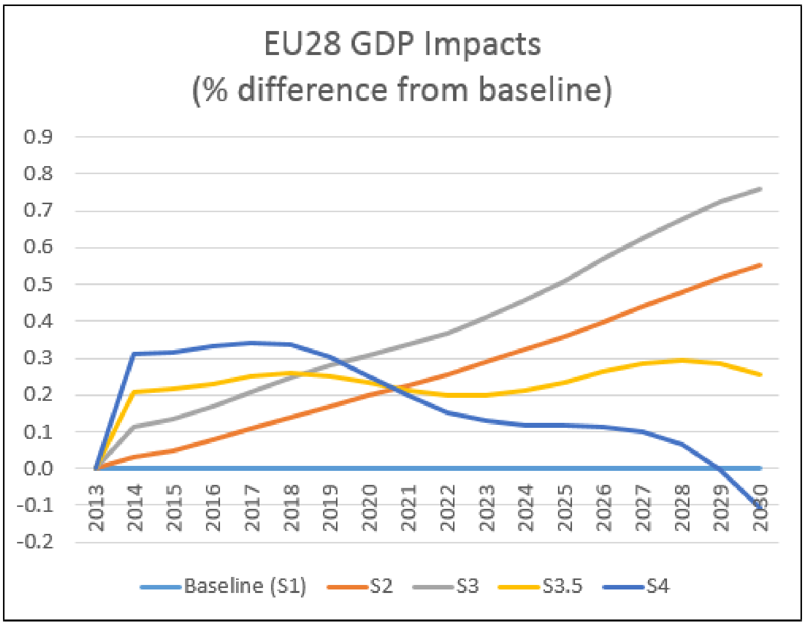
Resource productivity (RP) improves in line with the targets in each scenario. Figure 20 provides an overview of RP growth from the scenario results. The targets are set as annual average RP growth and therefore there is flexibility over the policy period. The step changes at 5 year interval represents changes in GDP projections taken from European Commission (2012) projections.

Figure 20: EU28 resource productivity growth rates (% growth)



5.3 EU28 economic and employment results

Figure 21: EU28 GDP impacts, % difference from baseline



Impacts on GDP

The E3ME results show that increases in resource productivity can have small but positive impacts on the EU economy (see Figure 21). The main driver for positive GDP results in the earlier part of the period is from investment in resource and energy efficiency technology. Over time this investment boost diminishes and the positive GDP results in the long run are driven by the revenue recycling which boosts household incomes (through lower income taxes) and lower labour costs to industries (lower employers' social security contributions). In Scenario 3.5 and Scenario 4 the targets of 2.5% pa and 3% pa are ambitious and over time the required RP improvement must come from more costly options. This is shown in the diminishing impacts on GDP compared to Scenario 2 and Scenario 3 where only the lower costs options are included.

In the sensitivity analysis we test the implication of our revenue recycling assumption.

The GDP impacts are driven by various factors in the scenarios. Figure 22 summarises the main drivers of the GDP results.

Figure 22: Main drivers of GDP in the scenarios

- ↑ Investment in resource and energy efficiency
- ↑ Revenue recycling
- ↑ Reduction in material and energy imports
- ↓ High material prices
- ↓ High energy prices
- ↓ Import substitution for domestic products (competitiveness effects)

Investment

Investment in resource and energy efficiency increases in relation to the resource productivity targets in the scenarios. It is a major driver for positive GDP results in the initial period.

Trade

Although imports of material and energy products fall in the scenarios, exports of EU goods and services also fall due to higher input costs to EU industries and associated competitiveness effects. Overall net impacts on the trade balance are small as the reduction in imports is cancelled out by a reduction in EU exports. It should be noted that trade impacts are more evident at sectoral level.

Consumer spending and inflation

Consumer spending increases in all the scenarios despite higher prices. Price increases come from higher material costs in the EU and these get passed through to consumer product prices. Aggregate inflation rates are particularly sensitive to changes in food prices as this makes up a large share of consumer expenditure. With the exception of Scenario 4, the overall price increases are therefore somewhat limited because the majority of the reduction in food consumption can be done at zero cost. In Scenario 4, where there is a cost associated with further improvement in food productivity, the inflationary effect is larger.

Consumer spending increases in the scenarios due to the lower income tax rates and higher employment from the revenue recycling. This increases real disposable income which leads to higher consumption.

Employment

Employment increases in all scenarios for three reasons. First, the increase in material input costs provides incentives for firms to substitute material with labour input (although this effect is small). Second, investments in resource and energy efficiency are likely to benefit the relatively labour-intensive construction and engineering sectors. Third, revenue recycling via lowering employers' social security contributions results in lower labour costs to industries, generating additional employment demand. The model results estimate that around 1 to 2 million additional jobs are created in Scenarios 3 and 4.

Table 10 provides a summary of the macroeconomic impacts in the scenarios as percentage differences from baseline.

Table 10: EU28 macroeconomic impacts, % difference from baseline (S1)

	S2	S3	S3.5	S4
2020				
GDP	0.2	0.3	0.2	0.2
Employment	0.2	0.3	0.4	0.5
Consumer spending	0.3	0.5	0.2	-0.2
Investment	0.2	0.4	0.8	1.2
Imports (extra-EU)	0.1	0.0	-0.2	-0.9
Exports (extra-EU)	-0.1	-0.4	-0.9	-1.4
Consumer price	0.2	0.4	1.1	2.5
2030				
GDP	0.6	0.8	0.3	-0.1
Employment	0.7	1.0	0.8	0.9
Consumer spending	0.9	1.3	0.3	-0.8
Investment	0.4	0.6	0.6	0.8
Imports (extra-EU)	0.2	0.0	-0.7	-1.9
Exports (extra-EU)	-0.2	-0.7	-2.0	-3.0
Consumer price	0.6	0.8	2.4	5.3

Source(s): E3ME, Cambridge Econometrics.

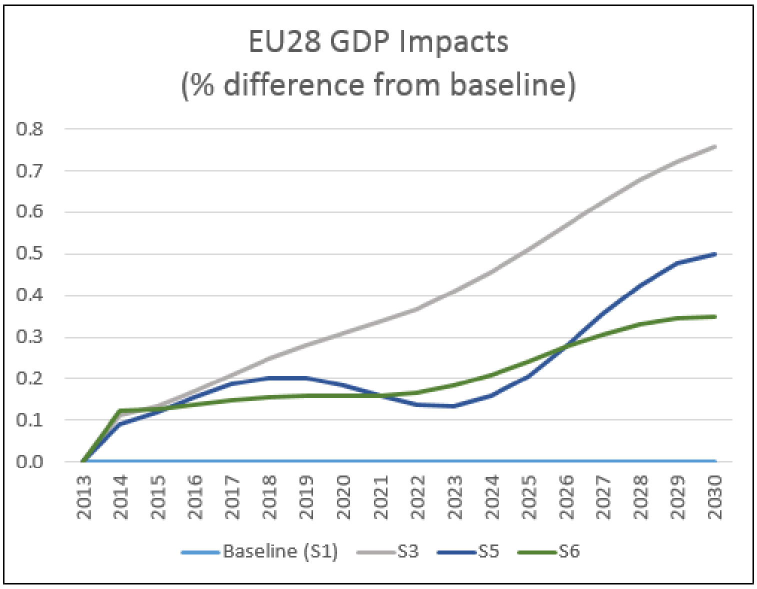
Constrained versus flexible scenarios

In Scenarios 2, 3, 3.5 and 4 we allowed for flexibility in achieving resource productivity targets. This implies one single cost for all resources and the reductions in consumption can be made where the costs are lowest. It should be noted that in the flexible scenarios construction minerals and metals do not contribute to the RP targets as much as other materials, as there is higher demand for these materials from investment in resource and energy efficiency.

