University of Southampton

Faculty of Engineering and the Environment

Environmental Assessment of
Waste to Energy Processes
Specifically Incineration and Anaerobic Digestion
Using Life Cycle Assessment

By
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Thesis submitted for the degree of Master of Philosophy

March 2014

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING AND THE ENVIRONMENT

Thesis for the degree of Master of Philosophy

ENVIRONMENTAL ASSESSMENT OF WASTE TO ENERGY PROCESSES SPECIFICALLY INCINERATION AND ANAEROBIC DIGESTION USING LIFE CYCLE ASSESSMENT

Anuda Tawatsin

Municipal solid waste is an issue every community in the world has to be concerned with. Without any management, municipal solid waste poses environmental and health risks to the community such as from water and air pollution. In selecting methods to deal with the waste, environmental impacts considerations are important to reduce these risks. Environmentally sustainable waste management processes should also decrease greenhouse gases contributing to global warming and climate change. Waste to energy (WtE) processes lessens and replaces the use of fossil fuels reducing greenhouse gases.

The research aims to assess the environmental impacts and energy recovery of WtE processes, specifically incineration or energy recovery facilities (ERF) and anaerobic digestion (AD) to select suitable options or any combinations thereof as part of an integrated waste management system for different locations and conditions by using life cycle assessment (LCA) methods.

WRATE (Waste and Resources Assessment Tool for the Environment) an LCA model is used to assess scenarios designed systematically with different combinations of incineration/ERF and AD. The study also varies other factors such as different recycling schemes and recycling rate, household waste composition and population density to determine the suitable combinations for different local conditions.

Results for both UK and Thailand confirm the need to reduce disposal of waste into landfills. The scenario with Incineration/ERF for heat recovery and a post collection recycling scheme and the combination scenario with Incineration/ERF for heat recovery and Anaerobic Digestion for vehicle fuel a post collection recycling scheme lead the ranking for most energy recovery and less environmental impacts.

The parameter exerting the greatest influence on LCIA of these set of scenarios is WtE technology. Second is recycling scheme with recycling rate as a subset. Third is energy recovery type. Population density also affects the outcome slightly by the magnitude of the values.

Keywords: Anaerobic Digestion, Incineration, Life Cycle Assessment, Municipal Solid Waste, Recycling, Waste to Energy, WRATE.

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DECLARATION OF AUTHORSHIP

I, Anuda Tawatsin

declare that the thesis entitled

Environmental Assessment of Waste to Energy Processes Specifically Incineration and Anaerobic DigestionUsing Life Cycle Assessment

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
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- none of this work has been published before submission

Siged: ……………………………………………………………………….

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Acknowledgements

First of all I would like to acknowledge and thank my parents and my sister for their love and support for every step of my life. Without my family I would not be alive. I am eternally grateful to my parents and my sister.

Secondly I would like to acknowledge and thank my supervisors, Dr. Sonia Heaven and Professor Charles Banks, for their advice, guidance and patience. Thank you to my examiners Dr. Stephen Burnley and Professor Ian Williams for their time and evaluation.

Thirdly I would like to acknowledge and thank Pollution Control Department, Thailand for giving me the opportunity to further my education.

I would also like to acknowledge and thank the Royal Thai Government .This research is made possible by the funding from the Royal Thai Government scholarship and the provision of the WRATE model by the Faculty of Engineering and the Environment, University of Southampton.

Last but not least I would like to acknowledge and thank my many friends (you know who you are) in many places that have helped me throughout the time taken to complete this thesis.

Thank you.

Abbreviations

AD	Anaerobic Digestion
APC	Air Pollution Control
BMW	Biodegradable Municipal Waste
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CRT TV	Cathode Ray Tube Television
DfE	Design for the Environment
Eq	Equivalence
ERF	Energy Recovery Facilities
FAETP	Freshwater Aquatic Ecotoxicity Potential
FBC	Fluidised Bed Combustion
GHG	Greenhouse Gases
GWP	Global Warming Potential
HDPE	High Density Polyethylene
HHV	Higher Heating Value
HTP	Human Toxicity Potential
HWRC	Household Waste Recycling Centres
IBA	Incineration Bottom Ash
IPP	Integrated Product Policy
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LHV	Lower Heating Value
MBT	Mechanical-Biological Treatment
MHT	Mechanical-Heat Treatment
MRF	Materials Recovery Facilities
MSW	Municipal Solid Waste
NTDP	New Technologies Demonstrator Programme
PET	Polyethylene Terephthalate
RCV	Refuse Collection Vehicle
RR	Recycling Rate
RDF	Refuse Derived Fuel

SELCHP	South East London Combined Heat and Power
SNCR	Selective Non-Catalytic Reduction
SRF	Solid Recovered Fuel
TA	Technology Assessment
WRATE	Waste and Resources Assessment Tool for the Environment
WEEE	Waste Electrical and Electronic Equipment
WtE	Waste-to-Energy

Chapter 1
Research Overview

1.1 Introduction

1.1.1 Sustainable Development

Efforts to alleviate world economic, social and health problems and growing concerns about the deterioration of the environment and the limitations on natural resources have led the global community to search for alternative ways leading to more sustainable development. The concept of sustainable development as defined in the Brundtland Report, Our Common Future (World Commission on Environment and Development, 1987) is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Countries all over the world have placed an importance on sustainability at the United Nations Conference on Environment and Development or Earth Summit 1992 in Rio de Janeiro. Sustainable development policies were agreed upon at the World Summit on Sustainable Development or Earth Summit 2002 in Johannesburg and reaffirmed and refined further at the Rio+20 or Rio Earth Summit in 2012 (United Nations, 2013).

1.1.2 Global warming and energy

The common concern is global warming and the consequences of climate change due to the notable increase of greenhouse gases (GHG) from industrial activities within the last century. The Kyoto Protocol adopted in 1997 in Kyoto, Japan, is an agreement linked to the United Nations Framework Convention on Climate Change. Developed countries, listed in annex B, committed to individual targets in reducing GHG during 2008-2012 with an average target of 5% GHG reduction from 1990 levels (UN, 2013). The European Union (EU) has reported that it has achieved beyond the targets of 8% reduction for EU-15 (15 member states at the time of agreement). From 2012 data it has reached 12.2% GHG reduction collectively. The EU is also preparing for further reductions by 2020, which will include newer EU members (EU, 2013). In 2012 governments convened at the UN Climate Change Conference in Doha, Qatar with outcomes including a new commitment period of 8 years starting from 1st January 2013 with targets of 18% GHG reduction from 1990 levels (UN, 2013).

Concentrations of carbon dioxide or CO_2, one of the main GHG, are strongly related to the use of fossil fuels. As the fuels are combusted to generate power, large amounts of carbon which have been stored in the fossil fuels are released as CO_2 at a faster rate than atmospheric carbon is being laid down elsewhere in the system. Therefore it is necessary to reduce the use of fossil fuels to limit the CO_2 emissions, as well as to prolong the use of fossil fuel reserves. There have been efforts all over the world to develop alternative energy sources including renewables such as solar, wind, wave and tidal energy. Other alternative energy sources focus on the use of resources that would naturally release CO_2 or methane, CH_4, in the decaying stage, such as biomass combustion and biogas from anaerobic digestion, AD.

