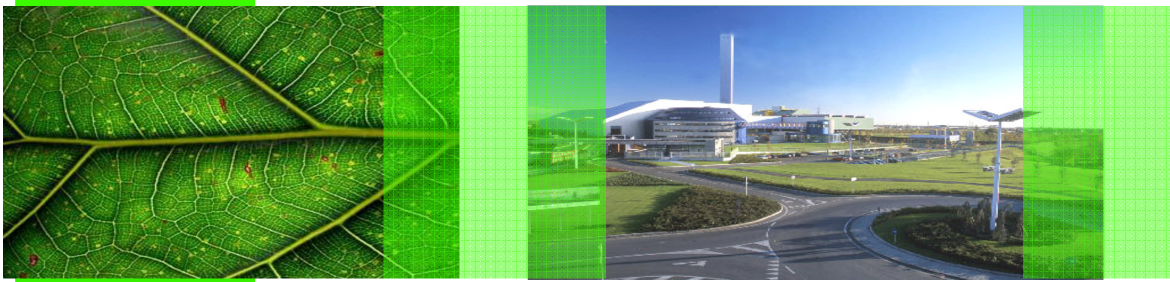

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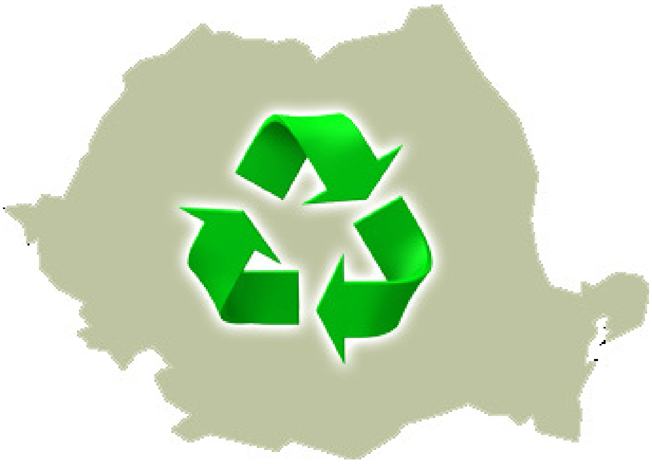

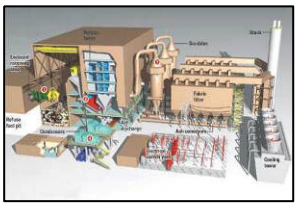

SOP2 PRIORITY AXIS AND PIPELINE REPORT

28th February 2012

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Executive Summary

Scope, Objectives and Approach

This summary report identifies beneficial waste management projects in Romania to be implemented in 2014-2020 and to be financed by the 2014-2020 Sectoral Operational Programme for the Environment (referred to in this report as SOP2) or by other sources.

The objective is to estimate the waste management situation in Romania's 42 counties at the end of the current 2007-2013 programming period (as a result of current planned waste management developments) and to identify a pipeline of new projects required within SOP2. These projects should meet the following targets and objectives:

- The 50% municipal waste recycling target for 2020 from the revised Waste Framework Directive. (Romania has not decided yet on the option to calculate the 50% target, but it may include the preparation for reuse and the recycling of paper, metal, plastic, glass and organic waste);
- The 2016 Landfill Directive target for diversion of biodegradable waste from landfills;
- Packaging Directive targets;
- Other fundamental requirements from European legislation, such as the obligation to adhere to the waste hierarchy;
- The potential projects proposed should also complement Romania's forthcoming waste management strategy.

The increased legislating requirements will require additional investment in waste infrastructure in the coming programming period. This assignment seeks to identify the most practical and cost effective 'pipeline' of projects to satisfy these objectives, as well as assessing the full likely capital cost of this new tranche of projects.

The approach used was to build a mass flow model for Romania's municipal waste which, county by county, considers waste collection, recycling, recovery, treatment and disposal. The mass flows identify the performance against targets and allows investigation of Scenarios which aim to meet these goals. In addition, it is used as a calculator for the capital costs of facilities and equipment associated with the proposed investments. Operational costs are also considered in order to give rounded view of the potential waste systems. The model is available as a spreadsheet appendix to this work; the results provide the outputs for this report.

Scenarios Assessed and a Proposed Pipeline of Projects

A key consideration for Romania is the high proportion of "organic waste" within municipal waste in Romania (over 50% of the total or 4.2million tonnes per annum across the country). This is understood to be mostly food and some plant/garden waste. Consequently, this material ought to be a key material in strategic waste planning. The

SOP2 scenarios selected, therefore, include the intensive collection of organic food waste. This subsequently favours the anaerobic digestion (AD) approach to treatment (since invessel composting does not operate well on high food content organics). Overall system costs can also favour this approach where garden waste is kept separate from food waste since garden waste can be composted through a simple open air composting at a much lower processing cost (the alternative of combining food and garden wastes means both need to be composted in in-vessel facilities at higher overall cost[1]).

What then remains is residual waste for which an improvement in management (diverting from landfill) is still desired. The two residual waste treatment technologies suitable to the Romanian situation are incineration or a biodrying/biostabilisation MBT (mechanical and biological treatment) process. These two treatment technologies are assessed to deal with the quantity of residual waste which requires diversion to meet targets in the first two Scenarios investigated for this work. A third Scenario takes a selective approach to residual treatment facilities to propose potentially 'workable' set of facilities which could be taken forward as the SOP2 pipeline of projects. This considers the minimum commercial plant sizes for the recovery and treatment plants in order to appraise the potential scales and locations for these facilities. A summary of these is given in Table A1 below.

Scenario 3 is perhaps the more realistic of the three Scenarios modelled as it allows diversity in residual waste treatment around the country to fit with local needs. Incineration is likely to be more suitable in higher populated cities, especially if district heating networks are already in place, and a demand for heat exists. Biodrying, with SRF generated in response to demand from cement kilns, is likely to be the preferred technology elsewhere. The project pipeline suggested in Table A1 is one such possible approach, although further work will be needed to firm up such selections.

Note in relation to Table A1: The residual waste treatment facilities proposed for a group of counties does not mean that residual waste needs to be transported across counties; by working in partnership as proposed, one county can provide enough treatment of its own residual waste for both counties combined obligations to be satisfied. It may be possible to use a similar approach for food waste collection if enough food waste can be collected in one county to suffice for a partnering neighbour. There is however a much higher likelihood that food waste will need to be collected in all counties and, where there is not sufficient tonnage in individual counties to justify construction of a local facility, transported across county borders to nearby AD facilities.

[1] Net organic waste.

Table A1: Pipeline of AD, Biodrying and Incineration Facilities for SOP2

County	SOP2 Proposed AD Plants (Scenario 3)	SOP2 Proposed Biodrying Plants (Scenario 3)	SOP2 Proposed Incinerators (Scenario 3)
Alba	37,740 inc Sibiu	-	-
Arad	To Timis (14,168)	49,013	-
Argeş	20,328	87,323	-
Bacău	32,247	-	At Iasi (40,333)
Bihor	40,593	-	-
Bistriţa-Năsăud	To Mures (10,593)	At Mures (20,231)	-
Botoşani	33,043	32,986	-
Braşov	65,283 inc. Covasna	-	-
Brăila	To Galati (14,985)	At Buzau (25,123)	-
Bucureşti & Ilfov	244,973	-	-
Buzău	-	75,261 inc. Braila and Vrancea	-
Caraş-Severin	21,570	-	-
Călăraşi	To Ialomita (10,562)	At Ialomita (22,949)	-
Cluj	84,360 inc. Salaj	-	-
Constanţa	-	-	160,000 inc. Tulcea
Covasna	To Brasov (6,075)	At Harghita (20,651)	-
Dâmboviţa	43,283 inc. Prahova	-	At Prahova (41,697)
Dolj	To Olt (13,901)	43,157	-
Galaţi	57,987 inc Tulcea	-	166,000 inc. Vrancea
Giurgiu	To Ialomita (7,350)	At Ialomita (11,774)	-
Gorj	To Mehedinti (6,216)	-	-
Harghita	-	35,443 inc. Covasna	-
Hunedoara	31,157	-	-
Ialomiţa	35,277 inc. Calarasi and Giurgiu	65,644 (inc. Calarasi and Giurgiu	-
Iaşi	25,161 inc. Neamt	-	168,000 inc. Vaslui, Neamt, and Bacau
Maramureş	48,819	At Suceava (15,474)	-
Mehedinţi	21,362	54,800	-
Mureş	35,343	-	-
Neamţ	To Iasi (3,202)	-	At Iasi (22,977)
Olt	61,017 inc. Dolj and Teleorman	32,319	-
Prahova	To Dambovita (2,281)	-	165,000 inc, Dambovita
Satu Mare	20,000	-	-
Sălaj	To Cluj (12,346)	-	-
Sibiu	To Alba (9,444)	45,930	-
Suceava	47,804	70,325 (inc. Maramures)	-
Teleorman	To Olt (12,933)	-	-
Timiş	58,819 (inc. Arad)	-	-
Tulcea	To Galati (1,065)	-	At Constanta (21,156)
Vaslui	32,064	-	At Iasi (28,701)
Vâlcea	-	-	-
Vrancea	To Bazau (11,497)	-	At Galati (20,928)

Financial Results

The capital investments during for the next programming period for the three modelled scenarios and the Business As Usual Scenario are shown in Table A2. This Business As Usual Scenario provides a point of reference which shows that continued investment in waste related services (including collection) is needed even without the long term strategic planning that aims to meet 2020 objectives. The three comparable Scenarios contain the same prerequisite investments in sorting plants and AD facilities to meet the 50% recycling target. The higher capital costs associated with providing CHP incineration capacity for treatment of the required amount of residual waste in Scenario 2 is substantially higher than the biodrying equivalent in Scenario 1. Scenario 3 (where the actual scale and location of biodrying, incineration and AD facilities are proposed according to Table A1 above) may therefore provide a rational alternative. As such, the possible capital cost requirement for SOP2 may be in the region of €1.3 billion excluding collection (vehicles and bins), or €2.1 billion including these costs.

Table A2: Summary Capital Cost Assessment for All Scenarios

Figures in million Euros	SOP2 Capital Investments: Summary									
	Collection (Total)	Sorting	AD of source separated organics	Biodrying	Incin-eration	Landfill closure	New landfills	Project support	Total Excluding Collection	Total Including Collection
BaU	€ 721	€ 0	€ 0	€ 0	€ 0	€ 9	€ 92	€ 15	€ 116	€ 837
Scenario 1	€ 753	€ 45	€ 399	€ 231	€ 0	€ 9	€ 68	€ 113	€ 864	€ 1,617
Scenario 2	€ 753	€ 45	€ 399	€ 0	€ 929	€ 9	€ 68	€ 217	€ 1,667	€ 2,420
Scenario 3	€ 753	€ 45	€ 399	€ 102	€ 520	€ 9	€ 68	€ 171	€ 1,314	€ 2,066

Key Observations from the Waste Policy and National Waste Strategy Review

As part of this assignment, we were asked to review the latest draft of the National Waste Management Strategy, and to consider this in the context of European waste policy. This review is contained within the Baseline Report. However, we summarise here a few key points in the context of the SOP2 assessment:

- The NWMP will need to be updated to meet various targets which it needs to achieve.
- Some implementing measures which could have been important have not yet been introduced (notably, a landfill tax).
- The rate of change that was envisaged in some areas seems to be quite slow.

Looking ahead with a focus on key policies, the following steps towards effective integrated waste management ought to be considered:

- Introduce landfill tax (key measure that will raise the cost of disposal of landfill, thus encouraging prevention and recycling);
- Variable charging;
- A measure to ensure that collection of recycling is robust (biowaste ordinance / producers mandated to fund packaging collection systems);
- Well managed procurement / enforcement / joint working;
- Training waste management officials and operators to improve the financial performance of their waste management activities.

Contents

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Abbreviations

Abbreviation	Definition
AD	Anaerobic Digestion
AF	Application Forms
B2B	Business to Business
B2C	Business to Consumer
BAT	Best Available Techniques
BATNEEC	Best Available Technology Not Entailing Excessive Cost
BaU	Business As Usual [Scenario]
BDW	Biodegradable Waste
BMW	Biodegradable Municipal Waste
Capex	Capital expenditure
CBA	Cost Benefit Analysis
CLRTAP	Convention on Long range Trans-boundary Air Pollution
CN	Completion Note
CP	County Plan
CSG	Community Strategic Guidelines
DDT	Dichlorodiphenyltrichloroethane
EfW	Energy from Waste
EGO	Emergency Government Ordinance
EIA	Environmental Impact Assessment
EN	English
EWC	European Waste Catalogue
FS	Feasibility Study
GNP	Gross National Product
HCB	Hexachlorobenzene
IPA	Instrument for Pre-Accession Assistance
ISPA	Instrument for Structural Policies for Pre-Accession
ISWM	Integrated Solid Waste Management
IT	Information Technology
J/V	Joint Venture
JASPERS	Joint Assistance to Support Projects in European Regions
JRC	Joint Research Center
LFs	Landfills
MA	Managing Authority
MAI or MIA	Ministerul Administratiei si Internelor
MBT	Mechanical and Biological Treatment
MEWM	Ministry of Environment and Water Management
MFP	Ministry of Public Finance
MoEF or MEF	Ministry of Environment and Forests
MoEF -DPE	Ministry of Environment and Forests - Directorate for Programs and Evaluation
MoEF-	Ministry of Environment and Forests - Directorate of Waste Management and

Abbreviation	Definition
DWMHS	Hazardous Substances
mn	Million
MP	Master Plan
MTCT	Ministry of Transport and Infrastructure
n/a	Not applicable
NGOs	Non-Governmental Organizations
NIMBY	Not In My Back Yard
NIS	National Institute of Statistics
NSRF	National Strategic Reference Framework
NWMS	National Waste Management Strategy
NWMP	National Waste Management Plan
Octa BDE	Octa Brominated Diphenyl Ether
OP	Operational Programme
Opex	Operational expenditure
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychloinated Biphenyls
Penta BDE	Penta Brominated Diphenyl Ether
POPs	Persistent Organic Pollutant
REPA	Regional Environmental Policy Agency
RO	Romanian
RoHS	Reduction Of Hazardous Substances
ROP	Regional Operational Programme
SOP or SOP1	Sectoral Operational Programme (2007-13)
SOP2	Sectoral Operational Programme (2014-20)
SOP ENV	Sectoral Operational Programme for Environment
SWM	Solid Waste Management
tn	Tonne
tn/y or tpa	Tonne per year (or annum)
ToR	Terms of Reference
TS	Transfer Station
UNECE	United Nations Economic Commission for Europe Convention
WEEE	Waste Electrical and Electronic Equipment
WFD	Waste Framework Directive
WID	Waste Incineration Directive
WM	Waste Management
WtE	Waste To Energy

1 Introduction

1.1 Note on Data Used For and Presented In This Report

The following report is based on data collected in November 2011. Many of the county waste project applications were still under development at that time, and progress to expected completion for individual counties remains a changing picture. This, in part, may lead to a differing outlook depicted in the following report from that reported elsewhere.

1.2 Background to Assignment

This summary report identifies beneficial waste management projects in Romania to be implemented in 2014-2020 and to be financed by the 2014-2020 Sectoral Operational Programme for the Environment (referred to in this report as SOP2) or by other sources. The objective is to estimate the waste management situation in Romania's 42 counties at the end of the current 2007-2013 programming period (as a result of current planned waste management developments) and to identify a pipeline of new projects required within SOP2. These projects should meet the 50% recycling target for 2020 in the revised Waste Framework Directive (WFD), the 2016 target for diversion of biodegradable waste from landfills, together with other core pieces of European legislation, and also complement Romania's forthcoming waste management strategy.

Although the infrastructure projects already specified for the current programming period ought to go a long way to improving the waste management situation in Romania, new European Directive targets have since superseded the objectives defining these SOP1 projects. The drivers in play for the SOP2 period can be summarised:[2]

- The 2008 revised WFD requires 50% recycling or composting of municipal waste by 2020;
- The biodegradable waste diversion objectives of the Landfill Directive become particularly onerous within the next programming period (the 2013 objective for landfill disposal of only 50% of 1995's biodegradable waste is reduced to 35% in 2016);
- The closure of non-compliant landfills (i.e. those that do not conform to Landfill Directive standards) needs to be complete by the 2017 deadline;

[2] Note that the Waste Electrical and Electronic Equipment (WEEE) Directive but has not been included in this assessment. WEEE is missing from the municipal waste composition data and therefore detailed analysis has not been possible. In addition, the challenges of compliance are somewhat different. Further comment is given in Section 6.3.

- As well as these core objectives for SOP2, other targets already in force remain unchanged – notably those imposed by the Packaging Waste Directive;
- The waste hierarchy (as defined in the 2008 WFD) which Member States are legally required to implement in policy and law.

These increased requirements will require additional investment in waste infrastructure in the coming programming period. This assignment seeks to identify the most practical and cost effective ‘pipeline’ of projects to satisfy these objectives, as well as assessing the full likely capital cost of this new tranche of projects.

1.3 Method for Calculation of the 50% Recycling Rate

Commission Decision of 18 November 2011 specifies the rules and calculation methods for compliance with the WFD percentage targets.[3] This document allows for Member States to calculate their recycling rate from any of the following summarised approaches:

Option 1: The preparation for reuse and the recycling of paper, metal, plastic and glass household waste;

Option 2: The preparation for reuse and the recycling of paper, metal, plastic, glass household waste and other single types of household waste or of similar waste from other origins;

Option 3: The preparation for reuse and the recycling of household waste; or

Option 4: The preparation for reuse and the recycling of municipal waste.

Romania has not decided yet on the option to calculate the 50% target, but option 2 with the inclusion of organic waste within the list of specified materials to be targeted for separate collection and ‘recycling’ is a worthwhile strategy for Romania and has been adopted to guide this work. Taking this approach to the calculation will contribute to a *‘rolling-up’* of the WFD waste hierarchy obligation into the recycling rate objective for the country. This approach fits well with the objectives for, and the obligations relating to, biowaste (notably separate collection and organic treatment), as is evident in the following extracts from the recent European Commission communication: [4]

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[3] European Commission (2011) *Commission Decision of 18 November 2011 establishing rules and calculation methods for verifying compliance with the targets set in Article 11(2) of Directive 2008/98/EC of the European Parliament and of the Council*, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:310:0011:0016:EN:PDF

[4] European Commission (2010) *Communication from the Commission to the Council and the European Parliament on future steps in bio-waste management in the European Union*, http://ec.europa.eu/environment/waste/compost/pdf/com_biowaste.pdf

“7.2 Actions to be taken by Member States

7.2.1. Waste Management Planning according to the "waste hierarchy"

While respecting specific local conditions, first and foremost Member States should implement the provisions of the WFD and **properly apply the "waste hierarchy"** [emphasis exists in main text] in national bio-waste management planning.

7.2.3. Promote separate collection and biological treatment of bio-waste

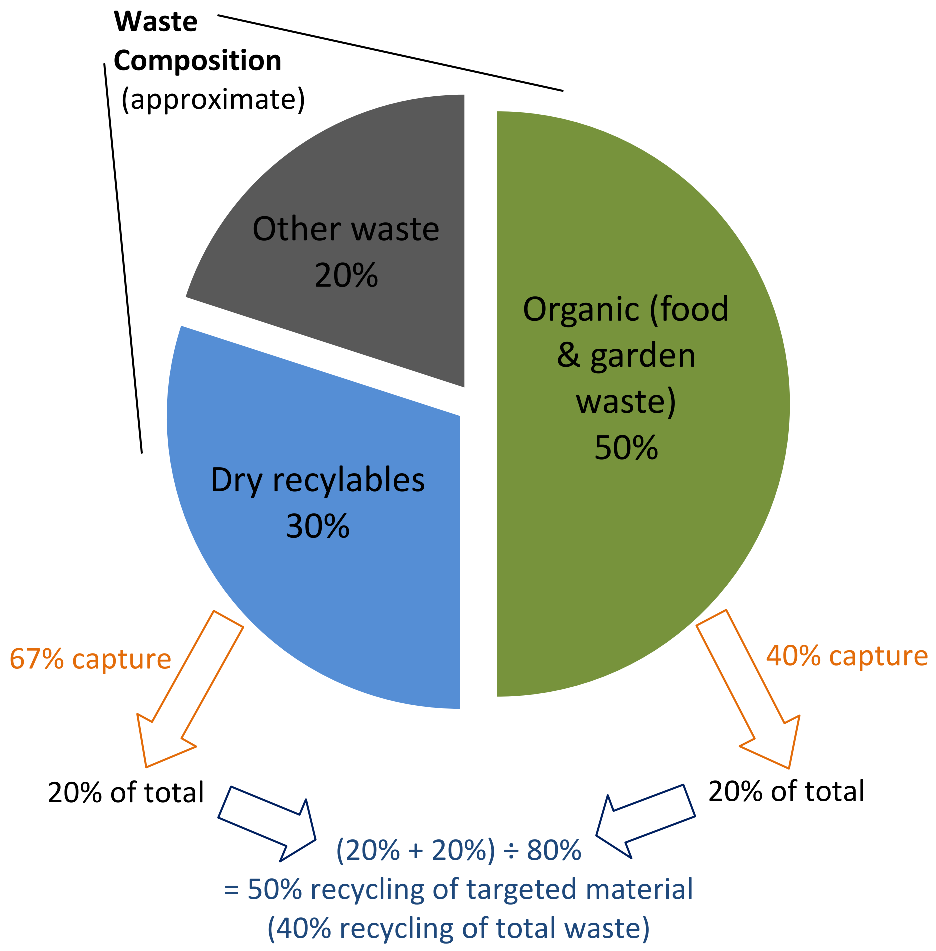
Composting and anaerobic digestion offer the most promising environmental and economic results for bio-waste that cannot be prevented.

7.2.5. Compost – a product of highest quality for better resource efficiency

Member States should promote the production and use of compost from "clean" (separately collected) bio-waste.”

A simplified representation of how the 50% recycling rate may be achieved under the official calculation (from option 2 of the Commission Decision paper summarised above) is displayed in Figure 1-1. The effect is that the “WFD Option 2 recycling rate” will be slightly higher than the total recycling rate as the ‘other waste’ is left out of the equation.

Figure 1-1: Stylised Demonstration of Achieving a 50% Recycling Target under the Selected Calculation Methodology

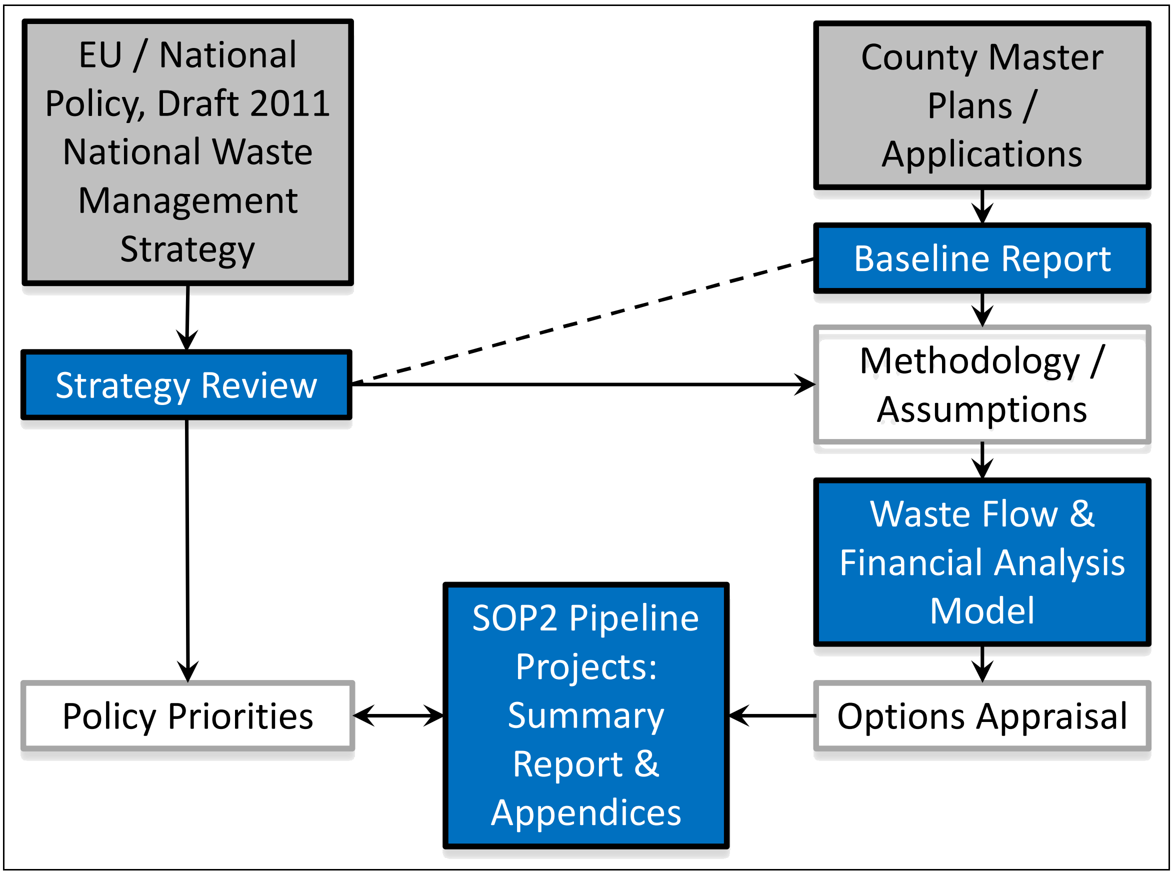


1.4 Approach: Core Components of the Work Conducted

The work conducted for this assignment is summarised in Figure 1-2.

