

Handbook

The European Reference model on Municipal Waste Management 2018



European Environment Agency
European Topic Centre on Waste and
Materials in a Green Economy



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Cover photo © iStock (898805304) Multicolor garbage bin (garbage container) for household and industrial waste, on green grass, ecology

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Glossary (all)

BMW	Biodegradable municipal waste
ETC/WMGE	European Topic Centre on Waste and Materials in a Green Economy
CE	Circular economy
C-file	Calculations file
C&O-file	Controls and Outputs file
EC	European Commission
EEA	European Environment Agency
EU	European Union
EUR	Euro
EURM_MSWM	European Reference Model on Municipal Solid Waste Management
GDP	Gross domestic product
IMF	International Monetary Fund
MS	Member State of the European Union
MBT	Mechanical biological treatment
MSW	Municipal solid waste
NPV	Net present value
OECD	Organisation for Economic Co-operation and Development
WEEE	Waste electrical and electronic waste
WACC	Weighted average cost of capital
WFD	Waste Framework Directive

1. Introduction

The *European Reference Model on Municipal Waste Generation and Management* (hereafter referred to as the waste model) was developed by a consortium led by Eunomia Research and Consulting Ltd. in support of the European Commission's (EC) impact assessment for the review of waste targets proposed in the 2015 Circular economy package (EC, 2015). Since early 2016, the European Environment Agency (EEA) has hosted it for the EC with support of its European Topic Centre on Waste and Materials in a Green Economy (ETC/WMGE).

This handbook describes how to run the current version of the waste model (2018 version) and reflects the experience of the EEA and the ETC/WMGE in hosting it in 2016–2018.

The waste model was developed as a Microsoft Excel based tool to model future municipal waste generation and management. It includes waste-flow scenarios, coupled with calculations of related costs and benefits. These include financial costs, environmental impacts, employment and other output parameters. The model optimises future flows of municipal waste so that targets on the recycling and landfill of municipal waste and the recycling of packaging waste are met. No cost optimisation or feedback mechanisms related to costs are included. The model is built on a country-by-country basis and covers EU Member States for the period 2010–2035.

In 2017, the EEA and ETC/WMGE updated key elements of the waste model, with support from the EC through a contract with a consortium led by Eunomia Research and Consulting Ltd. The main focus of the 2017 update was to revise the waste flows, mainly for the year 2015, as well as selected other data. Data covering the period prior to 2015 were not updated. More information on the procedure and which data were updated can be found in Annex 1.

Note on the country coverage:

The European Reference Model on Municipal Waste Generation and Management was developed before the withdrawal of the United Kingdom from the European Union. It therefore covers EU Member States including the UK (EU-28) as valid until the withdrawal in March 2019. As this handbook describes the content of the model as it exists, it refers usually therefore to the EU-28. This does not prejudice any political development.

Model users can generate EU-27 aggregates (i.e. EU Member States without the United Kingdom) in the model for all output parameters by calculating EU-28 and UK outputs separately and subtracting UK outputs from the EU-28 aggregates – see below for more detail. Changing the model to generate results for the EU-27 by default rather than the EU-28 would require model adjustments. This is not foreseen that this will be done by the EEA.

2. How to run the model

2.1. Introduction

The waste model consists of two (linked) files:

- EURM_MSWM – Controls and Outputs.xlsm: contains the user interface, assumptions used by the model and creates the results files;
- EURM_MSWM – Calculations.xlsm: calculates the scenarios.

These files should always be stored in one folder. To start, open the EURM_MSWM – Controls and Outputs file. The Calculations file is opened by the Controls and Outputs file and therefore should not be opened by the user for the purpose of model runs. Before starting work with the model, make sure both files refer to each other. To check this connection, do the following:

Path: Data – Queries & Connections – Edit Links

If the files are not linked to each other, link them:

Path: Data – Queries & Connections – Edit Links – Change Source

Before you can use the model, you must enable all macros in Excel:

Path: File – options – Trust Center – Trust Center Settings – Macro Settings – Enable all macros & trust access to the VBA project object model.

All the following information relates to the Controls and Output file. **To understand the following text, please open the EURM_MSWM – Controls and Outputs.xlsm.**

The model has been designed to work with Microsoft Excel version 2007 or higher, using the English language only. Make sure you use the latest excel version. The use of PCs purchased in 2010 or thereafter is advised to ensure optimal performance. It is also advisable to use a decimal dot for numbers and not a comma to ensure proper functioning of the model.

The model can be operated through the **user interface, or through operating directly in the stores**, which consist of several sheets in the EURM_MSWM – Controls and Outputs.xlsm that contain country specific information and assumptions used by the model. **However, operating the model through the stores is only recommended for very experienced users. This handbook only covers operating the model through the user interface, but Annex 1 briefly describes the ETC/WMGE experience with updating the model through the stores.**

2.2. The user interface

When opening the EURM_MSWM – Controls and Outputs.xlsm file, the user is guided to the user interface. This takes the user through six steps:

- Annual update, (2) Define Assumptions, (3) Waste Arisings Projections, (4) Set Up Waste Prevention (discussed in Chapter 3);
- (5) Set Up Policy Scenarios (discussed in Chapter 4); and
- (6) Set Up Sensitivity Analysis.

If you want to run the waste model from the **user interface**, first go to the Set Up Model sheet, and select the country for which you want to run the model. The model can run for a single country, or in EU

Operating Mode. In the EU Operating Mode, the model runs for all countries separately and adds up the country results to generate EU aggregate results. As the model was developed before the withdrawal of the UK from the EU, the EU Operating Mode calculates the EU aggregate outputs for 28 EU Member States. To generate results for EU-27, i.e. without the UK, you can generate results for the EU-28 and the UK separately and then subtract the UK results manually.