1.1.3 Municipal solid waste

Municipal solid waste, MSW, is an issue of concern to every community as waste is inevitably generated by the activities of the population. Most communities around the world are trying to better manage their MSW to alleviate the environmental problems that may arise from it. In less economically developed communities, household wastes may not even be collected and are subject to dumping on land, thrown into waterways or burnt in the open, all in the vicinity of populated areas. Air pollution, surface water and groundwater pollution as well as vermin problems can all cause detrimental health effects on the community members. In more economically developed communities, the collected household wastes are often disposed in landfills. Some of these landfills may not be proper sanitary landfills and can still cause environmental problems, as well as releasing CH_4 emissions as the waste decays. In many countries, landfill space is increasingly limited and alternative disposal methods are necessary. In the most economically developed communities, applications of integrated waste management may include segregating waste, recycling, composting, incineration, landfill, and energy recovery methods.

Figure 1.1 Open dumping at a landfill site in Thailand

The amount of MSW generated in each area is related to many factors, including economic development and geographical location. In Thailand the amount of MSW generation in 2011 was 15.98 million tonnes and the MSW generation per person was 0.65 kg/day, with only 40% disposed of by a proper method (Pollution Control Department, 2012). Figure 1.1 shows an example of improper method of disposal at a landfill site in Thailand. The waste is mainly dumped on the land with no daily cover. The landfill may have a compacted clay lining but the waste has overflowed the original boundaries, and leachate collection is a problem. The Pollution Management Plan for the years 2011-2015 established a target to increase the proper disposal of waste to 50% (Pollution Control Department, 2011b).

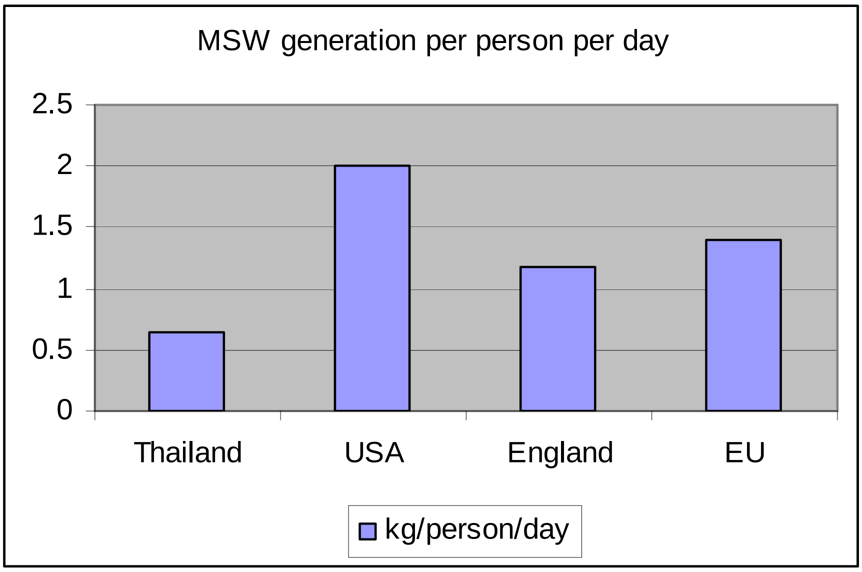

Figure 1.2 MSW generation per person per day

In the United States of America, USA, the amount of MSW generated in 2011 was 250.4 million tonnes and the MSW generation per person was 4.4 lb/day or 2 kg/day (U.S. EPA, 2013). In England the total amount of collected MSW in the financial year 2011/12 was 22.9 million tonnes and the MSW generation per person was 431 kg/ year or 1.18 kg/day (Defra, 2012b). In the EU, the amount of MSW generation in 2009 was 256 million tonnes and the MSW generation per person was 512 kg/year or 1.4 kg/day (European Commission, 2011). The MSW generation per person are compared and shown in Figure 1.2.

1.1.4 Policy

Within the European Union, EU, waste management policies were established according to the main concepts in the Waste Framework Directive (1975), amended in 2008 (2008/98/EC). The directive recommends the hierarchy of waste management where the priority is first placed on waste prevention, then waste reduction, reuse, recycling, material and energy recovery and lastly landfill. The Waste Incineration Directive in 2000 (2000/76/EC) sets more stringent emission limits and monitoring requirements for waste incineration. The Landfill Directive in 1999 (1999/31/EC) sets targets to reduce biodegradable waste disposed in landfills at 75% of 1995 levels by 2006, 50% of 1995 levels by 2009 and 35% of 1995 levels by 2016 with four year extended deadlines for countries that landfill more than 80% of their waste in 1995.

The EU Renewable Energy Directive (2009/28/EC) sets a target for 2020 that 15% of electricity must be from renewable sources. In the UK this is implemented by the Renewables Obligation Orders, which require that licensed suppliers of electricity must increase the amount from renewable sources (DECC, 2009). The use of biomass in any Waste to Energy (WtE) technology is eligible, and only non-fossil derived energy is eligible for new technologies such as pyrolysis, gasification and anaerobic digestion (Oakdene Hollins, 2005).

The Waste Strategy for England 2007 (Defra, 2007) establishes policies, targets and incentives to manage waste sustainably. Regarding the reduction of waste, the target for household waste not reused, recycled or composted was 15.8 million tonnes in 2010, 14.3 million tonnes in 2015 and 12.2 million tonnes in 2020 (Defra, 2007). In 2008/09 the target was met at 15.2 million tonnes (Defra, 2009a). As for the reduction of biodegradable waste sent to landfill, the target was 11.2 million tonnes in 2010, 7.5 million tonnes in 2013 and 5.2 million tonnes in 2020 (Defra, 2007). In 2008/09 the target was met at 10.6 million tonnes (Defra, 2009a).

Landfill tax, introduced as a deterrent to the disposal of waste to landfill, continued to increase by £8 per tonne on 1 April each year from 2011 to 2013 (Defra, 2009a). In 2011/2012 the rate was £56 per tonne and is expected to reach £80 by 2014/15 (Defra, 2011b). In 2009 the UK government also set a target for 34% reduction in GHG emissions from 1990 levels by 2020 (DECC, 2009) and 80% by 2050 (Defra, 2011b). The targeted waste fraction with high carbon impacts are food, metals (especially aluminium), plastics, textiles, paper and card and wood (Defra, 2011b). The Government Review of Waste Policy in England 2011 (Defra, 2011b) also emphasised the need for an increase in recycling of waste from household to meet the revised Waste Framework Directive target to recycle 50% by 2020.

In 2011 the Department for Environment, Food and Rural Affairs (Defra) published the Anaerobic Digestion Strategy and Action Plan: A Commitment to Increasing Energy from Waste through Anaerobic Digestion. The plan included steps to further improve the knowledge and legislation on AD, use of biogas and digestate, establishing financial assistance programmes to increase the use of AD in the UK and develop markets for digestate (Defra, 2011a).

1.1.5 Resource recovery

While waste prevention and waste reduction are important and are prioritised before resource recovery in the hierarchy, this current research addresses resource recovery and in particular energy recovery as necessary steps for sustainable management of the wastes that have been generated. A change in paradigm to regarding waste as a resource, and not just something to be disposed of, is the key to sustainable waste management practice (Lisney et al 2003). Resource recovery includes material and energy recovery. In less economically developed communities and developing countries recycling may be done informally by householders separating certain valuable components of the wastes, such as glass and plastic bottles and metal cans, to sell to recyclate buyers; or by scavengers collecting from the streets and dumpsites. In more economically developed communities and developed countries recycling is more formalised, and materials are collected by systems with varying degrees of householder participation in source segregation and advanced technology in waste segregation facilities, such as materials recovery facilities (MRF). Energy recovery practices are generally more prevalent in more economically developed communities and in communities in colder climates as heat is produced as well as electricity.

