Outlook for waste and material flows. Baseline and alternative scenarios

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Outlook for waste and material flows

Baseline and alternative scenarios

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Context

The Topic Centre has prepared this working paper for the European Environment Agency (EEA) under its 2002/2003/2004 work programmes as a contribution to the EEA's work on scenarios to support reporting and policy making.

Disclaimer

This **ETC/RWM working paper** has not been subjected to European Environment Agency (EEA) member country review. Please note that the contents of the working paper do not necessarily reflect the views of the EEA.

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Executive summary

Prospective analysis is one established 'building block' of EEA’s integrated assessment to support reporting and policy making. It aims at anticipating future trends of driving forces and environmental pressures. However, the existing models framework of the EEA, does not include waste and material flows which is why it had to be extended in order to generate projections on waste and material flows.

In 2002, the development of a macro-level module on prospective analysis began. The aim is to provide an assessment of the likely, future trends of waste quantities and material flows through the design of scenarios. The projections on waste and material flows have provided input for the State of the Environment and Outlook Report 2005.

Decoupling of environmental pressures and economic growth is one of the overall aims of the Sixth Environmental Action Programme. More specifically, the programme aims at breaking the linkages between economic growth and resource use. For waste the objective is to achieve a significant, overall reduction in the volumes of waste generated. Apart from these relatively general objectives, no quantitative reduction targets have been set at EU level.

Models for projection

Depending on the nature of the respective waste and/or material flow, three modelling types are used for making the baseline projections for material flows and waste.

In the general modelling type, which is also the one used for the majority of material flows and waste streams, the past developments in quantities of waste/materials, economic activities, number of households/size of population have been used to analyse if there are links between these. If that is the case, and these links have been reliable in the past, they may be used for scenarios using given projections of economic activities and other demographic variables.

In addition to the general modelling type, a population type model for projection of end-of-life-vehicles is used to project the amount of waste oils and tyres from cars. It is assumed that a certain quantity of waste oils and tyres arises per car and this quantity is multiplied with the projected number of cars.

The domestic extraction and the import of fossil fuel material flows have been estimated by ‘translating’ energy balance data (as obtainable from energy model outlooks) from energetic units into metric tonnes.

The time horizon for the projections is 2020.

Key assumptions of the scenarios

The key assumptions on socio-economic variables stem from the ‘Long Range Energy Modelling’ (LREM) baseline scenario. The LREM baseline scenario presents a projection of the EU energy and transport outlook to 2030 on the basis of current market trends and existing polices. The LREM baseline scenario is based on a quantitative analysis, with the use of PRIMES and ACE mathematical models, and in a consultation process with energy experts and organisations.

The LREM baseline scenario assumes an average, annual economic growth rate of 2.3% for the former EU-15 countries and 3.6-3.8% for the new EU-10. In comparison, the Low growth scenario assumes an annual economic growth rate of 1.6-1.7 % for the EU-15 and

3.4 % for the new EU-10. A relative decoupling of materials use and waste generation will be achieved provided they grow at a lower rate than the GDP.

In addition to the Baseline and the Low growth scenarios, a third scenario has been calculated for fossil fuels, the Sustainable Emission Pathway (SEP). This scenario is based on the long-term EU 6EAP climate change objective which is to limit the increase in the global temperature to maximum 2 degrees above post-industrial levels (requires a substantial reduction of EU GHG emissions by 2030).

Projections for waste generation

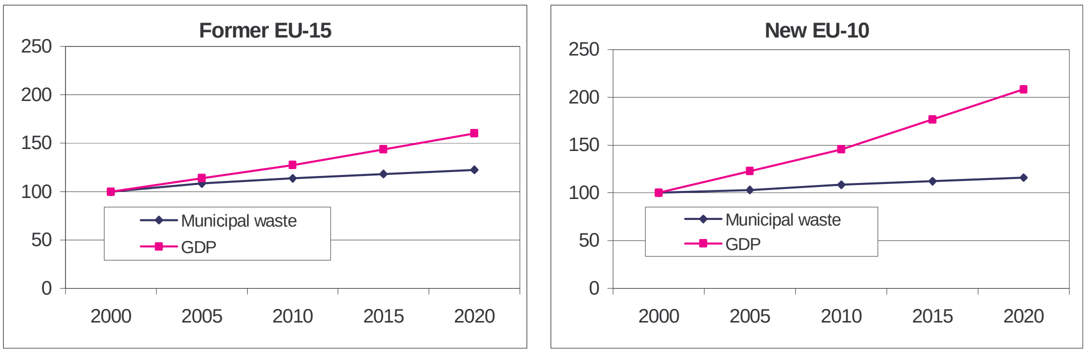
The projections for waste generation include eight streams which are either large streams or subject to specific political measures. It should be noted that the streams cannot be aggregated as there is some overlap between paper and cardboard, glass, packaging and municipal waste.

Municipal waste

Municipal waste is a mixed stream consisting of not only household waste but also similar waste from commerce, which blurs the ability to link the waste generation to household related parameters. The amount of commercial waste in the municipal waste stream varies from country to country. There are large variations in the quantity of municipal waste generated per capita. The Western European countries (former EU-15, Norway and Switzerland) produce more waste per capita than the new EU Member States and the candidate countries.

The Baseline scenario estimates an increase in quantity in 2020 of approximately 20-25 % for the EU-15 and 15-20 % for the new EU Member States. For the candidate countries, Bulgaria and Romania (CC2), the change is estimated to 5-10 % and less than 5 % for the EEA countries, Norway and Switzerland. Thus, a relative decoupling from the GDP is likely to take place as seen in the figure overleaf.

Baseline scenario for the former EU-15 and the new EU-10: municipal waste and GDP



For the EU-10, Bulgaria and Romania the projections are less solid which of course has to do with the situation in Eastern Europe in the 1990s. The substantial change in the economic situation in the past has affected the household income and thereby the generation of waste. To assume that the past trends will continue is questionable especially considering a projected increase in household consumption expenditure of approx. 3.5 - 4 % p.a. In comparison, the projected consumption expenditure for the EU-15 is about 2.3 % p.a. As a result, the generation of municipal waste for the EU-10 and CC2 is very likely to increase more than estimated by the model.

Biodegradable municipal waste (BMW)

Biodegradable waste from households consists of food and garden waste, paper and cardboard, textile and any other waste capable of undergoing aerobic or anaerobic decomposition.

The main measure for the management of biodegradable municipal waste is the Landfill Directive. Assuming that the BMW share of municipal waste given in 1995 remains constant, the former EU-15 is estimated to reduce landfilling in 2006 by 15 million tonnes of BMW due to the Landfill Directive. This waste will then need to be diverted towards other waste management options. In 2009, the amount will be 28 million tonnes, and in 2016 it is 41 million tonnes. However, as data on the BMW share are poor, a large uncertainty is attached to the estimate.

Based on the estimated diversion of BMW, the greenhouse gas savings have been calculated. In 2006 and 2016 they will constitute 0.8 % to 2.3 % respectively of the total greenhouse gas emission of the EU-15 in 2002.

Industrial waste

Industrial waste is one of the very large waste streams, typically much larger than municipal waste. The amount per capita varies from 0.5 tonnes in Germany, Spain, and Denmark to 3 tonnes in Finland. Figures for the generation of waste depend on the structure of industries, the technology in use and the definition of industrial waste.

In the Baseline scenario for the EU-15 industrial waste is projected to increase by 60-65 % in 2020 compared to 2000. In comparison, the Low growth scenario projects an increase of 45 %. These projected growth rates almost equal the projected growth rates of the GDP, and a decoupling from the economic activity is not likely to occur.

Waste from the construction and demolition sector

The definition and composition of waste from the construction and demolition sector varies greatly among countries. Especially the amount of excavated soil included may be an important factor for the actual amount of waste from the construction sector. Soil, stones etc. may amount to some 70 to 80 % of the total waste, which makes it difficult to compare the quantity of generated waste across countries.

Waste from the construction and demolition sector in the EU-15 is estimated to increase by approximately 30-35 % by 2020 in the Baseline scenario. The Low growth scenario estimates a more moderate increase of 15-20 %. Due to differences in composition, the estimate includes large differences between countries. When comparing the results with the estimated increase in economic activity, a decoupling is expected to take place over the twenty-year period.

Paper and cardboard

The consumption of paper varied in 2000 from 100-120 kg per capita in Greece, Ireland and Portugal to 305-310 kg per capita in Belgium and the Netherlands. Since 1990, consumption has increased by 10-50 % in the EU-15. It should be noted that there may be a certain overlap with the projection of packaging, as cardboard is often packaging. The degree of overlap, however, is not possible to evaluate.

The Baseline scenario results in an augmentation of paper consumption of 60-65 % in 2020, while the Low growth scenario estimates a growth of twenty percentage points less, i.e. 40-45 %. When looking at the past trends and the projected trends for each country, there are no significant changes in the projections, and it generally looks as if the growth continues at the same rate after 2000. Comparing this result to the assumed economic growth, it is questionable whether a decoupling will be achieved for paper and cardboard.

Glass
The projected growth in consumption of container glass is moderate. The Baseline scenario estimates an increase of 45-50 % in 2020, and the Low growth scenario a 25-30 % increase. As is the case with waste from the construction and demolition sector, there are rather big differences between the estimated trends for countries.

Packaging
The generated quantity of packaging varies significantly between the 15 EU Member States: in 2000 France and Ireland top with a generation of 212-210 kg/capita, while Finland and Greece have the lowest generation of only 86-88 kg/capita. The EU average is 174 kg/capita.

In the Baseline scenario, the total amount of packaging waste for the former EU-15 Member States is estimated to increase by 20-25 % over the next ten years compared to the reference year 2000. The Low growth scenario produces lower increases of approx. 15 % in 2010.

Tyres and Waste oil
The projected increase in used tyres and waste oil are almost identical as they are linked to the projection of vehicles. The EU-15 projection shows a modest increase, while the waste stream is projected to increase by 70-75 % in the new EU-10 and by 115 % for Bulgaria and Romania. A relative decoupling from the GDP may take place for the EU-15 and the new EU-10, whereas it is not likely to happen for the two candidate countries.

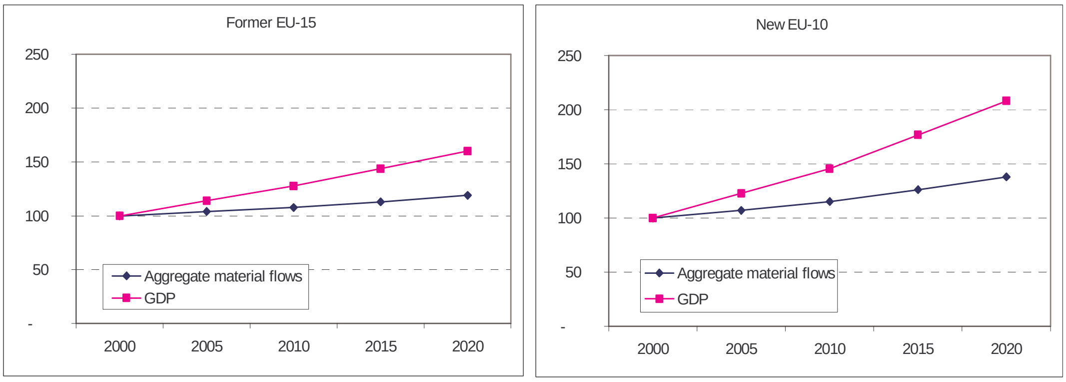
Projections for material flows

The projections for material flows comprise main components of the Domestic Material Consumption (DMC), a composite indicator showing how much materials are consumed by a national economy. Not all components of the DMC are included, but the components which have been projected represent about 95% of composite DMC and is therefore a good proxy for it.

During the last 20 years the EU has seen a more or less stagnating DMC whilst the GDP has been growing. The projections for the EU suggest that this development will not continue. Moreover, in both the Baseline scenario and the Low growth scenario, the aggregate material use is increasing, along with growing GDP. Indeed, relative decoupling will be achieved, but the pressure on the environment is not likely to be eased which would only be the case if material use would decrease in absolute terms. In the Baseline scenario for the EU-15, the GDP is almost doubling (+60%) between 2000 and 2020 whilst the aggregate material flows increase by around 19%. In the Low growth scenario, the GDP only rises by 39% whilst material use increases by 6%.

Both cases illustrate that according to a ‘business-as-usual’ development, technological progress in terms of resource productivity is not improving sufficiently to achieve an absolute decoupling. Further efforts are needed to increase resource productivity (in terms of GDP/DMC). As a minimum, resource productivity has to grow at the same growth rate as the GDP in order to achieve a stagnating material input. The productivity, however, rose only by 35% and 31% respectively in the Baseline and Low growth scenarios.

Baseline scenario for the former EU-15 and the new EU-10: aggregated material flows and GDP



Economic growth is projected to grow much more pronounced in the 10 new Member States. In the Baseline scenario, it almost doubles (+108%), and in the Low growth scenario it increases by about 94%. Also the aggregated material flows are projected to grow. They increase by 38% in the Baseline scenario, and by 33% in the Low growth scenario.

Although, productivity (GDP/aggregate material flows) in the new Member States is projected to grow faster than in the former EU-15 Member States (51% in the Baseline scenario and 46% in the Low growth scenario), this is by far not enough to stabilise material input. In order to achieve absolute decoupling, productivity growth would have to be at least at the same rate as economic growth, i.e. about two times stronger.

In the subsections below, the trends for each of the material flows which constitute the aggregate material flow are presented.

Minerals

The historical trend in domestic extraction of industrial minerals and ores is not continued in the Baseline scenario. In 2000 for the EU-15, the domestic extraction volumes were 150 million tonnes and from 2010, they will either grow with the same rate or a lower rate than the gross value added in the industry sectors. The actual growth rate depends on the assumptions made. The domestic extraction of construction minerals increases significantly by around 1 billion tonnes (2000 to 2020) in the Baseline scenario.

For the 10 new EU Member States the domestic extraction of all minerals shows a steep increase in the Baseline scenario: it doubles between 2000 and 2020. The overall picture is dominated by the largest country, Poland.

In the three candidate countries, Bulgaria, Romania and Turkey, the domestic extraction of all minerals shows a very steep increase; between 2000 and 2020 it grows from 150 to almost 330 tonnes by more than a factor 2. The overall growth is solely due to Turkey, whereas the domestic extraction of minerals in Bulgaria and Romania seems to remain stable.

The Low growth scenario produces only a slightly lower extraction than the Baseline scenario for all countries.

Biomass

In the Baseline scenario for the EU-15 the domestic extraction (harvest) of biomass steadily increases up from 2001. During the first 10 years, this increase is moderate and becomes steeper after 2010 leading to more than 1.6 billion tonnes. Alternatively, a Baseline scenario has been calculated for the EU-15 where the time parameter a_3 is not levelled out, i.e. remains constant throughout the projection period. In this case, the aggregated harvest of biomass remains fairly constant at around 1.4 billion tonnes from 2000 to 2020.

For the EU-10, the harvest of biomass is projected to increase considerably from around 350 million tonnes in 2000 to almost 500 million tonnes in 2020.

In the three candidate countries, the harvest of biomass is projected to increase considerably up from 2010. Compared to 1992, it almost doubles until 2020. The aggregated picture is dominated by Turkey where the biomass harvest even more than doubles.

The Low growth scenario produces only slightly lower values than the Baseline scenario for all countries.

Fossil fuels

The Baseline scenario shows a moderate increase of fossil fuel materials consumption from 1.49 billion tonnes in the year 2000 to 1.62 billion tonnes in 2020. In the Low growth scenario, the fossil fuel materials consumption of the EU-15 will remain fairly constant. Between 2000 and 2020, it will even decrease slightly from 1.49 to 1.44 billion tonnes. The Sustainable Emission Pathway scenario shows an absolute decrease in fossil fuel materials consumption for the EU-15: from 1.49 billion tonnes in 2000 to 1.40 billion tonnes in 2020.

For the EU-10, the Baseline scenario shows a slight decrease of fossil fuel materials consumption from 329 million tonnes in the year 2000 to 314 million tonnes in 2020. Different developments can be observed in countries, however. The decrease is caused by significant reductions in the Czech Republic and Estonia respectively. On the other hand, Lithuania and Slovakia show significant increases. In the Sustainable Emission Pathway scenario, the fossil fuel materials consumption shows a clear and steady decrease from 329 million tonnes in 2000 to 272 million tonnes in 2020.

Of particular interest is the development of domestic extraction versus net imports of fossil fuel materials. In all three scenarios, the domestic share will decrease, which need to be compensated by a net increase of imports of fossil fuel materials from outside the EU. As a result, the energy dependency (share of imports) of the EU will increase significantly. In the Sustainable Emission Pathway scenario the energy dependency will even be higher due to a changing energy mix from coal to oil and gas.

Decoupling of waste and material flows from the GDP

The projected trends for waste in the Baseline scenario show that a relative decoupling from the GDP is likely for municipal waste, construction and demolition waste, glass, and packaging waste in 2020. As regards used tyres and waste oil, a relative decoupling is likely to occur in the EU-15, but not in the EU-10 and candidate countries. The generation of paper and cardboard and industrial waste in the EU-15 however, are not likely to decouple from the GDP.

For material flows the projected trends in the Baseline scenario show that a relative decoupling is likely to take place for all material flows except fossil fuels in the EU-15 and biomass in the new EU-10. For fossil fuels in the EU-10 a slight absolute decoupling is estimated in 2020.

Baseline scenario: likelihood of a relative decoupling from the GDP?

	Former EU-15	New EU-10	Bulgaria and Romania	Norway and Switzerland
Municipal waste	Yes	Yes	Yes	Yes
Industrial waste	No			
Construction and demolition waste	Yes			
Paper and cardboard	No			
Glass	Yes			
Packaging waste	Yes			
Used tyres	Yes	No	No	
Waste oil	Yes	No	No	

Note: Blank: no projections have been made.

Baseline scenario: likelihood of a relative decoupling from the GDP?

	Former EU-15	New EU-10	Bulgaria, Romania and Turkey	Norway and Switzerland
Aggregate material flows	Yes	Yes		
Minerals		Yes	Yes	
- Industrial minerals and ores	Yes			
- Construction minerals	Yes			
Biomass	Yes	No	Yes	
Fossil fuels	No	Yes		

Note: Blank: no projections have been made.

1. Introduction

Prospective analysis is one established 'building block' of EEA’s integrated assessment to support reporting and policy making. It aims at anticipating future trends of driving forces and environmental pressures. Thus, emerging issues are identified as well as policies can be assessed as regards their objectives. In order to generate outlooks or projections for waste and material flows, the existing outlook models framework of the EEA should be extended.

The EEA's contribution to policy-making in the field of waste and resource management will be further developed by increasingly focusing work on analysing future trends rather than past historical developments. This implies a greater emphasis on modelling of future waste generation and material flows.

Decoupling of environmental pressures and economic growth is one of the overall aims of the Sixth Environment Action Programme. More specifically, the programme aims at breaking the linkages between economic growth and resource use. For waste the objective is to achieve a significant, overall reduction in the volumes of waste generated.

In 2002, the development of a macro-level module on prospective analysis began. The aim is provide an assessment of the likely, future trends of waste quantities and material flows, but also to be able to design alternative scenarios.

This working paper presents the work and results of the work to date. The first phase of the project has been to design a ‘waste and material flows-module’ (WMF-module) and to generate a baseline scenario. The second phase of the project has been to design a number of alternative scenarios. More specifically, these include: a scenario with lower economic growth than the baseline scenario, a sustainable energy pathway scenario with a decreased use of fossil fuels, and a scenario studying the implications of the Landfill Directive’s targets on the landfilling of biodegradable municipal waste. The scenarios are prepared as input for the EEA State of the Environment and Outlook Report in 2005. The current estimations are also suitable for analysing the potential for decoupling.

The projections should be seen for the four groups of countries: former EU-15 Member States; new EU-10 Member States; candidate countries (Bulgaria, Romania and Turkey) and Rest of EEA Countries (Norway and Switzerland) rather than for individual countries. Hence, the projection for each of the four groups of countries, is the aggregated sum of projections for all countries where projections are available. In general, the projections for the candidate countries and the 2 EEA countries are of some uncertainty since the two groups only contain few countries. The approach implies that the projections for large countries (Germany, France, the UK, Italy, Spain, Poland and Turkey) will have a major impact on the projection for the group.

For practical reasons, the ‘waste and material flows-module’ is split into four separate Excel workbooks: two for fossil fuels and two for waste and material flows (minerals and biomass), covering the former 15 EU Member States on the one hand and the 10 new EU Member States and the candidate countries on the other hand respectively.

The long-term objective is to improve the estimations and to include other elements such as environmental impacts and cost of implementing certain measures in order to be able to study effects of policies and instruments.

Chapter 2 presents the key assumptions of the scenarios as given by the LREM Baseline. In chapter 3, the three models used for the projections are described. Chapter 4 deals with the projections for waste, and chapter 5 with the projections for material flows. In the latter two chapters, the results for each waste stream and material flow include the Baseline scenario and the relevant alternative scenarios. In addition, an assessment is made of the robustness of the projections.

Frits Møller Andersen and Helge Larsen from the Systems Analysis Department at Risoe National Laboratory have contributed to the project by carrying out the estimations for and the programming of the waste module. Their work has been financed by the ETC/WMF via the Danish national contribution.

1.1. Objective

The objective of this second phase is to assess and improve the estimations for the Baseline scenario and to develop three alternative scenarios: Low growth scenario; Sustainable Emissions Pathway; and Biodegradable municipal waste.

The geographical coverage is the EU-25 countries, the three candidate countries, and Norway and Switzerland. However, as past economic data are more comprehensive for the former EU-15 Member States, some projections for waste are made for these countries only.

The primary target group for the modules are experts on waste and material flows in the ETC/WMF and the European Environment Agency. However, the output of the modules, i.e. the projections and scenarios, is relevant for DG Environment, national policy-makers and the informed public.

An important note is that the project mainly looks at trends in materials use and waste generation. In other words, the likely increases or decreases in the future quantities, providing that no new polices are introduced, are analysed. This implies that the actual, physical quantities are of secondary importance.

2. Key assumptions of the scenarios

The baseline scenario used in this context is the 'Long Range Energy Modelling' (LREM) baseline, developed by the NTUA on a framework contract for the DG TREN, Mantzos et al. (2003). The LREM baseline presents a projection of the EU energy and transport outlook to 2030 on the basis of current market trends and existing polices.

The LREM scenario is based on a quantitative analysis, with the use of PRIMES and ACE mathematical models, and in a consultation process with energy experts and organisations.

According to Mantzos et al. (2003), key assumptions for the EU-15 are:

- a continuation of current world energy market structures and taking a conventional view on fossil fuel reserves, world energy prices develop moderately as no supply constraints are likely to be experienced over the next 30 years under Baseline conditions.
- a continuation of economic modernisation, substantial technological progress, and completion of the internal market. Existing policies on energy efficiency and renewables continue; the fuel efficiency agreement with the car industry is implemented; and decisions on nuclear phase-out in certain Member States are fully incorporated.
- no introduction of new policies to reduce greenhouse gas emissions (for analytical purposes). This is to assist in identifying any remaining policy gaps in the energy and transport sectors with respect to the EU Kyoto commitments.
- a continuation of GDP growth of 2.3 % pa on average over the projection period, similar to that over the past 30 years. The assumed growth rates are modest compared with the ambitions of the Lisbon strategy but also high compared with the current weak state of the EU economy.

For the new EU-10, candidate countries and neighbouring countries (Norway and Switzerland), the energy import prices correspond with those of the EU-15. The policy assumptions are also similar to the EU-15 given the gradual accession of many of these countries and continuation of close economic and political relations with the others. The GDP growth in the new EU-10 and the candidate countries is projected to exceed that in EU-15 to 2030, Mantzos et al. (2003).

For the Clean Air For Europe (CAFE) programme, two baseline scenarios have been developed: one with and one without full Kyoto implementation. These scenarios are developed for DG Environment. The 'without climate policies' CAFE baseline scenario is almost identical to the LREM baseline scenario. However, small differences exist as regards the new EU-10 and candidate countries given that results provided are output of the PRIMES model (which has been developed in the meantime for those countries) and not the ACE model as was the case in the LREM scenario, Eerens et al. (2003).

The key economic and demographic assumptions for the LREM baseline scenario are presented in Table 1A and 1B.

The values for the gross domestic product (GDP), private final consumption (FPC) and the gross value added (GVA) of the LREM baseline scenario are repeated along with the changes of these values compared to the year 2000. To cover the same period as the waste and material flow projections, the LREM baseline scenario is only presented for the years 2000 to 2020. In Table 1B, the changes in 2010 and 2020 are compared with the baseline year 2000.

Table 1A. Baseline scenario: key demographic and economic assumptions

	1990	2000	2010	2020	'90-'00	'00-'10	'10-'20
EU-15					Annual % change		
Population (Million)	366.0	378.7	387.8	390.4	0.3	0.2	0.1
Average household size (persons)	2.6	2.4	2.2	2.1	-0.8	-0.8	-0.7
Number of households (Million)	141.3	157.7	174.2	187.3	1.1	1.0	0.7
GDP (bn Euro)	6982.1	8545.0	10859.1	13641.2	2.0	2.4	2.3
Households expenditure (bn Euro)	3998.7	4863.3	6147.2	7644.3	2.0	2.4	2.2
Gross Value Added (bn Euro)	6537.9	8003.5	10283.4	12993.0	2.0	2.5	2.4
New EU-10							
Population (Million)	75.1	74.7	73.4	71.7	-0.1	-0.2	-0.2
Average household size (persons)	2.9	2.7	2.4	2.3	-0.9	-0.8	-0.4
Number of households (Million)	25.7	28.1	30.0	30.5	0.9	0.7	0.2
GDP (bn Euro)	333.1	394.3	573.9	820.9	1.7	3.8	3.6
Households expenditure (bn Euro)	256.9	297.6	432.9	633.4	1.5	3.8	3.9
Gross Value Added (bn Euro)	295.5	347.0	509.3	737.4	1.6	3.9	3.8
CC3 + Norway + Switzerland							
Population (Million)	174.2	184.5	190.4	195.1	0.6	0.3	0.2
Average household size (persons)	3.3	3.1	2.8	2.7	-0.7	-0.8	-0.5
Number of households (Million)	52.3	59.6	67.0	72.1	1.3	1.2	0.7
GDP (bn Euro)	904.3	1086.1	1475.3	2107.1	1.8	3.1	3.6
Households expenditure (bn Euro)	690.4	826.0	1114.3	1614.5	1.8	3.0	3.8
Gross Value Added (bn Euro)	827.4	985.5	1346.7	1948.0	1.8	3.2	3.8

Note: Expenditures are in 2000-prices.
Source: Mantzos et al. (2003).

Table 1B. Baseline scenario: trends in key economic and demographic assumptions

	Gross Domestic product	Number of households	Population	Households expenditure	Gross Value Added (fqs)	Industry (fqd)	Construction (fqf)	Services	Agriculture (fqa)
EU-15									
2000-10	27.1%	10.5%	2.4%	26.4%	28.5%	26.5%	19.8%	31.0%	11.2%
2000-20	59.6%	18.8%	3.1%	57.2%	62.3%	59.9%	45.4%	67.1%	23.0%
EU-10									
2000-10	45.5%	6.8%	-1.8%	45.5%	46.8%	48.9%	44.2%	52.9%	14.1%
2000-20	108.2%	8.6%	-4.1%	112.8%	112.5%	109.4%	112.3%	130.7%	32.1%
CC3									
2000-10	44.2%	18.4%	7.3%	39.4%	42.9%	42.9%	20.9%	52.8%	16.2%
2000-20	147.2%	33.9%	13.6%	136.8%	143.5%	144.6%	113.9%	164.9%	82.4%

Source: Calculated, based on Mantzos et al. (2003).

The LREM baseline scenario assumes an average, annual growth rate of 2.3 % for the current EU countries and 3.6-3.8 % for the new EU-10[1]. In comparison, the Low growth scenario assumes an annual growth rate of 1.6-1.7 % for the EU-15 and 3.4 % for the new EU-10. Hence, decoupling of materials use and waste generation will be achieved provided they grow at a lower rate than the GDP. Table 2 presents the key assumptions for the Low growth scenario.

In contrast to all other waste and material flows, a Sustainable Emission Pathway scenario (SEP) has been performed for the fossil fuel material flows. The latter is based on the assumption of certain energy and climate policy measures influencing particularly the energy mix. These changes relate e.g. to increased shares of renewable energies and switches from carbon-intensive coal towards less carbon-intensive crude oil and gas fuels.

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[1] Compared to the base year 2000.

Table 2. Low growth scenario: trends in key economic and demographic assumptions

	Gross Domestic product	Households expenditure	Gross Value Added
EU-15			
2000-10	17.7%	16.9%	19.6%
2000-20	39.4%	36.7%	42.1%
EU-10			
2000-10	39.0%	37.5%	40.1%
2000-20	94.2%	100.2%	99.1%
CC3			
2000-10	47.0%	31.9%	44.6%
2000-20	140.0%	110.5%	132.8%

Source: NTUA (2003).

3. Models for projection

Depending on the nature of the respective waste and/or material flow, three modeling types are used for making the baseline projections for material flows and waste.

In the general model, which is also the one used for the majority of material flows and waste streams, the past developments in quantities of waste/materials, economic activities, number of households/size of population have been used to analyse if there are links between these. If that is the case, and these links have been reliable in the past, they may be used for scenarios using given projections of economic activities and other demographic variables.

In addition to the general model, a model for end-of-life-vehicles (population type of model) and a model for fossil fuel material flows have been used. A short description of all three models is given in this section.

The general model is applied for projection of the following material flows and waste streams:

- Domestic extractions of minerals (industrial minerals and ores, and construction minerals)
- Domestic extractions of biomass
- Municipal waste
- Industrial waste
- Waste from the C & D sector
- Packaging
- Paper and cardboard
- Glass.

The end-of-life-vehicles model has been used to project the trend for waste oil and used tyres.

The explanatory parameters (or driving forces) used to estimate the future trends of various waste streams are presented in Table 3. For municipal waste, industrial waste, C&D, paper and board, glass and packaging waste, the estimations are based on the key assumptions of the LREM scenarios. For waste oil and used tyres the projected car stock is the main driving force.

Table 3. Explanatory parameters for waste generation

Waste stream	Explanatory parameters
Municipal waste	No of households (population or PFC of food, beverages and clothing (01, 02, and 03)
Industrial waste	Production within industry (fqd), or total GVA
C & D waste	Production in the building and construction sector (fqf)
Paper & cardboard	PFC of food and non-alcoholic beverages (01), recreation and culture (09), production in trade (fqg), and market and non-market services (fqms and fqns)
Glass	PFC of food and non-alcoholic beverages (01), alcoholic beverages, etc. (02), and production within industry (fqd)
Packaging	Total PFC, GDP or total population
Waste oil	Car stock
Used tyres	Car stock

For the scenario projections for material flows, not all elements of the economy-wide material flow account could be used. Only material inputs have been considered, i.e.

material resources entering the national economy. Broadly speaking, material inputs are distinguished into domestic extractions and imports. Further, material inputs (domestic and imported) are broken down by material categories, namely fossil fuels, metal and ores, industrial minerals, and biomass.

As a result of the limited use of the overall material flow accounting framework, it was not possible to have projections of some prominent aggregate indicators (e.g. DMI or DMC). Projections have been made only for domestically extracted material inputs, with the exception of fossil fuels, where also the imports and exports (net-imports) have been projected:

Fossil fuels	domestic extraction	+	net imports	=	DMC$_{\text{fossil fuels}}$
Metals	domestic extraction		n.a.		n.a.
Construction minerals	domestic extraction		n.a.		n.a.
Biomass	domestic extraction		n.a.		n.a.
All	domestic extraction		n.a.		n.a.

The explanatory parameters applied in the projections for material flows are presented in Table 4.

Table 4. Explanatory parameters for material flows

Material flow	Explanatory parameter	
	EU-15	EU-10 and CC3
Fossil fuels	PRIMES model: ktoe is transformed to metric tonnes	PRIMES model: ktoe is transformed to metric tonnes
Industrial minerals & metal ores	Production within industry (fqd)	Minerals: Production within industry (fqd) and construction (fqf)
Construction minerals	Production within construction (fqf)	
Biomass	Production within agriculture and forestry (fqa)	Production within agriculture and forestry (fqa)

Note: ktoe: kilo tonnes oil equivalents.

Further potential explanatory variables, which may significantly determine the domestic extraction of minerals and biomass, are not considered. For instance, imports may play a significant role in the case of industrial minerals and metal ores and harvest of biomass; or investments into infrastructures may have a significant influence on the domestic extraction of construction minerals. Unfortunately, those socio-economic parameters (e.g. imports, investments) are not output parameters of the LREM baseline scenario.

3.1. The general model

The use of resources and generation of waste relate to a number of economic activities, and different economic activities generate different streams and quantities of resources and waste. Looking at past developments in such streams, economic activities and the size of population, links between amounts of resources/waste, economic activities and population are analysed. If the links have been reliable in the past, given forecasts of economic activities and the population, the links may be used for the generation of projections/scenarios for the development in the use of resources and the amounts of waste.

Mathematically, the general equation tested on past observations is:

$$\log(w_i) = a_{0i} + a_{1i} \cdot (s_i \cdot \log(A1_i) + (1 - s_i) \cdot \log(A2_i)) + a_{2i} \cdot \log(pop) + a_{3i} \cdot T + d \cdot Dummy$$

Eq. (1)

where w_i is the amount of waste (or resources) of waste stream (or resource) i, $A1_i$ and $A2_i$ are two different economic activities, e.g., the private consumption of categories of goods or the production within various branches, pop is the size of the population and T is time. T is included in the equation to catch trend-wise changes in the amount of waste. Such trends may occur due to structural changes, i.e. changes in the relative size of waste generating activities, or changes in the waste collection systems, what is included in the individual waste streams and how much of the waste generated is collected. Past trends may be extended into projections. However, large historical trends are not likely to continue in the long run. If they are to continue, this requires some specific explanation. Therefore, the module includes a possibility to phase out the trend over a specified period. Finally, the equation includes a dummy-variable that is zero in some years and one in other years. Dummy-variables may be included to correct for data breaks or outlayers.

The parameters $s_i, a_{0i}, a_{1i}, a_{2i}$ *and* a_{3i} are estimated on past observations. Interpreting parameters, s_i is the share of waste stream *i* linked to the economic activity $A1_i$, and $(1-s_i)$ is the share linked to activity $A2_i$, i.e., s_i is a figure between 0 and 1. If it is known what share of the waste stream is related to activity $A1_i$, s_i may be restricted to this value. If time series for the share are available the two equations relating the waste streams to $A1_i$ and $A2_i$, respectively might be formulated. However, if the share is not known, but only that the waste stream is related to two activities, the aggregated data for the waste stream are used to estimate s_i. Restricting s_i to either 1 or 0 implies that the waste stream is only linked to one economic activity, and Eq. (1) reduces to Eq. (2). The parameter a_{1i} is the elasticity of waste stream *i* with respect to the activity level, i.e., if the activity level increases by 1%, the amount of waste increases by $a_{1i}\%$. a_{i2} is the elasticity with respect to changes in the population and a_{i3} is a trend-wise annual change in the amount of waste.

$$\log(w_i) = a_{0i} + a_{1i} \cdot \log(A_i) + a_{2i} \cdot \log(pop) + a_{3i} \cdot T + d \cdot Dummy \qquad \text{Eq. (2)}$$

Equations (1) and (2) contain two sets of level variables $A1_i, A2_i$ and pop. Reasonable free estimations of parameters to both sets of variables are difficult to obtain and not easy to interpret. Therefore, in order to estimate Eq. (1) or Eq. (2), a number of parameter restrictions are imposed. However, the equation is formulated in the module as Eq. (1) and the parameter values (restricted or not) are specified in an input sheet.

Assuming that $a_{1i} = 1.0$ Eq. (2) reduces to:

$$\log\left({w_i}\big/{A_i} \right) = a_{0i} + a_{2i} \cdot \log(pop) + a_{3i} \cdot T + d \cdot Dummy \qquad \text{Eq. (3)}$$

i.e., the waste coefficient depends on the size of population and time.

Assuming $a_{2i} = 1.0$ Eq. (2) reduces to:

$$\log\left({w_i}\big/{pop} \right) = a_{0i} + a_{1i} \cdot \log(A_i) + a_{3i} \cdot T + d \cdot Dummy$$

i.e., the waste per inhabitant depends on the level of activity and time. This may be somewhat difficult to interpret. An easier equation to interpret is that the waste per inhabitant depends on the activity level per inhabitant and time. To obtain this formulation, the parameter restriction on Eq. (2) is $a_{2i} = 1.0 - a_{1i}$ and Eq. (2) reduces to:

$$\log\left(\frac{w_i}{pop}\right) = a_{0i} + a_{1i} \cdot \log\left(\frac{A_i}{pop}\right) + a_{3i} \cdot T + d \cdot Dummy \qquad \text{Eq. (4)}$$

Furthermore, imposing the restriction $a_{2i} = 0.0$ on Eq. (3), or $a_{1i} = 0.0$ on Eq. (4) and leaving out dummy-variables, the equations reduce to an annual change in the waste coefficient, or in the amount of waste per inhabitant:

$$\log\left(\frac{w_i}{A_i}\right) = a_{0i} + a_{3i} \cdot T \quad \text{or} \quad \log\left(\frac{w_i}{pop}\right) = a_{0i} + a_{3i} \cdot T \qquad \text{Eq. (5)}$$

Taking first differences in Eq. (5), it is seen that a_{3i} is the annual % change in the waste coefficient, or in the amount of waste per inhabitant:

$$\Delta \log\left(\frac{w_i}{A_i}\right) \quad or \quad \Delta \log\left(\frac{w_i}{pop}\right) = a_{3i}$$

i.e., if $a_{3i} = 0.02$, the waste coefficient, or amount of waste per inhabitant increases by 2% p.a.

Finally, if $a_{3i} = 0.0$ in Eq. (5), the equation reduces to assuming a constant waste coefficient, or amount of waste per inhabitant:

$$\log\left(\frac{w_i}{A_i}\right) \quad or \quad \log\left(\frac{w_i}{pop}\right) = a_{0i} \qquad \text{Eq. (6)}$$

If a_{0i} is estimated on past values, it represents the average waste coefficient or amount of waste per inhabitant. An alternative is to set a_{0i} equal to the value in the last observable year. This may be preferable if it is evaluated that the quality of waste data has improved over time, or that the most recent value best mirrors the future waste coefficient.

Testing the various specifications, Eq. 1 is, in general, estimated imposing the parameter restrictions given in Table 5. However, the inclusion of one or two activity variables is mainly decided from a priory consideration, i.e., for most of the waste streams, s_i is priory restricted to one or zero. Free estimation of s_i is tested only for waste streams linked both to private consumption categories and to the production within sectors. In the module (and in the following pages), the variable $A1_i$ is the private consumption, or some categories thereof, and $A2_i$ is the gross value added within some sectors. That is, if a waste stream is linked to private consumption, only, s_i is restricted to one and if a waste stream is linked to gross value added in some sectors, s_i is restricted to zero.

A general problem with modelling streams of waste is the limited number of historical observations. Given few historical observations, the number of parameters that may be freely estimated is also limited, and for a number of waste streams, this also limits the number of equations tested.

Table 5. Combinations of parameter restrictions in Eq. (1)

Equation \ parameter	s_i	a_0	a_1	a_2	a_3
eq. (1)	free	free	free	free	free
eq. (2)	1.0	free	free	free	free
eq. (3)	1.0	free	1.0	free	free
eq. (4)	1.0	free	free	$1-a_1$	free
eq. (4) alternative	1.0	free	free	$1-a_1$	0.0
eq. (5) activity	1.0	free	1.0	0.0	free
eq. (5) population	1.0	free	0.0	1.0	free
eq. (6) activity	1.0	free	1.0	0.0	0.0
eq. (6) population	1.0	free	0.0	1.0	0.0

In general, dummy variables are defined to be zero in projections, but may in the module be used for including exogenous evaluated changes in specific waste streams. If a dummy variable becomes one in the projection and the coefficient to this is 0.02, the waste stream increases by 2% in the year the dummy variable changes from zero to one.

3.1.1. Forecast methodology

In analyses of past developments, the activity variables are taken from Eurostat, and the LREM-baseline is used in forecasts. However, the two sets of data have different classifications and base-years. The Eurostat data are in constant 1995 prices and the LREM-baseline is in constant 2000 prices. Two sets of activity data are used: household consumption expenditure by category of goods and Gross Value Added by sectors.

Forecast of Household Consumption Expenditure

The LREM baseline only forecasts total private consumption expenditure. But in the development analyses of the amount of waste, for some waste streams, the amount is linked to the consumption of categories of goods, e.g., municipal waste is linked to the consumption of food, beverage and clothing.

To forecast categories of private consumption, the share of the category in total private consumption is simply calculated and it is assumed that past trends in shares continue in the future, i.e.:

Share of category *f* at time *t*: $Sf_t = Cf_t / Ct_t$

Average change in share of *f* in the observation period $Apf = \sqrt[n]{Sf_t / Sf_{(t-n)}}$

Future share of *f* : $Sf_{t+1} = Sf_t \cdot Apf$

Future consumption of *f* : $Cf_{t+n} = Ct_{t+n} \cdot Sf_{t+n}$

where Cf_t is the consumption of category *f*, Ct_t is total private consumption and Apf is the average annual change in this past share.

This is a very simple way to generate forecasts of categories of private consumption, not taking into account differences in income and price elasticities of the different categories of private consumption. However, with only forecasts of total private consumption, and lack of a demand system, simple alternatives are difficult to find.

The problem of different price base-years in the historical data and the LREM baseline is solved by transforming the LREM baseline into 1995-prices using the 1995-values in the two base-year calculations, i.e., the ratio:

$$Ct_{1995(Eurostat)} \Big/ Ct_{1995\,(Cafe-baseline)}$$

Using this for the calculation of consumption by categories of goods, it is implicitly assumed that the development in prices for each category of goods is equal to the price development for the total private consumption.