The baseline situation (according to data in the existing Master Plans, project Application Forms and other relevant documents) has been studied in detail and is reported separately in the 'Baseline Report' as part of this work. Detailed appendices have also been compiled for each county summarising the core information from the country planning documents in as replicable a form as has been possible.

Figure 1-2: Project Summary Flow Diagram



The National Waste Management Strategy and policy situation is reviewed and is presented within the Baseline Report (hence the dotted line within Figure 1-2).

A excel based model has been produced as part of this work, and is available as a 'spreadsheet appendix' to this report (Annex A.3). It is fundamentally a mass flow model which compiles the data from the Baseline report and applies simple (user modifiable) assumptions to gauge future recycling rates and the performance of individual counties against targets. As such, this model in the first instance provides an independent assessment of the likely effect of the projects delivered through SOP1. In addition, it allows for options appraisal and sensitivity analysis in order to investigate different approaches for the next programming period. All Scenarios can be investigated in the one copy of the model (a 'spinner' is provided on the three headline results {'County Targets', 'Facility Summary', and 'Financial Analysis'} sheets to change Scenarios). The financial results are generated by applying unit capital costs to facility annual capacities, and unit operational costs (lower than traditional 'per tonne' gate-fee costs due to the avoidance of financing of capital expenditure and profit) to the annual waste flows.

This report (supported by the modelling assumptions and methodologies appendix) presents the results of this modelling work and suggests the leading approaches that ought to be considered for SOP2, and the total capital costs that are likely to be involved.

2 SOP2 Scenarios Assessed

In addition to the "Business as usual" situation (i.e. how Romania is likely to perform against targets where there is no additional investment or development in waste management systems in the coming programming period), three core Scenarios were selected. These are defined in Table 2-1.

The rationale for the modelled scenarios is to meet the objectives described in the bullet points in Section 1.2 above by putting in place systems which will operate effectively for the waste streams produced in Romania.

A key consideration identified early in the project, and discussed with the steering group, was the high proportion of "organic waste" within municipal waste in Romania. This is understood to be mostly food and some plant/garden waste (which together, it may be noted, the Commission tends to refer to as biowaste). The national waste composition presented in Annex A.1.2 shows that organic waste is currently over 50% of the total, or 4.2million tonnes per annum across the country. Consequently, this material ought to be a key material in strategic waste planning. The benefits of targeting food waste for separate collection can be expected to be numerous:

- Separate organic waste collection for recycling purposes (composting or anaerobic digestion {AD}) will help to ensure that Romania is seeking to comply with the waste hierarchy obligation of the WFD;
- Diverting food waste in this manner will also strongly contribute to meeting the Landfill Directive biowaste diversion obligation;
- A food waste rich organic waste fraction is best suited to AD, from which 'green' energy as well as a soil improver product is generated.

It would appear that some investment in recycling infrastructure occurs as part of SOP1 projects, but the investment in systems to sustainably manage organic waste are more limited. The SOP2 scenarios selected, therefore, include the intensive collection of organic [food] waste.

Food waste is not suited to aerobic composting unless significant structural parks and garden waste material can be sourced, and process controls are carefully maintained. The operational costs of dealing with food waste can also favour the AD approach, especially since garden waste can then be kept separate and composted in simple open air windrows (the alternative of combining food and garden wastes means both need to be composted in in-vessel facilities at higher cost). AD is the obvious technology of choice due to the suitability of this approach to separately collected food waste. In addition, Romania will gain secondary benefits – most notably the production of renewable energy. Intensive organic waste collection combined with AD is thus a core component of the Scenarios assessed in this work.

What then remains is residual waste for which an improvement in management (diverting from landfill) is still desired. The two core options are incineration or a biodrying/biostabilisation MBT (mechanical and biological treatment) process. Both will help achieve Landfill Directive biodegradable waste diversion objectives, reducing the environmental damage from landfill, as well as helping preserve the void space in these facilities. The difference, therefore, between Scenario 1 and Scenario 2 is the MBT process in the former and regional incineration for the latter. Since there appears to be significant demand from cement kilns for solid recovered fuel (SRF) in Romania, we model the biodrying approach to MBT. However, it may be noted that these systems are relatively easy to switch from one mode of operation to another – the capital equipment for both modes tends to be the same.

Table 2-1: Scenarios Modelled for SOP2

Scenario	Detail
Business As Usual Scenario	SOP1 projects for which there is either a Master Plan or Application are all delivered. All facilities are modelled to be online by 2015 with the exception of the two incinerators (Brasov and Ilfov/Bucharest) which will be online in 2020.
Scenario 1	Business As Usual situation + intensive organic waste collection + anaerobic digestion of source separated food waste + biodrying MBT to meet landfill directive targets
Scenario 2	Business As Usual situation + intensive organic waste collection + anaerobic digestion of source separated food waste + regional incineration to meet landfill directive targets
Scenario 3	Business As Usual situation + intensive organic waste collection + anaerobic digestion of source separated food waste + mixture of incineration and biodrying to meet landfill directive targets. Incineration is proposed where necessary in the larger cities, and biodrying MBT for other counties.

In the next programming period, Romania will provide sufficient residual waste treatment to meet the high Landfill Directive diversion target (where just 35% of 1995 landfilled biodegradable waste can go to landfill). The approach, therefore, is to provide the minimum treatment capacity that will ensure that the relevant targets are met. This approach also leaves scope for further improvement in recycling as well as allowing for the impact of waste minimisation programmes which are obligated by the WFD and should feature as part of national waste planning in future.

An overprovision of treatment capacity is possible for a number of counties that are planning residual treatment features as part of their SOP1 plans. Alba, Caras-Severin, Cluj, and Gorj are all planning facilities for around 60% of waste arisings. Hunedoara, Mehedinti, Salaj and Timis are planning facilities for around 50% of waste arisings. By 2020, when recycling rates are high, this may lead to overprovision of residual waste treatment capacity (in these counties specifically). In these cases, we do not model how residual waste treatment overcapacities are to be utilised, but suggest that waste from neighbouring counties can be transported for use as the feedstock. This would, in turn, reduce the need for residual treatment in these neighbouring counties. However, since there is likely to remain sufficient residual waste across the country for all projected facilities, we do not factor down the need for new capacity in such neighbouring counties.

3 Summarised Methodology for the Numerical Analysis

Full assumptions and methodologies are given in Annex A.1. In addition, the spreadsheet model provided separately as Annex A.3 can be interrogated for further detail on the assumptions used (for the central case modelling) and the calculation methods. The following sub sections give a brief overview of the key assumptions and methodology employed, which are essential in order to understand and critique the results.

3.1 Mass Flow Modelling

The mass flow element of the model is a relatively straightforward calculator which predicts future recycling rates, assesses the impacts of planned facilities, and therefore projects the performance of individual counties against targets.

There is a stepwise logic to this mass flow modelling, the key elements of this are:

- Municipal waste arisings data is compiled for both rural and urban sources for each county. The data used has been extracted from the Baseline Report Appendix, which in turn takes its information from the detailed planning documents (Master Plans etc.) from the individual counties. Waste generation per capita tends to be much greater in urban than in rural situations;
- Waste compositional data (again sourced from the planning documents) is applied to the tonnages arising for both rural and urban waste. This gives the tonnage waste arisings material by material;
- Any plans for the provision of home composting bins are assumed to deduct a fixed amount of organic waste from the collected municipal waste.
- Organic waste collection is assumed to be undertaken for the correct number of properties in order to deliver the right amount of throughput for planned organic waste treatment facilities. This avoids the problem identified in Annex A.1.4 that organic waste collection is almost entirely absent from the current plans. It is

thus important that provision is made for organic collections in parallel to facility development.

- Dry recycling is assumed in the central case modelling to be provided to all urban households and 90% of rural households by the end of this programming period. A mix of bring site and door-to-door collections are expected. Higher captures are modelled for door-to-door collections.
- Sorting facilities are included in the SOP1 plans for most counties. We are informed that these facilities are for sorting of the cans and plastics which are deposited and collected mixed together (as collected both from bring sites and via the planned door to door collections), as well as to remove contamination from all separately collected dry recycling materials.[5] Where sorting facility capacities in a county are lower than the potentially collected tonnage of recyclables, then we limit the quantity of recycling that is collected (i.e. we take the assumption that collection systems will only be provided to keep pace with sorting facilities).
- MBT and incineration contribute further landfill diversion and a more limited amount of recycling.
- The timing of when facilities come on-stream can be specified in the model. On guidance from JASPERS we have set all SOP1 facilities to 2015, with the exception of the currently planned Bucharest and Brasov incinerators – these being expected in 2020.
- Although transfer stations feature as part of the SOP1 plans, we do not model the transport of waste from one county to another as we are seeking to evaluate the performance of the counties individually against targets. Nevertheless, these facilities are considered to be of beneficial use and we envisage that they can help to move material to appropriate recovery, treatment and disposal facilities in the coming years across county borders.

3.2 Financial Modelling

3.2.1 Unit Costs for Fixed Infrastructure

Our approach to establishing representative capital and operating costs for new-build facilities in Romania commences by obtaining representative costs from elsewhere in Europe. For each process technology, it is assumed that general technology costs, such

[5] Since 2011, the Romanian regulation (GD 247/2011) requires selective collection in three fractions: paper + cardboard, plastic + metal, and glass. Bring banks are organised in this manner. Door to door collections are understood also to collect these three fractions in separate sacks or otherwise.

as the cost of purchasing large capital items, will be the same as elsewhere in Europe (subject to efficient procurement). However, for the element of both capital and operating costs that relates to labour, we adjust these typical figures to account for the lower than average costs of labour in Romania (with the exception of incineration, as discussed at the end of Annex A.2.2.5). This leads to modelled costs we expect to be realistic for facilities to be constructed in Romania. The detailed methodologies and the supporting evidence bases are given in Annex A.2.

In addition, we have reviewed the current programming period project costs. A summary of the SOP1 costs is shown against our modelled expected costs in Table 3-1. Several observations are clear from this exercise:

- The variation in capital costs for SOP1 facilities is significant. In a number of cases this may be due to subtle differences in facility design, or (for those facilities with extreme cost variance) some are mere extensions of existing facilities. Nevertheless, there remains a fairly broad range of costs in the evaluated figures summarised in Table 3-1, hence the strong need to for the research in Annex A.2 to produce the modelled costs we use in the SOP2 modelling;
- The capital costs for MBT facilities are notably low compared to the costs modelled based on experience from elsewhere in Europe. However, this is perhaps not surprising given that most MBT designed so far are very simple ones. For the next programming period we propose more advanced facilities, referring to them specifically as biodrying or biostabilisation facilities.
- The average capital costs for ‘composting’ is similar to the evaluated cost for invessel composting (IVC) facilities. This leads us to suppose that this is the design intended for these facilities. This suggests that the correct type of material for the SOP1 organic treatment plants ought to be a mix of garden/parks waste and food waste. It may be noted that the organic treatment facilities proposed for SOP2 (as discussed in Section 2 above) are anaerobic digestion. In this manner, the SOP2 facilities for pure food waste treatment may be a good complement to a pre-existing network of IVC facilities.

Table 3-1: Summary of Evaluated SOP1 Financial Costs and Costs Modelled for SOP2

Technology	Facility type	SOP1 Projects (€/tonne)		Notes	Eunomia Modelling (€/t)	
		Average Unit Capital Cost	Range		Unit Capital Cost	Unit Operational & Maintenance Cost
Sorting facility	SOP1 projects	€ 123	€52 - 260	Figures high for a simple sorting facility		
					€ 80	€ 6
Organic treatment	SOP1 projects	€ 155	€38 - 323	Technologies mostly IVC or windrow		
	IVC				€ 166	€ 24
	Open air windrow				€ 90	€ 11
	AD				€ 350	€ 21
MBT	SOP1 projects	€ 109	€84 - 153	Referred to as "Simple MBT"		
	Biostabilisation			More advanced systems desirable for SOP2	€ 171	€ 45
	Biodrying			Biodrying applied for SOP2 due to cement kiln demand for SRF	€ 186	€ 44
Incineration	SOP1 projects	€ 735	€700 - 769			
				Small (≈100Ktpa) CHP facilities	€ 872	€ 37
				Medium (≈200Ktpa) CHP facilities	€ 743	€ 34
				Large (≈400Ktpa) CHP facilities	€ 656	€ 25
				SOP2 circa 165Ktpa CHP facilities	€ 788	€ 35
Transfer	SOP1 projects	€ 85	€20 - 225	Figures high for a simple transfer station		
					€ 15	€ 6
Landfill closure	Cost / site (€million)	€ 1.2m	€0.4 - 2.6m	Average per site from SOP1	€ 1.2	-
New landfill		€ 6.0m	€2 - 10.5m	<€6m because some additional cells at SOP1 compliant LFs	€ 4.0m	€ 16
Overheads	% of project cost	15%	0-90%	Project support costs including technical assistance, audit etc.	15%	-

Note: Unit operational and maintenance costs include any relevant revenues and subsequent disposal costs but exclude depreciation / capital financing costs. For detail on the modelled data please refer to Annex 2.

3.2.2 Costs for Continued Provision of Compliant Landfill Capacity

As part of the SOP2 modelling, we broadly intend to make provision for sufficient compliant landfill capacity through to 2027. High level modelling has been conducted to ascertain the likely need for additional landfill capacity in the individual counties, and to project a cost for this provision where relevant (note that some counties plan SOP1 landfills with 20 years of capacity – so no further provision is needed in such cases).

It has not been possible as part of this work to do this with any level of precision since to do so would require intricate knowledge of all landfills around the country, accurate data on their current remaining void, and true closure dates for non-compliant landfills. The data compiled for the Baseline Report does provide some information, but this data is variable in scope and usability. The existing and SOP1 planned landfills are often described only by their surface area; likely void capacity is thus unclear. We do take some basic assumptions in order to generate an estimate for the likely need for new landfill provision, but accuracy is not expected to be high. Furthermore, when applying costs to the need for new landfill capacity, we cannot say if entire new landfills will be needed, or if additional cells can be added to existing landfills (at lower cost). As such we do not intend to project landfill capital costs with any level of precision, and these results should be read with a degree of caution.

Where compliant landfill capacity is modelled to be exhausted by 2027 in any county, we project a simple fixed capital investment for a new landfill as shown in Table 3-1. The fixed cost modelled is based on the SOP1 average of €6m, but factored down to €4m due to the opportunities to construct additional cells at existing compliant sites.

3.2.3 Closure of Non-Compliant Landfills

The approach we adopt for the closure of the last remaining non-compliant landfills during the next programming period is to take the average site closure cost from the SOP1 projects. The cost of this activity is not large in proportion to overall costs across the country, and the sensitivity of the assumption used is small.

3.2.4 Collection Costs

In addition to the fixed infrastructure facilities discussed above, capital and operational costs for collection are also included in the financial modelling. The high level figures modelled are based on experience of bring site and door to door collection systems operating in the UK and elsewhere in Europe. In the case of collection systems, due to the relatively short lifetimes of capital equipment, we model vehicle and container capex as an annualised cost and then multiply by 7 years to give the full capital costs over the 2014-20 period. The methodology and assumptions are presented in Annex A.2.2.9.

The costs modelled are summarised in Table 3-2. Dry recycling collection operational costs are modelled net of material revenues. Organic waste collection operational costs (opex) do not include treatment as this is included separately in the unit operational and maintenance costs as shown in Table 3-1 above. Furthermore, the opex figures (by the nature of this assessment) exclude financing costs for the capital expense of bins and vehicles.

Table 3-2: Modelled Collection Costs (for SOP2)

Only organic waste capital costs included in costings	**Annualised Capex** (bins and vehicles)	**Opex** (staff, fuel, maintenance, insurance etc.; recycling costs net of material revenues)
Bring site dry recycling	€ 5.20 / tonne per year	€ 1.70 / tonne collected
Bring site organic waste	€ 6.20 / tonne per year	€ 15.10 / tonne collected
Door-to-door dry recycling	€ 13.40 / tonne per year	€ 15.60 / tonne collected
Door-to-door organic waste	€ 15.80 / tonne per year	€ 23.90 / tonne collected
Residual waste collection	€ 11.50 / tonne per year	€ 15.60 / tonne collected

Source: Modelled costs from experience of collection services; see assumptions in Annex A.2.2.9.

3.2.5 Project Support Costs

The SOP1 projects included provision for project development, technical assistance planning assistance, promotion etc. They tended to range from €1 to €25million per county and averaging around €5million per county or 15% of total project budgets (€170m nationally).

We include this same 15% in the calculations for the next programming period.

4 Results: Waste Flow Projections

4.1 Business As Usual Scenario

4.1.1 Headline Recycling, Organic Treatment and Disposal Results (Business As Usual Scenario)

Under the modelled Business As Usual situation, where the SOP1 investments have effect by 2015, the management of waste in the individual counties is expected to occur as represented Figure 4-1. Typically, where adequate provision of collection and sorting facilities are provided, dry recycling rates may be expected to reach (where the service provision is good) over 20% of the total waste generated. The composting rates shown separately are dependent on the organic waste treatment facilities (and home composting) planned for the individual counties, assuming (as discussed in Section 3.1) that adequate collection systems are provided for the collection of organic waste. The recycling rate to consider for the WFD 50% target is shown by the purple indicators within this chart. It may be noted that Buzau, Constanta, Harghita and Valcea meet the 2020 WFD 50% recycling target by 2015.

Residual waste treatment is somewhat variable across the country, and is displayed on the chart as the percentage of county MSW waste arisings – i.e. the chart shows the capacity provided, not the rate treated (in the event that there is overprovision of treatment capacity).

The resultant national picture of recycling and composting is as shown in Figure 4-2. Similarly, the resultant national performance against Landfill Directive biodegradable waste diversion obligations is as shown in Figure 4-3. These figures clarify that SOP2 projects (as presented in the alternative scenarios) are needed to meet the Landfill Directive biodegradable targets, and the WFD 50% recycling obligation.

Figure 4-1: Business As Usual Scenario Recycling/Composting Rates and Residual Treatment Provision by County in 2015

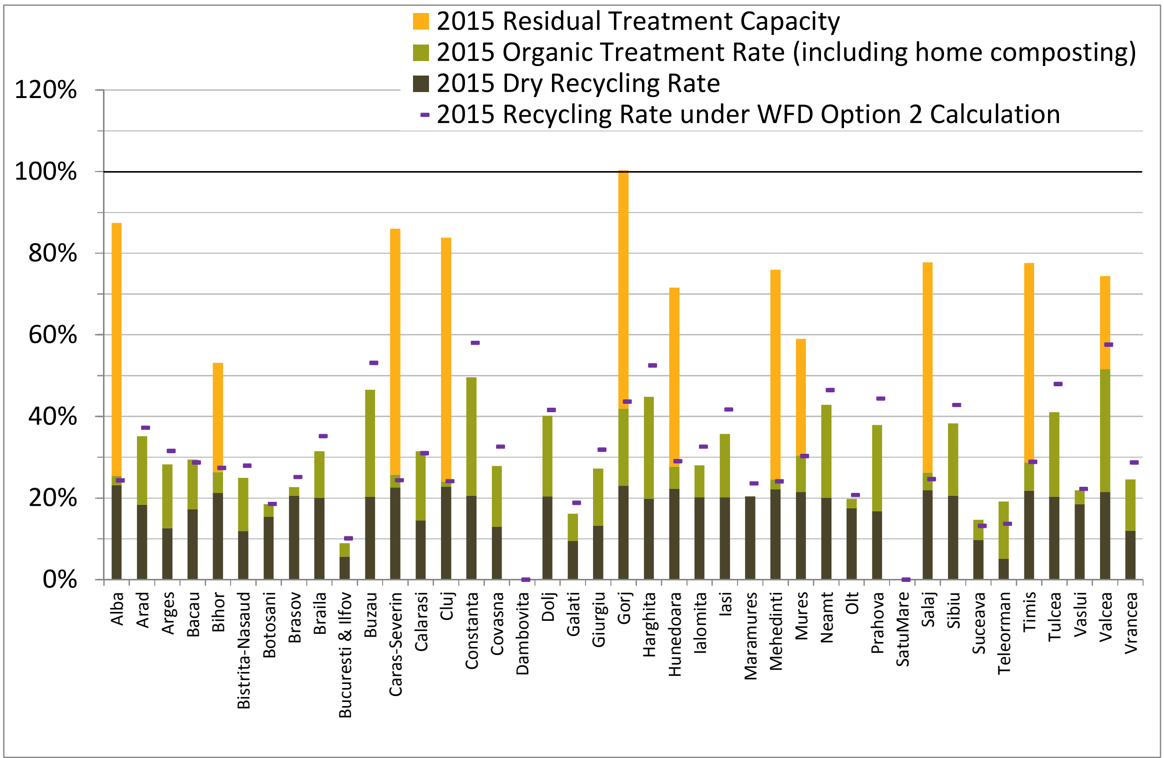


Figure 4-2: Business As Usual Scenario National Recycling & Composting Rates Achieved

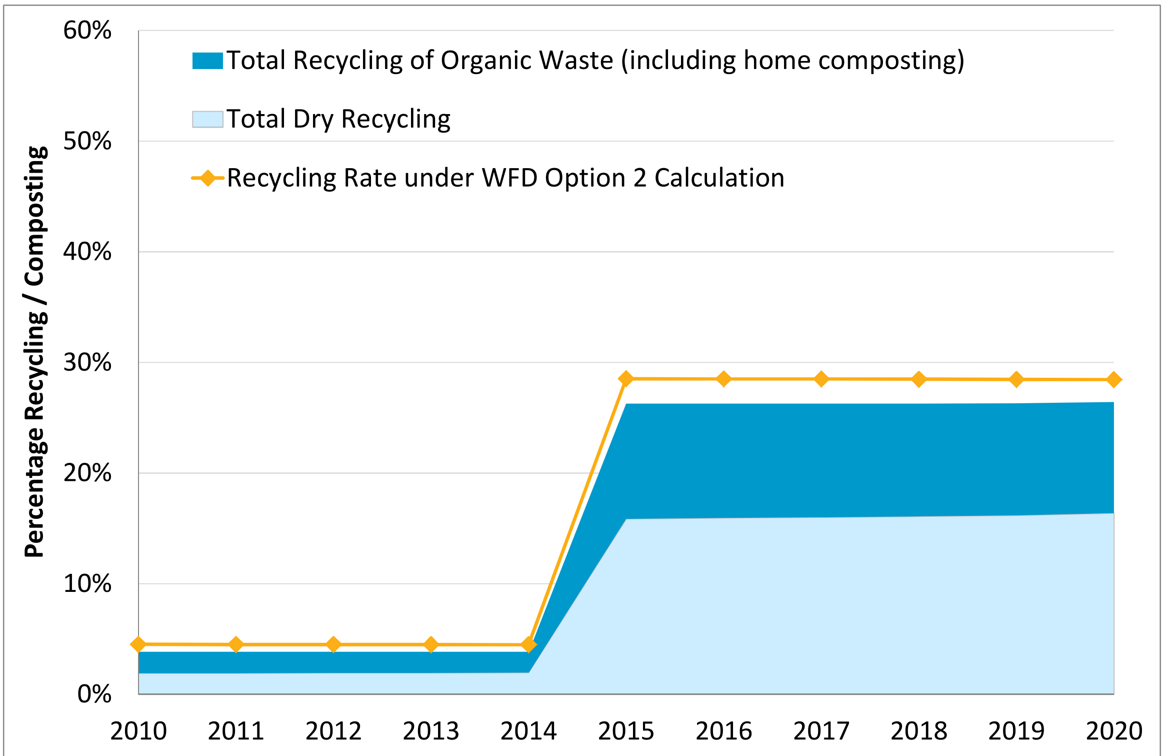
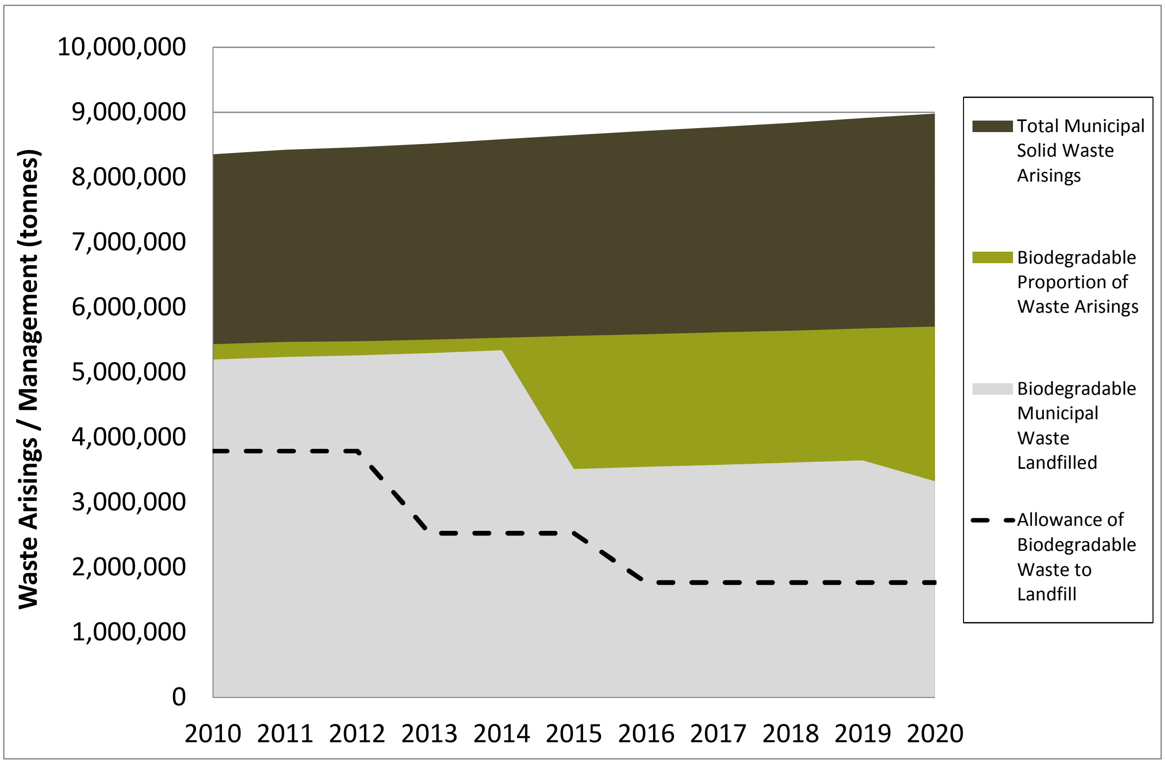