If you want to run the model for a single country, leave EU Operating Mode as No in the drop-down list. If you want to run the waste model for the EU-28 set EU Operating Mode to Yes from the list. If you have selected EU Operating Mode, the model will run for all 28 countries, even if you select a single country from the drop-down list.

Also choose the currency¹ you want to show your results in. Once this is done, click Step 1: Annual Update, which takes you to the Annual Update sheet (see Chapter 3 for more details on updating). To navigate through the user interface, click Mark Step as Checked and Next Step, after having carried out any data updates, scenario creation, etc. Doing this as the last step (Step 6: Set Up Sensitivity Analysis) will bring you back to the Set Up Model sheet. The model is now ready to run. Click Go to Run Model.

If you have changed the country to EU-28 (in the EU-28 mode), some of the buttons in the Set Up Model sheet will be disabled. This is because most of the information that is required is stored by country and cannot be correctly updated through the user interface if you have selected the EU-28 operating mode. You can, however, still navigate through the different steps by going to each sheet manually and then clicking Mark Step as Checked and Next Step. After marking all steps as checked, you can go either to the Set Up Model sheet, and click on Go to Run Model, or go directly to the Model Controls sheet.

When you have opted to add data to the model using the Store, you still should mark all steps as checked before running the model in order to avoid a warning.

In the **Model Controls** sheet you get an overview of all the steps you have to check and whether you have marked them as checked (cells G28:H34). If you have not, return to the relevant sheet, choose the desired settings/data/targets/scenarios, etc. and mark the step as checked. The second table (cells F39:49) shows the scenarios you have set up and which assumption set you have chosen to use. In cells I40:I50 of this table you can indicate which scenario you would like to run by choosing the options from the drop-down menu. You also have the option on this sheet of selecting the baseline scenario against which you want to compare the results (cells F52:H52). During the update of the model in 2017, however, the ETC/WMGE decided to only update Baseline 1, so only this should be used in the 2018 version of the model. Finally, you can also force all scenarios to use the same assumption set (cells F55:H55). This will override whatever you have defined while setting up a scenario.

When you have indicated which scenarios you would like to run and which assumption set you would like to use, click Run Results. If you would also like to run the sensitivity analysis, click Run Sensitivities (see Section **Error! Reference source not found.**).

If you have selected EU-28 in the Set Up Model sheet, the model will ask you to check the review summaries of cross checks in the results file, click OK. It will then tell you that you are about to run results for all EU-28 Member States. If this is your intention, click Yes. If not, click No, change EU Operating mode to No and select the country you want in the Set Up Model sheet, go through the different sheets to mark as checked, and click Run Results.

After the run, the model will inform you that a Results File has been created (a separate file is created for the results and the sensitivities in the same folder in which the two waste model files are stored), and asks

¹ All analyses done by the ETC/WMGE used euros (EUR) as the currency. If you want to use a national currency, for example Danish Crowns, the exchange rate should be updated as the exchange rates in the model have not been updated since 2014.

you to enter changes to the version log before saving. If you have made changes to the basics of the model (changed formulas, assumptions, etc.), add them to the log. If you have only added scenarios, these do not have to be added to the log. When you click OK, the EURM_MSWM – Controls and Outputs.xlsm will be saved, including the information you have added. If you click Cancel, your added information will not be saved.

2.3. Set up sensitivity analysis

The user of the model has the option to explore the influence of 50 predefined assumptions or variables on the modelled results, including:

- material revenues;
- collection system efficiencies;
- weighted average cost of capital (vehicles and infrastructure);
- energy prices;
- labour costs;
- global warming potential of methane;
- landfill gas capture rates;
- monetised value on greenhouse gas emissions;
- minimum share of renewables in electricity grid mix;
- waste prevention effects per household;
- material losses;
- reject rates.

You can choose which of the variables you would like to include in the sensitivity analysis. You can run five sensitivity analyses in one go, and you have the option to choose to use the five slots to analyse only one scenario, or use one sensitivity for five different scenarios, or a combination of the two. The output of the sensitivity analysis is shown in terms of net present value (NPV)² only. No other output parameters (greenhouse gas emissions, financial costs, employment, etc.) are shown separately, and model modifications would be needed to show sensitivity for other output parameters.

For each of the variables you can set a low and high variance (as percentages of the central value) or upper and lower boundaries (absolute value) – Table 2 Set Low and High Variance (K27:M76) and Table 3 Check outputs to Sensitivity (O27:P76) Analysis show the values which will be used by the analysis. If you do not enter your own variance or boundaries, the model will use its default values.

To set a sensitivity analysis, choose one of the sensitivity slots, and name it. Then choose the scenario for which you want to run the sensitivity. Select the variables you would like to include and set the variance or boundaries to the ones you selected (if you want to use user-defined variables) or use the pre-defined boundaries. Save your sensitivity. If you started from an existing one, save as New Sensitivity and rename it.

Then click Mark Step as Checked and Next Step. This will bring you to the Set Up Model sheet. Here you can confirm whether all steps have been checked. If this is the case, click Go to Run Model. This brings you to the Model Controls sheet. Running the sensitivity analysis can take from a few minutes to a few hours, depending on whether you are running a single country or the EU-28, the number of sensitivity scenarios you are running, and how many variables you have selected to run.

² NPV (net present value) is the sum of the present value of monetised flows over a period of time.

2.4. Results extraction

After a model run, a Results File is created for your specific run. The results run and the sensitivities run create separate files. The name of the file that is created includes the time and date, and is stored in the same folder as the EURM_MSWM – Controls and Outputs.xlsm file. This ensures different names for all runs done by the model.