Scenario 5 and Scenario 6 test this flexibility assumption and instead constrain the RP targets for all materials and all Member States. These two scenarios should be compared to Scenario 3 as they have the same RP target of 2% pa.

In Scenario 5 where each material must meet the 2% pa RP target, the GDP outcome is worse than in Scenario 3 because the reductions in consumption do not use the combination of options that leads to the most positive GDP outcome (see Figure 23).

Figure 23: EU28 GDP impacts – flexible vs. constraint targets



Similarly in Scenario 6, where each Member State must meet the 2% pa target, the GDP outcome is worse than in Scenario 3. This can be explained by missed opportunities in regions that already achieve RP of 2% pa in the baseline: Estonia, Latvia, Slovenia, Slovakia, Bulgaria and Croatia[57]. There are no further policies in these regions and they are therefore missing out on potential gains from reducing resource consumptions (investment, reduction in material import dependencies and revenue recycling).

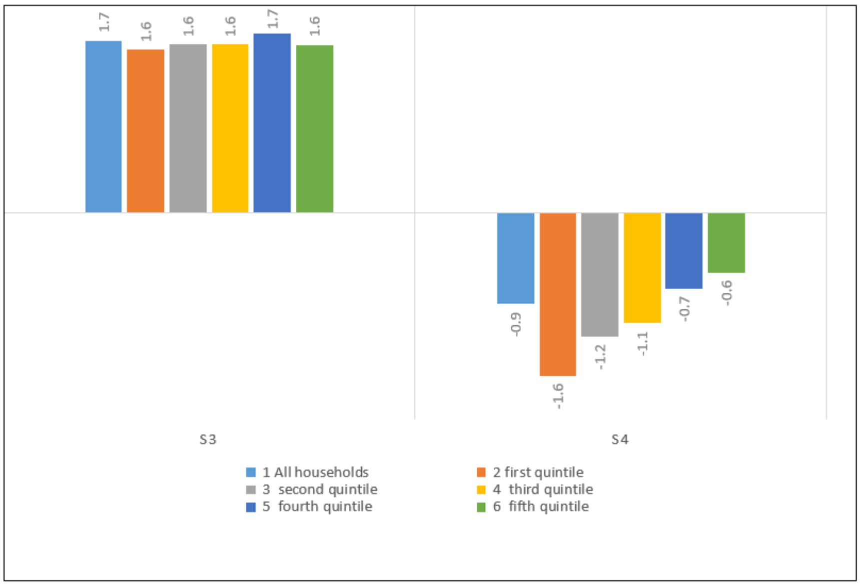
5.4 Impacts on income distribution

Impacts on real income for different income groups are fairly even in all the scenarios except for Scenario 4. In Scenario 3, all income groups experience positive impacts on their real disposable income from the reductions in income tax, as a result of the revenue recycling in the scenarios.

In Scenario 4 where the ambitious target can only be met if the reduction in food consumption goes beyond the zero cost options, food prices increase resulting in quite large distortionary impacts on income distribution. Lower income groups spend a higher share of their income on food and energy products which make them more vulnerable to material price increases. Careful policy design (e.g. using revenues to provide lump sum payments or to increase benefit rates to lower income groups) would help to eliminate these distortionary effects.

57 Based on historical trends.

Figure 24: Impacts on income for different income groups, EU28 average 2030, % difference from baseline



5.5 EU28 results at sectoral level

This section describes scenario results at sectoral level. The results shown in Table 11 are for Scenario 3 where the RP improvement target is 2% pa. Sectoral results for other scenarios are given in Appendix C: Detailed Sectoral Results.

Economic output

The figures in Table 11 show sectoral output, which is equivalent to production or turnover. The distinction here is important; as we are considering efficiency improvements, value added and GDP can increase without output increasing by as much. However, as it is the level of production that determines employment, we present results for output.

Intermediate sectors that sell raw materials: agriculture (food and feed), forestry (wood), and non-energy mining (metals and minerals) experience the biggest falls in sectoral output. The energy mining and utilities sectors do not see a big fall in output because there is no RP improvement requirement from fossil fuels in this scenario (they already exceed 2% pa in the baseline).

As intensive users of materials, we might expect output in the construction and manufacturing sectors to fall. However, these sectors benefit substantially from the additional investment in the scenario and therefore see a small increase in output, despite the price increases (see below).

Table 11: EU28 sectoral results in Scenario 3, % difference from baseline (S1)

	Output	Employment	Price
2020			
Agriculture, Fishing, Forestry	-1.4	-0.5	0.4
Energy mining	0.0	0.3	0.0
Non-energy mining	-3.2	-4.2	-0.1
Manufacturing	0.2	0.5	2.5
Utilities	0.3	0.3	0.4
Construction	0.9	1.0	0.8
Retail, Distribution	0.4	0.3	0.3
Transport, Communication	0.2	0.2	0.2
Other services	0.2	0.3	0.3
Total	0.2	0.3	1.1
2030			
Agriculture, Fishing, Forestry	-4.1	-0.8	1.2
Energy mining	0.3	0.3	0.0
Non-energy mining	-9.4	-9.4	-0.2
Manufacturing	0.6	1.2	2.6
Utilities	1.0	1.0	0.7
Construction	1.3	2.1	1.6
Retail, Distribution	1.2	0.7	0.6
Transport, Communication	0.5	0.5	0.2
Other services	0.6	1.0	0.8
Total	0.6	1.0	1.4

Source(s): E3ME, Cambridge Econometrics.

Employment

Employment impacts by sector to some extent follow economic output. However, the employment results are also affected by the revenue recycling assumption (lower employers' social security contribution rates) in the scenarios. By lowering labour costs to industries, there is more demand for labour. For example, in the transport sector there is an increase in employment, despite falling output. Increasing demand for labour is more obvious in the retail and services sectors which are more labour intensive.

Industry prices

Industry prices increase for sectors that consume materials. The costs to reduce material consumption, whether by MBI or regulation, are paid by the consumers of the materials and not by the intermediate industries that sell them. As a result, prices in the utilities, engineering, agriculture (trade within the industry) and construction sectors increase in the scenarios to reflect higher material costs.