Figure 4-3: Business As Usual Scenario National Performance Against Landfill Directive Targets



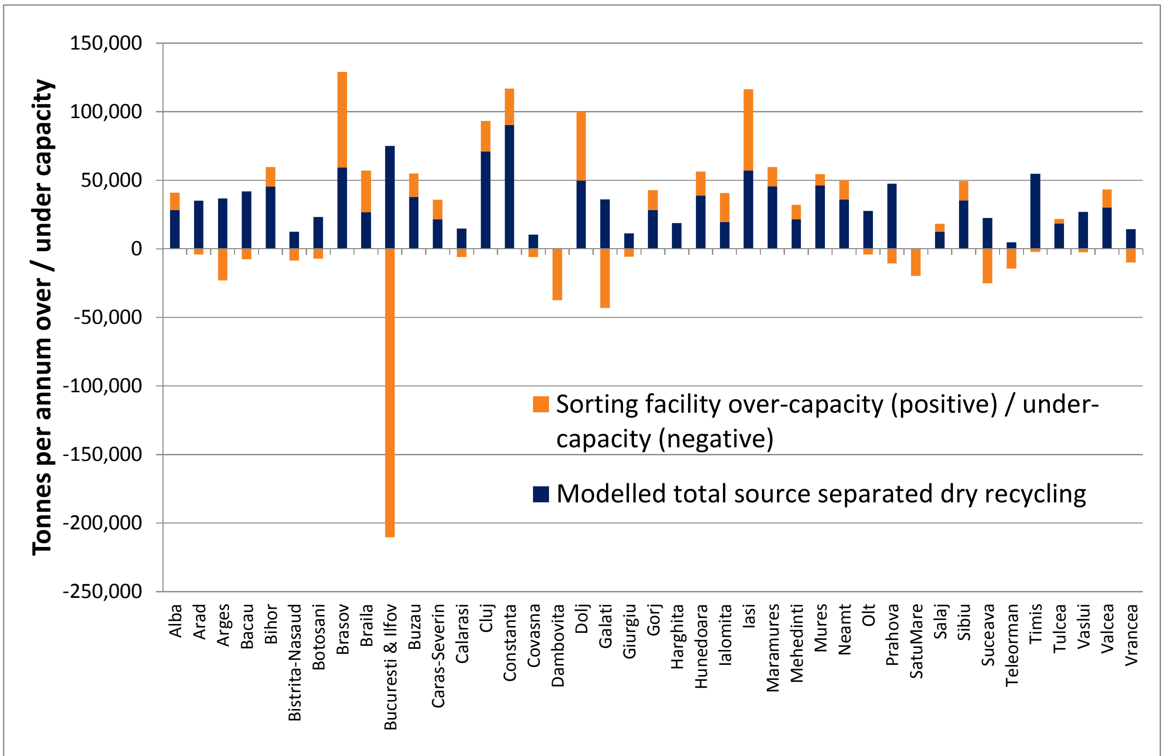
4.1.2 Sorting Facility Assessment (Business As Usual Scenario)

The spreadsheet model enables us to assess collected dry recyling tonnages against the sorting facility capacities that are planned. Acknowledging that the material captures are calculated with some fairly simplistic assumptions (though potentially as robust as any other method), the model projects the tonnages of dry recycling and compares to the planned sorting facility infrastructure in each county. This is shown in Figure 4-4. It would appear that in a reasonable number of cases, the sorting facility annual capacity (indicated by the top of the solid bars) is fairly close to county total dry recycling tonnages (indicated by the top of the blue bars). In a number of cases, the sorting facility capacities may be placing a constraint on the tonnage of recycling that can be collected and processed (as indicated by the negative orange bars); in these cases we limit the dry recycling which is separately collected. However, where a shortfall occurs in practice, it may be possible to double shift sorting facilities, or to transport material to other facilities around the country (which balances well with the overcapacity in other counties in this Business As Usual case).

Some doubt has been raised concerning the size of one sorting facility in Bucharest which is identified in the master plan as a 400,000tonne per annum facility. As is discussed in the baseline report, it has been suggested that this may be overstated and 40,000tpa may be are more feasible capacity for this facility. We adopt this figure within the model which does mean that Bucharest and Ilfov are constrained in their reprocessing capacity and will thus not meet 2015 packaging targets.

In total, there is around 0.65 million tonnes per annum (Mtpa) of sorting capacity currently in place and another 1.2Mtpa planeed for construction through SOP1. This means there is likely to be a total national sorting capcity of 1.85Mtpa. Set against this, we calculate that in total a maximum of 1.85Mt of recycling could be collected in 2015, but sorting facility capacity constraints in individual counties are modelled to limit the actual collected recycling to 1.4Mt (to which a reject rate of 5% is subsequently applied).

Figure 4-4: Assessment of Sorting Facility Capacities against Collected Commingled Recycling (for the Business As Usual Scenario in 2015)



4.1.3 Dashboard of County Performance Against Targets (Business As Usual Scenario)

The mass flow modelling leads to the performance against targets as summarised in Figure 4-5. It should be understood that the representation here is an independent assessment of the performance of individual counties, according to the mass flow spreadsheet model included with this work as Annex 3. This leads to a number of differences compared to the Baseline report which uses data published in the master plans. The data presented here is, thus, a useful objective assessment.

Assuming that the recycling services provided in individual counties are well delivered and operated, most counties would be able to meet packaging directive targets. However, in the modelling of the Business As Usual Scenario, the sorting facility capacity constraint means a number of counties are shown to fall short of the targets, although this could simply be rectified by increasing throughputs of sorting facilities (by double shifting facilities, facility expansion, or simply reducing the need for sorting by engendering collection systems that provide clean uncontaminated materials).

In relation to the future targets, four counties (Busau, Constanta, Harghita and Valcea) are expected to meet the WFD 50% recycling target and a number of others are also set to meet the 2016 Landfill Directive biodegradable diversion target ahead of the deadlines due to good planning in SOP1.

The “WFD 2015 (materials)” column signifies whether counties are understood to be separately collecting the range of dry recycling materials obligated by the framework directive. We assume that only where no project has been scoped is this objective not necessarily met.

Individual notes are included for specific counties in the figure itself.

Figure 4-5: Business As Usual Scenario Modelled Performance Against Targets - Dashboard

County	Packaging Directive Targets			Landfill Directive Biodegradable Tonnage Targets			Waste Framework Directive	
	2015 (targets as 2013)	2020	Notes	2016	2020 (targets as 2016)	**Notes.** Any transfer facility assumed not to reduce county BMW obligations.	2015 (mater-ials)	2020 (50% target)
Alba	Yes	Yes		Yes	Yes	MBT planned for SOP1	Yes	No
Arad	No	No	Sorting under-capacity	No	No		Yes	No
Argeș	No	No	Sorting under-capacity	No	No		Yes	No
Bacău	No	No	Sorting under-capacity	No	No		Yes	No
Bihor	Yes	Yes		No	No	MBT planned for SOP1	Yes	No
Bistrița-Năsăud	No	No	Sorting under-capacity	No	No		Yes	No
Botoșani	No	No	Sorting under-capacity	No	No		Yes	No
Brașov	Yes	Yes		No	No	SOP1 EfW 2020, no composting	Yes	No
Brăila	Yes	Yes		No	No		Yes	No
București & Ilfov	Yes	Yes		No	No	SOP1 EfW 2020, limited compost.	Yes	No
Buzău	Yes	Yes		No	No		Yes	Yes
Caraș-Severin	Yes	Yes		Yes	Yes	MBT planned for SOP1	Yes	No
Călărași	No	No	Sorting under-capacity	No	No		Yes	No
Cluj	Yes	Yes		Yes	Yes	MBT planned for SOP1	Yes	No
Constanța	Yes	Yes		No	No	Recyc. & compost., no treatment	Yes	Yes
Covasna	No	No	Sorting under-capacity	No	No		Yes	No
Dâmbovița	No	No	No SOP1 Project	No	No	No SOP1 Project	No	No
Dolj	Yes	Yes		No	No		Yes	No
Galați	No	No	Sorting under-capacity	No	No		Yes	No
Giurgiu	No	No	Sorting under-capacity	No	No		Yes	No
Gorj	Yes	Yes		Yes	Yes	MBT planned for SOP1	Yes	No
Harghita	Yes	Yes		No	No		Yes	Yes
Hunedoara	Yes	Yes		Yes	Yes	MBT planned for SOP1	Yes	No
Ialomița	Yes	Yes		No	No		Yes	No
Iași	Yes	Yes		No	No		Yes	No
Maramureș	Yes	Yes		No	No	SOP1 capcities unspecified	Yes	No
Mehedinți	Yes	Yes		Yes	Yes	MBT planned for SOP1	Yes	No
Mureș	Yes	Yes		No	No	MBT planned for SOP1	Yes	No
Neamț	Yes	Yes		No	No		Yes	No
Olt	No	No	Sorting under-capacity	No	No		Yes	No
Prahova	No	No	Sorting under-capacity	No	No		Yes	No
Satu Mare	No	No	No SOP1 Project	No	No	No SOP1 Project	No	No
Sălaj	Yes	Yes		Yes	Yes	MBT planned for SOP1	Yes	No
Sibiu	Yes	Yes		No	No		Yes	No
Suceava	No	No	Sorting under-capacity	No	No		Yes	No
Teleorman	No	No	No SOP1 Project	No	No	Some sorting planned -->	Yes	No
Timiş	Yes	Yes		Yes	Yes	MBT planned for SOP1	Yes	No
Tulcea	Yes	Yes		No	No		Yes	No
Vaslui	Yes	No	Waste growth affecting 2020	No	No		Yes	No
Vâlcea	Yes	Yes		Yes	Yes	MBT planned for SOP1	Yes	Yes
Vrancea	No	No	Sorting under-capacity	No	No		Yes	No

Notes: The outlook presented here is as from the mass flow modelling (the model is included as Annex A.3 alongside this report). This differs from the baseline report as discussed at the beginning of this Section (Section 4.1.3).

Vaslui has sufficient sorting capacity to meet the 2013 packaging targets in the displayed year 2015. However, following a period of expected waste growth, by 2020 the sorting capacity is modelled to be a limiting factor to the recycling rate and the target is then missed in this year. Of course, the true quantity of material collected for recycling (and that which is subsequently reprocessed) may not be constrained in this way, but the indication is shown here that the sorting capacity could be a constraint.

4.2 Scenario 1: Organic Waste Collection + AD + Biodrying of Residual Waste

4.2.1 Headline Recycling, Organic Treatment and Disposal Results (Scenario 1)

In the Business As Usual Scenario, a number of counties are modelled to collect over 20% dry recycling, although other counties with more limited sorting capacities are assumed to collect lower quantities, with the national total dry recycling rate at 18% of total MSW. In Scenario 1, additional sorting facility provision for specific counties means that all counties successfully capture over 20% dry recycling (from the total waste stream). The focus on organic waste collection then ensures that all counties meet or exceed the 2020 WFD 50% overall recycling target (according to the Option 2 calculation discussed in Section 1.3), as is demonstrated by the purple indicators in Figure 4-6.

Additional biodrying of residual waste is then proposed for waste associated with the majority of counties (a total of 1.2Mtpa nationally). **This however is not intended to imply that biodrying facilities are located in every county or, even, that every county has to treat its waste**. It is instead suggested that strategic planning and counties working in partnership should deliver this total quantity of residual waste treatment across Romania as a whole so that national targets are met. The location and scale of actual facilities, and the source of waste, can remain flexible as long as 1.2Mtpa of biodrying capacity is provided across the country in total. Nevertheless, for the purposes of this numerical analysis, waste from individual counties can be *'allocated'* to treatment facilities so that the targets can be shown to be met for each county independently.

There are four cases in Figure 4-6 where counties that plan significant levels of residual waste treatment through SOP1 projects will have treatment overcapacity (yellow bars in the chart exceed 100% of waste arisings) once the recycling rates hit the rates required to fulfil the WFD target. This can be seen for Alba, Caras-Severin, Cluj and Gorj. The combined overcapacity, however, equates to a mere 23Ktpa of excess capacity (compared to a total for these facilities of 439Ktpa). As such, this overprovision is not considered a significant issue. Any overcapacity can, in any case, be designated to waste from neighbouring counties.

The evolution in the national recycling and composting rate is shown in Figure 4-7.

National performance against the Landfill Directive is shown in Figure 4-8.

Figure 4-6: Scenario 1 Recycling/Composting Rates and Residual Treatment Provision by County in 2020

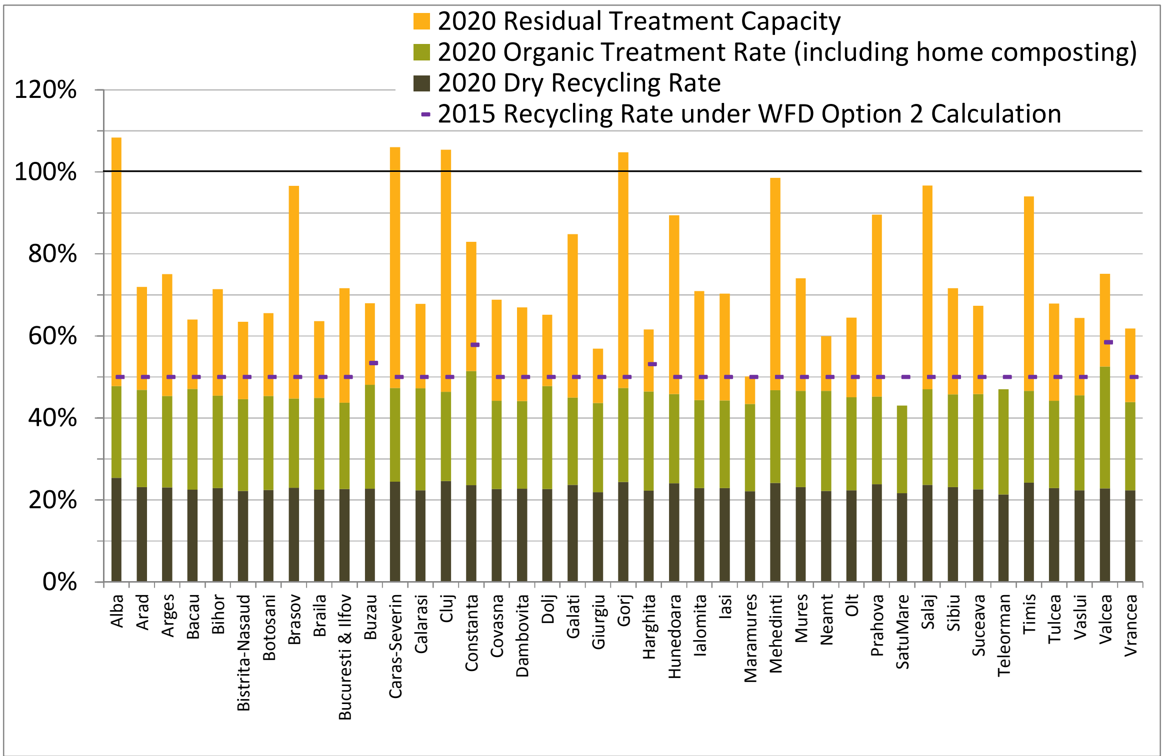


Figure 4-7: Scenario 1 National Recycling and Composting Rates Achieved

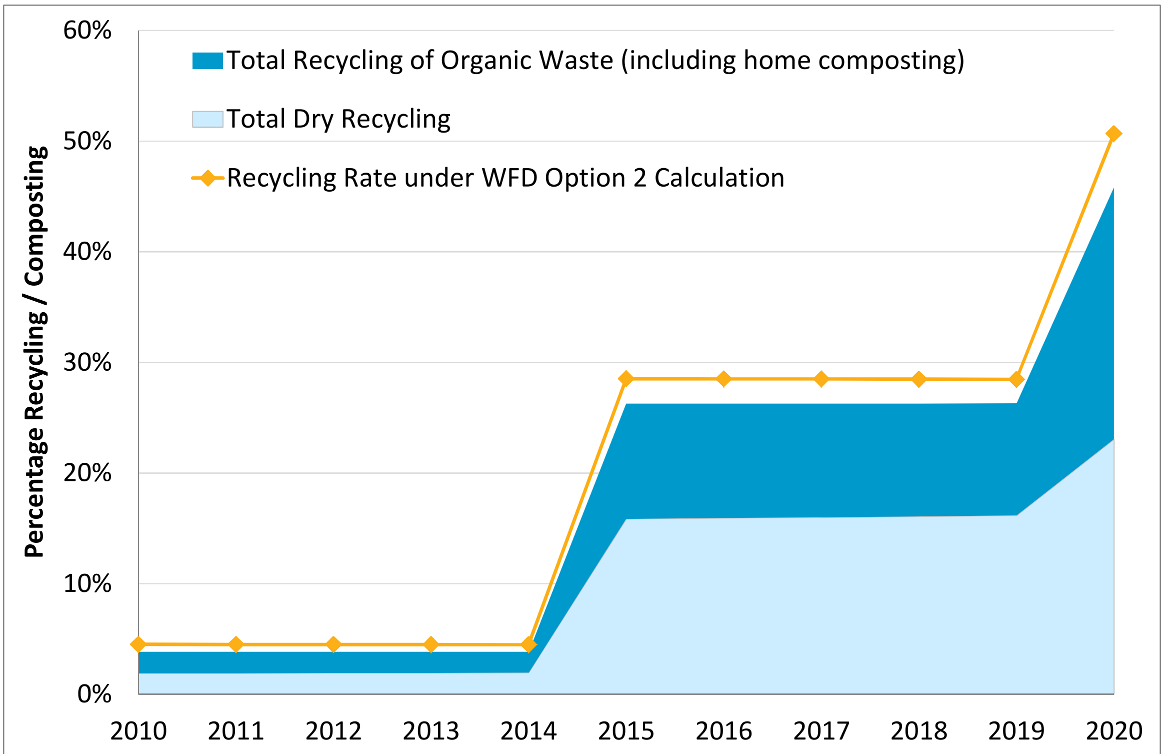
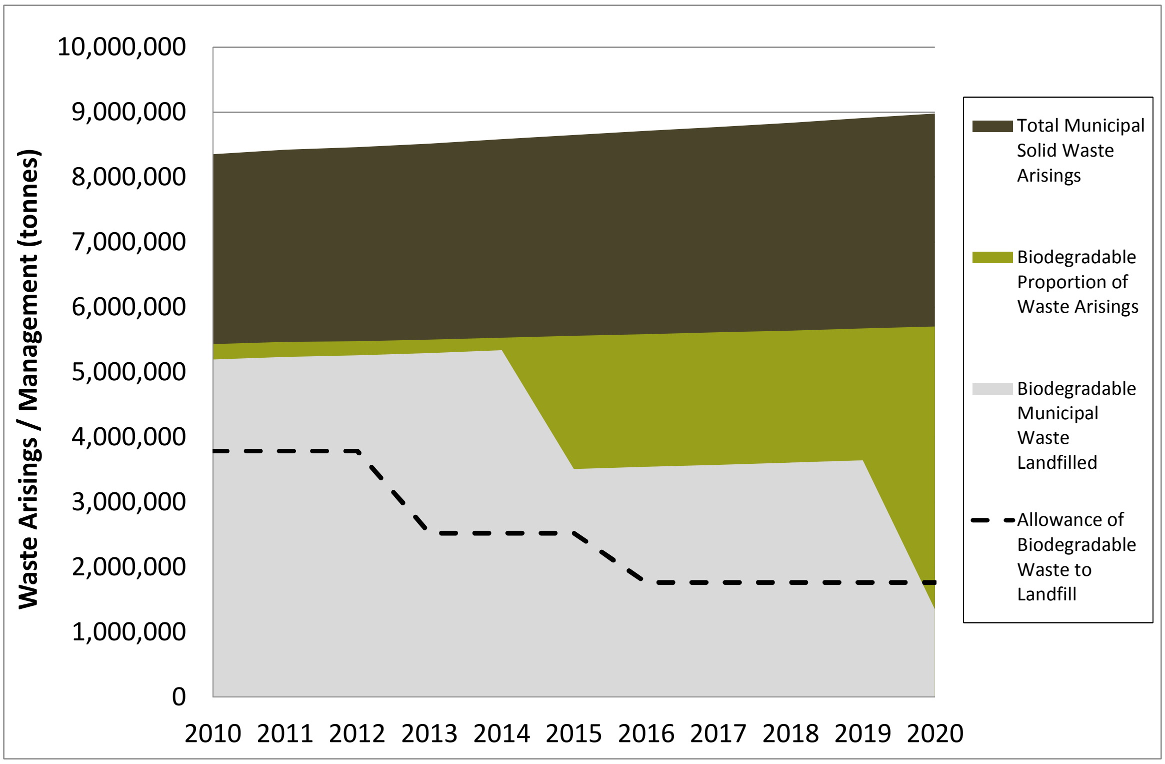


Figure 4-8: Scenario 1 National Performance Against Landfill Directive Targets



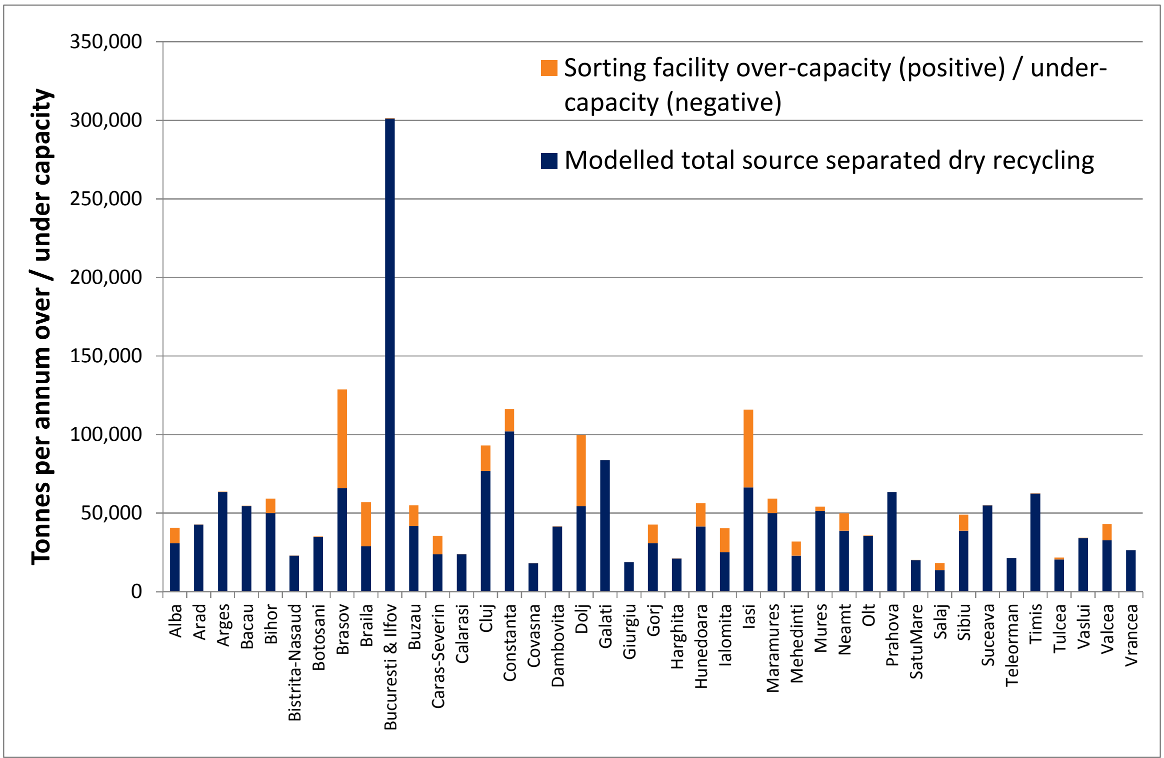
It can be seen from Figure 4-8 that with the facilities modelled under Scenario 1, the national Landfill Directive targets are comfortably satisfied from 2020. The slight overshooting of this target occurs because of individual counties who plan large residual treatment facilities as part of SOP1, which then exceed landfill diversion requirements once the 50% recycling target is also met.