Results can be viewed in different ways, in absolute terms or relative to the latest year or another scenario. Moreover, results for individual countries or for the EU-28 can be selected. A few charts are automatically created. The layout as well as the chart type can be easily adapted, according to your preferences.

The Results File includes different sheets.

- Results overview: this gives an overview of the results for either a selected scenario (Scenario to Display) or for a comparison of two scenarios (Select Scenarios to Compare). If the model was run for the EU-28, you can select for which country you would like to see the results (Select Country).
- Nine charts are automatically generated:
 - direct inputs (of wastes to the first treatment step);
 - employment;
 - compare collection systems;
 - final destinations (of wastes after sorting, pre-treatment, etc.);
 - collection system type;
 - greenhouse gas emissions;
 - externalities;
 - financial costs;
 - net costs and benefits.
- Compare Scenarios sheet: this sheet is used to compare scenario results.
- Scenario results: overview of the results per scenario that was run for each country (maximum of 10 sheets). This file gives a detailed overview of the calculated results and the assumptions used when modelling. It is an extract of the Full Model Outputs sheet from EURM_MSWM – Calculations.xlsm.
- Lists.
- Store: this sheet is a copy of the Store Sheet in EURM_MSWM – Controls and Outputs.xlsm that was created during the model run. It gives an overview of the assumptions used during modelling.

2.5. Lessons learned from running the model

- If you are running the model, it is preferable to do nothing else on your computer as it needs all the computer's capacity to run. During a run, the model copies/pastes quite a few times. If you are also copying/pasting other content, this will interfere with the model and may cause errors.
- Running the EU-28 with several scenarios will take some time – depending on the capacity of your computer, it can take up to a few hours. Running many scenarios for the EU-28 at the same time might not be possible on every computer. To reduce the running time of the model, make sure that only the relevant scenarios are selected on the sheet Model Controls. Choose from the drop-down menu (in column I39:I49) of each scenario in Table F39:I49, clicking Yes for the needed scenarios and No for all the others.
- As a default, the model starts running using the current year +1 to show results. You can, however, change this to show results starting from earlier years. This is done by changing the formula used in cells G105 and I292 in the Model Controls sheet.

3. Updating the model

There are two alternative approaches for updating model parameterisation and input variables: through the user interface or through the store sheets of the model which are part of EURM_MSWM – Controls and Outputs.xlsm. The user Interface also modifies these store sheets. The benefit of using the user interface is that mistakes can be avoided which may occur when filling in numeric values in large tables. On the other hand, when using the store sheets directly, you can also change some parameters and starting-point values for certain time series which cannot be modified through the User Interface. As this, however, requires a very deep understanding of the model, this handbook only describes updating through the user interface.

To start, go to the sheet Set Up Model, select the country for which you want to update data, leave EU Operating Mode at No and choose the currency you want your results to show. All analyses done by the ETC/WMGE used euros (EUR) as currency.

Once this has been done, click Annual Update, which brings you to the Annual Update sheet.

3.1. Annual update

In this sheet you can enter new **waste data** for the selected Member State. You can choose between two input approaches: manual or using the Eurostat Data Converter.

Selecting manual is recommended. In this case, first indicate in the drop-down menu (Cell G26) whether the information you have on recycling tonnages is based on separately collected waste for recycling (select Collected) or total amounts to recycling: post sorting, including from mechanical biological treatment (MBT) and mixed sorting (select Total Reported/Post-Sorting). Enter amounts per waste stream in Table F29:H80, in tonnes. The model does not allow the creation of other waste categories beyond the ones shown in the table, and not all categories have to be filled in. It is not a problem if no data are available for all of the pre-defined categories, with the exception of food and garden waste. If only the total amount of collected biowaste is available, the data for food and garden waste should be estimated. This can be done using the information on the latest data year available, shown in Table F29:H81. If the available information regarding waste streams other than food and garden waste does not fit with the predefined categories, try to recalculate it using the shares that are already in the model from the latest data year available (Table F29:H81). Fill out at least the categories for food, garden, paper/cardboard, textile, glass, metals, plastics and other wastes to ensure the model works properly.

Also enter information on the overall generation and treatment shares of municipal solid waste (MSW) in Table F86:H93. The total generated amount of waste (in tonnes) and shares of MSW going directly to given treatment options (MBT/mixed sorting³ or incineration) should be entered in the table. Also enter the collection rate – the share of population covered by waste collection services. Outputs from MBT or other pre-treatment operations should not be included here as this table is only concerned with the first treatment step. The shares collected for biowaste treatment, recycling and landfill are calculated by the model during the update. During this procedure the model takes account of whether the information regarding the amounts for recycling is based on separately collected waste or post-collection sorting.

The **Eurostat Data Converter approach** uses Eurostat data only for the update. This tool uses a number of additional assumptions that adds considerable uncertainty to the input data. The tool has not been used by the ETC/WMGE and is not described here in detail. Before potentially using it, the effects of the assumptions need to be carefully considered.

³ Sorting of mixed municipal waste

After entering this information click Update Annual Data. This action stores the data in the historic data store.

The update can only be done for one year at a time. If you want to update more than one year, start with the earliest year and then repeat for the following years.

Once you have entered all your updates, click Mark Step as Checked followed by Next Step.