5.6 Environmental impacts

CO_2 emissions

The relationship between material consumption and GHG emissions is a highly complex one, with both positive and negative feedback effects and strong variations between sectors. Although not the focus of this analysis, the E3ME model is also capable of estimating the levels of energy-related CO_2 emissions impacts in the scenarios. The results show that in all cases except Scenario 4, impacts on EU CO_2 emissions are small but there is an increase (less than 0.5% from baseline in 2030). This is due primarily to higher rates of economic activity but it should also be noted that the prices of some low-carbon equipment (which tends to be material-intensive) will increase in the scenarios.

In Scenario 4, where energy is included in the 3% pa RP target, EU CO_2 emissions are reduced by around 25% from baseline. Overall, the emissions results suggest that the RP targets could be complementary to the EU GHG targets.

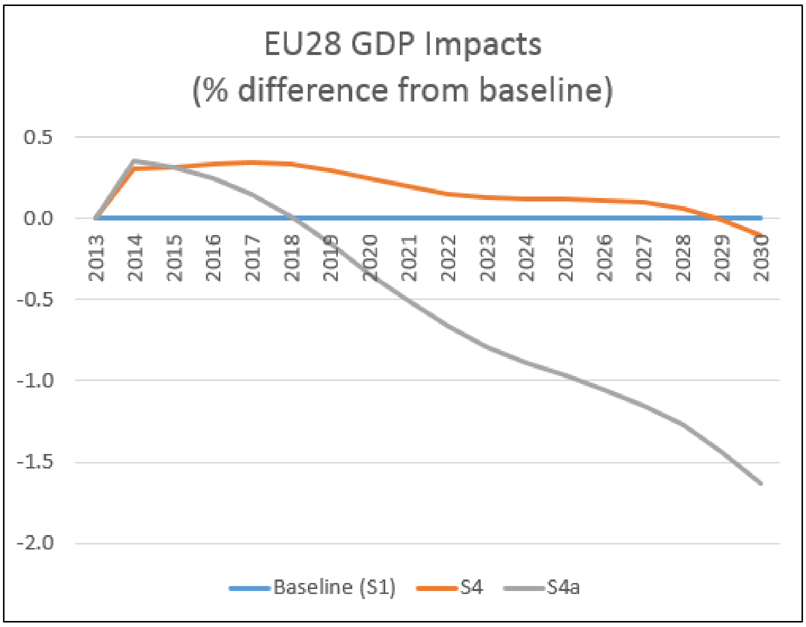
5.7 Sensitivity analysis

The impacts of revenue recycling

The scenario results suggest that reductions in resource consumption can be achieved with a positive impact on European GDP. This is mainly driven by our assumption for revenue recycling that the revenues generated get used to reduce income tax rates and employers' social security payments. This is the concept of 'Environmental Tax Reform (ETR)' where an environmental tax such as an emission tax is used to cut GHG emissions but revenues generated are used to simulate the economy at the same time.

Figure 25 shows the GDP impacts without the revenue recycling mechanism. Scenario 4a is a direct comparison to Scenario 4 but without revenue recycling.

Figure 25: Impact on GDP - a sensitivity without revenue recycling



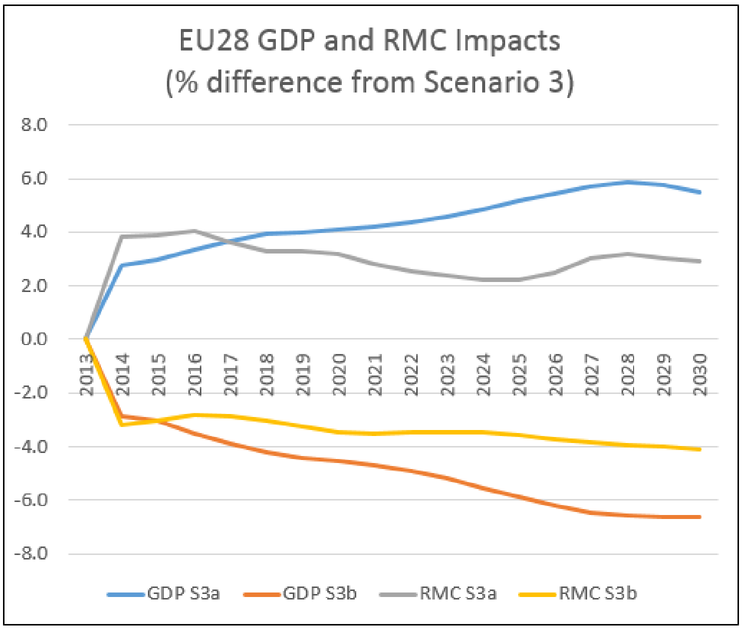
The GDP results for Scenario 4a show positive GDP impacts initially. This suggests that the first few years of resource consumption reduction (around 15% RP improvement[58]) could be done at negative cost (net benefits). After 2020 there is a positive cost as resource prices begin to rise which, without revenue recycling, pushes GDP results to negative sooner than in the main Scenario 4 scenario.

Manufacturing share in GVA

An additional two sensitivity scenarios are introduced to see what would happen to the resource productivity target if the manufacturing industry played different roles in the EU economy. In the first sensitivity we introduce exogenous growth to the manufacturing sector through additional trade and investment such that the share of manufacturing in the EU value added reaches 17.5% (15% in the baseline). The growth is additional and does not replace growth in other parts of the EU economy, so the overall increase in GVA is more than 2.5%.

The opposite changes to manufacturing trade and investment were also introduced as a sensitivity, in which the GVA share falls to 12.5%. In this scenario there this a net reduction in GDP. The two sensitivities are called Scenario 3a (positive) and Scenario 3b (negative) and are otherwise the same as Scenario 3.

Figure 26: GDP and RMC impacts in manufacturing growth sensitivities



Increasing the manufacturing share of GVA to 17.5% from 15% results in a net increase in GDP of almost 6% in 2030 (compared to Scenario 3) due to the higher demand for other sectors' products. Demand for raw materials does not increase at the same rate as GDP, so resource productivity is higher in Scenario 3a than in the main Scenario 3 (2% pa). This is partly due to scale effects, as larger production plants are able to produce more efficiently. In E3ME this relationship is estimated from historical data and the results often are less than one-to-one relationship. In other words a one percent increase in economic activity results in less than one percent increase in raw material demand.

58 Because although the target in Scenario 4 is 3% pa, we averaged this annual improvement over the period (2014-2030). The improvement in initial periods is slightly smaller than a 3% pa reduction.

Another reason for this is the investment. In the E3ME model we allow some of the additional manufacturing investment (which gets entered exogenously in this sensitivity) to represent investment in resource efficient equipment and machinery. Despite the initial increase in RMC from higher demand for investment goods, over time resource productivity improves. Consequently in this sensitivity we see relative decoupling in material demand from economic growth.

In Scenario 3b we see similar results but in the opposite direction. RMC falls but not by as much as the reduction in GDP. Lack of investment and R&D can also explain the RMC results. In this scenario RP grows at a lower rate than Scenario 3.