In Thailand in 2011, 3.39 million tonnes or 21.21 % of MSW was recycled, 0.12 million tonnes or 0.75 % of MSW utilised in electricity generation or as fuel alternative, and 0.59 million tonnes or 3.69 % composted or used in biogas generation (Pollution Control Department, 2012). In England in 2011/12, 43 % of MSW was recycled or composted, 14 % of MSW incinerated with energy recovery (Defra, 2012a). In the USA in 2011, 34.7 % of MSW is recycled or composted, and 11.7 of MSW % incinerated with energy recovery (U.S. EPA, 2013). In the EU in 2009, 59 million tonnes or 23.5 % of MSW is recycled, 45 million tonnes or 17.9 % composted and 51 million tonnes or 20.3 % of MSW incinerated with energy recovery. Sweden, an EU member state with advanced environmental technology and the political will to implement good practice, as demonstrated by a ban on the landfilling of combustible waste, has a high rate of 49% energy recovery from MSW in 2009 (European Commission, 2011). Figure 1.3 shows the percentage of MSW utilised in incineration with energy recovery.

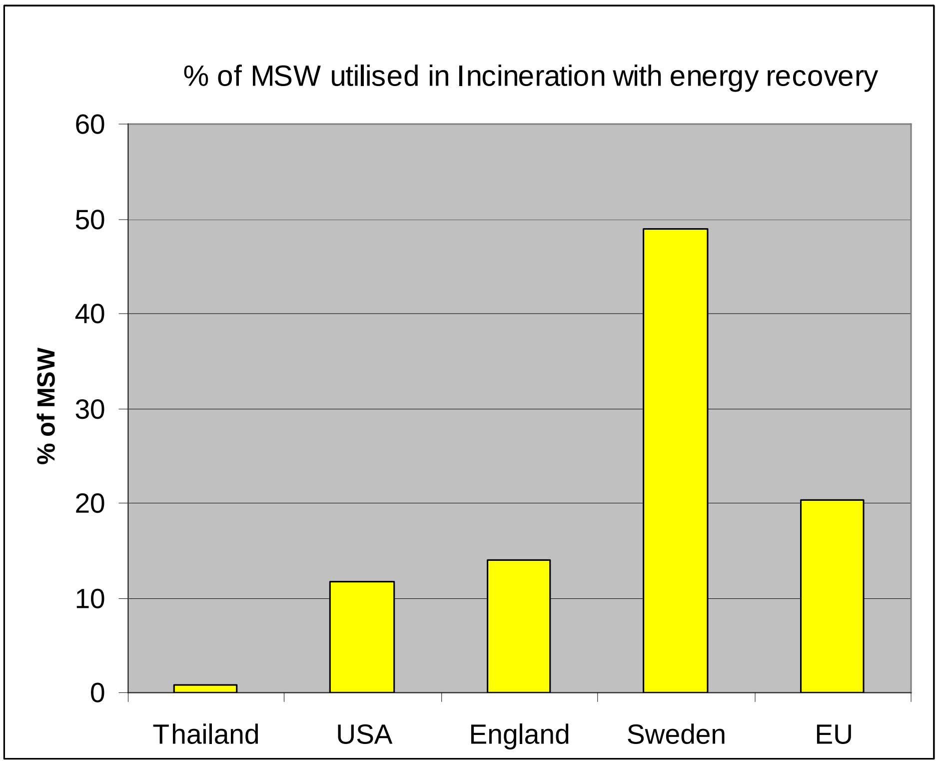

Figure 1.3 Percentage of MSW utilised in incineration with energy recovery

1.1.6 Energy from waste

With policies to reduce waste entering landfill and to increase renewable energy sources, local authorities in many nations are turning toward waste-to-energy (WtE) conversion technologies. The current commercially available WtE conversion technologies include thermal processes such as incineration, pyrolysis, gasification; and biological processes such as anaerobic digestion and landfill gas recovery. Mechanical-biological treatment (MBT) and mechanical-heat treatment (MHT) are pre-treatment methods that separate the MSW to reduce the volume of waste entering the landfill (Williams, 2005) as well as to separate the waste residue for refuse derived fuel (RDF) or solid recovered fuel (SRF) production for thermal processing. Historically, incineration or mass burn of MSW is the most common method of energy recovery and is widely used in Western Europe, the USA and Japan. In Europe, the top four countries recovering energy from MSW via thermal methods in 2007 were Germany, France, Netherlands and Sweden with MSW-treated amounts of 17.8, 12.3, 5.8 and 4.5 million tonnes a year respectively (CEWEP, 2007).

In the UK, Defra set up the New Technologies Demonstrator Programme (NTDP) in 2003 to encourage development of new technologies for reducing biodegradable waste entering the landfill and for resource recovery. The aim of the programme was to help local authorities implement these technologies to divert waste from landfills by establishing pilot plants (Brooks and Powrie, 2007). Among these pilot plants, two plants with energy recovery which continued operation after the trial were the Waste Gas Technology UK Limited in Isle of Wight using gasification and the Biocycle South Shropshire Biowaste Digester in Ludlow, Shropshire using anaerobic digestion (Defra, 2009b).

The gasification plant on the Isle of Wight using Energos technology was completed in 2008. The plant has a capacity of 30,000 tonnes/year of municipal waste and can generate 2.3 MW of electricity. In 2010 the emissions exceeded the dioxin standards and there was a temporary shutdown. It was discovered that the problem was due to contamination remaining in the system since the plant was retrofitted to an old incinerator and flue gas cleaning system. After modifications, the gasification plant is operating normally (Lightowler, 2012). The anaerobic digestion plant at Ludlow is capable of treating 5,000 tonnes/year of food waste. In the pilot period the plant received food waste from the local council’s household waste collection service. In 2010 the contract ended due to the council changing to a fortnightly collection system. The plant continued to operate with food waste from other local councils and commercial sources. In September 2012 operation was suspended when the contracts ended. In August 2013 the Cwm Harry Land Trust, an environmental charity, announced plans to resume the operation of the anaerobic digestion plant (Shropshire newsroom, 2013).

1.1.7 Evaluation and assessment tools

Figure 1.4 presents the main WtE options for management of MSW. As communities and countries strive towards integrated waste management and sustainable development, selection of a suitable WtE conversion technology for local conditions becomes an important decision. The climate, geographical location, economic and social development are some of the factors which can affect the composition and characteristics of MSW and consequently the potential for energy production. WtE conversion technologies also differ in the process itself, the feedstock requirements and the type of energy produced. Evaluation and assessment tools which have a good scientific foundation would be valuable in assisting decision makers in each area. This study focuses on incineration with energy recovery, or Energy Recovery Facilities (ERF), and AD. Incineration/ERF is selected because the technology is established and able to handle many types of waste. AD is selected because it is an established technology in the wastewater industry and its application in waste is growing. AD can also operate in various locations and climates, making it suitable for different countries in the world.