The 50% WFD target is also satisfied as shown in Figure 4-7.

4.2.2 Sorting Facility Assessment (Scenario 1)

Under the modelled scenario for 2020, new provision of sorting facilities has been provided to those counties with insufficient capacity to locally sort their own collected dry recycling. The total new provision in SOP2 is 375,000tpa across the country, bringing the national total up to 2.5Mtpa. As such, the summary shown in Figure 4-9 eliminates the under-capacities previously seen in Figure 4-4, and (for a number of counties at least) the total commingled dry recycling matches the sorting capacity. National overcapacity, however, remains at nearly 500,000tpa. There may therefore be an argument for better linkages between counties for sharing sorting capacities, rather than providing new capacities, or for making better use of existing facilities (either by double shifting sorting lines, or ensuring clean material streams which do not require sorting). However, since the cost of these facilities is low in proportion to full project costs, this is perhaps a less pressing issue.

Figure 4-9: Assessment of Sorting Facility Capacities against Collected Commingled Recycling (for Scenario 1 in 2020)



4.2.3 Dashboard of County Performance Against Targets (Scenario 1)

All counties meet their objectives by 2020 under Scenarios 1, 2 and 3. As such, the 'dashboard' of performance against targets need not be reproduced here (all counties receive green lights for the 2020 targets), yet this can still be found in the spreadsheet model (Annex A.3).

4.3 Scenario 2: Organic Waste Collection + AD + Incineration

The mass flow results and performance against targets for Scenario 2 match those of Scenario 1, so the charts and discussions are not reproduced here. Again, it ought to be noted that the intention for this scenario is treatment facilities (incinerators in this case) in key strategic locations, rather than facilities provided for each county independently. We do not specify here (or in the spreadsheet model) where the facilities ought to be constructed, and merely calculate the total residual waste tonnages for individual counties which need to be incinerated (1.2Mtpa nationally). It would be entirely reasonable under this scenario to incinerate more than the required quantity in one county with an incinerator, and less in other counties, as long as the total national incinerated quantity totalled 1.2Mtpa.

4.4 Scenario 3: Organic Waste Collection + AD + a Mixture of Biodrying and Incineration – Pipeline of Potential Projects

Scenario 3 follows the same recycling and organic waste systems as Scenarios 1 and 2 but to refine the possible options for residual waste treatment. The intention is to identify where CHP incineration may be suitable for the larger cities in the country, with biodrying provided elsewhere. The largest cities, their counties, and the requirement to divert residual waste in order to meet landfill directive targets in future years is summarised in Table 4-1. Possibilities for the residual treatment technologies are also suggested here. This table is, however, intended only to suggest that certain cities may be likely to have both a heat demand and a suitable heating network for which a CHP incinerator could beneficially link into. This may or may not be the case for the cities described here (and indeed other cities that haven't been selected may be suitable instead). Further work is needed to refine these options and scope up the true potential for individual projects, ideally whilst taking into account quantified social, environmental, local economic and other factors. The projection here, however, is a conceptual presentation of a project pipeline that includes both incineration and biodrying MBT.

For the facilities proposed, we have been careful not to allow incinerator capacities to exceed the total tonnage of available residual waste in a host county (even where a county is shown as operating in partnership with a neighbour). This prevents waste from *having* to be transported across borders (though it does not necessarily preclude it). For example:

- The proposed Prahova incinerator (for instance) is in a county with 166ktpa of residual waste;
- Prahova itself must divert 123ktpa of residual waste;
- Dambovita must divert 42ktpa;
- A partnership between the two is proposed with Prahova building a 165ktpa incinerator;
- Prahova incinerates all but 1ktpa of its residual waste;
- Dambovita landfills all of its residual waste;
- Between them however, they are delivering to target in partnership.

This principle that one county exceeds its targets while another county does not comply with the targets, but together they do comply was one of the basic rules used to develop the Regional Waste Management Plans (RWMPs). The implementation of such a rule will require careful attention and assessment in terms of:

- Calculation of tariffs for each of the counties;
- Impact on waste management plans (local and regional);

- Impact on environmental decisions with regards to associated planning.

In addition to this approach to identify the location and scale of incinerators, we have also sketched out the possible location and scale of both biodrying and AD facilities, according to the demand for treatment in each county, but also considering a sensible minimum commercial plant size for these facilities (30Ktpa for biodrying and 20Ktpa for AD). The summary *pipeline* of potential projects is, thus, given in Table 4-2.

In total, this scenario is modelled with 1,140Ktpa of new AD facilities, 550Ktpa of new biodrying facilities, and 660Ktpa of new incineration.

The waste flow projections for Scenario 3, by design, meet targets in the same way as Scenarios 1 and 2. As such, the charts, tables and discussions included for the other Scenarios above are not reproduced here.

Table 4-1: Scenario 3 Main Facility Siting (figures rounded)

Ranked City Size	City	County	SOP1 Project	SOP2 Project required?	Minimum Residual Waste Requiring Diversion (2020)	Total County Residual Waste (2020)	Incinerator/Biodrying Facility Covering Diversion Requirement for Counties…	Incinerator/Biodrying Facility Size (tonnes per annum)
1	Bucharest	Bucharest & Ilfov (combined)	✓ Incinerator	×	0	774,000	-	-
2	Iasi	Iasi	×	✓ Incinerator	76,000	175,000	Vaslui, Neamt, Bacau	168,000
3	Timisoara	Timis	✓ MBT	×	0	158,000	-	-
4	Cluj-Napoca	Cluj	✓ MBT	×	0	197,000	-	-
5	Constanta	Constanta	×	✓ Incinerator	139,000	234,000	Tulcea	160,000
6	Craiova	Dolj	×	✓ Biodrying	43,000	132,000	Dolj	43,000
7	Galati	Galati	×	✓ Incinerator	146,000	218,000	Vrancea	166,000
8	Brasov	Brasov	✓ Incinerator	×	0	169,000	-	-
9	Ploieşti	Prahova	×	✓ Incinerator	123,000	166,000	Dambovita	165,000
10	Braila	Braila	×	✓ Biodrying	25,000	73,000	(Facility at Buzau)	(Buzau 75,000)

Table 4-2: Pipeline of AD, Biodrying and Incineration Facilities for SOP2

County	SOP2 Proposed AD Plants (Scenario 3)	SOP2 Proposed Biodrying Plants (Scenario 3)	SOP2 Proposed Incinerators (Scenario 3)
Alba	37,740 inc Sibiu	-	-
Arad	To Timis (14,168)	49,013	-
Argeș	20,328	87,323	-
Bacău	32,247	-	At Iasi (40,333)
Bihor	40,593	-	-
Bistrița-Năsăud	To Mures (10,593)	At Mures (20,231)	-
Botoșani	33,043	32,986	-
Brașov	65,283 inc. Covasna	-	-
Brăila	To Galati (14,985)	At Buzau (25,123)	-
București & Ilfov	244,973	-	-
Buzău	-	75,261 inc. Braila and Vrancea	-
Caraș-Severin	21,570	-	-
Călărași	To Ialomita (10,562)	At Ialomita (22,949)	-
Cluj	84,360 inc. Salaj	-	-
Constanța	-	-	160,000 inc. Tulcea
Covasna	To Brasov (6,075)	At Harghita (20,651)	-
Dâmbovița	43,283 inc. Prahova	-	At Prahova (41,697)
Dolj	To Olt (13,901)	43,157	-
Galați	57,987 inc Tulcea	-	166,000 inc. Vrancea
Giurgiu	To Ialomita (7,350)	At Ialomita (11,774)	-
Gorj	To Mehedinti (6,216)	-	-
Harghita	-	35,443 inc. Covasna	-
Hunedoara	31,157	-	-
Ialomița	35,277 inc. Calarasi and Giurgiu	65,644 (inc. Calarasi and Giurgiu	-
Iași	25,161 inc. Neamt	-	168,000 inc. Vaslui, Neamt, and Bacau
Maramureș	48,819	At Suceava (15,474)	-
Mehedinți	21,362	54,800	-
Mureș	35,343	-	-
Neamț	To Iasi (3,202)	-	At Iasi (22,977)
Olt	61,017 inc. Dolj and Teleorman	32,319	-
Prahova	To Dambovita (2,281)	-	165,000 inc, Dambovita
Satu Mare	20,000	-	-
Sălaj	To Cluj (12,346)	-	-
Sibiu	To Alba (9,444)	45,930	-
Suceava	47,804	70,325 (inc. Maramures)	-
Teleorman	To Olt (12,933)	-	-
Timiş	58,819 (inc. Arad)	-	-
Tulcea	To Galati (1,065)	-	At Constanta (21,156)
Vaslui	32,064	-	At Iasi (28,701)
Vâlcea	-	-	-
Vrancea	To Bazau (11,497)	-	At Galati (20,928)

Note: The facilities proposed for a group of counties do not require transporting waste across counties, but the counties have been grouped for the purpose of this study in order to meet the targets (see commentary given above)

5 Financial Results

5.1 Capital Costs

The capital investments for the next programming period are shown in the following tables.

As well as results for the three modelling scenarios, we also include results for the Business As Usual Scenario (i.e. no new recycling, composting or residual treatment infrastructure projects are taken forward by 2020) since a number of non-compliant landfills still remain to be decommissioned, additional landfill capacity will be required, and waste collection (for the seven years of the next programming period) will operate somewhat differently to the main Scenarios. This Business As Usual Scenario, therefore, provides a point of reference which shows that continued investment in waste related services is needed even without the long term strategic planning that aims to meet 2020 objectives. The Baseline is therefore the non-compliant counterfactual to Scenarios 1, 2 and 3 which demonstrates that even in a *'running to stand still'* situation, significant investment costs are incurred.

The Business As Usual (BaU) Scenario, therefore, in Table 5-2 shows waste collection capital costs of €721 million over 7 years (noting that the equivalent figure to meet targets under the other scenarios is only marginally increased to €753 million) as well as a small amount for the remaining landfill closures (projected to cost around €9 million) and €92 million for new landfills. A cost is also included for technical assistance and other such costs at 15% of the total, as is done with Scenarios 1 to 3.

The investments required for Scenario 1 are shown in Table 5-3. In this case, €231 million of investment is made in biodrying MBT facilities. The costs for new landfills in this case, due to the increased recycling and residual waste treatment, are reduced to €68 million. Further investment totalling €399 million is made in AD facilities (this figure is common to Scenarios 1, 2 and 3). The other elements (project support, sorting facilities and landfill closure) bring the total capital costs calculated for Scenario 1 (excluding collection) to €0.86 billion.

The investments required for Scenario 2 are shown in Table 5-4. In this case, the same investment in AD facilities, landfill closure and new landfills is required. However, the higher capital costs associated with providing CHP incineration capacity for treatment of the required amount of residual waste requires capital expense of €930 million. It must be stressed that although costs are shown for individual counties, the regional facilities envisaged under this scenario are to be located in strategic (but unspecified) sites. In total, Scenario 2 leads to a headline capital cost figure excluding collection of €1.67 billion – the same level of performance but considerably more costly than Scenario 1.

Scenario 3 balances residual treatment between incineration and biodrying MBT in more or less equal proportion. The capital costs, thus fall mid way between Scenarios 1 and 2 with a projected figure of €1.31 billion.

Scenario 3 is perhaps the more realistic of the three modelled as it allows diversity in residual waste treatment around the country to fit with local needs. Incineration is likely to be more suitable in higher populated cities, especially if district heating networks are already in place, and a demand for heat exists. Biodrying, with SRF generated in response to demand from cement kilns, is likely to be the preferred technology elsewhere. The project pipeline hinted at in Table 4-1 and suggested in the county sheet appendices is one such possible approach, although further work will be needed to justify or amend these selections.

In addition to the full cost tables for individual counties (Table 5-2 to Table 5-5), we also provide a summary of all scenarios considered here in Table 5-1. It can be seen that all Scenarios contain the same investments in sorting plants and AD facilities since the 50% recycling target (in line with the discussion in Section 1.3) which these systems help towards is a prerequisite of all Scenarios. Total costs columns are shown both with and without the collection capital costs.

Table 5-1: Summary Capital Cost Assessment for All Scenarios

Figures in million Euros	SOP2 Capital Investments: Summary									
	Collection (Total)	Sorting	AD of source separated organics	Biodrying	Incin-eration	Landfill closure	New landfills	Project support	Total Excluding Collection	Total Including Collection
BaU	€ 721	€ 0	€ 0	€ 0	€ 0	€ 9	€ 92	€ 15	€ 116	€ 837
Scenario 1	€ 753	€ 45	€ 399	€ 231	€ 0	€ 9	€ 68	€ 113	€ 864	€ 1,617
Scenario 2	€ 753	€ 45	€ 399	€ 0	€ 929	€ 9	€ 68	€ 217	€ 1,667	€ 2,420
Scenario 3	€ 753	€ 45	€ 399	€ 102	€ 520	€ 9	€ 68	€ 171	€ 1,314	€ 2,066

Table 5-2: Business As Usual Scenario Capital Cost Assessment (maintaining existing waste management systems beyond 2015)

Figures in million Euros	SOP2 Capital Investments: BaU									
	Collection (Total)	Sorting	AD of source separated organics	Biodrying	Incin-eration	Landfill closure	New landfills	Project support	Total Excluding Collection	Total Including Collection
Alba	€ 11	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 16
Arad	€ 15	€ 0.0	€ 0	€ 0	€ 0	€ 1.2	€ 0	€ 0	€ 1	€ 17
Arges	€ 24	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 29
Bacau	€ 19	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 24
Bihor	€ 18	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 18
Bistrita-Nasaud	€ 9	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 13
Botosani	€ 13	€ 0.0	€ 0	€ 0	€ 0	€ 2.5	€ 4	€ 1	€ 7	€ 20
Brasov	€ 24	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 24
Braila	€ 11	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 11
Bucuresti & Ilfov	€ 108	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 108
Buzau	€ 16	€ 0.0	€ 0	€ 0	€ 0	€ 1.2	€ 4	€ 1	€ 6	€ 22
Caras-Severin	€ 8	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 13
Calarasi	€ 9	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 13
Cluj	€ 27	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 32
Constanta	€ 40	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 45
Covasna	€ 7	€ 0.0	€ 0	€ 0	€ 0	€ 1.2	€ 4	€ 1	€ 6	€ 13
Dambovita	€ 15	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 15
Dolj	€ 19	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 19
Galati	€ 31	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 36
Giurgiu	€ 8	€ 0.0	€ 0	€ 0	€ 0	€ 1.2	€ 4	€ 1	€ 6	€ 14
Gorj	€ 12	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 12
Harghita	€ 8	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 13
Hunedoara	€ 15	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 15
Ialomita	€ 9	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 9
Iasi	€ 26	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 26
Maramures	€ 18	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 23
Mehedinti	€ 8	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 8
Mures	€ 18	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 23
Neamt	€ 14	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 19
Olt	€ 13	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 18
Prahova	€ 25	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 25
SatuMare	€ 7	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 7
Salaj	€ 5	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 5
Sibiu	€ 14	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 14
Suceava	€ 20	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 24
Teleorman	€ 8	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 8
Timis	€ 22	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 27
Tulcea	€ 8	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 13
Vaslui	€ 12	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 0	€ 12
Valcea	€ 13	€ 0.0	€ 0	€ 0	€ 0	€ 1.2	€ 4	€ 1	€ 6	€ 19
Vrancea	€ 10	€ 0.0	€ 0	€ 0	€ 0	€ 0.0	€ 4	€ 1	€ 5	€ 15
All Counties	€ 721	€ 0	€ 0	€ 0	€ 0	€ 9	€ 92	€ 15	€ 116	€ 837

Table 5-3: Scenario 1 Capital Cost Assessment for SOP2 Investments

Figures in million Euros	SOP2 Capital Investments: Scenario 1									
	Collection (Total)	Sorting	AD of source separated organics	Biodrying	Incin-eration	Landfill closure	New landfills	Project support	Total Excluding Collection	Total Including Collection
Alba	€ 12	€ 0.0	€ 10	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 11	€ 23
Arad	€ 16	€ 0.6	€ 5	€ 9	€ 0	€ 1.2	€ 0	€ 2	€ 18	€ 34
Arges	€ 25	€ 2.3	€ 7	€ 16	€ 0	€ 0.0	€ 4	€ 4	€ 34	€ 59
Bacau	€ 20	€ 1.1	€ 11	€ 8	€ 0	€ 0.0	€ 0	€ 3	€ 23	€ 43
Bihor	€ 19	€ 0.0	€ 14	€ 0	€ 0	€ 0.0	€ 0	€ 2	€ 16	€ 36
Bistrita-Nasaud	€ 9	€ 0.9	€ 4	€ 4	€ 0	€ 0.0	€ 4	€ 2	€ 14	€ 23
Botosani	€ 14	€ 1.0	€ 12	€ 6	€ 0	€ 2.5	€ 4	€ 4	€ 29	€ 43
Brasov	€ 25	€ 0.0	€ 21	€ 0	€ 0	€ 0.0	€ 0	€ 3	€ 24	€ 49
Braila	€ 11	€ 0.0	€ 5	€ 5	€ 0	€ 0.0	€ 0	€ 1	€ 11	€ 23
Bucuresti & Ilfov	€ 115	€ 19.0	€ 86	€ 0	€ 0	€ 0.0	€ 0	€ 16	€ 121	€ 236
Buzau	€ 16	€ 0.0	€ 0	€ 7	€ 0	€ 1.2	€ 4	€ 2	€ 14	€ 31
Caras-Severin	€ 9	€ 0.0	€ 8	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 9	€ 18
Calarasi	€ 9	€ 0.8	€ 4	€ 4	€ 0	€ 0.0	€ 0	€ 1	€ 10	€ 19
Cluj	€ 29	€ 0.0	€ 25	€ 0	€ 0	€ 0.0	€ 0	€ 4	€ 29	€ 58
Constanta	€ 40	€ 0.0	€ 0	€ 27	€ 0	€ 0.0	€ 4	€ 5	€ 36	€ 76
Covasna	€ 7	€ 0.6	€ 2	€ 4	€ 0	€ 1.2	€ 4	€ 2	€ 14	€ 21
Dambovita	€ 16	€ 3.5	€ 14	€ 8	€ 0	€ 0.0	€ 0	€ 4	€ 30	€ 46
Dolj	€ 19	€ 0.0	€ 5	€ 8	€ 0	€ 0.0	€ 0	€ 2	€ 15	€ 34
Galati	€ 33	€ 4.0	€ 20	€ 28	€ 0	€ 0.0	€ 4	€ 8	€ 65	€ 98
Giurgiu	€ 8	€ 0.6	€ 3	€ 2	€ 0	€ 1.2	€ 4	€ 2	€ 12	€ 20
Gorj	€ 12	€ 0.0	€ 2	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 3	€ 14
Harghita	€ 8	€ 0.2	€ 0	€ 3	€ 0	€ 0.0	€ 0	€ 0	€ 3	€ 12
Hunedoara	€ 16	€ 0.0	€ 11	€ 0	€ 0	€ 0.0	€ 0	€ 2	€ 13	€ 28
Ialomita	€ 10	€ 0.0	€ 6	€ 6	€ 0	€ 0.0	€ 0	€ 2	€ 14	€ 24
Iasi	€ 26	€ 0.0	€ 8	€ 15	€ 0	€ 0.0	€ 0	€ 3	€ 26	€ 52
Maramures	€ 20	€ 0.0	€ 17	€ 3	€ 0	€ 0.0	€ 4	€ 4	€ 28	€ 47
Mehedinti	€ 9	€ 0.0	€ 7	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 9	€ 17
Mures	€ 19	€ 0.0	€ 12	€ 0	€ 0	€ 0.0	€ 4	€ 2	€ 19	€ 38
Neamt	€ 15	€ 0.0	€ 1	€ 4	€ 0	€ 0.0	€ 4	€ 1	€ 11	€ 26
Olt	€ 14	€ 0.7	€ 12	€ 6	€ 0	€ 0.0	€ 4	€ 3	€ 26	€ 40
Prahova	€ 25	€ 1.3	€ 1	€ 24	€ 0	€ 0.0	€ 0	€ 4	€ 30	€ 55
SatuMare	€ 8	€ 1.7	€ 7	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 10	€ 18
Salaj	€ 5	€ 0.0	€ 4	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 5	€ 10
Sibiu	€ 15	€ 0.0	€ 3	€ 9	€ 0	€ 0.0	€ 0	€ 2	€ 14	€ 28
Suceava	€ 21	€ 2.7	€ 17	€ 10	€ 0	€ 0.0	€ 4	€ 5	€ 39	€ 60
Teleorman	€ 8	€ 1.4	€ 5	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 7	€ 15
Timis	€ 24	€ 0.7	€ 16	€ 0	€ 0	€ 0.0	€ 4	€ 3	€ 23	€ 47
Tulcea	€ 8	€ 0.0	€ 0	€ 4	€ 0	€ 0.0	€ 4	€ 1	€ 10	€ 18
Vaslui	€ 13	€ 0.6	€ 11	€ 6	€ 0	€ 0.0	€ 0	€ 3	€ 20	€ 33
Valcea	€ 13	€ 0.0	€ 0	€ 0	€ 0	€ 1.2	€ 4	€ 1	€ 6	€ 19
Vrancea	€ 11	€ 1.0	€ 4	€ 4	€ 0	€ 0.0	€ 4	€ 2	€ 15	€ 26
All Counties	€ 753	€ 45	€ 399	€ 231	€ 0	€ 9	€ 68	€ 113	€ 864	€ 1,617

Note: AD and biodrying figures for individual counties represent the relative tonnages requiring treatment in order for each county to meet targets. These figures are not to imply a large number of small facilities specific to individual counties. The location and scale of actual facilities are not specified for Scenario 1. A potential 'pipeline' of suitably scaled facilities is instead proposed for Scenario 3.