The modelling results also show that increasing manufacturing’s share of GDP to 17.5% generates only 2-3% additional RMC demand for the EU28. This may seem counter-intuitive as manufacturing is often considered to be resource intensive. However, compared to the construction sector manufacturing is a less intensive user of materials. This means that the RP targets can be achieved even in the case of a higher manufacturing share in the EU GDP.

6 Conclusion

RMC indicator

This study provides modelling analysis of the different EU resource productivity targets. Resource productivity in this study is measured by GDP per unit of raw material consumption (RMC). The RMC indicator helps overcome the shortfalls of the Domestic Material Consumption (DMC) indicator which records material trade in weights as they cross the borders. The RMC indicator adjusts traded materials to be in Raw Material Equivalent (RME) units. Resource productivity as measured by GDP/RMC is currently being proposed as a key indicator in the EU Resource Efficiency Roadmap.

E3ME macroeconomic model

The study makes use of the E3ME model, which contains a detailed treatment of raw material modelling. The model is highly regarded for providing macroeconomic assessment of climate and energy policies and in recent years has been used to provide similar analysis for wider resource-related policies.

The E3ME model was extended to include RMC as an indicator and material data have been updated to 2011 to cover the latest data available from Eurostat. The model baseline for energy and emissions is calibrated to the DG Energy's projections in 2010 and for economic variables to DG ECFIN's Ageing Report, 2012. The baseline for RMC in E3ME is calibrated to the results presented in Chapter 3.

RMC Baseline

The 'business as usual' baseline for RMC was constructed based on the main drivers identified for material resource consumption: economic development, population, industry structure and energy policies. The baseline scenario takes into account the adopted climate and energy targets in the EU, which results in an increase in bioenergy (+80%) and a decrease in fossil fuels (-22%) in 2030. Metal and mineral RMC is expected to continue to grow until 2030 (39% and 26%, respectively) as these are still closely coupled to economic activity, and we assume that these materials are needed for future renewable energy installations and developing infrastructure. In total, RMC is expected to increase by 0.7% pa on average until 2030. With the GDP projections, this entails that the baseline scenario assumes relative decoupling with resource productivity increasing by an average 0.8% per year until 2030 – in line with past trends.

Scenario descriptions

There are six main scenarios in this study, all based around different resource productivity targets, ranging from modest improvement in RP (1% pa) to ambitious improvements (3% pa); and in the flexibility of these targets – whether improvement can be made anywhere in the EU or strictly in all materials or all Member States.

Policy assumptions

Various resource efficiency policies were considered for the scenarios. It was decided that the scenarios should contain a mix of simple and transparent policies to ease interpretation of the modelling results. The final policy mix includes:

- 1/3 publicly funded investments in the capital stock to improve resource efficiency
- 1/3 privately funded business measures (such as recycling systems)

- 1/3 market-based instruments (MBI) (such as tax)

Each of these policies contributes a third of the RP improvement in the scenarios.

RMC reductions

RMC reductions in the scenarios come from the least cost (or highest benefit) options first and move on to more expensive ones as the RP targets become more ambitious. Prior to the scenario modelling, the E3ME model was set up to calculate the costs (in terms of GDP) per unit of RMC reduction for each user of material for each type of policy. The outcome of this exercise provides a list of options (material x user x policy) to be included in each scenario; these were then ranked by cost. In the most ambitious scenario (3% pa) we assumed that all options must be included.

In addition to the three policy options, the scenarios allowed for some small improvement in resource efficiency from zero-cost regulation. These are based on previous bottom-up studies which suggest that cutting down waste and better information could help to reduce material consumption at very small or zero cost.

Revenue neutrality assumption

Further assumptions were made for the use of revenues collected by government from market-based instruments to reduce income and labour tax rates. This assumption has a significant implication in our modelling results.

Economic impacts

The modelling results show that absolute decoupling of material consumption is possible. Cutting down resource consumption helps boost EU28 GDP by promoting resource and energy efficiency R&D investment, reducing EU dependency on raw material imports and boosting household income by using tax revenues to reduce other tax rates.

Impacts on jobs and incomes

Around two million additional jobs in the EU could be created in Scenario 3 (2% RP improvement per annum) by 2030 partly from investment and partly from using MBI revenues to reduce labour costs.

The distributional impacts of the policies are fairly even unless reductions in food material consumption result in cost increases. Revenue recycling via income taxes may benefit higher income groups more but without it these groups will see a bigger fall in their real income as they tend to spend more on products that consume raw materials (excluding food).

Sectoral impacts

Most sectors that consume raw materials face higher material input costs in the scenarios. As a result they become less competitive in the international market as their product prices increase. However, boosts to investment, lower labour costs, reductions in imported material input and higher consumer demand means that the negative impacts of higher material costs can be compensated. Sectors that sell raw materials see reductions in their economic outputs due to less raw material input requirement from other sectors.

Rebound effects

In the scenarios where flexibility in resource productivity improvements is allowed, construction minerals and metals do not contribute as much to the targets because they are required for producing investment goods. In the constraint scenario where resource productivity improvement must happen in all materials, the modelling results show smaller GDP impacts as the reductions are not made based on the least-cost options.

The EU GDP impacts are slightly smaller in the constrained scenario where resource productivity improvements must be made in all countries. Countries that already achieve the improvement target in the baseline do not introduce further policies. This results in missed opportunities to benefit from further improvements in resource productivity and the induced benefits from such policies.

CO_2 impacts

Impacts on CO_2 emissions in the RP scenarios are very small except in the ambitious scenario where there is a sizable emission reduction as energy is included in the 3% pa target. The emission results suggest that the RP targets can be set as a complementary target to the existing EU GHG target.

Sensitivity analysis

The modelling results are quite dependent of the revenue recycling assumption. In a sensitivity run where we removed this assumption, the positive GDP impacts only last for an initial six years. After this period there are costs to the economy associated with further reductions in material consumption. This result highlights the importance of policy design which can alter the final economic outcome and has distributional impacts.

The future role of the manufacturing sector in the EU economy could have an important role in determining resource consumption. Two sensitivities were introduced to investigate the possible impacts of manufacturing industries on the resource productivity target. In one case the manufacturing share of value added in the EU economy increases to 17.5% from 15% in the baseline, driven by higher exports and investment. In this scenario, absolute demand for raw material increases but not by as much as the increase in GDP, resulting in an improvement in resource productivity. Over time higher investment and R&D lead to a small reduction in resource consumption. The results show the importance of investment in new technologies to promote resource productivity. This means that the RP targets can be achieved even in the case of a higher manufacturing share in the EU GDP.

Comparison to other studies

The economic outcome of RP improvement from this study is based on full macroeconomic modelling and cannot be used to draw a direct comparison to previous bottom-up studies, which aggregated costs/benefits at sectoral level. For example, a sector-specific study may suggest reduction in waste results in an €X bn savings to the Food and Drink industry and use this as a proxy for GDP improvement. In the full macroeconomic modelling, those who supply raw material to the Food and Drink industry, i.e. agriculture, will see reduction in their outputs. Although some of the reduction in food material will come from lower food imports, domestic industries that supply food will also see some reduction. This makes the net GDP impacts from macroeconomic modelling smaller than what the bottom-up studies would suggest.