Various tools and approaches have been used to assess these options such as the energy footprint or energy and material balance studies. Life Cycle Assessment (LCA) for waste management is another tool that can be applied for evaluation of alternatives. LCA uses the concept of “cradle to grave” to address the issue of energy as well as environmental impacts. Initially LCA was used for product analysis and design. The “cradle” was the point of origin where the materials involved with the product were extracted from the environment, and the “grave” was the point where materials in the product were recycled or disposed. For waste management LCA it is common to consider the “cradle” of the waste as the moment when the object is considered to be of no use and is thrown out by the householder, and the “grave” as the point where materials in the waste are recycled or disposed. Waste management LCA can be used for planning purposes where many future options are explored (prospective) or to analyse past or existing systems (retrospective) where actual data on the processes in the system can be collected and used (Finnveden et al., 2005). Waste and Resources Assessment Tool for the Environment (WRATE) is an LCA software model from the Environment Agency in UK, which compares the environmental impacts of different municipal waste management systems.

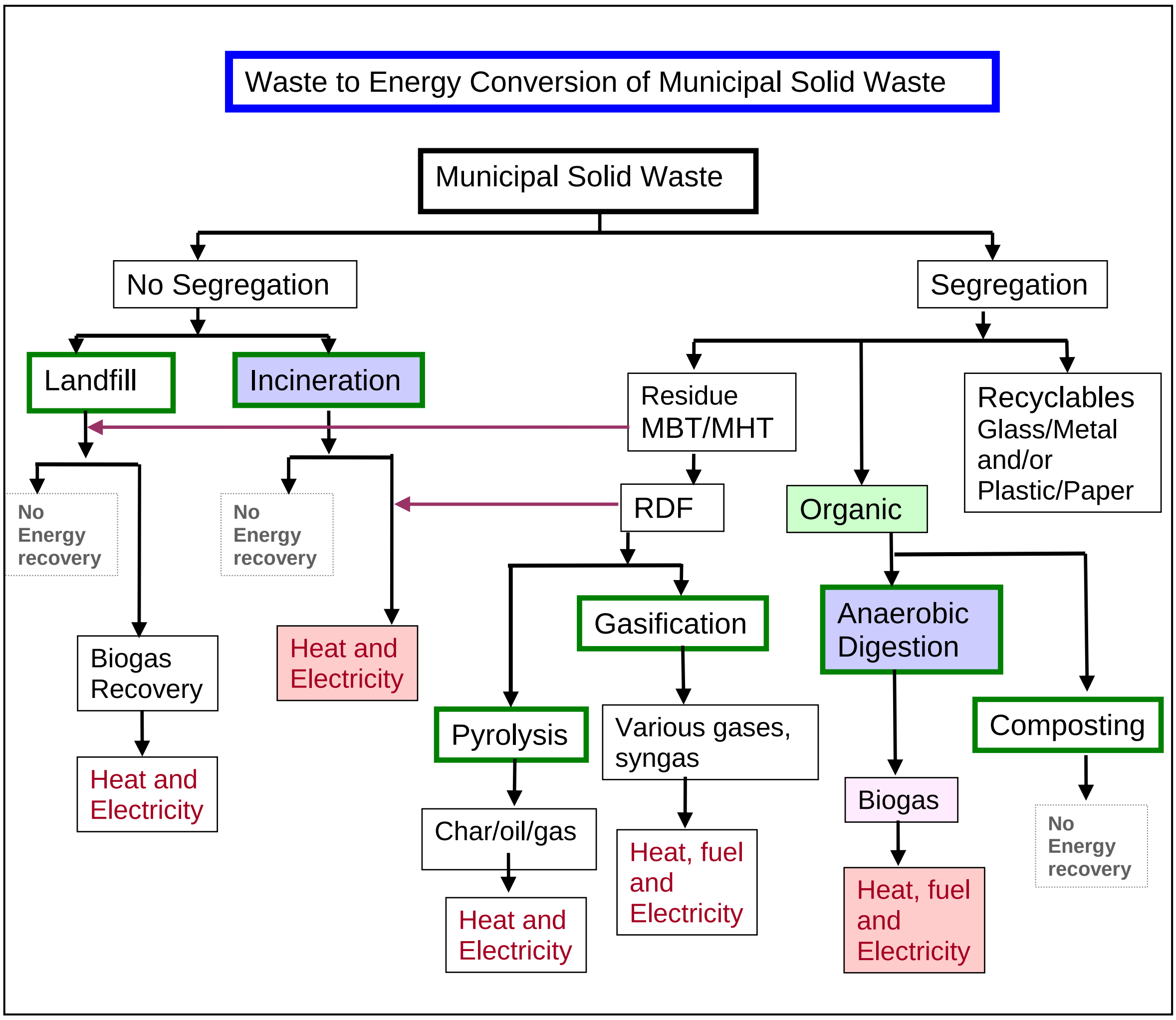

Figure 1.4 Waste Management Practices with WtE conversions

This study focuses on finding suitable waste management options with WtE technologies, namely Incineration/ERF and AD and their combinations, for various locations and conditions by using Life Cycle Assessment for waste management.

1.2 Research aim and objectives

1.2.1 Aim

The aims of this research are;

1. to determine which parameters are likely to exert the greatest influence on energy performance and environmental impacts for strategic decision-making and policy formulation in energy recovery from municipal solid waste through thermal and biological processing, by applying a comprehensive scenario analysis using Life Cycle Assessment with WRATE software.

2. to use this enhanced understanding as the basis to create a simplified assessment and screening methodology.

1.2.2 Objectives

The above research aims are met by the achievement of the following objectives;

1. To evaluate the performance of WRATE in terms of quantitatively measuring the environmental impacts and energy performance of incineration and anaerobic digestion.
2. To define a number of scenarios for energy recovery from municipal solid waste using anaerobic digestion and/or incineration.
3. To check that the above scenarios are representative of the range likely to be encountered in practice, as a means of validating the approach adopted.
4. To vary key input parameters within the ranges likely to be encountered, and/or those permitted within WRATE, for a selection of the scenarios, in order to determine their influence on the LCA output.
5. To rank these scenarios in terms of energy performance and life cycle impact assessment output, and to compare these rankings in order to identify optimal solution(s) for energy gain with minimum environmental burdens.
6. To develop a method by which the above relationship(s) between energy and environmental impact can be displayed, simply assessed and used as a basis for strategic decision-making and policy formulation of waste to energy schemes.
7. To test the outcome by screening specific case study scenarios to validate the decision-making process.

The linkages of research aim, objectives and methodology are shown in Table 1.

Originality of work

The original contribution of the work consists in providing a novel means of demonstrating and quantifying any trade-offs and compromises that need to be made between maximising energy output and minimising environmental impacts in waste-to-energy schemes; and in the development and implementation of this understanding as a rapid screening and innovative assessment process for the formulation of schemes for energy recovery from municipal solid waste.

1.2.3 Scope

The research scope focuses on exploring the options of incineration/ERF and AD in different scenarios of recycling scheme, type of energy recovered, waste composition and city/population size and density. The research does not include any economic study, cost estimations or financial assessments.

The boundary of the system starts from the generation of wastes and the analysis proceeds through collection from households, to wastes segregation (if any), to any pre-treatment required prior to entering the WtE conversion processes, to the WtE conversion processes, ending at the materials recovered or reprocessed or the disposal of residues.

