Modelling Milestones for Achieving Resource Efficiency: Economic Analysis of Waste Taxes

Draft Report for the European Commission (DG Environment)

November 2013

Cambridge Econometrics
Covent Garden
Cambridge
CB1 2HT
UK

Tel +44 1223 533100
Fax +44 1223 533101
Email hp@camecon.com
Web www.camecon.com

Revision and Authorisation History

Version	Date	Authorised for release by	Description
1.0	14/7/2013	Anthony Barker	1st Draft
2.0	02/11/2013	Hector Pollitt	Revised version
2.1	08/11/2013	Hector Pollitt	Minor revisions

This study does not necessarily represent the views of the European Commission.

Contents

Executive Summary

Method and approach

- The context of this study is the target of increasing the share of tax receipts from environmental taxes to 10% in 2020. The share in 2010 was 6.17% (Eurostat) which could be increased slightly (by up to 0.4%) by phasing out fossil fuel subsidies. However, in many Member States, revenues from excise duties on transport fuels are falling.
- The analysis considers how an EU tax on waste could contribute to meeting the remaining 3-4% gap. Several Member States, notably the UK, already have taxes on landfilled waste; this exercise broadens the taxes to cover a wider group of waste products over the whole of the EU.
- The aim of the exercise is to estimate both the potential revenues from a waste tax, but also the impact on economic output (GDP) and jobs. A macroeconomic modelling approach is used, based on Cambridge Econometrics' E3ME econometric model.
- The economic model has been expanded to take into account physical waste streams, which is a relatively new and untested development. Various uncertainties in data and the relationship between price and quantity of waste mean that the model can only produce rough estimates of waste generation. However, these assumptions have less impact on the economic results, which may be considered as robust.
- Seven scenarios are developed to test different waste taxes. The scenarios are for the main part sequential, with each one building on the results of the previous one. A tax rate of €50/tonne of landfilled waste was used, with an additional tax of €25/tonne for incinerated waste added in later scenarios. It is assumed that this tax is levied in addition to any existing taxes that are already set at Member State level. All tax revenues (except those from the mining sector, see below) are used to reduce employers' labour costs.

Key results

- The model results suggested that revenues from the tax could account for around 0.6% of total taxation, which would help toward, but not close the gap with, the 10% target. Sensitivity testing suggests that this could be increased to 0.8% of total taxation if the waste tax rate was increased to €70/tonne.
- However, in the scenarios that generate these revenues, over 60% of the taxes are paid by the mining sector. Given the globalised nature of many mining operations, it is not clear that the sector would be able to support this level of taxation, so this is an important area for further analysis. The modelling assumes that all revenues from the mining companies are recycled back to the sector in lump sum form, so that the sector is able to reduce waste while remaining competitive (this is similar to industry's EU ETS allocations).

- The impact on GDP is very close to zero. This is because the recycling of tax revenues to the mining sector roughly cancels out any positive or negative impacts. Within other sectors, companies that generate large amounts of waste may see a reduction in profitability, but all employers benefit from lower labour costs.
- These lower labour costs mean that there is a small net increase in EU employment by 2020, in the range of 100,000 jobs. The increase in jobs is spread across all economic sectors, reflecting the lower labour costs across Europe's economy.
- There is very little impact on other macroeconomic indicators. Competitiveness effects are very limited (outside the mining sector) because many of the main generators of waste (e.g. construction, households) do not compete internationally. However, there may be cases for further analysis in a small number of detailed manufacturing sectors.

Policy conclusions

- This analysis finds there could be justification for introducing, broadening or increasing waste taxes in Europe. The model results suggest that, if implemented efficiently, the taxes may have almost no impact on GDP and could lead to slightly higher employment.
- However, there are still some areas where further analysis is required. This in particular relates to the mining sector, but also some behavioural issues like whether landfill is diverted to incineration or recovery, or what the impact may be on illegal disposal of waste. This further analysis should include both bio-physical and macroeconomic modelling, combined with a more qualitative assessment.

1 Introduction

1.1 Background and objectives

Overview

The background to this report is the EU's *Roadmap to a Resource Efficient Europe*[1]. In the roadmap, the EU has set a series of objectives that cover a range of different resource types. The document presents a long-term vision and a set of milestones for steps to achieving this vision. It also provides suggestions for policies that would contribute towards meeting the targets.

Environmental Tax Reform

The roadmap provides the following milestone on page 11:

By 2020 a major shift from taxation of labour towards environmental taxation, including through regular adjustments in real rates, will lead to a substantial increase in the share of environmental taxes in public revenues, in line with the best practice of Member States.

According to Eurostat, the 2010 share of environmental taxes in total taxation was 6.17%, with a target of 10% for 2020. However, it is possible that, without changes in policy, the share will fall in the period up to 2020 due to reductions in receipts from excise duties on motor fuels.

It is therefore likely that new or revised tax instruments will be required to meet the target. In this study we consider an example of a shift in taxation through a new waste tax that is compensated by reductions in labour taxes. This could also help to achieve the milestone for waste that is provided on page 8 of the roadmap.

Model-based, quantitative analysis

The question addressed in this report is the possible macroeconomic impacts of introducing a tax on waste generation. We have used existing taxes on waste generation in certain Member States as a starting point, but then extended the taxes to cover a broader range of waste categories. The aim of this exercise is to assess the economic impact rather than the political feasibility of waste taxes, but the scenarios are designed around previous qualitative analysis of possible policies (see Chapter 2).

A modelling approach is applied. Waste is not typically included in macroeconomic models, so part of the task is to develop a modelling methodology. By necessity the approach is quite stylised in nature and makes simplifying assumptions about behavioural responses to different tax rates. In reality, progress towards EU targets has been in part driven by policy initiatives at the local level, but it is difficult to incorporate this into the type of modelling approach that is required to derive macroeconomic estimates.

The general approach is documented in Chapter 3. We use the E3ME macroeconomic model[2] that is maintained and developed by Cambridge Econometrics (CE) to provide the overall framework for the analysis. The model was used to assess seven main scenarios, also described in Chapter 3.

---

[1] http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf

[2] See Appendix A or www.e3me.com for further details.

1.2 Structure of this report

Chapter 2 provides a brief summary of key information regarding the current waste management policies in Europe and a selection of its Member States.

Chapter 3 details the scenarios that were modelled and how these were processed in the expanded E3ME model, while chapter 4 presents the model results.

Chapter 5 draws conclusions from the model outputs and places them in the context of the future prospects for waste management policy.

A brief description of the E3ME model is contained in Appendix A. A full description is available on the model website (www.e3me.com).

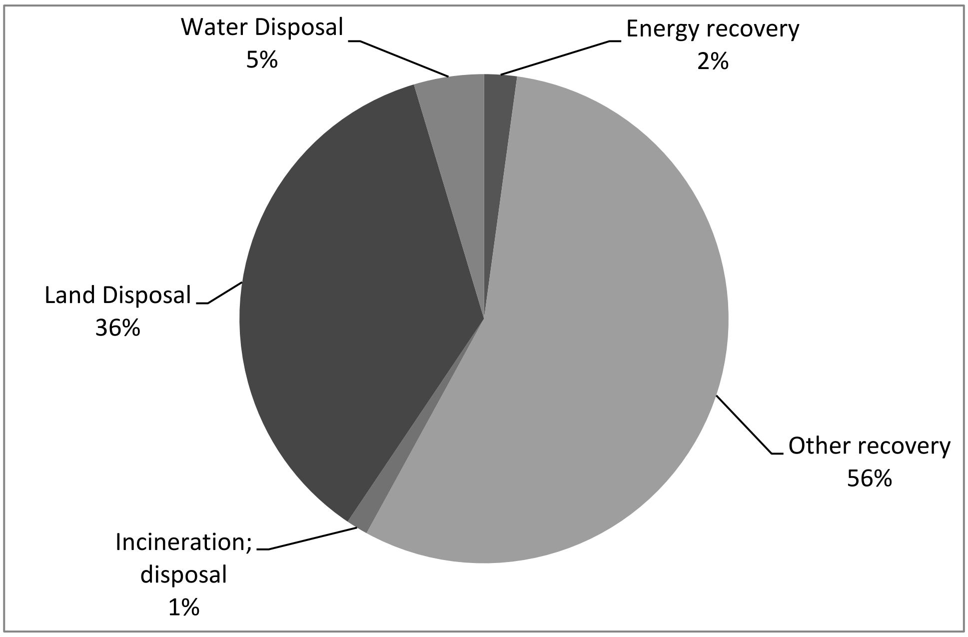
2 The Current EU Position

2.1 Introduction

In this report, our analysis is based on the available data from Eurostat. According to the latest figures, the EU generated almost 2.9bn tonnes of waste in 2010. Around 56% of this waste was recovered (mainly recycled), while 36% was sent to landfill (see Figure 2.1). The remaining waste was either incinerated (sometimes to generate heat or electricity) or released into water.

However, these aggregate figures hide a wide variation in the statistics at Member State level (see Figure 2.2). For example, land and water disposal account for less than 10% of total waste disposal in Belgium and Italy, but more than 90% in Bulgaria and Romania.

Figure 2.1: EU breakdown of waste disposal methods in 2010 (Eurostat)



Sectoral breakdown of waste

The national figures are also heavily influenced by the levels of sectoral activity in each Member State. When all types of waste are taken into consideration, the mining sector produces by far the largest share by quantity; this means that countries with larger mining industries will be likely to produce higher volumes of waste that is disposed on land.

Figure 2.3 shows the full sectoral breakdown of waste generation by sector at EU level. Aside from mining, the construction sector is the largest contributor, although it has higher rates of recovery. Together these two sectors produce 60% of the total waste by weight, while households contribute 11%.

The sectoral breakdown of waste generation is important when interpreting the modelling results.