Forecast of Production by sectors
The LREM baseline includes a sector classification that differs from the classification in Eurostat (b_a17_k) used for analyses of past developments. However, the following links may be established between the two classifications:

Eurostat b_a17_k	code	LREM-baseline
Agriculture etc	a, b	Agriculture
Energy and mining	c, e	Energy
Manufacturing	d	Industry
Construction	f	Construction
Wholesale, Hotels, Transport	g, h, i	Trade
Finance, Real estade	j, k	Market services
Public administration	l, m, n, o, p	Non-market services

Concerning price-levels, the LREM baseline is translated to 1995 constant prices using the GVA-price in the two sources for 1995. Hereby, it is implicitly assumed that from 1995 to 2000, the price development in the individual branches was identical.

3.2. Model for end-of-life vehicles

The number of end-of-life vehicles is modelled from the population, the vehicle density (number of vehicles per 100 capita) and the lifetime of vehicles. This paper gives a summary concerning the number of end-of-life vehicles (ELV) in the EU-15 countries.

Population:
Historical data on population in EU-15 from 1970-2000 as well as projected data for 2001-2015 are given in Eurostat New Cronos data. Prognosis for 2000, 2010 and 2020 is found in Europe's Environment: Statistical Compendium for the Second Assessment. European Environment Agency, 1998.

Vehicle density:
Historical data on car density valid for EU-15 in 1970-1998 (number of passenger cars per 100 capita) are from Eurostat (EU Transport in Figures. Statistical Pocketbook 2000. Eurostat.).

To get forecasts until 2015, it is assumed that car density over the years develops as an S-shaped curve starting with a small yearly increase followed by a period with larger increase and ending at a certain saturation level. Mathematically, this is represented by a three-parameter Gomperts function:

$$F(t) = G / Exp\{Exp[A*(t-2000)+B]\}$$

where t is the year and G, A and B are constants estimated from historical values. G, A and B are country specific. F(t) models a curve with an asymptotic upper limit G (saturation value).

Forecasts of the stock of cars are found by multiplying projections for population by car density.

Lifetime:
Vehicles do not have the same lifetime. Some are scrapped after a few years while others are used for a long period, e.g., 20 years. Therefore, the lifetime of vehicles is modelled by a modified Weibull distribution. For EU-15, the parameters for this distribution are transferred from the CASPER model where they are estimated from empirical data. For Denmark, the parameters are updated based on new data. The parameters are assumed to depend on the country, but not on the vintage.

The Weibull parameters for W-Germany are used for the entire Germany, including former GDR. For the new countries, Finland and Austria, it is chosen to use the Weibull parameters for Denmark. For Sweden, the UK parameters are chosen. These choices are based on climate, vehicle density, and the level of taxation of purchase of vehicles.

For Iceland and Norway, parameters equal to those of Denmark are chosen (mean lifetime 14.3 years), and for Liechtenstein, parameters equal to those of Germany are chosen (mean lifetime 12 years). A rather long mean lifetime of 20 years is expected for Central and Eastern Europe - almost corresponding to Portugal. For Turkey and Cyprus, a lifetime equal to that of Greece has been chosen (mean lifetime 22.8 years), and for Malta, a lifetime equal to that of Italy (mean lifetime 12.7 years).

The modified Weibull distribution is given by:

$$F(t) = \mathrm{Exp}\left\{ -\left[(t+b) / T \right]^{b} \right\} \qquad F(0) = 1$$

t	Time (year)
$F(t)$	Life time function Gives the fraction of vehicles that are still in operation after t years
T	Weibull parameter # 1. Time parameter
b	Weibull parameter # 2. Combined failure steepness and translocation

Vintage distribution:
Computations start in 1970. For this year, a vintage distribution is transferred from the CASPER model. This distribution is assumed to be the same for all countries.

End-of-life vehicles:
The calculations start in 1970 and continue until 2015. For each year, the number of vehicles of each vintage is recorded. For a specific year, the main lines of the calculations are as follows. Firstly, for each vintage, the number of scrapped vehicles is calculated from the stock and the Weibull distribution. Then the number of new cars is calculated as the difference between the empirical, or forecasted stock, and the calculated total stock reduced by the number of scrapped cars.

The calculations can be summarised by the following algorithm:

```
For $v < t$:
    $\mathrm{Stock}(t,v) = \mathrm{Stock}(t-1,v) * F(t-v)/F(t-v-1)$
    $\mathrm{Scrap}(t,v) = \mathrm{Stock}(t,v) - \mathrm{Stock}(t-1,v)$

For $v = t$:
    $\mathrm{Stock}(t,v) = \mathrm{New}(t) = \mathrm{TotalStock}(t) - \sum_{v1<v} \mathrm{Stock}(t,v1)$
    $\mathrm{Scrap}(t,v) = 0$
```

where

t	Year
v	Vintage
Scrap(t,v)	Number of scrapped cars of vintage v in year t
Stock(t,v)	Stock of cars of vintage v in year t
New(t)	New cars in year t
TotalStock(t)	Total stock of cars in year t
F	Modified Weibull distribution as defined above

The main results of the calculations are shown in Table 6. The car stock in the EU-15, EU-10 and CC2 are shown in Annex I.1.

Table 6. Number of end-of-life vehicles in the EU-15

Thousands	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015
Austria	35	75	107	129	168	195	217	257	290	299
Belgium	630	227	329	375	407	461	515	552	587	620
Denmark	32	66	90	90	97	104	112	118	125	132
Finland	21	45	62	71	94	120	135	136	139	156
France	602	1045	1274	1471	1849	1885	2117	2247	2348	2475
Germany	785	1343	1459	1910	2410	2664	3113	3490	3631	3965
Greece	1	1	6	16	24	39	70	91	106	129
Ireland	50	41	44	70	75	69	94	111	113	126
Italy	396	852	928	1283	1590	1820	2335	2476	2549	3072
Luxembourg	22	8	13	15	19	22	27	31	36	40
Netherlands	666	287	423	532	576	635	687	706	775	786
Portugal	3	6	20	35	38	54	85	121	147	185
Spain	164	236	276	626	785	879	1223	1349	1528	1699
Sweden	291	237	223	297	296	347	355	361	395	395
UK	1491	1223	1202	1605	1620	2041	2156	2330	2633	2699

3.3. Model for fossil fuel material flows

The domestic extraction and the import of fossil fuel material flows have been modelled using a ‘coefficient-approach’. The principle is to ‘translate’ energy balance data – externally obtained – from energetic units into metric tonnes.

For the different scenarios, the quantity of various energy carriers (hard coal, lignite, natural gas, etc.) has been projected by an external model: PRIMES. These projections include primary production and net imports. However, the results are reported in energetic units [ktoe (kilo tonnes oil equivalents)] which have been transformed into metric tonnes by using country specific energy coefficients [kt/ktoe]. Those country specific energy coefficients were obtained from historical energy balances files which contain for each flow and energy carrier both metric tonnes and ktoe. Hence, it was possible to calculate country specific coefficients for each energy carrier and each flow (primary production and import). For most countries, these coefficients could be calculated for the year 2001; in general, the most recent year was used.

The Austrian example in the following table may illustrate the approach. Row-wise, the table shows the different energy carriers; aggregates like ‘totals’, ‘solids’, ‘liquids’, and ‘gas fuels’ are summed up, i.e. no coefficient exists for those aggregates. Column-wise, the table shows for primary production as well as for net imports three columns: (1) the value in energetic units [ktoe], (2) the specific energy coefficient as derived from Eurostat energy balances, and (3) the value in 1000 metric tonnes obtained from simply multiplying columns (1) and (2).

For instance, the import of 4,094 ktoe of hard coal transforms to 6,016 kt by applying an energy coefficient of 1.47.

Table 7. Example for transforming fossil fuels from energetic units to metric tonnes by using specific energy coefficients, Austria, 2030 (baseline scenario)

	PRIMARY PRODUCTION			NET IMPORTS		
	ktoe	coefficient (kt/ktoe)	1000 metric tonnes	ktoe	coefficient (kt/ktoe)	1000 metric tonnes
	1	*2*	*3=1*2*	*1*	*2*	*3=1*2*
Solids:						
Hard coal	0	1.49	0	4094	1.47	6018
Patent fuels	0		0	0	1.35	0
Coke	0		0	576	1.47	847
Tar, pitch, benzol	0		0	0		0
Lignite	0	4.27	0	0	4.23	0
Other solids	0		0	2	2.17	4
Crude oil	0	1.021510261	0	9553	1.02151444	9759
Feedstocks	0		0	673	0.985131992	663
Liquids:						
Refinery gas	0		0	0	0.84	0
Liquified petroleum gas	0		0	109	0.910154726	99
Gasoline	0		0	-326	0.951517898	-310
Kerosene	0		0	216	0.973731884	210
Naptha	0		0	0	0.952380952	0
Diesel oil	0		0	2271	0.989787667	2248
Fuel oil	0		0	-436	1.046746759	-456
Other liquids	0		0	533	0.99735993	531
Gas fuels:						
Natural gas	274	1.013351773	278	9642	1.013351757	9771
Coke-oven gas	0		0	0	1.403857953	0
Blastfurnace gas	0		0	0		0
Gasworks gas	0		0	0		0
Total	274		278	26855		29383

4. Projections for waste generation

The projections for waste generation include eight streams: municipal waste; industrial waste; construction and demolition waste; paper and cardboard; glass; packaging waste; used tyres and waste oil.

The geographical coverage is mainly the EU-15 as waste statistics historical data for economic activities are more comprehensive in general than is the case for the EU-10 and CC2. Thus, projections for municipal waste; waste oil; and used tyres are made for the EU-10 and CC2. In addition, a projection for Norway and Switzerland is made for municipal waste.

4.1. Municipal waste

Municipal waste[2] includes household waste and similar waste. The definition includes bulky waste (e.g. white goods, old furniture); and yard waste, if managed as waste. In addition it includes waste originating from: commerce and trade, small businesses, office buildings and institutions (schools, hospitals, government buildings). It also includes waste from selected municipal services, i.e. waste from park and garden maintenance, waste from street cleaning services (street sweepings, the content of litter containers, market cleansing waste) if managed as waste.

In general, there are large variations between countries in the quantity of municipal waste generated per capita. The Western European countries (former EU-15, Norway and Switzerland) produce more waste per capita than the new EU Member States and the candidate countries. In 2000, the generated waste per capita varied between 422 kg in Greece and 655 kg in Luxembourg, while Norway and Switzerland generated 622 and 669 kg. In the 10 new Member States, Lithuania generated 293 kg while Hungary generated 458 kg. Malta and Cyprus have a particular status with 503 and 676 kg per capita. The Candidate countries Bulgaria and Romania generate 352 and 396 kg per capita respectively.

The projections for the EU-15, the new EU-10, CC2 and EEA2 are all estimated as a sum of the projections for the countries where projections are available. For example, no projections are available for Luxembourg for municipal waste, paper & board, glass, packaging and waste oil.

4.1.1. Estimations

EU-15 Member States

For municipal waste, it is chosen to test only economic activity variable; the private consumption of food, beverage and clothing, assuming that these categories of private consumption are the main activities generating municipal waste. Other explanatory parameters tested are the size of population and the number of households.

For the combinations of parameter restrictions given in Table 5, estimation results for individual countries have been tested. For EU-15 countries, the central estimations for the model are summarised in Table 8. Given the limited number of observations for municipal waste, the estimations tested show, not surprisingly, multi-colliniarity between the private consumption, the size of population/the number of households and the trend. This implies that free estimation of the parameters gives estimates that are not interpretable.

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[2] According to the definition used by Eurostat in the Joint Questionnaire

Another conclusion from the estimations tested is that for most countries a very large share of the development in the amount of municipal waste is explained by either the development in the economic activity level or in the size of population/the number of households. However, for most of the countries, the explanatory power of the equation is significantly improved by the inclusion of a trend (t-statistics for the trend coefficient a_3 are quite large) i.e., changes in the activity level or the size of population/number of households explain most of the past changes in the amount of municipal waste, but for most of the countries, the waste coefficient is changing over time (trend-wise).

From a theoretical point of view priority is given to explaining the amount of municipal waste as dependent on the private consumption, to the effect that an increase in the consumption increases the amount of waste. From the estimations it is concluded that for most countries the size of population or the number of households are closer correlated with the amount of waste than the level of private consumption, i.e. the model is a trend-wise change in the amount of waste per inhabitant or per household. The difference between using the population or the number of households as the explaining variable is mainly a change in the size of the trend. Historically, for most countries the number of persons per households has decreased over time (trendwise), i.e. the number of households increases faster than the size of the population and the estimated trend-coefficient should become smaller when the number of households is used in the equation.

From Table 8 it is seen that this is also the general change, but there are exceptions. In the model the number of households and the activity level are preferred as explaining variables. Concerning projections, large historical trends may continue for some years, but given the limited historical time series, a continuation of these in the long-term is not well founded. From Table 8, it is noticed that past trends are large for Austria, Belgium, Denmark, Italy, Portugal Sweden and especially Spain. Furthermore, it is noticed that the DW-statistics are very low for Portugal. That is, for Portugal the model has systematic errors and the equation lacks important explanatory variables. From the estimations tested, it is concluded that for Portugal, the DW-statistics are not significantly improved by the inclusion of the private consumption as an explanatory variable.

Table 8. Model parameters for municipal waste, EU-15

Country	Equation	No. of obs.	a_0	a_1	a_2	s	a_3	d	R^2	DW
AT	eq. (5) activ.	6	-3.488	1.000	0.000	1.000	0.018	0.303	0.933	3.332
			(-4.65)				*(2.31)*	*(6.40)*		
	eq. (5) pop.	6	-1.647	0.000	1.000		0.010	0.243	0.945	2.580
			(-2.42)				*(1.50)*	*(5.66)*		
	eq. (5) househ.	4	-1.557	0.000	1.000		0.019	0.248	0.986	3.167
			(-1.07)				*(1.28)*	*(6.50)*		
BE	eq. (5) pop.	10	-2.879	0.000	1.000		0.023		0.974	1.658
			(-21.39)				*(15.85)*			
	eq. (5) househ.	8	-1.771	0.000	1.000		0.021		0.941	1.542
			(-6.28)				*(7.01)*			
DE	eq. (5) pop.	5	0.991	0.000	1.000		-0.017		0.379	2.315
			(1.30)				*(-2.06)*			
	eq. (5) househ.	4	0.372	0.000	1.000		-0.002		0.334	2.863
			(0.73)				*(-0.35)*			
DK	eq. (5) pop.	9	-2.722	0.000	1.000		0.023		0.961	2.459
			(-15.19)				*(11.96)*			
	eq. (5) househ.	9	-1.317	0.000	1.000		0.017		0.957	2.252
			(-7.00)				*(8.24)*			
FI	eq. (5) activ.	3	-0.739	1.000	0.000	1.000	-0.009		0.983	2.982
			(-0.64)				*(-0.72)*			
FR	eq. (5) pop.	6	-1.703	0.000	1.000		0.011		0.975	1.977
			(-16.86)				*(10.29)*			
	eq. (5) househ.	6	-0.018	0.000	1.000		0.003		0.986	2.881

Country	Equation	No. of obs.	a_0	a_1	a_2	s	a_3	d	R^2	DW
			(-0.24)				*(3.34)*			
GR	eq. (5) activ.	6	-2.433	1.000	0.000	1.000	0.006	-0.164	0.872	2.026
			(-3.47)				*(0.74)*	*(-1.47)*		
IE	eq. (6) pop.	2	-0.579	0.000	1.000		0.000		na.	na
			(-87.51)							
	eq. (5) househ.	2	-0.549	0.000	1.000		0.000		na.	na
			(-69.24)							
IT	eq. (5) pop.	9	3.850	0.000	1.000		0.318	-0.103	0.982	2.537
			(7.60)				*(6.11)*	*(-1.44)*		
	eq. (5) househ.	6	-0.584	0.000	1.000		0.009		0.851	2.846
			(-1.19)				*(1.72)*			
LU	eq. (5) pop.	10	-1.460	0.000	1.000		0.010	-0.163	0.956	1.440
			(-4.37)				*(2.85)*	*(-7.40)*		
	eq. (5) househ.	8	0.2130	0.000	1.000		0.007	-0.169	0.913	2.285
			(-0.15)				*(0.50)*	*(-2.48)*		
NL	eq. (6) activ.	11	-1.389	1.000	0.000	1.000	0.000	-0.281	0.919	2.385
			(-104.50)					*(-9.00)*		
PT	eq. 5) pop.	9	-5.156	0.000	1.000		0.044		0.968	0.672
			(-18.10)				*(14.54)*			
	eq. (5) househ.	7	-2.610	0.000	1.000		0.029		0.958	1.092
			(-7.87)				*(8.39)*			
ES	eq. (5) pop.	12	-4.427	0.000	1.000		0.040	-0.305	0.991	2.215
			(-15.02)				*(13.42)*	*(-10.84)*		
	eq. (5) househ.	9	-2.852	0.000	1.000		0.033	-0.286	0.987	1.959
			(-3.35)				*(4.19)*	*(-6.71)*		
SE	eq. (5) pop.	6	-2.783	0.000	1.000		0.020		0.930	3.617
			(-9.51)				*(6.13)*			
UK	eq. (6) activ.	5	-1.427	1.000	0.000	1.000	0.000	0.293	0.767	3.221
			(-57.13)					*(5.24)*		
	eq. (5) pop.	6	-3.660	0.000	1.000		0.029		0.986	2.844
			(-16.59)				*(12.94)*			
	eq. (5) househ.	6	-2.230	0.000	1.000		0.023		0.994	1.280
			(-18.87)				*(19.39)*			

Note: Equations marked with yellow are the ones chosen in the estimations.

New EU-10 Member States

For the new EU Member States selected estimations for municipal waste are shown in Table 9. In general, municipal waste is linked to the number of households or the size of population. For the Czech Republic only, the inclusion of private consumption instead of the population improves the estimation results. This may be due to a limited reliability of consumption data for the new Member States in general.

Another general observation is that for almost all 10 countries breaks in the waste coefficient are observed within the observation period i.e. dummy variables are included. Most of the dummy variables are included to correct for a data shift in the years 1999 or 2000. All dummy variables are zero in the projections.

Commenting on specific countries, for Lithuania the amount of waste has decreased considerably implying a negative trend of 3 %. Considering the large structural changes in the past, the trend should be modified in the projection.

Table 9. Model parameters for municipal waste, EU-10

Country	Equation	No. of obs.	a_0	a_1	a_2	s	a_3	d	R^2	DW
CY	eq. (5) pop.	8	-3.124	0.000	1.000		0.027		0.888	1.636
			(-6.14)				*(5.12)*			
	eq. (6) househ.	1	0.181	0.000	1.000				n.a.	n.a.
CZ	eq. (6) pop.	6	-1.300	0.000	1.000			0.149	0.643	2.217
			(-25.44)					*(2.66)*		
	eq. (6) househ.	6	-0.341	0.000	1.000			0.185	0.713	2.363
			(-7.44)					*(3.68)*		
	eq. (6) activ.	6	-2.125	1.000	0.000	1.000		0.216	0.823	2.470
			(-58.37)					*(5.41)*		
EE	eq. (6) pop.	5	-0.772	0.000	1.000			-0.158	0.743	3.320
			(25.129					*(-4.60)*		
	eq. (6) househ.	5	0.139	0.000	1.000			-0.127	0.528	1.973
			(3.03)					*(-2.55)*		
HU	eq. (5) pop.	6	-1.680	0.000	1.000		0.009	0.095	0.933	2.330
			(-2.82)				*(1.48)*	*(4.44)*		
	eq. (5) househ	6	-0.396	0.000	1.000		0.006	0.071	0.862	3.324
			(-0.63)				*(0.96)*	*(2.49)*		
LV	eq. (5) pop.	6	1.003	0.000	1.000		-0.022	-0.271	0.985	2.689
			(2.77)				*(-6.07)*	*(-14.28)*		
	eq. (6) househ.	1	-0.293	0.000	1.000				n.a.	n.a.
LT	eq. (5) pop.	7	8.178	0.000	1.000		-0.093	0.001	0.706	2.490
			(2.15)				*(-2.46)*	*(0.01)*		
	eq. (5) househ.	8	2.848	0.000	1.000		-0.030	0.220	0.915	1.316
			(1.60)				*(-1.68)*	*(2.61)*		
	eq. (6) activ.	7	-1.654	1.000	0.000	1.000		0.4807	0.5219	1.91
			(2.95)							
MT	eq. (6) pop.	4	-0.758	0.000	1.000				0.815	0.872
			(-27.06)							
PL	eq. (5) pop.	7	-1.746	0.000	1.000		0.005	0.085	0.864	3.296
			(-4.49)				*(1.27)*	*(4.82)*		
	eq. (5) househ.	6	-1.738	0.000	1.000		0.018		0.508	1.950
			(-2.15)				*(2.12)*			
SK	eq. (5) pop.	4	-1.009	0.000	1.000		-0.001	-0.004	0.990	3.214
			(-71.14)				*(-10.08)*	*(-8.81)*		
	eq. (5) househ.	3	-1.142	0.000	1.000		0.012		0.966	3.000
			(-23.37)				*(24.75)*			
SI	eq. (6) pop.	2	-0.600	0.000	1.000				na.	na.
			(-9.38)							

Note: Equations marked with yellow are the ones chosen in the estimations.

Candidate countries and rest of EEA countries

For Bulgaria the explanatory power of the equation is improved significantly by the inclusion of a trend. However, looking at the data a considerable decrease in the waste coefficient is seen form 1995 to 1997, but after this decrease the waste coefficient is relatively constant. For Romania the equation has no explanatory power. However, the amount of waste and the number of households is relatively constant with random variation, i.e. the waste coefficient is relatively constant, but the changes in the amount of waste are not related to changes in the number of households.

For Norway and Switzerland, the population is used as the explanatory parameter as no Eurostat data for private consumption or number of households exist for these two countries. The Eq. (5) has been chosen, i.e. the projected trend includes trendwise changes (a_3) in the population.

Table 10. Model parameters for municipal waste, candidate countries, Norway and Switzerland

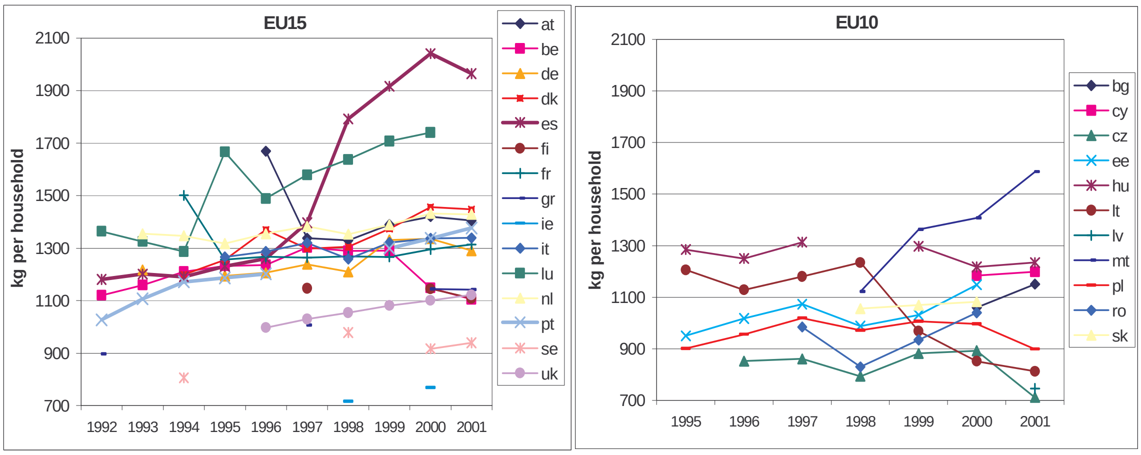
Country	Equation	No. of obs.	a_0	a_1	a_2	s	a_3	d	R^2	DW
BG	eq. (6) pop.	8	-0.837	0.000	1.000			-0.387	0.581	0.964
			(-18.55)					*(-3.03)*		
	eq. (6) househ.	1	0.148	0.000	1.000				n.a.	n.a.
			-							
RO	eq. (6) pop.	6	-1.132	0.000	1.000				0.049	1.616
			(-32.69)							
	eq. (6) househ.	4	-0.058	0.000	1.000				0.226	1.967
			(-1.20)							
NO	eq. (5) pop.	10	-1.163	0.000	1.000		0.007	-0.156	0.900	1.553
d9094			*(-1.39)*				*(0.82)*	*(-2.93)*		
CH	eq. (5) pop.	10	-0.489	0.000	1.000		0.000	-0.054	0.893	0.961
d9098			*(-3.06)*				*(-0.28)*	*(-3.50)*		

For the EU-15, the past trend (a3 parameter) is phased out over 5 years. This is due to the assumption that over the past 10 years collection systems have been extended and improved to cover more households (and commerce) and more waste streams, resulting in more waste being collected, managed and registered. Several EU Directives have been adopted in the late 1980s and the 1990s that set requirements for the definition and management of certain waste streams, thereby enhancing the focus on waste. However, it is unlikely that this past trend will continue in the future. Similarly, the trend has been phased out for the new EU-10, although at a longer time horizon of 10 years as there is still some room for improvement of collection systems.

4.1.2. Results

In general, the number of households has proved to be the best parameter to explain the development of municipal waste. In total, the trend for municipal waste has been estimated for 20 countries (with the exception of Finland, Greece, the Netherlands, Sweden, Czech Republic, Malta, Slovenia, Norway and Switzerland) using the number of households as the explanatory variable. For the remaining nine countries either the economic activity level or the size of population is used as the driving force.

Figure 1. Historical development of the waste per household, EU-15 and EU-10



To illustrate how the amount of municipal waste per household has developed in the past, the waste coefficients are presented in Figure 1. For the former EU-15 countries the quantity has risen steadily from some 1150-1300 kg per household to 1300-1450 kg. In 2000, the average amount per household for EU-15 was 1324 kg. There are also exceptions such as Spain that has experienced a major rise in collected quantities from 1996-2000. For the EU-10 the level of municipal waste per household is lower than in the EU-15, and it is difficult to see a general trend. For countries such as Lithuania and Hungary, the ratio has decreased while it has increased for Malta and Estonia.

The Baseline scenario estimates an increase in quantity in 2020 of approximately 20-25 % for the EU-15 and 15-20 % for the new EU Member States. For the candidate countries, Bulgaria and Romania, the change is estimated to 5-10 % and less than 5 % for the EEA countries, Norway and Switzerland. The projected trend is presented in Table 11.

It is also seen that the Low growth scenario deviates from the Baseline scenario by a few percentage points only, which is due to the fact the number of households and the size of population are assumed not to change. For the CC2 and EEA2 there is no deviation as the number of households and the population are the only explanatory variables here.

Table 11. Projection for municipal waste

%	Baseline scenario				Low growth scenario			
	EU-15	EU-10	CC2	EEA2	EU-15	EU-10	CC2	EEA2
2000-10	13.8	11.1	6.8	1.9	12.3	9.3	6.8	1.9
2000-20	22.5	16.8	6.0	3.5	20.3	14.6	6.0	3.5
2000-30	29.4	20.3	4.0	4.9	26.4	16.8	4.0	4.9

Note: The figures are from output files and should be interpreted with caution.

The Baseline scenarios for the EU-15, the EU-10, and the CC2 and EEA2 are presented in Figures 2, 3 and 4.

Figure 2. Baseline scenario for municipal waste, EU-15

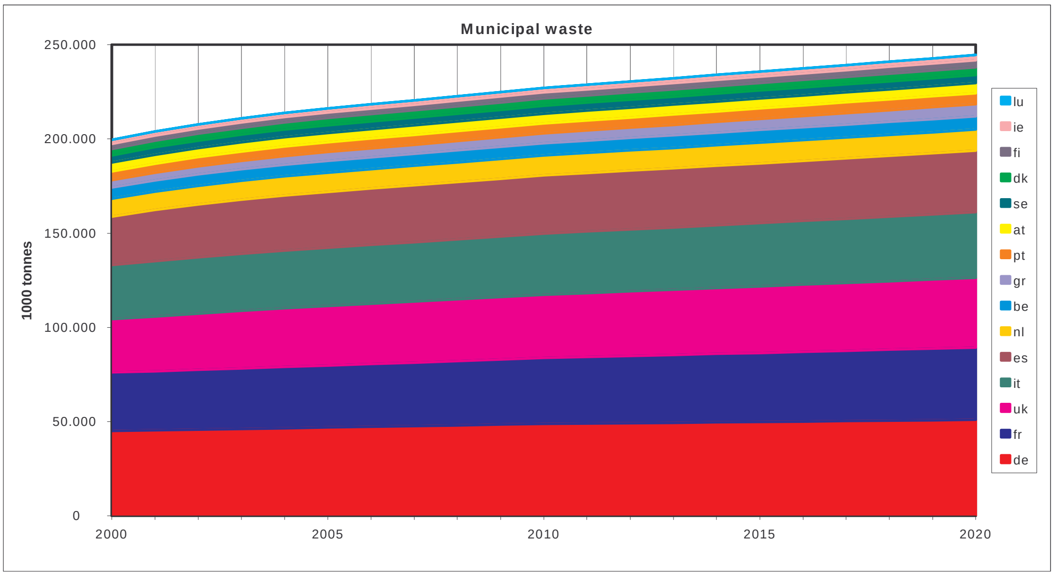


Figure 3. Baseline scenario for municipal waste, EU-10

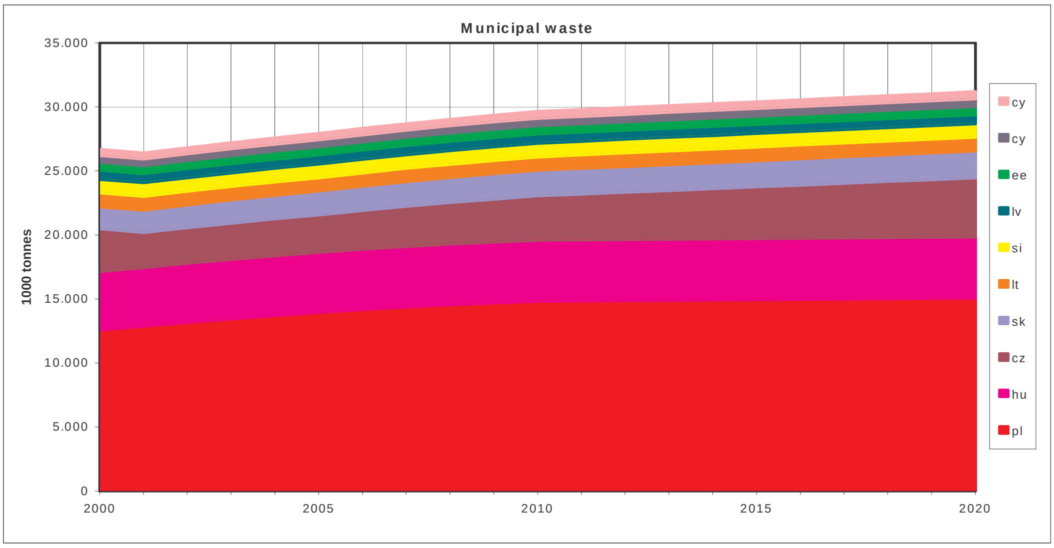
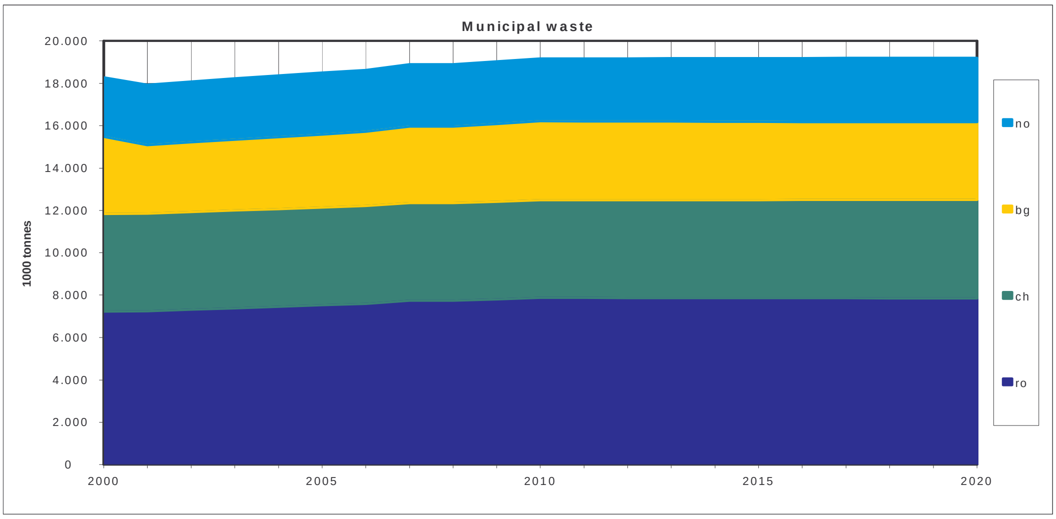


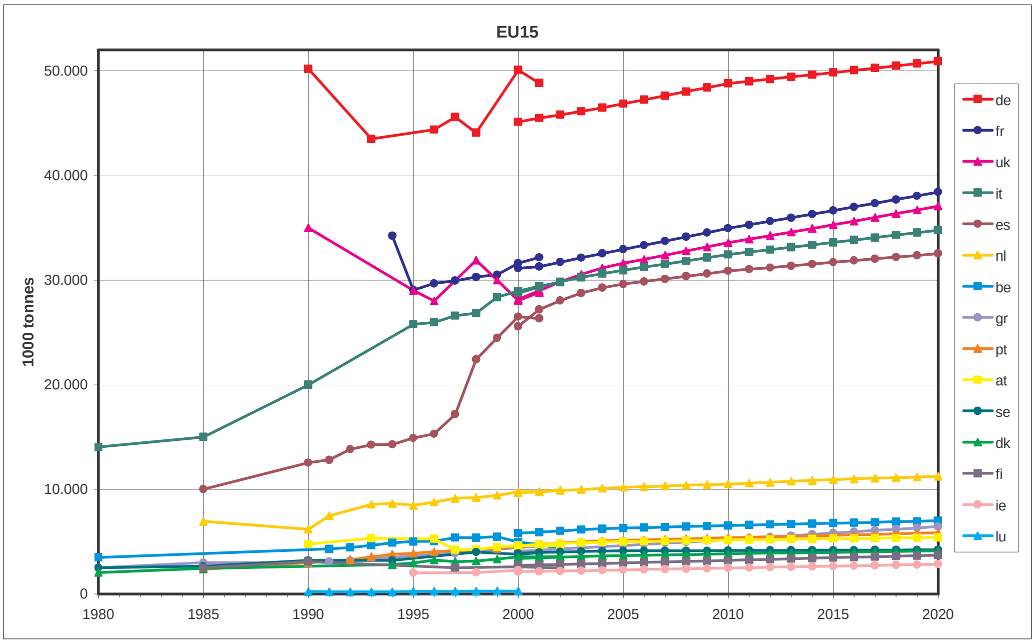
Figure 4. Baseline scenario for municipal waste, candidate countries, Norway and Switzerland



The historical quantities (1990-2001) of municipal waste and the Baseline scenario from 2000 to 2020 are presented in Figure 5 for the former EU-15, in Figure 6 for the new EU-10, and in Figure 7 for the CC2 and EEA2. Hence, the overlapping graphs in the years 2000 and 2001 show the difference between the actual quantities and the estimated ones. It should also be noted that the projection for the UK is in fact for England only as the available data for England seemed more reliable (or exact) than the ones for the UK reported to Eurostat.

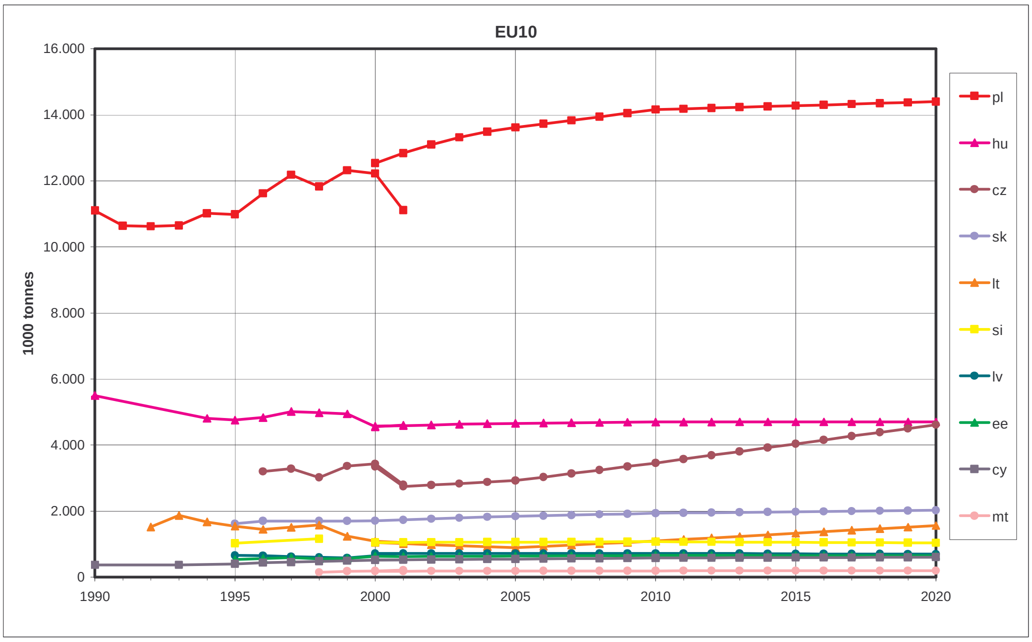
For the EU-15, the Baseline scenario shows some differences between countries. For Greece the projected quantity will increase by 55-60 %, while for Finland, Ireland and England (the UK) the projected increase is around 30-35 %. The smallest change projected is for Sweden with less than 10 %.

Figure 5. **Baseline scenario for municipal waste, EU-15, actual quantities 1990-2001 and projected trends 2000-2020**



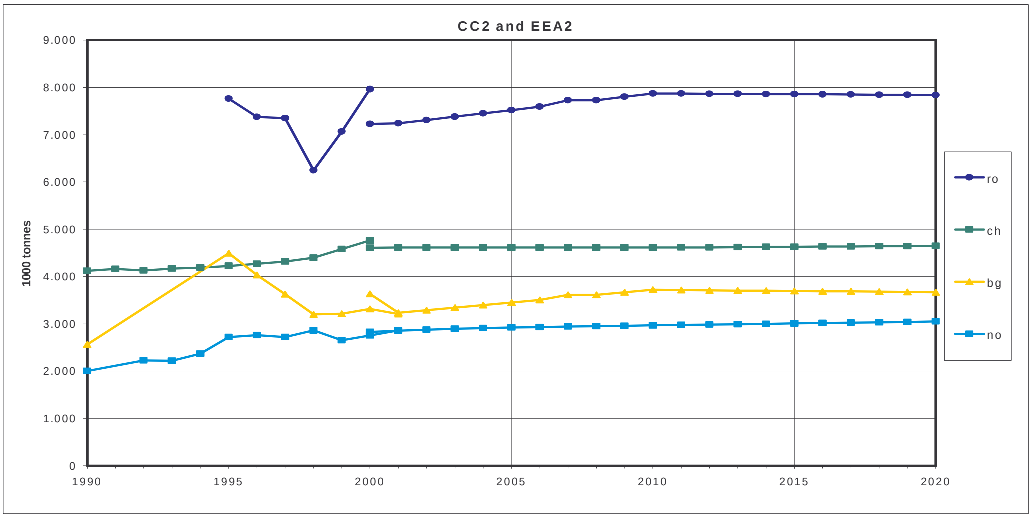
The Baseline scenario for the EU-10 shows a minor decrease in the total quantity for the year 2001 compared to the base year 2000. The reason for this is decreasing quantities in the Czech Republic, Lithuania and Estonia. From 2002 onwards the quantity is projected to increase. Estonia reaches the 2000-level in 2004, while the Czech Republic reaches the 2000-level in 2009 and Lithuania in 2025.

Figure 6. **Baseline scenario for municipal waste, EU-10, actual quantities 1990-2001 and projected trends 2000-2020**



In Figure 7 the Baseline scenario for Bulgaria, Romania, Norway and Switzerland is presented. For Bulgaria and Romania the explanatory variable is the amount of households and for Norway and Switzerland it is the population. The amount of municipal waste is projected to rise at very modest levels in all countries, except for Bulgaria where a minor decrease in the total quantity is projected.

Figure 7. **Baseline scenario for municipal waste, CC2 and EEA2, actual quantities 1990-2001 and projected trends 2000-2020**



Looking at the amount of waste estimated per capita, it can be concluded that waste is estimated to increase at a higher rate than the population which implies that the waste per capita is increasing during the period. According to the LREM Baseline, the population in the EU-10 is even projected to decrease by some 4 % in 2020. Figures 8 and 9 present the projected quantity per capita.