Table 1.1 Linkages of Research aim, objectives and methodology

<table>
<tr><th colspan="7">Aim</th></tr>
<tr><td colspan="4">1. To determine which parameters are likely to exert the greatest influence on energy performance and environmental impacts for strategic decision-making and policy formulation of energy recovery from municipal solid waste through thermal and biological processing, by applying a comprehensive scenario analysis using Life Cycle Assessment with WRATE software</td><td colspan="3">2. To use this enhanced understanding as the basis to create a simplified assessment and screening methodology.</td></tr>
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<tr><th colspan="7">Methodology</th></tr>
<tr><td>1.1.1 Assemble data and information on Incineration and Anaerobic Digestion and other related waste management processes.</td><td>1.2.1 Plan and develop possible combinations of Incineration and Anaerobic Digestion waste management scheme.</td><td>1.3.1 Conduct LCA of the scenarios using WRATE and interpret the results</td><td>1.4.1 Conduct life cycle assessments of the scenarios with the different parameters and analyse the results.</td><td>2.1.1 Establish the method to determine the comparison of energy performance and life cycle impact assessment in order to rank the scenarios.</td><td>2.2.1 Construct the decision making matrix of suitable scenarios of Incineration and Anaerobic Digestion.</td><td>2.3.1 Identify case studies and the relevant national and local policies.</td></tr>
<tr><td></td><td>1.2.2 Map each of the scenarios of Incineration and Anaerobic Digestion and their combinations in WRATE.</td><td>1.3.2 Compare the scenarios with examples encountered in practice.</td><td></td><td>2.1.2 Compile the scenarios according to the energy performance and life cycle impact assessment ranking of the scenarios for each parameter.</td><td></td><td>2.3.2 Apply the rapid screening method for decision-making of waste to energy schemes for the case studies.</td></tr>
<tr><td></td><td></td><td>1.3.3 Modify the scenarios to better represent existing waste management practice.</td><td></td><td></td><td></td><td>2.3.3 Utilise the results to improve the policies related to the selected case studies.</td></tr>
</table>

Chapter 2

Literature Review

2.1 Municipal Solid Waste

2.1.1 Composition

Knowledge of the waste composition is important in determining the best option for treating the wastes. Wastes high in biodegradable material and moisture content may be better managed biologically, such as by anaerobic digestion; and wastes with higher combustible content may be better managed thermally. Municipal Solid Waste (MSW) is comprised of waste discarded from households, waste from streets and parks, and depending on each local authority in different countries, MSW may include waste from household waste recycling centres or civic amenities sites, and waste from commercial sources.

A direct and detailed comparison of MSW waste composition from different countries may not always be possible. One reason for this is the use of different categorisation rules, such as one local authority categorising plastic waste into dense plastic and plastic film, while another may categorise plastic waste into bags, bottles, food packaging, Styrofoam etc. (Pollution Control Department 2003 and Parfitt and Bridgwater, 2009). Another reason is different data collection methods. For example, one place might gather data from collected waste at the disposal site; another at the household before diversion to different disposal schemes (Open University, 2008). Some countries do not have household waste recycling centres or civic amenities sites. Some countries include waste collected from commercial sources (restaurants, shops, hotels, and businesses), institutional sources (schools, hospitals, and government buildings) and markets as MSW while others do not (Pollution Control Department 2003). Some countries do not have data on Waste Electrical and Electronic Equipment (WEEE) since this waste fraction has only recently been identified as needing separate management. The main waste fractions can usually be compared however, and detailed waste fractions could be adjusted to aid in the comparison. MSW composition data from different countries and household waste composition from England and Thailand has been collected and organised in Table A1 in Appendix A. A summary of a selection of waste composition is shown in Table 2.1.

Table 2.1 Summary of selected MSW and household waste composition (% wet weight)

Category	Defra, 2008	Parfitt, 2002	Cherubini et al, 2008	US.EPA, 2007	Zhao et al, 2008	adapted from PCD, 2003 , an average from two seasons	Liamsanguan and Gheewala, 2008
	Household-England *	**England**	**Italy**	**USA**	**China**	**Household-Thailand ***	**Phuket, Thailand**
Organic	40.1	42.0	50.8	30.9	56.9	67.1	31.8
Paper/board	25.3	18.0	18.8	32.7	8.7	6.7	11.5
Plastic	11.0	4.0	22.9	12.1	12.1	16.2	27.7
Textiles	2.9	3.0	2.4	4.7	2.5	1.4	3.1
Leather			0.3	2.9			
Rubber			0.3				1.9
Misc. combustibles	5.5	3.0				2.5	
Fines	1.6	3.0					
Glass	6.5	7.0	1.5	5.4	1.3	2.1	
Metals	3.4	8.0	2.8	8.2	0.4	3.4	
Misc. non - combustibles	2.4	5.0		1.5	16.2		15.4
Furniture and Mattresses	0.03						
WEEE	0.9						
Hazardous	0.4					0.2	
Other			0.2	1.7			8.7

Sources: see Appendix A. * Selected for modelling

From the data obtained it can be seen that typically there is a higher percentage of organic waste or biodegradable municipal waste (BMW), more specifically food waste, in less economically developed societies: 56.6 % in Sri Lanka (Menikpura and Basnayake, 2009) and 56.9% in China (Zhao et al., 2008) compared to 17% in the UK (Parfitt, 2002) and 12.5% in the USA (US.EPA, 2007). This also applies to household waste. In Thailand the percentage of food waste in household waste is 66.3 % (Pollution Control Department, 2003) while in England it is 24.8% (Defra, 2008). One possible explanation is that fruits and vegetables are pre-trimmed in more economically developed societies and in more urban societies, while in less economically developed societies the fruits and vegetables are peeled and trimmed in the home kitchen. Food waste is also high in moisture content and has a higher uncompacted density than most other waste fractions. In less economically developed societies such as Thailand MSW often includes waste from markets, supermarkets, food vendors, and restaurants, while in more economically developed societies such as the UK, the aforementioned wastes are collected separately by private waste service companies. Also in the USA food waste grinders are commonly installed in the kitchen sink to grind food wastes which are then treated at the municipal wastewater treatment plant (Tchobanoglous et al., 1993). Within the EU, Spain and Italy, both have high percentages of biodegradable organic waste of 48.9 % in Spain (Gómez et al.) and 49.5 % in Italy (Cherubini et al., 2008). This corresponds with Spain treating a large amount of BMW by AD (De Baere, 2006). Reported values for the proportion of BMW in England and the UK range from 20% to 42%, with the higher value reflecting the collection of garden wastes (Biffaward, 2003) and (Parfitt and Bridgwater, 2009).

Organic waste in Table 2.1 includes kitchen waste, garden waste, and wood. Organic waste is biodegradable and high in moisture content and can be converted to energy by using AD. Separation of food waste at the source is more efficient for the AD plant but requires a system of segregated food waste collection. More popular is composting, although large-scale composting consumes energy. A study of greenhouse gas emissions between centralised treatment and home composting of food waste found that the emissions of centralized treatment were 10 to 40 times more than home composting (Knipe, 2007).

Paper and card fractions are the next largest component in MSW with higher percentages in more economically developed countries, ranging from 8.7% in China (Zhao et al., 2009) to 32.7% in the USA (Tchobanoglous et al., 1993). Packaging contributes to the high percentage of paper and card waste in more economically developed countries. Behaviour patterns also account for the differences as in less economically developed countries paper and card are resources that are often reused in various forms before eventually being sold to junk shops and thus a certain amount of paper and card does not enter the waste stream. Paper and card fractions can be treated biologically as they are biodegradable and also thermally as they have a significant heat value.