3.2. Define assumptions

This sheet shows a selection of **assumptions** used in the model. The assumptions shown in the user interface were selected by the model developers based on their expert knowledge and the relevance of the assumptions themselves. In addition to these assumptions, the model contains a large number of other assumptions that cannot be changed through the user interface. The sheet provides the source of each of the assumptions in the user interface. A more detailed description of the assumptions, and the reasoning of why they are used can be found in the relevant annexes of EC (EC, 2014). Grey cells show the default assumptions used in the model. If you wish to use your own assumptions, these can be entered in the white cells with blue borders. Some assumptions can be entered for each year, while for others the assumption is fixed for the entire period. These assumptions do not overwrite the default assumptions made in the model. They are temporarily stored as user defined assumptions in the Assumptions Datastore sheet. When the user changes the country, the user defined assumptions are overwritten by default assumptions.

Data on the energy mix are needed when calculating which type of energy source would be replaced by additional energy generated from waste management. In the evaluation, marginal or average energy mixes can be used. Since the reasoning behind these values is different (consequential versus attributional), it is important to use one set of numbers depending on the analysis wanted. The waste model allows calculating both the impact related to a given scenario and the difference in impact of varying scenarios. When comparing scenarios, the marginal energy mix can be used, while when showing one scenario only, using the average energy mix is more appropriate. This choice has to be made when setting up the model in the Define Assumptions sheet by using the drop-down menu. When you have entered all user defined assumptions you want, click Mark Step as Checked and Next Step.

3.3. Waste projections

In the model, five different **waste projections** can be entered. Projection 1 was set up using the information provided by Member States for the 2017 model update. The projections are complemented by an econometric approach carried out by the ETC/WMGE to estimate future waste projections when the Member States did not provide their own projections or only supplied them for a part of the 2015–2035 period.

New projections can be added using either five-yearly projection points or per year. If you want to add a new projection, click View or Edit Projection and select an empty projection slot. Enter the name for your projection in Projection Name.

Choose if you want to add either a five-yearly projection or a projection for each year, then enter the projected amounts of waste generated. If you choose a five-yearly projection, linear interpolation will be used to fill in the intermediate years.

If wanted, you can also enter a (new) detailed Material Composition – the composition of MSW. If you want to do this, select Yes and enter the composition. When doing this, it should be kept in mind that the

material composition should be given as percentages of the total MSW generated, not only household waste or residual waste, and that it should be consistent with data on the amounts of waste that are collected separately for recycling (which can be added to the model in the Annual Update sheet, Table Recycling Tonnage, see Section 2.2, otherwise the model will create an error. For instance, if a given fraction is collected separately for recycling, it should also be present in the total MSW composition.

Once you have entered your information, click Save Projection.

You can also start from an existing projection, change the information where needed and create a new projection. If you prefer this approach, click Save as New Projection. You will see a pop-up which indicates which projection slot will be used and you will then be asked to enter a name for your projection.

Then click Mark Step as Checked, then Next Step.

3.4. Set up Waste prevention

On this sheet you have the option to model a set of predefined waste prevention initiatives. As this option is meant only to show the effect of new initiatives, existing ones should not be selected as it is assumed that their effect is already reflected in the amount of generated MSW.

If you would like to include one or more initiatives click No and choose Yes from the drop-down menu. You then have the opportunity to add some specific information regarding a chosen initiative. The model shows reference prices and assumptions which you can choose to keep or change.

If you have chosen more than one initiative, these will be used as a group.

Once you have entered your information, click Mark Step as Checked followed by Next Step.

Note that the waste prevention tool has not yet been used by the EEA for producing results, and underlying assumptions have not been updated since 2014 when data on the quantitative effects of waste prevention measures in Europe were rather scarce. The underlying assumptions are available in Appendix 3 – Waste prevention module of Development of a Modelling Tool on Waste Generation and Management (EC, 2014).

4. How to create policy scenarios

The model has 10 slots for the creation of scenarios. The first two are intended for baseline scenarios. In the Waste Model 2014, two baseline scenarios were defined but in the 2017 update (Waste Model 2019) only one baseline scenario is in use and was updated (Baseline 1 in scenario slot 1). This presents an objective view of likely future waste management based on realistic expectations for the performance of waste management systems. It was created by waste experts from the ETC/WMGE and EEA based on information provided by Member States through a questionnaire in 2017. The focus of the Baseline 1 scenario is 2015–2025, and for most countries waste treatment shares are kept constant after 2025. This scenario is intended to represent what might be the outcome if nothing happens other than:

- waste recycling/preparation for reuse measures whose implementation has already begun;
- collection systems remain as they are, unless a clear programme or roll-out of new systems is underway or committed to;
- residual waste facilities for municipal waste either already built or under construction are fully utilised. These plants will affect the assumptions on how residual waste is managed.

The second baseline scenario slot is currently empty. It can be used to define another baseline based on a user's own assumptions. As the two baseline scenario slots do not use the model's Goal Seek function and thus cannot be used to optimise policy goals, they can only be used to calculate a scenario that is predefined by the user.

The third slot in the 2018 model version contains a scenario that reflects the targets of the revised waste directives adopted in 2018 – Directive 2018/851/EU amending the Waste Framework Directive (WFD) (2008/98/EC), Directive 2018/850/EU amending the EU Landfill Directive (1999/31/EC), and Directive 2018/852/EU amending the EU Packaging and Packaging Waste directive (94/62/EC). These targets comprise:

- recycling targets for municipal waste;
- landfill reduction target;
- packaging waste targets.

The scenario also takes account of the time derogations that Member States are entitled to request.

Thus, you can enter a second baseline scenario and seven other policy scenarios.

If you have to create one or more policy scenario(s) for a single country, you can start from the user interface. This has as the advantage that it provides some background information and is well structured⁴.

If you want to add a scenario, click on the drop-down menu next to Select a Scenario to Load and choose either the scenario you want to start from or an empty slot. If you choose an empty slot you will be asked to enter a scenario name.