Figure 2.2: Waste disposal methods in EU Member States, 2010 (Eurostat)

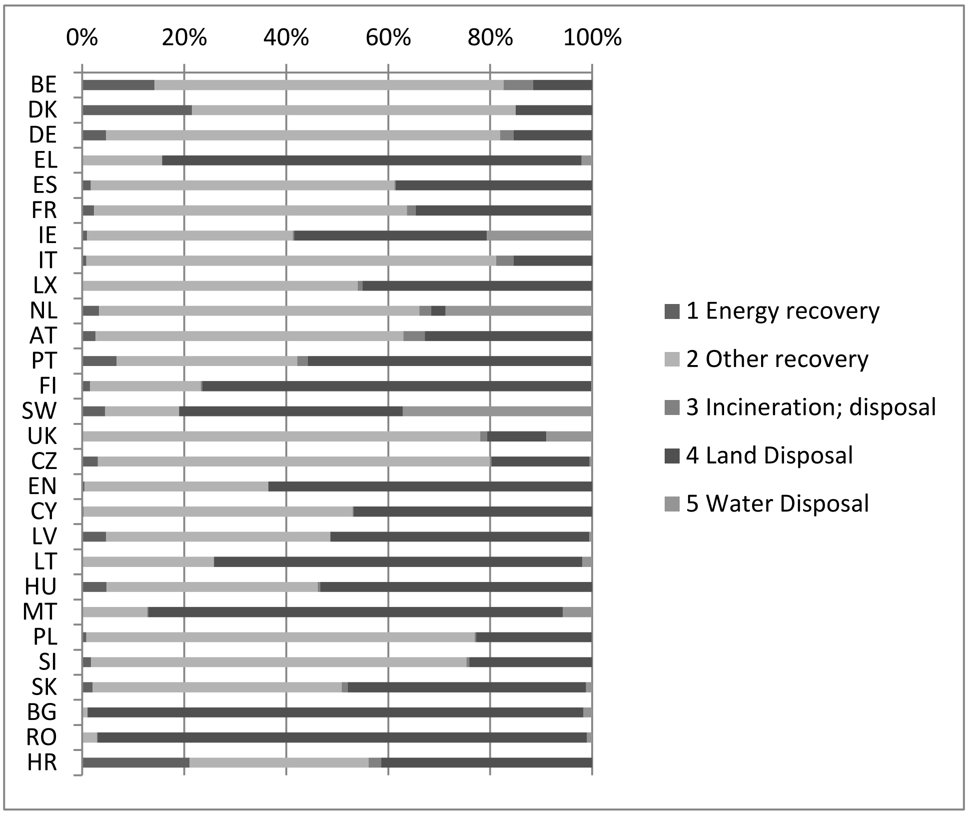
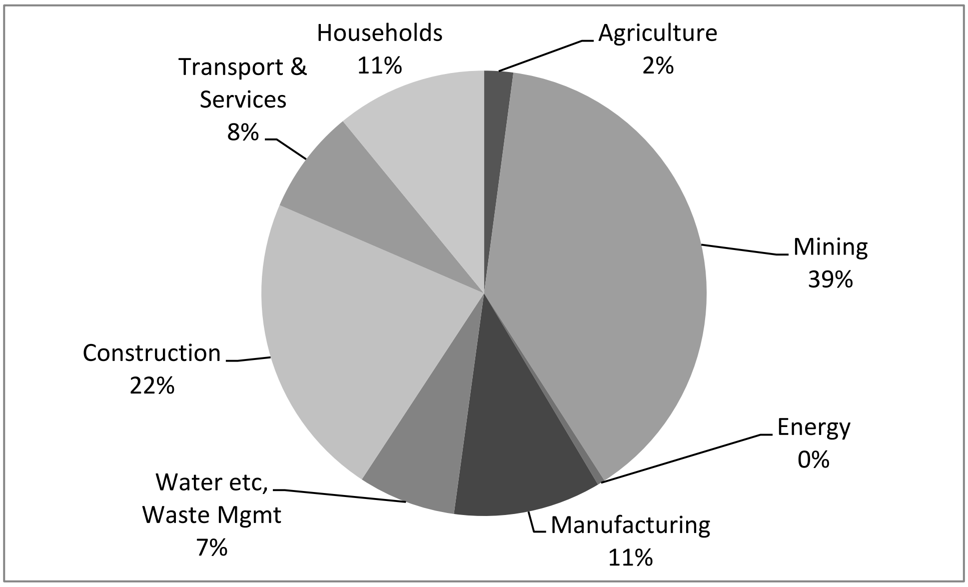


Figure 2.3: EU breakdown of waste generation by sector, 2010 (Eurostat)



Case study countries

The remainder of this chapter provides an overview of current waste management policy in Europe, including existing taxes or duties on waste. The ten countries reviewed are chosen to reflect a variation of legal structures, taxation rates, and history of waste management; not all have well-established policies already in place.

This information has been gathered largely from a recent DG Environment report conducted by Bio Intelligence Service, 'Use of Economic Instruments and Waste Management Performances', Final Report, 10 April 2012. The Confederation of European Waste to Energy Plants also provides recent information about landfill costs[3].

The information in the following sections was used in the design and interpretation of the scenarios presented in the next chapter.

The ten countries are:

- Austria
- Bulgaria
- Czech Republic
- Denmark
- Finland
- France
- Netherlands
- Romania
- Sweden
- United Kingdom

2.2 Austria

There has been a landfill tax regime in place in Austria since 1989. The tax was differentiated in 1996 with regard to the type of waste processed and the level of technology used by the landfill site. Landfills with better technology pay a much lower rate than sites without any anti-pollution provisions. In 2004, for example, the standard rate for landfills with high technology status was €21.80 per tonne whereas it was 65 €/t for others (sites without anti-pollution provision). This taxation system has created an incentive to modernise Austrian landfill sites. In 1999 all but four sites met the technological standards[4], whereas in 1996 21 sites did not meet the standards. The landfill tax, together with other measures, has helped to encourage recycling and recovery of waste. The result has been a reduction in the quantity of waste going to landfill.

2.3 Bulgaria

Landfill taxation legislation came into force in Bulgaria in January 2011. It is a two-tiered tax system based on the type of waste; currently both of these rates are very low. The rate of the higher tier is equivalent to 1.53 €/t, which covers municipal and non-hazardous waste landfills. It should be noted that this rate applies to landfills in compliance with the EU Landfill Directive; the rate is double for those which do not comply. The tax level for the lower tier is equivalent to 0.26 €/t, which covers inert

[3] http://www.cewep.eu/media/www.cewep.eu/org/med_557/955_2012-04-27_cewep_-_landfill_taxes__bans_website.pdf

[4] i.e. anti-pollution provisions such as prevention of greenhouse gas leakage.

waste to landfill from construction and demolition. These rates are expected to increase significantly in the coming years; with the higher rate for municipal and non-hazardous waste reaching about 18 €/t by 2014.

2.4 The Czech Republic

In 1992 a landfill tax was introduced with initial low rates. The charge for all landfills consists of two components: a basic charge (paid for municipal, hazardous and other waste) and a risk charge (paid only for hazardous waste). The components of the charge have been set to grow progressively, particularly for hazardous waste.

The revenue from the basic charge is channelled to the municipalities and constitutes the major component of the money raised. The revenue from the risk charge is channelled to the State Environmental Fund.

2.5 Denmark

The full landfill tax rate in Denmark is 63.3 €/t. Until 2010, landfills for hazardous waste were exempt from the tax but from 2012 those landfills are required to pay 21.3 €/t, and the full tax by 2015. €69m was gathered from the tax in 1993 but revenues declined to €12m in 2010.

The tax revenue is included in the ordinary state budget. When the tax was first introduced a large part of the revenue was spent on supporting recycling and cleaner technology projects; the share devoted to this activity has since decreased. Total waste reaching landfill has dropped from 3.5m tonnes in 1985 to 0.8m tonnes in 2009.

2.6 Finland

There has been a gradual increase in the Finnish landfill tax, from 15.15 €/t in 1996 to 40 €/t in 2011. The tax is planned to rise to 50 €/t in 2013. The revenue gathered from the tax is passed to the general budget and is made available to fund contaminated land remediation. Waste which has not been pre-treated, is biodegradable or is compostable is banned from landfill. However, the rule has not been effectively enforced[5].

The number of landfill sites operating in Finland has decreased considerably as in 2007 many failed to meet a tougher operating requirement and were subsequently closed.

The taxation of waste is considered not to have been an effective incentive to encourage waste prevention as it is not high enough to change waste generators' behaviour. However it appears to have stimulated development and increased the rate of waste recovery.

Reports commissioned by the central government have indicated that waste taxation has helped to reduce the amount of waste ending up in public landfills. This is despite a rise in consumption during the tax's lifetime. The most significant reductions have been in construction, commercial and industrial waste.

[5] Bio Intelligence Service, 'Use of Economic Instruments and Waste Management Performances', Final Report to DG Environment, European Commission, 10 April 2012.

2.7 France

The French landfill tax was initially implemented in 1993 and has since become part of the broader TGAP (general tax on polluting activities) legislative package. The current legislation builds on a law from 2008 and, as well as raising the rate of the landfill tax, also establishes a tax on incineration. The tax on general landfill waste will increase to 40 €/t by 2015 with some exceptions. The corresponding tax for incinerated waste will be 14 €/t by 2015.

The tax consists of two elements. The first tax is levied on the operation of the landfill site, which is determined by the environmental impact of the facility but not by the quantity of waste received. The second tax is dependent on the quantity of waste received and the environmental impact, with different rates for hazardous and non-hazardous waste.

The landfill tax has so far worked to alter the relative prices for methods of waste disposal; the result is that recycling waste has become a more attractive option. The prices in 2008, inclusive of taxes, were as follows; landfilling - 65 €/t, incineration - 80 €/t, and recycling - 70 €/t. By 2015 it is scheduled that this balance should have been altered further so that the prices inclusive of taxes will be as follows; landfilling - 95 €/t, incineration - 92 €/t, whilst recycling will remain at 70 €/t.

The collected revenue is allocated to ADEME (French Environment and Energy Management Agency) for the financial support of recycling facilities and programmes aimed at preventing and reducing waste. For period of 2009-11, €520m was allocated in this manner to waste management policies.

Over 1995-2009 the share of recycled waste in France rose from 18% to 34%, whilst the share of landfilled waste declined from 45% to 32%. However, over the same period the per capita amount of municipal waste in France has increased by 13%.

2.8 The Netherlands

In the Netherlands a landfill tax was introduced in 1995. However, since then more restrictions have been applied on the materials which can be landfilled in order to encourage other methods of waste management. The following items are banned from landfill if there is a possibility for reuse, recycling or incineration: municipal waste, recyclable waste, separated construction waste and demolition waste. However, it is notable that in some circumstances, because of the limited capacity for incineration of waste, permits for landfill of banned waste have been awarded.