The proportion of plastic components in the waste stream varies between all studies depending on the recycling or recovery rate by the informal and formal sectors. The values range from 5.9% in Sri Lanka (Menikpura and Basnayake, 2009) to 27.7% in Phuket, Thailand (Liamsanguan and Gheewala, 2008). Phuket is a tourist destination with a high economic activity and the plastic component percentage is two to three times the national figure of 10% and 16.24% reported in other studies (Patumsawad and Cliffe, 2002 and Pollution Control Department, 2003). In Thailand the highest plastic waste sub-fraction is plastic bags at 10.7% (Pollution Control Department, 2003). Regulations on charging a fee for plastic bags at stores may decrease the number of waste plastic bags. In Thailand plastic bottles are valuable and sold to junk shops, therefore the amount of plastic drinks bottles is 0.51% (Pollution Control Department, 2003). In many countries plastic waste with high calorific values combined with textiles, rubber, leather and other combustibles such as disposable nappies are feedstock for thermal treatments.

Glass and metal waste fractions also vary in all the studies depending on the recycling or recovery rate, with values for glass ranging from 1.3% in China (Zhao et al., 2009) to 15% in Santiago (Zsigraiova et al, 2009); and for metals from 0.4% in China (Zhao et al., 2009) to 9.5% in the USA (Tchobanoglous et al., 1993). Glass and metal waste fractions are valuable to recycle in terms of resource, environmental impact and energy and most countries have either informal or formal systems that collect and recycle these two waste fractions. Glass and metal waste fractions are not biodegradable and have very high melting point temperatures. Glass and metals are often hindrances in both biological and thermal processing of MSW and should be removed from the feedstock before treatment.

2.1.1.1 Excavated Waste Composition

Chiemchaisri et al. (2009) carried out a study on excavated waste from open dumping disposal site at various ages. The results shown in Table 2.2 indicated that the paper component is reduced in the open dumping disposal site by about 2/3 within two years and fully degraded before five years, while food waste fractions are not found in the 2-year sample at all. Wood fraction is the only organic waste fraction left not fully degraded in the sample. The study also showed that the plastic component in a dumpsite does not degrade over the time period sampled (2, 5, 7 and 10 years), and ranges from 25% to 45%. Significant amounts are plastic bags and film. Styrofoam also remains in the plastic component, ranging from 0.6 %-1.75%. Styrofoam food containers are widely used by food vendors in Thailand. Glass and metal waste fractions are low, ranging from 1.2% to 4.8% for glass and from 1.7% to 4.2% for metals (Chiemchaisri et al., 2009). These values are similar to the national average of 2.1% for glass and 1.9% for metals in Thailand (Pollution Control Department, 2003). The composition of excavated waste is of interest for WtE using RDF and for extending the life of a landfill.

Table 2.2 Composition of excavated waste from landfill (%)

	Excavated waste from landfill after various duration			
Category	**2 years**	**5 years**	**7 years**	**10 years**
Organic	7.66	3.42	9.77	1.2
Paper/board	4.09	0	0	0
Plastic	36.75	24.64	44.83	35.34
Textiles	11.51	7.45	10.21	1.8
Rubber	0.6	0.83	1.18	0
Glass	1.79	4.03	1.21	4.79
Metals	1.79	1.66	3.34	4.19
Misc. noncombustible	34.09	57.42	28.59	52.09

(adapted from Chiemchaisri et al., 2009)

In order to focus the research on a specific source, the household waste fraction, was chosen to align the data from the UK and Thailand and exclude other waste sources in the area such as commercial waste, street and park waste, civil amenities site waste. Household waste is defined as waste from residential dwellings and in some data sources is identified as kerbside collected household waste.

2.1.2 Proximate analysis

Proximate analysis is mainly used to determine the combustible components of MSW for thermal treatments. Moisture content is also important for biological treatments. The waste characterisation tests include the determination of moisture, volatile matter, fixed carbon and ash. The test methods follow standard methods such as the ASTM International (formerly American Society for Testing and Materials), or British or European standard. For example BS EN 14346: 2006 is for determination of moisture content. Moisture is calculated from change in weight when the waste is heated to 105± 3ºC for 1 hour or until the dry weight is constant. Volatile matter is determined by the weight loss after burning the waste at a high temperature (950ºC) in a covered crucible (Tchobanoglous et al., 1993). Fixed carbon is determined by the weight loss after burning the waste at 950ºC. Ash is determined from the weight of residue after combustion in an open crucible (Vesilind, P.A et al, 2002).

Proximate analysis MSW data from different studies is presented in Table A2 in Appendix A. The range of values from proximate analysis of various waste fractions is shown in Table 2.3. Fractions with higher moisture content tend to be lower in volatile matter, indicating that biological treatment might be the best option. Food waste has the highest moisture content with values ranging from 62.8 – 70.0%. Fruit and vegetable wastes in particular have high moisture contents with values ranging from 78.3 – 78.7%, but a lower volatile matter contents of 16.6 – 17.1%. Meat and fat wastes have low moisture contents with values ranging from 0 – 38.8% and very high volatile matter contents of up to 97.6%. Garden waste excluding wood and leaves also has a high moisture content, with values ranging from 58.0 – 60.0% and volatile matter content of 30.0 – 65.1%. Wood waste has low moisture content, with values ranging from 1.3 – 22.0% and volatile matter content of 67.9 – 88.1%. In general mixed paper has moisture content, with values ranging from 6.0 – 10.2% and volatile matter content of 75.9%. Mixed plastics have low moisture contents ranging from 0.2 – 16.1% and very high volatile matter of 74.9 – 95.8%. Textile, rubber and leather also have high volatile matter contents of 57.1 – 89.0%. Glass and metal fractions have low moisture contents of 0 – 5.0%, low volatile matter 0.8 – 7.5% but very high ash contents of 90.5 – 99.1%. In summary food waste, fruit and vegetable waste, and garden waste appear more suitable for biological treatment, meat and fat waste, wood waste, paper, plastic are suitable for thermal treatment and glass and metals should be recycled.