You have the opportunity to specify a set of policy measures you would like to model in each scenario except the Baseline scenario. You have the option to include measures regarding the following.

- Waste prevention (see also Section 3.4) – do you want to include the prevention measures you selected in the previous sheet?
- Municipal recycling and preparation for reuse targets – you can specify whether the WFD target⁵ for 2020 should be met in your scenario and which of the four calculation methods should apply.

⁴ The ETC/WMGE has not used the user interface to update the model, so only has limited experience with it.

⁵ WFD (2008/98/EC) target: 50 per cent recycling by 2020. Member States can choose between four methods to calculate recycling.

You can also enter future recycling target rates for specified target years if the option to meet the WFD target is selected – you do not need to choose to meet the WFD target first.

- Packaging recycling and preparation for reuse targets – you can specify specific recycling targets for packaging waste. To be able to enter targets for future years, you first must enter target years and then specify your packaging recycling targets (see previous bullet).
- Residual waste treatment targets – you can specify two different targets you would like to reach: diversion of biodegradable municipal waste (BMW) from landfill (related to the amount generated in 1995, following the definition of the targets in the 1999 Landfill Directive), and reduction of MSW sent to landfill (as a share of MSW landfilled related to MSW generated in the same year). If you would like to meet the Landfill Directive Target on diversion of BMW from landfill⁶, select Yes from the drop-down menu in cell G72 (Table H71:I72 shows the target year and the target in terms of BMW landfilled as share of BMW generated in 1995 for the selected country).
- Furthermore, you can **define residual treatment** by choosing between three options. These choices decide how the model allocates the waste diverted from landfill to the other treatment options for residual municipal waste.
 - *Set landfill reduction* (reduce the amount of waste sent to landfill to meet the Landfill Reduction Target on reducing the total amount of MSW sent to landfill⁷): the remaining waste will be split across MBT and incineration using the shares they represent in the baseline. If you select this option, also define the year the target is announced, by when it has to be met, and define the target (what share of the MSW can still go to landfill).
 - *Residual split*: you set the shares of residual treatment. Define the split across MBT, incineration and landfilling for the target years chosen, and the shares per type of MBT and incineration for these target years.
 - *Neither*: the split across treatment as defined in the baseline is used.
- Collection coverage – set which proportion of the population is covered by a formal waste collection service. The model automatically allocates generated but non-collected waste to landfill.

You also have the option to define whether you would like to use the default or user defined assumption set and which Waste Projection (i.e. waste generation projection) you would like to use for your scenario.

Then click Save Scenario, or, if you started from an existing scenario, Save as New Scenario and enter a name. The assumptions selected and used in the added scenario will then be stored in the Sheet Store.

Click Mark Step as Checked and then Next Step.

Policy scenarios can also be created directly in the Store Sheet. More information can be found in the file EURM_MSWM – Controls and Outputs.xlsm.

⁶ Landfill Directive Target: The Landfill Directive (1999/31/EC) obliges Member States to reduce the amount of biodegradable municipal waste that they landfill to 35 per cent of 1995 levels by 2016 or 2020 for some countries.

⁷ Revised Landfill Directive Target, including that Member States shall take the necessary measures to ensure that by 2035 the amount of municipal waste landfilled is reduced to *10 per cent* of the total amount of municipal waste generated.

5. Improvement needs of the model

Numerous potential technical improvements have been identified but these could not be implemented during the EEA's hosting of the waste model due to resource constraints (Table 1).

Table 5.1 Overview and description of improvement needs

	NAME	IDENTIFIED IMPROVEMENT NEED
1	2nd LANDFILL TARGET	The Landfill Directive includes an interim target on landfilling municipal waste for countries that apply for a derogation, and you might want to model different interim landfill targets. The current model can only operate with one (a single) target year.
2	BIO versus DRY RECYCLING	Currently, the model cannot differentiate between dry materials recycling and biowaste treatment but combines these to calculate the total recycling rate in the Goal Seek procedure. Separating the calculations for biowaste and dry recyclables would enable a better reflection of both the recycling rates of these waste streams and the actual capture rate of specific waste fractions.
3	EXTENSION BEYOND 2035	The current model covers the period to 2035. The derogations for certain countries on the 2035 landfill target mean that it currently cannot model the full impact of the targets. An extension to 2040 or beyond would be a major change to the model requiring considerable resources for both extending the assumptions, for example on projections for national energy mixes and waste generation projections, and technical modifications of hundreds of tables and macros. The current technical setup of the model does not allow for an easy extension.
4	REUSE	The targets refer to the sum of municipal waste reused and recycled. The current model, however, does not differentiate between reuse and recycling, not least because there is currently no data available on reuse. Data on reuse is, however, expected to become available in the coming years. Considerable development work would be needed to include reuse in the waste model.
5	STORE SHEET - CREATION AND VERSIONING	The Store Sheet (EURM_MSWM – Controls and outputs.xlsm) captures all information that is needed as input for a run. The sheet can be composed by filling out all sheets placed before the Model Controls sheet (EURM_MSWM – Controls and outputs.xlsm). This is a very time-consuming procedure. However, in the past the team was frequently faced with difficulties regarding the correct composition of the Store Sheet. Thus, a tool that helped with filling out of the Store Sheet, and was not time consuming, would be very helpful. After the creation of a correct Store Sheet, a strategy for versioning should follow, so that it is clear exactly which Store Sheet format had been used for producing scenario results.
6	METHOD 2 CALCULATIONS	For Member States applying method 2 for showing compliance with the 50 per cent recycling target by 2020 of the 2008 WFD, the model calculations were adjusted to align with the assumptions made by Member States about which waste streams are included in their specific calculations. These modifications, however, are currently not taken into account by the Goal Seek procedure. The added calculations could be further embedded in the model so that the additional information can also influence the decision-making procedure of the model.