Figure 8. **Baseline scenario for municipal waste per capita, EU-15**

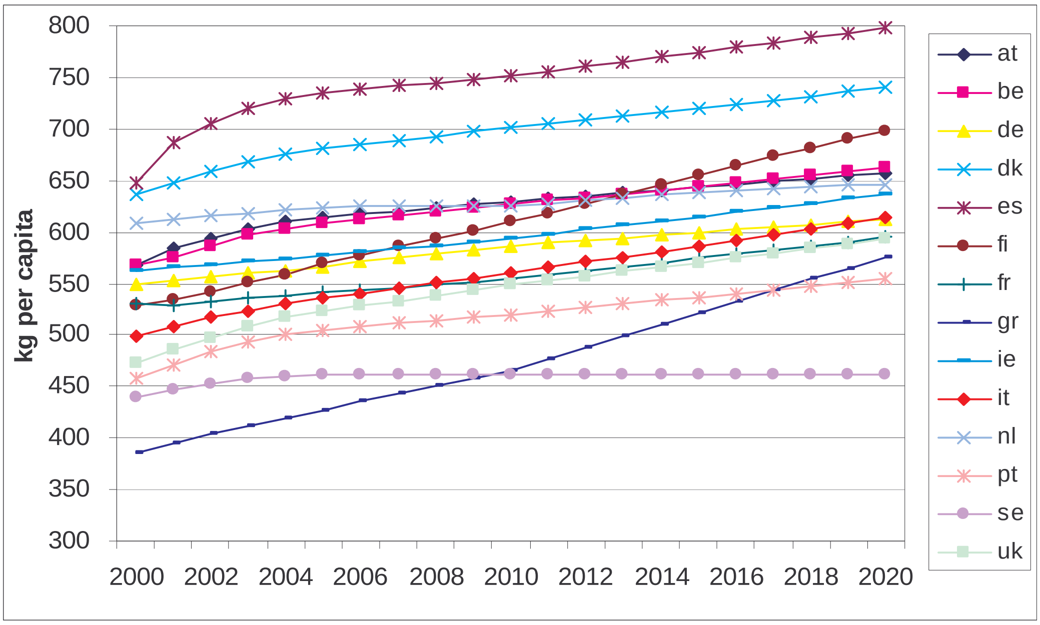
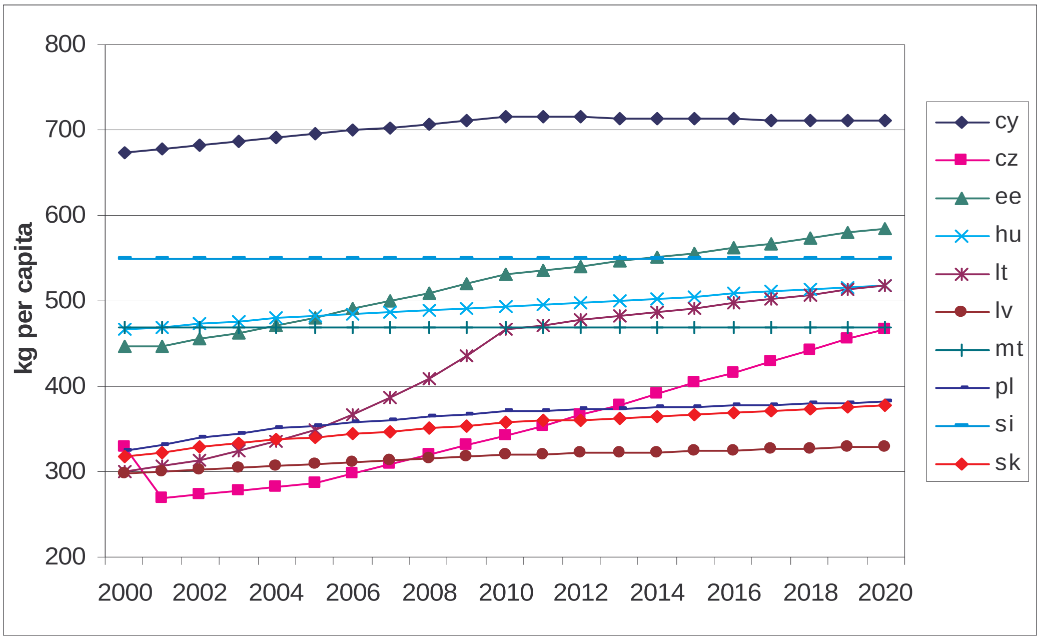


Figure 9. Baseline scenario for municipal waste per capita, EU-10



The Low growth scenario for the EU-15 and the EU-10 is showed in Figures 10 and 11 but does not present any major changes from the Baseline scenario.

Figure 11. Low growth scenario for municipal waste, EU-15

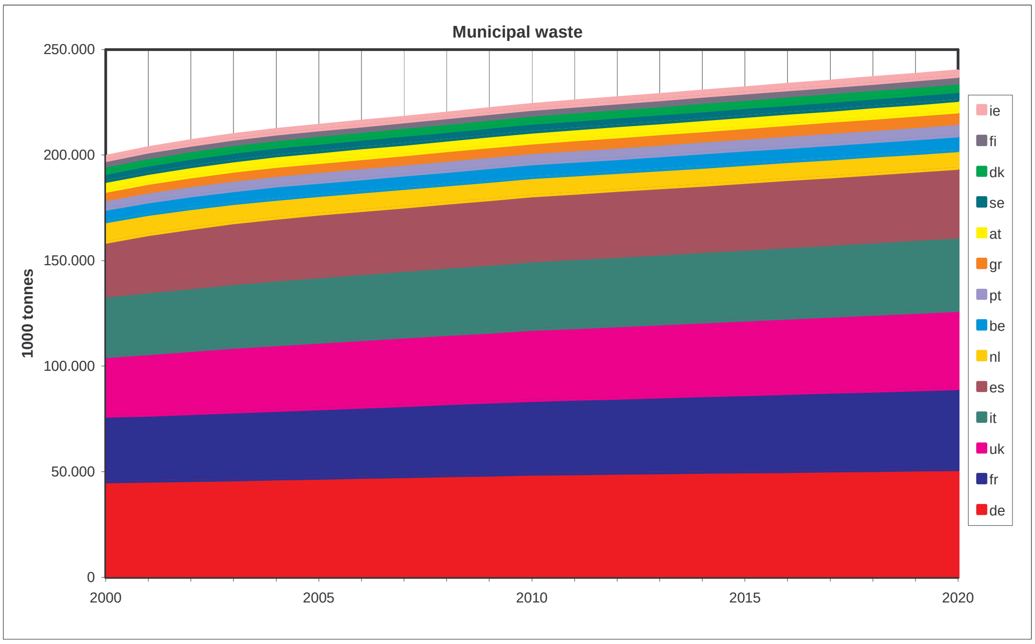
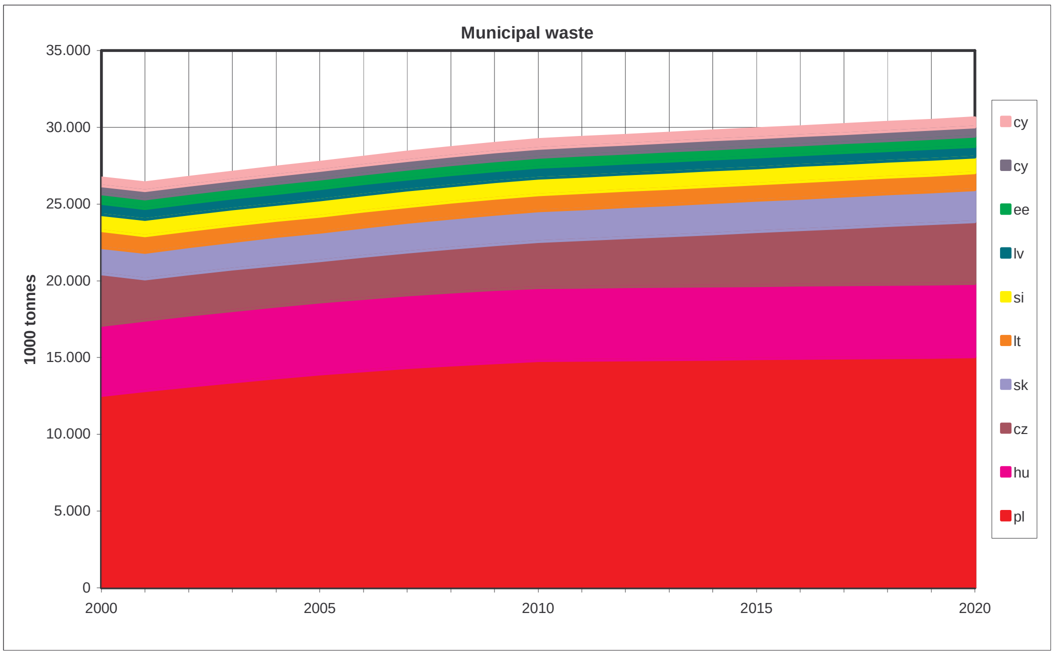


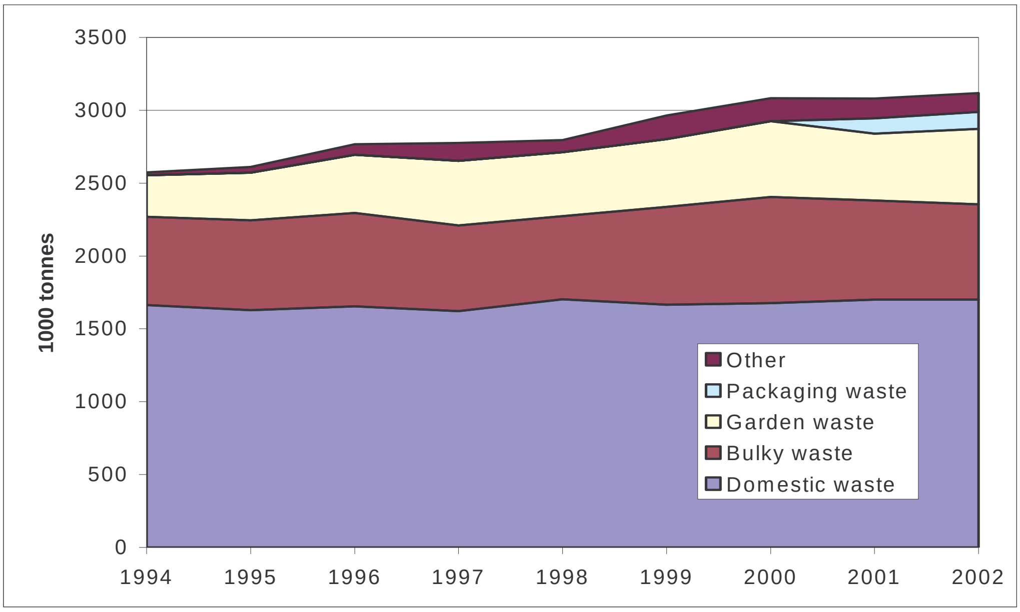
Figure 11. Low growth scenario for municipal waste, EU-10



4.1.3. *Analysis of municipal contra domestic waste*

Municipal waste includes a number of waste categories that have increased considerably in the past, partly due to improved collection of these waste streams, i.e. the amount of municipal waste increases partly due to improved waste collection and not necessarily due to increased generation of waste. To analyse this, we have looked at data for Denmark, where it has been possible to obtain a time series for the composition of municipal waste. Figure 12 shows the development in household waste by categories in Denmark.

Figure 12. Amount of household waste in Denmark, 1994-2002



It is noticed that while the total amount of municipal waste increases by about 2.4% p.a., the amount of domestic waste is almost constant, increasing by 0.3% p.a., only. The amount of garden waste and other waste more than doubled over the period, and this is mainly due to improved collection, not increased generation.

In addition, one may not expect this increase to continue for the next 20 years. Therefore, in this section we analyse estimations on domestic waste for Denmark and compare the results with estimations on municipal waste.

Table 12 shows estimations for municipal and domestic waste respectively, related to the size of population or the number of households. In addition, for domestic waste two estimations are shown where the amount of waste is related to the private consumption of food, beverage and clothing. Comparing estimations for municipal - and domestic waste, the table shows a significant positive trend in municipal waste and that the trend in domestic waste is close to zero, a difference of about 2% p.a. Concerning R^2-values, the higher value for municipal waste mainly reflects the higher trend.

The last two estimations where the amount of domestic waste is related to relevant categories of private consumption show that when the private consumption per inhabitant or per household increases by 1% the amount of domestic waste per inhabitant or per household increases by 0.3 to 0.4%. Similar estimations for municipal waste give coefficients that are not interpretable, i.e. municipal waste is too inhomogeneous a waste stream to be related to specific categories of private consumption while, at least for Denmark, it gives sense to relate domestic waste to categories of private consumption.

Concluding on these estimations, the large growth in the amount of municipal waste in Denmark is due to increases in mainly garden and other waste subject to improved collection systems and not necessarily increased waste generation. For domestic waste, where the collection system has been more or less the same in the period analysed, the amount collected has been almost constant. For forecasts, assuming unchanged collection systems, a continuation of the past trend in municipal waste of about 2.5% would imply an overestimation of the amount. For Denmark a trend between zero and 1% p.a. in the amount of municipal waste collected under an unchanged collection system would be a central estimate. If the development in other countries is similar to the experience in Denmark, the estimated past trends for municipal waste overestimate the development, and a sensitivity analysis where the past trends are reduced by 1% to 2% p.a. seems reasonable. However, to make firm conclusions, additional estimations for country-specific comparisons of domestic – and municipal waste should be performed.

Table 12. Estimation results for Denmark comparing municipal and domestic waste

Equation	No. of obs.	a_0	a_1	a_2	a_3	R^2	DW
Eq. (5) mun - pop	9	-2.974 *(-7.42)*		1.000	0.025 *(6.20)*	0.881	1.992
Eq. (5) mun - househ	9	-1.984 *(-4.96)*		1.000	0.023 *(5.71)*	0.881	2.013
Eq. (5) dom - pop	9	-1.205 *(-6.59)*		1.000	0.001 *(0.28)*	0.451	2.859
Eq. (5) dom -househ	9	-0.215 *(-1.148*		1.000	-0.002 *(-0.80)*	0.425	2.853
Eq. (4) dom - fcp, pop	9	-1.358 *(-4.12)*	0.334 *(0.57)*	(1-a1)	-0.002 *(-0.41)*	0.480	2.891
Eq. (4) dom - fcp, househ	9	-0.760	0.376	(1-a1)	-0.004	0.458	2.860

4.1.4. Assessment

The historical data for municipal waste are considered relatively good as data are available for most countries for a period of 10 years.

However, municipal waste is a mixed stream consisting of not only household waste but also similar waste from commerce, which blurs the ability to relate the generation to household related parameters. The amount of commercial waste in the municipal waste stream varies from country to country and no real estimation of the share exists.

Historical data for the private final consumption of various groups of goods (COICOP 1-12) are limited for the EU-10 to a few countries or groups only. Likewise, data do not exist for Luxembourg. This limitation has made it impossible to test the link between economic activity and the generation of municipal waste.

Despite these shortcomings, the overall assessment is that the projections for the EU-15, Norway and Switzerland are fairly solid. For the EU-10 and CC2 the projections are less solid which of course has to do with the situation in Eastern Europe in the 1990s. The substantial change in the economic situation in the past has affected the standard of living and thereby the generation of waste. To assume that the past trends will continue is questionable especially considering a projected increase in household consumption expenditure of approx. 3.5 - 4 % p.a. In comparison, the projected consumption expenditure for the EU-15 is about 2.3 % p.a. As a result, the generation of municipal waste for the EU-10 and CC2 is very likely to increase more than estimated by the model.

As mentioned in the introduction, the projection for each of the four groups of countries, EU-15, EU-10, CC3 and EEA2, is the aggregated sum of projections for all countries where projections are available. In general, the projections for the candidate countries and the two EEA countries are of some uncertainty since the two groups only contain two countries each. When comparing the the projected values with the actual, generated waste quantities in 2001 and 2002, the projection diverges for three countries (Germany, Belgium and Finland) in the EU-15, four countries in the new EU-10, and Bulgaria, Romania and Norway. Thus, the major changes in the Eastern European countries does make it more difficult to project the future trends.

4.2. Biodegradable municipal waste (BMW)

Biodegradable waste from households consists of food and garden waste, paper and cardboard, and any other waste capable of undergoing aerobic or anaerobic decomposition.

While a certain amount of garden composting has been the norm in the past, it is only in recent years that there has been pressure to divert food and garden waste away from the mixed waste stream and landfill. The main measure for the management of biodegradable municipal waste is the Landfill Directive[3], which sets out progressive targets for the diversion of BMW away from landfill. All targets are based on the historical quantity generated in 1995, or the latest year before 1995 for which standardised data are available. The main implication of this is that there is an absolute limit placed on the quantity of biodegradable municipal waste that can be landfilled by the specific target dates. This means that if BMW quantities continue to grow, increasing quantities will need to be diverted from landfill. The targets set out in the directive for the diversion of BMW from landfill are shown in Table 13.

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[3] Council Directive 1999/31/EC of 26 April 1999 on the Landfill of waste (OJ L 182, 16.7.99, p. 1)

A derogation of not more than four years for each of the above targets (i.e. 2010, 2013 and 2020) is available for Member States which in 1995, or the latest year for which standardised Eurostat data are available, landfilled more than 80% of their collected municipal waste.

Table 13. Targets for diversion of BMW from landfill

Year to achieve target	On the basis of biodegradable municipal waste generated in 1995[1], biodegradable municipal waste going to landfill must be reduced to:
16 July 2006	75 %
16 July 2009	50 %
16 July 2016	35 %

Note 1: Or the latest year before 1995 for which standardised Eurostat data are available.
Source: Council Directive 99/31/EC of 26 April on the Landfill of waste

4.2.1. Estimations and results

The general approach for assessing the consequences of the Landfill Directive is to estimate the amounts of BMW that would have been generated and landfilled in the absence of the directive and then to subtract the maximum quantities to be landfilled with the directive. It is assumed that all countries actually achieve the targets and achieve them in time.

In Crowe et al (2002) the share of BMW of municipal waste has been estimated for the base year[4]. The amount of BMW is estimated on the basis of the amount of municipal waste projected in section 4.1.2, and under the assumption that the share of BMW of municipal waste remains constant over the entire period.

Table 14 shows the key figures for the estimation. Columns 1-3 are the amount of municipal waste, produced BMW and the share of BMW of municipal waste in the base year 1995. Columns 4-6 show the maximum amount of BMW to be landfilled in 2006, 2009 and 2016 if targets are to be met. Columns 7-9 show the estimated amount of BMW (BMW share multiplied with the projected amount of municipal waste). Hence, columns 10-12 show the additional BMW to be diverted from landfill, and are columns 7-9 minus columns 4-6.

If all the additional BMW to be diverted from landfill in Table 14 would have been landfilled in the absence of the Landfill Directive, the environmental impact would equal the ‘saved’ emissions from landfill of additional BMW (mainly methane and nitrous oxide) plus emissions from alternative management (composting, incineration, etc.). However, waste management practices as regards biodegradable waste differ greatly among Member States, and in order to assess the real effect of the Landfill Directive it is necessary to study these practices in the base year 1995. In this scenario the scope of the analysis (system boundary) is limited to selected impacts from landfilling only. Extending the analysis to include incineration (with energy recovery) and composting would also imply that alternative consequences and impacts would have to be considered, e.g. changes in the production and use of energy, fertiliser, etc. The available information on landfilling of BMW is presented in Figure 13.

Five countries (regions) already fulfil the targets of the Directive (Austria, Belgium/ Flanders, Denmark, Germany/Baden-Württemberg and the Netherlands) as they landfill less than 35 % of the generated BMW. Several countries landfill significant amounts of BMW, Ireland and the UK both landfilled more than 80 % of BMW in 1998.

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[4] Or the latest year with available information.

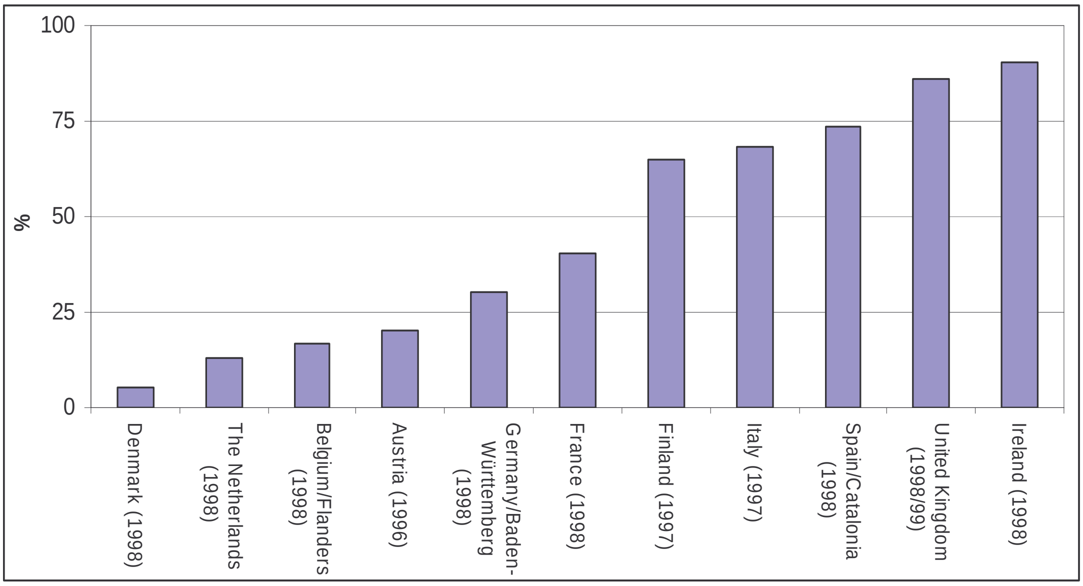
Table 14. Generation of BMW and maximum amounts to be landfilled in 2006, 2009 and 2016

1000 tonnes	Municipal waste	Produced BMW	BMW share of MW	Maximum amount of BMW to be landfilled if targets are met			BMW projected, assuming a constant 1995 BMW share of MW			Additional BMW to be landfilled		
Year	1995	1995	1995	2006	2009	2016	2006	2009	2016	2006	2009	2016
Column no.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Austria	5 270	1 495	28.4%	1 121	748	523	1 427	1 455	1 505	306	707	982
Belgium	5 014	4 312	86.0%	3 234	2 156	1 509	5 454	5 584	5 857	2 220	3 428	4 348
Germany	43 486	28 700	66.0%	21 525	14 350	10 045	31 175	31 946	33 036	9 650	17 596	22 991
Denmark	2 959	1 813	61.3%	1 360	907	635	2 275	2 336	2 455	916	1 430	1 821
Spain	14 914	11 633	78.0%	8 725	5 817	4 072	23 296	23 885	24 856	14 571	18 068	20 785
Finland	2 510	1 664	66.3%	1 248	832	582	2 001	2 097	2 331	753	1 265	1 749
France	29 057	15 746	54.2%	11 810	7 873	5 511	18 067	18 721	20 046	6 257	10 848	14 535
Greece	3 200	2 688	84.0%	2 016	1 344	941	3 983	4 260	4 998	1 967	2 916	4 057
Ireland	2 030	990	48.8%	743	495	347	1 137	1 191	1 313	394	696	966
Italy	25 780	9 170	35.6%	6 878	4 585	3 210	11 111	11 434	12 034	4 234	6 849	8 824
Luxembourg	240	160	66.7%	120	80	56	n/a	n/a	n/a	n/a	n/a	n/a
Netherlands	8 465	4 830	57.1%	3 623	2 415	1 691	5 856	5 963	6 275	2 234	3 548	4 585
Portugal	3 884	3 301	85.0%	2 476	1 651	1 155	4 403	4 524	4 802	1 927	2 874	3 647
Sweden	3 200	2 656	83.0%	1 992	1 328	930	3 422	3 436	3 479	1 430	2 108	2 549
United Kingdom	29 000	16 366	56.4%	12 275	8 183	5 728	18 053	18 725	20 110	5 778	10 542	14 382
Total EU-15	179 009	105 524	n/a	79 143	52 762	36 933	131 659	135 557	143 098	52 636	82 875	106 220

Note: The main objective is to estimate the total effect of the directive for the former EU-15. Hence, the country specific figures should mainly be seen as intermediate calculations in order to make this estimation. The figures may well be too detailed to be used for individual countries and are included only to illustrate the approach.

Source: Crowe et al (2002) and ETC/WMF estimations.

Figure 13. Landfill of BMW, % of total BMW produced



Source: Crowe et al (2002).

In order to estimate the generated amount of BMW, the existing waste management shares in Figure 13 are assumed to remain the same. Countries that already have set up systems to divert biodegradable waste away from landfill are supposed to keep such systems, and thereby a constant share, despite an increasing generation of BMW. As a rough estimate, the regions of Flanders, Baden-Württemberg and Catalonia are assumed to represent the waste management practices of their country.

Based on the figures in Table 14, the effect of the Landfill Directive is estimated in Table 15. The table shows the amount that will be landfilled assuming the share of BMW landfilled remains constant. The maximum amount of BMW landfilled is deducted from this amount and, if the figure is positive, it is listed in the column, ‘Effect of directive’.

Austria, Belgium (Flanders), Denmark, Germany (Baden-Württemberg), and the Netherlands all landfill less than 35% (the 2016 target), and since the amounts of BMW are not projected to increase significantly, the directive does not have any effect for these countries. To indicate this the column, ‘Effect of directive’, is left blank.

Two other countries have met some of the targets already. France already meets the 2006 and 2009 targets and thus no effect is registered for these years. Sweden is also assumed to fulfil the 2006 and 2009 target, but due to a projected increase in the quantity in 2009, some effect is registered.

The total effect of the directive for the former EU-15 in 2006 is estimated to reduce landfilling by 15 million tonnes of BMW that now need to be diverted towards other waste management options. In 2009, the amount is 28 million tonnes and in 2016 it is 41 million tonnes.

Table 15. Estimated effect of the Landfill Directive: BMW diverted away from landfill

	Share land-filled	Amount landfilled	Diff. Max landfill	Effect Direc-tive	Amount landfilled	Diff. Max landfill	Effect Direc-tive	Amount landfilled	Diff. Max landfill	Effect Direc-tive
	1995	2006			2009			2016		
Austria	20.4	291	-830	-	297	-451	-	307	-216	-
Belgium	16.7	911	-2.323	-	932	-1.224	-	978	-531	-
Germany	30.2	9 415	-12 110	-	9 648	-4 702	-	9 977	-68	-
Denmark	5.3	121	-1 239	-	124	-783	-	130	-504	-
Spain	73.4	17 099	8 374	8 374	17 531	11 715	11 715	18 244	14 173	14 173
Finland	64.9	1 299	51	51	1 361	529	529	1 513	931	931
France	40.3	7 281	-4 529	-	7 544	-329	-	8 079	2 568	2 568
Greece	80.0	3 187	1 171	1 171	3 408	2 064	2 064	3 998	3 058	3 058
Ireland	90.3	1 026	284	284	1 076	581	581	1 185	839	839
Italy	68.4	7 600	723	723	7 821	3 236	3 236	8 231	5 022	5 022
Luxembourg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Netherlands	13.1	767	-2 855	-	781	-1 634	-	822	-868	-
Portugal	70.0	3 082	606	606	3 167	1 516	1 516	3 361	2 206	2 206
Sweden	50.0	1 711	-281	-	1 718	390	390	1 740	810	810
United Kingdom	86.2	15 561	3 287	3 287	16 141	7 958	7 958	17 335	11 607	11 607
Total EU-15	n/a	-	-	14 495	-	-	27 989	-	-	41 212

Notes: 1) The share landfilled for Greece, Portugal and Sweden is not known and is therefore estimated. No data are available for Luxembourg. 2) The main objective is to estimate the total effect of the directive for the former EU-15. Hence, the country specific figures are included only to illustrate the approach.

So far, it has been assumed that all countries meet the targets in time. As the only country known at this stage, the United Kingdom is expected to make use of the possibility of a derogation of four years. The effect of the derogation for the EU-15 is estimated to be limited and the effect of the Landfill Directive will thereby be 13 million tonnes in 2006, 24 million tonnes in 2009 and 40 million tonnes in 2009, provided that the reduction follows a linear trend.

To estimate the environmental impact, or rather contributions to the greenhouse potential, emission factors per tonne of BMW landfilled are necessary. White et al (1995) estimates a figure of 250 Nm^3 landfill gas per tonne of biodegradable waste (organic, paper and textile fractions) as a realistic figure. However, large variations in landfill gas potentials for MSW exist, and the above should only be seen as a rough estimate. The content of greenhouse related components in the landfill gas is presented in the table below.

Table 16. Greenhouse gas potential based on selected air emissions from landfilling

	Landfill gas (mg/Nm^3)	Characterisation factor[1)] ($g\ CO_2/g$ emission)	CO_2 equivalents (g/Nm^3)
CO_2	883 930	1	884
CH_4	392 860	21	8 250
N_2O	-	310	-
Total	-	-	*9 134*

Note 1: 100-year time horizon
Source: Based White et al (1995)

In Table 17 below the greenhouse gas emissions saved are calculated using the potential of 250 Nm^3 landfill gas per tonne of biodegradable waste and taking into account the greenhouse potential as calculated in the table above.

Table 17. Saved greenhouse gas emissions

Year	Diverted amount (tonnes)	Avoided LFG production (Nm^3)	Saved greenhouse gas emissions (tonnes CO_2-equivalents)
2006	15 000 000	3 750 000 000	34 252 000
2009	28 000 000	7 000 000 000	63 938 000
2016	41 000 000	10 250 000 000	93 623 000

It should be noted that the effect of the derogation is not included in the above table.

To better get an idea of the order of magnitude of the saved greenhouse gas emissions the figures will be related to the total emissions of greenhouse gases in the EU-15 as shown in Table 18.

Table 18. Emission of CO_2 and total amount of greenhouse gas in the EU-15 (tonnes CO_2-equivalents)

	1999	2000	2001	2002
CO_2	3 306 447 430	3 328 207 040	3 392 201 740	3 382 270 480
Greenhouse gas	4 082 541 080	4 090 065 690	4 143 902 590	4 123 251 590

Note: The time horizon for the characterisation of greenhouse gas emissions in the table is not known

Source: Eurostat (2004)

Based on the total emission data in the above table it is calculated that the greenhouse gas savings reached in 2006 and 2016 only constitute 0.8 % to 2.3 % respectively of the total greenhouse gas emission of the EU-15 in 2002.

4.2.2. Assessment

The assumption of a constant BMW share of municipal waste in the entire period may well be too restrictive because in principle there may be a limit to the amount of potatoes a household can consume. Increased wealth is more likely to result in a change in consumption towards more expensive goods, e.g. to consume more meat instead of vegetables which may not imply increasing quantities of BMW. As paper/cardboard and textiles are also included in the BMW, it may not decrease as much as if it was organic waste only.

Likewise, the assumption of constant waste management practices is also a simplified approach. In most countries it is becoming increasingly difficult to find locations for landfill sites and therefore local authorities may choose other options than disposal in the long run.

The emission figures for landfill gas are also of some uncertainty and should be examined further before making any firm conclusions.

In summary, the estimates for biodegradable municipal waste should be seen as a first estimate of the effects of the Landfill Directive. Eunomia Research & Consulting (unknown) has made an economic analysis of options for managing BMW.

4.3. Industrial waste

In the projections non-hazardous industrial waste constitutes waste that is generated by the manufacturing industries (NACE code D).

Industrial waste is one of the very large waste streams, typically much larger than municipal waste. The amount per capita varies from 0.5 tonnes in Germany, Spain, and

Denmark to 3 tonnes in Finland. Figures for the generation of waste depend on the structure of industries, the technology in use and the definition of industrial waste.

Unfortunately, the statistics for industrial waste are generally poor. When the estimations were made only Denmark and the Netherlands had a time series of 7 observations for industrial waste. Three to four observations appear to be most common and two countries only have one observation. Since then, more countries have made reports on the generation of industrial waste, including Germany, but the overall picture remains the same.

4.3.1. Estimations

The time series for the amounts of industrial waste are limited and, for most countries, too short for estimation of advances equations. Therefore, in general, the equation for industrial waste reduces to a constant waste coefficient (i.e., Eq. 6 with estimation of a_{0i} and possibly only a dummy).

For Denmark and the Netherlands, a small positive trend in the waste coefficient has been estimated. For France, Italy and Portugal, the DW-statistics are very low. By including a trend for these countries, the DW-statistics are significantly improved. However, the estimated trend coefficients become very large (negative for France and Portugal and positive for Italy). That is, for France, Italy and Portugal, the model may generate biased forecasts, but given the very short time series, it is not reasonable to include large historical trends in the forecasts. As a result, it has been chosen to use the Eq. 6 only.

The activity variable is the production within manufacturing (fqd), or total gross value added (fqs), depending on whether data for manufacturing are available. For most of the countries where the amount of industrial waste is available for more than one year, the waste coefficients are reasonably constant, i.e., R^2 values for the equation with a_1 restricted to one and only the production as an explanatory variable are reasonably high. However, due to differences in industrial structure, technology used and definition of industrial waste, coefficients vary considerably between countries.

Table 19. Model parameters for industrial waste, EU-15

Country	Equation	No. of obs.	Act. Var.	a_0	a_1	s	a_3	d	R^2	DW
AT	eq. (6) activ.	3	fqd	-0.894 *(-65.64)*	1.000	0.000	0.000		0.956	2.933
BE	eq. (6) activ.	5	fqs	-2.730 *(-206.4)*	1.000	0.000	0.000	0.121 *(4.08)*	0.880	2.943
DE *old*	eq. (6) activ.	4	fqd	-3.188 *(-33.95)*	1.000	0.000	0.000	1.533 *(11.54)*	0.984	2.776
DE *new*	eq. (6) activ.	4	fqd	-2.191 *(-410.4)*	1.000	0.000	0.000	0.070 *(9.22)*	0.989	1.458
DK	eq. (5) activ.	7	fqd	-2.897 *(-10.08)*	1.000	0.000	0.008 *(2.81)*		0.798	2.169
DK *new*	eq. (6) activ.	7	fqd	-2.091 *(-104.00)*	1.000	0.000	0.000		0.553	0.631
FI	eq. (6) activ.	2	fqd	-0.294 *(-1.76)*	1.000	0.000	0.000		na.	na.
FR	eq. (5) activ.	3	fqs	-2.405 (-44.18)	1.000	0.000	0.000		0.888	1.042
GR	eq. (6) activ.	1	fqd	-0.516	1.000	0.000	0.000		na.	na.
IE	constructed	0	fqd	-1.556						
IT	eq. (6) activ.	3	fqd	-1.986 *(-29.00)*	1.000	0.000	0.000		0.894	1.358
LU	constructed		fqd	-0.055						

Country	Equation	No. of obs.	Act. Var.	a_0	a_1	s	a_3	d	R^2	DW
NL	eq. (5) activ.	7	fqs	-3.340	1.000	0.000	0.004	-0.586	0.999	2.070
				(-16.88)			*(2.09)*	*(-35.47)*		
NL	eq. (6) activ.	7	fqs	-2.927	1.000	0.000	0.000	-0.613	0.999	1.255
new				*(-255.70)*				*(-45.24)*		
PT	eq. (6) activ.	5	fqs	-2.005	1.000	0.000	0.000		0.437	1.100
				(-18.28)						
ES	eq. (6) activ.	1	fqd	-1.162	1.000	0.000	0.000		Na.	na.
SE	eq. (6) activ.	2	fqs	-2.322	1.000	0.000	0.000		Na.	na.
				(-25.76)						
UK	eq. (6) activ.	4	fqs	-2.708	1.000	0.000	0.000		0.690	
				(-40.75)						

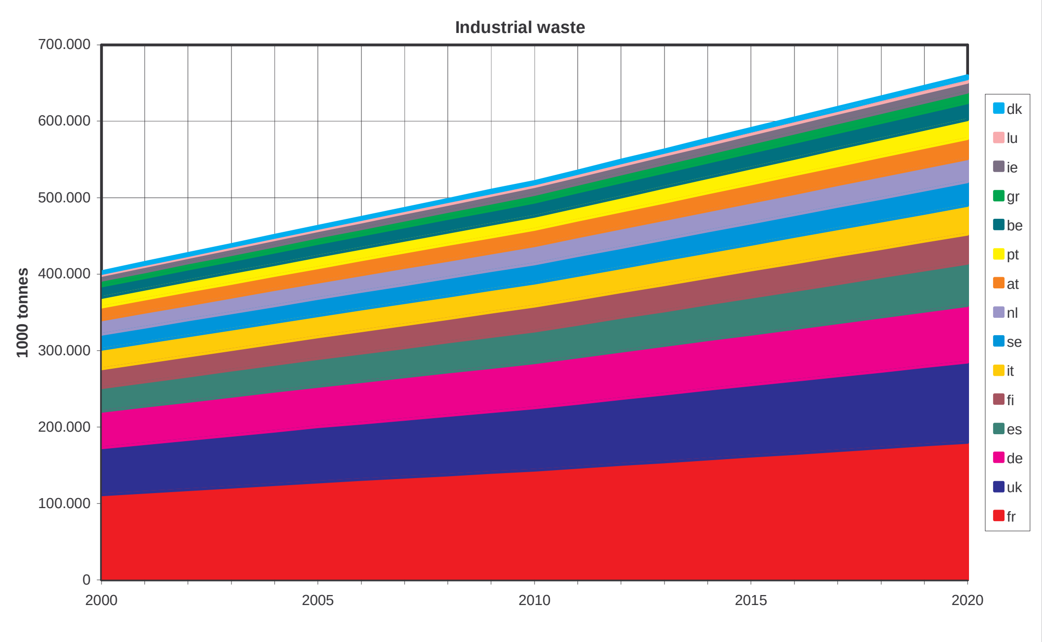
Note: Equations marked with yellow are the ones chosen in the estimations.

4.3.2. Results

In the Baseline scenario for the EU-15 industrial waste is projected to increase by 60-65 % in 2020 compared to 2000. In comparison, the Low growth scenario projects an increase of 45 %. The two scenarios are shown in Figures 14 and 15.

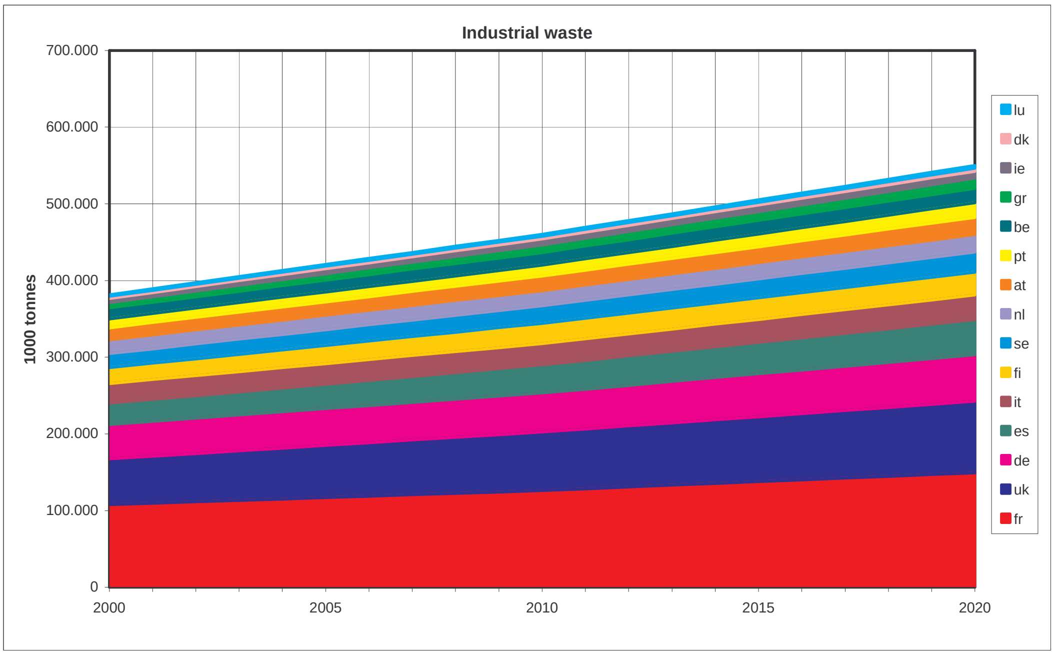
There are variations between countries though. The highest increases are estimated for Luxembourg, Ireland and Portugal with some 90 to 100 %, whereas Italy and Denmark are expected to experience increases of 45-50 % over the twenty-year period.

Figure 14. Baseline scenario for industrial waste, EU-15



An interesting feature is that measured in physical quantities, the largest amount of industrial waste is produced in France. In total about 100 million tonnes is generated. The UK is the second largest producer with 50 million tonnes. Germany, which generally is the major producer due to its size, produces around 45 million tonnes.

Figure 15. Low growth scenario for industrial waste, EU-15



The explanatory variables in the estimations are either the total gross value added or the gross value added for industry. The growth rates in the LREM Baseline scenario for these variables are 2.4 % p.a. which results in an increase of 60 % in 2020. In the Low growth scenario the growth rates are 1.6 – 1.7 % p.a. corresponding to 40 % increase in 2020. These figures are practically equal to the projected trends for industrial waste and therefore it does not seem as if a decoupling from the economic activity will occur.

4.3.3. Assessment

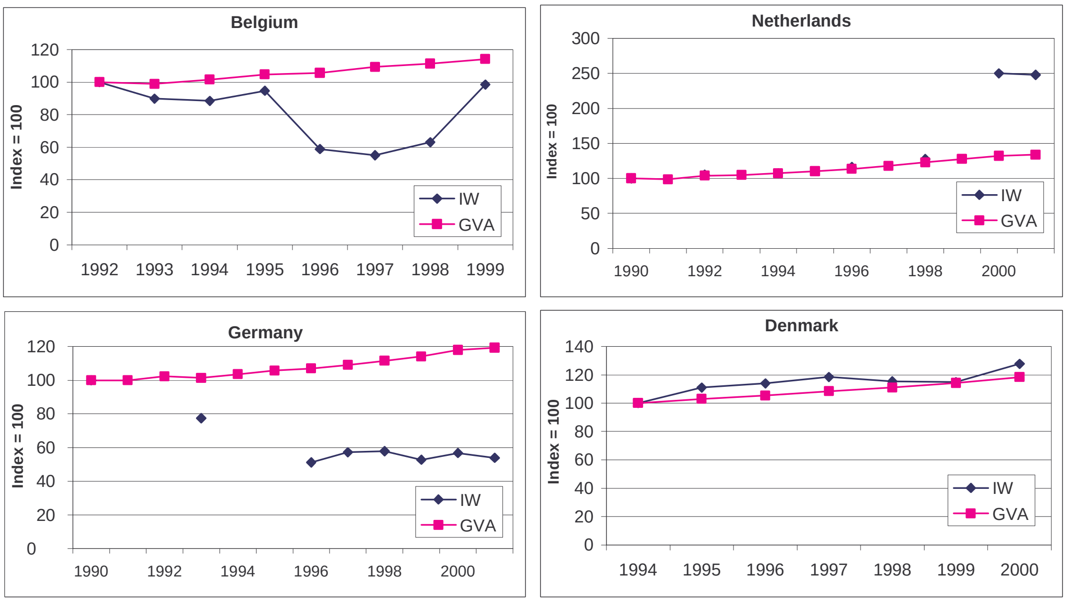
The projections for industrial waste are considered relatively uncertain. The lack of reasonable time series is an obstacle for making an adequate analysis of the links between past trends of waste generation and economic activity.