When introduced, the tax was set at a flat rate of 13 €/t but from 2000 a two-tiered system was implemented based upon the density of the waste. Waste with a density over 1,100 kg/m^3 was assumed to be non-combustible and was therefore eligible for the lower tax rate[6]. From 2005 there was a considerable increase in the top tier rate, whilst the lower rate increased only a small amount. Prior to the abolition of the tax the high tax for banned waste landfilled with a permit was 107.49 €/t while the low tax rate for inert waste (not banned) was 16.79 €/t.

The revenues from the tax were not earmarked for specific use and were part of the overall government budget. Revenue from the tax fell dramatically in line with the

[6] The default was for landfilling to always be charged with a high tax, because it is assumed that incineration is an alternative for all waste except for waste with a density greater than 1,100 kg/m^3.

reduction of waste landfilled and in January 2012 the Ministry of Finance decided to eliminate the tax on landfill as part of a simplification of the tax system.

In 1996 42% of total household waste was recycled, 35% was incinerated and 23% was landfilled. By 2005 these rates were 52% for recycling, 43% for incineration and 4% for landfill. The combination of the landfill ban and an increasing landfill tax was significant in bringing greater treatment capacity. The current combination of tax and gate fees[7] means that it costs approximately 127 €/t to landfill waste compared to around 90 €/t for incineration.

2.9 Romania

There is no landfill tax currently in place in Romania. The total level of recycling in Romania is very low generally and it has not increased during the last ten years. There is clearly room for improvement in the area of waste policy and management although this would require substantial investment to make improvements in the necessary infrastructure.

2.10 Sweden

In 2000, a landfill tax was introduced in Sweden which is levied on the owner of the landfill site. The current arrangements include a system of taxation in addition to certain types of waste now being banned from landfill. Landfill of sorted combustible waste was banned in 2002 and landfill of all organic waste was banned in 2005. The tax was first introduced at a rate approximately equivalent to 27 €/t and this rate was increased in 2002 and 2003. In 2006 the rate was further increased to its current rate of approximately 47 €/t.

There are numerous exemptions to the general rules. These include:

- plants where less than 50 tonnes of waste/year is landfilled or stored for more than three years
- waste intended for the running of a landfill
- if waste is intended for composting, incineration or the production of solid storable fuel

Banned material exemptions include:

- rock from the mining industry
- sand from the mining industry
- radioactive waste
- waste water sludge
- contaminated soil from cleaning up ground sites
- sludge from different metallurgical processes

Since the introduction of the tax the revenue has decreased significantly; in 2009 the income generated was 15% of the level raised in 2000, indicating that the tax has provided a strong incentive to divert waste away from landfilling. Incineration activity for example has been increased due to the landfill tax.

[7] Gate fees are the charges for landfilling waste additional to tax coverage, i.e. to cover the operational costs of the site.

2.11 The UK

The UK introduced a landfill tax in 1996 and initially the levels were set at 10 €/t for active waste and 2.9 €/t for inert waste. By 2010/11 rates had increased to approximately 55 €/t for active waste and 2.85 €/t for inactive waste and the UK is expected to increase the landfill tax by approximately 10 €/t each year until 2014/15 when it will reach around 91 €/t for active waste. Exemptions from the tax include waste arising from mining and quarrying operations, waste arising from clearance of contaminated land and waste used for the restoration of landfill sites.

The tax was designed to be revenue neutral through a reduction in employers' national insurance contributions and in 2010 the revenues raised from the tax were €1.2bn. These revenues are not earmarked and are added to the national budget. The amount of waste going to landfill has almost halved in the UK since the tax was introduced, from 90m tonnes in 1998 to 46m tonnes in 2010. In 2009 46% of municipal waste was landfilled and 51% recovered, in contrast to 84% and 16% respectively recorded in 1998.

3 Outline of the Modelling

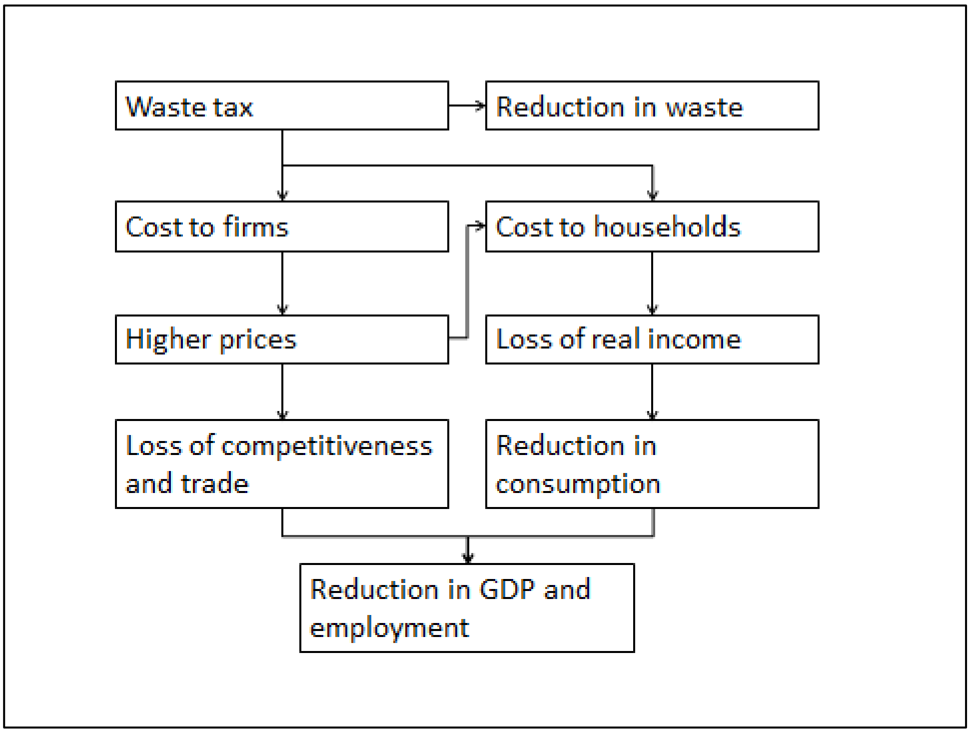
3.1 Introduction

This chapter describes the modifications made to the E3ME model to assess the waste tax scenarios. It is important to bear in mind that the analysis is economic in nature; we are not aware of this type of analysis having been carried out before so the methodology and assumptions could be refined further, especially if more information becomes available. Understanding the key challenges is an important outcome of the exercise.

Although the results include physical indicators of waste, these are for the main part approximations of likely outcomes at the European level. They are used as inputs to the economic analysis.

Figure 3.1 shows an overview of the main economic interactions that are included in the modelling. Taxes on waste are treated as a cost that industry and households must pay per unit of waste produced. This feeds through the National Accounting system and may (in the case of costs on industry) be passed on to final consumers. There may also be a loss of international competitiveness due to the higher costs faced by firms.

Figure 3.1: Overview of Model Linkages



The following section describes the basic modifications to the E3ME model. Section 3.3 provides a description of the baseline and Section 3.4 describes the scenarios. The results are presented in the next chapter.

3.2 Model development

The treatment of waste in E3ME is a new development to the model. This section contains a detailed description of the model improvements carried out.

Additional variables and classifications

New waste generation and disposal variables are created using the data available from Eurostat. These variables are broken down into the classifications listed in Table 3.1.

- Waste by Generator - This is a time series (in thousands of tonnes) that depicts how the amount of waste (in ten types) produced by the different waste generators has changed over time (2004-10).
- Waste by Disposal Method - This is also a time series variable (in thousands of tonnes) which depicts how the amount of each of the ten waste types is disposed of over time (2004-10).
- Waste Generation Coefficients - This variable determines the amount of each of the ten waste types produced by each waste generator category, per unit of economic output.
- Waste Disposal Coefficients - This variable determines how each of the ten waste types is disposed.
- Waste disposal switching coefficient matrix (WDSC) - There are two possible ways for industries to reduce landfill; either by reducing total generation of waste or switching to a different method of disposal. This variable holds the coefficient values which determine how a reduction in disposal of a material is met by an industry. These coefficients are applied to the taxes to calculate the reduction in amount of disposal by a given method.

Table 3.1 Classifications of new waste variables

Classifications		
Waste Type Titles	***Waste Generator Titles***	***Waste Disposal Titles***
1 Animal & Vegetable	1 Agriculture	1 Energy recovery
2 Common Sludge	2 Mining	2 Other recovery (including recycling)
3 Mineral from Cons.	3 Energy	3 Incineration; disposal
4 Other Mineral & Solid	4 Food, Drink & Tobacco	4 Land Disposal
5 Metallic	5 Wood & Paper	5 Water Disposal
6 Chemical	6 Chemicals	6 Unallocated
7 Glass, Rubber etc.	7 Non-metallic Minerals	
8 Wood, Paper etc.	8 Metals	
9 Discarded Equipment	9 Engineering etc.	
10 Mixed Ordinary	10 Other Industry	
	11 Water etc, Waste Mgmt	
	12 Construction	
	13 Transport & Services	
	14 Households	
	15 Unallocated	

New model routines Two additional fortran model routines link the waste variables to economic activity in E3ME.

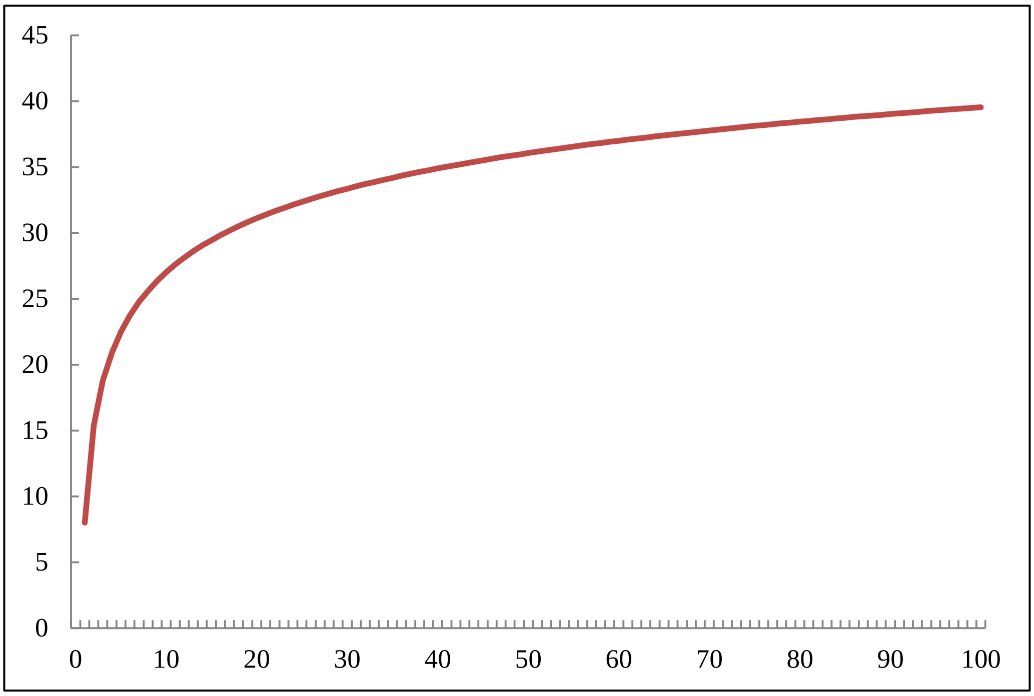
Waste generation This routine formulates the relationship between waste generation and economic output. The projected generation of each of the ten waste types by waste generator is calculated using a constant coefficient derived from waste generation and economic output in the final year of historical data.