Table 5-4: Scenario 2 Capital Cost Assessment for SOP2 Investments

Figures in million Euros	SOP2 Capital Investments: Scenario 2									
	Collection (Total)	Sorting	AD of source separated organics	Biodrying	Incin-eration	Landfill closure	New landfills	Project support	Total Excluding Collection	Total Including Collection
Alba	€ 12	€ 0.0	€ 10	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 11	€ 23
Arad	€ 16	€ 0.6	€ 5	€ 0	€ 37	€ 1.2	€ 0	€ 7	€ 50	€ 66
Arges	€ 25	€ 2.3	€ 7	€ 0	€ 65	€ 0.0	€ 4	€ 12	€ 91	€ 115
Bacau	€ 20	€ 1.1	€ 11	€ 0	€ 32	€ 0.0	€ 0	€ 7	€ 51	€ 71
Bihor	€ 19	€ 0.0	€ 14	€ 0	€ 0	€ 0.0	€ 0	€ 2	€ 16	€ 36
Bistrita-Nasaud	€ 9	€ 0.9	€ 4	€ 0	€ 15	€ 0.0	€ 4	€ 4	€ 27	€ 36
Botosani	€ 14	€ 1.0	€ 12	€ 0	€ 25	€ 2.5	€ 4	€ 7	€ 50	€ 64
Brasov	€ 25	€ 0.0	€ 21	€ 0	€ 0	€ 0.0	€ 0	€ 3	€ 24	€ 49
Braila	€ 11	€ 0.0	€ 5	€ 0	€ 19	€ 0.0	€ 0	€ 4	€ 28	€ 39
Bucuresti & Ilfov	€ 115	€ 19.0	€ 86	€ 0	€ 0	€ 0.0	€ 0	€ 16	€ 121	€ 236
Buzau	€ 16	€ 0.0	€ 0	€ 0	€ 29	€ 1.2	€ 4	€ 5	€ 39	€ 56
Caras-Severin	€ 9	€ 0.0	€ 8	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 9	€ 18
Calarasi	€ 9	€ 0.8	€ 4	€ 0	€ 17	€ 0.0	€ 0	€ 3	€ 25	€ 34
Cluj	€ 29	€ 0.0	€ 25	€ 0	€ 0	€ 0.0	€ 0	€ 4	€ 29	€ 58
Constanta	€ 40	€ 0.0	€ 0	€ 0	€ 110	€ 0.0	€ 4	€ 17	€ 131	€ 171
Covasna	€ 7	€ 0.6	€ 2	€ 0	€ 15	€ 1.2	€ 4	€ 4	€ 27	€ 34
Dambovita	€ 16	€ 3.5	€ 14	€ 0	€ 33	€ 0.0	€ 0	€ 8	€ 58	€ 75
Dolj	€ 19	€ 0.0	€ 5	€ 0	€ 32	€ 0.0	€ 0	€ 6	€ 43	€ 62
Galati	€ 33	€ 4.0	€ 20	€ 0	€ 115	€ 0.0	€ 4	€ 21	€ 164	€ 197
Giurgiu	€ 8	€ 0.6	€ 3	€ 0	€ 9	€ 1.2	€ 4	€ 3	€ 20	€ 28
Gorj	€ 12	€ 0.0	€ 2	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 3	€ 14
Harghita	€ 8	€ 0.2	€ 0	€ 0	€ 11	€ 0.0	€ 0	€ 2	€ 13	€ 21
Hunedoara	€ 16	€ 0.0	€ 11	€ 0	€ 0	€ 0.0	€ 0	€ 2	€ 13	€ 28
Ialomita	€ 10	€ 0.0	€ 6	€ 0	€ 23	€ 0.0	€ 0	€ 4	€ 34	€ 44
Iasi	€ 26	€ 0.0	€ 8	€ 0	€ 60	€ 0.0	€ 0	€ 10	€ 78	€ 104
Maramures	€ 20	€ 0.0	€ 17	€ 0	€ 12	€ 0.0	€ 4	€ 5	€ 38	€ 57
Mehedinti	€ 9	€ 0.0	€ 7	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 9	€ 17
Mures	€ 19	€ 0.0	€ 12	€ 0	€ 0	€ 0.0	€ 4	€ 2	€ 19	€ 38
Neamt	€ 15	€ 0.0	€ 1	€ 0	€ 18	€ 0.0	€ 4	€ 3	€ 27	€ 41
Olt	€ 14	€ 0.7	€ 12	€ 0	€ 24	€ 0.0	€ 4	€ 6	€ 47	€ 61
Prahova	€ 25	€ 1.3	€ 1	€ 0	€ 97	€ 0.0	€ 0	€ 15	€ 114	€ 139
SatuMare	€ 8	€ 1.7	€ 7	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 10	€ 18
Salaj	€ 5	€ 0.0	€ 4	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 5	€ 10
Sibiu	€ 15	€ 0.0	€ 3	€ 0	€ 34	€ 0.0	€ 0	€ 6	€ 43	€ 58
Suceava	€ 21	€ 2.7	€ 17	€ 0	€ 41	€ 0.0	€ 4	€ 10	€ 74	€ 95
Teleorman	€ 8	€ 1.4	€ 5	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 7	€ 15
Timis	€ 24	€ 0.7	€ 16	€ 0	€ 0	€ 0.0	€ 4	€ 3	€ 23	€ 47
Tulcea	€ 8	€ 0.0	€ 0	€ 0	€ 17	€ 0.0	€ 4	€ 3	€ 24	€ 32
Vaslui	€ 13	€ 0.6	€ 11	€ 0	€ 23	€ 0.0	€ 0	€ 5	€ 40	€ 53
Valcea	€ 13	€ 0.0	€ 0	€ 0	€ 0	€ 1.2	€ 4	€ 1	€ 6	€ 19
Vrancea	€ 11	€ 1.0	€ 4	€ 0	€ 16	€ 0.0	€ 4	€ 4	€ 29	€ 40
All Counties	€ 753	€ 45	€ 399	€ 0	€ 929	€ 9	€ 68	€ 217	€ 1,667	€ 2,420

Note: AD and incineration figures for individual counties represent the relative tonnages requiring treatment in order for each county to meet targets. These figures are not to imply a large number of small facilities specific to individual counties. The location and scale of actual facilities are not specified for Scenario 2. A potential 'pipeline' of suitably scaled facilities is instead proposed for Scenario 3.

Table 5-5: Scenario 3 Capital Cost Assessment for SOP2 Investments

Figures in million Euros	SOP2 Capital Investments: Scenario 3									
	Collection (Total)	Sorting	AD of source separated organics	Biodrying	Incin-eration	Landfill closure	New landfills	Project support	Total Excluding Collection	Total Including Collection
Alba	€ 12	€ 0.0	€ 10	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 11	€ 23
Arad	€ 16	€ 0.6	€ 5	€ 9	€ 0	€ 1.2	€ 0	€ 2	€ 18	€ 34
Arges	€ 25	€ 2.3	€ 7	€ 16	€ 0	€ 0.0	€ 4	€ 4	€ 34	€ 59
Bacau	€ 20	€ 1.1	€ 11	€ 0	€ 32	€ 0.0	€ 0	€ 7	€ 51	€ 71
Bihor	€ 19	€ 0.0	€ 14	€ 0	€ 0	€ 0.0	€ 0	€ 2	€ 16	€ 36
Bistrita-Nasaud	€ 9	€ 0.9	€ 4	€ 4	€ 0	€ 0.0	€ 4	€ 2	€ 14	€ 23
Botosani	€ 14	€ 1.0	€ 12	€ 6	€ 0	€ 2.5	€ 4	€ 4	€ 29	€ 43
Brasov	€ 25	€ 0.0	€ 21	€ 0	€ 0	€ 0.0	€ 0	€ 3	€ 24	€ 49
Braila	€ 11	€ 0.0	€ 5	€ 5	€ 0	€ 0.0	€ 0	€ 1	€ 11	€ 23
Bucuresti & Ilfov	€ 115	€ 19.0	€ 86	€ 0	€ 0	€ 0.0	€ 0	€ 16	€ 121	€ 236
Buzau	€ 16	€ 0.0	€ 0	€ 7	€ 0	€ 1.2	€ 4	€ 2	€ 14	€ 31
Caras-Severin	€ 9	€ 0.0	€ 8	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 9	€ 18
Calarasi	€ 9	€ 0.8	€ 4	€ 4	€ 0	€ 0.0	€ 0	€ 1	€ 10	€ 19
Cluj	€ 29	€ 0.0	€ 25	€ 0	€ 0	€ 0.0	€ 0	€ 4	€ 29	€ 58
Constanta	€ 40	€ 0.0	€ 0	€ 0	€ 110	€ 0.0	€ 4	€ 17	€ 131	€ 171
Covasna	€ 7	€ 0.6	€ 2	€ 4	€ 0	€ 1.2	€ 4	€ 2	€ 14	€ 21
Dambovita	€ 16	€ 3.5	€ 14	€ 0	€ 33	€ 0.0	€ 0	€ 8	€ 58	€ 75
Dolj	€ 19	€ 0.0	€ 5	€ 8	€ 0	€ 0.0	€ 0	€ 2	€ 15	€ 34
Galati	€ 33	€ 4.0	€ 20	€ 0	€ 115	€ 0.0	€ 4	€ 21	€ 164	€ 197
Giurgiu	€ 8	€ 0.6	€ 3	€ 2	€ 0	€ 1.2	€ 4	€ 2	€ 12	€ 20
Gorj	€ 12	€ 0.0	€ 2	€ 0	€ 0	€ 0.0	€ 0	€ 0	€ 3	€ 14
Harghita	€ 8	€ 0.2	€ 0	€ 3	€ 0	€ 0.0	€ 0	€ 0	€ 3	€ 12
Hunedoara	€ 16	€ 0.0	€ 11	€ 0	€ 0	€ 0.0	€ 0	€ 2	€ 13	€ 28
Ialomita	€ 10	€ 0.0	€ 6	€ 6	€ 0	€ 0.0	€ 0	€ 2	€ 14	€ 24
Iasi	€ 26	€ 0.0	€ 8	€ 0	€ 60	€ 0.0	€ 0	€ 10	€ 78	€ 104
Maramures	€ 20	€ 0.0	€ 17	€ 3	€ 0	€ 0.0	€ 4	€ 4	€ 28	€ 47
Mehedinti	€ 9	€ 0.0	€ 7	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 9	€ 17
Mures	€ 19	€ 0.0	€ 12	€ 0	€ 0	€ 0.0	€ 4	€ 2	€ 19	€ 38
Neamt	€ 15	€ 0.0	€ 1	€ 0	€ 18	€ 0.0	€ 4	€ 3	€ 27	€ 41
Olt	€ 14	€ 0.7	€ 12	€ 6	€ 0	€ 0.0	€ 4	€ 3	€ 26	€ 40
Prahova	€ 25	€ 1.3	€ 1	€ 0	€ 97	€ 0.0	€ 0	€ 15	€ 114	€ 139
SatuMare	€ 8	€ 1.7	€ 7	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 10	€ 18
Salaj	€ 5	€ 0.0	€ 4	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 5	€ 10
Sibiu	€ 15	€ 0.0	€ 3	€ 9	€ 0	€ 0.0	€ 0	€ 2	€ 14	€ 28
Suceava	€ 21	€ 2.7	€ 17	€ 10	€ 0	€ 0.0	€ 4	€ 5	€ 39	€ 60
Teleorman	€ 8	€ 1.4	€ 5	€ 0	€ 0	€ 0.0	€ 0	€ 1	€ 7	€ 15
Timis	€ 24	€ 0.7	€ 16	€ 0	€ 0	€ 0.0	€ 4	€ 3	€ 23	€ 47
Tulcea	€ 8	€ 0.0	€ 0	€ 0	€ 17	€ 0.0	€ 4	€ 3	€ 24	€ 32
Vaslui	€ 13	€ 0.6	€ 11	€ 0	€ 23	€ 0.0	€ 0	€ 5	€ 40	€ 53
Valcea	€ 13	€ 0.0	€ 0	€ 0	€ 0	€ 1.2	€ 4	€ 1	€ 6	€ 19
Vrancea	€ 11	€ 1.0	€ 4	€ 0	€ 16	€ 0.0	€ 4	€ 4	€ 29	€ 40
All Counties	€ 753	€ 45	€ 399	€ 102	€ 520	€ 9	€ 68	€ 171	€ 1,314	€ 2,066

Note: Again, the incineration (and biodrying) figures for individual counties represent the relative tonnages requiring treatment in order for each county to meet targets. These figures are not to imply a large number of small facilities specific to individual counties. The proposed location and scale of actual facilities are specified in Table 4-2.

5.2 Operational and Maintenance Costs

For interest, the model also projects the operating and maintenance costs for the waste systems proposed in the various scenarios. This is not to infer how these costs are to be paid, but is merely shown as a matching data to the capital costs presented in the previous section.

The total costs for all Romania are shown in Table 5-6. It may be noted that the total operational and maintenance costs are higher in Scenarios 1, 2 and 3 than they are in the Business As Usual Scenario. This, however, is not surprising due the low cost of landfill. In any case, the overall differences are small and one scenario may not be precluded over another on the basis of operational costs.

Table 5-6: Annualised Operational and Maintenance Cost Assessment for SOP2 Scenarios

Figures in million Euros	SOP2 Annualised Operational & Maintenance Costs (2020)								
	Collection (Total)	Sorting	IVC	AD of source separated organics	Biodrying	Incin-eration	Landfill disposal	TOTAL	TOTAL €/CAPITA
BaU	€ 135	€ 8	€ 18	€ 0	€ 39	€ 19	€ 87	€ 306	€ 14.75
Scenario 1	€ 144	€ 12	€ 18	€ 24	€ 92	€ 19	€ 46	€ 355	€ 17.12
Scenario 2	€ 144	€ 12	€ 18	€ 24	€ 38	€ 60	€ 47	€ 342	€ 16.52
Scenario 3	€ 144	€ 12	€ 18	€ 24	€ 62	€ 42	€ 47	€ 348	€ 16.79

Note: Excludes capital costs (or the costs of financing of capital) for vehicles and containers, as well as for the fixed infrastructure – hence the low €/capita figures calculated. Includes operating and maintenance costs for all facilities (whether SOP1 or SOP2).

In terms of economic efficiency, it is important not to consider capital costs and operational costs in isolation. Therefore, while providing separate figures for capital and operational costs, we have also modelled the 'break-even' gate fee that would be required for a facility to cover its costs in a competitive market. This calculation takes account of the real full annualised capital cost (at a weighted average cost of capital), the annual operational and maintenance costs, and revenues that may be obtained by the facility.

The figure thus derived represents the amount that will have to be paid per tonne of waste sent to through a particular management route (where the cost of capital is accounted for through this gate fee). The important point is that whoever pays, all things being equal, the treatment route with the lowest break even gate fee is the most cost-effective route.

Accordingly we present in Table 5-7 the break even gate fees for the residual waste treatment management routes evaluated in this study. It can be seen that for residual waste, landfill requires the lowest gate fee to cover costs. However, in moving away from landfill, the two MBT configurations modelled provide a more cost-effective treatment route than incineration. It is important to note that the gate fees are not directly comparable to those for facilities funded under SOP1, where funding was provided for 90% of capital costs. We understand that gate fees for CHP facilities in Brasov and Bucharest are in the range of €60-70 per tonne. In our model, if we reduce the capital costs by 90%, we calculate a gate fee of €60 per tonne.

Table 5-7: Break Even Gate Fees for Residual Waste Treatments

Landfill	**Incineration – CHP (at medium scale, 200Ktpa)**	**Biostabilisation MBT, Output to Landfill**	**Biodrying MBT, SRF to Cement Kiln**
€ 44.9 / tonne	€ 167/ tonne	€ 90.6 / tonne	€ 77.3 / tonne

Note: Landfill costs as displayed here assume a unit capital cost for new landfills of €200 per tonne per year disposed at the landfill. This is higher than the costs for compliant landfill sites planned through SOP1 projects which range between €26 and €163 per tonne. The deliberate use of the higher (€200 per tonne) figure is so as to represent European best practice, incorporating high quality leachate and gas control etc. It is acknowledged that gate fees currently charged across Romania are around €10-15/tonne; a €15/tonne gate fee is equivalent to a site with a unit capital cost of €50 per tonne per annum.

For organic waste, the break even gate fees are presented in Table 5-8. Direct comparison cannot readily be done between these prices as windrow is suited to garden waste, AD to food waste, and IVC to a mixture of both. Nevertheless, it can be seen that these are all lower cost treatment routes than those for residual waste. For each, it is assumed that 5% of the input tonnage is destined for landfill, with compost offtake at zero cost. Thus the landfill gate fee is already included in the break even gate fee.

Table 5-8: Break Even Gate Fees for Organic Waste Treatments

Open Air Windrow	**In-Vessel Composting**	**Anaerobic Digestion - Electricity Generation Only**
€ 22.7 / tonne	€ 46.5 / tonne	€ 67.7 / tonne

It is important to note that none of these costs include the relative environmental damages (this is outside the scope of this study).

5.3 Sensitivity Analysis

5.3.1 Sensitivity Analysis 1: Higher Dry Recycling Rates

Since there are intentions within the SOP1 plans to provide dry recycling services within the current programming period, we have not included any change to these services in the SOP2 period other than to provide the same levels of service in counties where plans are not currently programmed and to provide sufficient sorting facility capacity so that recycling is not constrained.

The main modelled scenarios through to 2020 are shown to achieve a modelled 23% dry recycling rate (of total MSW).

If more intensive [door-to-door] recycling systems were to be provided in the coming programming period, higher dry recycling could be achieved. For this sensitivity analysis, we modify several factors in the modelling:

- The central case assumption of 90% rural connection to recycling services is changed to 100%;
- The central case assumption of 50% urban connection to door-to-door recycling is changed to 90%.

We do not change organic waste collection coverage or capture rates, but suggest that there may remain considerable scope for increasing collection services and diverting this material from landfill since we model composting and home composting rate to total 2.0 million tonnes per annum from a total of 4.2 million tonnes of arisings.

The impacts are:

- Assuming all door to door collection systems operated use the commingled collection approach, then 164,000 tpa of additional sorting facility infrastructure (in addition to that proposed in Scenarios 1-3) will be needed across Romania as a whole;
- The WFD Option 2 recycling rate peaks slightly higher at 56% in 2020 as opposed to 51% in the central case;
- Collection capital costs increase by €30 million. Sorting facility capital costs are also a little higher but residual waste treatment costs are sizably reduced and the net impact (to Scenario 3 in 2020) is a reduction of €60 million.
- Operational costs are relatively unchanged.

It should be noted that while we have modelled higher recycling rates here, we think there is considerably more potential for lower recycling rates to be achieved in practice if collection systems are not well procured, promoted and operated (including significant door-to-door recycling and segregated organic waste collection). We do not, however, model lower performance as Landfill Directive and WFD targets will not be achieved.

5.3.2 Sensitivity Analysis 2: Invessel Composting as Opposed to Anaerobic Digestion

The discussion in Annex A.1.4 makes clear that the high quantities of food waste in Romania, and the provision of aerobic composting facilities in SOP1, means that the technology of choice for SOP2 ought to be anaerobic digestion. Nevertheless, if less capital cost intensive IVC type facilities were procured in the next programming period (assuming they could be made to operate effectively), then €400 million of capital costs for organic waste treatment would reduce to €190 million.

5.3.3 Sensitivity Analysis 3: Unit Capital Costs Sensitivity Analysis

In the central case results we have modelled expected facility costs where procurement processes are efficient, good value for money is achieved, and plant commissioning and operation goes according to plan. However, we can test the sensitivity of the results against a situation where this is not achieved, or where variations to the technical solution may alter the unit capital costs. As such, the financial sensitivity tests are conducted as listed in Table 5-9.

Table 5-9: Unit Capital Cost Sensitivity Analysis

Unit capex per tonne per annum	Central Case	Low Cost Sensitivity	High Cost Sensitivity
Sorting Facility	€80	€52 (matching low cost from SOP1 projects)	€123 (matching average cost from SOP1 projects)
Organic treatment (AD)	€350	€300	€400
Biodrying	€186	€109 (matching average cost from SOP1 projects)	€200 (Central case modelled cost is relatively high, significant uplift is thus not required)
Incineration	€788	€656 (assuming larger [400Ktpa] facilities)	€872 (assuming smaller facilities, or those with higher levels of emissions abatement etc.)
Landfill closure	€1.2M per site	€0.4M per site (matching low cost from SOP1 projects)	€2.6M per site (matching high cost from SOP1 projects)

The sensitivity analysis results according to the values listed above are given in Table 5-10.

Table 5-10: Capital Cost Sensitivity Analysis Results

Figures in million Euros	SOP2 Capital Investments: Sensitivity Analysis									
	Collection (Total)	Sorting	AD	MBT	Incin-eration	Landfill closure	New landfills	Project support	Total Excluding Collection	Total Including Collection
BaU - low	€ 721	€ 0	€ 0	€ 0	€ 0	€ 3	€ 92	€ 14	€ 109	€ 830
BaU - central	€ 721	€ 0	€ 0	€ 0	€ 0	€ 9	€ 92	€ 15	€ 116	€ 837
BaU - high	€ 721	€ 0	€ 0	€ 0	€ 0	€ 18	€ 92	€ 17	€ 127	€ 848
Scenario 1 - low	€ 753	€ 29	€ 342	€ 135	€ 0	€ 3	€ 68	€ 87	€ 664	€ 1,417
Scenario 1 - central	€ 753	€ 45	€ 399	€ 231	€ 0	€ 9	€ 68	€ 113	€ 864	€ 1,617
Scenario 1 - high	€ 753	€ 69	€ 457	€ 248	€ 0	€ 18	€ 68	€ 129	€ 989	€ 1,741
Scenario 2 - low	€ 753	€ 29	€ 342	€ 0	€ 773	€ 3	€ 68	€ 182	€ 1,398	€ 2,151
Scenario 2 - central	€ 753	€ 45	€ 399	€ 0	€ 929	€ 9	€ 68	€ 217	€ 1,667	€ 2,420
Scenario 2 - high	€ 753	€ 69	€ 457	€ 0	€ 1,028	€ 18	€ 68	€ 246	€ 1,885	€ 2,638
Scenario 3 - low	€ 753	€ 29	€ 342	€ 60	€ 433	€ 3	€ 68	€ 140	€ 1,075	€ 1,828
Scenario 3 - central	€ 753	€ 45	€ 399	€ 102	€ 520	€ 9	€ 68	€ 171	€ 1,314	€ 2,066
Scenario 3 - high	€ 753	€ 69	€ 457	€ 109	€ 575	€ 18	€ 68	€ 194	€ 1,491	€ 2,243

5.3.4 Sensitivity Analysis 4: Zero Waste Direct to Landfill

The main modelling scenarios presented in this report consider the minimum plant sizes that are needed to satisfy the Landfill Directive targets. Larger plant sizes are of course possible. Reflecting this, in Table 5-11 below we show a capital cost assessment where all residual waste that remains in the three scenarios (3.6 million tonnes per annum) is put through either biodrying or incineration. It should however be noted that any increase in reuse and recycling (for which there remains additional scope) or any waste prevention effect (compared with the projections made by the master plans and used in the modelling) which may be achieved, will reduce the quantity of available residual waste.

Table 5-11: Zero Waste to Landfill, Maximised Residual Waste Treatment Sensitivity

Figures in million Euros	Maximum Residual Waste Treatment Sensitivity									
	Collection (Total)	Sorting	AD	Biodrying	Incin-eration	Landfill closure	New landfills	Project support	Total Excluding Collection	Total Including Collection
Sensitivity of main scenarios with maximum biodrying	€ 753	€ 45	€ 399	€ 663	€ 0	€ 9	€ 68	€ 178	€ 1,361	€ 2,114
Sensitivity of main scenarios with maximum incineration	€ 753	€ 45	€ 399	€ 0	€ 2,808	€ 9	€ 68	€ 499	€ 3,828	€ 4,581

6 Headlines, Conclusions & Recommendations

The following headline findings can be summarised from the work:

6.1 Findings in Relation to SOP1 Projects

The current wave of [SOP1] projects has the following characteristics and implications:

- The majority of SOP1 projects are set to put in place a basic dry recycling infrastructure, transfer stations and (in most counties) composting plants;
- A smaller number of basic MBT facilities are planned, the majority of these are scaled to treat between 50% and 60% of waste arisings in the counties;
- Two incinerators are currently funded in the SOP1 projects, though it is quite likely that these will not be procured, constructed, commissioned and operational until the end of this decade;
- The expected late delivery of the majority of these projects means that counties will be chasing the short term packaging waste and Landfill Directive targets:
    - Although we only have limited information concerning the precise nature of collection systems that are to be operated (as well as related promotion and enforcement etc.), it is possible that the packaging waste recycling targets may be met – albeit potentially a little late. Indeed it would appear that the SOP1 projects may have been well designed to collect the obligated packaging materials and help achieve the specified recycling rates once the collection and processing systems are online and well integrated;
    - Landfill Directive biodegradable waste diversion targets however remain hard to reach. The SOP1 projects, in the majority of cases, appear to aim to achieve the 2013 Landfill Directive targets by recycling of biodegradable municipal waste materials (most notably paper and card), and some home composting or centralised composting of organic food and/or garden waste. The more onerous demands of the 2016 Landfill Directive targets (and the new WFD obligations) mean more needs to be done concerning biodegradable waste into the next programming period.

The revised WFD obligations (50% recycling of MSW and a stronger and clearer adherence to the waste hierarchy) did not exist when SOP1 projects were originally being composed. As such, the onus into the next programming period needs to step up a gear to meet these high rates of recycling and divert sufficient biodegradable material from landfill. Any new projects ought to reflect the legally binding objectives of the WFD to facilitate those activities associated with the top of the waste hierarchy (as well as reducing the damages caused by those at the bottom).