Table 2.3 Range of Proximate analysis % by wet weight

Type of waste	**Moisture**	**Volatile matter**	**Fixed carbon**	**ash**
Organic fraction	63.4 – 70.0	21.0 - 27.6		5.0 – 9.0
Food waste mix	62.8 – 70.0	21.4 - 63.4	3.6 - 9.1	5.0 - 27.5
Fruit and Vegetable	78.3 - 78.7	16.6 - 17.1	3.5 – 4.0	0.7 - 1.1
Meat and Fat	0 - 38.8	56.3 - 97.6	1.8 - 2.5	0 - 3.1
Garden waste mix	58.0 – 60.0	30.0 - 65.1	9.5 - 12.2	0.5 - 22.7
Wood	1.3 – 22.0	67.9 - 88.1	11.3 -18.5	0.1 - 2.9

Type of waste	Moisture	Volatile matter	Fixed carbon	ash
Paper mix	6.0 - 10.2	75.9 - 75.9	8.4	5.4 – 6.0
Cardboard	2.7 - 5.2	77.5 - 80.4	11.2 - 12.3	5.0 - 5.7
Plastics mixed	0.2 - 16.1	74.9 - 95.8	2.0	2.0 – 10.0
Textile	3.6 - 41.9	66.0 – 89.0	3.5 - 17.5	0.5 - 8.4
Rubber	1.2	83.9	4.9	9.9
Leather	7.5 – 10.0	57.1 - 68.5	12.5 - 14.3	9.0 - 21.5
Glass	0 – 5.0	0.8 – 5.0	0.1	95.0 - 99.1
Metals	0 – 5.0	0.8 - 7.5	0.1	90.5 - 99.1
MSW	18.4 – 60.0	26.0 - 72.7	4.0 - 8.2	10.0 - 39.4
RDF	1.7 - 19.7	49.1 - 88.8	0.9 - 10.8	10.3 - 20.4

Sources: see Appendix A

2.1.3 Ultimate analysis

Ultimate analysis of MSW involves the determination of the percentages of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash. It is used for characterising the chemical composition of the organic matter and in estimating the heat values for thermal treatment and biogas generation in biological treatments. It is also used for determining the mix in biological treatment for suitable C/N ratios in the treatment process and the fertiliser product. The estimation for biogas generation in anaerobic conditions (Peavy et al., 1985) applicable to both AD and landfill gas (Tchobanoglous et al., 1993) is given as follows:

$$C_aH_bO_cN_d + \tfrac{1}{4}(4a-b-2c-3d)\ H_2O \rightarrow 1/8(4a+b-2c-3d)\ CH_4 + 1/8(4a-b+2c+3d)\ CO_2 + dNH_3 \qquad (1)$$

Another equation is given by Buswell and Mueller, to estimate biogas yields (Buswell and Mueller, 1952) is given as follows:

$$C_nH_aO_b + (n - a/4 - b/2)\ H_2O \rightarrow (n/2 - a/8 + b/4)\ CO_2 + (n/2 + a/8 - b/4)\ CH_4 \qquad (2)$$

Ultimate analysis MSW data from different studies is presented in Table A3 in Appendix A. A range of Ultimate analysis of MSW % by weight (dry basis) is shown in Table 2.4.

Table 2.4 Range of Ultimate analysis (% by weight – dry basis)

	Percent by weight - dry basis					
Type of waste	**Carbon**	**Hydrogen**	**Oxygen**	**Nitrogen**	**Sulfur**	**Ash**
Food waste	48.0 - 73.1	6.2 - 11.5	14.8 - 39.5	0.4 - 2.6	0.1 - 0.4	0.2 – 5.0
Garden waste	46.0 - 52.1	6.0 - 6.6	30.3 - 42.3	0.1 – 7.0	0.1 - 0.4	6.3
Wood waste	44.9 - 50.5	5.7 - 6.7	38.3 - 45.5	0.1 - 0.2	0 - 0.1	0.4 - 2.4
Paper mix	43.4 - 43.5	5.8 – 6.0	44.0 - 44.3	0.3	0.2	6.0
Cardboard	41.7 – 44.0	5.7 - 6.4	43.5 - 44.9	0.1 - 0.3	0.2	5.0
Plastics all types	45.2 -87.1	5.3 - 14.2	1.6 - 22.8	0 – 6.0	0 - 0.4	0.3 – 10.0
Textile	43.3 – 55.0	6.1 - 6.6	31.2 - 46.4	0.3 - 4.6	0.1 - 0.2	2.5 -3.2
Rubber	10.0 - 77. 7	2 - 10.4	10.0		0 – 2.0	20.0 -78.0
Leather	8.0 – 60.0	5.3 – 10.0	10.0 - 22.8	0.4 – 10.0	0.4 -11.6	10.0 – 60.0
Glass	0.5	0.1	0.4	0.1	0	98.9
Metals	4.5 - 26.3	0.6 – 3.0	2.0 - 4.3	0.1 - 0.5	0 - 0.2	68.0 - 90.5
MSW	18.0 - 53.2	2.5 - 8.5	20.0 - 42.3	0.2 - 3.5	0 - 0.7	13.9 – 33.0
RDF	44.7 -69.1	3.8 - 8.2	19.6 - 38.4	0.6 - 1.9	0.1 - 0.3	9.9
Bituminous Coal	73.8	4.9	9.1	1.4	0.8	9.8

Sources: see Appendix A

Food waste, garden waste, and wood waste have similar high carbon contents, at 48 – 73.1% for food waste, 44.0 – 52.1% for garden waste, and 44.9 – 50.5% for wood waste. Of all the biodegradable waste fractions, food waste would produce the highest methane content from AD. Nitrogen content is also of interest for the fertiliser quality of compost. It is 0.4 – 2.6% for food waste and 0.14 – 7.0% for garden waste. Leaves have the highest nitrogen content at 7.0 %. Paper has carbon content of 43.4 – 43.5% and hydrogen content of 5.8 – 6.0 %. Plastics have high carbon content of 45.2 – 87.1% and a hydrogen content of 5.3 – 14.2 %. Textiles have carbon content of 43.3 – 55.0% and hydrogen content of 6.1 – 6.6 % which is similar to paper. Glass and metal fractions have low carbon and hydrogen content, but very high ash content of 90.0 – 99.0% confirming the unsuitability of these two waste fractions for combustion. Most of the other waste fractions have low ash content. Overall values for MSW have also been reported with a carbon content of 18.0 – 53.2% and hydrogen content of 2.5 – 8.5 %. Samples of RDF are reported with carbon content of 44.7 – 69.1% and hydrogen content of 3.8 – 8.2 %. For comparison, values are shown for bituminous coal, normally used as fuel for power generation, with a carbon content of 73.1% and a low value of ash content of 9.8%. It is noted that RDF values closely resemble bituminous coal, so if MSW can be converted to RDF then it can substitute conventional fuel more efficiently than MSW.

2.1.4 Heating values

Heating values are used to determine the energy content of MSW. The upper or higher heating value (HHV) calculations include the heat of condensation of the water vapour from the combustion process while the lower heating value (LHV) does not include it (Young, 2010). In other terms, HHV calculations use the latent heat of vaporisation of water in the combustion products and are used when the thermal treatment process condenses the water into liquid form at the end. LHV is selected for use if the thermal treatment process releases the water vapour and does not condense the water vapour from the combustion process (Young, 2010). These heating values can be determined in a laboratory using a bomb calorimeter, or by calculation from the ultimate analysis data. A variety of empirical formulas exist for determining heating values, for example the following equation (3) can be used to calculate HHV from the ultimate and proximate analyses (Channiwala and Parikh, 2002 cited in Young, 2010, p.142):

$$\text{HHV (MJ/kg)} = 34.91\,C + 117.83\,H - 10.34\,O - 1.51\,N + 10.05\,S - 2.11\,\text{Ash} \qquad (3)$$

where C, H, O, N, S and ash represent the mass fractions of the elements from the ultimate and proximate analyses.