6. Overview of model documentation

Model documentation provided by the model developers:

- [Development of a Modelling Tool on Waste Generation and Management](#) (EC, 2014) Headline Project Report and its appendices:
 - Appendix 1 – Baseline reports
 - Appendix 2 – Mass flow modelling
 - Appendix 3 – Waste prevention module
 - Appendix 4 – Financial modelling
 - Appendix 5 – Collections modelling (Note: updated version available, see below)
 - Appendix 6 – Environmental modelling
 - Appendix 7 – Distance to target modelling
 - Appendix 8 – Resource efficiency indicators
 - Appendix 9 – Employment in municipal waste management operations
 - Appendix 10 – Feedback from non-Member State stakeholders
 - Appendix 11 – Member State results for the relative scenarios
- Annexes to *Support to the waste targets review and annexes* (EC, 2016)
 - [Technical Guidance on Collections Modelling \(updated version\)](#)
 - [Technical Guidance on the Packaging Waste Module](#)

ETC/WMGE – documents: Updated country and non-country specific data:

- [Documentation of the 2017 update of country specific waste data and baseline](#) (ETC/WMGE, 2018a)
- [Documentation of 2017 update of the waste model with respect to material revenues, electricity revenues and reject rates](#) (ETC/WMGE, 2018b)

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Annex 1 Experience from the data update carried out in 2017

Data on waste volumes, composition, collection and treatment were collected from all Member States for the 2017 update of the waste model carried out by the ETC/WMGE in 2017 (ETC/WMGE, 2018a and 2018b). Below, the experiences from the updating exercise are summarised.

The waste model requires detailed data on waste flows that are currently not available in European waste statistics collected by Eurostat. In order to update the model, such data therefore need to be collected directly from Member States or national statistics and reports. Experience shows that data available on a national level are not necessarily available in the format required for the model. This means that, in many cases, the available data need to be fitted into the model by applying additional assumptions. In addition, not all countries collect the data needed as inputs to the model. While some data are available from national statistics or reports, other data will have to be estimated for some Member States. **Note that data now found in the model have been customised to fit the model and are not equal to the data provided by the respective Member State.** This customisation process is described in the documentation of the baseline update (ETC/WMGE, 2018a).

During the 2017 update, the ETC/WMGE encountered several issues with the data availability and how to fit available data into the model. All data fed into the model needed to be harmonised, but within a specific country, waste data are often collected from different sources and not necessarily fully compatible. Also, where data are not harmonised between countries, such as waste composition data, model results will not be fully harmonised across the EU.

Country specific waste data

Country specific waste data are stored in the model on many sheets and in different tables. Furthermore, these data are either time series data or single values. Time series data implies that such a parameter has a projection (user or pre-defined), or that this parameter is evaluated by the model annually with the user-defined value as the starting point. For time series, estimates of the values between the last available data year and the model's starting year are needed for model consistency. For example, if the latest available data refers to 2014 and the model run starts from 2018, the values between these years need to be either collected or estimated. On the other hand, some data in the model are kept constant over the whole modelling period. Such parameters are stored in smaller tables without the need for filling in the gap between data gathering years.

These two aspects – many locations for data and different types of data – make it very important to handle the updating systematically and, if possible, not manually.

To understand the impacts of changes to country specific data on results, the update should also be done, at least in the first place and for the first time, sequentially. Furthermore, result comparisons of different model runs with different parameterisations are useful. This can be done, for example, by comparing the result files of different model runs between data updating steps.

Other data updates

Some shortcomings and errors had been spotted and corrected. One such, corrected in 2017, concerned the targets and target years for the diversion of BMW from landfill in several countries.

Analysis was done to identify the variables to which the model is most sensitive, and resulted in the extension of the model to include both **average and marginal energy mixes**. Originally, the model contained only one set of data, in which the values reflected marginal or average energy mixes according to what was provided by the Member State. The dataset has been extended so that a set of data for marginal as well as for average energy mixes is made available for all Member States. Additionally, a

feature was added to the user interface allowing the choice of either energy mix – the model takes the marginal mix as a default.

Several types of **economic/financial data** are used in the model to evaluate the financial costs and benefits of policy options. These include:

- gross domestic product (GDP) deflator;
- discount rate for NPV calculation;
- energy costs;
- material revenues;
- labour costs.

In the waste model, some of these data are country specific – GDP deflator, electricity costs and labour costs – while others are the same for all countries. The EEA and ETC/WMGE updated the electricity costs, reject rates and material values in 2017.

Finally, reject or loss rates – material rejected during sorting operations sent to landfill or incineration – were updated. In the waste model, reject rates differ by material and collection method and are the same for all countries.

How to collect data from Member States

For the 2018 version, data collection was mainly done through a questionnaire sent to all Member States and followed up by a consultant of DG Environment. Twenty-seven out of 28 countries answered the questionnaire and, in general, the information supplied was of reasonable quality.

→ Questionnaire for data collection

The ETC/WMGE prepared a questionnaire requesting up-to-date statistics, as well as information on expected future developments and strategies on the management of MSW in Member States. The questionnaire (ETC/WMGE, 2017) was divided into three sections:

- the current situation, including MSW composition, generation and treatment in place, as well as existing treatment capacities;
- expectations for the future, including projections of MSW generation, details of policies under implementation that will have an impact in the near future, future treatment capacity, and planned and potential changes to the collection systems;
- recently implemented and planned measures for increasing MSW recycling rates.