Limitation from this analysis

The analysis was carried out using simple and transparent, but arbitrary, policy assumptions. As the sensitivity analysis shows, these assumptions can have significant impacts on the final economic outcomes.

The modelling also did not take into account potential gains from cutting down material waste. For example, waste management and landfill costs would be substantially lower. Similarly the modelling did not include an assumption on the possible use of recycling as a mean to increase resource productivity.

Nonetheless the analysis highlights possible ways to improve resource efficiency and reduce material consumption, while at the same time providing an economic and employment boost to the EU economy.

Appendix A: RMC calculations and results

Raw material categories

Domestic extraction of materials in Eurostat's economy-wide material flow accounts (EW-MFA) distinguish on the most detailed level some 50 material categories which can be grouped/aggregated to four main material categories (i.e. biomass, metal ores, non-metallic minerals and fossil fuel resources). These main material categories have been used but certain sub-categories were defined for the purposes of this study (the sub-categories were disaggregated according to material characteristics and to better be aligned with the E3ME macro-economic model).

The categories used are indicated in the following tables.

Table A.1: Biomass categories used in this study in comparison to Eurostat's EW-MFA categories

Categories used in this study	Includes
Cereals	Cereals (MF111)
Other food	Roots, tuber (MF112)/ Sugar crops (MF113)/ Pulses (MF114)/ Nuts (MF115) / Vegetables (MF117)/ Fruits (MF118)/ Fish catch (MF141)/ All other aquatic animals and plants (MF142)/ Hunting and gathering (MF143)
Feed	Other crop residues (sugar and fodder beet leaves, other) (MF1212)/ Fodder crops (incl. biomass harvest from grassland) (MF1221)/ Grazed biomass (MF1222)
Bioenergy*	Wood fuel and other extraction (MF132)/ Oil bearing crops (MF116)
Wood	Timber (Industrial roundwood) (MF131)
Other biomass	Fibres (MF119)/ Other crops n.e.c. (MF1110)/ Straw (MF1211)

*The above attribution of elements within each biomass category is simplified. The simplification is based on the fact that the bioenergy part the biomass raw material categories (other than bioenergy category) is small:

- Crop residues: The share of crop residues used for bioenergy purpose seems to be in the 5-10% range.
- Cereals and Sugar crops: JRC Scientific and Policy Reports (2013) Impacts of the EU Biofuel policy on agricultural markets and land use. The share of cereals and sugar crops used for bioenergy production is small in comparison to "other uses".

Table A.2: Metals categories used in this study in comparison to Eurostat's EW-MFA categories

Categories used in this study	Includes
Ferrous ores	Iron ores (MF21)
Copper	Copper (MF221)
Gold – gross ores	Gold – gross ores (A.2.2.6.1)

Bauxite and other aluminium	Bauxite and other aluminium (MF227)
Other non-ferrous ores	Nickel (MF222)/ Lead (MF223)/ Zinc (MF224)/ Tin (MF225)/ Silver – gross ores (A.2.2.6.2)/ Platinum and other precious metal ores – gross ore (A.2.2.6.3)/ Uranium and thorium (MF228)/ Tungsten – gross ore (A.2.2.9.1)/ Tantalum – gross ore (A.2.2.9.2)/ Magnesium ores – gross ore (A.2.2.9.3)/ Titanium – gross ore (A.2.2.9.4)/ Manganese – gross ore (A.2.2.9.5)/ Chromium – gross ore (A.2.2.9.6)/ Other metal ores – gross ore (A.2.2.9.7)

Table A.3: Minerals categories used in this study in comparison to Eurostat's EW-MFA categories

Categories used in this study	Includes
Sand and gravel	Sand and gravel (MF38)
Other construction minerals	Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate) (MF31)/ Slate (MF33)/ Limestone and gypsum (MF36)/ Chalk and dolomite (MF32)
Industrial minerals	Chemical and fertilizer minerals (MF34)/ Salt (MF35)/ Clays and kaolin (MF37)
Other non-metallic minerals	Other non-metallic minerals n.e.c (MF39)

Table A.4: Energy categories used in this study in comparison to Eurostat's EW-MFA categories

Categories used in this study	Includes
Lignite (brown coal)	Lignite (brown coal) (MF411)
Hard coal	Hard coal (MF412)
Oil shale and tar sands	Oil shale and tar sands (MF413)
Peat	Peat (MF414)
Crude oil, condensate and natural gas liquids (NGL)	Crude oil, condensate and natural gas liquids (NGL) (MF421)
Natural gas	Natural gas (MF422)

The following tables provide the evolution of RMC in the EU28 between 2001 and 2011.

Table A.5: Evolution of EU28 RMC (1000 tonnes RME) between 2001 and 2011

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total materials	8,130,396	8,124,859	8,082,344	8,270,058	8,306,735	8,582,566	8,703,314	8,600,511	7,750,513	7,458,582	7,742,307
Biomass	1,694,550	1,708,024	1,587,769	1,790,826	1,715,355	1,647,860	1,710,026	1,737,859	1,679,085	1,608,707	1,696,194
Metal ores	707,309	832,281	843,195	679,861	627,612	737,818	694,501	712,115	746,794	730,348	735,572
Non-metallic minerals	3,728,275	3,625,766	3,661,859	3,770,866	3,938,770	4,167,586	4,309,275	4,163,775	3,513,586	3,336,363	3,527,935

Fossil energy resources	1,999,498	1,957,581	1,988,538	2,026,994	2,023,431	2,027,785	1,988,259	1,985,624	1,809,954	1,781,422	1,781,530

Table A.6: Evolution of EU28 RMC for biomass between 2001 and 2011

		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Biomass	**RMC (1000 tonnes RME)**	**1,694,550**	**1,708,024**	**1,587,769**	**1,790,826**	**1,715,355**	**1,647,860**	**1,710,026**	**1,737,859**	**1,679,085**	**1,608,707**	**7,742,307**
Cereals	RMC (1000 tonnes RME)	273,573	285,931	241,773	322,367	277,890	260,458	266,533	310,167	277,007	250,157	272,962
	% change/ year	+4.5%	-15.4%	+33.3%	-13.8%	-6.3%	+2.3%	+16.4%	-10.7%	-9.7%	+9.1%	2001-2011 : -0.2%
Other food	RMC (1000 tonnes RME)	360,180	369,851	345,993	373,821	357,596	328,743	330,693	319,660	334,765	308,694	332,442
	change/ year	+2.7%	-6.5%	+8.0%	-4.3%	-8.1%	+0.6%	-3.3%	+4.7%	-7.8%	+7.7%	2001-2011 : -7.7%
Feed	RMC (1000 tonnes RME)	578,516	573,700	523,907	577,590	564,589	561,517	601,971	591,343	586,517	550,919	580,698
	change/ year	-0.8%	-8.7%	+10.2%	-2.3%	-0.5%	+7.2%	-1.8%	-0.8%	-6.1%	+5.4%	2001-2011 : +0.4%
Bioenergy	RMC (1000 tonnes RME)	97,622	93,823	99,444	99,927	97,603	104,248	106,052	114,276	114,370	115,537	119,737
	change/ year	-3.9%	+6.0%	+0.5%	-2.3%	+6.8%	+1.7%	+7.8%	+0.1%	+1.0%	3.6%	2001-2011 : +22.7%
Wood	RMC (1000 tonnes RME)	225,889	228,448	235,230	241,984	257,183	244,389	260,649	229,102	203,385	228,933	231,572
	change/ year	+1.1%	+3.0%	+2.9%	+6.3%	-5.0%	+6.7%	-12.1%	-11.2%	+12.6%	+1.2%	2001-2011 : +2.5%
Other biomass	RMC (1000 tonnes RME)	159,270	156,806	141,958	175,631	160,898	148,896	144,768	173,861	163,605	154,940	159,404
	change/ year	-1.5%	-9.5%	+23.7%	-8.4%	-7.5%	-2.8%	+20.1%	-5.9%	-5.3%	+2.9%	2001-2011 : +0.08%