Waste disposal The second routine links together waste type and disposal method. Specially, this calculates the projections of waste disposal method for each of the ten waste types. Again this uses a constant coefficient which is derived from the relationship between total generation of a given waste type, and method of disposal of a given waste type, in the last year of history. Note that in each year, total generation is adjusted to be consistent with the reduction in waste disposals.

Price elasticities The modelling assumes a simple logarithmic relationship between tax rates and reductions in waste generation (see Figure 3.2). This is not quite the same as an elasticity because we do not have a consistent non-tax waste price with which to compare the taxes (see below). However, the difference is slight and the approach is very similar to setting an elasticity of -0.08 in which all the cost is tax. This means that a 1% increase in costs leads to a 0.08% reduction in waste generated.

There is considerable uncertainty about what the true values of the elasticities are and they will in reality vary between regions, sectors and over time. In this analysis we do not make any assumptions about flanking measures such as policies to promote recycling. A review of the elasticities used in published literature is given in Chapter 4 of OECD (2004)[8]. The value we have used is broadly consistent with many of the findings.

Figure 3.2: % Reduction in Waste for Tax up to €100/tonne



[8] OECD (2004) 'Addressing the Economics of Waste', OECD, Paris.

The results for our main scenario, when coupled with the elasticity described above, suggest that current landfill charges are €20-25/tonne. We have applied this to all of Europe. This is a simplifying assumption that reflects the data available (see previous chapter); we believe it is roughly accurate for around half of the Member States we could obtain data for. It is likely to be too low for Scandinavia and the UK (where a large landfill tax already exists) but is likely to be too high for Portugal and some central European countries. It is possibly also too high for the countries for which we were not able to obtain data. However, it should also be noted that many countries have variable rates and exemptions that could make it difficult to estimate a single rate.

Given the uncertainties around the reduction in landfill in response to a tax (e.g. supplementary policy), this approach does not seem unreasonable, although it could clearly be improved upon if better data became available. However, this range of uncertainty should be taken into consideration when considering the model results for reductions in waste. In our view these assumptions do not have a notable impact on the economic results, which are the main subject of this report.

Substitution of waste

Another important issue is the substitution of waste treatments. In the modelling we have adopted some very simple assumptions; half of the reduction in landfilled waste goes to a combination of incineration and recovery[9]. Half of a reduction in incinerated waste is instead recovered.

In reality, the substitution effects will be at least partly determined by local policy but this is almost impossible to identify at a macroeconomic level. The assumptions are therefore an approximation that could be replaced if more detailed bottom-up analysis became available. It should be noted that these assumptions are important for the model results on physical waste but have only a limited impact on the economic results.

Finally, it should be noted that we do not make any assumptions about fly-tipping or other illegal activities. This would need to be considered in a separate analysis but, again, it has no impact on the economic results.

Revenue recycling

Environmental Tax Reform includes both an increase in environmental taxes and a compensating reduction in other taxes.

It was necessary to assume that revenues from mining firms were recycled back to the sector as it may otherwise be unable to meet the costs (see next chapter). The remaining tax revenues were used to reduce labour costs across the whole economy, with the aim of stimulating higher employment.

Limitations

It should be noted that there are some quite strong limitations to the modelling analysis and the scenarios assessed. In the main these relate to the treatment of waste in the model, rather than the economic impacts; but the two are linked in that total revenue raised depends on the volume of waste. The main limitations are described above, but summarised here:

- Generation of waste – A simple linear relationship is assumed between sectoral (economic) production and waste generation. This is then adjusted for price effects in the scenarios.

[9] An arbitrary figure was chosen for this exercise but, in future, this assumption could be refined to affect realistic possibilities. In this exercise we use the same coefficient for all sectors except mining, where incineration is set to zero.

- Price elasticities – As described above, the logarithmic curve used to determine a reduction in waste generation in response to a tax is a simplification of complex processes. Although the focus of the modelling is on economic impacts, the amount of waste generated determines total tax revenues and costs to industry/households.
- Fly-tipping – Similarly we do not make any assumptions about fly-tipping. Reductions in waste generated lead to lower tax revenues, whether this is due to a reduction in total waste or illegal disposal.

Many of these limitations could be improved upon in future if better information becomes available.

Revenues for the waste processing sector

Another area of potential improvement is in modelling the economic relationship between the sectors that produce waste and the waste processing sector. This is represented in the modelling by the relevant input-output coefficients. If the landfill tax results in reduced waste levels through efficiency improvements then this would reduce revenues for the waste processing sector. Alternatively, if recovery rates increase, this may lead to higher revenues for the waste processing sector.

In our scenarios we have a mixture of both options so the impacts on the waste processing sector are not clear, in either direction or magnitude (and would vary by country and sector). We therefore have not changed the input-output coefficients in this particular exercise but note that this could be improved upon in future modelling work.

3.3 Baseline specification

Overview of the baseline

A forward-looking, *ex ante*, assessment requires a baseline projection with which to compare the different policy scenarios. This is not necessarily presented as a *forecast* of future developments, but rather as a neutral viewpoint for the purposes of comparison, since many of the model-based results are presented as (percentage) difference from baseline. Nevertheless, the values in the baseline are important in themselves (see below). It is therefore important that a robust and credible baseline should be established.

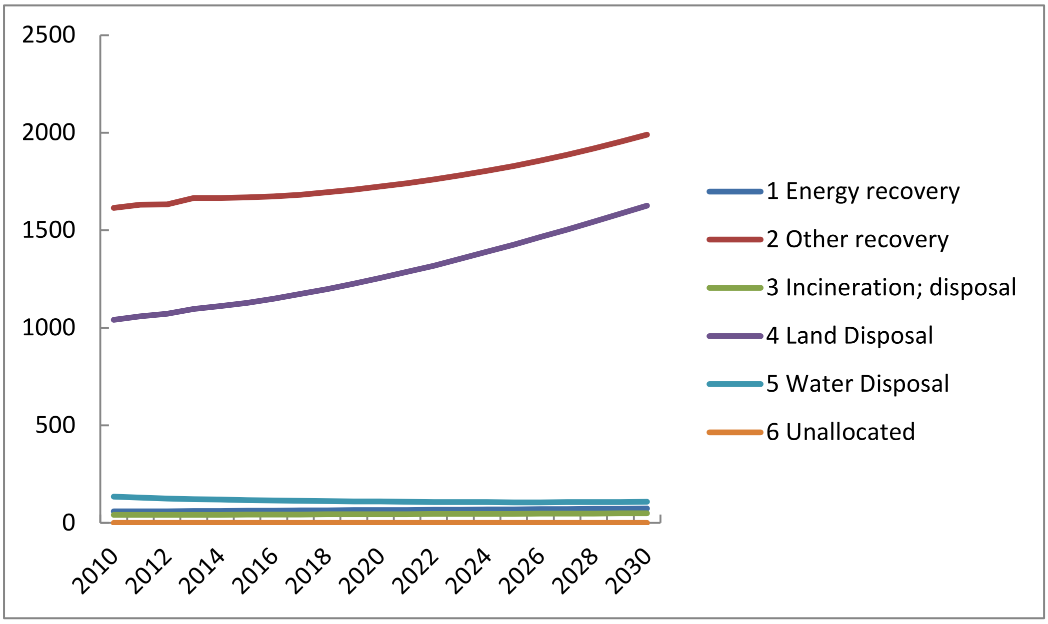
The baseline for this exercise is the same one that was applied in this project for the recent analysis of fossil fuel subsidies. It is based on the current policy initiatives (CPI) scenario from the Energy Roadmap. This is the result of a simulation made using the PRIMES energy model with inputs from the GEM-E3 economic model. The baseline is assumed to include the existing Member State waste management legislation in its current form.

Waste generation in the baseline

The baseline projections of waste are important because they determine the tax base for the policies in the scenarios. A higher volume of waste generation will mean a higher impact of the tax, both in terms of revenues and economic impact. Unfortunately there are at present no authoritative projections of waste generation to inform the baseline, so we had to form a basic set for this modelling exercise. The outcomes are presented in Figure 3.3.

The results are based largely on a projection of current economic trends (including recovery from recession) in the absence of any additional waste policy and should not be viewed as a prediction of future outcomes. Incidence of land disposal grows slightly faster than recovery of waste over the projection period, although current policy may well reverse this policy – and there is considerable uncertainty about trends after 2020.

Figure 3.3: Baseline EU28 Waste Disposal, m tonnes



Notes: Consistent with Eurostat disposal data.

3.4 Scenario specification

The testing scenarios

There are seven scenarios set up for testing different taxes. Scenarios 1-4 are sequential and are designed to model the impact of adding new waste taxes across sectors and waste types. In this way Scenario 4 encompasses the policies included in scenarios 1-3 as well as a unique element. Scenario 7 includes the full range of coverage and so is the most extreme case which was modelled.

This stepwise approach has been chosen as this type of modelling allows us to depict how the waste management hierarchy can be shaped by the choice of taxes. As the size of each tax is the same in each case these scenarios can be interpreted as a set of switches. This allows the results to be representative of the marginal impact that levying an additional tax would create. Once the preferred combination of taxes and incentives has been discovered further modelling work to discover the optimal level of taxation for each element would be advisory.