Another feature for industrial waste is the possibility of changes and differences in national definitions of industrial waste. When looking at the historical trends there are unexplainable jumps in quantities for some countries.

The differences become obvious when comparing countries. It is striking that Germany, as the biggest economy in the EU, generates only half the amount of industrial waste as France does and some 5 million tonnes less than the United Kingdom. In addition, judging from the shares of manufacturing of the total gross value added in 2000, Germany earns 22.5 % of its production value from manufacturing while France and the UK earn 18 %. In other words, manufacturing is a relatively larger sector in Germany, and therefore it could be expected that the amount of waste would be higher.

To illustrate some differences, Figure 16 shows the past trends for generation of industrial waste and the total gross value added. For Germany there seems to be a relative decoupling of waste generation from the economic activity, whereas for the Netherlands, Denmark and Belgium there is a clear coupling. For the Netherlands the coupling is almost 100 % up till 1998, and in 2000 and 2001 the amount of waste suddenly doubles, which indicates a change in the waste definition or a major change in industrial structure. A similar situation applies to Belgium where there has been a significant decrease in the waste quantity for the years 1996-1998, although it is difficult to say whether it is due to a change in waste definition or a real decrease. The former could be an explanation considering the fact that in 1999 the quantity has returned to the level as before the decrease.

Figure 16. Generation of industrial waste and total gross value added for Belgium, Germany, the Netherlands and Denmark



4.4. Waste from the construction and demolition sector

Data for construction and demolition waste are available for EU-15, but the time series are even shorter than for industrial waste and for some countries figures are not very updated.

The waste consists mainly of building materials and soil, including excavated soil. Here, it has been chosen to focus on waste arising from the construction and demolition sector rather than construction and demolition waste which is includes C & D waste from all economic sectors. The reason for this choice is that data seem more consistent and it is easier to explain the development in waste generation.

The amount of excavated soil included in the figures may be an important factor for the actual amount of waste from the construction sector, which also makes it a little difficult to compare the quantity of waste across countries.

Table 20. Composition of C & D waste

Country	Year of statistics	Sub-total 'Core' C&D waste	Soil, stones, etc.	Total
Austria	1997	4.7	20.0	26.4
Belgium	1990-92	6.8	27.0	34.7
Denmark	1996	2.7	7.7	10.7
Finland	1997	1.3	8.0	9.4
France	1990-92	23.6	n/a	n/a
Germany	1994-96	59.0	215.0	300.0
Italy	1995-97	20.0	n/a	n/a
Spain	1997	12.8	n/a	n/a
UK	1996	30.0	29.5	67.0
EU-15	-	179.7	n/a	> 450

Source: Extract of figure 7.1 in Symonds (1999)

An analysis made for the European Commission (Symonds, 1999) estimates the amount of 'core C&D waste' and other elements, such as soil, stones, etc. An extract from the table in the report is shown in Table 20. As can be seen, considerable amounts of waste may arise from soil and stones rather than 'core' C & D waste.

4.4.1. Estimations

The amount of construction and demolition waste is related to the activity within the construction sector (fqf).

The waste coefficients vary considerably, both between countries and over time. Differences and changes in waste coefficients mirror differences and changes in structure and technology used within the building and construction sector, but also differences in what is categorised as construction and demolition waste.

For Belgium, Germany and the United Kingdom, small positive trends (a_3) in the waste coefficient are estimated. However, in order to avoid a continuation of the past trends, which may not be justifiable, it has been chosen to reduce the equation for construction and demolition waste to a constant waste coefficient (i.e., Eq. 6 with estimation of a_{0i} and possibly a dummy).

Since no data on generation of C & D waste exist for Sweden, it has not been possible to estimate any model parameters, and thus Sweden is not included in the projections. For Ireland two observations exist but they do not seem consistent as the quantity doubles in three years. As a result, a coefficient has been constructed for Ireland.

In conclusion, the model is very simple (a constant waste coefficient) and from the limited number and reliability of observations, it is difficult to say whether this is a reliable model.

Table 21. Model parameters for C&D waste, EU-15

Country	Equation	No. of obs.	Act. Var.	a_0	a_1	s	a_3	d	R^2	DW
AT	eq. (6) activ.	4	fqf	0.606 *(15.07)*	1.000	0.000	0.000		0.726	2.570
BE	eq. (5) activ.	7	fqf	-2.014 *(-1.31)*	1.000	0.000	0.016 *-1.000*	0.127 *-1.780*	0.553	2.329
BE	eq. (6) activ.	7	fqf	0.475 *(-19.35)*	1.000	0.000	0.000	0.066 *(-1.77)*	0.441	2.118
DE *old*	eq. (6) activ.	3	fqf	-3.772 *(-37.68)*	1.000	0.000	0.000		0.133	2.662
DE *new*	eq. (5) activ.	5	fqf	-1.665 *(-2.47)*	1.000	0.000	0.025 *(3.55)*	-0.049 *(2.45)*	0.969	2.980
de *new alt*	eq. (6) activ.	5	fqf	0.723 *(51.75)*	1.000	0.000	0.000	-0.111 *(5.01)*	0.802	2.686
DK	eq. (6) activ.	8	fqf	-0.714 *(-17.62)*	1.000	0.000	0.000	-0.507 *(-4.42)*	0.804	1.632
FI	eq. (6) activ.	4	fqf	0.403 *(2.92)*	1.000	0.000	0.000	1.550 *(5.63)*	0.941	1.478
FR	eq. (6) activ.	1	fqf	-1.530	1.000	0.000	0.000		na.	na.
GR	eq. (6) activ.	1	fqf	-1.098	1.000	0.000	0.000		na.	na.
IE	constructed	0	fqf	-0.600						
IT	eq. (6) activ.	2	fqf	-0.630 *(-8.52)*	1.000	0.000	0.000		na.	na.
LU	eq. (6) activ.	3	fqf	0.957 *(46.36)*	1.000	0.000	0.000	-1.007 *(-39.82)*	0.999	2.500

Country	Equation	No. of obs.	Act. Var.	a_0	a_1	s	a_3	d	R^2	DW
NL	eq. (6) activ.	2	fqf	-0.146 *(-20.55)*	1.000	0.000	0.000		na.	na.
PT	eq. (6) activ.	4	fqf	-4.397 *(-23.20)*	1.000	0.000	0.000	4.959 *(18.50)*	0.994	2.064
ES	eq. (6) activ.	2	fqf	-0.525 *(-5.75)*	1.000	0.000	0.000		na.	na.
SE	eq. (6) activ.	0								
UK	eq. (5) activ.	4	fqf	0.005 *(0.01)*	1.000	0.000	0.005 *(0.75)*		0.531	2.033
UK	eq. (6) activ.	4	fqf	0.517 *(24.03)*	1.000	0.000	0.000		0.135	2.116

4.4.2. Results

Waste from the construction and demolition sector in the EU-15 is estimated to increase by approximately 30-35 % by 2020 in the Baseline scenario. The Low growth scenario estimates a more moderate increase of 15-20 %.

The Baseline scenario estimate is for the entire EU-15 and includes large differences between countries. The extreme values are estimated for Ireland (120 % increase), Greece, Portugal and Spain (90 %), and for Germany (15 %).

When comparing the results with the estimated increase in activity in the construction sector in 2020 of 45 %, a decoupling could take place over the twenty-year period.

Figure 16. Baseline scenario for construction and demolition waste, EU-15

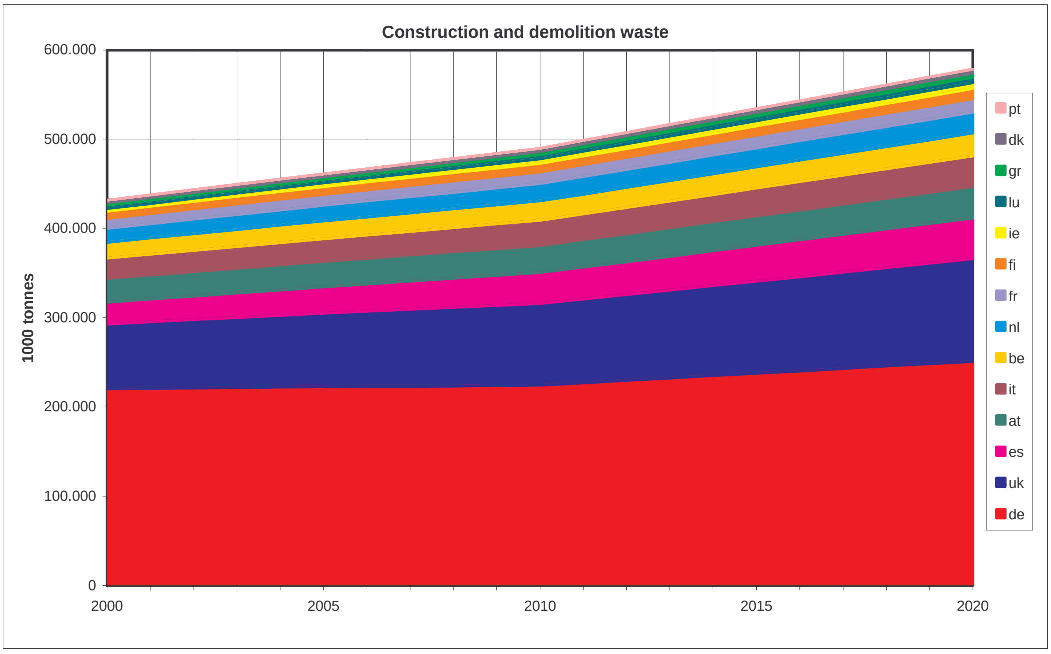
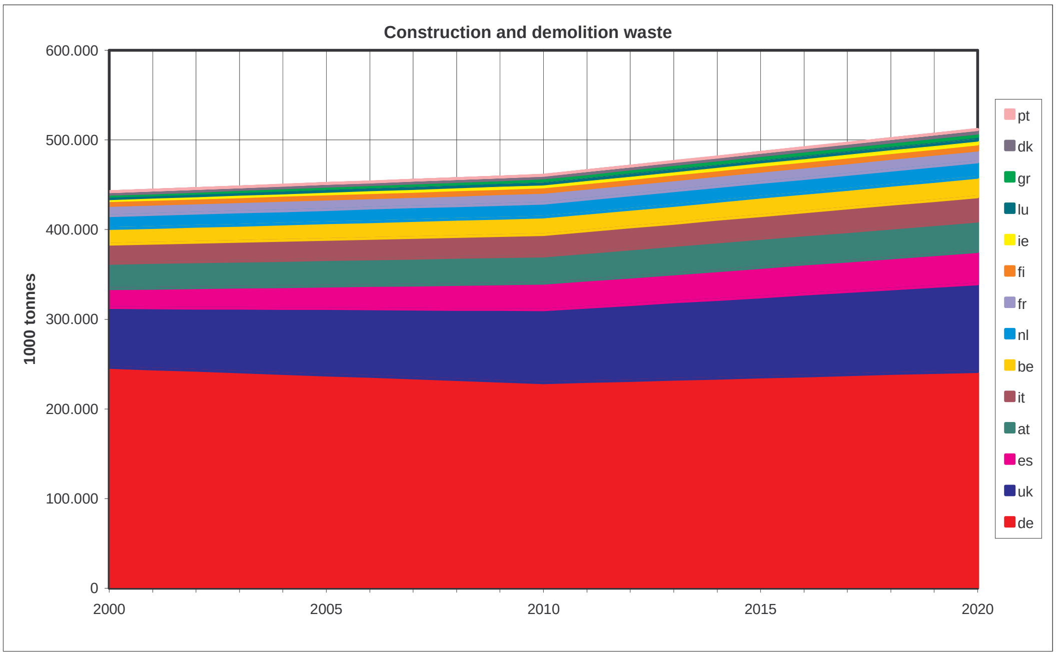
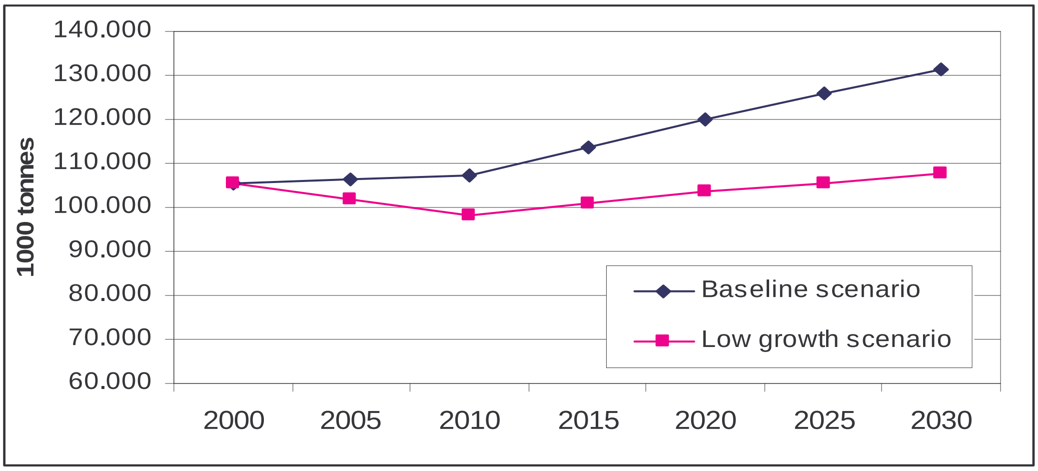


Figure 17. Low growth scenario for construction and demolition waste, EU-15



The future trend for the EU-15 is influenced by the development in the German construction sector. As seen in Figure 18, the Baseline scenario for Germany assumes an almost constant GVA in the construction sector between 2000 and 2010, where after it starts to increase. In the Low growth scenario however, the GVA is assumed to decrease until 2010 and then a modest growth will occur. This influence is clearly seen in Figures 16 and 17 for the year 2010.

Figure 18. GVA construction for Germany, Baseline and Low growth scenarios



4.4.3. Assessment

In general the estimates are uncertain due to insufficient data for waste from the construction sector. The model is also simple in the sense that constant waste coefficients are assumed to explain past developments and form the basis for projections some 20 years ahead.

The quantities of construction waste cannot be compared across countries because there may be huge variations in the amount of waste being ‘real’ or ‘core’ construction waste and excavated soil and stones.

In the Low growth scenario for Germany the initial value in 2000 is estimated at 246 million tonnes, but in the Baseline scenario it is only estimated at 220 million tonnes. The reason for this difference is not readily explainable. Thus, excluding Germany from the projections for EU-15, the growth is estimated at 55 % in the Baseline scenario and 40 % in the Low growth scenario.

4.5. Paper and cardboard

The main source of data on consumption of paper and cardboard is the Confederation of European Paper Industries (CEPI). The consumption of paper is defined as ‘Consumption of paper equals the domestic deliveries plus imports from other CEPI countries and plus imports from countries outside CEPI’.

The CEPI data may not equal national data on paper and cardboard consumption, since the CEPI data include paper and board printed outside the country and then imported, e.g. brochures or newspapers. They also include data on packaging.

Compared to data on waste, the time series for consumption of paper and cardboard are fairly long: 18-20 years for several countries.

The consumption of paper varied in 2000 from 100-120 kg per capita in Greece, Ireland and Portugal to 305-310 kg per capita in Belgium and the Netherlands. The data also show that since 1990 the consumption has increased by 10-50 % in the EU-15.

4.5.1. Estimations

The dependent variable is the consumption (not the collected waste) of paper and cardboard, and it is evaluated that this consumption depends on activities within both the private consumption and the production within sectors. In the detailed approach, the paper and cardboard consumption is linked to the private consumption of food and non-alcoholic beverages (category 01), recreation and culture (category 09) and to the production within the sectors of wholesale and retail trade (g), financial intermediation (j), public administration (l) and education (m). In the aggregated approach (when detailed data are not available), the consumption of paper and cardboard is linked to total private consumption and gross domestic product.

Due to limited data and multi-collinearity problems, it is not possible to freely estimate coefficients to both consumption and production variables (consumption and production in a country are not completely independent variables). Therefore, the two categories of private consumption are aggregated to one activity variable ($A1_i$ in Eq. (1)), and production within the four sectors is aggregated to another activity variable ($A2_i$ in Eq. (1)). In this case, the interpretation of Eq. (1) is that the share s_i of paper and cardboard is linked to private consumption and the share linked to production is $(1-s_i)$, i.e., s_i should be between 0 and 1. If free estimation of s_i is negative, s_i is restricted to 0 and if free estimation of s_i is larger than 1.0, s_i is restricted to 1.0. Scaled by this share, a relative change in either consumption or production implies the same relative change in the consumption of paper and cardboard (a_{1i}).

For paper and cardboard, the chosen equations are summarised in Table 22. It is noted that the inclusion of both private consumption and production creates problems. For all countries, s_i is restricted to be either zero or one. From the estimations, it is concluded that the estimate on s_i varies considerably between specifications and depends on restrictions on Eq. (1). The main reason is that developments in consumption and production are multi-collinear variables.

Another conclusion from the estimations is that constant or trend-wise changing coefficients explain most of the changes in the consumption of paper and cardboard. All estimated trends are positive and, except for Greece, Ireland and Italy, moderate. The DW-statistics reveal that there are systematic errors in the equations for Ireland and the UK. However, in general, R^2 and DW statistics are reasonable.

All the trend coefficients have been leveled out over 10 years. In doing so it is assessed that an increased demand for paper, e.g. due to printers becoming cheaper, will not necessary continue another 20 years into the furture, as other options may have become available by then.

Greece: The problem is that the activity increases considerably and so does the waste. If pop is used the trend in the model will decrease. If activity is chosen the economic trend will continue.

Table 22. Model parameters for paper and cardboard, EU-15

Country	Equation	No. of obs.	Act. var.	a_0	a_1 or a_2	s	a_3	D	d2	R^2	DW
AT	eq. (6) activ.	12	detail	-4.871 *(-16.18)*	1.000	1.000	0.022 *(6.78)*			0.953	1.637
BE	eq. (5) activ.	18	aggr	-6.366 *(-40.57)*	1.000	0.000	0.020 *(11.88)*			0.975	1.928
DE	eq. (6) activ.	9	detail	-2.630 *(-272.4)*	1.000	1.000	0.000			0.629	1.575
DK	eq. (5) pop.	18	detail	-2.193 *(-7.80)*	1.000		0.008 *(2.59)*	-0.120 *(-3.72)*		0.917	1.268
FI	eq. (6) activ.	17	detail	-2.268 *(-151.8)*	1.000	1.000	0.000			0.750	1.883
FR	eq. (5) activ.	21	aggr	-6.050 *(-59.08)*	1.000	0.000	0.013 *(11.53)*			0.979	1.685
GR *1990-2000*	eq. (5) pop.	11	pop	-8.860 *(-10.26)*	1.000		0.066 *(7.30)*			0.870	1.800
GR *1991-2000*	eq. (5) pop.	10	pop	-3.386 *(-5.18)*	1.000		0.011 *(1.78)*	-0.519 *(-8.64)*	-0.253 *(-6.75)*	0.988	2.336
d dummy 9193; d2 dummy 9499											
IE	eq. (5) pop	18	pop	-5.759 *(-7.17)*	1.000	0.000	0.037 *(4.40)*	0.104 *(1.15)*		0.778	0.920
IT	eq. (5) activ.	18	detail	-5.984 *(-52.42)*	1.000	1.000	0.035 *(27.99)*	-0.644 *(-22.77)*		0.991	2.303
NL	eq. (5) activ.	13	aggr	-5.598 *(-36.02)*	1.000	0.000	0.012 *(7.04)*	-0.400 *(-16.82)*		0.979	2.282
PT	eq. (6) activ.	13	aggr	-4.644 *(-238.6)*	1.000	0.000	0.000	0.033 *(1.05)*		0.903	2.064
PT	eq. (6) pop.	13	pop	-7.928 *(-21.29)*	1.000	0.000	0.057 *(14.67)*	0.249 *(8.38)*		0.965	2.120
ES	eq. (5) activ.	18	aggr	-6.306 *(-64.25)*	1.000	0.000	0.019 *(18.11)*			0.993	2.170
SE	eq. (6) activ.	8	aggr	-4.503	1.000	0.000	0.000	-0.127		0.940	2.953

Country	Equation	No. of obs.	Act. var.	a_0	a_1 or a_2	s	a_3	D	d2	R^2	DW
UK	eq. (5) activ.	18	aggr	*(-256.5)* -5.316 *(-42.91)*	1.000	0.000	0.010 *(7.46)*	*(-5.10)*		0.977	0.982

4.5.2. Results

The Baseline scenario results in an augmentation of paper consumption of 60-65 % in 2020 while the Low growth scenario estimates a growth of twenty percentage points less, i.e. 40-45 %. The results of the scenarios are shown in Figure 19.

The major growth rates in the Baseline scenario are estimated for Spain and Portugal (+90-100 %), but also Austria and the UK could expect considerable increases. In contrast, development for Denmark is very low with less than 10 %.

Figure 19. Baseline scenario for generation of paper and cardboard, EU-15

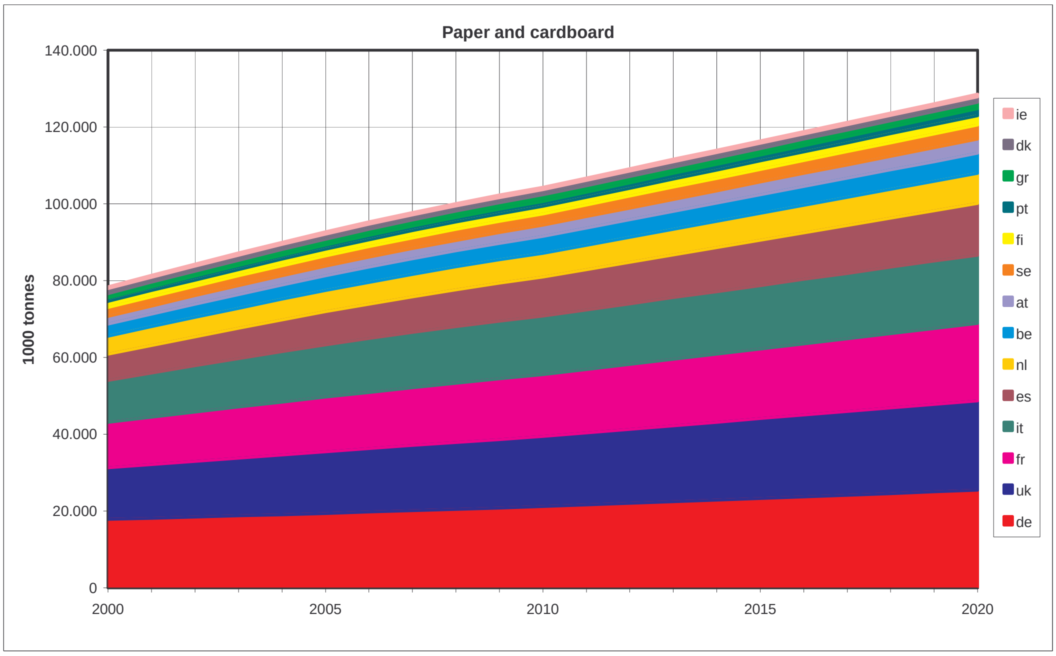
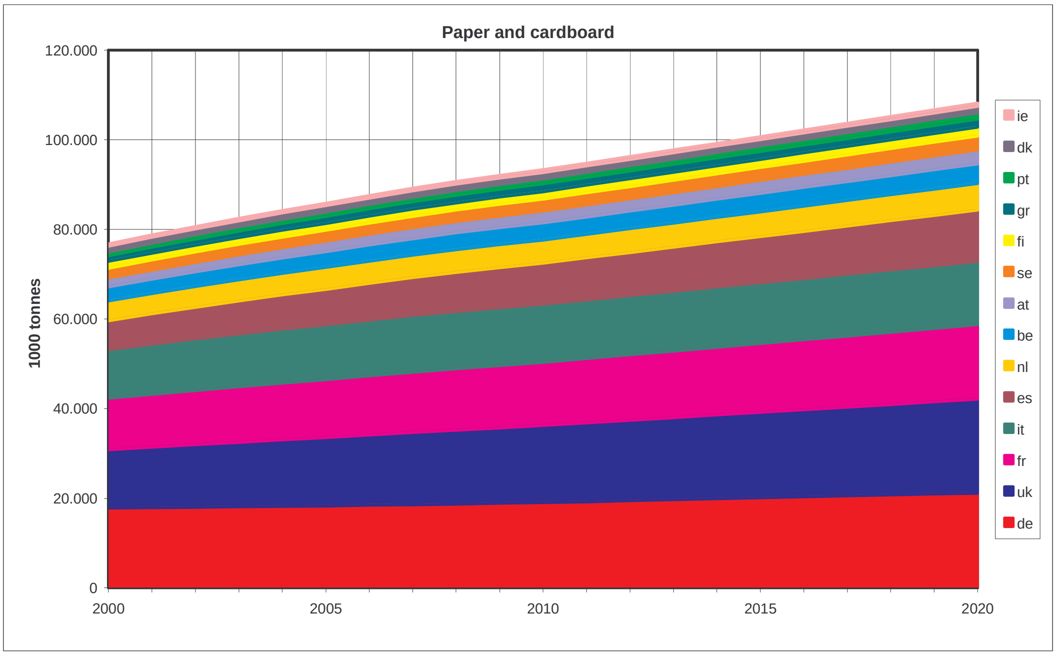


Figure 20. Low growth scenario for paper and cardboard, EU-15



Comparing these figures to the assumed growth in private final consumption of households and the GDP, which are the key driving factors in the model, it is questionable whether a decoupling will be achieved for paper and cardboard. The PFC and the GDP are both assumed to rise by just below 60 %.

4.5.3. Assessment

The figures used in the projection do not fully equal national figures on either consumption of paper or collected paper for recycling. Hence, the projection will probably be able to show a trend, or growth rate, for consumption of paper, but the actual physical quantities may be less exact.

In using the consumption figures to estimate the generation of paper waste it is assumed that paper and cardboard will become waste at some point in time. In reality, a certain amount of paper will probably be stored (as reports, books, letters, etc.) for many years and so only a part of the generation will become waste within a relatively short period of time (as is also the case with packaging).

It should also be noted that there may be a certain overlap with the projection of packaging, as cardboard is often packaging. The degree of overlap, however, is not possible to evaluate.

When looking at the past trends and the projected trends for each country, there are no major jumps in the projections, and it generally looks as if the growth continues at the same rate after 2000. The relatively long time series should also provide a reasonable basis for assessing the links between consumtion and explanatory variables. In conclusion, the projection appears to be reasonable.

4.6. Glass

The main source of data on consumption of packaging or container glass is the European Container Glass Federation (FEVE).

The generation of waste from packaging glass or container glass is estimated as apparent consumption of container glass. Hence, packaging placed on the market equals produced packaging glass plus import of empty glass packaging minus export of empty glass packaging (import and export of filled packaging glass are not taken into account).

The data may not equal national data on consumption of glass packaging, since they include exports of goods in glass, e.g. wine. Measured in consumption per capita, the wine producing countries (France, Portugal, Spain, Italy and Germany (in this order)) have the highest consumption per capita in the EU. In quantities the consumption per capita is: France: 71.8 kg, Portugal: 62.4 kg, Spain: 53.3 kg, Italy: 52.1 kg, and Germany: 44.3 kg. The consumption in a non-wine producing country such as the UK is 30 kg glass per capita and this has been very stable over the 10-year period.

The time series starts in 1990, and thereby the maximum number of observations is 12.

4.6.1. Estimations

As for paper and cardboard, the dependent variable is the consumption of glass and not the collected amount.

The activity variables are the private consumption of food and non-alcoholic beverages (category 01) and alcoholic beverages, etc., (category 02), and the production within manufacturing. In the aggregated case (when detailed data are not available), the activity variables are total private consumption and gross domestic product. Equations chosen for the model are summarised in Table 23.

Conclusions from the estimations are much the same as for paper and cardboard. However, free estimation of s_i gives reasonable results for Germany, Denmark and Finland. One significant difference between estimations for paper and cardboard and glass is that for about half of the countries, the development in population is a better explanatory variable than either private consumption or production. Another difference is that, in general, waste coefficients are not increasing.

For Greece and Portugal Eq. 6 with a constant waste coefficient has been chosen.

For the remaining countries, Eq. 5 using either the economic activity or the population as the explanatory parameter is used. A trend coefficient improves the estimation for the majority of countries, but these are generally moderate with maximum coefficients for Sweden (3.4 %) and Austria, Denmark and France (about 2.2 %). As is the case for other projections, the a_3 parameter is phased out to zero over 10 years.

Looking at individual countries, it is noted that the model is not able to explain the development in Germany, Finland and the United Kingdom. For these countries, the explanatory power of the model (the R^2-value) is very poor.

Table 23. Model parameters for glass, EU-15

Country	Equation	No. of obs.	Act. var.	a_0	A_1 or a_2	s	a_3	d	R^2	DW
AT	eq. (5) pop.	11	pop	-1.377	1.000		-0.022	-0.199	0.729	1.875
				(-3.01)			*(-4.53)*	*(-3.78)*		
BE	eq. (5) pop.	7	pop	-2.656	1.000		-0.008	0.147	0.978	3.216
				(-8.79)			*(-2.40)*	*(11.32)*		
DE	eq. (1)	9	detail	-1.412	0.803	0.865	-0.001		0.474	2.117
				(-0.25)	*(1.58)*	*(2.29)*	*(-0.25)*			
DK	eq. (1)	7	detail	-6.944	1.000	0.735	0.027		0.967	3.504

Country	Equation	No. of obs.	Act. var.	a_0	A_1 or a_2	s	a_3	d	R^2	DW
				(-21.48)		*(-3.93)*	*(7.52)*			
FI	eq. (1)	7	detail	-5.547	1.000	0.572			0.454	1.595
				(-42.70)		*(-2.90)*				
FR	eq. (5) activ.	12	detail	-5.539	1.000	1.000	0.022	-0.322	0.973	1.12
				(-7.31)			*(2.83)*	*(-6.01)*		
GR	eq. (6) activ.	12	aggr	-6.365	1.000	0.000	0.000	-0.247	0.741	2.193
				(-208.6)				*(-3.30)*		
IE	eq. (5) pop.	7	pop	-2.445	1.000		-0.012	-0.385	0.970	1.347
				(-1.64)			*(-0.75)*	*(-6.03)*		
IT	eq. (5) activ.	12	detail	-5.572	1.000	0.000	0.015	-0.436	0.988	2.092
				(-8.79)			*(2.27)*	*(-9.72)*		
NL	eq. (5) pop.	7	pop	-2.731	1.000		-0.008	0.084	0.963	3.471
				(-12.33)			*(-3.39)*	*(8.76)*		
PT	eq. (6) activ.	11	detail	-3.256	1.000	1.000		-0.863	0.914	1.783
				(-41.19)				*(-8.71)*		
ES	eq. (5) activ.	12	aggr	-6.161	1.000	0.000	0.006	-0.296	0.979	2.585
				(-8.84)			*(0.85)*	*(-6.01)*		
SE	eq. (5) pop.	7	pop	-7.197	1.000	-	0.034		0.589	1.972
				(-5.25)			*(2.27)*			
UK	eq. (5) activ.	12	aggr	-4.606	1.000	0.000	-0.016		0.185	1.84
				(-7.08)			*(-2.41)*			

4.6.2. Results

The projected growth in consumption of container glass is moderate. The Baseline scenario estimates an increase of 45-50 % in 2020, and the Low growth scenario a 25-30 % increase.

As is the case for all projections for the group of countries, the EU-15, the projection for the five large countries makes up about 70-80 % of the total quantities. The estimation for glass shows rather big differences between countries, e.g. for Spain the growth is expected to be 85 %, in the UK 50 %, and in Germany 30 %. The highest rise will be for Greece with an estimated increase of 100 %, whereas the growth in Austria may actually be negative with about 8 %.

Figure 21. Baseline scenario for generation of glass, EU-15

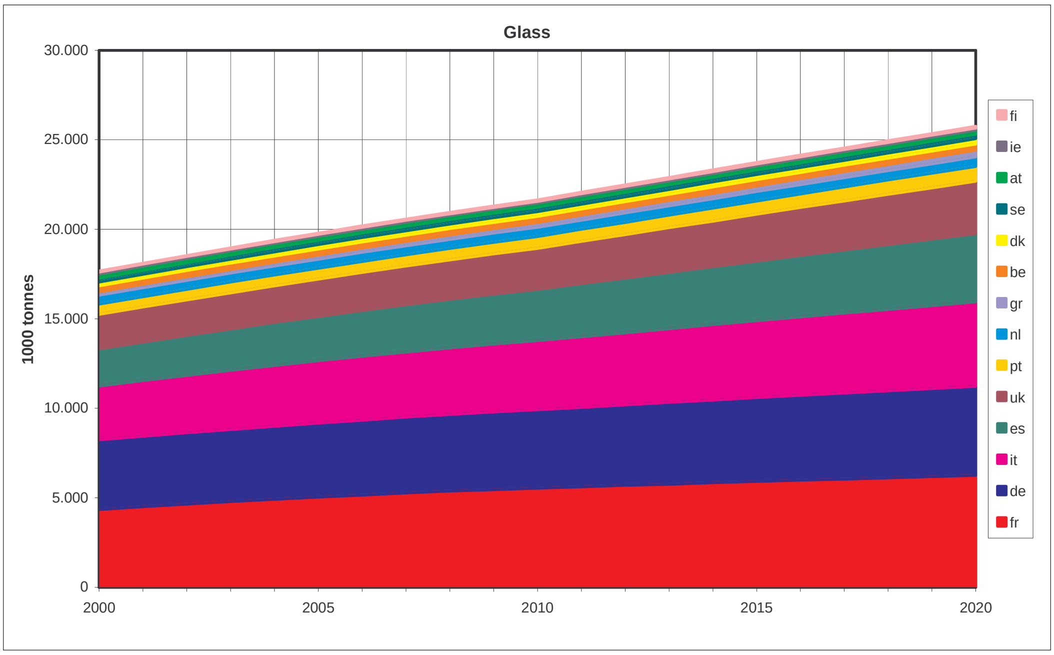
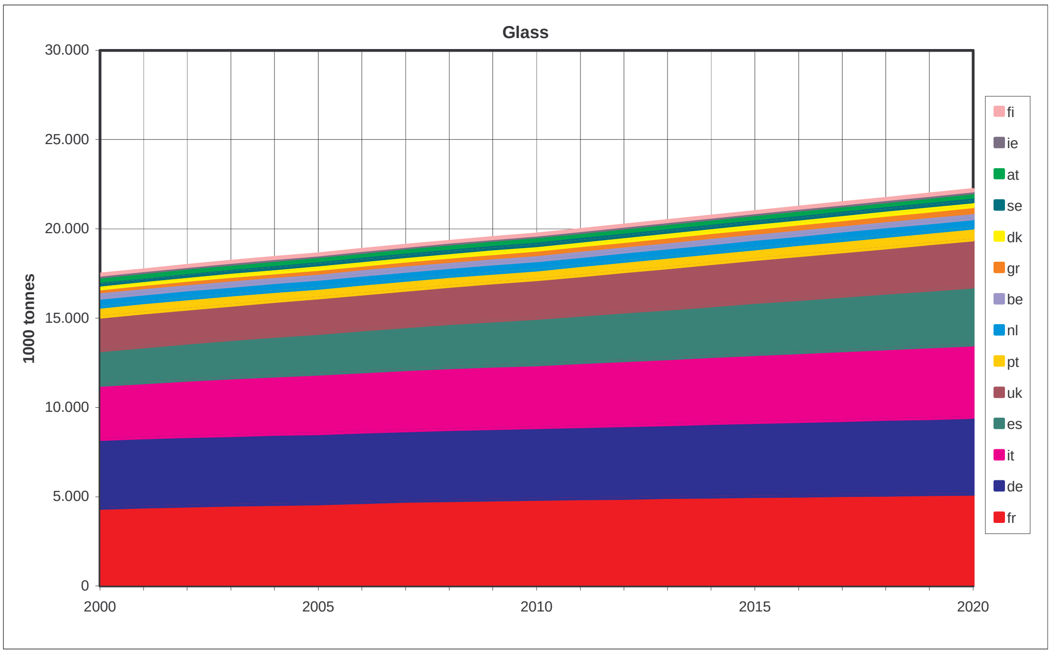


Figure 22. Low growth scenario for glass, EU-15



4.6.3. Assessment

The estimations for Germany and the United Kingdom are uncertain due to failure of model estimations. As these are large countries with a clear impact on the total estimation for the entire EU-15, the estmated quantities should be interpreted with some caution.

4.7. Packaging

The generated quantity of packaging varies significantly between the 15 EU Member States: in 2000 France and Ireland top with a generation of 212-210 kg/capita while Finland and Greece have the lowest generation of only 86-88 kg/capita. The EU average is 174 kg/capita.

The EU Directive on Packaging and Packaging Waste (94/62/EC) provides that Member States must take measures to prevent the generation of packaging waste, but no quantitative targets have been set. The directive also sets targets for the recovery and recycling of packaging waste in 2001. In 2004, the Packaging Directive was revised (2004/12/EC) and higherrecovery and recycling targets were set, to be achieved by 31 December 2008.

4.7.1. Estimations

For packaging, the dependent variable is the amount of packaging consumed and not the packaging waste collected. As a first model, the amount of packaging generated is linked to aggregated private consumption, production or the total population, depending on which variable gives the best explanation of the development in the amount of packaging. The equations chosen for the model are summarised in Table 24.

First of all, it is noted that the model is based on very few observations, with a maximum of 5 years. For four countries (Greece, Ireland, Italy and Portugal) only three observations were available when the estimations were made. The quantity of packaging placed on the market has been reported annually by the former EU-15 since 1997 as required by the Packaging Directive.

Second, it is seen that in general packaging coefficients are relatively constant (small trend coefficients (a_3) and high R^2-values). For Belgium, Germany, Denmark and Ireland Eq. (5) activ. has been chosen, which means that the projection depends on an annual change in the waste coefficient (i.e. a_3). Similarly, for Sweden and Finland the future trend is estimated using the annual change in the amount of waste per capita (Eq. (5) pop.).

For Austria and the UK, Eq. (4) has been chosen, i.e., packaging per inhabitant depends on private consumption or GDP per inhabitant. For the Netherlands, the historical observations are not explained by neither the economic activity nor the population, and therefore a constant amount per capita is assumed in the projections.

For the remaining countries, the future trend is estimated using a constant waste coefficient (a_0).

Conclusively, the consumption of packaging is in general explained by changes in the population and economic activity. However, given the few observations, the reliability of the model for projections is limited.

Table 24. Model parameters for packaging, EU-15

Country	Equation	No. of obs.	Act. Var.	a_0	a_1	s	a_3	d	R^2	DW
AT	eq. (4) altv.	4	fcs	-3.412 *(-7.24)*	0.561 *(3.19)*	1.000	0.000		0.901	2.123
BE	eq. (5) activ.	4	fcs	-4.931 *(-6.98)*	1.000	1.000	0.005 *(0.74)*		0.912	2.123
DE	eq. (5) activ.	4	fqs	-5.597 *(-29.91)*	1.000	0.000	0.007 *(3.85)*		0.994	3.281
DK	eq. (5) activ.	5	fcs	-5.335 *(-97.28)*	1.000	1.000	0.009 *(15.45)*	0.130 *(66.92)*	0.999	3.349
FI	eq. (5) pop.	4	pop	-4.315 *(-7.92)*	1.000		0.019 *(3.37)*		0.880	3.196
FR	eq. (6) activ.	5	fqs	-4.615 *(-744.8)*	1.000	0.000	0.000		0.919	1.776
GR	eq. (6) activ.	3	fcs	-4.570 *(-123.3)*	1.000	1.000	0.000		1.000	1.027
IE	eq. (5) activ.	3	fcs	-3.495 *(-1.161)*	1.000	1.000	-0.004 *(-0.14)*		0.863	3.000
IT	eq. (6) activ.	3	fqs	-4.369 *(-110.7)*	1.000	0.000	0.000		0.922	1.354
NL	eq. (6) activ.	4	pop	-1.766 (-59.87)	1.000	0.000	0.000		0.191	1.883
PT	eq. (6) activ.	3	fcs	-3.987 *(-96.65)*	1.000	1.000	0.000		0.934	1.482
ES	eq. (5) activ.	5	fcs	-4.484 *(-211.0)*	1.000	1.000	0.000	0.139 *(5.838)*	0.868	3.267
SE	eq. (5) pop.	4	pop	-3.994 *(-8.71)*	1.000		0.018 *(3.86)*		0.888	2.006
UK	eq. (4) alt.	4	fqs	-2.603 *(-2.19)*	0.278 *(0.65)*	0.000	0.000	0.117 *(4.59)*	0.983	2.003

4.7.2. Results

The past trends are continued, which results in a steady increase in the amount of packaging placed on the market. Packaging is a short-lived commodity and the general assumption is that all packaging placed on the market will become waste within a year.

In the Baseline scenario that is presented in Figure 23 the total amount of packaging waste for the former EU-15 Member States is estimated to increase by 20-25 % over the next 10 years compared to the reference year 2000, as shown in Table 25. The Low growth scenario produces lower increases of approx. 15 % in 2010.