Table A.7: Evolution of EU28 RMC for metal ores between 2001 and 2011

		2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Metal ores	**RMC (1000 tonnes RME)**	**707,309**	**832,281**	**843,195**	**679,861**	**627,612**	**737,818**	**694,501**	**712,115**	**746,794**	**730,348**	**735,572**
Ferrous ores	RMC (1000 tonnes RME)	189,875	186,046	200,021	208,840	213,486	224,131	226,840	219,216	112,208	165,953	171,383
	% change/ year	-2.0%	+7.5%	+4.4%	+2.2%	+5.0%	+1.2%	-3.4%	-48.8%	+47.9%	+3.3%	2001-2011 : -9.7%
Copper	RMC (1000 tonnes RME)	162,082	155,715	152,892	154,474	176,957	182,162	178,869	165,007	142,068	152,051	150,324
	% change/ year	-3.9%	-1.8%	+1.0%	+14.6%	+2.9%	-1.8%	-7.8%	-13.9%	+7.0%	-1.1%	2001-2011 : -7.3%
Gold-gross ore	RMC (1000 tonnes RME)	115,827	254,250	247,212	76,082	-9,786	64,748	26,166	96,159	319,035	163,878	160,318
	% change/ year	+119.5%	-2.8%	-69.2%	-112.9%	-761.7%	-59.6%	+267.5%	+231.8%	-48.6%	-2.2%	2001-2011 : +38.4%
Bauxite and other aluminium	RMC (1000 tonnes RME)	38,565	36,685	38,853	41,172	42,751	42,538	45,371	41,965	29,391	36,243	38,869
	% change/ year	-4.9%	+5.9%	+6.0%	+3.8%	-0.5%	+6.7%	-7.5%	-30.0%	+23.3%	+7.2%	2001-2011 : +0.8%
Other non-ferrous ores	RMC (1000 tonnes RME)	201,378	199,637	204,188	199,676	204,658	224,815	217,907	190,340	143,582	212,130	214,498
	% change/ year	-0.9%	+2.3%	-2.2%	+2.5%	+9.8%	-3.1%	-12.7%	-24.6%	+47.7%	+1.1%	2001-2011 : +6.5%

Table A.8: Evolution of EU28 RMC for non-metallic minerals between 2001 and 2011

		2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Non-metallic minerals	**RMC (1000 tonnes RME)**	**3,728,275**	**3,625,766**	**3,661,859**	**3,770,866**	**3,938,770**	**4,167,586**	**4,309,275**	**4,163,775**	**3,513,586**	**3,336,363**	**3,527,935**
Sand and gravel	RMC (1000 tonnes RME)	2,501,806	2,383,226	2,364,658	2,395,005	2,511,080	2,646,310	2,717,950	2,605,350	2,253,798	2,129,785	2,340,300

	% change/ year	-4.7%	-0.8%	+1.3%	+4.8%	+5.4%	+2.7%	-4.1%	-13.5%	-5.5%	+9.9%	2001-2011 : -6.5%
Construction minerals	RMC (1000 tonnes RME)	899,784	923,198	971,322	1,040,150	1,079,550	1,154,317	1,215,920	1,242,289	1,013,685	953,007	934,117
	% change/ year	+2.6%	+5.2%	+7.1%	+3.8%	+6.9%	+5.3%	+2.2%	-18.4%	-6.0%	-2.0%	2001-2011 : +3.8%
Industrial minerals	RMC (1000 tonnes RME)	211,321	204,112	205,685	214,230	215,018	215,847	215,995	203,638	155,223	165,025	169,769
	% change/ year	-3.4%	+0.8%	+4.2%	+0.4%	+0.4%	+0.1%	-5.7%	-23.8%	+6.3%	+2.9%	2001-2011 : -19.7%
Others non-metallic minerals	RMC (1000 tonnes RME)	117,739	117,538	122,221	124,077	135,550	154,277	164,145	116,696	93,775	90,893	85,780
	% change/ year	-0.2%	+4.0%	+1.5%	+9.2%	+13.8%	+6.4%	-28.9%	-19.6%	-3.1%	-5.6%	2001-2011 : -27.1%

Table A.9: Evolution of EU28 RMC for fossil energy resources raw between 2001 and 2011

		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Fossil energy resources	**RMC (1000 tonnes RME)**	**1,999,498**	**1,957,581**	**1,988,538**	**2,026,994**	**2,023,431**	**2,027,785**	**1,988,259**	**1,985,624**	**1,809,954**	**1,781,422**	**1,781,530**
Lignite (brown coal)	RMC (1000 tonnes RME)	441,918	443,073	445,129	442,161	435,463	434,636	440,496	427,934	410,280	398,844	428,098
	% change/ year	+0.3%	+0.5%	-0.7%	-1.5%	-0.2%	+1.3%	-2.9%	-4.1%	-2.8%	+7.3%	2001-2011 : -3.1%
Hard coal	RMC (1000 tonnes RME)	416,628	380,405	391,913	417,485	402,363	411,759	416,061	389,940	318,114	311,039	321,499
	% change/ year	-8.7%	+3.0%	+6.5%	-3.6%	+2.3%	+1.0%	-6.3%	-18.4%	-2.2%	+3.4%	2001-2011 : -22.8%
Oil shale and tar sands	RMC (1000 tonnes RME)	9,913	10,497	12,509	13,323	13,935	12,863	14,987	14,582	13,894	16,903	17,468
	% change/ year	+5.9%	+19.2%	+6.5%	+4.6%	-7.7%	+16.5%	-2.7%	-4.7%	+21.7%	+3.3%	2001-2011 : +76.2%
Peat	RMC (1000 tonnes RME)	14,994	16,646	17,136	11,669	17,643	21,494	10,628	12,629	16,944	17,278	15,205
	% change/ year	+11.0%	+2.9%	-31.9%	+51.2%	+21.8%	-50.6%	+18.8%	+34.2%	+2.0%	-12.0%	2001-2011 : +1.4%
Crude oil, condensate and natural gas liquids (NGL)	RMC (1000 tonnes RME)	700,350	682,330	685,619	694,552	693,970	687,617	668,791	680,724	621,563	600,153	586,773
	% change/ year	-2.6%	+0.5%	+1.3%	-0.1%	-0.9%	-2.7%	+1.8%	-8.7%	-3.4%	-2.2%	2001-2011 : -16.2%
Natural gas	RMC (1000 tonnes RME)	416,949	425,868	437,531	449,124	461,419	460,937	438,873	461,127	430,504	438,521	413,557
	% change/ year	+2.1%	+2.7%	+2.6%	+2.7%	-0.1%	-4.8%	+5.1%	-6.6%	+1.9%	-5.7%	2001-2011 : -0.8%