It should be noted that all of these taxes are treated as <u>additional</u> to any taxes in the baseline. This is a simplifying assumption that could be relaxed if a complete set of data regarding taxes on sectors and disposal methods at Member State level becomes available. However, with the exception of the UK, the scale of the taxes considered in these scenarios is quite a lot larger than any existing measures[10] so the difference should be fairly small.

---

[10] According to the report by BIO IS, current waste taxes generate €2bn revenue annually, of which more than half is in the UK. In comparison, S7 results have annual revenues of €35bn. The assumption means that the modelling slightly

The scenarios are:

1 A tax of €50/tonne on municipal waste to landfill

2 Number 1 + €50/tonne tax on waste from construction waste to landfill

3 Number 2 + €50/tonne tax on other mineral waste to landfill

4 Number 3 + €50/tonne tax on all other waste to landfill

5 A tax of €50/tonne on discharges to water

6 A tax of €25/tonne on waste that is incinerated without energy recovery

7 Number 4+5+6 (i.e. all of the above)

The amounts of waste involved in Scenarios 4 and 6 are quite small so we would not expect to see much impact from the measures introduced in these scenarios but the tax in S3 would be considered high by industry. Table 3.2 summarises the tax inputs in the main scenarios. All the tax rates are given in current prices and are stepped up gradually to 2020. They are applied to all the countries in the E3ME model (EU28 plus three EU candidate countries, Norway and Switzerland) but we only report results for the EU28.

Revenue recycling

Due to the nature of its markets (see next chapter) it is assumed that the mining sector receives compensation in all the scenarios (at national level). All other tax receipts are recycled through reductions in labour taxes (employers' social contributions). Thus the scenarios represent a shift from taxation on labour to taxation on waste.

Sensitivity analysis

An additional version of S7 with higher tax rates (€70/tonne rather than €50/tonne) was set up to test the sensitivity of results to the tax rate. The results from this scenario are also reported in the next chapter.

Another sensitivity test considers how the arbitrary assumptions about alternatives to land disposal might impact on the results. It was found that there could be some interaction with other tax rates (e.g. if waste was diverted from landfill to incineration and there was also a tax on that) but no other economic impacts.

Table 3.2: Summary of inputs to the scenarios

Tax on:	municipal waste to land disposal, €/t	waste from construction to land disposal, €/t	mineral waste to land disposal, €/t	discharges to water, €/t	incinerated waste, €/t
Baseline	-	-	-	-	-
S1	50	-	-	-	-
S2	50	50	-		-
S3	50	50	50	-	-
S4	50	50	50	-	-
S5	-	-	-	50	-
S6	-	-	-	-	25
S7	50	50	50	50	25

Sources: E3ME, Cambridge Econometrics.

over-estimates the reductions in waste generation (given the elasticity) and therefore slightly underestimates the revenues. It does not have any major impact on the economic results or conclusions.

4 Results

4.1 Introduction

This chapter presents the results from the modelling exercise. In the next section we present the results from the scenarios that were set up to test the model properties. The final section in this chapter shows the results of the sensitivity analysis, with different tax rates tried.

4.2 Results for the test scenarios

Table 4.1 presents the summary results for the main scenarios. Total annual revenue raised reaches €35bn in 2020 (in 2005 prices, around €41bn in today's prices) in the highest scenario, accounting for around 0.3% of EU28 GDP. As can be seen when comparing scenarios, the bulk of this comes from the inclusion of mineral waste in the tax (S3). As discussed later in this chapter, this has important sectoral implications for the taxes.

It should also be noted that there is an important interaction between the different waste treatments. When a tax on landfill is introduced this can lead to higher rates of incineration, which generate revenues if incineration is also taxed. This is why the revenues in S7 are greater than the sums of S4-S6.

In our modelling the total reduction in waste generation is up to 12% for a tax rate of €50/tonne. Most of this is a reduction in land disposal (-31%) while recovery rates also increase. However, it should be noted that there is considerable uncertainty around these ranges as we do not make assumptions about supplementary local policies (see previous chapter).

Table 4.1: Summary Results for the EU28 in 2020 (S1-7, % from base)

	S1	S2	S3	S4	S5	S6	S7
Revenue (€2005m)	3,689	5,276	30,627	30,966	2,842	648	34,680
GDP	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
Employment	0.01	0.02	0.04	0.04	0.00	0.00	0.04
Household Consumption	-0.01	0.00	0.01	0.01	0.00	0.00	0.00
Investment	-0.01	-0.01	-0.01	-0.01	0.00	0.00	-0.01
Exports	0.00	0.00	-0.03	-0.03	-0.01	0.00	-0.03
Imports	0.00	0.00	-0.01	-0.01	0.00	0.00	-0.01
Consumer Prices	0.01	0.00	0.02	0.02	0.01	0.00	0.03
Waste Generation	-1.53	-2.36	-10.28	-10.47	-0.78	-0.42	-11.67

Sources: E3ME, Cambridge Econometrics.

Impact on GDP and employment

The effect on annual GDP is very limited as the revenue recycling cancels out the effects of the waste tax at macroeconomic level. Although there is a transfer of resources from companies that produce waste to companies that employ people, this has very little impact on overall GDP.

There is, however, a small but noticeable increase in employment. The potential 0.04% increase in total EU employment translates to around 100,000 jobs. This is driven by the use of the revenues to reduce labour taxes and lower the cost of employment; although there will be some new jobs in the waste processing sector, the net increase in employment comes from a range of different economic sectors.

Impact on other economic indicators

There is a very small reduction in aggregate exports, due to competitiveness effects associated with the higher waste costs. Consumer prices also increase very slightly overall from these costs being passed on into final products. It should be stressed that these effects are very small.

Sectoral impacts

Table 4.2 summarises who pays the taxes in S7 and the effects that this has on economic output. A very large part of the total falls on the domestic mining sector (both energy and non-energy), because of the mineral waste that the sector produces. It is not clear that the sector would be able to pay this tax and remain solvent without additional support, so this is an area that requires particular further analysis.

In our scenarios we assume that national governments provide a lump-sum rebate to the mining sector so that it has the incentive to reduce waste, while still being able to compete in the international market place. This is rather like the method used to allocate allowances in the EU ETS. While it has the advantage of compensating for higher costs at the sectoral level, it means that a large share of the revenues generated could not be used for offsetting other taxes.

Table 4.2 Additional taxes paid and change in output, EU28, 2020

	Taxes, €2005m	Change in output (%)
Agriculture	44	0.00
Extraction Industries	21,216*	-0.01
Basic manufacturing	3,411	-0.02
Engineering and transport equipment	734	-0.01
Utilities	1,442	-0.02
Construction	2,409	-0.01
Distribution and retail	254	0.00
Transport	91	0.00
Communications	276	0.00
Business services	654	0.00
Public services	428	0.00
Households	3,720	

Notes: * Mining sector taxes are assumed to be recycled back to the sector.
Sources: E3ME, Cambridge Econometrics.

Across the other sectors, the impacts are quite small and fairly evenly spread. The sectors that produce the most waste (manufacturing, utilities and construction) face a very small reduction in output but there is no change in the large service sectors. All the sectors benefit slightly from lower labour costs.

Results at Member State level

The modelling results show that no Member States stand out as having major GDP impacts from the tax reforms. The range is -0.06% to +0.08%, although all Europe's major economies see impacts even less than this. The minor differences between results for Member States in the main depend on labour market conditions and competitiveness effects between each other.

Table 4.3: Results by Member State, 2020

	Revenue, S7 (€2005m)	GDP (S7) % from base	Empl (S7) from base (000s)
Belgium	134	-0.01	0.61
Denmark	43	-0.01	0.06
Germany	3,784	0.00	4.57
Greece	1,495	0.00	1.60
Spain	1,389	-0.01	7.96
France	4,500	-0.01	18.95
Ireland	227	-0.06	0.23
Italy	839	-0.02	2.79
Luxembourg	102	0.03	0.18
Netherlands	1,311	0.04	2.09
Austria	344	0.00	2.14
Portugal	265	0.01	2.89
Finland	3,663	0.05	3.39
Sweden	1,784	-0.01	-0.03
UK	1,796	-0.01	11.10
Czech Republic	148	-0.06	-0.20
Estonia	370	-0.04	0.63
Cyprus	36	-0.01	0.29
Latvia	16	-0.06	0.39
Lithuania	108	0.06	2.61
Hungary	200	0.01	5.40
Malta	59	0.08	0.83
Poland	765	0.01	6.71
Slovenia	45	-0.01	0.28
Slovakia	137	-0.01	1.75
Bulgaria	6,720	-0.01	11.94
Romania	4,385	-0.04	6.93
Croatia	16	-0.01	0.08

Sources: E3ME, Cambridge Econometrics.

The employment effects are generally positive. Employment only falls (very slightly) in two Member States. The number of jobs created per unit of revenue varies due to a number of factors, including national labour market conditions and competitiveness effects. As would be expected, the high-wage, high-productivity northern Member States create fewer jobs per unit of revenue.

Longer-term impacts

Although the focus of this analysis is the year 2020, the scenarios are run out to 2030 to assess longer-term impacts. It is assumed that the waste taxes continue to increase in a linear fashion.

Overall the pattern of impacts is quite similar, although larger in scale to reflect the higher tax rates. From our estimates, €75bn could be raised annually (up to 0.5% of GDP), although this result has large error bands due to the uncertain nature of future trends in waste generation (i.e. the baseline projections). In the scenario there is a 15% reduction in waste generation compared to the baseline.

Overall, there is a slight fall in GDP (-0.01%) but a larger increase in employment (190,000 jobs). There are two reasons for the reduction in GDP: the first is the loss of competitiveness that increases in line with the tax rates. The second reason is that a large proportion of the (non-mining) waste is generated by sectors that are involved in producing investment goods (notably construction). Higher prices for these goods lead to a slight reduction in investment and production capacity.

Table 4.4 : Summary Results for the EU in 2020 and 2030 (S7, % from base)

	2020	**2030**
Revenue (€2005m)	34,680	74,553
GDP	0.00	-0.01
Employment	0.04	0.08
Household Consumption	0.00	0.02
Investment	-0.01	-0.03
Exports	-0.03	-0.07
Imports	-0.01	-0.02
Consumer Prices	0.03	0.04
Waste Generation	-11.67	-15.13

Sources: E3ME, Cambridge Econometrics.