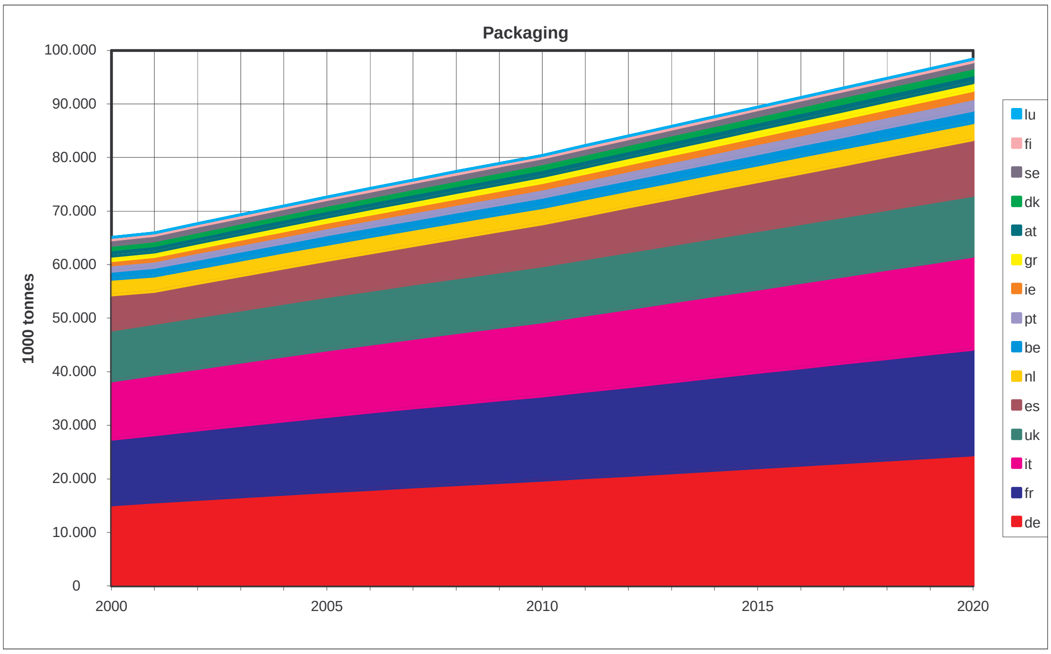
Table 25. Projection of packaging waste, EU-15

%	Baseline scenario	Low growth scenario
2000-10	23.6	15.1
2000-20	51.1	33.4
2000-30	82.8	53.6

The projected values for 2020 and 2030 are also shown in Table 25, but it should be stressed that these values are highly uncertain considering the fact that the historical observations are very few. It is therefore doubtful whether they are sufficiently robust to be extended 20 or 30 years into the future.

The largest increases in packaging waste are estimated for Ireland, Portugal and Greece (25-55 % in 2010) while the lowest increases are estimated for the Netherlands, Sweden, the United Kingdom, Austria and Finland (5-15 % in 2010).

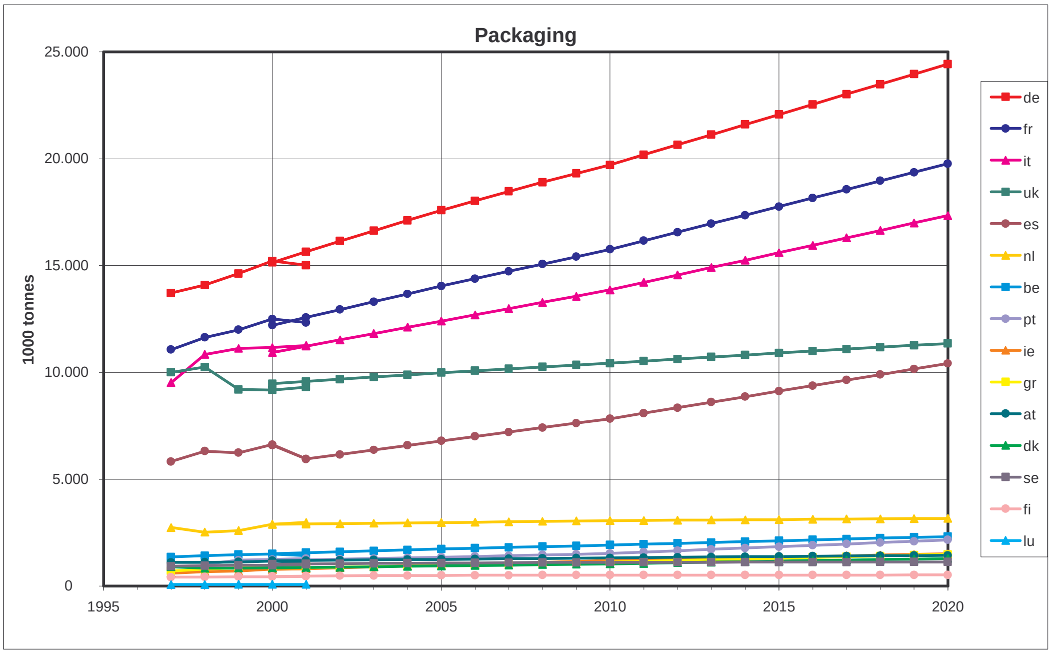
Figure 23. Baseline scenario for packaging waste, EU-15



Note: No projection is made for Luxembourg.

For the six countries where the trend coefficient (a_3) appears in the estimations, the past trend has been phased out to zero over 10 years. However, as the trend coefficient is very low this does not have any real impact on the total projection. The a_3 parameter is highest (annual changes of 1.8 and 1.9 %) for Finland and the United Kingdom where the population is the explanatory variable, but these countries also have a rather low increase in the waste quantity as stated above.

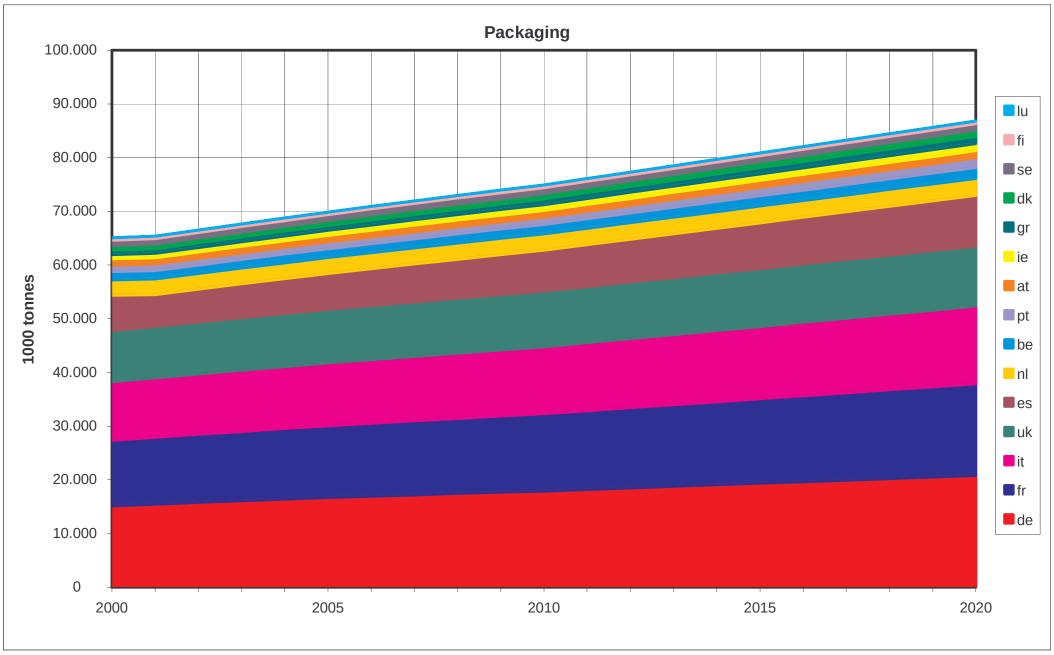
Figure 24. Baseline scenario for packaging waste 2000-2020, EU-15, Actual generation of packaging waste 1997-2001



In Figure 24 the Baseline scenario is presented together with the historical observations for 1997-2001. This implies that for the years 2000 and 2001 the figure shows two values: the actual reported amounts by Member States and the projected ones.

The Low growth scenario is shown in Figure 25. The general picture is the same as in the Baseline scenario except that the slope is more flat and the ascent is lower.

Figure 25. Low growth scenario for packaging waste, EU-15



Note: No projection is made for Luxembourg.

4.7.3. Assessment

As noted the time series is rather short and when looking at the historical data it seems fair to conclude that several countries have spent the first two years to establish and fine-tune the data collection methodology and system. The majority of Member States set up a packaging waste management system as a direct consequence of the 1994 Packaging Directive, and from a data point of view packaging is a relatively ‘new’ waste stream. Hence, the first two observations may not reflect the actual quantities due various ‘start problems’ with the data collection methodology and the packaging waste management system itself. As a result, the basis for extending past trends is weak, so the longer the time horizon the greater the uncertainty about the projection.

In order to see whether a decoupling of packaging from economic growth may be achieved, the projected increases are compared to the private final expenditure of households. The private expenditure is one of the parameters used to project packaging and thus some correlation is bound to exist between the two. For 2010 the development in packaging and household expenditure shows almost the same growth rate: 20-25 % for packaging and 26.4 % for household expenditure. In other words, a relative decoupling might just take place.

It is often stated that the size of households is a driving factor in the generation of packaging and thus packaging waste. The motivation is that households are becoming smaller, which increases the demand for smaller portions, more ready-made food and ‘TV dinners’. Including household size as an explanatory parameter may therefore improve the model.

Reuse systems exist in several countries but they are generally under pressure from often cheaper and more convenient one-way packaging, thus increasing the total amount of packaging waste. One such example is a hugely increased demand for mineral water in one-way plastic bottles.

4.8. Tyres

Data on used tyres are even more sparse than for any of the other waste streams. The available data on tyres per car are shown in Table 26.

Table 26. Tyres per car, kg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Denmark[1]							9.6	10.4	10.7	11.1	19.1
Ireland	10.3	9.4	12.3	10.0	12.1	8.8		10.1	13.5		
Sweden[2]							13.0	11.8	13.8	15.1	15.5

Note: Calculated on the basis of used tyres and the number of cars in the relevant year. Note 1: From 1 April 2000 the scheme included tyres from all motor vehicles. Note 2: Collected tyres. Source: Irish EPA (1998), Danish EPA, Swedish EPA, and Kilde and Larsen (2001a).

Denmark has statistics for used tyres from cars, vans and motorbikes in the waste statistics for the years 1996-2000. By 1 April 2000 the scheme was extended to cover tyres from all motor vehicles. The amount of tyres per car (i.e. the waste coefficient) is relatively constant for the period 1996-1999, but for year 2000, the coefficient almost doubles due to an enlargement of the collection scheme to include tyres from lorries, etc.

Information on the quantities of waste tyres in Ireland from 1990-1995 is based on information from Semperit Ireland, the major producer of tyres, which has ceased operations. Best estimates of arisings since 1995 can be made from the net imports into the country assuming that all imports are replacements for existing tyres[5]. The figures include all tyres and are much higher than for Denmark. Also, the figures vary considerably from one year to the next. Looking at tyres from vehicles only, the amount is about the same as in Denmark, i.e., between 10 and 13 kg tyres per vehicle.

Data for Sweden are from the Swedish Tyre Recycling Association and include the quantity of tyres collected via the producer responsibility obligation[6]. The amount of collected tyres is slightly larger than in Denmark, and the number of used tyres is 1.5 kg greater than the collected tyres.

4.8.1. Estimations

In the model, the use of tyres and the amount of waste oil is linked to the number of vehicles.

If it is decided to concentrate on tyres from private vehicles (excluding lorries and off-road equipment), a central value of the coefficient is evaluated to be between 12 to 16 kg tyres per vehicle. In the projection model, without additional information, a first guess for other EU-15 countries is 15 kg tyres per vehicle. Hence, for the projections a standard assumption has been made saying that each car generates 15 kg of used tyres annually regardless of country and year.

This assumption is mainly based on information from three countries: Denmark, Ireland and Sweden. The 15 kg/car applies to all 25 countries. The waste coefficients are shown in Table 27.

Table 27. Waste coefficients for used tyres

Country	Equation	No. of obs.	Year	Average period used	Waste coefficient: average kg tyres/vehicle	Waste coefficient: Last Year
Denmark	eq. (6) no. vehicles	5	1996-2000	1996-1999	10.44	19.11
Ireland	eq. (6) no. vehicles	9	1990-1998	1990-1998	23.68	26.14
Sweden	eq. (6) no. vehicles	5	1995-1999	1995-2000	13.81	15.46

Source: Danish EPA , Irish EPA (1998), Swedish EPA, and Kilde and Larsen (2001a).

4.8.2. Results

The amount of used tyres for the EU-15 is projected to rise by 25 % from 2000 to 2020. The increase in the same period for the EU-10 is 70-75 % and 115 % for Bulgaria and Romania (CC2).

The projection is directly linked to the model for end-of-life-vehicles, and the significant increases in the EU-10 and CC2 are due to the fact that the number of cars is projected to rise by the same amount.

The key assumptions for the Low growth scenario do not affect the Baseline scenario for used tyres as it is projected using the model for end-of-life-vehicles.

The Baseline scenario for the EU-15 and EU-10 is presented in Figure 26 and Figure 27.

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[5] Irish EPA (1998)

[6] Swedish EPA

Figure 26. Baseline scenario for waste from tyres, EU-15

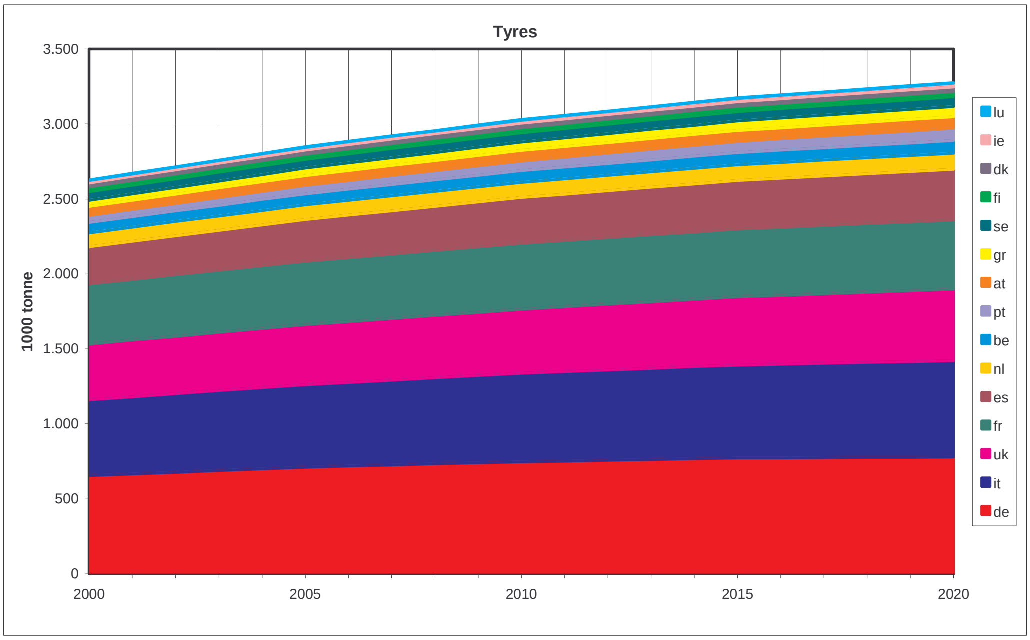
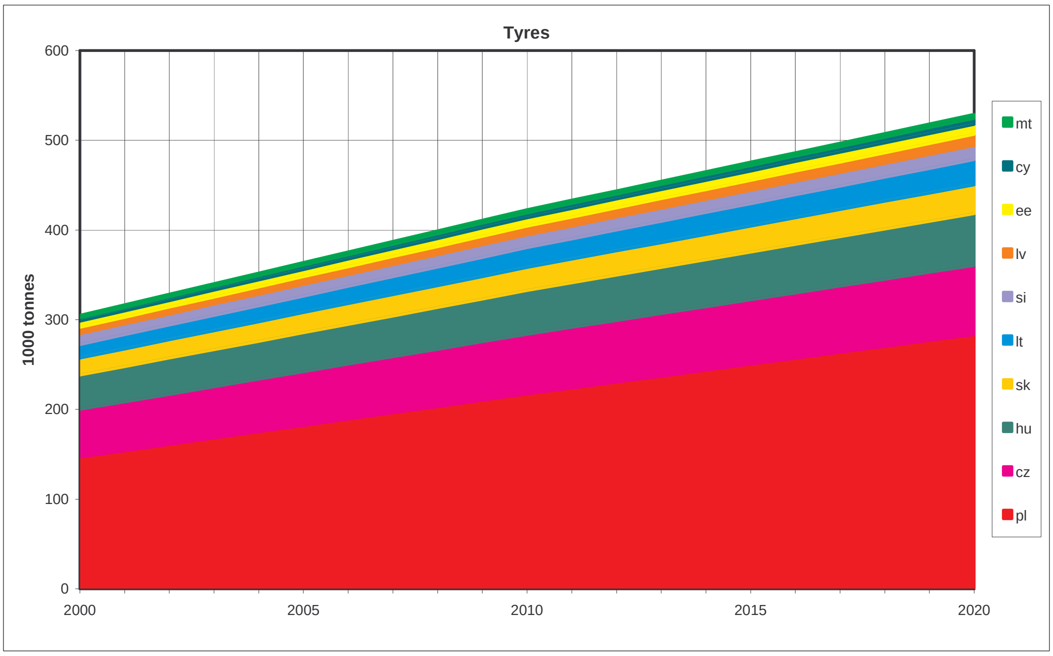


Figure 27. Baseline scenario for waste from tyres, EU-10



4.8.3. Assessment

The projected trend, i.e. the projected changes, for used tyres is assessed to be good. However, the assumption of a constant waste coefficient of 15 kg per car per year for all countries is quite rough, and should be improved when possible. As a result, the acual amounts of waste from tyres are clearly more uncertain.

4.9. Waste oil

The EU Directive on Waste Oil applies to any mineral-based lubrication or industrial oils which have become unfit for the use for which they were originally intended, and in particular used combustion engine oils and gearbox oils, and also mineral lubricating oils, oils for turbines and hydraulic oils.

The majority of data on generation of waste oil have been published in the report from the Commission[7] on the implementation of the Directive on Waste Oils. The data are all from the period 1995-1997, except from Belgium where the data are from 1998.

4.9.1. Estimations

Contrary to the other waste streams (except used tyres), time series are not used for waste oils. Here, data for the latest available year are chosen. Table 28 shows that the amount of waste oil varies between 12 and 27 kg oil per vehicle. However, for most of the countries, the amount of waste oil is within the interval of 12 to 18 kg waste oil per vehicle. The extreme values are for Finland and Greece. No data on the generation of waste oils are available for Denmark and Sweden.

Table 28. Waste coefficients for waste oil

Country	Equation	No. of obs.	Year	Waste coefficient kg. oil/vehicle
AT	eq. (6) no. vehicles	3	1997	11.89
BE	eq. (6) no. vehicles	2	1998	12.69
DE	eq. (6) no. vehicles	3	1997	18.39
DK	eq. (6) no. vehicles	0	-	-
FI	eq. (6) no. vehicles	1	1997	25.71
FR	eq. (6) no. vehicles	3	1997	14.33
GR	eq. (6) no. vehicles	1	1995	27.23
IE	eq. (6) no. vehicles	3	1997	12.48
IT	eq. (6) no. vehicles	2	1997	12.75
NL	eq. (6) no. vehicles	3	1997	14.68
PT	eq. (6) no. vehicles	1	1995	17.60
ES	eq. (6) no. vehicles	1	1995	17.63
SE	eq. (6) no. vehicles	0	-	-
UK	eq. (6) no. vehicles	3	1997	20.28

Note: Calculated on the basis of generated waste oil and the number of cars in the relevant year.
Source: Waste Base, and Kilde and Larsen (2001a).

Differences in the amount of waste oil per vehicle are caused by

- Differences in size and use of vehicles;
- The share of lorries (waste oil from lorries are included in the amount of waste, but the coefficient is only based on the number of private cars and vans).

This may explain variations between most of the countries, but the extreme values for Finland and Greece require additional explanations that we have not found at present.

4.9.2. Results

The Baseline scenario projects a rise in waste oil by 25-30 % up to 2020 for the EU-15, 70-75 % for the EU-10 and 115 % for the CC2. The Baseline scenario for the EU-15 and EU-10 is presented in Figure 28 and Figure 29.

The projection is directly linked to the model for end-of-life-vehicles, and since the number of cars is projected to increase significantly this also affects the projection for used oil. For the EU-10 and CC2 the projected trend for used tyres and waste oil is the same,

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[7] Report from the Commission to the Council and the European Parliament on the implementation of community waste legislation. Directive 75/439/EEC on Waste oils for the period 1995-1997

but for the EU-15 there is a slight difference as data on generated waste oil are not available for all countries.

The key assumptions for the Low growth scenario do not affect the Baseline scenario for waste oil as the projection is based on the model for end-of-life-vehicles.

A relative decoupling of the generation of waste oil from the GDP may take place for the EU-15 and the EU-10, whereas it is not likely to happen for the two candidate countries, at least if the projections prove to be correct.

Figure 28. Baseline scenario for waste oil, EU-15

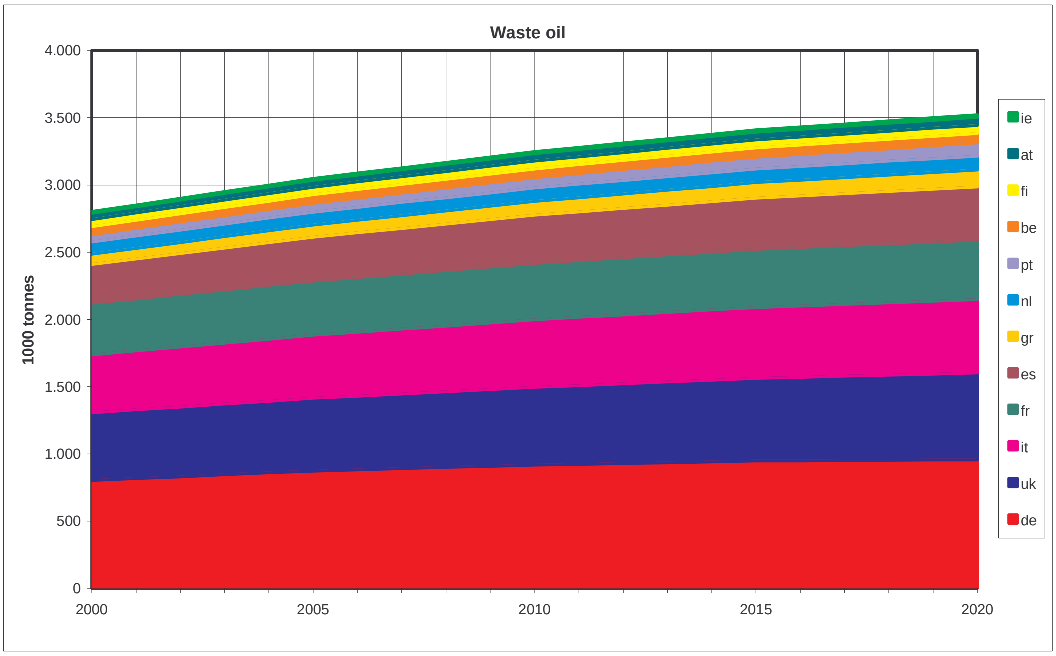
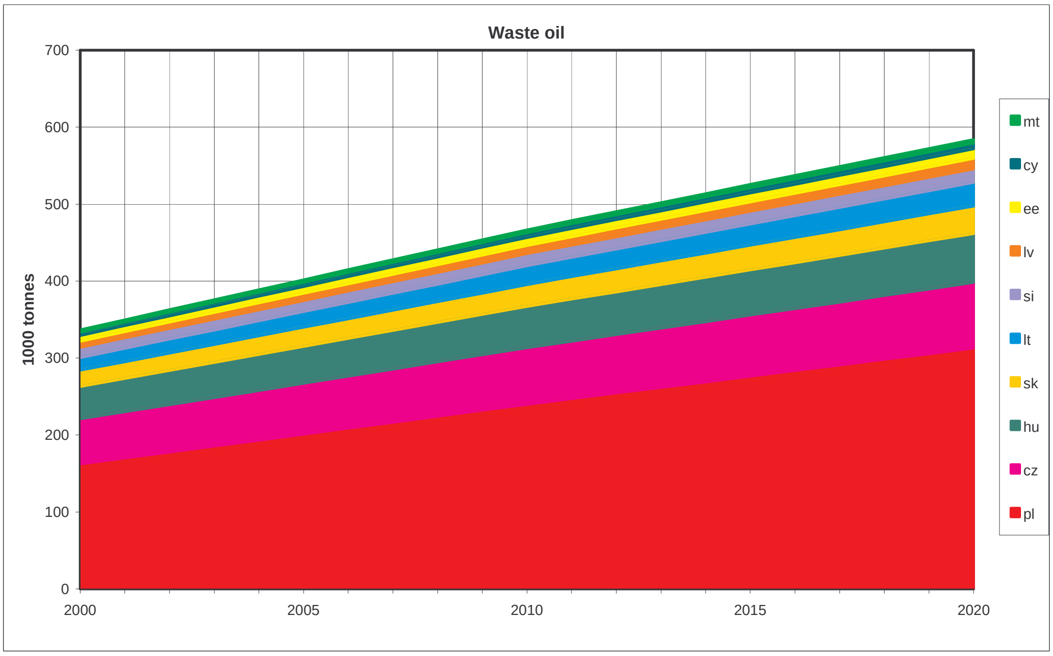


Figure 29. Baseline scenario for waste oil, EU-10



4.9.3. Assessment

The assessment is the same as the one for used tyres.

Detailed statisitics on used oil for France indicate that if only waste oil from car repairs, car demolition and transport is included, it would imply that the waste coefficient reduces to 5-6 kg of waste oil per vehicle. This is about one third of the amount used for France in this projection. The conclusion for used tyres therefore also applies to waste oil: data should be assessed and improved when possible.

5. Projections for material flows

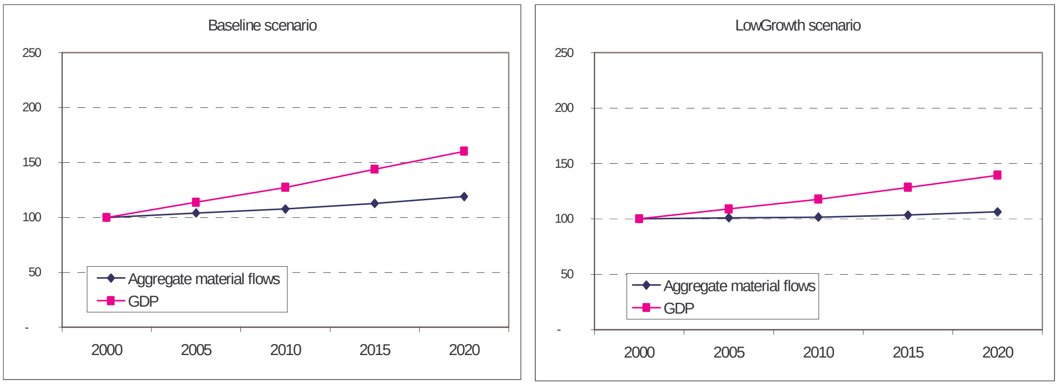
The projections for material flows comprise main components of the Domestic Material Consumption (DMC), a composite indicator showing how much materials are consumed by a national economy. Not all components of the DMC are included, but the components which have been projected represent about 95% of composite DMC and is therefore a good proxy for it.

Recently, the DMC indicator has been used to monitor decoupling of environmental pressures of resource use from economic growth (e.g. EEA 2003) – an objective put forward by the Sixth Environment Action Programme (CEC 2001). During the last 20 years the EU has seen a more or less stagnating DMC whilst the GDP has been growing – this is called relative decoupling (in contrast to absolute decoupling where the DMC would have declined absolutely and hence most likely also the associated environmental pressures).

During the last 20 years the EU has seen a more or less stagnating DMC whilst the GDP has been growing. The projections for the EU suggest that this development will not continue. Moreover, in both the Baseline scenario and the Low growth scenario, the aggregate material use is increasing, along with growing GDP. Indeed, relative decoupling will be achieved, but the pressure on the environment is not likely to be eased which would only be the case if material use would decrease in absolute terms. In the Baseline scenario for the EU-15, the GDP is almost doubling (+60%) between 2000 and 2020 whilst the aggregate material flows increase by around 19%. In the Low growth scenario, the GDP only rises by 39% whilst material use increases by 6%.

Both cases illustrate that according to a 'business-as-usual' development, technological progress in terms of resource productivity is not improving sufficiently to achieve an absolute decoupling. Further efforts are needed to increase resource productivity (in terms of GDP/DMC). As a minimum, resource productivity has to grow at the same growth rate as the GDP in order to achieve a stagnating material input. The productivity, however, rose only by 35% and 31% respectively in the Baseline and Low growth scenarios.

Figure 30. **Decoupling of aggregate material flows and GDP in the Baseline and Low growth scenarios, the former EU-15**

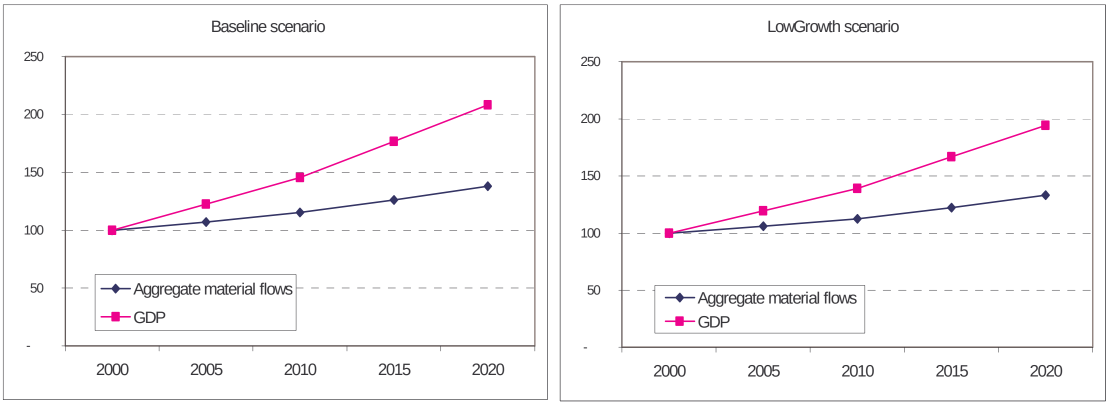


For the new Member States (EU-10) the projection results are given in Figure 31. Economic growth is projected to grow much more pronounced in the 10 new Member States.

In the Baseline scenario, it almost doubles (+108%), and in the Low growth scenario it increases by about 94%. Also the aggregated material flows are projected to grow. They increase by 38% in the Baseline scenario, and by 33% in the Low growth scenario.

Although, productivity (GDP/aggregate material flows) in the new Member States is projected to grow faster than in the former EU-15 Member States (51% in the Baseline scenario and 46% in the Low growth scenario), this is by far not enough to stabilise material input. In order to achieve absolute decoupling, productivity growth would have to be at least at the same rate as economic growth, i.e. about two times stronger.

Figure 31. Decoupling of aggregate material flows and GDP in the Baseline and Low growth scenarios, the new EU-10



In the following sections, the projections for the single components of DMC are presented and discussed in more detail.

5.1. DEU - Minerals

5.1.1. Industrial minerals and ores – EU-15

With some 0.4 tonnes per capita, the domestic extraction of industrial minerals and metal ores is by far the quantitatively smallest material flow category in the European Union (EU-15).

From 1980 to 2000, the domestic extraction of industrial minerals and metal ores in the European Union (EU-15) has been continuously decreasing from some 240 million tonnes to about 150 million tonnes. Many Member States have closed mines during the last decades. On the other hand, imports of metal ores and concentrates have been increasing accordingly.

According to different geological equipping and industrial structures, the per capita domestic extraction of industrial minerals and metal ores varies significantly across countries, ranging from around 50 kg per capita in Belgium and Luxembourg to more than 3 tonnes per capita in Sweden.

Estimations

In general, equation (5) activity has been used for this material flow component; with the exceptions of Ireland and the UK, where equation (5) population has been used. The parameters have been estimated based on historical time series (Eurostat New Cronos). The number of observations varies across countries due to data availability.

The economic activity variable A_i chosen is gross value added (in constant 1995 prices) in the mining, manufacturing and energy sectors (NACE sections C, D, and E). Although the domestic extraction of industrial minerals and ores takes place only in the mining sector, it can be argued that the entire industry sector (i.e. NACE C, D, and E) determines the demand for these materials. In addition, the gross value added in the mining sector (NACE C) is not forecasted in the economic model. We also test a relation where the domestic extraction depends on the size of population, however, a theoretical argument for this link is hard to find. For Ireland and the UK population has been used as the activity variable since no historical data on sectoral gross value added were available.

The estimated parameters vary quite considerably across countries. A general conclusion from the estimations is that the past development in domestic extraction is mainly characterised by dummy-shifts and a negative trend. From a theoretical point of view, what determines domestic extraction are relative prices/wages and the competition in the world market including transport costs, and that is what should be modelled in an economic model determining domestic extraction. Dummy shifts are due to closing/starting of large extraction units and a trend may be interpreted as a changing share of extraction relative to the industrial production. As mentioned, many EU Member States have reduced their domestic mining activities and have shifted to importing metallic and mineral raw materials instead. This is also derivable from the negative trend observed in most countries.

It has to be noted that using *eq.(5)activ.* and fixing parameter a_1 equal to 1 implies a general positive relationship between gross value added and domestic extraction of industrial minerals and ores. An increase in industry's gross value added (as it is projected by the econometric model) also implies an increase of projected material flow. However, in the past, this was not true for many countries; i.e. domestic extraction of industrial minerals and ores decreased while industry's gross value added was on the increase. This historical negative trend is reflected by the parameter a_3 expressing how much the ratio w/A (i.e. material extracted per unit GVA) is changing each year. Like this, it is possible that w (materials extracted) is decreasing whilst A (GVA) is growing. However, it has to be noted that the time trend (parameter a_3) is levelled out over the first 10 projection years: i.e. after 2010 it equals zero. Thus, the main parameter determining the projection results after 2010 is parameter a_1 (being fixed to equal 1). This implies that after 2010 growing GVA also will lead to increasing extractions.

Table 29 shows the estimation results for the individual countries. The equations marked yellow have been chosen. A closer look at the parameter a_3 in the following table reveals that France and Spain show strong negative trends. The w/A ratio decreases every year by 7-8%. Considerable decrease rates for the ratio w/A (around -4%) also exist in Austria, Belgium and Luxemburg, Finland, Italy, and the Netherlands. In these countries domestic mineral extraction has been absolutely decreasing as long as the economic growth in industry remained below around 4%. Only 2 countries (Germany and Greece) show a positive parameter a_3 of around 1-2% implying that with economic growth in industry also domestic extraction of industrial minerals has been increasing. Whereas for Greece the R^2 is remarkably high, the R^2 for the German estimate is almost zero.

Table 29. Domestic extraction used (DEU) – industrial minerals and ores, EU-15

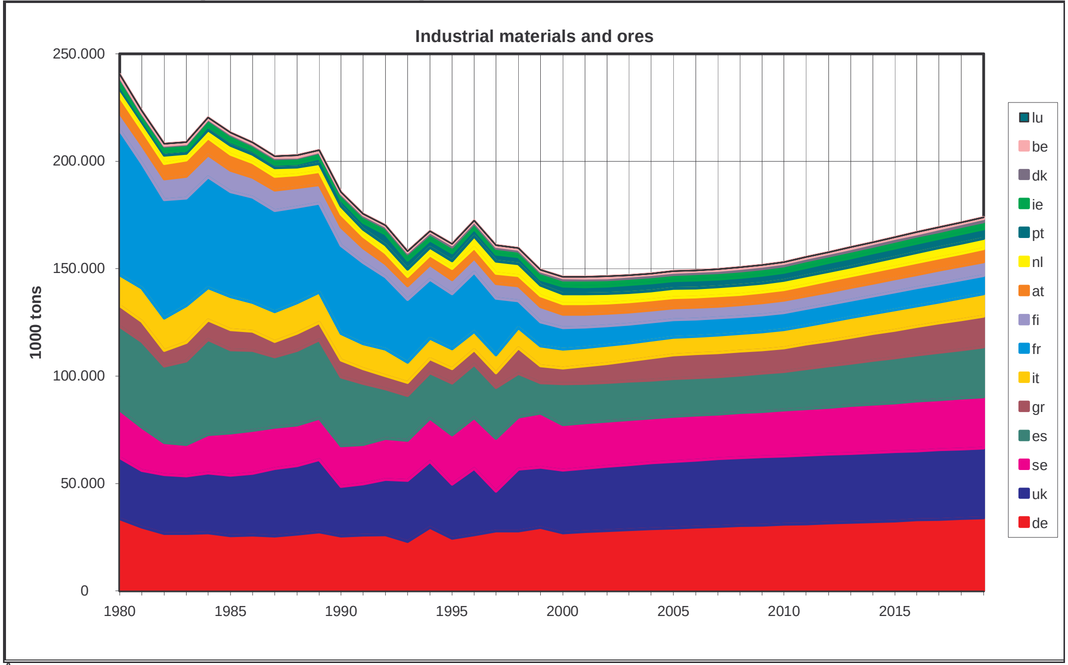
Country	Equation	No. of obs.	a_0	a_1	a_2	a_3	d	d1	Dxxyy	D1xxyy	R^2	DW
at	eq. (5) activ.	21	1,803	1,000		-0,041	0,168		8090		0,884	0,842
			(3,62)			*(-7,87)*	*(2,67)*					
	eq. (5) pop	21	1,23		1,000	-0,018	0,217		8090		0,867	1,000
			(2,30)			*(-3,40)*	*(3,22)*					
be	eq. (5) activ.	6	-0,156	1,000		-0,045					0,927	2,397
			(-0,85)			*(-24,02)*						
	eq. (5) pop	21	-1,705		1,000	-0,013	0,429	0,127	8081	8290	0,969	1,423
			(-5,92)			*(-4,29)*	*(8,06)*	*(3,84)*				
de	eq. (5) activ.	10	-3,757	1,000		0,010					0,078	2,642
			(-4,27)			*(1,05)*						
	eq. (5) pop	21	-0,485		1,000	0,007					0,155	1,692
			(-1,96)			*(-2,44)*						
dk	eq. (5) activ.	21	-2,112	1,000		-0,014	-0,463	-0,264	8084	8591	0,921	1,686
			(-3,31)			*(-2,12)*	*(-4,65)*	*(-4,24)*				
	eq. (5) pop	21	-2,676		1,000	0,008	-0,362	-0,180	8084	8591	0,947	1,396
			(-5,20)			*(1,53)*	*(4,49)*	*(3,57)*				
fi	eq. (5) activ.	21	2,971	1,000		-0,045	0,155		8090		0,796	0,748
			(4,95)			*(-7,21)*	*(2,04)*					
	eq. (5) pop	21	0,418		1,000	-0,002	0,354		8090		0,869	1,048
			(0,88)			*(-0,33)*	*(5,90)*					
fr	eq. (5) activ.	9	4,259	1,000		-0,074	0,695		8097		0,986	1,468
			(3,99)			(-6,87)	(10,34)					
	eq. (5) pop	21	4,317		1,000	-0,060	0,669		8097		0,987	0,771
			(15,21)			*(-21,10)*	*(13,59)*					
gr	eq. (5) activ.	6	-2,303	1,000		0,017	0,497		98		0,998	2,536
			(-8,06)			(5,75)	(36,98)					
	eq. (5) pop	21	-1,365		1,000	0,010	0,291	0,525	8090	98	0,792	1,128
			(1,58)			*(1,10)*	*(3,46)*	*(5,49)*				
ie												
	eq. (5) pop	21	0,686		1,000	-0,009	-0,146		8090		0,178	1,381
			(0,81)			*(-1,07)*	*(-1,36)*					
it	eq. (5) activ.	21	1,389	1,000		-0,046	0,154		8292		0,911	1,460
			(4,75)			*(-14,78)*	*(4,05)*					
	eq. (5) pop	21	-0,022		1,000	-0,019	0,254		8092		0,929	1,356
			(-0,05)			*(-4,17)*	*(4,60)*					
nl	eq. (5) activ.	13	1,039	1,000		-0,037	-0,498		8095		0,966	1,660
			(2,18)			*(-7,56)*	*(-12,58)*					
	eq. (5) pop	13	1,146		1,000	-0,023	-0,498		8095		0,978	1,991
			(3,13)			*(-6,09)*	*(-15,82)*					
pt	eq. (5) activ.	12	0,794	1,000		-0,026	-0,773		8088		0,406	1,017
			(0,34)			*(-1,07)*	*(-2,53)*					
	eq. (5) pop	21	-0,084		1,000	-0,011	-0,826		8088		0,819	1,096
			(-0,07)			*(-0,87)*	*(-5,37)*					
es	eq. (5) activ.	6	5,952	1,000		-0,077	-0,406		99		0,936	2,257
			(3,48)			(-4,36)	(-5,03)					
	eq. (5) pop	21	1,476		1,000	-0,021	0,286	-0,400	8090	99	0,925	1,840
			(1,67)			*(-2,28)*	*(3,41)*	*(-4,09)*				
se	eq. (5) activ.	8	1,693	1,000		-0,025					0,942	1,107
			(3,54)			*(-5,01)*						
	eq. (5) pop	21	0,005		1,000	0,010	-0,238		8283		0,684	0,364
			(0,02)			*(2,61)*	*(-3,09)*					
uk	eq. (5) activ.											
	eq. (5) pop	21	-1,849		1,000	0,011	0,253		8089		0,285	2,466
			(-2,36)			*(1,33)*	*(2,53)*					

Results

In the Baseline scenario (with levelling out of w/A ratio after 10 years; Figure 32) the historical trend in domestic extraction of industrial minerals and ores is not continued. For the aggregated EU-15, the domestic extraction volumes show a smooth increase up from the year 2000 – the lowest point (below 150 million tonnes). After 2010, the increase becomes steeper. This latter development can be explained by the intrinsic characteristics of the estimation method as explained above: between 2000-2010, the change rate of *w/A* ratio – which is expressed by parameter a_3 and which is for most of the countries negative – is levelled out to zero. That implies that up from 2010 the domestic extraction of industrial minerals and ores is growing to the same extent as the gross value added is growing in the industry sectors (NACE sections C, D, and E). Whereas, between

2000-2010 the domestic extraction volumes are growing less rapidly than the gross value added.