6.2 Findings in Relation to the Financial Modelling and SOP2 Assessment

Three Scenarios have been assessed against the Business As Usual Scenario with new waste management systems coming online by 2020 in order to meet the targets. The financial modelling gives the following key headline results:

- Business As Usual Scenario (no change to waste systems beyond SOP1 plans – hence targets not met):
    - A small amount of capital expenditure needed (€0.12 billion) for landfill closure and new compliant landfills (with technical support included);
    - A total of €0.72 billion on waste collection capital;
    - €0.30 billion annual operational and maintenance costs (during operational lifetime of the plant).
- Scenario 1 (systematic organic waste collection, AD and MBT of residual waste):
    - €0.9 billion capital expenditure on new facilities in the central case;
    - The sensitivity analysis suggests a capital cost range of €0.7 - 1.0 billion;
    - A total of €0.75 billion on waste collection capital;
    - €0.35 billion annual operational and maintenance costs (during operational lifetime of the plant).
- Scenario 2 (systematic organic waste collection, AD and EfW for residual waste):
    - €1.7 billion capital expenditure on new facilities;
    - The sensitivity analysis suggests a capital cost range of €1.4 – 1.9 billion;
    - A total of €0.75 billion on waste collection capital;
    - €0.34 billion annual operational and maintenance costs (during operational lifetime of the plant).
- Scenario 3 (systematic organic waste collection, AD and mixture of Biodrying and EfW for residual waste according to the identified pipeline of projects):
    - €1.3 billion capital expenditure on new facilities;
    - The sensitivity analysis suggests a capital cost range of €1.1 - 1.5 billion;
    - A total of €0.75 billion on waste collection capital;
    - €0.35 billion annual operational and maintenance costs (during operational lifetime of the plant).

A fundamental observation here is that both Scenario 1 and Scenario 2 meet objectives, but the latter is considerably more costly than the former. There is merit, therefore, in the *Priority Axis* for the next programming period having a strong emphasis on organic waste collection, anaerobic digestion and biodrying (or biostabilisation) of residual waste. As such, under Scenario 3, we show a potential pipeline of projects for SOP2. These facilities are summarised in Section 4.4 (and Table 4-2 specifically). The financial costs of building and operating these systems understandably fall between the costs of Scenarios 1 and 2.

The longer term objectives considered within this work for SOP2 may suggest that those lesser progressed projects which are being pursued as part of SOP1 may be revisited and reconfigured (with updated master plans etc.). Although we have assumed that all SOP1 facilities are delivered as planned, there may remain scope for optimisation between the SOP1 and proposed SOP2 facilities.

6.3 Issues and Omissions from the Work Conducted for this Assignment

In addition to individual points discussed in the body of this report, the following points of concern and elements of work that may require further attention ought to be identified here:

- The composition data compiled from the master plans and related sources is greatly variable from county to county, between urban and rural settings, and through the course of time. We cannot comment on the accuracy of these individual assessments but we ought to note that accurate compositional data is as elusive as it is influential in waste management planning. Nevertheless, for the work here, a strong observation is that 'organic waste' is the most abundant element of the waste stream (hence a strong focus on this material for SOP2 projects), and at the very least food waste must be split from garden waste in future compositional work in order to better aid waste planning;
- Environmental considerations have not been taken into account in this analysis, other than in as much as respecting the waste hierarchy as defined by the 2008 revised WFD helps deliver environmental good practice;
- The WEEE directive has not been considered both because data is not available within the waste composition used for this work, and the challenges of compliance are somewhat different to the large scale approaches for all municipal waste considered here. Achieving the associated targets is a separate, but still important, issue.

6.4 Key Observations from the Waste Policy and National Waste Strategy Review

As part of this assignment, we were asked to review the latest draft of the National Waste Management Strategy, and to consider this in the context of European waste policy. This review is contained within the Baseline Report. However, we summarise here a few key points in the context of the SOP2 assessment:

- The NWMP will need to be updated to meet various targets which it needs to achieve.
- Some implementing measures which could have been important have not yet been introduced (notably, a landfill tax).

- The rate of change that was envisaged in some areas seems to be quite slow.

Looking ahead with a focus on key policies, the following steps towards effective integrated waste management ought to be considered:

- Closure of non-compliant landfills (or other efforts will be un-rewarded);
- Policy to prevent back yard burning;
- Introduce landfill tax (key measure which underpins prevention / recycling);
- Producer responsibility;
- Variable charging;
- A measure to ensure that collection of recycling is robust (biowaste ordinance / producers mandated to fund packaging collection systems);
- Well managed procurement / enforcement / joint working.

ANNEX 1: MASS FLOW MODELLING METHODOLOGIES & ASSUMPTIONS

A.1 Mass Flow Modelling

A brief summary of the 'logic' behind the mass flow modelling is given in Section 3.1. The model itself is provided separately as Annex A.3. The detail provided in the following subsections here intends to bridge the gap between the simple operational logic of the model, and the detailed data which can be ascertained from the model itself.

A.1.1 Data Sources

The data used for the mass flow modelling on waste arisings, proposed facility types and annual throughputs is extracted from the annexes to the baseline report, with reference to the individual county 'Master Plans', 'Regional Plans', 'Feasibility Studies', 'Application Forms' and 'Completion Notes' where necessary for clarification. Since Harghita shares a common Master Plan with Covasna, these counties are combined within the modelling. The same is true for Ilfov and Bucharest.

A.1.2 Waste Composition

Waste composition, where available in the data sources identified in A.1.1, is variable from county to county. Different figures are given for urban and rural, and from year to year. We have compiled the data from the individual counties to produce a "national average MSW composition" for urban and rural households in both 2010 and 2020. Linear interpolation is used for the years in between these dates. The figures used are presented in Table A. 1; the combined national dataset is also shown here. It is notable that 'organic' waste is a very high proportion of the total. Although this is projected to reduce gradually in proportion over time, this is due to the growth in arisings of other materials over time; organic waste it does not reduce in total – in fact the modelled figures show quantities staying quite stable from year to year at 4.2m tonnes per annum.

Table A. 1: Modelled National Municipal Waste Composition

	Urban		**Rural**		**Total**	
	2010	**2020**	**2010**	**2020**	**2010**	**2020**
Paper & Cardboard	13.3%	15.3%	8.6%	11.1%	12.2%	14.3%
Glass	5.4%	6.1%	4.4%	5.1%	5.2%	5.9%
Metal	5.2%	5.9%	4.7%	5.7%	5.1%	5.8%
Plastic	11.4%	12.9%	8.3%	9.8%	10.7%	12.1%
Wood	2.0%	2.1%	2.4%	2.4%	2.1%	2.2%
Organic (biowaste)	48.6%	45.2%	57.6%	52.9%	50.6%	47.0%
Other	14.0%	12.5%	14.0%	13.1%	14.0%	12.6%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

A.1.3 Home Composting Assumptions

Home compositing bins are a common feature of the plans within the current programming period to meet 2013 Landfill Directive targets. The concept is generally to provide bins typically to rural households in order to encourage the diversion of organic waste from disposal.

The master plans commonly assume that around 200 kg/year is diverted for each bin provided. Some, however, assume up to around 500 kg/bin/year which is a worryingly high figure as this is significantly more than the total organic waste arisings for rural households. The 200kg/year figure itself appears to rely on 100% uptake (usage) of the bins provided, and that most of the organic waste generated by these households then does not go to disposal. As such, this remains a questionable figure as the simple provision of a bin cannot guarantee such a stark behaviour change. Indeed, there is no reason why home composting of organic waste, or indeed the feeding of waste organics to livestock, will not occur in the absence of such bins.

Nevertheless, for the purposes of the modelling conducted, we adopt the commonly used figure of 200kg/bin/year of organic waste diversion. We apply this figure uniformly for every county where bins are provided during the current programming period.

Due to the dubious nature of the effect of home composting bin provision, we assume that there is no further scope for home composting bins to be provided (or further biowaste diversion to be achieved in this manner) during the next programming period.

A.1.4 Organic Waste Collection and Treatment

The baseline report makes the following notable observation concerning organic waste:

> *'Apart from some limited sources (garden and market waste in selected areas), in general separate collection of organic waste has not been adopted* [as part of the SOP1 investment plans] *in the counties.'*

There is clearly a major issue for Romania's waste management systems. The composting facilities which are to be constructed as part of SOP1 projects will not be effectively used without plans for systematic organic waste collection. It is likely that there could be some relatively easy sources of material which could be segregated for composting such as the material referred to in Master Plans as "Parks and gardens waste", and potentially also "Waste from markets", although effort will be needed to keep this a pure source of organic waste without contamination from other waste materials. These sources alone (even if their management does mean that pure organic waste streams can be delivered to the composting facilities), are not sufficient to fully utilise the planned composting facilities; household organics need also to be targeted for separate collection.

More focussed attention would appear to be necessary to how composting facilities will operate in relation to the *'mix'* of organic material collected. In simple terms:

- Separately collected garden waste is best treated by open air windrow composting (a low cost process);
- Mixed food and garden waste is best treated by invessel composting, although the mix of material has to be carefully managed (sufficient structural garden waste material is needed to keep the process aerobic);
- Separate food waste is best treated by anaerobic digestion.

Since no source separated organic waste collection systems are currently planned, we cannot be certain of what is intended to be treated in these facilities. Mixed residual waste would be a very unusual source of waste to attempt to "compost", if indeed this is the intention. In essence, an MBT biostabilisation facility performs a composting-like process on residual waste in order to reduce the biodegradability of material subsequently sent to landfill. However, this process is reliant on very different infrastructure; an invessel composting facility (if indeed the facilities planned in SOP1 are invessel facilities – this is not clear) is not suited to treatment of residual waste.

It is perhaps then no surprise that the Baseline Report goes on to remark:

> *'Source separation of the organic waste stream is a critical sector that EU is currently emphasising following the release of the "Green paper on the Management of biowaste in EU". Biowaste management and separate collection scoping to produce clean and safe compost should be a priority in the new SOP 2014-2020.'*

The modelling undertaken assumes that where a composting facility is planned (as part of SOP1) then a separate collection system is provided to households for organic waste by 2015 so that the full capacity of the planned plants is utilised. The coverage of separate collection systems is, thus, back calculated from the plant capacities planned in SOP1 and the expected capture rates for organic waste collection[6].

For the 'pipeline project' facilities for SOP2 we model the coverage of organic waste collection for individual counties so that the 50% recycling target (as defined in Section 1.3) is met by 2020. This determines the plant capacities proposed for SOP2.

[6] Capture rates for household collected organic waste is modelled at 70% of the total for door-to-door collections. This is suggested to be a reasonable figure for such systems, informed by experience of separate food waste collections in the context of charging for residual waste in Italy. Capture rates for a bring system approach would be expected to be much lower – we model 20%. Bring systems are only modelled for a small fraction of urban properties (i.e. to account for those in large blocks of flats who share communal waste facilities).

A.1.5 Dry Recycling Collection

Dry recycling figures for each county are calculated as follows:
Waste arisings
× Connection rates to a recycling service (assuming 100% once SOP1 projects are in place)
× Capture rates for the different materials depending on whether the systems provided are door to door services (high captures) or bring site (lower captures).

The capture rates modelled are shown here in Table A. 2 (note that it is possible to vary these in the model at the top of the "Assumptions" sheet). We suggest the figures used may be reasonable for the systems provided, but they may still be contingent on factors such as service quality, collection frequencies, residual waste charging policies etc.

Table A. 2: Dry Recycling Capture Rates Modelled

	Bring Collection Systems	**Door-to-Door Recycling**
Paper & Cardboard	50%	85%
Glass	60%	85%
Metal	40%	65%
Plastic	25%	55%
Wood	15%	30%

In addition, we assume that there is only limited connection to dry recycling collection systems at present (a simple 25% coverage for urban properties and 0% in rural settings). We assume that by the end of the current tranche of projects that this changes to 100% coverage for urban, and 90% for rural properties (to account for particularly difficult to access properties).

The types of recycling services provided to properties are summarised in Table A. 3.

Table A. 3: Dry Recycling System Provision Modelled

	Urban			**Rural**		
	Prior to SOP1 projects	**With SOP1 projects in place**	**With SOP2 projects in place**	**Prior to SOP1 projects**	**With SOP1 projects in place**	**With SOP2 projects in place**
Bring sites	100%	50%	50%	0%	0%	0%
Door to door commingled recycling	0%	50%	50%	100%	100%	100%
Door to door on-vehicle-sort recycling	0%	0%	0%	0%	0%	0%

A.1.6 Dry Recycling Sorting

The SOP1 plans include the provision of sorting plants for most counties. It is rational to presume that these are intended to be used to separate all commingled collected dry recyclables – i.e. the material that is collected from household door-to-door (bin based) dry recycling. Again, we have not seen strong evidence on the design of these facilities but we can assume that they comprise of a system of conveyors with various manual and automatic separation systems.

Assuming that all door-to-door collection systems in Romania are intended to be the bin system where materials are collected commingled, a potential constraint may be imposed on the recycling rate where sorting facilities in a county are not sufficient to deal with the material collected. In practice, this may not be the case as transfer stations may be used so that dry recyclables can be sorted in neighbouring county facilities. Nevertheless, we take the assumption that any restriction in sorting capacity in a county restricts the tonnage of material that can be recycled (practically, commingled collection systems are unlikely to be provided where a sorting facility is not available for separating the recyclables).

The bring site approach, however, must be considered in a different manner. Recyclables at bring sites are placed into different containers (i.e. separated at source) prior to collection. Therefore, assuming contamination can be kept within tolerable levels (as is comfortably achieved across the rest of Europe) through good service design and site controls, bring site recyclables presumably do not need to be ‘sorted’ at such facilities. As such, we take the assumption that bring site recycling is not limited by the capacity of sorting plant.

In general very few counties are modelled to exceed their sorting capacities (for commingled door to door waste). Indeed, there is commonly a significant excess of sorting facility capacity in most counties. This is partly due to the source separated bring site material modelled (which does not require sorting plant)

In the Master Plans a typical contamination level of 20% is assumed for the dry bin. This is understood to be one reason for the oversizing of the sorting plants. The model does not limit input to the facility due to these "additional material" contaminants, but it does reject some captured recyclables (5% of targeted materials) due to fouling.

A final point that ought to be raised in the context of this work relates to door-to-door collection services. It appears that no ‘kerbside sorting’ of door-to-door collected recyclables has been considered in Romania so far. Under this system, materials are sorted by collection staff onto different compartments of collection vehicles. There are key advantages to this approach which are likely to be especially relevant for Romania – material quality is high, contamination is not collected, capital costs (vehicles and bins) are greatly reduced, and employment is higher. For Romania we anticipate that overall system costs are likely to be lower for this approach compared to commingled door-to-door collection due to the relatively low labour costs in the country.

A.1.7 Timing for Delivery of Facilities and Change in Waste Management Operations

Information in the detailed Baseline Report appendices (compiled from master plans and application forms etc.) gives the latest estimate for completion of SOP1 projects and of when facilities are likely to be up and running. However, JASPERS advise that delays are currently being experienced and are likely to continue in project procurement, construction and commissioning. The provision of collection systems which match with the material demands of facilities are also expected to take some time to be established. The proposal from JASPERS, which we have adopted in the modelling, is that the coming changes in waste management due to SOP1 projects will occur only from 2015. We are also advised to take the assumption that the two currently planned incinerators (Brasov and Bucharest) will not be online until 2020.

A.1.8 Incineration

Incinerators are modelled to achieve 100% diversion of biodegradable waste from landfill from all municipal waste treated. The mass loss in the process leads to 25% of total inputs going to non-hazardous landfill. 30% of metals in the input to incinerators are modelled to be recycled.

We do not include the disposal of hazardous fly ash in the mass flows as the financial modelling includes a full gate fee for hazardous waste disposal in the operational costs (3% of the weight of the input to the plant), i.e. hazardous waste disposal is managed by another party in an unspecified location. Nevertheless, it should be understood that hazardous waste landfill capacity will be needed to manage the 3% of the input tonnage to incinerators.

A.1.9 Biodrying / Biostabilisation (MBT)

MBT facilities typically achieve at least 75% diversion of biodegradable waste from landfill (this tends to be a guaranteed standard achieved by such facilities operating elsewhere in Europe). The figure for facilities operating in a biodrying mode tends to be higher as the organics are concentrated in the solid recovered fuel (SRF) for combustion; as such, we model a figure of 95% for biodrying facilities. The mass loss in a biostabilisation process leads to 65% of total inputs going to non-hazardous landfill, or 25% for biodrying (where SRF is generated for energy use). 70% of metals and 20% of the plastics in the input to MBT facilities are modelled to be recycled.

A.1.10 Transfer

Although transfer stations feature as part of the SOP1 plans, we do not model the transport of waste from one county to another as we are seeking to evaluate the performance of the counties individually against targets.

ANNEX 2: EUNOMIA FINANCIAL MODELLING

A.2 Eunomia Financial Modelling

The financial modelling is undertaken using a 'private metric', i.e. applying a weighted average cost of capital (WACC), using retail prices, including taxes and subsidies. This represents the market conditions facing those developing and operating facilities. This approach not only includes consideration of the capital costs, but allows the calculation of a 'break even' gate fee, at a level which means the facility is covering its capital and operating costs.

A.2.1 Cost Modelling Assumptions

A.2.1.1 Calculating Costs Applicable to Romania

Our approach to establishing representative capital and operating costs for new-build facilities in Romania is to firstly obtain representative costs from elsewhere in Europe. For each process technology, it is assumed that general technology costs, such as the cost of purchasing large capital items, will be the same as elsewhere in Europe. However, for the element of both capital and operating costs that relates to labour, we adjust these typical figures to account for the lower than average costs of labour in Romania.

Table A. 4: Proportion of Capex and Opex Attributable to Labour

Treatment	Labour Proportion of Capex	Labour Proportion of Opex
Landfill	20%	50%
Incineration	16%	18%
MBT	30%	34%
AD	25%	30%
Windrow	17%	21%
IVC	25%	15%

The most recent figures available, for 2009, show the typical hourly labour cost for the EU27 to be €22.50, while that for Romania is €3.30.[7] The explanation of the attribution

[7] Eurostat (2011) Labour Cost Index – Recent Trends, Manufacturing, available at http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Labour_cost_index_-_recent_trends (accessed November 2011)

of the proportion of capital and operating costs to labour in the standard European costs is given alongside the process specific assumptions in section A.2.2. The proportions attributable to labour for each process are summarised in Table A. 4.

Accordingly, the labour proportion of capex and opex is multiplied by 3.30/22.50 to obtain Romania-specific costs.

A.2.1.2 Costs and Gate Fees

Where matters of cost are concerned, the waste sector is typically used to dealing with the issue in terms of 'gate fees'. Gate fees are not 'costs', and there are various reasons why the gate fee at a facility may differ from average costs, or marginal costs, as they might be conventionally understood. Gate fees may, depending upon the nature of the treatment, be affected by, inter alia:

- Local competition (affected by, for example, haulage costs);
- Amount of unutilised capacity;
- The desire to draw in, or limit the intake of, specific materials in the context of seeking a specific feedstock mix;
- Strategic objectives of the facility operator; and
- Many other factors besides.

Any one of these can influence the market price, or gate fee, for a service offered by a waste management company.

A.2.1.3 Weighted Average Cost of Capital

The waste sector's weighted average cost of capital is affected by the risk associated with the investment being made. As the waste sector in Europe shifts away from 'traditional ways' of doing things, and to the extent that contract structures seek to ensure risk is borne, where appropriate, by the private sector, so the cost of capital appears to have increased.

Many investments in the municipal sector are financed using project finance, with Special Purpose Vehicles (SPVs) set up for the purpose of delivering a specific service, or range of services. SPVs are financed using debt and equity, with the equity investors expecting greater returns on their investment. The ratio of debt:equity will therefore have an influence on the effective cost of capital to the company concerned. It may well be that in the future, more investments are financed corporately, with associated impacts on the weighted cost of capital. In the UK, Ernst & Young, advisers on many Private Finance Initiative (PFI) projects in the waste sector, assumed a 15% real pre-tax cost of capital for gasification, pyrolysis and anaerobic digestion, and a 12% cost of capital for incineration with CHP. These figures seem to reflect risks experienced in the context of municipal contracts.

It seems possible that the average cost of capital may be lower in 'merchant' transactions (where plant are developed to treat waste on the open market rather than as part of a local authority contract) where the transfer of risk is not explicitly priced in to the cost of capital. However, obtaining financial support for a given project may be more difficult owing to the issues associated with securing supply of waste into the project. Moreover, for fixed-throughput infrastructure, such as incinerators, investors would expect a higher rate of return than for a municipal contract where the supply is secure.

We have taken the following approach:

- We have used Ernst & Young's figure of 15% for large capital items of infrastructure (incineration and MBT);
- We have used a figure of 12% for items of infrastructure where the quantum of capital required is lower (IVC and AD plants). This reflects the fact that treatment facilities are likely to be constructed outside of public contracts on a more commercial basis; and
- We have used a lower figure of 10% for landfill and open air windrow composting facilities.

This reflects, we believe, a reasonable assessment of the opportunity cost of capital going forward. It seems reasonable to suggest, however, that there might be variations in the cost of capital across technology types, and between contract (and risk-sharing) structures.

This broadly accords with research into the Romanian energy sector showing that investors expected rates of return are in the range 10% - 13%. Romania's Standard & Poors rating for the foreign currency credit is BB+, which places Romania in the high risk category. The rating for long-term foreign currency credit attributed to Romania by Fitch is BB. Given these ratings, a review of the costs of capital in Romania suggests, for projects in the energy sector, a nominal pre-tax WACC of 11.7% to 13.5%.[8] It is not unreasonable to imagine that the specific nature of the risks concerned with waste infrastructure projects in Romania would lead, on balance, to slightly more elevated costs of capital.

A.2.1.4 Revenue from Electricity Sales

The weighted average (wholesale) price on the day ahead market according to OPCOM (Romanian Electricity Exchange) for the period January 2010 – October 2010 was

[8] Reported in European Commission (2011) State aid SA. 33134 2011/N – RO: Green certificates for promoting electricity from renewable sources, available at http://ec.europa.eu/competition/state_aid/cases/240906/240906_1239907_192_2.pdf

€37/MWh. The electricity price decreased in the last months of 2010 so that the average electricity price for 2010 was €36.5/MWh. Furthermore, the forward price for December 2011 as of June 2011 was €36/MWh.[9]

We assume the representative wholesale price to be €36/MWh and model on the basis that a generator only receives 90% of the wholesale price of electricity under Power Purchase Agreements. [10]

A.2.1.5 Support for Renewable Electricity Generation

The Romanian Green Certificate scheme for renewable electricity has implemented a price trading range of between €22 and €55 per certificate. Previously, one certificate was issued per MWh of renewable electricity generated regardless of technology. Now support is 'banded' as shown in Table A. 5.

Table A. 5: Romanian Green Certificate Levels for Waste-related Technologies

RES	Type of power plant/group	GC/MWh	Support period (years)
BIOMASS (regardless of its aggregation form)	(new) – from all types of bio-waste	2GC	15
	(new) – from energy crops	3GC	15
	High efficiency cogeneration (additional to GC for biomass plants mentioned above)	1 additional GC	15
Landfill gas and sewage treatment plant gas	(new)	1GC	15

We assume 45% of residual waste destined for incineration is biogenic, and thus the Green Certificate is eligible on this fraction.

A.2.1.6 Landfill Tax

There is currently no landfill tax in Romania

[9] European Commission (2011) State aid SA. 33134 2011/N – RO: Green certificates for promoting electricity from renewable sources, available at http://ec.europa.eu/competition/state_aid/cases/240906/240906_1239907_192_2.pdf

[10] As is the case elsewhere in Europe.

A.2.1.7 Hazardous Landfill Gate Fee

We assume a disposal cost of €180.

A.2.2 Process Specific Assumptions

A.2.2.1 Open Air Windrow Composting

Open-air windrow composting schemes are relatively low-cost processes.

Eunomia suggested, in 2002, costs for open-air windrow facilities of €20 - €40 per tonne (net of compost sales) for low- and high-specification windrow facilities.[11] These figures are only marginally higher today.

AEA Technology examined the effects of scale on gate fees for open air windrow composting. These figures seem high, with gate fees supposedly never dropping below around €28.75 per tonne, even at a scale of 200,000 tonnes (which is more or less unprecedented for such facilities).[12] The AEA study gave no information on unit capital costs, even though the study sought to demonstrate economies of scale at different plant sizes.

Eunomia has studied the capital and operational costs related to OAW facilities across Europe.[13] Capital costs vary less across the plants than operating costs. France, for example, has reported operating costs between €4 and €13 for a 12,000 tonne plant. The cost in Ireland is considerably higher at between €16 and €23. From this it is clear that there is a variation of operating costs across the EU 27.