4.3 Sensitivity analysis

Table 4.5 summarises the results from a sensitivity analysis of increasing the tax of mineral waste to land disposal to €70/t (S7b). The other inputs are as in Scenario 7. Overall, the pattern of results in the sensitivity analysis is similar to the main scenario and reflects the higher tax rate. The higher tax rates result in additional tax revenues of €12bn in 2020 and a 1pp reduction in waste generation, as the marginal effects are much smaller. Revenues as a share of total tax receipts are around 0.8%.

Overall, there is still no net change in GDP, with a slightly higher increase in employment (130,000 jobs) compared to baseline. The pattern on other macroeconomic indicators is similar to that described above.

A final sensitivity was tested in which there was no revenue recycling (with the exception of the mining sector, as described above). This is a rather unrealistic scenario as it assumes that the revenues raised by the tax are removed from the European economy. Nevertheless it can be insightful in providing a description of the worst-case outcome. In the scenario, the modelling found that there was a fall in GDP overall, but it was less than 0.1%.

Table 4.5 : Summary Results for the EU in 2020 (S7-7b, % from base)

	S7	**S7b**
Revenue (€2005m)	34,680	46,363
GDP	0.00	0.00
Employment	0.04	0.06
Household Consumption	0.00	0.01
Investment	-0.01	-0.02
Exports	-0.03	-0.05
Imports	-0.01	-0.01
Consumer Prices	0.03	0.04
Waste Generation	-11.67	-12.64

Sources: E3ME, Cambridge Econometrics.

5 Conclusions

5.1 Waste taxes in the context of 2020 targets

According to the latest data from Eurostat, environmental taxes accounted for 6.17% of total receipts from taxes and social security contributions in 2011. The target is to increase this share to 10% by 2020.

Previous analysis shows that the phasing out of fossil fuel subsidies would increase slightly the share of environmental taxes, when applied to subsidies that are tax exemptions. Our estimate is that this could provide an additional 0.3-0.4% of total revenues. However, assuming that existing tax receipts stay constant as a share of GDP, there is still a gap of 3.5 percentage points that must be met by 2020. It should also be noted that revenues from fuel duties, the largest contribution to existing environmental taxes, are falling in many Member States and are likely to do so further if new vehicles meet the EU's fuel efficiency targets.

It is therefore important to consider the possibility for introducing new environmental taxes across the EU. In this report we have focused on the potential for taxes on waste.

Several Member States already have taxes on waste in operation, which generated around €2bn of revenues in 2010[11]. In this modelling exercise we impose an additional tax across all Member States.

Waste is not something that is typically included in macroeconomic models, so it is necessary to make several assumptions along the way, particularly regarding the responses of business and households to new or higher taxes. It is noted that more detailed modelling of physical waste streams is currently being carried out and insights from this could be incorporated into future economic analyses. It is also not clear what supplementary policies would be implemented in each country (or local area), which could for example influence recycling and incineration rates.

However, unless there is a very large reduction in waste generation, our most comprehensive scenario (S7) suggests that a tax of (an additional) €50/tonne on all waste being deposited on land would raise revenues equivalent to around 0.6% of total tax receipts. If the tax rate was increased to €70/tonne, the figure could increase to more than 0.8%. This would cover around a quarter of the gap to the 10% target.

The role of the mining sector

This tax would fall heavily on the mining sector, which would be expected to pay more than 60% of the total costs, unless it was able to reduce its volume of waste substantially. It seems unlikely that the sector would remain economically viable without compensating measures, which we have included in these scenarios in the form of lump-sum payments back to the industry. Given the scale of the sums involved this looks like a clear area for further study, for example to consider how individual companies (and different types of mines) could react and whether it is a sensible type of waste to target. It is noted that mining waste is not covered by the Waste Framework Directive.

[11] Fischer, C., Lehner M., and McKinnon, D.L. (2012) 'Overview of the use of landfill taxes in Europe', ETC/SCP working paper 1/2012. See also http://www.cewep.eu/media/www.cewep.eu/org/med_557/955_2012-04-27_cewep_-_landfill_taxes__bans_website.pdf

5.2 The economic impacts of the waste taxes

The modelling is designed to assess the economic impacts of the waste taxes; the economic results are based on the national accounting structure and can be considered as robust.

Leaving aside the mining sector, which would require a special treatment, the economic impacts of the waste taxes (at €50/tonne) are small. Assuming that the revenues from the tax are recycled, there is zero net impact on GDP. If the revenues are used to reduce labour taxes (as was modelled here) there could be an increase in European employment of up to 100,000 jobs.

Manufacturing, construction and utilities (as well as households) would face the largest tax bill from the taxes. They see a very small fall in output as a result. However, all sectors, including services, benefit from reduced labour costs. Overall there may be some localised competitiveness effects but these would be small when considered at macroeconomic level.

The pattern of impacts is fairly consistent across Member States.

5.3 Policy conclusions

Although there are some existing taxes on waste in the EU's Member States, they are in most cases too small to make a meaningful contribution to the target of 10% of tax revenues coming from environmental taxes by 2020. This report provides an initial assessment of the economic impacts of broadening and scaling up taxes on waste in Europe. It is assumed that in practical terms it is possible to replicate waste taxes from one Member State to another, but it would be necessary to assess whether widening the scope is feasible to enforce in reality.

One point that becomes obvious rather quickly in the analysis is that the tax must be applied to the waste from the mining sector if it is to raise significant revenues. This raises several questions, such as whether this is the type of waste that should be targeted and how the sector would be able to cope with such high charges. The scenarios assume that the sector is compensated fully, meaning that mining operations in Europe would remain financially viable, but reducing the possibility of using the revenues for other purposes. Although the scenarios do not include direct compensation to other sectors, in reality they may also demand 'special treatment'.

Aside from mining, the sectors most affected by the waste tax are:

- households
- basic manufacturing
- construction
- utilities

Of these, only basic manufacturing is subject to a high degree of international competition. This means that the economic effects are in general relatively benign at the macroeconomic and sectoral levels, although an investigation at firm level may show more substantial localised impacts.

It is important that the revenues that are raised from the taxes are used efficiently. Our analysis suggests that using the new revenues to reduce labour taxes could lead to the creation of 100,000 jobs across Europe. An inefficient use of the revenues could lead to a small reduction in GDP (less than 0.1%) and a similar-sized reduction in employment.

In summary, this modelling exercise has shown that a Europe-wide tax on waste need not have a major economic cost, if implemented efficiently. Further analysis is required to assess the practical feasibility of introducing such a tax.

Appendix A: Description of E3ME

This appendix provides a short non-technical description of the Energy-Environment-Economy Model for Europe (E3ME), developed by Cambridge Econometrics (CE).

For further details, including the full technical manual, the reader is referred to the E3ME website: http://www.e3me.com. E3ME is also described in the IA Tools model inventory.

For a list of acknowledgements see the preface of the model manual.

A.1 Introduction to E3ME

E3ME is a computer-based model of Europe's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe for policy assessment, for forecasting and for research purposes.

E3ME's structure

The structure of E3ME is based on the system of national accounts, as defined by ESA95 (European Commission, 1996), with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, with estimated sets of equations for labour demand, supply, wages and working hours. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, and international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2010 and the model projects forward annually to 2050[12]. The main data sources are Eurostat, DG Ecfin's AMECO database and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. Gaps in the data are estimated using customised software algorithms.

The main dimensions of the model

The other main dimensions of the model are:

- 33 countries (the EU member states, Norway and Switzerland and three candidate countries)
- 69 economic sectors, including disaggregation of the energy sectors
- 43 categories of household expenditure
- 22 different users of 12 different fuel types
- 14 types of air-borne emission (where data are available) including the six greenhouse gases monitored under the Kyoto protocol
- 13 types of household, including income quintiles and socio-economic groups such as the unemployed, inactive and retired, plus an urban/rural split

Typical outputs from the model include GDP and sectoral output, household expenditure, investment, international trade, inflation, employment and unemployment, energy demand and CO2 emissions. Each of these is available at national and EU level, and most are also defined by economic sector.

The econometric specification of E3ME gives the model a strong empirical grounding and means it is not reliant on the assumptions common to Computable General

[12] See Chewpreecha and Pollitt (2009).

Equilibrium (CGE) models, such as perfect competition or rational expectations. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (e.g. up to 2020) and rebound effects[13], which are included as standard in the model's results.

E3ME's key strengths

In summary the key strengths of E3ME lie in three different areas:

- the close integration of the economy, energy systems and the environment, with two-way linkages between each component
- the detailed sectoral disaggregation in the model's classifications, allowing for the analysis of similarly detailed scenarios
- the econometric specification of the model, making it suitable for short and medium-term assessment, as well as longer-term trends

A longer description of E3ME is provided in the next chapter. For further details, the reader is referred to the model manual available online from www.e3me.com.

A.2 A brief history of E3ME

The first version of the E3ME model was built by an international European team under a succession of contracts in the JOULE/THERMIE and EC research programmes. More recently, the model has been supported solely through application for policy analysis. E3ME has been used to contribute to several high-profile European Impact Assessments, including reviews of the EU ETS, Energy Taxation Directive, SO_2/NO_x trading and Energy Efficiency Directive. E3ME is also now applied at the national, as well as European, level.

A full list of recent projects involving E3ME is available from the model website. As a result of its programme of continuing application and improvement, E3ME is now firmly established as a tool for policy analysis in Europe. The current version is closely linked to the global E3MG[14] model, which is similar in structure and dimensions.

[13] Where an initial increase in efficiency reduces demand, but this is negated in the long run as greater efficiency lowers the relative cost and increases consumption. See Barker et al (2009).

[14] See www.e3mgmodel.com

A.3 The theoretical background to E3ME

Economic activity undertaken by persons, households, firms and other groups in society has effects on other groups after a time lag, and the effects persist into future generations, although many of the effects soon become so small as to be negligible. But there are many actors, and the effects, both beneficial and damaging, accumulate in economic and physical stocks. The effects are transmitted through the environment (with externalities such as greenhouse gas emissions contributing to global warming), through the economy and the price and money system (via the markets for labour and commodities), and through the global transport and information networks. The markets transmit effects in three main ways: through the level of activity creating demand for inputs of materials, fuels and labour; through wages and prices affecting incomes; and through incomes leading in turn to further demands for goods and services. These interdependencies suggest that an E3 model should be comprehensive, and include many linkages between different parts of the economic and energy systems.