Table A.10: Evolution of EU28 RMC (expressed in TOE), Gross Inland Energy Consumption (in TOE) and GHG emissions (in thousands of tonnes CO2 eq)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
RMC (TOE) Solid fuels	315,858	296,521	303,318	315,751	307,295	313,013	314,456	298,102	256,139	250,134	261,079
RMC (TOE) Total petroleum products	689,734	672,163	675,815	684,757	684,314	677,851	659,812	671,444	613,211	592,821	579,803
RMC (TOE) Gas	447,381	456,951	469,466	481,904	495,097	494,580	470,905	494,783	461,926	470,528	443,741
GIC (TOE) Solid fuels	323,219	320,324	330,311	327,430	318,137	329,723	328,889	305,742	269,088	282,860	287,492
GIC (TOE) Total petroleum products	675,260	669,886	673,837	676,396	677,371	672,180	655,409	654,550	617,151	612,010	591,179
GIC (TOE) Gas	406,361	407,867	424,679	435,364	445,263	440,350	435,111	443,938	415,554	447,157	403,844
Total emissions (thousands of tonnes CO_2 eq)	5,142,906	5,098,755	5,187,853	5,191,729	5,159,610	5,147,762	5,091,464	4,983,579	4,622,601	4,733,816	4,578,469

Energy (thousands of tonnes CO_2 eq)	4,078,342	4,048,881	4,138,318	4,132,251	4,106,849	4,102,932	4,039,130	3,959,346	3,680,648	3,784,411	3,634,727

Appendix B: Marginal Abatement Analysis

This appendix provides an overview of outcomes from the abatement analysis carried out using E3ME before the main scenarios. It ranks GDP impacts per tonne of material reduction (euro/tonne) for each user of materials under different policies. Green colour represents higher benefit (net negative costs) and red represents lower benefit (or net positive costs).

MBI	Regulations	Investment
Non-Ferrous Ores _ Mining	Industrial Minerals _ Mining	Food _ Basic Metals
Food _ Agriculture	Wood _ Services	Food _ Mining
Food _ Food, Drink & Tobacco	Food _ Mining	Food _ Non-metallic Minerals
Industrial Minerals _ Non-metallic Mine	Food _ Energy	Food _ Energy
Food _ Services	Food _ Wood and Paper	Wood _ Transport
Industrial Minerals _ Mining	Food _ Chemicals	Food _ Wood and Paper
Ferrous Ores _ Non-metallic Minerals	Food _ Non-metallic Minerals	Industrial Minerals _ Agriculture
Industrial Minerals _ Construction	Food _ Basic Metals	Industrial Minerals _ Other Industry
Ferrous Ores _ Energy	Food _ Engineering etc	Wood _ Basic Metals
Non-Ferrous Ores _ Construction	Food _ Other Industry	Non-Ferrous Ores _ Agriculture
Non-Ferrous Ores _ Energy	Food _ Construction	Industrial Minerals _ Chemicals
Non-Ferrous Ores _ Basic Metals	Food _ Transport	Wood _ Non-metallic Minerals
Wood _ Wood and Paper	Wood _ Mining	Industrial Minerals _ Food, Drink & Tob
Ferrous Ores _ Basic Metals	Wood _ Energy	Food _ Engineering etc
Non-Ferrous Ores _ Engineering etc	Wood _ Food, Drink & Tobacco	Industrial Minerals _ Services
Wood _ Agriculture	Wood _ Chemicals	Wood _ Engineering etc
Non-Ferrous Ores _ Other Industry	Wood _ Non-metallic Minerals	Industrial Minerals _ Transport
Construction Minerals _ Construction	Wood _ Basic Metals	Wood _ Mining
Food _ Mining	Wood _ Engineering etc	Food _ Construction
Food _ Energy	Wood _ Other Industry	Industrial Minerals _ Energy
Food _ Wood and Paper	Wood _ Construction	Wood _ Energy
Food _ Chemicals	Wood _ Transport	Wood _ Food, Drink & Tobacco
Food _ Non-metallic Minerals	Industrial Minerals _ Agriculture	Industrial Minerals _ Non-metallic Mine
Food _ Basic Metals	Industrial Minerals _ Energy	Non-Ferrous Ores _ Wood and Paper
Food _ Engineering etc	Industrial Minerals _ Food, Drink & Tob	Industrial Minerals _ Engineering etc
Food _ Other Industry	Industrial Minerals _ Wood and Paper	Non-Ferrous Ores _ Transport
Food _ Construction	Industrial Minerals _ Basic Metals	Industrial Minerals _ Basic Metals
Food _ Transport	Industrial Minerals _ Engineering etc	Industrial Minerals _ Mining
Wood _ Mining	Industrial Minerals _ Other Industry	Non-Ferrous Ores _ Other Industry
Wood _ Energy	Industrial Minerals _ Transport	Non-Ferrous Ores _ Services
Wood _ Food, Drink & Tobacco	Industrial Minerals _ Services	Non-Ferrous Ores _ Engineering etc
Wood _ Chemicals	Ferrous Ores _ Engineering etc	Ferrous Ores _ Engineering etc
Wood _ Non-metallic Minerals	Non-Ferrous Ores _ Agriculture	Food _ Other Industry
Wood _ Basic Metals	Non-Ferrous Ores _ Wood and Paper	Non-Ferrous Ores _ Mining
Wood _ Engineering etc	Non-Ferrous Ores _ Services	Non-Ferrous Ores _ Basic Metals
Wood _ Other Industry	Non-Ferrous Ores _ Energy	Industrial Minerals _ Wood and Paper
Wood _ Construction	Construction Minerals _ Construction	Ferrous Ores _ Non-metallic Minerals
Wood _ Transport	Ferrous Ores _ Energy	Non-Ferrous Ores _ Construction
Industrial Minerals _ Agriculture	Non-Ferrous Ores _ Mining	Ferrous Ores _ Chemicals
Industrial Minerals _ Energy	Non-Ferrous Ores _ Other Industry	Ferrous Ores _ Energy
Industrial Minerals _ Food, Drink & Tob	Ferrous Ores _ Basic Metals	Industrial Minerals _ Construction
Industrial Minerals _ Wood and Paper	Non-Ferrous Ores _ Engineering etc	Non-Ferrous Ores _ Energy
Industrial Minerals _ Basic Metals	Non-Ferrous Ores _ Construction	Ferrous Ores _ Basic Metals
Industrial Minerals _ Engineering etc	Wood _ Wood and Paper	Wood _ Services
Industrial Minerals _ Other Industry	Non-Ferrous Ores _ Basic Metals	Wood _ Other Industry
Industrial Minerals _ Transport	Non-Ferrous Ores _ Transport	Wood _ Chemicals
Industrial Minerals _ Services	Ferrous Ores _ Non-metallic Minerals	Wood _ Agriculture
Ferrous Ores _ Engineering etc	Wood _ Agriculture	Construction Minerals _ Construction
Non-Ferrous Ores _ Agriculture	Industrial Minerals _ Construction	Wood _ Wood and Paper
Non-Ferrous Ores _ Wood and Paper	Ferrous Ores _ Chemicals	Food _ Chemicals
Non-Ferrous Ores _ Services	Industrial Minerals _ Non-metallic Mine	Wood _ Construction
Wood _ Services	Industrial Minerals _ Chemicals	Food _ Services
Industrial Minerals _ Chemicals	Food _ Agriculture	Food _ Food, Drink & Tobacco
Ferrous Ores _ Chemicals	Food _ Services	Food _ Agriculture
Non-Ferrous Ores _ Transport	Food _ Food, Drink & Tobacco	Food _ Transport