The first part (Section 1) of the questionnaire consisted of quantitative questions which aimed to update the most relevant waste flow data in the model. The second part (Sections 2 and 3), made up of context questions, aimed at getting a good understanding of Member States' waste management systems and their likely future development. Other than the waste generation projections, the information collected through Sections 2 and 3 was not used directly as inputs to the model, but for developing the Baseline scenario.

→ Gap filling

The ETC/WMGE team scrutinised the data and information provided through the questionnaires, identified gaps and shortcomings, and asked Member States some follow-up questions.

As not all information was or could be provided by Member States, significant gap filling was done. For the adjustments and gap filling, a good understanding of the quality and level of uncertainty in the data were important. One key element of the analysis of the questionnaires was respect for Member States' answers.

Thus, whenever the Member State's answers were not contradictory in any sense, they were used for the update of the model. However, many gaps were filled after consultations with Member States, and therefore their opinions on gap filling were not always available.

Inconsistencies in the responses to the questionnaires were corrected based on the most reliable data; gaps were also filled based on the 2014 version of the model or other available data. The data entry considered to be most reliable was used as a reference for all Member States, with other data modified to match them. Gap filling for all Member States followed the same methodology and principles wherever possible.

The main questions encountered during the gap filling were as follows.

- For many countries, data on waste composition and amounts collected for recycling were not harmonised, which resulted in capture rates for certain recyclables higher than 100 per cent in several cases. Such data had to be adjusted as the model cannot handle capture rates higher than 100 per cent. Furthermore, cross-year storage may affect statistics on treatment when waste generated in one year is treated in the next – impacting treatment rate statistics in both years. In this case the main concern was to decide waste generation or waste collected for treatment data reported by the Member State should be customised.
- There was a wide heterogeneity in the reported data on waste composition: some countries provided composition data related to household waste, others to total municipal waste. Some referred to total MSW generation while others to residual waste generation. Where only composition of residual waste was provided, the ETC/WMGE used data on separately collected MSW for recycling to calculate the composition of total MSW.
- Some countries did not provide requested details in relation to specific waste shares within material fractions, for example food versus garden waste. This required the application of assumptions on the basis of estimated waste shares.
- Some Member States reported recycling at different stages of the recycling process – for example waste collected for recycling or inputs to final recycling processes. As the waste model operates on waste flows starting from collected waste, such situations required the calculation of the separately collected amounts for inputting. These calculations had to be done by relying on data validation processes based, where needed, on expert judgement.
- Some countries reported only scattered data in terms of time – years of reference – or geographical coverage – for example, effectively only providing information on sub-regions.

→ ***Lessons learned and recommendations for improvement***

Not all the information needed for the model is collected in all Member States and, therefore, significant gap filling needs to be done. As also seen in other statistics, and as documented in the previous section, waste data collected using different methodologies or from different sources are often incompatible, although actually covering the same activities. This could also be seen in the data collected through the questionnaires, where, for example, collected and generated waste data were not always compatible although a 100 per cent collection rate was reported. In order to successfully fill gaps, a deep knowledge of the model, waste management in general and the waste management in the specific country is needed. Furthermore, dialogue with Member States during the gap filling process is recommended.

In order to make data processing easier, Member State waste (data) experts should be involved in the gap filling process. One solution would be to build a gap filling function into the questionnaire – through which the most reliable data would have been decided upon before the questionnaire is sent out, and related data are compared to the most reliable data set. In the questionnaire used for the 2017 update, data in Tables 2-1 and 2-3 could be checked against data in table 2-2; where the data were contradictory, Tables 2-1 and 2-3 would automatically be updated according to suggested gap filling principles and the Member State have the opportunity to provide feedback and suggestions on the gap filling. This would provide

Member States with better insights on data manipulation in the model in cases where available data do not directly fit to the model's requirements.

The questionnaire used in 2017 had a long contextual section, which could have been somewhat reduced. Many Member States tended to copy and paste answers to several of the questions regarding future plans.

Generation of baselines

After analysing the data, the ETC/WMGE team modelled a set of baselines. ETC/WMGE and EEA waste management experts first analysed the questionnaire answers and other available data and information, and then formed an expert opinion on the most likely scenario for the future management of MSW in each Member State. This scenario is intended to present a critical view of the effects of policy measures under implementation or firmly planned, and planned capacity. Thus, it is one of several possible futures, helping to identify the potential risk of not meeting the 2020 target for recycling and forming a basis for discussion.

For projections of future waste generation, the first priority was to use data provided by Member States. If the projection provided was not up to 2035, the latest year of projected data was used as a new reference point for generating projections for the remaining years using an econometric model.

For some Member States, the ETC/WMGE generated a projection for MSW generation up to 2035. These projections are based on an econometric forecasting model, developed by the ETC/WMGE and consistent with current academic literature, that looks at the drivers of the generation of MSW and identifies wealth (for example, GDP) and population growth as the main drivers of waste generation (Mazzanti and Zoboli 2009). This method does not, however, take account of waste prevention policy measures and their impacts on waste generation.

Projections of MSW generation by Member States follow a two-step procedure. First, the relationship between MSW generation, GDP and population is estimated using historical data. Second, estimated parameters are used in combination with projected values of population and GDP to estimate future trends in MSW generation. Historical data on MSW generation for the period 2000–2014 were retrieved from Eurostat. Data on GDP, at 2010 prices for 2000–2015, and population (2000–2015) were also retrieved from Eurostat. As for projections, those for population (up to 2060) were available from Eurostat's main scenario. Where GDP projections were required, Organisation for Economic Co-operation and Development (OECD) projections, complemented with extrapolated International Monetary Fund (IMF) projections for non-OECD European countries, were used.