These economic and energy systems have the following characteristics: economies and diseconomies of scale in both production and consumption; markets with different degrees of competition; the prevalence of institutional behaviour whose aim may be maximisation, but may also be the satisfaction of more restricted objectives; and rapid and uneven changes in technology and consumer preferences, certainly within the time scale of greenhouse gas mitigation policy. Labour markets in particular may be characterised by long-term unemployment. An E3 model capable of representing these features must therefore be flexible, capable of embodying a variety of behaviours and of simulating a dynamic system. This approach can be contrasted with that adopted by general equilibrium models: they typically assume constant returns to scale; perfect competition in all markets; maximisation of social welfare measured by total discounted private consumption; no involuntary unemployment; and exogenous technical progress following a constant time trend (see Barker, 1998, for a more detailed discussion).

A.4 E3ME as an E3 model

The E3ME model comprises:

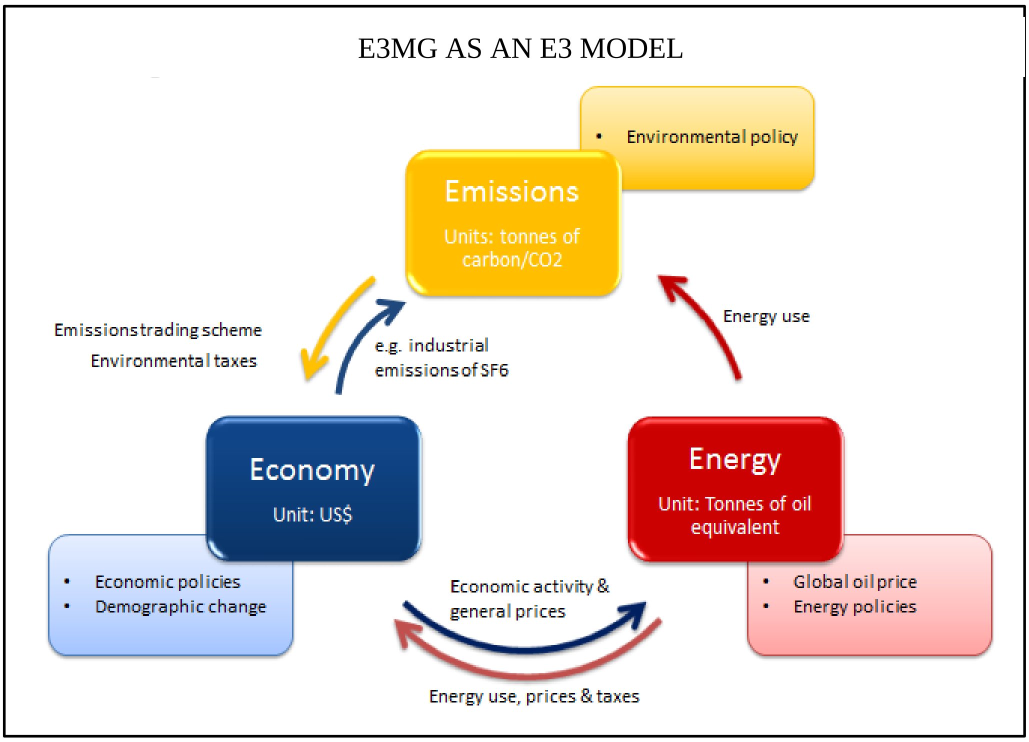
- the accounting balances for commodities from input-output tables and the national accounts, for energy carriers from energy balances, and flows of emissions and material consumption
- a large historical database covering the period from 1970 annually
- 33 sets of time-series econometric equations (aggregate energy demands, fuel substitution equations for coal, heavy oil, gas and electricity; intra-EU and extra-EU commodity exports and imports; total consumers' expenditure; disaggregated consumers' expenditure; industrial fixed investment; industrial employment; industrial hours worked; labour participation; industrial prices; export and import prices; industrial wage rates; residual incomes; investment in dwellings; normal output equations and physical demand for seven types of materials)

Energy supplies and population stocks and flows are treated as exogenous.

The E3 interactions

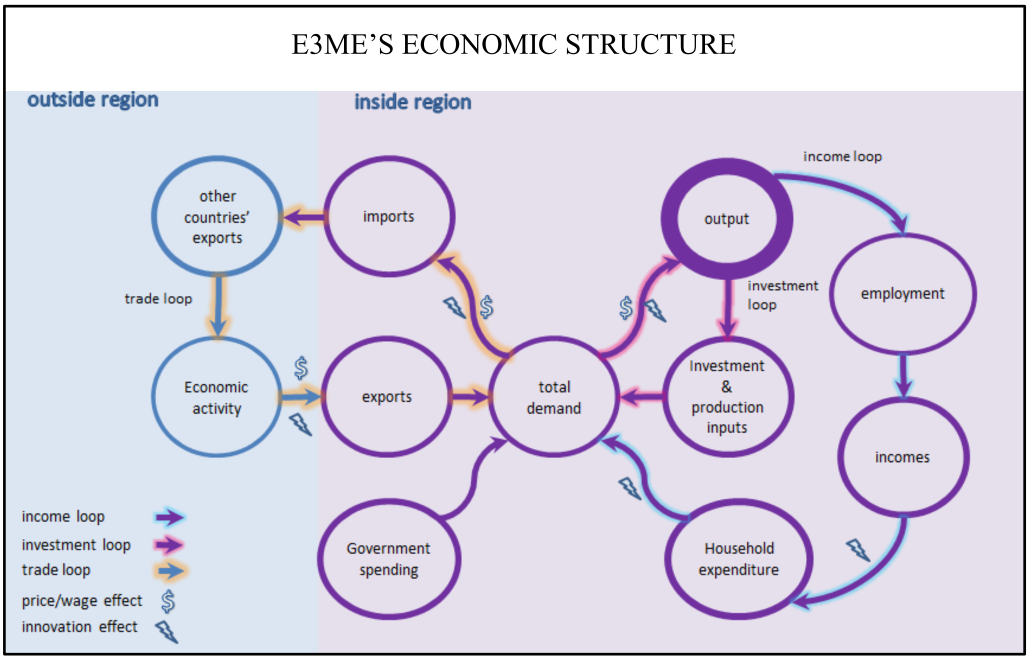
Figure A.1 shows how the three components (modules) of the model - energy, environment and economy - fit together. Each component is shown in its own box with its own units of account and sources of data. The linkages between the components of the model are shown explicitly by the arrows that indicate which values are transmitted between components.

Figure A.1 E3MG as an E3 Model



15 http://www.externe.info/tools.html

Figure A.2: E3ME's economic structure



The chart shows three loops or circuits of economic interdependence, which are described in the paragraphs below. In addition there is a dependence loop between sectors through their input-output linkages; this is not shown in the macro-level linkages in the figure but is similar to a Type I multiplier. The second loop, through incomes and household expenditure, provides something similar to Type II multipliers. The other loops are through investment and through international trade.

Determination of output

Output, measured in gross terms, is determined through the macroeconomic identity as the sum of intermediate and final demands. Intermediate demand is the demand from other economic sectors and is determined by input-output relationships (including domestic and import supplies). Final demand consists of household and government demand, investment and exports.

In E3ME imports are defined as a negative demand. Imports are subtracted from total demand to provide output by sector.

GDP

GDP on the expenditure side is an identity that is defined as the sum of the final components of demand.

Gross Value Added

GVA by sector is determined as the difference between gross output (i.e. turnover) and intermediate costs, corrected for taxes. GVA includes wage costs and profit margins, plus taxes on production.

International trade

E3ME includes export and import equations for the trade of commodities within and outside of Europe. The basic assumption is that, for most commodities, there is a 'pool' into which a country supplies part of its production and from which the country satisfies part of its demand. *This might be compared to national electricity supplies and demands: each power plant supplies to the national grid and each user draws power from the grid and it is not possible or necessary to link a particular supply to a particular demand.*

The demand for a country's exports of a commodity is related to three factors:

- domestic demand for the commodity in all the other countries, weighted by their economic distance (determined by OECD bilateral trade data)
- the quality of national produce, determined by the technical progress indicators
- relative prices, including the effects of exchange rate changes

Econometric equations are estimated to determine the magnitude of these effects.

Investment

Forecast changes in output are important determinants of investment in the model. Other determinants of investment are the relative price of capital, real interest rates and position in the economic cycle.

Investment and output

Sectoral investment is transformed by a converter matrix to go from the sector making the investment, to the one that receives the payment (e.g. construction or engineering). The resulting vector is a component of output (see above), providing the feedback loop between output and investment.

Accumulation of knowledge and technology

Gross fixed investment, enhanced by R&D expenditure in constant prices, is accumulated to provide a measure of the technological capital stock. This avoids problems with the usual definition of the capital stock and lack of data on economic scrapping. The accumulation measure is designed to get round the worst of these problems. Investment is central to the determination of long-term growth and the E3ME model embodies endogenous technical change and a theory of endogenous growth which underlies the long-term behaviour of the trade and employment equations.

Incomes and household expenditure

As described below, increases in economic output generate employment which, when multiplied by average wage rates, provides incomes to households. These are some of the largest payments to the personal sector, but not the only ones. There are also payments of interest and dividends, transfers from government in the form of state pensions, unemployment benefits and other social security benefits. Payments made by the personal sector include mortgage interest payments and personal income taxes. Personal disposable income is calculated from these accounts, and deflated by the consumer price index to give real personal disposable income.

Employment and wages

E3ME includes equation sets for headcount employment, average wages, working hours and labour market participation. Increased economic output is expected to lead to higher levels of employment, greater wage demands and more incentive to work. Higher wage rates, however, are a deterrent to job creation.

Unemployment is calculated as the difference between employment and labour supply. It is an important determinant in wage bargaining.

Household expenditure

Totals of consumer spending are derived from consumption functions estimated from time-series data. These equations relate consumption to real personal disposable income, a measure of wealth for the personal sector, inflation and interest rates.

Sets of equations have been estimated from time-series data for each of the 43 consumption categories. Consumption in these categories is then scaled to be consistent with the total above.

Consumption and output

Household consumption by product is converted to demand by sector using a transition matrix. This also subtracts consumption taxes, such as VAT. The resulting vector is used in the calculation of sectoral output. Sectors that typically benefit from higher rates of consumption include retail, hotels and catering and other personal services.

Prices Each real economic variable has an associated price variable that goes with it. The relationships between prices and quantities are often complex and are estimated using behavioural relationships. It is also important to note the interaction between prices and wages. While inflation pushes up wage rates, higher unit wage costs for sectors lead to price increases which, when aggregated, lead to higher rates of inflation. There is thus a strong feedback loop in price effects.