Appendix C: Detailed Sectoral Results

This appendix provides sectoral results for all scenarios: output, employment and industry prices. The results shown are as percentage difference from baseline.

Table C.1: EU28 sectoral output results, % difference from baseline (S1)

	S2	S3	S3.5	S4	S5	S6
2020						
Agriculture, Fishing, Forestry	-0.4	-1.4	-2.6	-5.6	-3.1	-1.8
Energy mining	0.0	0.0	0.1	-1.4	0.2	0.1
Non-energy mining	-1.4	-3.2	-3.9	-4.1	-2.6	-3.9
Manufacturing	0.2	0.2	0.2	0.4	0.0	0.0
Utilities	0.2	0.3	0.0	-1.8	0.6	0.2
Construction	0.3	0.9	1.6	2.3	0.3	0.8
Retail, Distribution	0.3	0.4	0.2	-0.1	0.3	0.1
Transport, Communication	0.2	0.2	0.1	-0.1	0.0	0.0
Other services	0.1	0.2	0.1	0.2	0.2	0.1
Total	0.2	0.2	0.2	0.2	0.1	0.1
2030						
Agriculture, Fishing, Forestry	-1.0	-4.1	-8.1	-18.0	-9.2	-5.4
Energy mining	0.2	0.3	0.4	-1.5	0.3	0.2
Non-energy mining	-3.9	-9.4	-11.3	-11.5	-7.5	-8.6
Manufacturing	0.5	0.6	-0.1	0.1	-0.2	0.1
Utilities	0.6	1.0	0.3	-2.6	1.5	0.6
Construction	0.7	1.3	1.3	1.5	0.4	0.8
Retail, Distribution	0.9	1.2	0.2	-0.7	1.0	0.4
Transport, Communication	0.4	0.5	0.0	-0.6	0.2	0.2
Other services	0.4	0.6	0.2	0.1	0.5	0.3
Total	0.5	0.6	0.0	-0.3	0.2	0.2

Source(s): E3ME, Cambridge Econometrics.

Table C.2: EU28 sectoral employment results, % difference from baseline (S1)

	S2	S3	S3.5	S4	S5	S6
2020						
Agriculture, Fishing, Forestry	-0.1	-0.5	-0.9	-1.9	-1.1	-0.7
Energy mining	0.0	0.3	0.5	-7.5	1.4	0.5
Non-energy mining	-1.5	-4.2	-4.8	-6.1	-3.2	-5.4
Manufacturing	0.3	0.5	0.7	1.1	0.9	0.4
Utilities	0.2	0.3	0.0	-1.2	0.4	0.1
Construction	0.4	1.0	1.2	1.2	1.1	0.9
Retail, Distribution	0.2	0.3	0.1	0.0	0.2	0.1
Transport, Communication	0.1	0.2	0.3	0.6	0.3	0.1

Other services	0.2	0.3	0.4	0.7	0.4	0.2
Total	0.2	0.3	0.4	0.5	0.4	0.2
2030						
Agriculture, Fishing, Forestry	0.1	-0.8	-1.8	-3.4	-2.2	-1.5
Energy mining	0.1	0.3	0.4	-9.6	0.9	0.3
Non-energy mining	-3.4	-9.4	-10.9	-11.4	-7.3	-8.7
Manufacturing	0.6	1.2	1.8	2.4	2.7	1.1
Utilities	0.7	1.0	0.3	-1.6	1.3	0.4
Construction	1.2	2.1	1.7	0.9	3.1	2.2
Retail, Distribution	0.5	0.7	0.1	-0.4	0.5	0.2
Transport, Communication	0.3	0.5	0.3	1.0	0.5	0.1
Other services	0.8	1.0	0.9	1.4	0.9	0.5
Total	0.7	1.0	0.8	0.9	1.1	0.6

Source(s): E3ME, Cambridge Econometrics

Table C.3: EU28 industry price results, % difference from baseline (S1)

	S2	S3	S3.5	S4	S5	S6
2020						
Agriculture, Fishing, Forestry	0.1	0.4	1.8	3.2	1.6	0.6
Energy mining	0.0	0.0	0.0	0.0	0.1	0.0
Non-energy mining	0.0	-0.1	-0.1	0.0	0.0	0.0
Manufacturing	0.3	2.5	6.0	7.1	10.8	3.2
Utilities	0.1	0.4	0.9	7.1	0.9	0.4
Construction	0.3	0.8	1.4	1.6	2.1	1.1
Retail, Distribution	0.2	0.3	0.5	1.1	0.5	0.2
Transport, Communication	0.0	0.2	0.7	2.3	0.9	0.3
Other services	0.2	0.3	0.8	1.5	0.6	0.3
Total	0.2	1.1	2.5	3.6	4.2	1.3
2030						
Agriculture, Fishing, Forestry	0.1	1.2	6.0	10.2	4.8	1.8
Energy mining	0.0	0.0	0.0	-0.1	0.0	0.0
Non-energy mining	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1
Manufacturing	0.5	2.6	7.5	10.3	13.9	3.7
Utilities	0.3	0.7	1.8	10.3	1.5	0.5
Construction	0.6	1.6	2.7	3.1	4.7	2.3
Retail, Distribution	0.5	0.6	1.0	1.9	0.7	0.3
Transport, Communication	0.0	0.2	1.0	5.5	1.1	0.2
Other services	0.6	0.8	1.5	3.0	0.8	0.3
Total	0.5	1.4	3.6	5.7	5.5	1.6

Source(s): E3ME, Cambridge Econometrics