We have modelled on the basis of a facility of the order of 20,000 tonnes and have taken figures from previous studies undertaken by ourselves, and inflated these to give a unit capital cost, including land, of €105 per tonne of throughput.[14] We have tested this with industry representatives who have confirmed this as a sensible figure. We assume a lifetime of capital of 15 years.

[11] Eunomia (2002) *The Legislative Driven Economic Framework Promoting MSW Recycling in the UK*, Final Report to the National Resources and Waste Forum.

[12] AEA Technology (2007) *Economies of Scale – Waste Treatment Optimisation Study* by AEA Technology, Final Report, April 2007

[13] Eunomia (2002), *Costs for Municipal Waste Management in the EU: Annexes, Final Report to DG Environment, European Commission,* http://europa.eu.int/comm/environment/waste/studies/pdf/eucostwaste.pdf

[14] Eunomia (2002) *The Legislative Driven Economic Framework Promoting MSW Recycling in the UK*, Final Report to the National Resources and Waste Forum;

Operating costs have been estimated at €6.50 per tonne of throughput before disposal of rejects. Annual maintenance costs are modelled as 3% of unit capital cost per tonne, which equates to €3.15/tonne.

For rejects, we have assumed 5% of input material has to be landfilled. This is assumed to attract landfill tax at a standard rate.

The revenues from sales of compost are frequently ignored in studies assessing treatment costs. However, revenues from compost sales have the potential to increase in significance as energy prices increase. In most countries with more mature compost markets, as more material becomes available, so there tends to be more effort spent in marketing products, and refining them for specific end-use markets. This does not always translate into higher revenues. However, the revenues are likely to be higher as the costs of gas (and other energy sources) increases, with gas being a feedstock for synthetic nitrogen fertilisers.

ADAS reports a figure for the value of nutrients of the order of €12.50 per tonne of compost. A report for the Joint Research Centre shows average values for composts obtained in different countries (see Table A. 6). All of these are positive with median EU figures being between €0.6 and €15.30 per tonne of fresh matter, adjusting for the anomalies of higher priced small bags. We have assumed a typical value of €3.50 per tonne of waste input for compost (equivalent to around €7 per tonne of compost, towards the mid-range suggested in Table A. 6).

In a well-developed market for compost, we would attribute this €3.50 per tonne revenue, but here we make the conservative assumption that compost is taken free of charge, i.e. presenting no disposal cost to the facility, nor any revenue.

Table A. 6: Average Market prices for Compost in Different Sectors (€/t fresh matter)

Sector	BE/FI	CZ	DE	Fi	ES	GR	HU	IE	IT	NL-bio	NL green	SE	SI	UK	EU Mean
Agriculture (food)	1.1		14.0	0.0	27.0	-	15.0	-	3.0	-4.0	2.0	0.0	-	2.9	**6.1**
vineyards, orchards	1.1	-	-	-	-	-	-	-	12.0	-	-	-	-	2.9	**5.3**
Organic farming	1.1	-	-	-	-	42.0	-	-	-	-	-	-	-	2.9	**15.3**
Horticulture & greenhouse production	1.1	-	15.0	-	-	42.0	-	-	-	-	-	-	-	2.9	**15.3**
Landscaping	2.5	4.5	15.0	2.0	-	-	18.0	-	25	4.0	-	-	-	6.5	**9.7**
Blends	1.1[2)]	-	-	2.0	-	-	-		-	3.5	-	-	-	2.9	**2.4**
Blends (bagged[1)])	-	-	-	-	-	-	-	90.0	200.0	-	-	-	-	-	**(145)**
Soil mixing companies	1.1	-	-	2.0	-	-	-	-	-	-	-	-	-	6.5	**3.2**
Wholesalers	1.1	-	-	-	-	-	-	-	-	-	-	-	12.0	-	**6,6**
Wholesalers (bagged[1)])	-	-	160.0	-	-	-	-	-	-	-	-	-	-	-	**(160)**
Hobby gardening	7.2	4.5	-	10.0	-	-	20.0	-	13.0	0.3	-	-	21.0	20	**12.0**
Hobby gardening (bagged[1)])	-	-	-	-	-	300.0	-	-	-	-	-	-	-	-	**(300)**
Mulch	-	-	-	-	-	-	-	-	-	-	-	-	-	3.6	**3.6**
Land restoration, landfill covers	1.1	-	-	0.7	-	0.0	-	-	-	-	-	-	-	0.7	**0.6**

1) High prices because sold in small bags (5 to 20 litres)

2) Price for compost when sold to the substrate producer!

Source: J. Barth, F. Amlinger, E. Favoino, S. Siebert, B. Kehres, R. Gottschall, M. Bieker, A, Löbig and W. Bidlingmaier (2008). Compost Production and Use in the EU. Report for the European Commission DG/JRC.

Romanian Costs for OAW

The cost of a windrow composting facility is heavily dependent on:

- The choice of technology, and;
- Legal and quality constraints applied to the output.

In order to extract the civils costs of an open air windrow facility we have taken the example previously used by Eunomia. We have assumed that civils costs are the portion of capital costs that are not related to the actual construction of the facility. In this instance this includes:

- Surface Improvements and Hard-standing;
- Landscaping; and
- Services.

17% of the capital expenditure can be attributed to civils costs, which is taken to represent the labour element of the capital cost.

The operational cost of an open air windrow has been taken from the Eunomia 2002 study. The 'per tonne' operating cost is assumed to have an associated labour cost of 21%. The labour costs detailed refer to three full time employees operating the plant.

Therefore the capital cost is revised downwards from €105/tonne to €90/tonne, and the operating cost is revised downwards from €6.50/tonne to €5.90/tonne.

A.2.2.2 In-Vessel Composting

IVC systems come in various shapes and sizes. They can be vertical or horizontal. Unit capital costs depend upon, for example:

- Scale of facility;
- Nature of process used (and the degree to which the process is managed through 'fixed capital' rather than mobile equipment);
- Materials treated;
- Nature of exhaust air treatment; and
- Time spent in the intensive and maturation phases.

Typically capital costs have been relatively low (of the order €190 per tonne of capacity). However, there might be reasons to expect these to be somewhat higher in cases where:

- The food waste component is higher, giving rise to a need for more thorough management of the input materials (notably to ensure adequate structural material is present through mixing), requiring more expensive treatment of exhaust air; and

- Concerns regarding odour are expected to be significant, again affecting exhaust air treatment.

Jacobs suggest a figure for capital costs of €182.50 per tonne for a 30,000 tonne plant.[15] An EEA report from 2002 indicates that capital costs will vary significantly as the scale increases.[16] For a 30,000 tonne plant a capital cost of €100 per tonne is estimated. This, however, is low as the study includes open air and enclosed composting facilities. We have used a figure of €205 per tonne. It should be noted that some systems are relatively more costly (in terms of capital commitment) than others. We assume a lifetime of capital of 20 years.

For operating costs, Jacobs suggest a figure of €22.50 per tonne at a 30,000 tonne plant. This is considered to be higher than the industry average. We have used a figure of €12.50 per tonne. Maintenance is taken to be 5% of capital costs, at €10.25/tonne.

We assume rejects are 5% of input material and that these are sent to landfill.

In a well-developed market for compost, we would attribute a revenue of €3.50 per tonne, but here we make the conservative assumption that compost is taken free of charge, i.e. presenting no disposal cost to the facility, nor any revenue.

Ammonia Scrubber

There is potential for GHG abatement through the use of scrubbers before biofilters at in-vessel compost plants

The costs of the scrubber relate to the volume of air-flow through the scrubber. For a 20,000 tonne per annum plant, the airflow would be, at a maximum, around 40,000 m3/hr. A suitable scrubber with circulation pump, tank for sulphuric acid and tank for ammonium sulphate would cost of the order €125,000 including additional piping (somewhat less –€87,500 or so - for the scrubber alone). We therefore model on the basis of a capital cost of €6.25/tonne. Operating costs associated with electricity use, use of concentrated sulphuric acid, use of water, maintenance, and management of residue (ammonium sulphate) have been estimated at €1.55 per tonne of waste input.

Romanian Costs for IVC

Eunomia (2002) shows that between 20 and 30% of the total investment cost will be reflected in labour. This labour cost includes the development of the site and technical installations. Therefore we have assumed that 25% of the capital expenditure will relate to the civils costs.

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[15] Jacobs (2008) *Development of a Policy Framework for the Tertiary Treatment of Commercial and Industrial Wastes: Technical Appendices*, Report for SNIFFER / SEPA, March 2008.

[16] EEA (2002) *Biodegradable municipal waste management in Europe: Part 3 Technology and market issues*, available at: http://www.eea.europa.eu/publications/topic_report_2001_15

Eunomia (2002) shows that between 20 and 30% of the total investment cost will be reflected in labour. This labour cost includes the development of the site and technical installations. Therefore we have assumed that 25% of the capital expenditure will relate to the civils costs.

Therefore, the capital cost is revised downwards from €205/tonne to €161/tonne, and the operating cost is revised downwards from €12.50/tonne to €12.20/tonne. The costs for ammonia scrubbing have likewise been reduced from €6.25/tonne to €4.90/tonne, and from €1.55/tonne to €1.50/tonne

A.2.2.3 Anaerobic Digestion

Like IVC systems, AD facilities come in different shapes and sizes. Most digesters have vertical tanks, but some are horizontal. Mechanisms vary considerably and a number of patented processes exist. Processes may:

- Operate at high or low solids content:

  Wet digestion processes are carried out at a Total Solids (TS) content of no more than 15% by weight, most commonly within the range of 7-12% TS. Usually, water must be added to the feedstock at the slurrying stage to dilute the waste (organic materials range from 10-30% TS). Mixing in process tanks can be achieved by mechanical mixers within the tanks, or by gas mixing, using recirculated biogas, if TS in the digester is below 10%. Most wet digestion processes use a completely mixed reactor.

  Dry digestion processes are carried out at a Total Solids (TS) content of over 15%, with 25-40% being the most common TS range. This material is too thick for liquid-handling pumps, and therefore dry digestion technologies use concrete pumps and screw conveyors. Mechanical and gas mixing equipment cannot usually handle the high solids concentrations of dry digestion, and therefore mixing is achieved by the configuration of the digester and recirculation of waste through the digester. The tank is usually a plug flow reactor, rather than a completely-mixed reactor as normally used in wet digestion;

- Operate at mesophilic or thermophilic temperatures:

  AD can function over a large range of temperatures from so-called psychrophilic temperatures (around 10 ^{o}C) to extreme thermophilic temperatures (>70^{o}C). Temperature influences the speed (kinetics) of anaerobic reactions. In particular, methanogenesis is affected by temperature, with rates and yields increasing with temperature. Reactor temperature affects not only the reaction velocities of physico-chemical processes, but also, biochemical conversion rates.

  The average value of temperature over a long time period fixes the bacterial population thus defining the two major groups of micro-organisms. These are usually classified in association with two temperature ranges, around 35^{o}C in the mesophilic range (25^{o}C-40^{o}C), and around 55^{o}C (45^{o}C-65^{o}C) in the thermophilic range. A variation of reactor temperature within the specified ranges can change reaction velocity.

The vast majority of digestion, especially of OFMSW, is carried out in these two temperature ranges. In the year 2000, more than 60% of capacity for treating municipal-type waste was in the mesophilic range with thermophilic accounting for just less than 40%.[17]

- Be one- or two- stage in nature:

  As investigations concerning anaerobic digestion have proceeded, concerns regarding inhibitors of the reaction process, and as to what might be the rate-limiting step in the process have given rise to processes which, rather than occurring in one tank, are carried out in separate reactors in more than one stage. The rationale for this is that the conversion of organic wastes to biogas is mediated by a sequence of reactions which are not necessarily optimized under the same conditions. Typically, two stages are used in which the first harbours the liquefaction-acidification reactions (with a rate limited by the hydrolysis of cellulose) and the second harbours the acetogenesis and methanogenesis, the rate of which is limited by the slow microbial growth rate. If the stages occur in separate reactors, the rate of methanogenesis can be enhanced through biomass retention schemes (or other means) whilst the rate of hydrolysis can be speeded up through using microaerophilic conditions.

  Various reactor designs have emerged over time. However, although in theory, the design of multi-stage systems should improve performance, in practice, the main advantage appears to be reliability in treating wastes which exhibit unstable performance in single-stage systems. Amongst these more problematic materials are those with very low C/N (Carbon/Nitrogen) ratios, such as market / wet kitchen wastes. Hence, Bernal et al observed that, under thermophilic conditions, if the feedstock has high biodegradability (as with market wastes), the rate of acidogenesis may create more acids than can be converted by methanogenesis, affecting the stability of the process.[18] This problem could be overcome by using separate reactors. Yet the comparative disadvantage which single stage systems have in this regard can be overcome by co-digesting these more problematic wastes with other materials, biological reliability being improved by buffering and

[17] L. De Baere (2000) State of the art of Anaerobic Digestion of Solid Waste in Europe, *Water Science and Technology*, Vol.41, No.3, pp.283-90.

[18] O. Bernal, P. Llabres, F. Cecchi and J. Mata-Alvarez (1992) A Comparative Study of the Thermophilic Biomethanization of Putrescible Organic Wastes, *Odpadny vody / Wastewaters*, Vol. 1, No.1, pp.197-206.

mixing. Hence, multi-step processes still account for only 10% or so of the market for digesters dealing with solid wastes; and

- Be continuous or batch processes:

  Most systems are continuous systems. Batch systems are usually simply filled with fresh wastes (with or without seed material) and are allowed to go through all stages of degradation in the dry phase. Sometimes described as being akin to 'landfill in a box', these systems generate much more biogas than landfills because of the continuous recirculation of leachate (effecting a partial mixing through distribution of inoculant, nutrients and acids) and the higher temperature of operation.

We assume a lifetime of capital of 20 years, and a rate of rejects to landfill of 5%.

AD with Electricity Generation

Greenfinch gave figures for capital costs of €5 million for 20kt, and operating costs of €25 per tonne including rejects, but before revenues.[19] These are likely to be lower costs than would be realizable under a contractual situation. Capital costs for AD facilities used to deal with household, or industrial food wastes (and other biowastes) tend to be of the order €312 - €437 per tonne depending upon scale and the nature of the facility.

In a feasibility study for Northern Ireland, suppliers were asked about the capital costs for facilities of given sizes.[20] The results are shown in Table A. 7. It can be seen that the capital costs vary enormously, rather more for a given scale plant than the operating costs. This, combined with the different ways of treating capital costs, makes it difficult to generalize concerning the costs of digestion plants. Particularly when dealing with source segregated fractions of municipal waste, digesters tend to be more or less heavily engineered to deal with potential contraries. In addition, post-digestion processes vary across suppliers.

Table A. 7: Key Financial Data for Digestion Plant (rounded to the nearest €)

CAPACITY	**10,000**	**20,000**	**25,000**	**50,000**	**50,000**	**50,000**	**75,000**	**165,000**
Total Investment Cost	4	4	16	8	22	20	20	25
Unit Investment Cost	391	188	634	150	440	400	267	152
Unit Operating Cost	34	25	25	23	20	35	28	28

19 Greenfinch (2003) *Presentation by Greenfinch Ltd Based on Anaerobic Digestion: City Solutions Day*, New & Emerging Technologies for Waste, February 2003.

20 Eunomia (2004) *Feasibility Study Concerning Anaerobic Digestion in Northern Ireland*, Final Report for Bryson House, ARENA Network and NI2000.

A Juniper report invited offers for a mock facility treating 30,000 tonnes of food waste and 10,000 tonnes of slurry. The figures obtained from respondents using extensive pre-treatment were of the order €5.25 - €6.25 million (or €175 – 209 per tonne capex if one considers the food only).[21] The operating costs were quoted as €425,000, or around €14 per tonne. We assume these are net of revenues from energy sales since they are so low.[22]

One can see, therefore, a very wide variation in the capital cost figures being quoted, and the variation cannot be explained by appeal to factors such as scale alone, partly because of the variety of technical designs on offer.

We have used a figure of €445 for unit capital costs. For operating costs, we have good reason to believe that if one is seeking a figure before revenue generation from energy sales, and disposal of rejects, the figures above are all too low. We have used a figure of €37.50 per tonne. We believe this to be representative of facilities of scale 20-30,000 tonnes capacity, with appropriate post-treatment of the digested biowaste.

Romanian Costs for AD with Electricity Generation

A Canadian feasibility study notes that a separate digestion facility has an associated labour cost of 51%.[23] This is considered to be high and may include the cost of materials. Eunomia (2002) examined the cost of building and operating several AD plants in Europe. The labour element of the capital cost ranges from 25% to 35%. Due to the potential for labour to be transferred from one country to another, and thus less likely to vary across member states we have deemed it prudent to assume that 25% of the capital cost can be attributed to labour.

Therefore the capital cost is revised downwards from €445/tonne to €350/tonne, and the operating cost is revised downwards from €37.50/tonne to €30.10/tonne.

A.2.2.4 Landfill

The landfill model is broken down into:

- The capital costs for the site.

  Evidently, these may vary in unit (i.e. per annual tonne treated) terms depending upon the size of the site. We have modelled on the basis, broadly, of:

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[21] The slurry was deemed to have only 5% solids content so only 5% or so of the solids would be in the slurry.

[22] Juniper (2007) *Commercial Assessment: Anaerobic Digestion Technology for Biomass Projects*, Report for Renewables East, June 2007.

[23] Electrigaz Technologies Inc. (2008) Feasibility Study – Biogas upgrading and grid injection in the Fraser Valley, British Columbia

  - A fill rate of 250,000 tonnes per annum and a lifetime of 12 years;

    Of course, fill rates and life times vary, as will the total available void of a given site. This was felt to be broadly representative of a modern site, or extension;

  - Capex, including site assessment, acquisition, and site development, is modelled at €145 per tonne of material accepted at the site each year (in other words, the landfill is being treated as a facility with a 250,000 tonne throughput, with capex of €145 per tonne of that annual throughput);

  - We acknowledge that site acquisition is a large factor in determining the capital cost of a landfill, and that these costs may vary by location.

- Operating costs are estimated at €8.75 per tonne, before revenues from energy generation, whilst restoration, post-closure and aftercare are estimated to cost a further €8.75 per tonne. Annual maintenance is taken to be 5% of capital costs.

Romanian Costs for Landfill

Site assessment represents a significant proportion of civils costs associated with landfill capex. We have assumed this to be at 1% based on the landfill extension detailed by Eunomia and summary of landfill costs produced by Enviros.[24,25] Other components of the civils cost relate to site development and the engineering requirements. Figures provided for these costs are not conclusive. Enviros note that engineering costs could increase to 15% of the capital expenditure in future years.

Based on the facility outlined above, the Eunomia study of 2002, and from our experience of the landfill market we have estimated the percentage of capex associated with labour to be 20%.

The operating cost of landfill is essentially composed of labour costs and the cost of operating equipment. We have assumed that approximately 50% of the operating cost is comprised of labour. This assumption accounts for the labour intensive nature of landfill operation.

Therefore the capital cost for such a landfill would be revised downwards from €145/tonne to €120/tonne, and the operating cost/post closure and aftercare costs revised downwards from €8.75/tonne to €5/tonne. However, we anticipate that future landfills in Romania may be smaller in scale. Given a requirement for 5,000,000 tpa to

[24] Eunomia (2002), *Costs for Municipal Waste Management in the EU: Annexes, Final Report to DG Environment, European Commission*, http://europa.eu.int/comm/environment/waste/studies/pdf/eucostwaste.pdf

[25] Enviros Consulting Ltd. (2003) *Landfill Financing and Contracts*, available at: http://www.landfill-site.com/Landfill_Costs_Paper_Sardinia_2003.pdf

landfill (a level between that of the Business As Usual and the alternative Scenarios), over 42 counties, if assuming one landfill per county, that would lead to an average annual fill rate of around 120,000 tonnes per landfill.

Accordingly to account for the reduced economies of scale, of the halving of capacity, we increase the capital costs by two thirds to €200/tonne, increase the operating cost to €8.33/tonne, and the post-closure and aftercare costs to €8.33/tonne.

A.2.2.5 Incineration with Combined Heat and Power (CHP)

Quotes from public sources on incinerator costs (electricity generation only) are given in Table A. 8.

Table A. 8: Publicly Quoted Sources of Incinerator Cost Information

	Capacity (kt)	Capex (€ mn)	Unit Capex (€/tpa)	Opex (€/t)	Opex Average (€/t)	Gate Fee (indicative) (€/t)
McLanaghan (SU) (2002)	63	16-24	254-381	44-67	56	
	125	31-45	248-360			
	188	48-56	255-298			
	250	50-73	200-292			
	500	91-125	182-250			
	625	100-131	160-210			
AEAT (North London) (1999)	563	104	185			31
	338	77	228			38
AEAT (EA) (elec only) (1999)	125	44	352	30		
	250	66	264	28		
	500	113	226	21		
AEAT (EA) (CHP) (1999)	125	51	408	33		
	250	79	316	30		
	500	133	266	23		
Ilex (2005)	200	73	366			
Jacobs (2008)	250	108	432			
Dijkgraaf (2001)	648	436	673			
SITA Roosendaal (2011)	291	200	687			

Note: AEAT capex figures exclude costs of land, and gate fees exclude costs of dealing with residues.

Sources: S. McLanaghan (2002) Delivering the Landfill Directive: The Role of New and Emerging Technologies, Report for the Strategy Unit, 0008/2002; AEAT (1999) Waste Pre-treatment: A Review, Agency R & D Report Reference No PI-344/TR; Ilex Consulting (2005) Eligibility of Energy from Waste – Study and Analysis, Final Report to the DTI, March 2005; Jacobs (2008) Development of a Policy Framework for the Tertiary Treatment of Commercial and Industrial Wastes: Technical Appendices, Report for SNIFFER / SEPA, March 2008; Dijkgraaf, E., Aalbers, R.F.T., Varkevisser, M. (2001) Effects of open national borders on waste incineration: The Netherlands, Prepared for the 2nd Annual International Management Waste-to-Energy 2002.

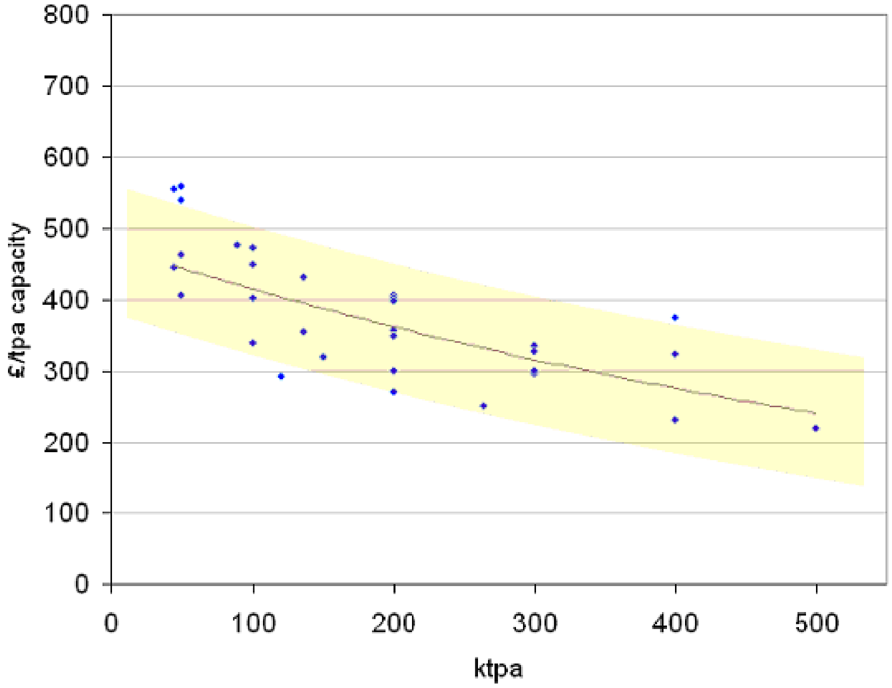
The variation in these costs (in Table A. 8.), and the number of years over which they have been gathered serves to highlight the paucity of good, publicly available information, as well as the dependence of costs on issues unrelated to the plant itself. Notable in this respect is the fact that in 2001, the unit capital costs for a Dutch facility of 648,000 tonnes per annum were reported as €673/tonne, whereas for a smaller Dutch facility, recently opened, of 291,000 tonnes per annum, unit capital costs in 2011 were reported as €687/tonne. All things being equal, one would have expected a much lower cost for the larger facility back in 2001 due to recent cost inflation in construction projects, and the impact of economies of scale on unit operating costs. The costs of such facilities are particularly sensitive to planning risks, and the nature of the procurement process.

We begin by describing the basic configuration, i.e. electricity generation only, and then describe the additional costs associated with CHP.