A.6 Energy-Environment links

Top-down and bottom-up methodologies E3ME is intended to be an integrated top-down, bottom-up model of E3 interaction. In particular, the model includes a detailed engineering-based treatment of the electricity supply industry (ESI). Demand for energy by the other fuel-user groups is top-down, but it is important to be aware of the comparative strengths and weaknesses of the two approaches. Top-down economic analyses and bottom-up engineering analyses of changes in the pattern of energy consumption possess distinct intellectual origins and distinct strengths and weaknesses (see Barker, Ekins and Johnstone, 1995).

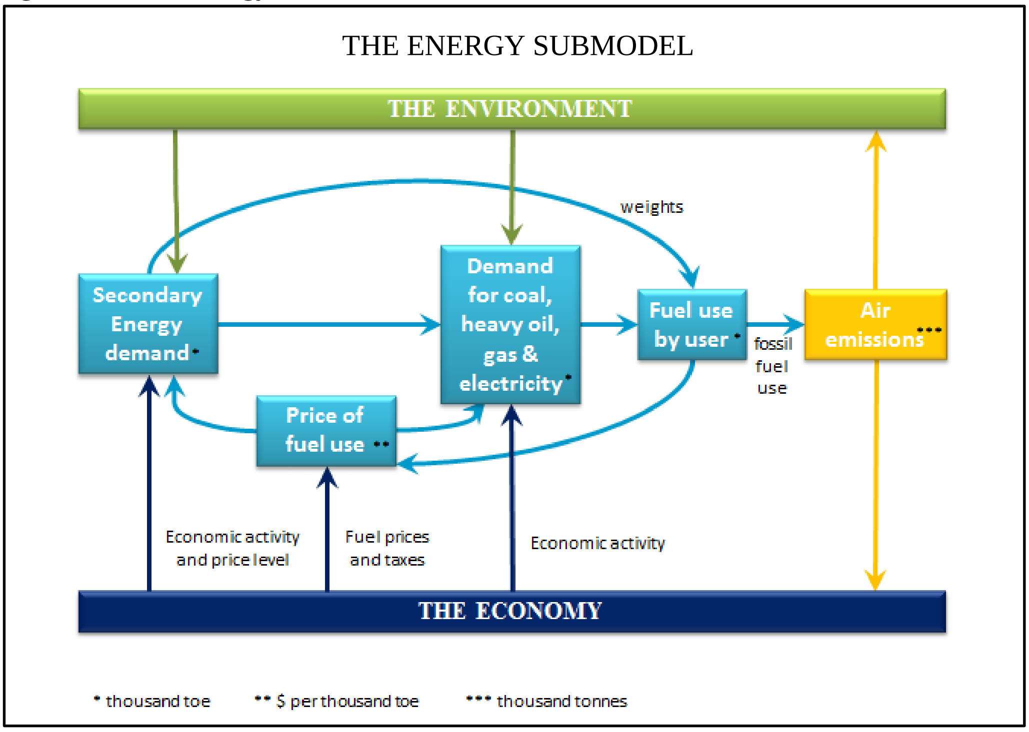
A top-down submodel of energy use The energy submodel in E3ME is constructed, estimated and solved for 22 fuel users, 12 energy carriers (termed fuels for convenience below) and 33 countries. Figure A.3 shows the inputs from the economy and the environment into the components of the submodel and Figure 8.3 shows the feedback from the submodel to the rest of the economy.

Determination of fuel demand Aggregate energy demand, shown at the top of Figure A.3, is determined by a set of co-integrating equations[16], whose the main explanatory variables are:

- economic activity in each of the 22 fuel users
- average energy prices by the fuel users relative to the overall price levels
- technological variables, represented by investment and R&D expenditure, and spill overs in key industries producing energy-using equipment and vehicles

[16] Cointegration is an econometric technique that defines a long-run relationship between two variables resulting in a form of 'equilibrium'. For instance, if income and consumption are cointegrated, then any shock (expected or unexpected) affecting temporary these two variables is gradually absorbed since in the long-run they return to their 'equilibrium' levels. Note that a cointegration relationship is much stronger relationship than a simple correlation: two variables can show similar patterns simply because they are driven by some common factors but without necessarily being involved in a long-run relationship.

Figure A.3: The energy submodel



Fuel substitution Fuel use equations are estimated for four fuels - coal, heavy oils, gas and electricity – and the four sets of equations are estimated for the fuel users in each region. These equations are intended to allow substitution between these energy carriers by users on the basis of relative prices, although overall fuel use and the technological variables are allowed to affect the choice. Since the substitution equations cover only four of the twelve fuels, the remaining fuels are determined as fixed ratios to similar fuels or to aggregate energy use. The final set of fuels used must then be scaled to ensure that it adds up to the aggregate energy demand (for each fuel user and each region).

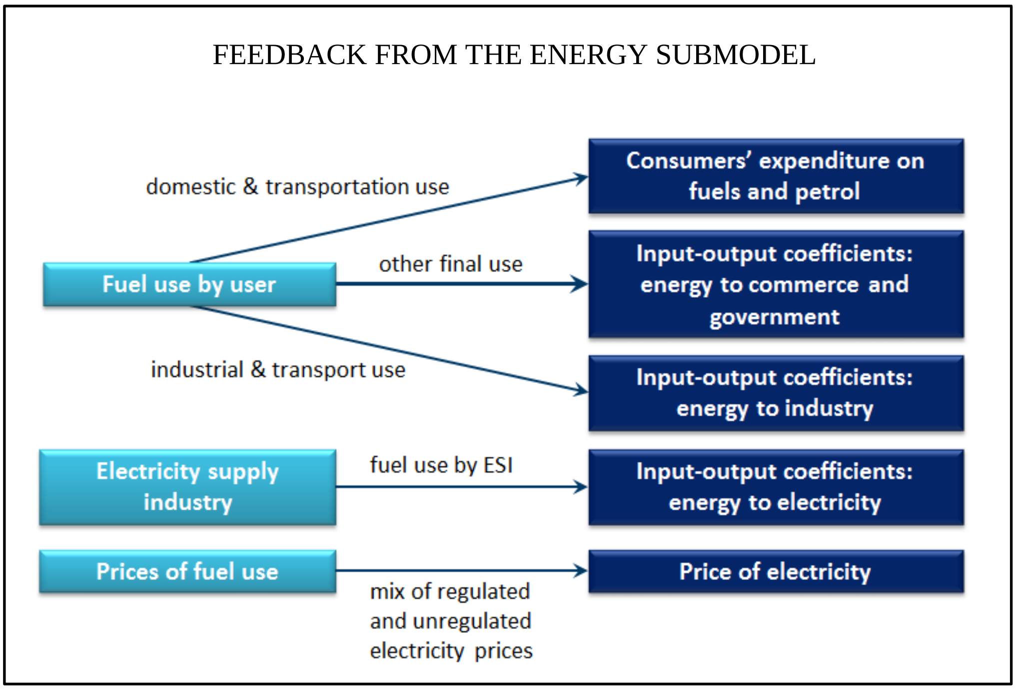
Emissions submodel The emissions submodel calculates air pollution generated from end-use of different fuels and from primary use of fuels in the energy industries themselves, particularly electricity generation. Provision is made for emissions to the atmosphere of carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), methane (CH_4), black smoke (PM10), volatile organic compounds (VOC), nuclear emissions to air, lead emissions to air, chlorofluorocarbons (CFCs) and the other four greenhouse gases: nitrous oxide (N2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF_6). These four gases together with CO2 and CH4 constitute the six greenhouse gases (GHGs) monitored under the Kyoto protocol. Using estimated (ExternE) damage coefficients, E3ME may also estimate ancillary benefits relating to reduction in associated emissions e.g. PM10, SO_2, NOx.

CO_2 emissions Emissions data for CO_2 are available for fuel users of solid fuels, oil products and gas separately. The energy submodel estimates of fuel by fuel user are aggregated into these groups (solid, oil and gas) and emission coefficients (tonnes of carbon in CO_2 emitted per toe) are calculated and stored. The coefficients are calculated for each year when data are available, then used at their last historical values to project future emissions. Other emissions data are available at various levels of disaggregation from a number of sources and have been constructed carefully to ensure consistency.

Feedback to the rest of the economy

Figure A.4 shows the main feedbacks from the energy submodel to the rest of the economy. Changes in consumers' expenditures on fuels and petrol are formed from changes in fuel use estimated in the energy submodel, although the levels are calibrated on historical time-series data. The model software provides an option for choosing either the consumers' expenditure equation solution, or the energy equation solution. Whichever option is chosen, total consumer demand in constant values matches the results of the aggregate consumption function, with any residual held in the unallocated category of consumers' expenditure. The other feedbacks all affect industrial, including electricity, demand via changes in the input-output coefficients.

Figure A.4: Feedback from the energy submodel



A.7 Parameter estimation

The econometric model has a complete specification of the long-term solution in the form of an estimated equation that has long-term restrictions imposed on its parameters. Economic theory, for example the recent theories of endogenous growth, informs the specification of the long-term equations and hence properties of the model; dynamic equations that embody these long-term properties are estimated by econometric methods to allow the model to provide forecasts. The method utilises developments in time-series econometrics, in which dynamic relationships are specified in terms of error correction models (ECM) that allow dynamic convergence to a long-term outcome. The specific functional form of the equations is based on the econometric techniques of cointegration and error-correction, particularly as promoted by Engle and Granger (1987) and Hendry et al (1984).

A.8 Limitations to the analysis

The main limitation of E3ME is the sectoral disaggregation of its sectors. The industry classification is relatively detailed, covering 69 sectors at the NACE 2-digit level.

However, due to the availability of the data, it is not possible to go into more detail, for example to the firm-based level, or to very detailed product groups. For this type of analysis our recommendation is that the model (which provides an indication of indirect effects) is used in conjunction with a more detailed bottom-up or econometric analysis (which can capture detailed industry-specific effects).

The other main limitations to the model relate to its dimensions and boundaries. Broadly speaking E3ME covers the economy, energy and material demands and atmospheric emissions. While it is possible to provide an assessment of other policy areas, it is necessary to make assumptions about how this is translated into model inputs. Other limitations, such as the geographical scope (Europe) and time horizon (2050) are more obvious, although it should be noted that the global E3MG model can be used to address the first of these issues. A global version of the E3ME model is expected to be available from late 2013.