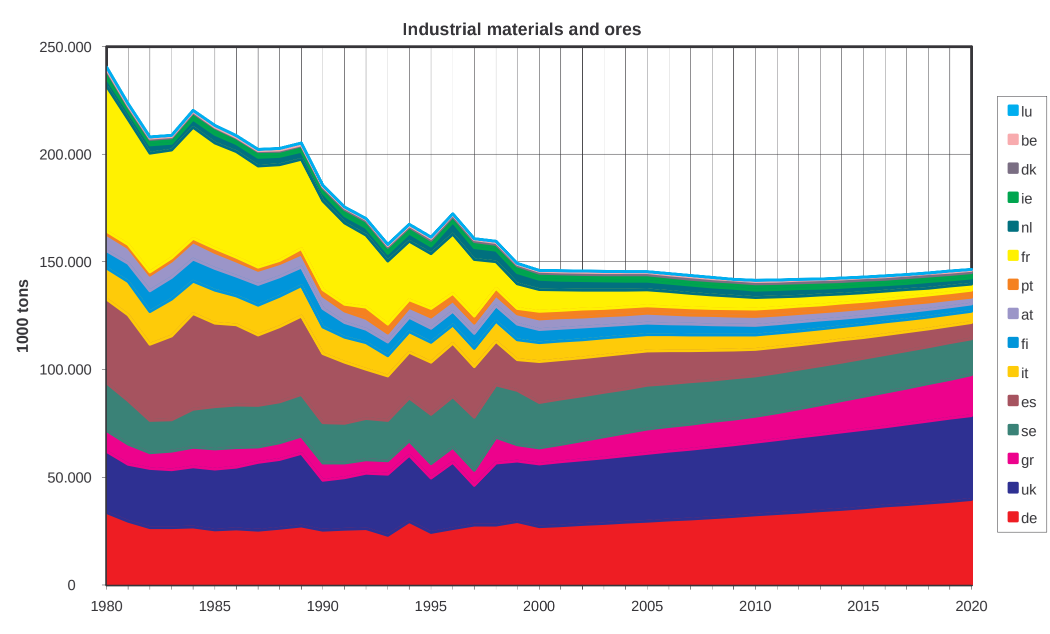
Figure 32. Domestic Extraction of Industrial Minerals and Ores ($DEU_{industrial+metals}$), EU-15 Baseline scenario[A]



[A]: with parameter a_3 is levelling out to Zero between 2000 and 2010

Alternatively, a Baseline scenario was calculated without levelling out of parameter a_3. This implies that for the most countries the *w/A* ratio is decreasing with time (see Figure 33). As a consequence the domestic extraction of industrial minerals and metal ores develops much flatter after 2000 – it remains below 150 million tonnes. Germany, the UK, Greece and Sweden increase their domestic mining of industrial minerals and metal ores. For Germany and Greece this can be explained by a positive sign of parameter a3. For the UK, it can be explained by the fact that *equation (5) population* has been chosen, and the population will increase. Sweden is a special case: although parameter a3 has a negative sign, the forecasted growth of gross value added in the industry sectors seems to compensate this effect.

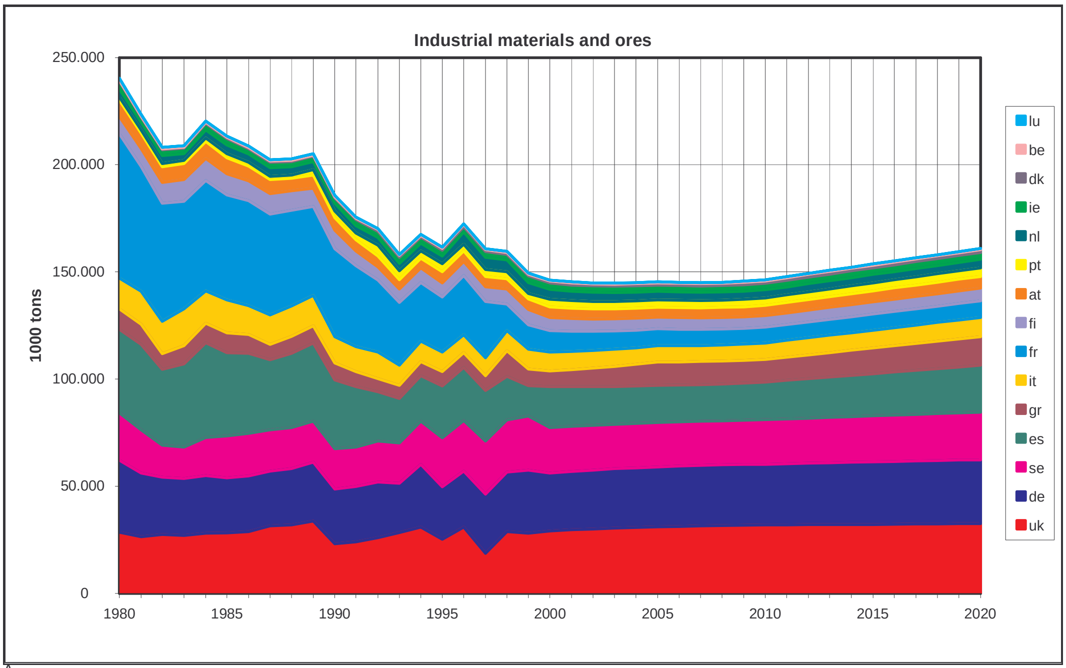
Figure 33. **Domestic Extraction of Industrial Minerals and Ores ($DEU_{industrial+metals}$), EU-15 Baseline scenario^B**



^{B}: with keeping parameter a_3 constant between 2000 and 2020

In the Low growth scenario the historical trend in domestic extraction of industrial minerals and ores is also not continued (Figure 34). However, between 2000-2010, the aggregated domestic extraction volumes remain more or less stable below 150 million tonnes. After 2010, we see again a steady increase. The constant level between 2000-2010 can be explained as follows: the negative change rate of the *w*/*A* ratio (parameter a_3) is apparently in the same order of magnitude as the growth rate of gross value added in the industry sectors. In other words, the economic growth rate is counterbalanced or out levelled by the decrease rate of the *w*/*a* ratio. The increase after 2010 is explained by the parameter a_3 set to zero.

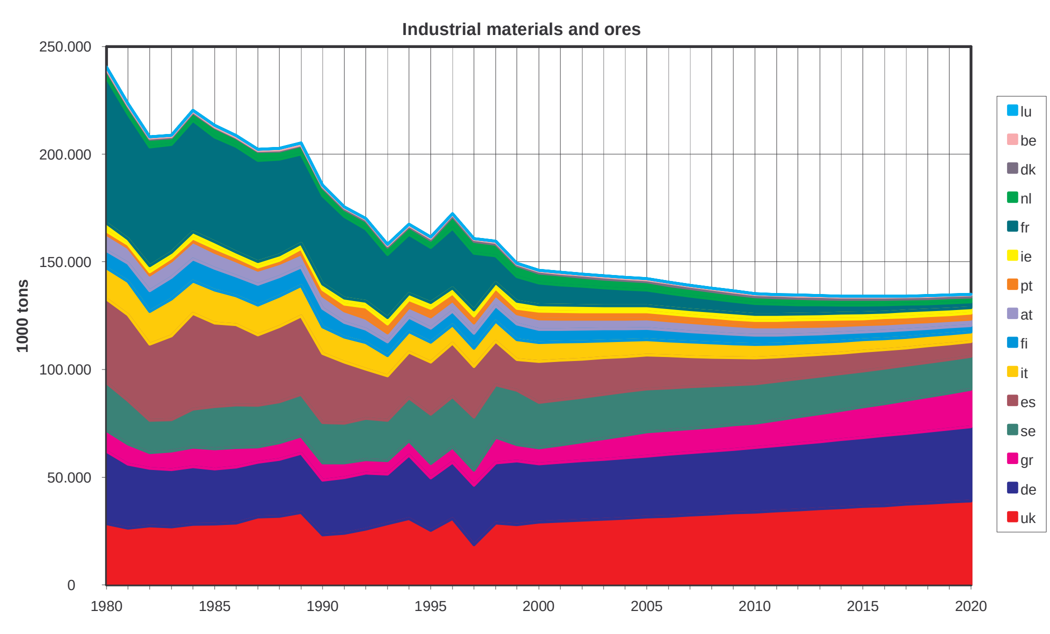
Figure 34. Domestic Extraction of Industrial Minerals and Ores (DEUindustrial+metals), EU-15 Low growth scenario[A]



[A]: with parameter a_3 is levelling out to zero between 2000 and 2010

Alternatively, a Low growth scenario was again calculated without levelling out of parameter a_3 (Figure 35). This clearly leads to a continuation of the historical trends, i.e. the domestic extraction of industrial minerals and metal ores is decreasing for the EU-15. Again, those countries increase which have a positive parameter a_3 (Germany, Greece) or are linked to population instead of GVA (UK). Even Sweden decreases due to a lower GVA growth.

Figure 35. Domestic Extraction of Industrial Minerals and Ores ($DEU_{industrial+metals}$) , EU-15 Low growth scenario[B]



[B]: with keeping parameter a_3 constant between 2000 and 2020

Assessment

Quantitatively, the flow of industrial minerals and ores is of minor importance. Domestic extraction within EU-15 has been steadily decreasing on the account of increasing imports (which are not modelled within this project). From a theoretical point of view, the correct approach would be to use world market prices and domestic extraction costs for industrial minerals and ores to estimate the future trends. As such a model is not available, it has been chosen to use a more simple estimation method – i.e. *equation(5)activity*. Obviously, linking the DEU of industrial minerals and ores to the GVA in the industry sectors (NACE C, D, and E) is not sufficiently reflecting the main determinants for this extraction activity. The historical trend of decreasing domestic extractions on the account of increasing imports cannot be extrapolated by using the chosen method. Choosing variant B (keeping parameter a_3) instead of variant A seems most reasonable for both scenarios. This implies rather constant (Baseline) or even decreasing (Low growth) domestic extraction which seems most likely given the historical trend of increasing imports of industrial minerals and metal ores. Putting more effort into the elaboration of a more sophisticated projection method/model is questionable since the benefits will be limited due to the minor quantitative relevance of this material flow. It may be considered to merge this material flow with construction minerals to one aggregate for (non-renewable) minerals (as it is done in the case of AC13).

5.1.2. Construction minerals – EU-15

Quantitatively, this material flow category is of most importance with some 2.6 billion tonnes for the EU-15 throughout the 1990s. Construction minerals are almost exclusively extracted domestically; imports of construction goods are less pronounced (with the exception of small countries).

In the EU-15, the historical development of construction minerals extraction shows a significant increase from the mid 1980s to the early 1990s. Throughout the 1990s domestic extraction of construction minerals fluctuated around a more or less constant level. Thereby, quite close links with the economic cycles could be observed. For instance, the EU wide economic recession in 1993 is clearly recognisable.

For the EU-15 on average, the domestic extraction of construction minerals amounts to about 6.9 tonnes/capita (average 1980-2000). Across countries, it varies considerably: from 3.3 tonnes/capita (the Netherlands, average 1980-2000) up to 18.4 tonnes/capita (Finland, average 1980-2000).

Estimations

Since the demand for construction minerals is closely linked to the construction sector's activity, the domestic extraction of construction minerals has been linked to the gross value added in the construction sector (NACE section F). In other words, economic activity variable A_i is the GVA in constant prices in the construction sector.

In general, *equation (5) activity* has been used for this material flow component; with fixing parameter a_1 equal to 1. Alternatively, also a free estimation of parameter a_1 has been tested (see Table 30). When parameter a_1 differs from 1, we have increasing or decreasing return to scale, which may be the case if changes in the level of production within construction imply structural changes and the required mineral input differs between types of production. In addition, parameter a_1 may differ from 1 if there are short term capacity limits in the extraction sector and changes in construction imply larger marginal import share of minerals, or if decreases in domestic construction imply increased export of minerals.

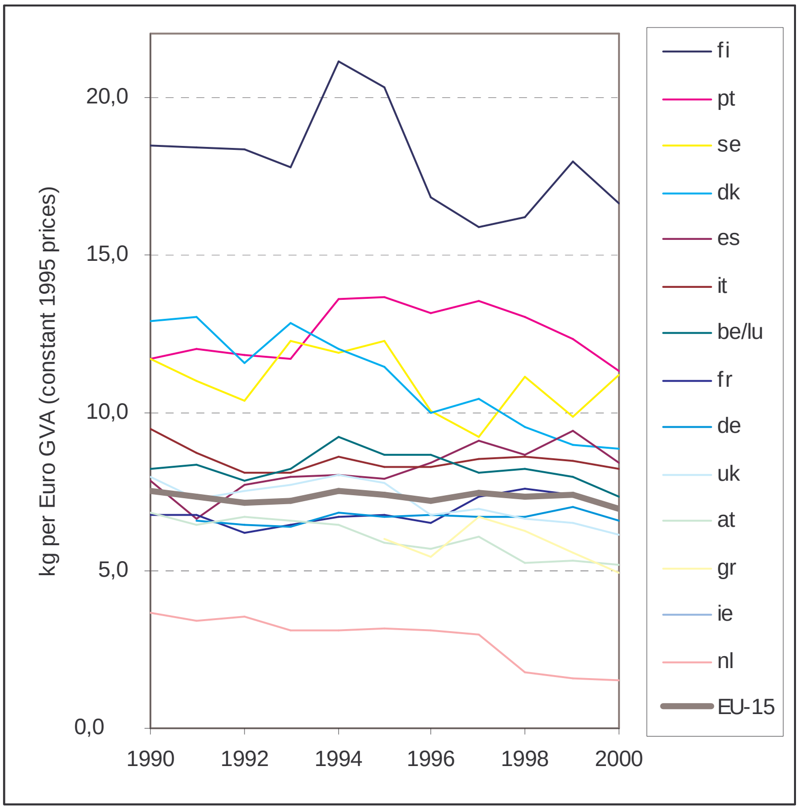
Table 30 shows the estimated coefficients for extraction of construction minerals estimating parameter a_1 free and restricting parameter a_1 to equal 1. For most countries, restricting parameter a_1 to 1 is acceptable; however, when the free estimate differs significantly from 1 this implies changes in the trend coefficient. Looking at individual countries, for Greece we have very few observations and the equation is very poor. For Italy the free estimate of parameter a_1 is not acceptable, however, restricting parameter a_1 to 1 is acceptable and changes the estimated equation only marginally. For Ireland, *equation (5) population* has been used due to lack of historical economic data.

Table 30. Domestic extraction used (DEU) – construction minerals, EU-15

Country	Equation	No. of obs.	a_0	a_1	a_3	d	d1	Dxxyy	D1xxyy	R^2	DW
at	eq. (5) activ.	21	3,010	1,000	-0,013					0,694	0,897
			(15,40)		*(-5,94)*						
	eq. (5) activ.	21	6,26	0,538	-0,001					0,749	0,972
			(5,00)	*(3,05)*	*(-0,22)*						
be	eq. (5) activ.	20	1,944	1,000	0,001					0,880	0,931
			(9,69)		*(0,68)*						
	eq. (5) activ.	20	2,071	0,982	0,002					0,880	0,917
			(1,44)	*(4,97)*	*(0,39)*						
de	eq. (5) activ.	10	1,309	1,000	0,006					0,818	2,453
			(4,95)		*(2,23)*						
	eq. (5) activ.	10	-1,168	1,203	0,007					0,818	2,469
			(-0,44)	*(5,62)*	*(2,41)*						
dk	eq. (5) activ.	20	2,121	1,000	0,001	0,230		8097		0,547	1,432
			(5,12)		*(0,22)*	*(3,43)*					
	eq. (5) activ.	20	4,885	0,678	0,002	0,195		8097		0,557	1,276
			(3,25)	*(4,01)*	*(0,41)*	*(3.00)*					
fi	eq. (5) activ.	21	2,948	1,000	-0,001					0,828	1,523
			(16,82)		*(-0,52)*						
	eq. (5) activ.	21	4,543	0,827	-0,002					0,832	1,548
			(4,89)	*(8,34)*	*(-1,14)*						
fr	eq. (5) activ.	20	1,500	1,000	0,005	-0,060		8097		0,743	1,597
			(6,74)		(2,21)	(-1,66)					
	eq. (5) activ.	20	2,320	0,922	0,005	-0,049		8097		0,744	1,533
			(1,38)	*(5,84)*	*(2,22)*	*(-1,14)*					
gr	eq. (5) activ.	6	3,852	1,000	-0,021					0,165	1,828
			(1,60)		(-0,87)						
	eq. (5) activ.	6	6,128	0,497						0,194	1,839
			(1,39)	*(0,98)*							
ie											
	eq. (5) pop	20	1,806			-0,155		8090		0,456	0,623
			(48,48)			*(-2,94)*					
it	eq. (5) activ.	20	2,967	1,000	-0,009	0,115		8591		0,707	0,687
			(15,96)		*(-4,35)*	*(4,69)*					
	eq. (5) activ.	20	12,410	0,088	-0,006	0,116		8591		0,835	1,214
			(2,42)	*(0,38)*	*(-3,69)*	*(6,44)*					
nl	eq. (5) activ.	20	1,248	1,000	-0,008	0,655		8097		0,948	1,852
			(4,33)		*(-2,71)*	*(14,02)*					
	eq. (5) activ.	20	2,053	0,838		0,714		8097		0,927	1,602
			(0,93)	*(3,70)*		*(14,03)*					
pt	eq. (5) activ.	13	2,070	1,000	0,005	-0,160		8089		0,867	0,921
			(3,31)		*(0,73)*	*(-2,35)*					
	eq. (5) activ.	13	2,310	1,025		-0,189		8089		0,859	0,946
			(1,46)	*(5,55)*		*(-3,26)*					
es	eq. (5) activ.	20	2,937	1,000	-0,008	-0,153	-0,286	8083	91	0,793	0,888
			(6,97)		(-1,83)	(-2,07)	(-3,00)				
	eq. (5) activ.	20	5,733	0,655		-0,163	-0,230	8083	91	0,833	0,897
			(4,95)	*(5,83)*		*(-2,75)*	*(-2,72)*				
se	eq. (5) activ.	20	3,904	1,000	-0,016	0,077		98		0,650	1,150
			(12,77)		*(-4,74)*	*(0,86)*					
	eq. (5) activ.	20	8,005	0,541	-0,016					0,693	1,639
			(3,62)	*(2,24)*	*(-5,27)*						
uk	eq. (5) activ.	21	3,755	1,000	-0,019					0,843	1,093
			(25,54)		*(-11,50)*						
	eq. (5) activ.	21	1,962	1,209	-0,023					0,844	1,238
			(1,82)	*(9,69)*	*(-7,45)*						

Most of the countries (Austria, Belgium and Luxembourg, Finland, Greece, Italy, the Netherlands, Spain, Sweden, and the UK) show a negative time trend of the ratio *w*/*A*. In principle, a negative change (parameter a_3) of the *w*/*A* ratio expresses a decoupling of material extraction from GVA growth in the construction sector. However, the change rates (parameter a_3) for the *w*/*A* ratio are marginal with around -1% or even less. Three countries (Germany, France, and Portugal) have a positive time trend in the *w*/*A* ratio, however only around +0.5%. Countries with negative time trend a_3 more or less outlevel countries with positive trends a_3 so that for the aggregated EU-15, the time trend is fairly moderate with about -0.7% annually (see Figure 36). Further it has to be noted that the *w*/*A* ratio varies across countries between roughly 5-13 kg per Euro. Outliers are Finland (around 18 kg/Euro) and the Netherlands (around 3 kg/Euro), both with a negative time trend.

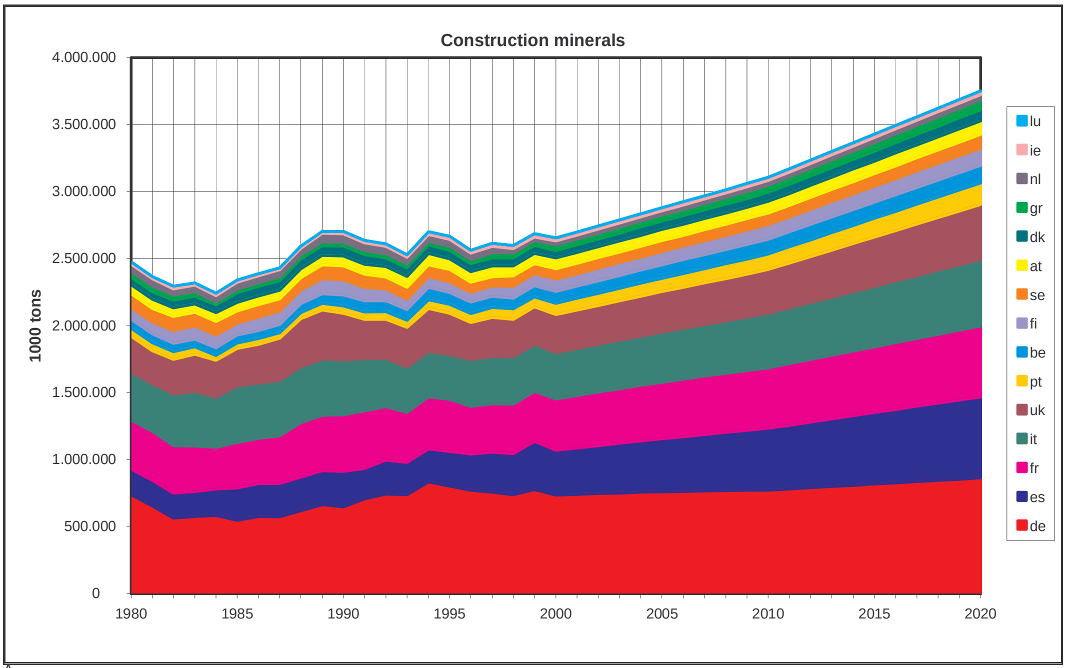
Figure 36. **Historical development of *w*/*A*-ratio – Domestic Extraction of Construction Minerals (DEU$_{construction}$), EU-15**



Results
In the Baseline scenario (Figure 37), domestic extraction of construction minerals increases significantly by around 1 billion tonnes (2000 to 2020). The main driver is the projected growth in gross value added in the construction sector. The increase becomes slightly steeper after 2010. This is due to the levelling out of the change rate of the *w*/*A* ratio; i.e. after 2010, a constant *w*/*A* ratio is assumed.

The overall trend is determined by the five largest EU Member States (Germany, Spain, France, Italy, the UK). Apparently, only for Spain significant increases in the domestic extraction of construction minerals are seen. The other “big four” have only moderate increases. This can be explained with a relatively high maturity of infrastructures in Germany, France, Italy and the UK; whereas Spain is still in the process of catching up with regard to infrastructure construction.

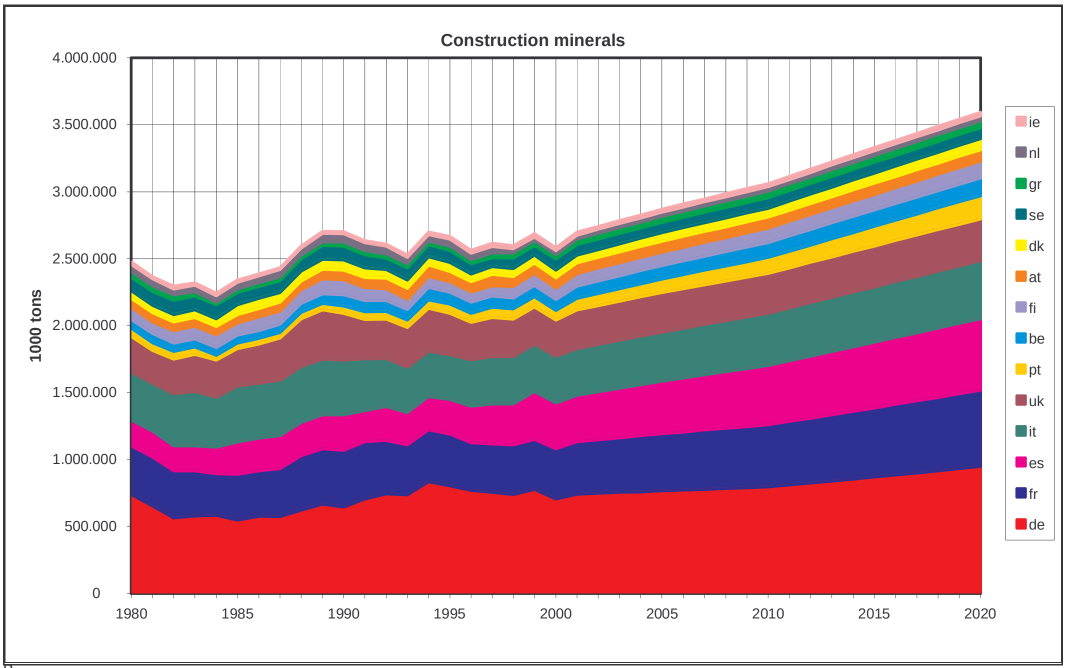
Figure 37. **Domestic Extraction of Construction Minerals ($DEU_{construction}$), EU-15 Baseline scenario[A]**



[A]: with parameter a_3 is levelling out to Zero between 2000 and 2010

Alternatively, a Baseline scenario was calculated with keeping the time trend a_3 for the entire period (Figure 38). The increase between 2000 and 2020 remains with almost 1 billion tonnes but becomes more linear.

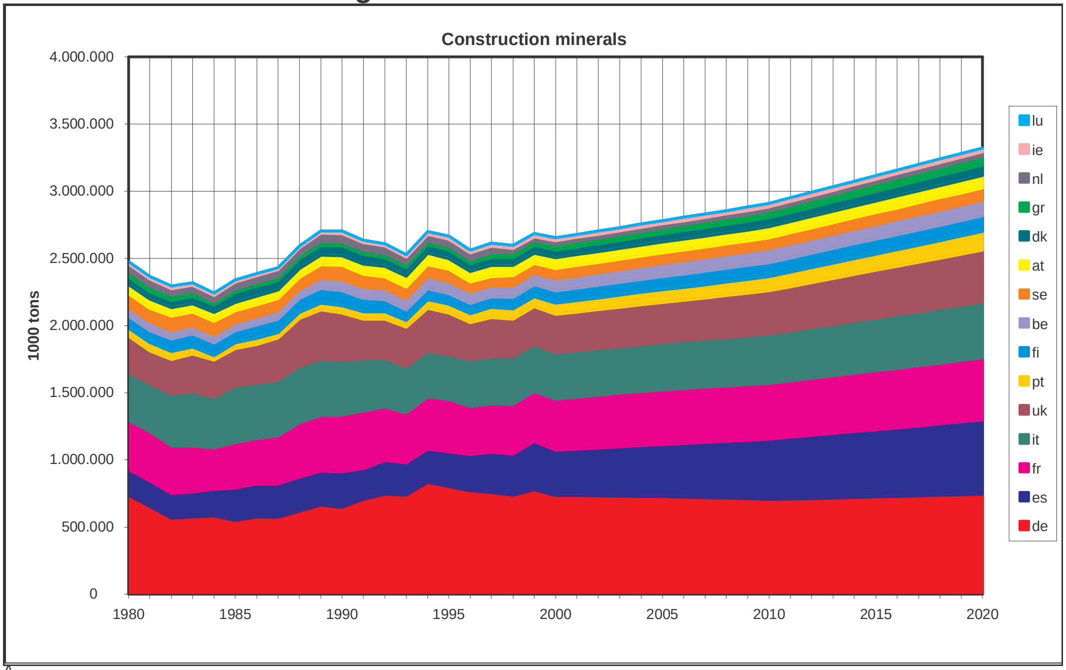
Figure 38. **Domestic Extraction of Construction Minerals ($DEU_{construction}$) EU-15 Baseline scenario[B]**



[B]: with keeping parameter a_3 constant between 2000 and 2020

In the Low growth scenario, domestic extraction of construction minerals is also increasing after 2000 (Figure 39). However, with some 0.5 billion tonnes the growth is less pronounced as the Baseline scenario. This is clearly linked to the lower growth of gross value added in the construction sector. Again, the increase becomes slightly steeper after 2010 (see above).

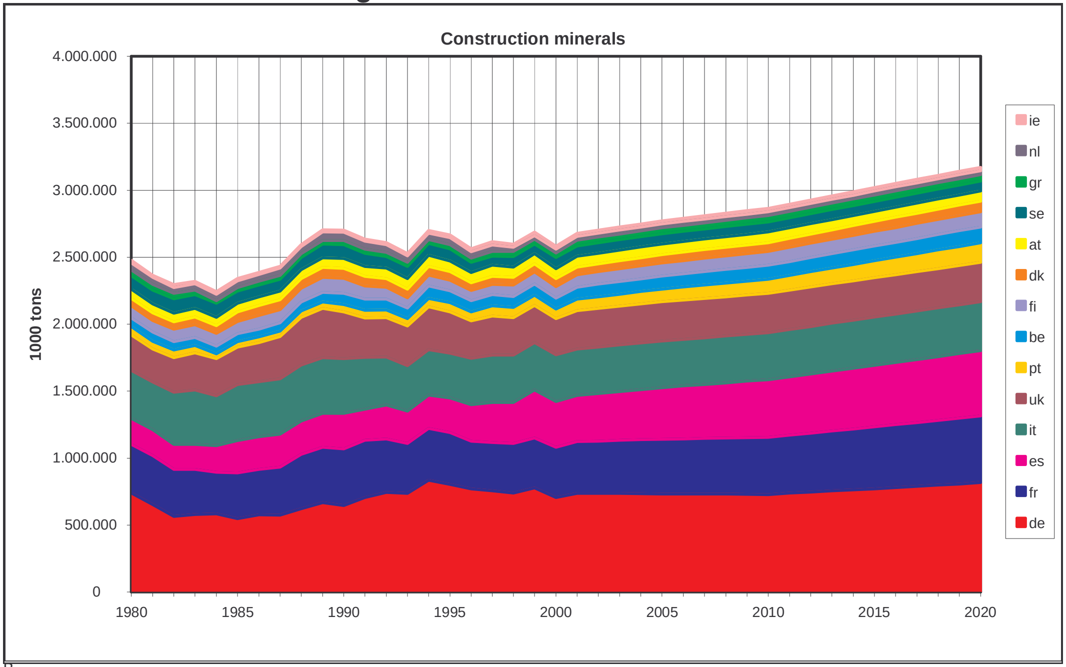
Figure 39. Domestic Extraction of Construction Minerals ($DEU_{construction}$), EU-15 Low growth scenario^{A}



^{A}: with parameter a_3 is levelling out to zero between 2000 and 2010

Alternatively, a Baseline scenario was calculated with keeping the time trend a_3 for the entire period (Figure 40). Also in this scenario, the domestic extraction of construction minerals is increasing, however more linear.

Figure 40. Domestic Extraction of Construction Minerals ($DEU_{construction}$), EU-15 Low growth scenario^{B}



^{B}: with keeping parameter a_3 constant between 2000 and 2020

Assessment

Quantitatively, the flow of construction minerals is by far the most important. In general, the projection results look reasonable. For instance, the Low growth *scenario* comes close to an extrapolation of the historical time trends. However, it has to be noted that the chosen approach (i.e. linking with gross value added in construction sector) cannot forecast any structural changes within the construction sector since it is solely based on historical trends. For instance, some ‘mature’ national economies such as Germany have shown a slow-down of construction activities which may be due to a saturation of new infrastructures and buildings. Such a ‘saturation effect’ cannot be projected by the modelling approach chosen.

5.1.3. Minerals (all) – EU-10

For the 10 new EU Member States (EU-10), all minerals have been projected as one aggregate (i.e. industrial minerals and ores plus construction minerals). This is due to data availability of historical time series. The historical time series is limited to 8 years only (1991-1999), which is comparably little for a projection period of 20 years. In addition, it has to be considered that the 1990s have been characterised by transitional economic structural changes in most of the new 10 EU Member States.

The historical data show an increase in domestic mineral extractions up to 1998, followed by a temporal decrease in 1999 caused solely by Poland. The per capita values differ significantly across countries, ranging from around 1 tonne/capita in Lithuania and Latvia to 17.4 tonnes/capita in Cyprus.

Estimations

For all 10 new Member States, *equation (5) activity* has been used. The activity variable A_i is gross value added in industry including construction (NACE sections C, D, E, and F). A general conclusion is that parameter a_1 varies considerably across countries, but for most countries restricting a_1 to 1 is acceptable. For Malta the material flow data are constant from 1995 and the model includes just two constants; before and after 1995.

The trend parameter a_3 differs from zero only in Estonia, Hungary, and Slovenia. In all three cases the trend parameter a_3 is negative, implying a decreasing w/A ratio over time. With around -6% annually, these negative trends (parameter a_3) are comparably high. Thus, the time parameter a3 has been levelled out to zero between 2000 and 2010. For the remaining 7 countries, no time trend has been considered, i.e. implying a constant w/A ratio over time.

Table 31. Domestic extraction used (DEU) – industrial and construction minerals and ores, EU-10

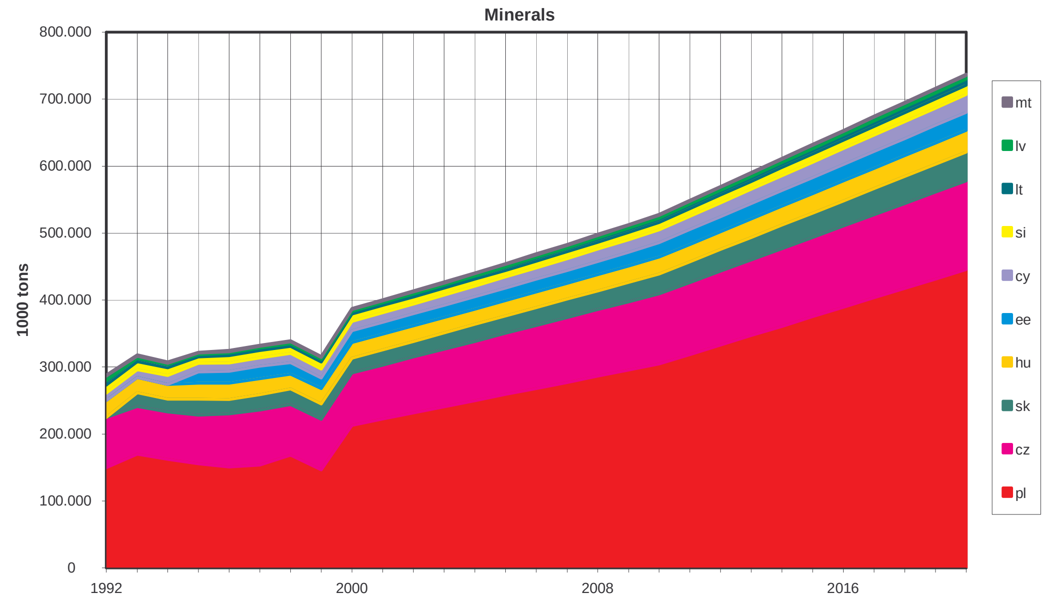
Country	Equation	No. of obs.	a_0	a_1	a_3	d	d1	Dxxyy	D1xxyy	R^2	DW
cy	eq. (5) activ.	6	-0,843	1,501	-0,007	-0,062		96		0,615	3,101
			(-0,05)	*(0,64)*	*(-0,39)*	*(-1,60)*					
	eq. (5) activ.	6	2,16	1,000		-0,059		96		0,574	2,914
			(184,20)			*(-2,07)*					
cz	eq. (5) activ.	8	5,685	0,517	0,006					0,806	1,754
			(4,49)	*(3,76)*	*(1,36)*						
	eq. (5) activ.	8	1,594	1,000						0,735	1,322
			(106,50)								
ee	eq. (5) activ.	5	8,229	1,001	-0,054					0,476	1,969
			(2,63)	*(1,29)*	*(-1,31)*						
	eq. (5) activ.	5	8,231	1,000	-0,054					0,476	1,967
			(5,16)		*(-2.36)*						
hu	eq. (5) activ.	6									
	eq. (5) activ.	6	7,288	1,000	-0,067					0,428	1,444
			(4,67)		*(-3,97)*						
lt	eq. (5) activ.	5	5,779	0,155	0,014					0,680	1,868
			(3,88)	*(0,37)*	*(0,57)*						
	eq. (5) activ.	5	0,828	1,000						0,604	1,474
			(29,09)								
lv	eq. (5) activ.	7	4,221	2,059	-0,025					0,600	2,300
			(-0,85)	(1,93)	(-0,63)						
	eq. (5) activ.	7	0,805	1,000						0,561	1,888
			(18,60)								
mt											
two levels	eq. (5) activ.	7	7,601	0,000		0,095		9394		na	na
			na	na		na					
pl	eq. (5) activ.										
	eq. (5) activ.	7	1,518	1,000						0,310	0,399
			(17,75)								
si	eq. (5) activ.	8									
	eq. (5) activ.	8	6,231	1,000	-0,057	-0,157		95		0,901	1,747
			(14,56)		*(12,63)*	*(-5,06)*					
sk	eq. (5) activ.	7	6,337	0,230	0,018					0,449	3,432
			(1,86)	*(0,40)*	*(0,76)*						
	eq. (5) activ.	7	1,448	1,000						0,370	3,011
			(50,45)								

Results

In the Baseline scenario (Figure 41), domestic extraction of all minerals in the 10 new EU Member States shows a steep increase; it doubles between 2000 and 2020. The overall picture is dominated by the biggest country, namely Poland.

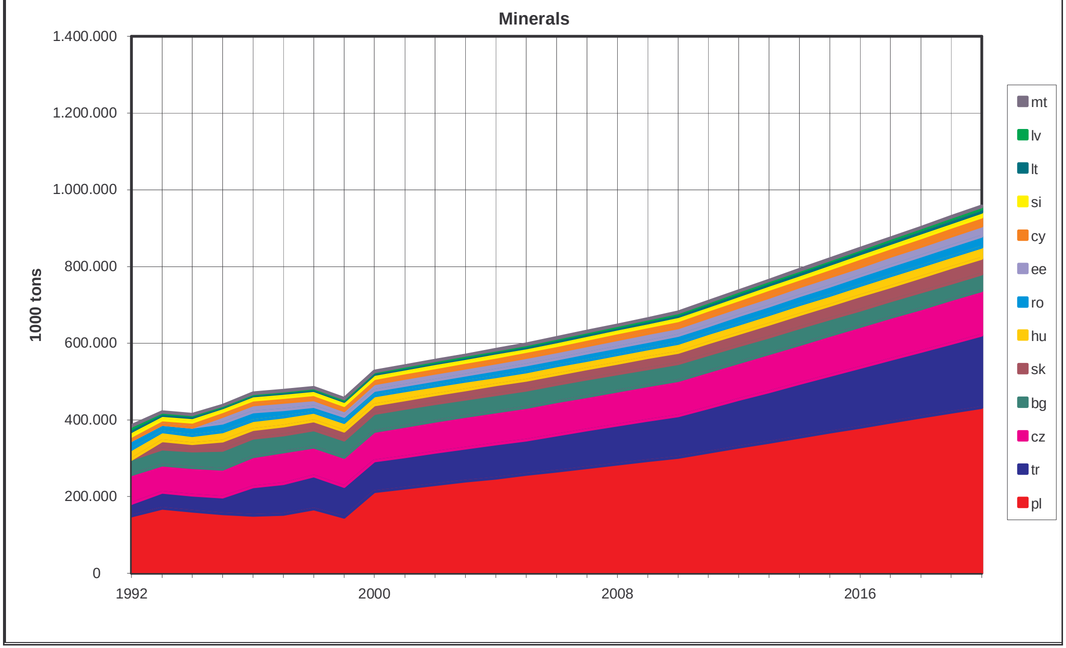
The growth in minerals extraction is closely related to the forecasted growth in gross value added in industry and the construction sector. Again, the growth becomes slightly steeper after 2010 since trend parameter a_3 (i.e. annual change in *w*/*A* ratio) is levelled out to zero after 2010 (but only for 3 countries).

Figure 41. Domestic Extraction of all Minerals ($DEU_{MINERALS}$), EU-10 & CC3 Baseline scenario



The Low growth scenario (Figure 42) shows also an increase in minerals extractions, however, less pronounced than in the Baseline scenario This is caused by the lower growth assumption.

Figure 42. Domestic Extraction of all Minerals ($DEU_{MINERALS}$), EU-10 and CC3 Low growth scenario



Assessment

For the 10 new EU Member States the relative short historical time series of material flow data may limit the robustness of the projections. Using *equation (5) activity* with a constant *w*/*A* ratio over time more or less implies an extrapolation of a strong coupling between economic growth and minerals extraction which has been observed in the 1990s. The historical strong growth in minerals extractions is mainly caused by construction activities in the 10 new EU Member States reflecting in particular the need to catch up with the EU in infrastructure development. The Low growth scenario looks reasonable in so far as it extrapolates the growth of the 1990s. However, it has to be noted that it seems likely that the construction activities in the 10 new EU Member States may flatten after a certain level of new infrastructures and buildings has been established. However, when this threshold will be reached is not foreseeable.