The model does not distinguish between future collection of dry recyclables – recycling of dry materials such as paper and card, metals, glass, plastics, textiles, waste electrical and electronic waste (WEEE), wood, etc. – and collection for biowaste recycling, but the division between these remain the same as for the last year of data. For the baseline, the future collection for recycling was separated between dry recyclables and biowaste recycling – but fed into the model combined. The separation between dry recyclables and biowaste recycling was mainly done to generate proper future scenarios and ensure plausible capture rates for both dry recyclables and biowaste recycling. After generating future recycling scenarios, the future residual treatment split between MBT, incineration and landfilling was estimated to reflect the reported plans of Member States. If no indication was given by the Member State of changes in this split, the ETC/WMGE kept the split as included in the 2014 version or reduced the waste treatment lowest in the waste hierarchy, in most cases landfilling. It was assumed that many Member States would prioritise the diversion of waste from landfills when increasing volumes collected for recycling, thus keeping the MBT and incineration shares constant. Some Member States also provided information on plans to increase MBT and/or incineration, and provided data on future treatment capacities, which were taken into consideration when generating baselines.

Updates made in 2017 with reference to data not included in the questionnaire

Several data, which were available from other sources and were therefore not included in the questionnaires sent to Member States, were checked to see whether updates would be needed and feasible. These are mostly of a financial/economic nature and are used in the model to evaluate the costs and benefits of policy options. A (non-exhaustive) list includes:

- GDP deflator;
- discount rate for NPV calculations;
- energy costs;
- reject rates;
- material revenues;
- labour costs.

These data are in general not country specific in the sense that they apply to all countries, with some exceptions such as energy costs. Some can be updated by making use of Eurostat data – GDP deflator and energy costs – while other variables, such as material revenues, reject rates and the discount rate can only be updated by referring to specific sources. For more detail of data updates, please see the documentation on the 2017 update of electricity revenues, material revenues and reject rates (ETC/WMGE, 2018b).

→ *Difficulties and recommendations for improvement*

Some economic variables can be updated based on regular Eurostat data, such as the GDP deflator and energy costs; for some others, including discount rate, reject rates and material revenues, existing reports or other external sources were used; for the latter, the updating process required significant expert judgement in some cases, which may impact the results. As the updating of economic variables may be very time consuming, prioritisation of what needs to be updated must be clear from the outset so that limited resources can be concentrated on the most crucial ones or those most in need of updating.

Furthermore, the updating of economic variables may turn out to be especially cumbersome due to very specific definitions or to the widespread use of those variables within the model. Labour costs, for example, were not updated because in the model they are defined for all countries as *relative to the same costs in the United Kingdom*. Data on damage costs were also not updated due to difficulties in finding and putting together up-to-date sources within the available time and budget.

In other cases, updating was not done as no major changes were evident, or deemed as crucial, in relation to specific variables when the updating decision was taken. This was the case for the GDP deflator and the discount rate.

Other parameters which should be updated in the model

The ETC/WMGE (ETC/WMGE, 2016) and, previously, Enumia (EC, 2016) analyses on sensitivities showed a high sensitivity of model's results to the following variables:

- labour costs associated with collection;
- material losses;
- material revenue from paper and card;
- collection system efficiencies;
- energy prices;
- waste treatment facility capital cost;
- weighted average cost of capital (WACC);
- direct revenue for supplying electricity to grid.

→ *Other data recommended to be updated*

- Inflation: the inflation rate currently used is 2 per cent.
- GDP deflator: a deflator used to calculate price ratios relative to current year prices. These price ratios are used in the model to calculate all costs in current year real terms. Two options are possible, either using the price ratios for individual Member States or using a general EU deflator.
- Renewable energy support: energy support systems have evolved quite rapidly over the years. Because the model results are quite sensitive to energy prices, a check is needed to check whether the ones used in the model are still in force. However, this is only needed if the private metric is applied in the model while they are not relevant for the calculation of social costs.
- Landfill and incineration taxes: as these are significant when calculating the overall cost of incineration and landfilling, a check is recommended ensure that they are still valid. Note that these taxes only matter when dealing with private costs, while they are considered as net transfers when dealing with social costs – they do not appear in social costs.
- Treatment costs: as the model results (financial costs and NPVs) are sensitive to the waste treatment facility capital cost, a check for recent information availability is recommended.
- Cost of labour, taxes and social security and associated rates: possible sources: tax rates from Deloitte Tax Guides and Highlights (<https://dits.deloitte.com/#TaxGuides>), other data from (and calculated from) Eurostat labour cost levels. Note that labour taxes and social security contributions also only matter when dealing with private costs, while they are considered as net transfers when dealing with social costs – they do not appear in social costs.
- Collection system efficiencies: these have a significant influence on the model results, a check for information availability is recommended.
- Weighted average cost of capital (WACC): The identification of the WACC is based on expert judgement and is assumed to be the same for all treatment technologies and for all countries. The social metric is assumed to be same as private metric.

Practical lessons learned from updating the model

During the 2017 data update model store sheets were used.

- Updating the store sheets needs a systematic approach and the best option for that is to use programmed data handling rather than manual updating. This is especially important for time-series type data.
- Automating updating and changing values back to previous ones is beneficial for comparing model results before and after updating.
- Dividing the data update into relevant blocks, for example waste composition and the baseline, and updating these sequentially helps keeping track of impacts of each data block. This has at least two benefits: the final result is understandable, and for future updating the importance of different parameters becomes clearer. This serves as simple sensitivity analysis. It can also help to identify mistakes made during the data updating process.

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