We initially develop costings on the basis of a large scale plant (for regional treatment of waste) averaging around the order 400,000 tonnes per annum capacity. We then amend these costs for smaller facilities. We assume a lifetime of capital of 20 years. The incineration model is broken down into:

- A capital cost element:
  - Unit capital costs could, as seen above, be quite variable in any given situation and would depend upon scale, the nature of risk transfer, the detailed plant design, the requirements in terms of architecture, the nature of the flue gas cleaning technology etc. Quoted figures do not always include the costs of land. SLR looked at plants already built and found that capital costs varied with scale as in Figure A. 1. Given cost inflation in construction projects over the past few years, these figures are probably rather low for new-build facilities.

Figure A. 1: Variation in Incinerator Capital Cost with Scale



Note: £/tpa refers to the "capital cost (in UK pounds here) per tonne of waste treated"; ktpa refers to "thousands of tonnes of waste treated per annum

Source: SLR (2008) Cost of Incineration and Non-incineration Energy-from-waste Technologies, Report to the Mayor of London, January 2008.

- A number of more recent cost estimates are shown in Table A. 9.

Table A. 9: Recent Incinerator Capital Cost Assessment

Facility	Start of Operation	Capital Cost (€m)	Capacity (ktpa)	Unit Capital Cost (€/tonne)
Covanta, Merthyr Tydfil, Wales (UK) (CHP)	Proposal abandoned in Oct 2011	480	750	640
WRG, Allington, Kent (UK)	2008	180	500	360
SITA, Cornwall (UK)	Not yet commenced	140	300	468

SITA, Roosendaal (NL)	2011	200	291	687
SITA, New Blakenham, Suffolk (UK) (CHP)	Not yet commenced	222	269	825

Sources: Ecoprog (2011) Waste-to-Energy Monitor 22/2011, available at http://www.ecoprog.com/fileadmin/user_upload/leseproben/ecoprog__WTE_Monitor_22-2011.pdf ; Kent Enviropower (2011) Key Facts and Figures webpage, available at http://www.kentenviropower.co.uk/enviropower.asp?ID=65 ; Ecoprog (2011) Waste-to-Energy Monitor 22/2011; BBC News (2011) Vital funding for Cornwall's incinerator at risk, 24 November 2011, available at http://www.bbc.co.uk/news/uk-england-cornwall-15869814 ; Waste Management World (2011) 32MW Dutch Waste to Energy Facility Opened, 2 November 2011, available at http://www.waste-management-world.com/index/display/article-display.articles.waste-management-world.waste-to-energy.2011.11.32_MW_Dutch_Waste_to_Energy_Facility_Opened_.QP129867.dcmp=rss.page=1.html ; Bury Free Press (2011) Industry to Join Waste Plan, 24 November 2011, available at http://www.buryfreepress.co.uk/news/business-news/industry_to_join_waste_plan_1_3258336

- Taking account of the above figures, for an electricity only plant of circa 400,000 tonnes capacity, we model capital costs of €625 per tonne.

➢ An operating cost element:

- For operating costs, before revenues from electricity generation and costs of dealing with residues, we have used a figure of €25 per tonne;
- Revenues from electricity generation are estimated on the basis of net delivered energy;
- Revenues from renewable energy subsidies are likewise on the basis of net delivered value. We assume that support is received for energy generation from the biogenic fraction of waste, taken to be 45% of the total tonnage throughput;
- Costs of dealing with residues:
  - For fly ash, taken to be 3.5% of input tonnage, the waste is assumed to be landfilled at a hazardous waste landfill. We have not modelled this explicitly but have used a fixed figure of €180 for the costs of landfilling hazardous waste.
  - For bottom ash, modelled at 25% of input tonnage, we assume that on average around one-third of material is put to some form

of use in the construction industry. The remaining two-thirds are assumed to be landfilled at non-hazardous waste sites.

Additional Costs of CHP

It is difficult to estimate, with any degree of accuracy, exactly what could be the costs of a CHP system given that so many variables exist. Costs will depend upon the specific design of a given CHP scheme. Not only are there differences related to the nature of the infrastructure required, but also, there will be differences in the impact on the plant itself, depending upon whether the intention is merely to use low grade heat for district heating, or medium or high pressure steam extraction. The former will have little impact on power generation; the latter will have a more significant effect.

Ilex estimated the costs of a CHP system on behalf of BERR.[26] The estimated costs of CHP were based around the development of a 400,000 tonne per annum plant, partly because a previous report had suggested that larger plants of this size were likely to be developed.

Costs of CHP relate to:

- Costs of providing heat from the facility (relative to costs of providing electricity only);
- Costs of securing a market for the heat; and
- Loss of revenue from power sales.

The first of these includes the costs of tapping into the steam turbine where the initial design allowed for this (and several have done so, or are planning to do so), provision of heat exchangers, and (depending on the nature of the recipients) provision of back-up boilers. In addition, the infrastructure for heat supply to the users has to be put in place if it does not already exist. The nature of the heat consumer(s) is likely to be a key determinant of these network-related costs. It is difficult to generalise these costs, given the wide variation in the possible networks. In principle, co-location alongside a major industrial heat user would be likely to give lower costs, but in practice, the likelihood of this occurring at conventional incinerators may be low. There might be a higher likelihood of merchant facilities being developed for the off-take of solid recovered fuel (SRF), especially where the heat user is involved in the project itself. Ilex estimated costs for different CHP plant as shown below in Table A. 10. These figures were intended to be indicative of costs. The 43 MW capacity relates to a heat generation efficiency of around 24%. This is the only CHP option considered by Ilex which seems likely to qualify as 'good quality CHP' as the net efficiency, however measured, is relatively low for the other

[26] Ilex Energy Consulting (2005) Extending ROC Eligibility to Energy from Waste with CHP, a supplementary report to the DTI, September 2005.

options considered. The figures in Table A. 10 show that the main costs are related to the provision of the network and customer connections, and that in the Ilex assumptions, these show some clear increase with scale, which might not be the case depending upon the nature of customers.

In reviewing the Leeds scheme, Fichtner comments on Jacobs' costs associated with a CHP system which, it is claimed, have been taken directly from a scheme considered for a 250,000 t/a EfW facility.[27] The capital costs for the CHP scheme were £33.8 million and the annual operating cost is £320,951 per annum. The 250 ktpa facility is, in fact, a 400ktpa facility, and one with a power efficiency of 20% and a heat efficiency of 12%. This would imply efficiency of heat generation of the order 20% for a 250ktpa facility, which is quite a low figure (and would, arguably, imply a very poor use of capital in the investment in the heat network).

Table A. 10: Capex and Opex Assumptions for 400kt/year incinerator with CHP

Thermal Capacity	**Capex (€m)**			**Annual Opex (€m/year)**			
	Heat Exchan-ger	Heat Network	Customer Connections	Pumping	Heat Exchan-ger	Heat Network	Customer Connections
3	0.24	2.99	1.19	0.01	0.00	0.01	0.03
11	0.78	8.50	3.85	0.03	0.01	0.04	0.08
20	1.10	18.54	6.99	0.04	0.01	0.09	0.14
23	1.13	19.76	8.04	0.05	0.01	0.10	0.16
28	1.13	24.06	9.79	0.06	0.01	0.13	0.20
30	1.19	25.78	10.49	0.06	0.01	0.13	0.21
34	1.19	29.21	11.89	0.08	0.01	0.15	0.24
43	1.23	36.95	15.04	0.09	0.01	0.19	0.30
66	1.25	56.71	23.08	0.14	0.01	0.29	0.46

Note: Costs for heat networks, to a lesser extent, customer connections, will be very site specific and these numbers are intended only to be illustrative

[27] Fichtner (2007) Jacobs Leeds Energy-from-Waste: Validation of EFW Costs, 7 September 2007.

Source: Ilex Energy Consulting (2005) Extending ROC Eligibility to Energy from Waste with CHP, a supplementary report to the DTI, September 2005.

The CHP option which most closely reflects our technical options are those with the higher thermal capacity (even though we are considering a smaller plant). The heat network and the customer connections would, using Ilex's figures, imply additional capital costs of the order €53.8-€81.3 million. Perhaps unsurprisingly, in Ilex's analysis, these scenarios – where the heat generation is greatest – are those which appear least favourable from a financial perspective given the power penalty implied by the increase in heat demand. Interestingly, the bottom row of the Table implies a heat generation efficiency of only 24%, with power generation at 17%, implying a much higher power to heat ration than might be expected in many CHP systems which had what one might call a 'serious' focus on heat provision.

In a report carried out at the turn of the decade for the European Commission, investment costs for power and CHP schemes in Finland were as set out in Table A. 11. What this shows is the relative costs of power only schemes to those generating heat and power. The differentials are not trivial. Given that these figures are expressed in Euros in 2000, then accounting for exchange rate movements and for inflation over the last decade, the figures do not seem so different to those provided by Ilex.

Table A. 11: Investment Costs for CHP in Finland (in €, year 2000 values)

	Heating	Power / heating	Heating	Power / Heating
Capacity, tons/year	40,000	40,000	300,000	300,000
Investment	13,336,000	24,248, 000	52,490,000	95,437,000

Source: Eunomia (2002), Costs for Municipal Waste Management in the EU: Annexes, Final Report to DG Environment, European Commission, http://europa.eu.int/comm/environment/waste/studies/pdf/eucostwaste.pdf

In another report, Jacobs suggest that at 25,000 tonnes capacity, unit capital cost figures increase by £135 (€169) per tonne (or around a 40% increase in costs relative to their power only estimate).

In our analysis, we have used Ilex's figures at the 43 MW size, for a 400,000 tonne per year plant, implying heat generation at around 30% of input energy. For such a scheme, the following applies:

- Additional capital costs of €53.75 million;
- Additional operating costs of €0.58 million;

We therefore model on the basis of additional capex of €134 per tonne, and additional opex of €1.45 per tonne. However, due to the uncertainties inherent in these figures, to avoid giving the impression of spurious accuracy, we round up to give a total capex of €760 per tonne and total opex of €27 per tonne.

For this project we will be modelling facilities of different scales. Broadly applying the variations in capital costs with scale seen in Figure A. 1, i.e. shifting the trend line upwards based on the estimated capital costs for a 400ktpa facility, we obtain the following capex figures:

- 400ktpa - €760/tonne;
- 200ktpa - €860/tonne; and
- 100ktpa - €1010/tonne.
- A report for the UK's Environment Agency identifies the following unit operating costs per tonne for a CHP plant:[28]400ktpa - £18/tonne;
- 200ktpa - £24/tonne; and
- 100ktpa - £26/tonne.

It can be seen that the opex for a 200ktpa facility is 33% higher per tonne than for a 400ktpa facility. For a 100ktpa facility the increase in per tonne opex over the 400ktpa facility is 44%.

Applying these uplifts gives the following unit opex figures:

- 400ktpa - €27/tonne;
- 200ktpa - €36/tonne; and
- 100ktpa - €39/tonne.

Romanian Costs for Incineration with CHP

The 2002 report for the UK's Environment Agency suggests that civil engineering costs represent 16% of the capital costs of incineration plant at scales of 100ktpa, 200ktpa and 400ktpa capacity.[29] Therefore technology costs are taken to be 84% of the total capital cost of the facilities considered here. From the same report, the labour element of operational costs is taken to be 18%.

Therefore the capital and operational costs may be revised downwards to account for the lower than average costs of labour in Romania (see Section A.2.1.1), As shown in Table A. 12

[28] Environment Agency (2002) Waste Pre-Treatment: A Review, R&D Technical Report P1-344. Report by AEA Technology for the Environment Agency.

[29] Environment Agency (2002) Waste Pre-Treatment: A Review, R&D Technical Report P1-344. Report by AEA Technology for the Environment Agency.

Table A. 12: CHP Capex and Opex amended for Romania

Cost category	Typical EU cost (€/tonne)	Calculated cost in Romania (€/tonne)
Unit Capex – 400ktpa	€760	€656
Unit Capex – 200ktpa	€860	€743
Unit Capex – 100ktpa	€1010	€872
Unit Opex - 400ktpa	€27	€25.39
Unit Opex - 200ktpa	€36	€33.85
Unit Opex - 100ktpa	€39	€36.67

A.2.2.6 Mechanical and Biological Treatment (MBT)

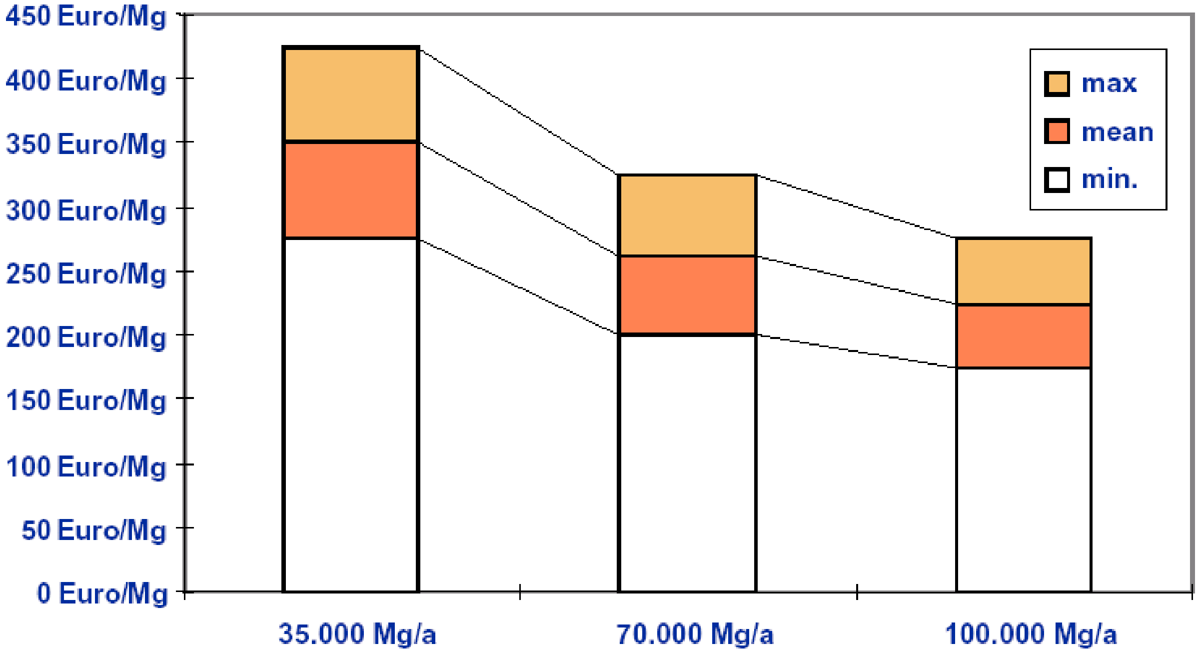
MBT facilities can be configured in various different ways. Generally, outputs include more than one of the following:

- Recyclables;
- A stabilised biowaste, which may find use as a 'compost like output', but which may have to be landfilled;
- A fraction to be sent to landfill; and
- A refuse derived fuel.

For some facilities of this nature, particularly lower capital cost MBT processes based on aerobic treatment, 60,000 tonnes or so is believed to be a near-optimum scale from a technical (if not a project) perspective. Figure A. 2 showing the results of analysis of tenders for German plants over one year, suggests that economies of scale may already be limited at a capacity of 100,000 tonnes.

It should also be noted that this review covered a range of plant sizes with 60,000 tonne facilities falling in the middle of this range. This type of capacity is far from unusual for MBT plants. Indeed, the average size for the German facilities is around 70,000 tonnes.

Figure A. 2: Range of Unit Capital Costs Reported in German Tenders for MBT Facilities (by capacity)



Our analysis assumes essentially two types of biological treatment process:

- Aerobic stabilisation system with the output being delivered to landfill; and
- Aerobic biodrying system to produce an SRF with the output sent to a cement kiln.

Aerobic Stabilisation

Stabilisation technologies are low capital cost treatments for residual waste. We have used a figure of €230 per tonne, and an operating cost of €19 per tonne before disposal costs. A French study into the cost of MBT found that a 30,000 tpa stabilisation system with residues to landfill will cost €4.5 million in 2005 prices. This suggests a cost of €150 per tonne.[30] This is considered to be quite a low cost. In the UK an examination of various MBT configurations from 2005 has suggested that for a stabilisation facility of this nature would incur a capital cost of €201 per tonne.[31]

30 ENGREF (2006) Mechanical biological treatment of waste : advantages, drawbacks, costs and stakeholders, Technical Synthesis

31 Milton Keynes (2005) Costings, mass balances and BMW mass balances for various MBT concepts, Report for Milton Keynes Council

These costs are similar to those for in-vessel composting, reflecting similarities in technology, though scale will usually be larger, and there are costs of residue disposal to be considered. We have assumed all residues are landfilled except in the case where a 'compost like output' is deemed capable of being used on land.

Aerobic Biodrying Facility Preparing SRF

In principle, the costs of this type of system will be different depending upon whether the SRF which is being prepared is to be of higher or lower quality. The waste is unloaded into a reception pit where it is transferred to a shredder to reduce the size. The waste is then transferred to a biodrying area. The aerobic fermentation occurs in windrows. We have used figures for the capital cost of €250 per tonne, with operating costs of €21 per tonne before residue disposal.[32] These estimates are supported by the data gathered by Juniper Consulting in 2003.[33] It should be noted that the reality is that both the capital costs and the costs of dealing with residues will depend upon the detailed configuration of the system and the specification to which SRF is being produced. We have assumed that the SRF produced is used in a cement kiln, with a cost for the off-take of SRF from the MBT facility of €20/tonne, plus €15/tonne transport (i.e. a total cost of €35/tonne).

Romanian Costs for MBT

Labour costs are not readily available for all MBT processes in their various forms and combinations. Juniper Consulting carried out an extensive survey of current MBT processes and technologies.[34] The civil works for two plants are provided. The reference plant produces bio-stabilised output which is used as a soil improver or landfilled. Some of the processes produce SRF as an output. The cost figures from this study were compared to a separate system - a SRF producing 'reverse air flow' MBT proposed for the DEFRA New Technologies Demonstrator Programme.[35] For the proposed DEFRA facility, 37% of the capex was attributed to labour cost. The Juniper study suggests that between 41% and 45% of the capex will be allocated to labour costs. Other examples have suggested that a lower labour cost, at 29% of total capex, is to be expected. It was deemed prudent that a mid-range estimate of 30% be taken as the civils cost associated

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32 Cllr Eddy Alcock (2006) *Study Tour of Selected German Waste Processing Plants*, available at: http://www.suffolk.gov.uk/NR/rdonlyres/056D566A-5B88-4F3C-928F-D4CDEF5BD4C0/0/NotesofGermanVisitMemberDirectorFINAL.pdf

33 Juniper Consulting (2003) *Mechanical-Biological-Treatment: A Guide for Decision Makers Processes, Policies and Markets (Annexe D: Process Reviews)*, Report for SITA Environmental Trust 2005

34 Juniper Consulting (2005) *Mechanical-Biological-Treatment: A Guide for Decision Makers Processes, Policies and Markets (Annexe D: Process Reviews)*, Report for SITA Environmental Trust 2005

35 DEFRA (2005), *New Technology Demonstrator Programme: Catalogue of Applicants*, available at: http://www.urbanmines.org.uk/assets/files/n/newtechnologescataloguepdffile_288.pdf

with the capex of an MBT facility. We have assumed that the labour costs associated with capital expenditure will not vary significantly across the variety of MBT processes that are available.

Operating costs for an MBT facility in a Defra New Technologies proposal showed 24% of the operational cost for the plant attributable to labour. An ILEX study expects the labour element of operating costs to be higher, at 34%. Other operational MBT facilities indicate a still higher labour element. We have, therefore, used a figure of 34% for each configuration of an MBT facility in the absence of better information.

The capital cost for an aerobic stabilisation MBT facility is revised downwards from €230/tonne to €171/tonne, and the operating cost is revised downwards from €19/tonne to €14.50/tonne.

The capital cost for an aerobic biodrying facility preparing SRF is revised downwards from €250/tonne to €186/tonne, and the operating cost is revised downwards from €21/tonne to €16/tonne.

A.2.2.7 Transfer Stations

The cost per tonne of a residual waste transfer station will vary considerably based on:

- The cost of land;
- The annual throughput; and
- The nature of the task undertaken, be it simply aggregating waste for onward transfer, or compacting.

We model on the basis of a transfer station of 30,000 tpa having a capital cost of approximately €500,000, giving a capital cost of €15/tonne. Operating costs would comprise of staff, fuel and administrative overheads and may total €150,000 per annum, giving a cost of €5/tonne. Maintenance is at 5% of unit capital costs.

Lifetime of capital is 15 years, and cost of capital is 12%.

A.2.2.8 Landfill Closure

As shown in Annex A.2.2.4, we model landfill post-closure and aftercare costs for new landfills to equal €8.33 for each tonne to landfill over the facility lifetime. These are included as annual payments for the future management of the landfill at and beyond end-of-life. Assuming an annual landfill capacity of 120,000 tonnes over a 12 year lifetime, these costs would total €11,995,200 for the whole site. Costed on the basis of the annual input tonnage, these would equal €99.96 per tonne.

An important distinction has to be made between restoration, involving the initial capping, and aftercare which can be ten times more expensive, and may continue for decades. This will include the extraction and management of further landfill gas, (which will provide a source of revenue in the early years) and the monitoring of leachate. Furthermore, the costs attributable to a specific site will vary depending on whether the focus is simply on the site itself, or whether responsibility is taken for managing any downstream impacts from leachate. For a poorly constructed and managed site, where a greater amount of leaching has taken place over the site's operational lifetime, there will be less leachate to deal with *in situ*, which will reduce this cost. However, the negative impacts downstream would obviously be all the greater.

An additional factor is that for non-compliant landfill, a cost for retrospective capping would have to be included. Amongst other things this would enable gas capture. The additional cost, associated with capping and gas infrastructure, is modelled at 15% of capex. Taking the modelled annualised capital costs of €29.35 per tonne input, this represents a retrospective capping cost of €4.40 per tonne input. Assuming an annual landfill capacity of 120,000 tonnes over a 12 year lifetime, these costs would total €6,340,175 for a whole site of this size. Costed on the basis of the annual input tonnage, these would equal €53 per tonne of annual non-compliant landfill capacity.

A.2.2.9 Collection Costs Methodology

Collection costs modelled can be found in the Financial Assumptions within the Annex 3 mass flow model. They are based on integrated collection systems operating in the UK and elsewhere in Europe. The figures developed draw upon typical cost and performance indicators for waste and recycling collection services in the UK (from our own experience in auditing collection service operations and in specifying collection fleets), prior to adapting them to the Romanian specific situation. The assumptions used are listed as follows.

Vehicle capital costs are modelled at €132,000 for refuse collection vehicles and €96,000 for top-loading bring site service vehicles, both with an operational life of 7 years. Recycling and organic waste vehicles are assumed to collect 10 tonnes per vehicle per day, and residual waste vehicles – 12 tonnes per day, and all over 220 operational days per vehicle per annum.

Bin capital costs (€22 per wheeled bin) are modelled over a 10 year life, with an assumption of 500kg and 300kg of for residual and organic waste respectively collected per bin per annum. Sacks for recycling are assumed to cost €0.05 and hold 10kg. Bring site containers are assumed not to need replacement during the period in question so these costs are not included.

Operational costs for door to door collection systems are calculated from full annualised service costs per household for typical services operating in the UK, based on our extensive experience of collection systems. The capital element of the total annualised service cost (which in the UK tends to be about 20% of the total service cost) is stripped out to give the effective annual operational expense (opex). The opex per tonne is then calculated based on typical UK tonnage per household figures (so as to match with the service being provided). The labour proportion of the opex in the UK tends to be about 70% of the total, allowing calculation of the non-labour related element of the opex. This ‘non-labour opex’ is then added to a Romanian adjusted labour cost based on the relative costs of labour between the UK and Romania.

Opex for recycling services are net of material revenues, but organic and residual waste do not include treatment and disposal costs as these are applied separately in the modelling.

Operational costs for bring sites are based on a total service cost for running collection vehicles of €120,000 to €140,000 per annum (based on experience of evaluating tenders for services in the UK waste collection market) and then following the same technique to strip out the capital cost element. In the case of bring recycling, the material revenues are netted off from the opex at an average €36 per tonne across all materials.

Costs in the model are based on data in UK pounds and converted at €1.2 per UK pound. The methodologies described here lead to the modelled data presented in Table 3-2 in the main report above.

ANNEX 3: MASS FLOW MODEL (SPREADSHEET)

A.3 Spreadsheet Model Provided To Accompany This Report: "JASPERS Massflow Model V7 0.xls"

ANNEX 4: COUNTY DATA SHEETS

A.4 County Data Sheets – Proposed Investments: Scenario 3 (see separate file)