5.1.4. Minerals (all) – CC3

For the three candidate countries (CC3) also, all minerals have been projected as one aggregate due to data availability. Again, the historical time series is limited to 8 years only (1991-1999), which is comparably little for a projection period of 20 years.

The historical data show a steep increase in domestic mineral extractions until 1996 for the aggregate of the three countries. From 1996 to 1999 it looks more stable. Turkey has increased significantly, whereas Bulgaria remained stable and Romania even decreased. The per capita values differ significantly across the three countries. With around 5.5 tonnes/capita, Bulgaria shows a considerably higher value than Romania and Turkey with 0.7 and 1.2 tonnes/capita respectively.

Estimations

Also for CC3, the historical time series used to estimate parameters have been significantly shorter than for EU-15 (1992-1999).

For Romania and Turkey, *equation (5) activity* has been used. The activity variable A_i is gross value added in industry including construction (NACE sections C, D, E, and F). With +3%, the trend parameter a_3 is extremely high for Turkey. Surprisingly, for Romania the trend parameter a_3 is highly negative (-6%). For both countries, the trend parameter a_3 has been levelled out to zero between 2000 and 2010. For Bulgaria, *equation (5) population* has been used.

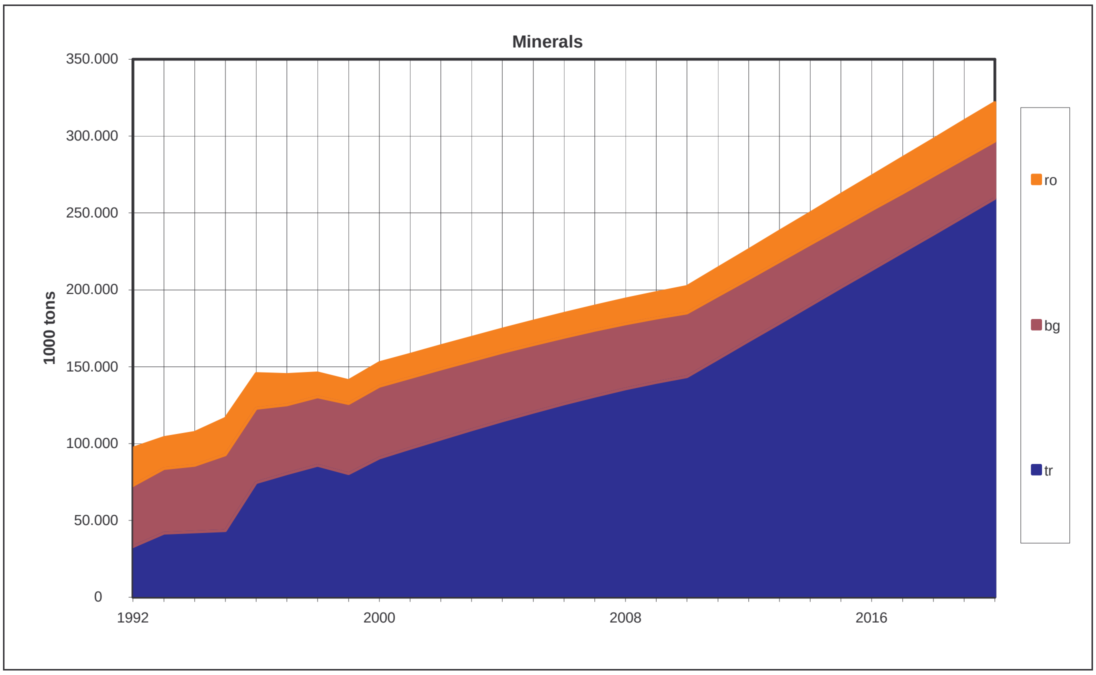
Table 32. Domestic extraction used (DEU) – industrial and construction minerals and ores, CC3

Country	Equation	No. of obs.	a_0	a_1	a_3	d	d1	Dxxyy	D1xxyy	R^2	DW
bg	eq. (5) pop.	8	-5,770	1,848	-0,002	-0,153		9294		0,692	1,178
			(-0,02)	*(0,07)*	*(-0,01)*	*(.1,55)*					
	eq. (5) pop.	8	1,722	1,000		-0,128		9294		0,677	1,016
			(89,88)			*(-4,10)*					
ro	eq. (5) activ.	8	0,890	1,635	-0,063					0,940	2,959
			(0,30)	(5,09)	(-7,62)						
	eq. (5) activ.	8	6,618	1,000	-0,062					0,901	1,884
			(6,86)		*(-6,15)*						
tr	eq. (5) activ.	8	-2,890	1,000	0,035	-0,373		9295		0,984	1,967
			(-0,49)	*(1,55)*	*(1,42)*	*(-3,30)*					
	eq. (5) activ.	8	-2,888	1,000	0,035	-0,373		9295		0,984	1,967
			(-1,62)		*(1,92)*	*(-4,46)*					

Results

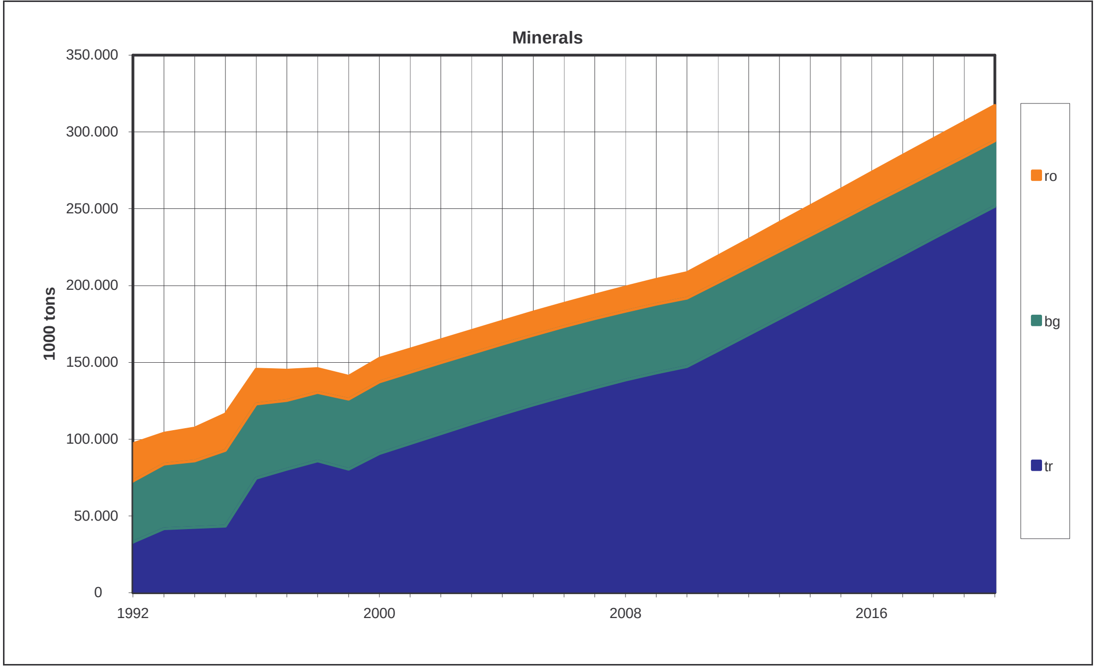
In the Baseline scenario (Figure 43), domestic extraction of all minerals in the three candidate countries shows a very steep increase; between 2000 and 2020 it grows from 150 to almost 330 tonnes by more than a factor 2. The overall growth is solely due to Turkey, whereas the domestic extraction of minerals in Bulgaria and Romania seems to remain stable.

Figure 43. Domestic Extraction of all Minerals ($DEU_{MINERALS}$), CC3 Baseline scenario



The Low growth scenario shows also a strong increase in minerals extractions in CC3. The growth is only slightly less pronounced than in the Baseline scenario.This is caused by the lower growth assumption, in particular for Turkey.

Figure 44. Domestic Extraction of all Minerals ($DEU_{MINERALS}$), CC3 Low growth scenario



Assessment

As for the 10 new EU Member States, the short historical time series of material flow data may limit the robustness of a 30-year projection in general. The estimated trend parameter a_3 is very high for Turkey (positive) and Romania (negative). Both may be due to temporary structural changes in the respective economies in the 1990s and it seems questionable, whether these can be extrapolated. The Low growth scenario looks more reasonable as it continues more or less the historical trends of the 1990s. There seems no plausibility for an accelerated growth up from 2010.

5.2. DEU - Biomass

5.2.1. Biomass – EU-15

On average (1980-2000), the domestic extraction (harvest) of biomass amounted to about 3.8 tonnes per capita in the European Union (EU-15). This per capita value has been almost constant throughout the period 1980-2000. This may indicate that the extraction (harvest) of biomass is closely linked to population, or more precisely to nutrition needs which are more or less constant on a per capita basis. Slight fluctuations in total biomass harvest may be due to temporal changes in the harvest of biomass from forestry and structural shifts in nutrition patterns (e.g. more meat).

Estimations

Domestic extraction (harvest) of biomass has been forecasted using *equation (5) activity*. The economic activity variable A_i used is gross value added in the agriculture and forestry sectors (NACE sections A and B).

As shown in Table 33, alternatively to fixing parameter a_1 to 1 also a free estimation of parameter a_1 has been tested. If the production in constant prices equals a measure in physical units (as it should) a_1 should equal 1; however, as seen from Table 33, in many countries free estimations of a_1 are significantly different from 1. When a_1 is less than 1.0, as in most countries, this implies structural changes where the agricultural and forestry production output has become of larger value per weight unit, e.g. production has changed from crops with a low value per tonne to crops with a larger value per tonne or from grass to grain. It also indicates decoupling of biomass harvest from economic growth in the agriculture and forestry sectors. This is reasonable since the physical amount of biomass harvested is rather linkable to nutrition needs, which are likely to be constant as long as population remains constant.

Restricting a_1 to 1.0 implies that we need to include a trend in the equation (parameter a_3). For the EU-15 the trend is in general negative, implying a decoupling. That is the structural changes in EU-15 imply a higher value derived from one tonne of biomass harvested. Only in Finland and Portugal, the annual change in the w/A ratio (parameter a_3) is positive with about +2%.

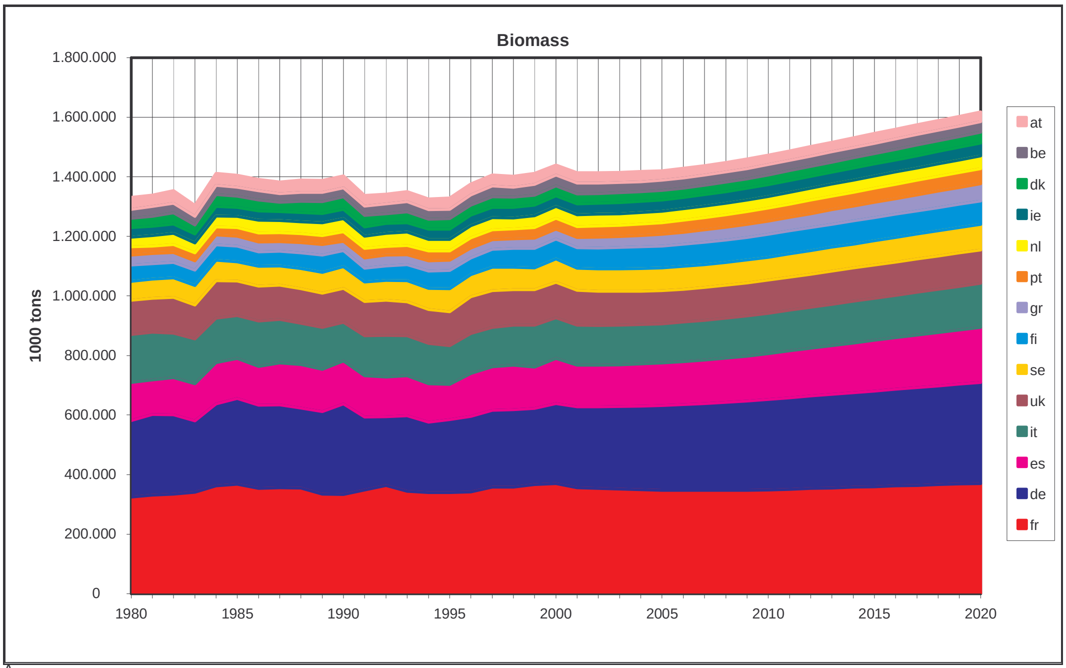
Table 33. Domestic extraction used (DEU) – biomass, EU-15

Country	Equation	No. of obs.	a_0	a_1	a_3	d	d1	Dxxyy	D1xxyy	R^2	DW
at	eq. (5) activ.	21	5,135	1,000	-0,031	-0,049	0,121	85	94	0,401	0,753
			(23,79)		*(-12,81)*	*(-0,73)*	*(1,82)*				
	eq. (5) activ.	21	8,58	0,414	-0,016	-0,010	0,047	85	94	0,479	1,085
			(8,50)	*(2,45)*	*(-3,34)*	*(-0,17)*	*(0,84)*				
be	eq. (5) activ.	20	3,571	1,000	-0,013	0,031		96		0,737	1,395
			(18,53)		*(-6,10)*	*(0,70)*					
	eq. (5) activ.	20	6,685	0,463		0,018		96		0,842	2,050
			(15,21)	*(8,42)*		*(0,62)*					
de	eq. (5) activ.	9	2,713	1,000	-0,004	-0,071		99		0,820	1,955
			(8,33)		*(-1,04)*	*(-2,54)*					
	eq. (5) activ.	9	4,547	0,784		-0,061		99		0,839	2,308
			(3,19)	*(5,54)*		*(-2,12)*					
dk	eq. (5) activ.	21	4,811	1,000	-0,029	0,145		90		0,500	1,710
			(23,61)		*(-12,76)*	*(2,26)*					
	eq. (5) activ.	21	3,883	1,161	-0,033	0,145		90		0,503	1,545
			(1,99)	*(3,44)*	*(-3,45)*	*(2,20)*					
fi	eq. (5) activ.	21	0,712	1,000	0,020					0,738	1,039
			(3,85)		*(9,78)*						
	eq. (5) activ.	21	3,370	0,712	0,017					0,760	1,070
			(2,51)	*(4,93)*	*(7,51)*						
fr	eq. (5) activ.	17	3,619	1,000	-0,014	-0,062		90		0,629	1,599
			(22,97)		(-12,30)	(-2,58)					
	eq. (5) activ.	17	5,983	0,741	-0,011	-0,610		90		0,638	1,313
			(3,58)	*(4,06)*	*(-3,68)*	*(-2,63)*					
gr	eq. (5) activ.	6	2,200	1,000	-0,008	-0,045		98		0,739	2,429
			(4,80)		(-1,71)	(-2,07)					
	eq. (5) activ.	6	8,224	0,297	-0,005	-0,045		98		0,958	2,068
			(6,19)	*(1,93)*	*-2,65)*	*(-5,76)*					
ie											
	eq. (5) pop	21	2,087	1,000	-0,002	-0,040		8090		0,784	1,650
			(10,51)		*(0,79)*	*(-1,57)*					
it	eq. (5) activ.	21	3,115	1,000	-0,015					0,865	2,019
			(38,54)		*(-17,10)*						
	eq. (5) activ.	21	4,734	0,830	-0,014					0,871	1,935
			(3,28)	*(5,47)*	*(-10,38)*						
nl	eq. (5) activ.	21	3,760	1,000	-0,025					0,321	1,226
			(16,84)		*(10,04)*						
	eq. (5) activ.	21	5,665	0,698	-0,016					0,332	1,204
			(2,41)	*(1,88)*	*(-1,34)*						
pt	eq. (5) activ.	13	0,540	1,000	0,017	0,102		9091		0,584	0,711
			(1,38)		*(4,05)*	*(2,38)*					
es	eq. (5) activ.	21	3,476	1,000	-0,017					0,501	0,608
			(18,99)		(-8,20)						
	eq. (5) activ.	21	6,756	0,577	-0,007					0,539	0,851
			(4,48)	*(2.99)*	*(-1,43)*						
se	eq. (5) activ.	21	2,927	1,000	-0,001					0,710	1,377
			(21,18)		*(-0,86)*						
	eq. (5) activ.	21	5,180	0,716						0,743	1,327
			(6,42)	*(7,41)*							
uk	eq. (5) activ.	20	3,808	1,000	-0,017	-0,181		8095		0,533	1,195
			(25,54)		*(-11,50)*	*(-6,19)*					
	eq. (5) activ.	20	8,954	0,363	-0,007	-0,105		8095		0,667	2,359
			(10,93)	*(3,62)*	*(-3,80)*	*(-5,25)*					

Results

In the Baseline scenario for the EU-15 the domestic extraction (harvest) of biomass steadily increases up from 2001 (Figure 45). In the first 10 years until 2010, this increase is moderate and becomes steeper after 2010 leading to more than 1.6 billion tonnes. This is due to the levelling out of parameter a_3, i.e. the annual change rate of the w/A ratio (parameter a3) which is negative in most of the countries.

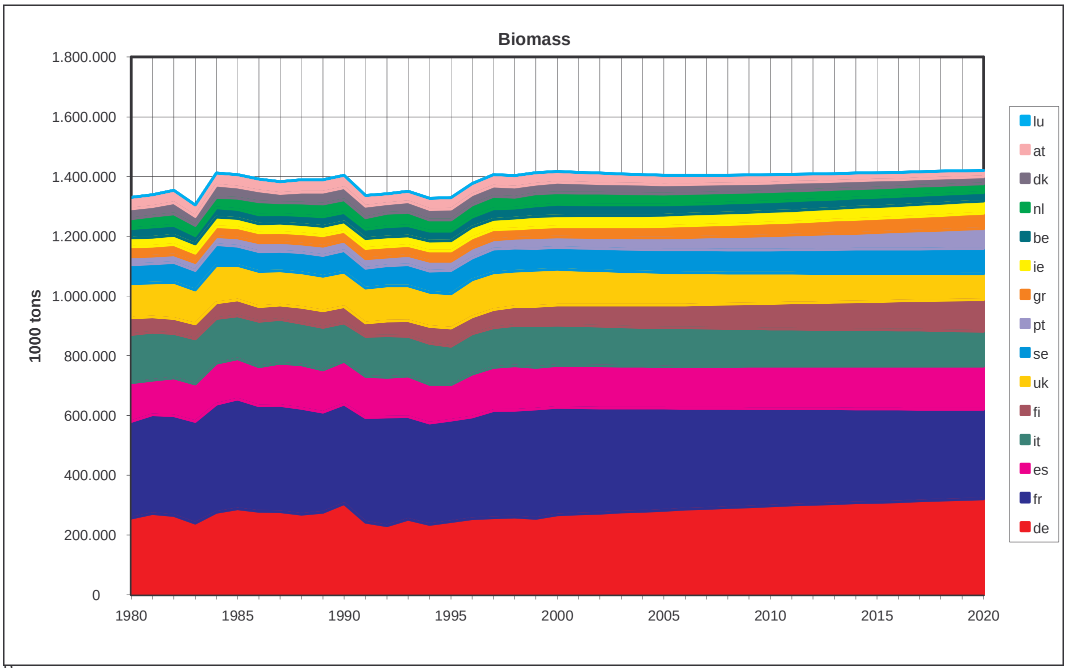
Figure 45. Domestic Extraction of Biomass ($DEU_{BIOMASS}$), EU-15 Baseline scenario^A



^{A}: with parameter a_3 is levelling out to Zero between 2000 and 2010

Alternatively, a Baseline scenario has been calculated for the EU-15 where the time parameter a_3 is not levelled out, i.e. remains constant throughout the projection period (Figure 46). In this case, the aggregated harvest of biomass remains fairly constant at around 1.4 billion tonnes from 2000 to 2020.

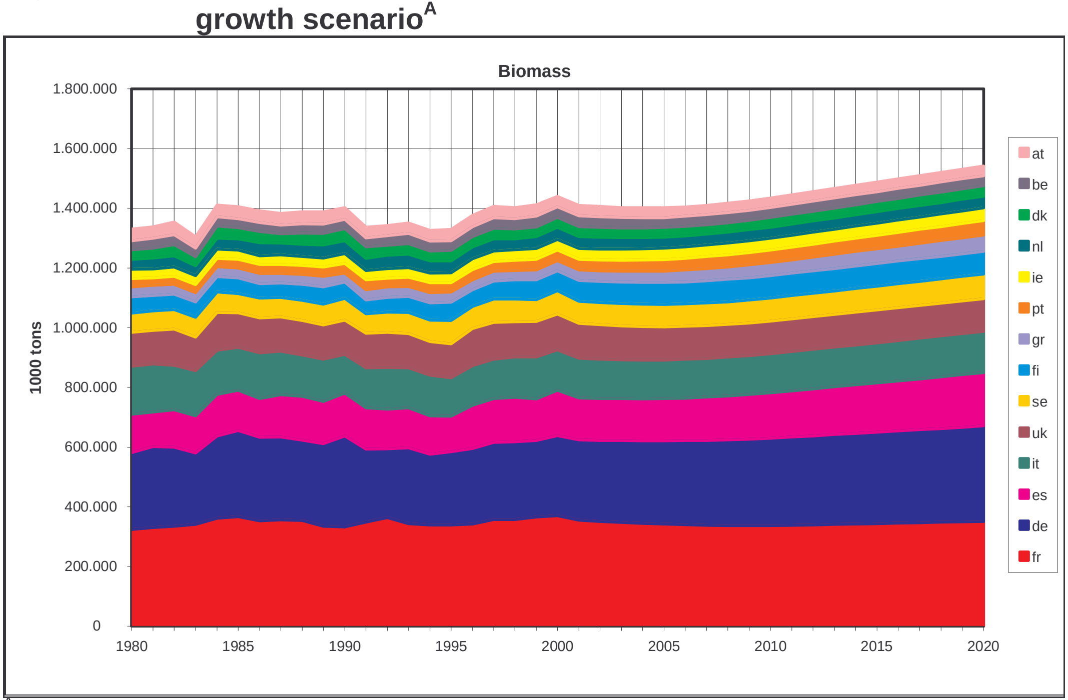
Figure 46. Domestic Extraction of Biomass ($DEU_{BIOMASS}$), EU-15 Baseline scenario^B



^{B}: with keeping parameter a_3 constant between 2000 and 2020

The Low growth scenario shows an almost constant level of biomass harvest between 2000 and 2007. Around 2010, it starts increasing slightly (Figure 47).

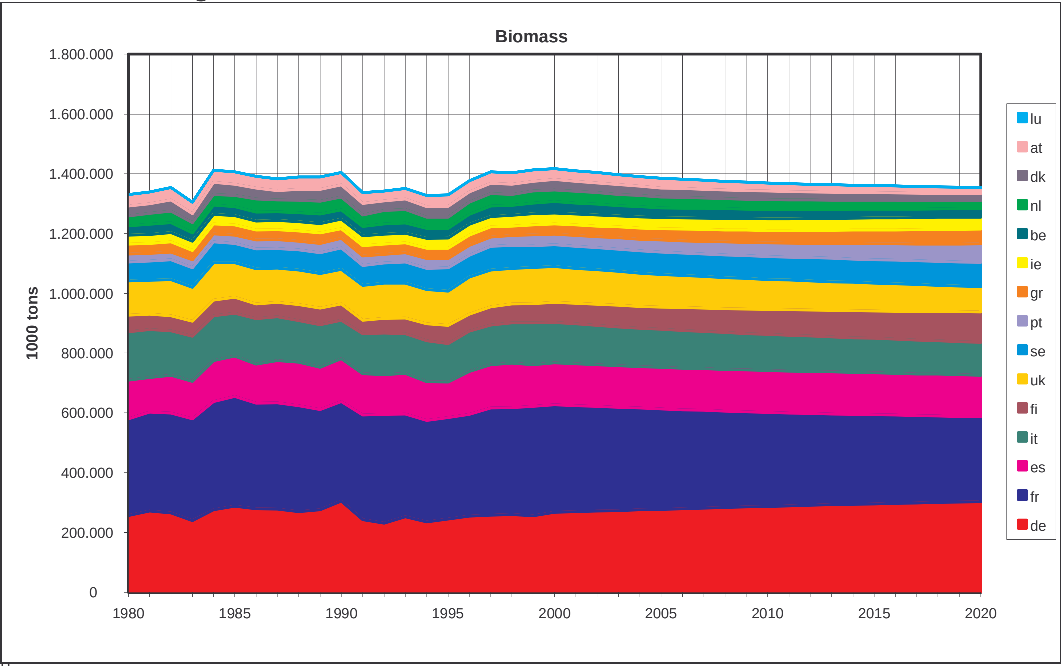
Figure 47. **Domestic Extraction of Biomass ($DEU_{BIOMASS}$), EU-15 Low growth scenario**[A]



[A]: with parameter a_3 levelling out to zero between 2000 and 2010

Also for the Low growth scenario an alternative has been calculated with keeping trend parameter a_3 constant over the entire projection period (Figure 48). In this case, the biomass harvest of aggregated EU-15 is even decreasing slightly up from 2000.

Figure 48. **Domestic Extraction of Biomass ($DEU_{BIOMASS}$), EU-15 Low growth scenario**[B]



[B]: with keeping parameter a_3 constant between 2000 and 2020

Assessment

Biomass harvest in the 1980s and 1990s has been more or less constant in the EU-15, i.e. it has always been decoupling from the economic growth within the agricultural sector. This is reasonable due to a close link to population's nutrition needs, which remain constant on a per capita basis in developed countries such as the EU-15. Therefore, using *equation (5) activity* might be reflected on. The levelling out of parameter a_3 (to zero in 2010, variant A) does not seem reasonable since it implies a recoupling after 2010. Therefore, it is recommended to use variant B (i.e. keeping parameter a_3 constant. Using *equation (5) pop* would also be a reasonable approach.

5.2.2. Biomass – EU-10

On average (1992-1999), the domestic extraction (harvest) of biomass in EU-10 amounted to about 4.6 tonnes per capita, which is slightly more than in EU-15. On a per capita basis, there is a wide range across countries: from less than 2 tonnes/capita on the islands of Cyprus and Malta (where most biomass needs to be imported) to more than 8 tonnes/capita in the Baltic States (Latvia even 16 tonnes/capita) where biomass harvest from forestry has been playing a particular role during the 1990s.

Estimations

Domestic extraction (harvest) of biomass has been forecasted using *equation (5) activity*. The economic activity variable A_i used is gross value added in the agriculture and forestry sectors (NACE sections A and B).

With the exception of Malta, parameter a_1 has been fixed to 1. Restricting a_1 to 1 implies that we need to include a trend in the equation (parameter a_3). Whereas for the EU-15 the trend is in general negative, for many of the 10 new EU Member States the trend is positive (Estonia (+4.2%), Hungary (+1.6%), Latvia (+7.7%), Slovenia (+1.8%)). The high annual change rates in Estonia and Latvia can be explained by forestry.

Table 34. Domestic extraction used (DEU) – biomass, EU-10

Country	Equation	No. of obs.	a_0	a_1	a_3	d	d1	Dxxyy	D1xxyy	R^2	DW
cy	eq. (5) activ.	6	3.808	1.463	-0.054					0.979	3.078
			(5.15)	*(10.84)*	*(-9.13)*						
	eq. (5) activ.	6	5.64	1.000	-0.045					0.954	2.258
			(5.72)		*(-4.41)*						
cz	eq. (5) activ.										
	eq. (5) activ.	8	7.730	1.000	-0.049	-0.308		93		0.166	1.585
			(5.88)		*(-3.55)*	*(-3.25)*					
ee											
	eq. (5) activ.	7	0.427	1.000	0.042	0.054		9496		0.889	2.548
			(0.60)		*(5.65)*	*(1.81)*					
hu	eq. (5) activ.	8	6.025	0.431	0.014	-0.166		9294		0.885	2.965
			(1.02)	*-0.600*	*(0.90)*	*(-2.27)*					
	eq. (5) activ.	8	1.461	1.000	0.016	-0.169		9294		0.868	2.347
			(1.01)		*(1.10)*	*(-2.40)*					
lt	eq. (5) activ.	6	7.164	0.507	0.000					0.753	2.520
			(5.95)	*(2.70)*	*(0.04)*						
	eq. (5) activ.	6	4.112	1.000						0.752	1.275
			(157.40)								
lv	eq. (5) activ.	8	6.490	0.189	0.032					0.639	1.645
			(2.70)	(0.90)	(2.30)						
	eq. (5) activ.	7	-2.428	1.000	0.077					0.357	1.396

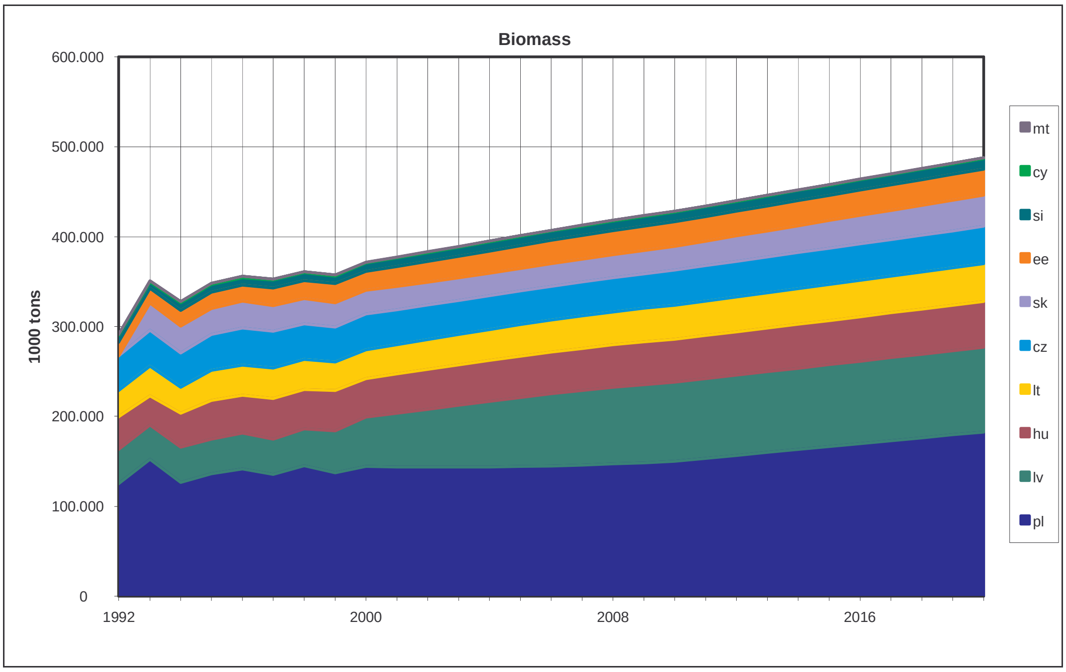
Country	Equation	No. of obs.	a_0	a_1	a_3	d	d1	Dxxyy	D1xxyy	R^2	DW
			(-1.85)		*(5.58)*						
mt											
	eq. (5) activ.	8	0.629	1.000	-0.015	-0.020		9295		0.838	0.719
			(0.41)		(-0.93)	(-2.83)					
pl	eq. (5) activ.	6	3.450	1.239	-0.025					0.910	3.707
			(2.04)	*(4.19)*	*(-2.36)*						
	eq. (5) activ.	7	4.780	1.000	-0.017					0.900	3.496
			(12.00)		*(-4.14)*						
si	eq. (5) activ.	8	-10.810	2.866	0.018					0.760	2.375
			(-1.48)	*-2.330*	*(1.64)*						
	eq. (5) activ.	8	0.205	1.000	0.026					0.646	2.155
			(0.21)		*(2.50)*						
sk	eq. (5) activ.	7	9.954	0.424	-0.027	0.066		96		0.965	2.107
			(8.18)	*(1.37)*	*(-2.86)*	*(2.85)*					
	eq. (5) activ.	7	7.705	1.000	-0.044	0.105		96		0.928	3.101
			(36.43)		*(-19.76)*	*(8.35)*					

Results

In the ***Baseline** scenario* for EU-10 (Figure 49), domestic extraction (harvest) of biomass is projected to increase considerably up from 2000 from around 350 million tonnes to almost 500 million tonnes.

The overall picture is dominated by the largest country, namely Poland, however, growth is moderate in Poland due to a negative trend parameter a_3 of -1.7%. The strong increase in Latvia mainly causes the growth of the aggregated EU-10. This seems not reasonable since historical harvest of biomass in Latvia (1992-1999) was determined by unusual high logging activities, which may not be continued in the future.

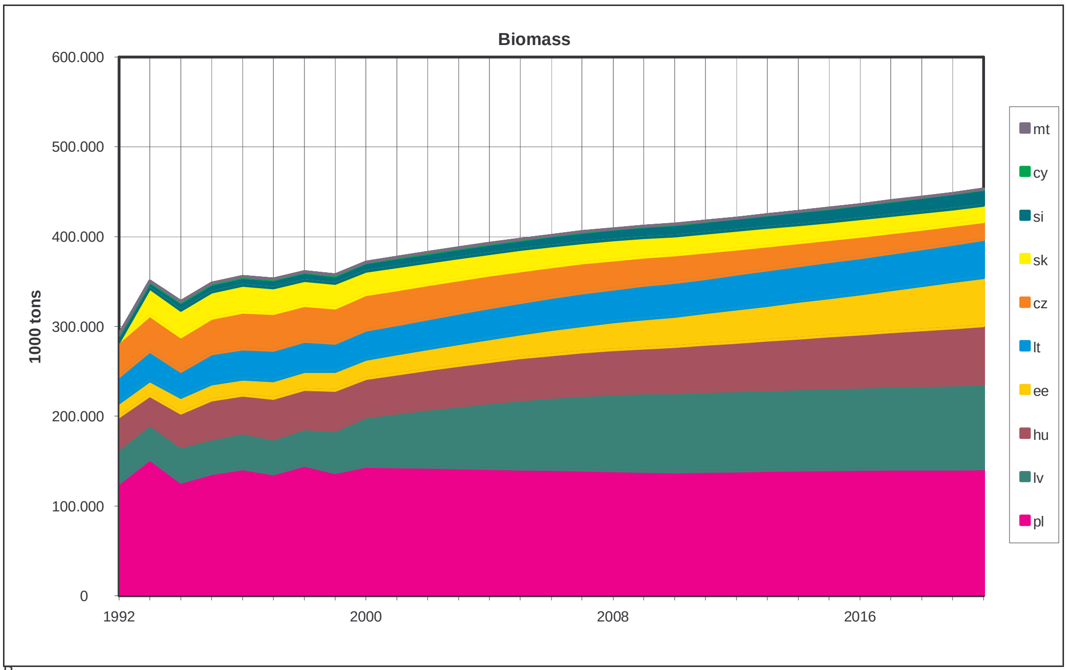
Figure 49. Domestic Extraction of Biomass ($DEU_{BIOMASS}$), EU-10 Baseline scenario^A



^{A}: with parameter a_3 is levelling out to zero between 2000 andFigure 2010

Alternatively, a Baseline scenario for EU-10 has been calculated without levelling out of time parameter a_3, with the exception of Latvia (Figure 50). This projection looks much more reasonable with a moderate overall increase up to around 450 million tonnes. Still, Latvia is unreasonably high.

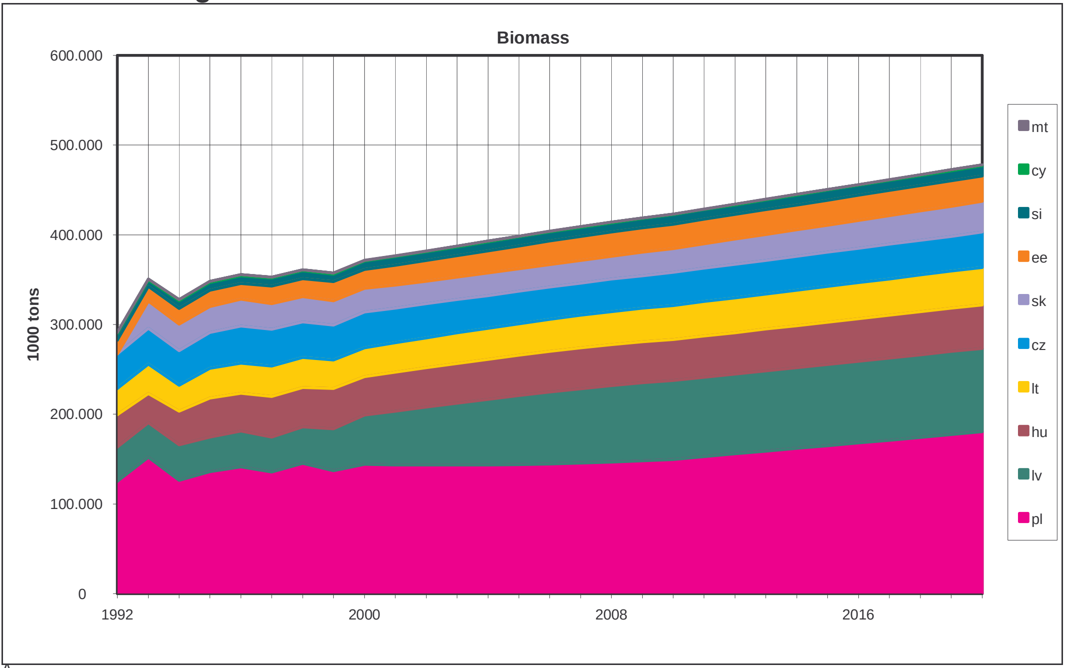
Figure 50. Domestic Extraction of Biomass (DEU$_{\text{BIOMASS}}$), EU-10 Baseline scenario[B]



[B]: with keeping parameter a_3 constant between 2000 and 2020 (with the exception of Latvia, where it is levelled out to Zero)

The Low growth[A] scenario for the EU-10 (Figure 51) shows only a slightly lower growth than the Baseline[A] scenario for EU-10 (Figure 49).

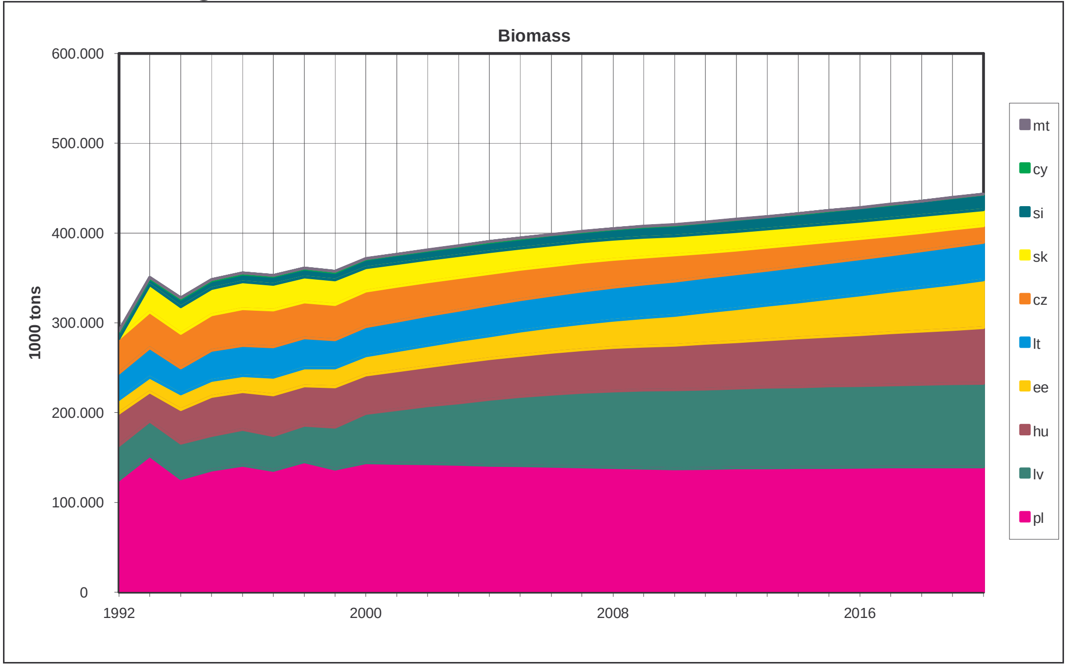
Figure 51. Domestic Extraction of Biomass (DEU$_{\text{BIOMASS}}$), EU-10 Low growth scenario[A]



[A]: with parameter a_3 is levelling out to Zero between 2000 and 2010

Again, a Low growth^B scenario was calculated for the EU-10 (Figure 52) without levelling out of time parameter a_3 (with the exception of Latvia). This also shows only a slightly lower growth than the Baseline^B scenario for EU-10 (Figure 50).

Figure 52. Domestic Extraction of Biomass ($DEU_{BIOMASS}$), EU-10, Low growth scenario^B



Assessment

In general, basing 30-year projections for a relative short historical time series (1992-1999) may limit the quality of results. In addition, the historical period has been characterised by unique structural changes from central planning to market economies. The relation between biomass harvest and economic growth in agriculture is varying across the 10 new EU Member States; most show a decoupling (i.e. negative values for parameter a_3,) which seems most reasonable as it could already be observed for the old EU-15. Using variant B, i.e. a continuation of decoupling seems reasonable for those countries. Latvia and Estonia show strong coupling which may not be reasonable to extrapolate to the future. In general, it might be considered to use *equation (5) pop* due to the close causal link between biomass harvest and nutrition patterns and population respectively. All in all, the Low growth *scenario* looks most reasonable, at least until around 2010. It may be expected that biomass harvest will stop growing at a certain point in time due to its close link with population (saturated nutrition needs).

5.2.3. Biomass – CC3

On average (1992-1999), the domestic extraction (harvest) of biomass in CC3 amounted to about 3.9 tonnes per capita, which is about the same as in EU-15. On a per capita basis, the harvest of biomass in CC3 ranges from 3.2 tonnes/capita in Bulgaria over 3.6 tonnes/capita in Turkey to 4.9 tonnes/capita in Romania.

Estimations

For Romania and Turkey, domestic extraction (harvest) of biomass has been forecasted using *equation (5) activity* (Table 35). The economic activity variable A_i used is gross value added in the agricultural and forestry sectors (NACE sections A and B) thereby fixing parameter a_1 to 1. A time trend for (parameter a_3) was only significant for Romania (+2.7%). For Turkey, no time trend has been used (i.e. biomass harvest is assumed to linearly increase with economic growth in the agricultural sector). For Bulgaria, *equation (5) population* has been used.

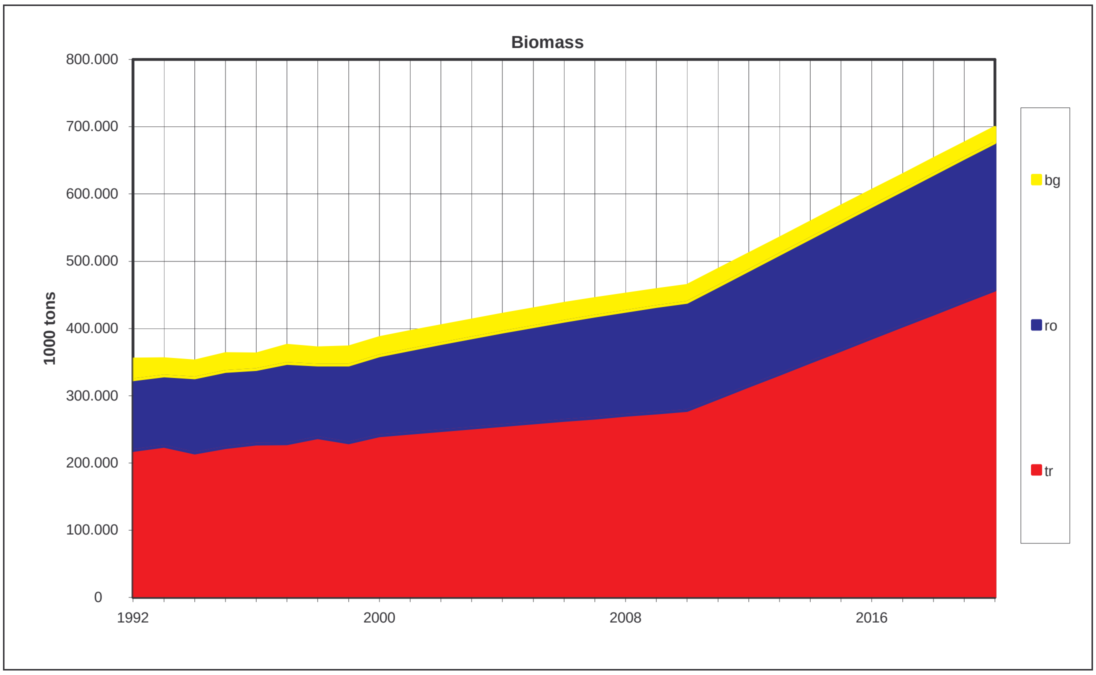
Table 35. Domestic extraction used (DEU), biomass, CC3

Country	Equation	No. of obs.	a_0	a_1	a_3	d	d1	Dxxyy	D1xxyy	R^2	DW
bg	eq. (5) pop.										
	eq. (5) pop.	6	0,185	1,000	0,010	-0,111		96		0,829	2,915
			(0,31)		*(1,57)*	*(-3,84)*					
ro	eq. (5) activ.	7	3,598	0,693	0,022					0,728	2,958
			(1,32)	(2,63)	(3,18)						
	eq. (5) activ.	7	0,489	1,000	0,027					0,709	1,882
			(0,92)		*(4,96)*						
tr	eq. (5) activ.	8	6,342	0,575	0,003					0,817	3,160
			(3,01)	*(2,40)*	*(0,71)*						
	eq. (5) activ.	8	2,384	1,000						0,798	2,879
			(368,90)								

Results

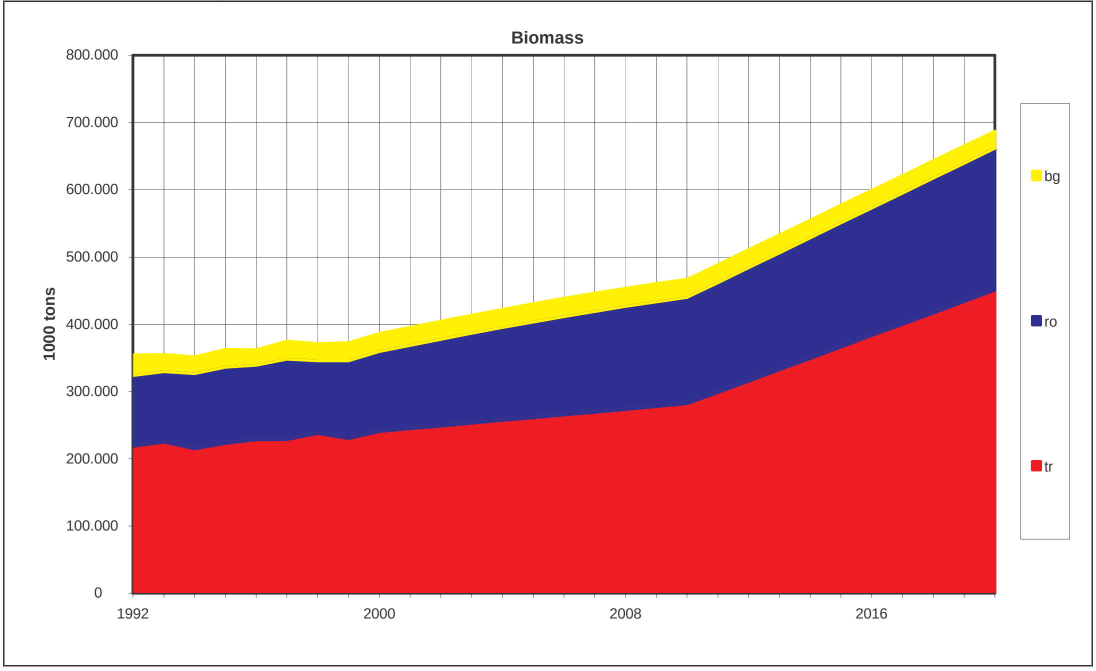
In the Baseline scenario for CC3, domestic extraction (harvest) of biomass is projected to increase considerably up from 2010 (Figure 53). Compared to 1992, it almost doubles until 2020. The aggregated picture is dominated by Turkey where the biomass harvest even more than doubles. This particular development is explained by the equation chosen and it reflects a strong increase in gross value added in the agricultural and forestry sectors.

Figure 53. Domestic Extraction of Biomass ($DEU_{BIOMASS}$), CC3, Baseline scenario



The Low growth scenario for CC3 is presented in Figure 54. The overall growth is only slightly below the Baseline scenario.

Figure 54. Domestic Extraction of Biomass ($DEU_{BIOMASS}$), CC3, Low growth scenario



Assessment

Again, the relatively short historical time series on which the projections are based constitute a limitation. For Turkey, only Low growth scenario looks reasonable and for the aggregated CC3, the doubling of biomass harvest in both scenarios seems too high. Using population as the explanatory variable may be considered as an alternative.

5.3. DMC – Fossil fuels

Material flows of fossil fuels have been projected by using a different approach. Energy use has been projected by a separate model called PRIMES. The results from PRIMES are expressed in energetic units (tonnes oil equivalent [toe]). These have been "translated" into metric tonnes by using country-specific coefficients (toe per metric tonne), which have been derived from historical energy balances by Eurostat.

Not only domestic extraction of fossil fuels has been projected, but also net imports. This enables us to calculate the aggregate of both – the so-called DMC (Domestic Materials Consumption) of fossil fuel material flows.

In addition to the Baseline and the Low growth scenarios, a third scenario has been calculated – Sustainable Emission Pathway (SEP).

5.3.1. Fossil Fuels – EU-15

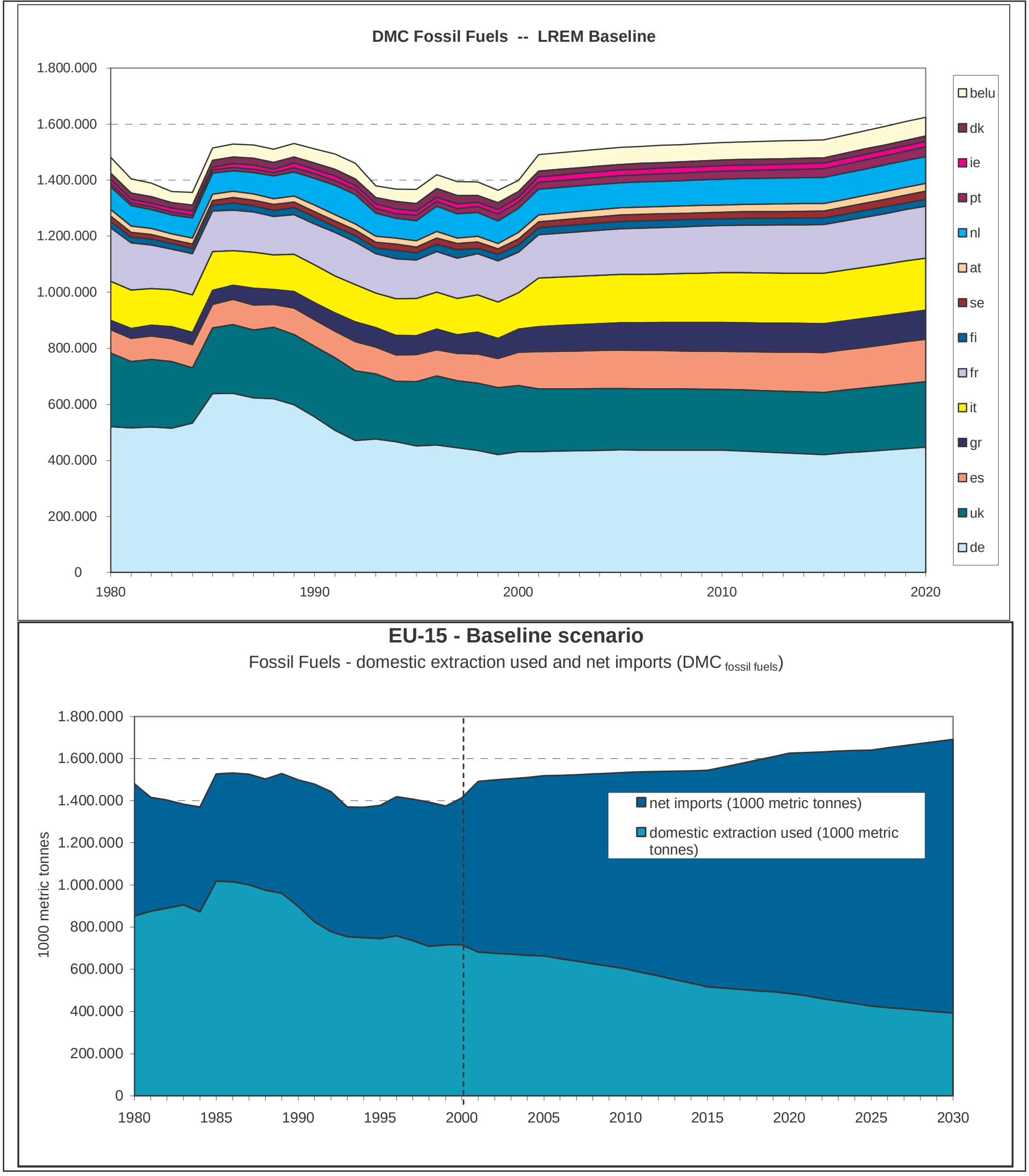
Between 1980 and 2000, the Direct Material Consumption of fossil fuels ($DMC_{\text{Fossil Fuels}}$) has been significantly fluctuating. After slightly decreasing between 1980 and 1984, it steeply increased in 1985 and remained at a high level above 1.5 billion tonnes until around 1990. In the early 1990s, it decreased again below 1.4 billion tonnes. In 1996, it peaked again slightly above 1.4 billion tonnes and returned below until 1999. This overall fluctuating picture is widely determined by Germany.

Results

The Baseline scenario shows a moderate increase of fossil fuel materials consumption from 1.49 billion tonnes in the year 2000 to 1.54 billion tonnes in 2015. Between 2015 and 2020 it increases slightly steeper up to 1.62 billion tonnes. Denmark shows a significant decrease between 2000-2020 (-8%) whereas Sweden doubles its fossil fuel material consumption within the same period.

Of particular interest is the development of domestic extraction versus net imports of fossil fuel materials. For the aggregated EU-15, the domestic share is continuously going down from 0.69 billion tonnes in 2000 to 0.49 billion tonnes in 2020, and even 0.39 billion tonnes in 2030. This decrease is compensated by a net increase of imports of fossil fuel materials from outside the EU-15 borders. The net imports increase by more than 60% from 0.8 billion tonnes in 2000 to 1.3 billion tonnes in 2030. Energy dependency of the EU-15 will significantly increase; more than three quarters of total fossil fuels materials consumption will be imported in the year 2030.

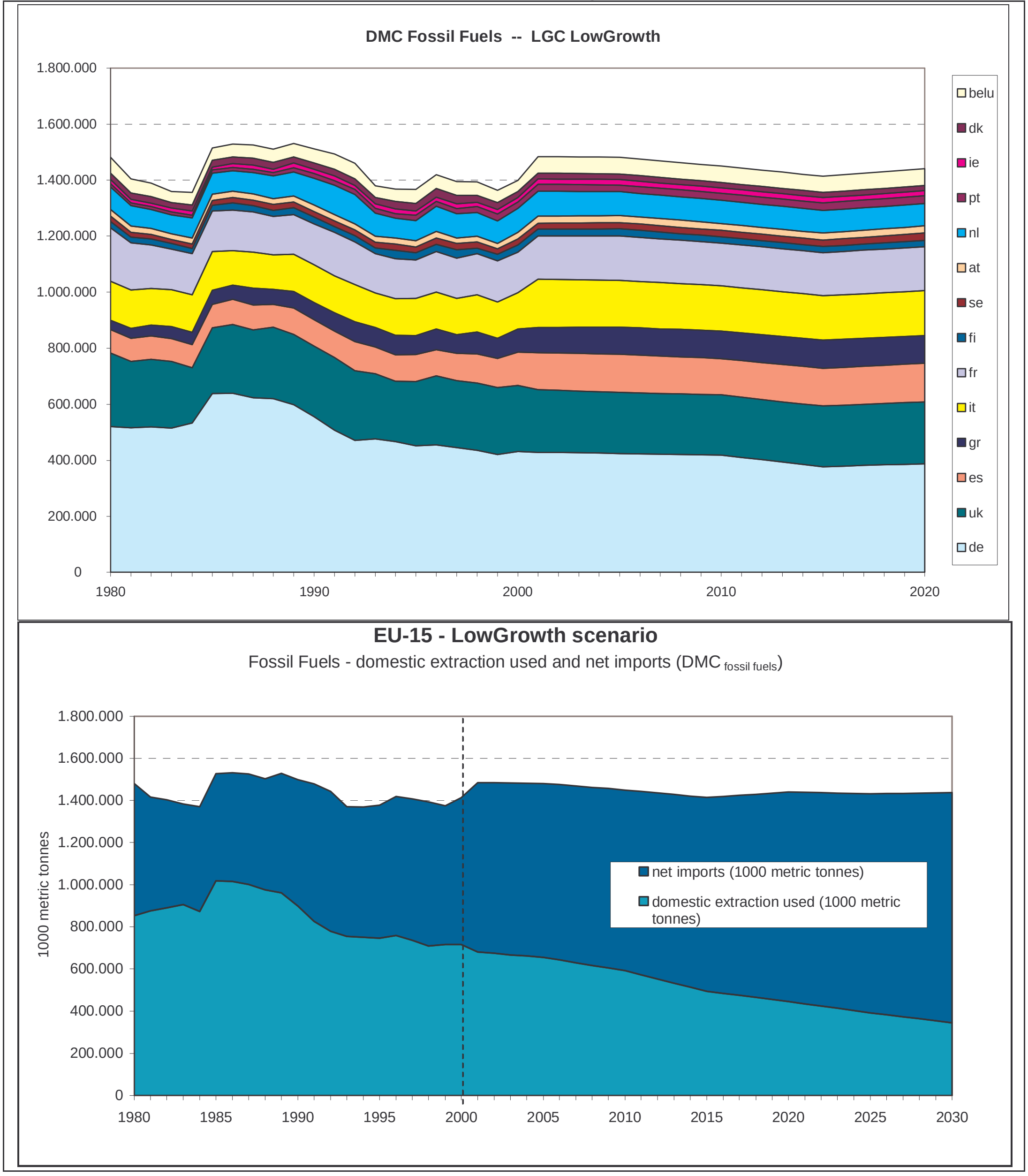
Figure 55. Domestic Material Consumption of Fossil Fuels ($DMC_{FOSSIL\ FUELS}$) EU-15 Baseline scenario



In the Low growth scenario, the fossil fuel materials consumption of the EU-15 will remain fairly constant. Between 2000 and 2020, it will even decrease slightly from 1.49 to 1.44 billion tonnes. Germany, Italy, and The Netherlands will mainly contribute to this overall reduction. Whereas Spain, Sweden, and Portugal will increase their fossil fuel materials consumption also in this scenario.

Again, the domestic extraction is significantly decreasing on the account of imports. With 76%, energy dependency will be as high as in the Baseline scenario.

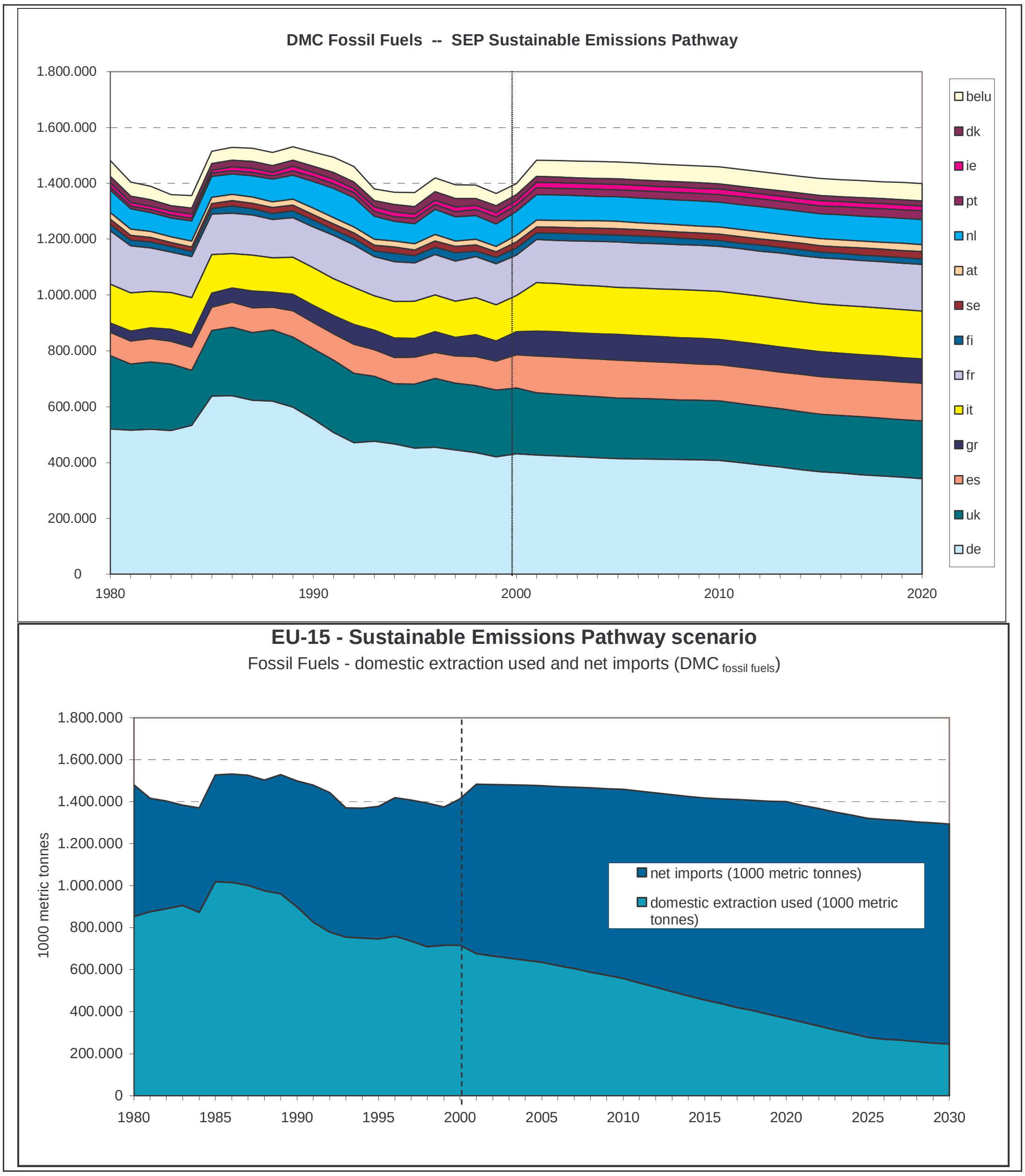
Figure 56. Domestic Material Consumption of Fossil Fuels ($DMC_{FOSSIL\ FUELS}$) , EU-15 Low growth scenario



The Sustainable Emission Pathway scenario shows an absolute decrease in fossil fuel materials consumption for the EU-15; from 1.49 billion tonnes in 2000 to 1.29 billion tonnes in 2030. Germany, the UK, and Greece contribute most to this decrease – all three countries having significant coal mining.

Also in this scenario, domestic extraction is going down on the account of increasing imports of fossil fuel materials. In 2030, the energy dependency will even be higher than in the other scenarios with about 81%. This is due to the changing energy mix from coal to oil and gas. Environmentally benign oil and gas have to be imported due to the lack of reserves within EU-15.

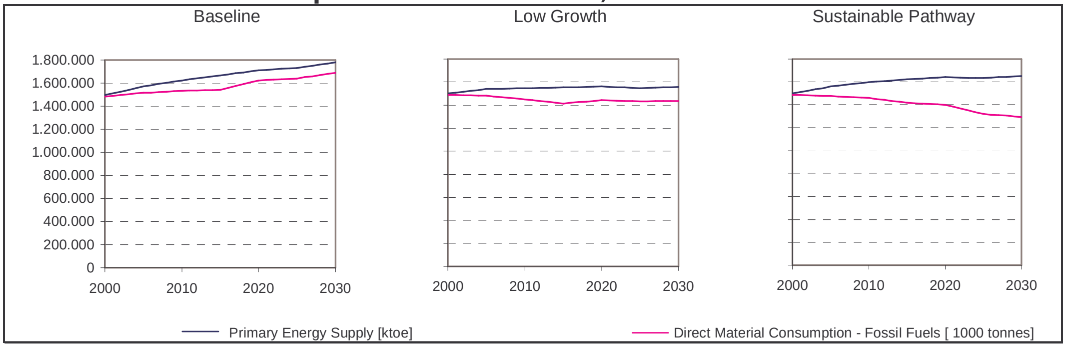
Figure 57. Domestic Material Consumption of Fossil Fuels ($\mathrm{DMC}_{\mathrm{FOSSIL\ FUELS}}$), EU-15, Sustainable Emission Pathway scenario



Assessment

The role of a changed energy mix can be drawn from the following “decoupling graphs” (Figure 58). They show the Primary Energy Supply in energetic units (ktoe) and the fossil fuel materials consumption in metric tonnes. In the Baseline scenario as well as in the Low growth scenario, the “dematerialisation” of energy use is less pronounced than in the Sustainable Emission Pathway scenario. The latter shows a clear absolute decrease of fossil fuel materials consumption whilst primary energy supply is growing. This can be explained by a significant change in the energy mix from material intensive coal towards “lighter” oil and gas. In addition, a significant increase in renewable energy contributes to this “dematerialisation”.

Figure 58. Decoupling of Primary Energy Supply and Direct Material Consumption of Fossil Fuels, EU-15



5.3.2. Fossil Fuels – EU-10

The historical data time series is limited to a relative short period of 8 years (1992-1999). For the historical period 1992-1999, only the Direct Material Input (DMI = domestic extraction + imports) is available for fossil fuel materials, whereas the DMC (= domestic extraction + imports – exports) is projected for the years 2000-2030.

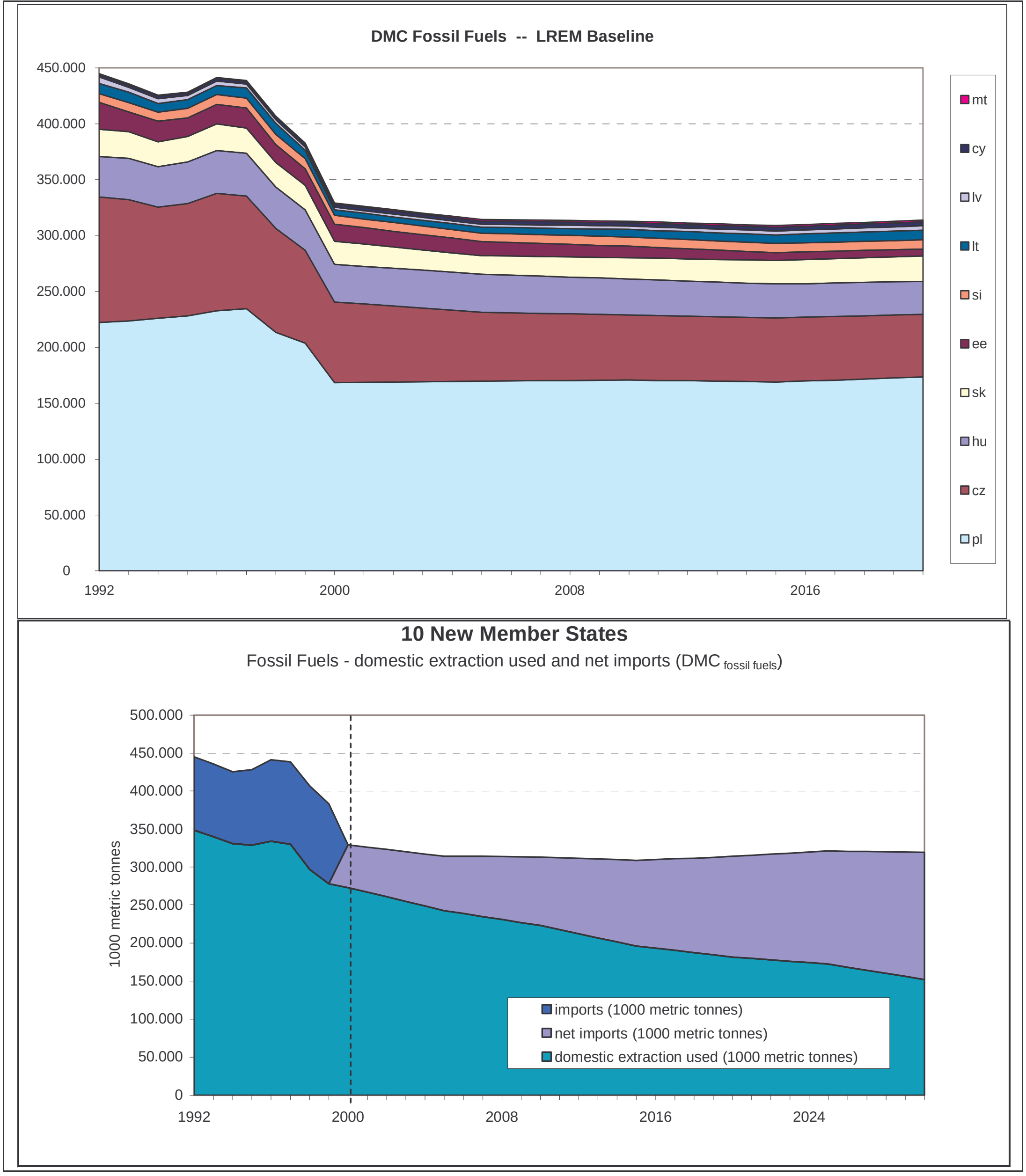
The 1990s have been characterised by unique structural changes in the economies of the 10 new EU Member States due to transitions from central planning to market economies. In the 10 new Member States, the Direct Material Input of fossil fuel materials ($DMI_{Fossil\ Fuels}$) has been significantly decreasing from 349 million tonnes in 1992 to 278 million tonnes in 1999.

5.3.3. Results

For EU-10, the Baseline scenario (Figure 59) shows a slight decrease of fossil fuel materials consumption from 329 million tonnes in the year 2000 to 319 million tonnes in 2030. On single country level, different developments can be observed. The aggregated decrease is caused by significant reductions of 15 and 9 million tonnes in Czech Republic and Estonia respectively. On the other hand Lithuania and Slovakia show significant increases with 5 and 4 million tonnes respectively.

Similar to the old EU-15, the domestic extraction of fossil energy carriers is projected to fall significantly on the account of imports. The share of imports (energy dependency) will rise from 13% in 2000 to 52% in 2030 in the new Member States.

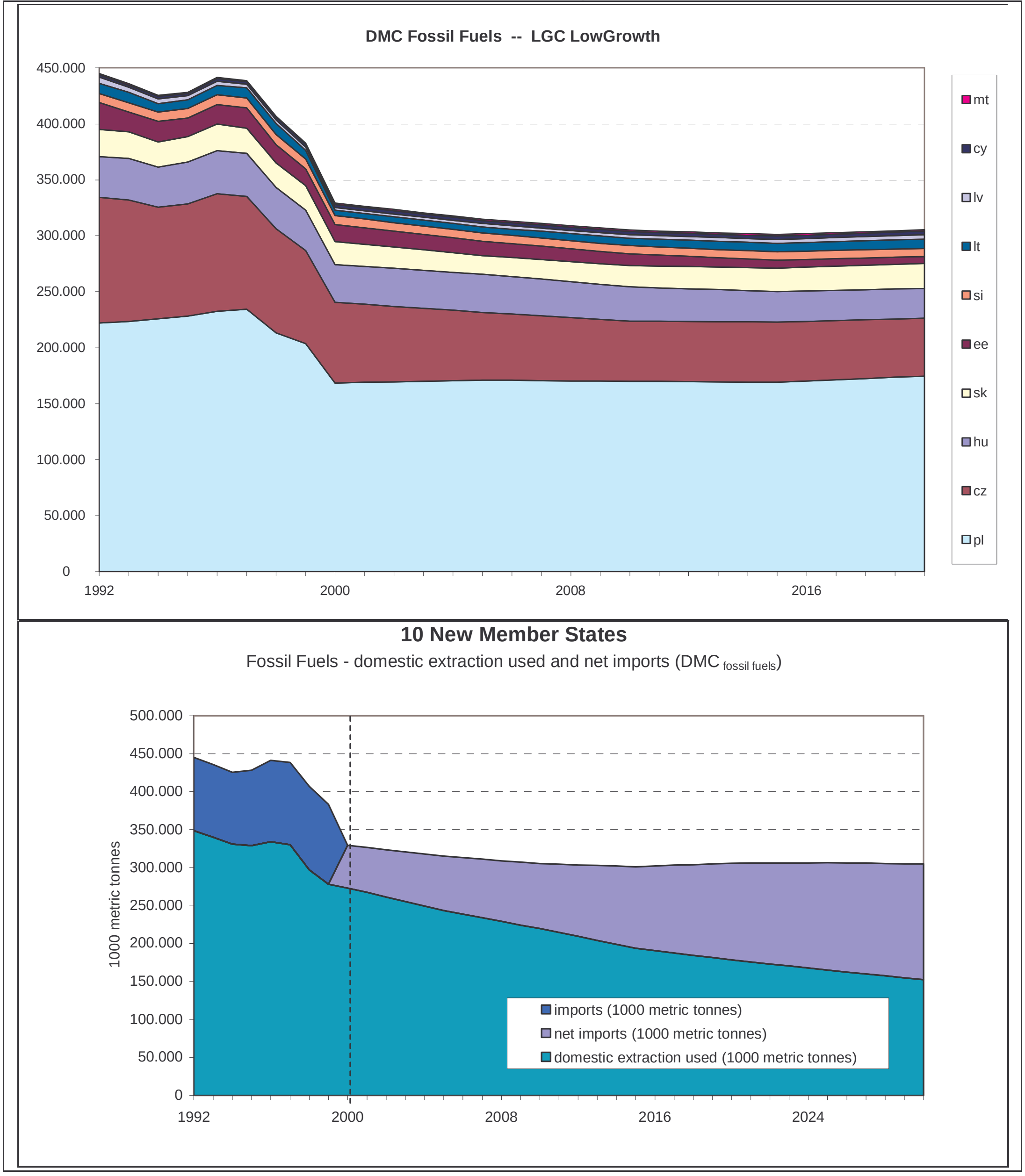
Figure 59. Domestic Material Consumption of Fossil Fuels ($DMC_{FOSSIL\ FUELS}$), EU-10, Baseline scenario



Note: Domestic Material Input of fossil fuels ($DMI_{FOSSIL\ FUELS}$) until 1999!

For the EU-10, the Low growth scenario (Figure 60) does not vary much from the Baseline scenario.

Figure 60. **Domestic Material Consumption of Fossil Fuels (DMC$_{\text{FOSSIL FUELS}}$), EU-10, Low growth scenario**

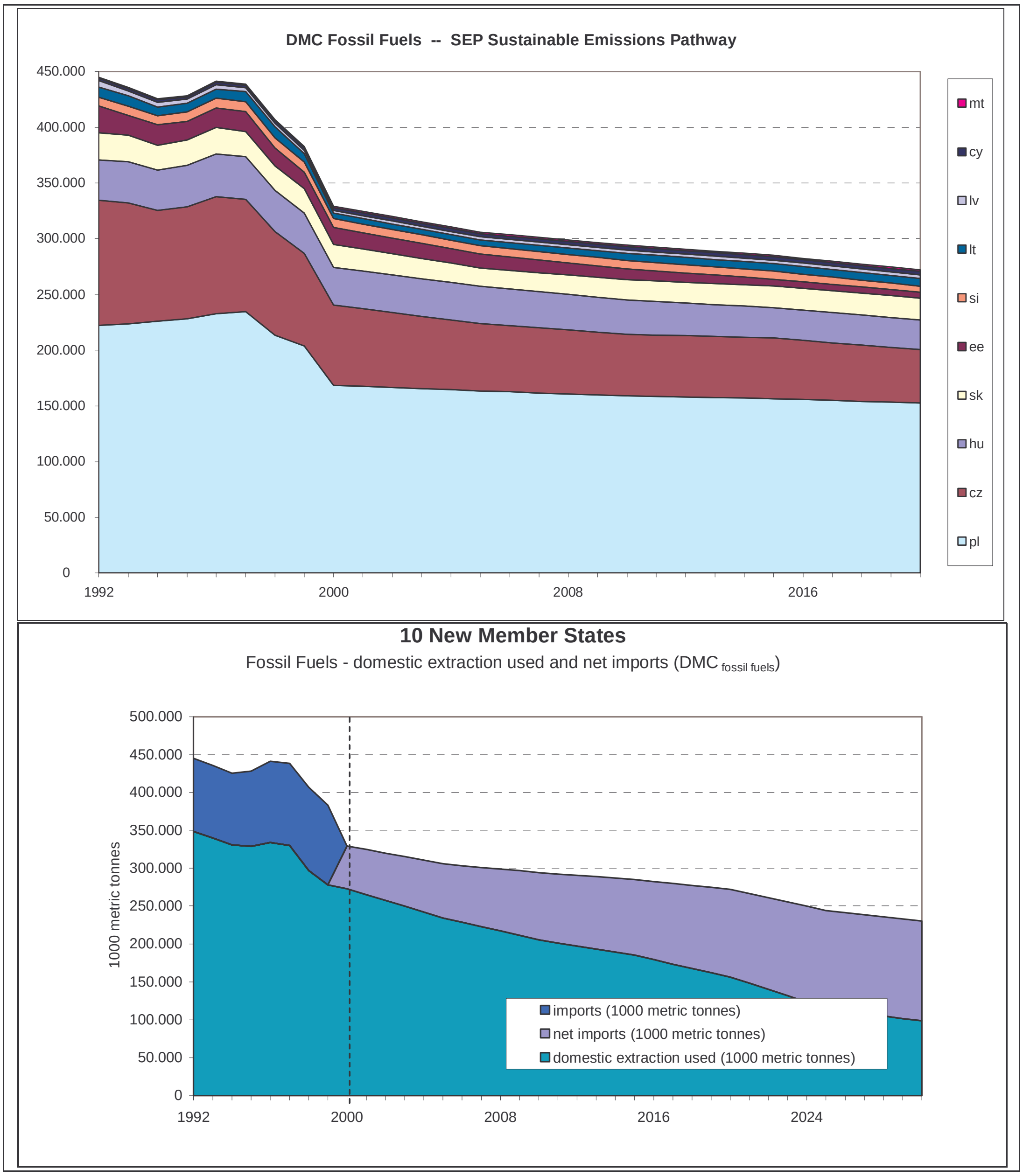


Note: Domestic Material Input of fossil fuels (DMI$_{\text{FOSSIL FUELS}}$) until 1999!

In the Sustainable Emission Pathway scenario, the fossil fuel materials consumption shows a clear and steady decrease from 329 million tonnes in 2000 to 230 million tonnes in 2030 (-30%). With the exception of Lithuania, Malta and Cyprus, all countries contribute to this significant reduction.

The energy dependency (share of imports) is more pronounced than in the Baseline scenario and increases up to 57%.

Figure 61. **Domestic Material Consumption of Fossil Fuels ($\text{DMC}_{\text{FOSSIL FUELS}}$), EU-10, Sustainable Emission Pathway scenario**



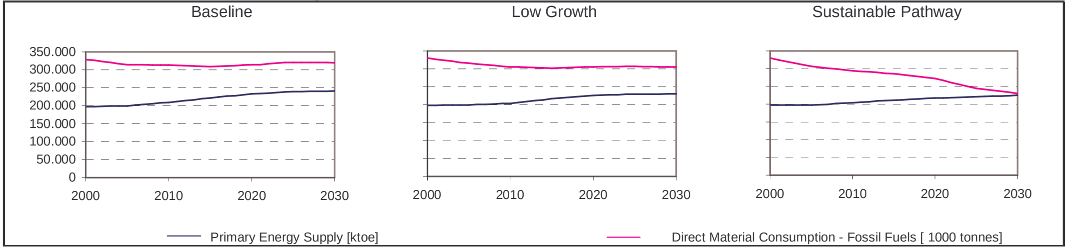
Note: Domestic Material Input of fossil fuels ($\text{DMI}_{\text{FOSSIL FUELS}}$) until 1999!

5.3.4. Assessment

The following charts compare the Primary Energy Supply (in energetic values [kt oil equivalents]) against Direct Materials Consumption of fossil fuels (in 1000 metric tonnes) for the three scenarios (62). In all three scenarios, the Primary Energy Supply increases for the EU-10. The fossil materials consumption, however, decreases indicating a “dematerialisation” of energy supply. This “dematerialisation” is most pronounced in the Sustainable Emission Pathway scenario, indicating a significant shift in energy mix from material intensive coal towards lighter energy carriers (oil and gas) as well as renewable energy carriers. In the Sustainable Emission Pathway scenario, the fossil fuel materials consumption (in 1000 metric tonnes) meets the primary energy supply (in ktoe). For the EU-15, this level of dematerialisation has been met already around the year 2000 (see

Figure 62). In other words, the EU-15 is much more advanced in "dematerialising" its primary energy supply than the EU-10.

Figure 62. Decoupling of Primary Energy Supply and Direct Material Consumption of Fossil Fuels, EU-10



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I.1. Annex. Car stock in the EU-15, EU-10 and CC2

Table I.1. Car stock in the EU-15, 1000 cars

	AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE	UK
1970	1.193	2.064	15.184	1.072	2.364	715	12.410	227	393	10.155	72	2.548	426	2.273	11.651
1980	2.249	3.161	25.799	1.389	7.527	1.226	19.077	858	736	17.672	128	4.531	913	2.881	15.607
1990	2.976	3.902	35.363	1.591	11.845	1.935	23.754	1.731	775	27.383	188	5.515	1.855	3.590	21.548
2000	3.936	4.594	43.585	1.804	16.482	2.093	26.709	2.755	1.111	33.799	263	6.188	3.144	3.839	24.829
2005	4.301	4.908	47.386	1.887	18.506	2.192	28.223	3.303	1.182	36.752	298	6.518	3.774	4.013	26.676
2010	4.591	5.184	49.766	1.958	20.233	2.261	29.316	3.793	1.308	39.388	330	6.772	4.404	4.136	28.541
2015	4.830	5.419	51.438	2.014	21.586	2.309	30.153	4.217	1.437	41.391	359	6.969	4.995	4.248	30.311
2020	5.028	5.620	51.931	2.064	22.531	2.342	30.788	4.553	1.563	42.766	386	7.136	5.531	4.360	31.873
2025	5.191	5.789	52.448	2.114	23.207	2.363	31.263	4.843	1.677	43.771	414	7.286	6.014	4.470	33.451
2030	5.310	5.920	52.534	2.157	23.691	2.369	31.597	5.093	1.778	44.422	438	7.404	6.451	4.555	34.780

Table I.2 Car stock in the EU-10 and CC2, 1000 cars

	BG	CY	CZ	EE	HU	LT	LV	MT	PL	RO	SI	SK
1970	160	56	690	30	238	40	40	42	488	40	150	160
1980	815	93	1.748	133	964	250	177	65	2.490	240	421	550
1990	1.308	180	2.370	236	1.969	486	295	110	5.337	1.300	575	880
2000	1.972	262	3.542	461	2.548	1.000	466	191	9.787	3.226	799	1.272
2010	2.613	359	4.437	632	3.243	1.471	644	248	14.476	5.618	952	1.715
2020	3.176	456	5.140	754	3.848	1.869	823	290	18.888	8.025	1.047	2.147
2030	3.613	540	5.568	811	4.296	2.135	964	317	22.419	10.012	1.088	2.517