An alternative equation for calculating HHV using mass fractions of the elements from the ultimate analysis is the Dulong equation as follows (Perry and Chilton, 1973 cited in Young, 2010, p.144):

$$\text{HHV (MJ/kg)} = 33.86C + 144.4\,(H - O/8) + 9.428\,S \qquad (4)$$

Heating values of MSW fractions from different studies are presented in Table A4 in Appendix A. Ranges of different waste types are reported in Table 2.5, with the heating value of bituminous coal which is used for electric power generation. The HHV range for total MSW is 6 – 18 MJ/kg, considerably lower than the HHV of bituminous coal of 30 MJ/kg. Therefore combustion of the whole MSW will not be an equal replacement for fuel for electric power generation. The main priority of thermal treatment of MSW is reducing the amount of waste entering the landfill and any energy gained will be a lesser priority. However, the HHV range of the RDF is 14-25 MJ/kg and the utilisation of RDF for electric power generation is thus more efficient. In areas where RDF is not produced, waste separation at the household level improves the heating value of MSW. If food waste with the HHV range of 6-19 MJ/kg and incombustible waste fractions such as glass and metals with the HHV range of 0.2-0.7 MJ/kg are removed via recycling and biological treatment, the residual waste will have a higher heating value. From the data gathered the paper, plastics, textiles, rubber, leather and wood components are suitable for thermal treatment. The plastics fraction has a high range of HHV of 23-45 MJ/kg. In regards to plastics, some local authorities with thermal treatment facilities such as Southampton City, UK (Southampton City Council, 2014) and Fukuoka City, Japan (Yamaura, 2013), ask the citizens to recycle only the Polyethylene Terephthalate (PET) and High Density Polyethylene (HDPE) bottles while the remaining plastics fraction in the residual MSW could raise the HHV of the waste entering the thermal treatment process.

Table 2.5 Ranges of Heating values of MSW and coal

	LHV in MJ/kg	HHV in MJ/kg
Food waste (excluding meat and fat)	2 – 7	6 – 19
Garden waste	5 – 20	7 – 21
Paper	11 – 26	13 – 27
Plastics	21 – 40	23 – 45
Textiles, rubber and leather	9 – 26	11 – 26
Glass and metal	0.1 – 0.7	0.2 – 0.7
Total MSW	5 – 14	6 – 18
RDF	13 – 24	14-25
Bituminous Coal	29	30

Sources: see Appendix A

2.2 Waste to Energy conversions

2.2.1 Biological conversions

2.2.1.1 Anaerobic Digestion

Anaerobic Digestion is the process of degradation of organic matter in the absence of oxygen by microorganisms producing biogas, a mixture of methane and carbon dioxide in a controlled and closed environment (Mata-Alvarez, 2003). There are four steps in the digestion process with different groups of microorganisms working at each step: hydrolysis, acidogenesis, acetogenesis and methanogenesis (Rapport et al., 2008). The products from AD include biogas, heat, electricity and fertiliser from utilisation of digestate. A simple flow diagram of an AD plant is shown in figure 2.1.

There are numerous options in the design of AD plants, of which only the key ones will be discussed. The first is the choice between wet digestion (low solids, TS < 20%) and dry digestion (higher solids, TS > 20%) (Hartmann and Ahring, 2006). In Europe 56% of AD plants for MSW are dry digesters and 44% are wet digesters (De Baere, 2006). The second option is between single phase and two phase, in which separating the hydrolysis and methanisation steps is expected to enhance the process. In Europe 87% of digestion capacity is single phase (De Baere, 2006). The third option is between the operating temperatures of mesophilic (35-40ºC) or thermophilic (50-55 ºC). In Europe 75% of digestion capacity is mesophilic, with the majority of thermophilic plants being dry systems (De Baere, 2006). The last option is between digestion of residual waste or segregated biowaste. In Europe 48.3% of digestion capacity is treating biowaste (De Baere, 2006). Figure 2.2 shows the alternatives for anaerobic digestion.

Anaerobic digestion of MSW has steadily increased since 1990, especially in Europe due to limited landfill space and the Landfill Directive (1999/31/EC). In 2006 Spain, Belgium, Holland, Switzerland and Germany had the highest AD capacity per capita (De Baere, 2006). Other countries outside of Europe such as Canada, Australia, Japan, China and India have begun implementing AD for MSW since 2000. In the USA interest in AD has not been as active as Europe as landfill space is still available, but with waste diversion targets in place AD may be implemented in the future in states such as California (Rapport et al., 2008). From a demonstration AD plant in Ludlow, UK, using food waste as feedstock the reported total potentially recoverable energy per wet tonne of feedstock was 405 kWh or 1458 MJ/tonne (Banks et al., 2011).

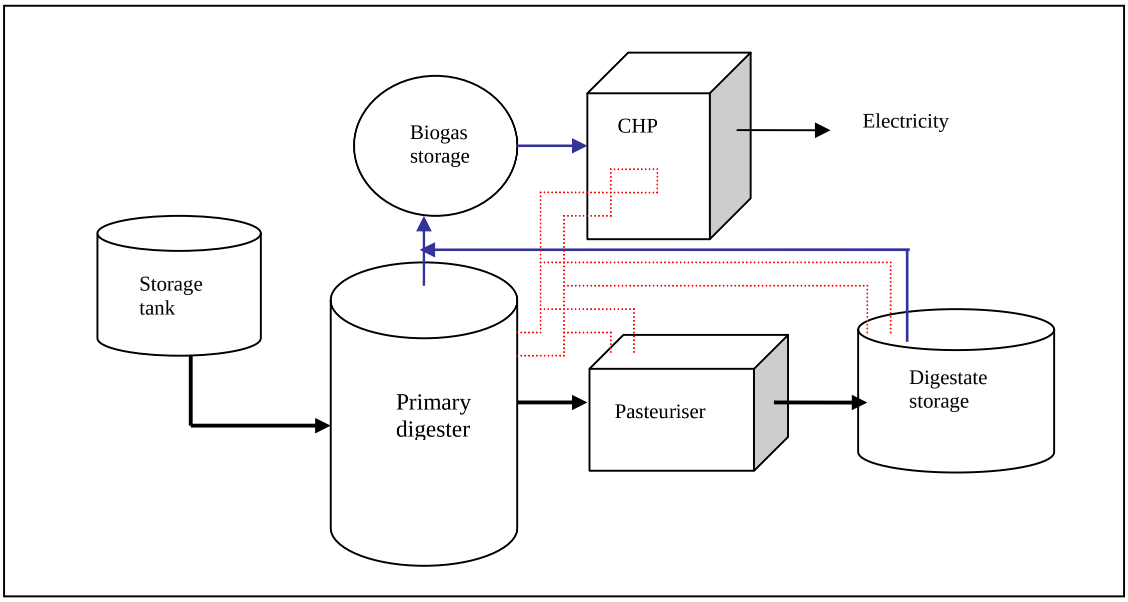


Figure 2.1 Single phase AD plant with pasteuriser (adapted from Salter, 2009)

2.2.1.2 Landfill Gas Recovery

Landfill gas is a product of the degradation of organic waste in anaerobic conditions. The main components are methane and carbon dioxide (Williams, 2005). As landfills become larger it is more important to capture the greenhouse gas emissions, and becomes more economically viable to set up a collection system. It is estimated that in the lifetime of a landfill 150-250 m^3 of landfill gas per tonne of waste deposited could be generated (Williams, 2005). Gas is collected in perforated pipelines throughout the landfill, and treated then combusted with energy recovery. The gas can also be utilised as vehicle fuel or chemical feedstock. Types of landfill include conventional landfill with energy recovery, standard bioreactor landfill, flushing bioreactor landfill and semi-aerobic landfill (Manfredi and Christensen, 2009).

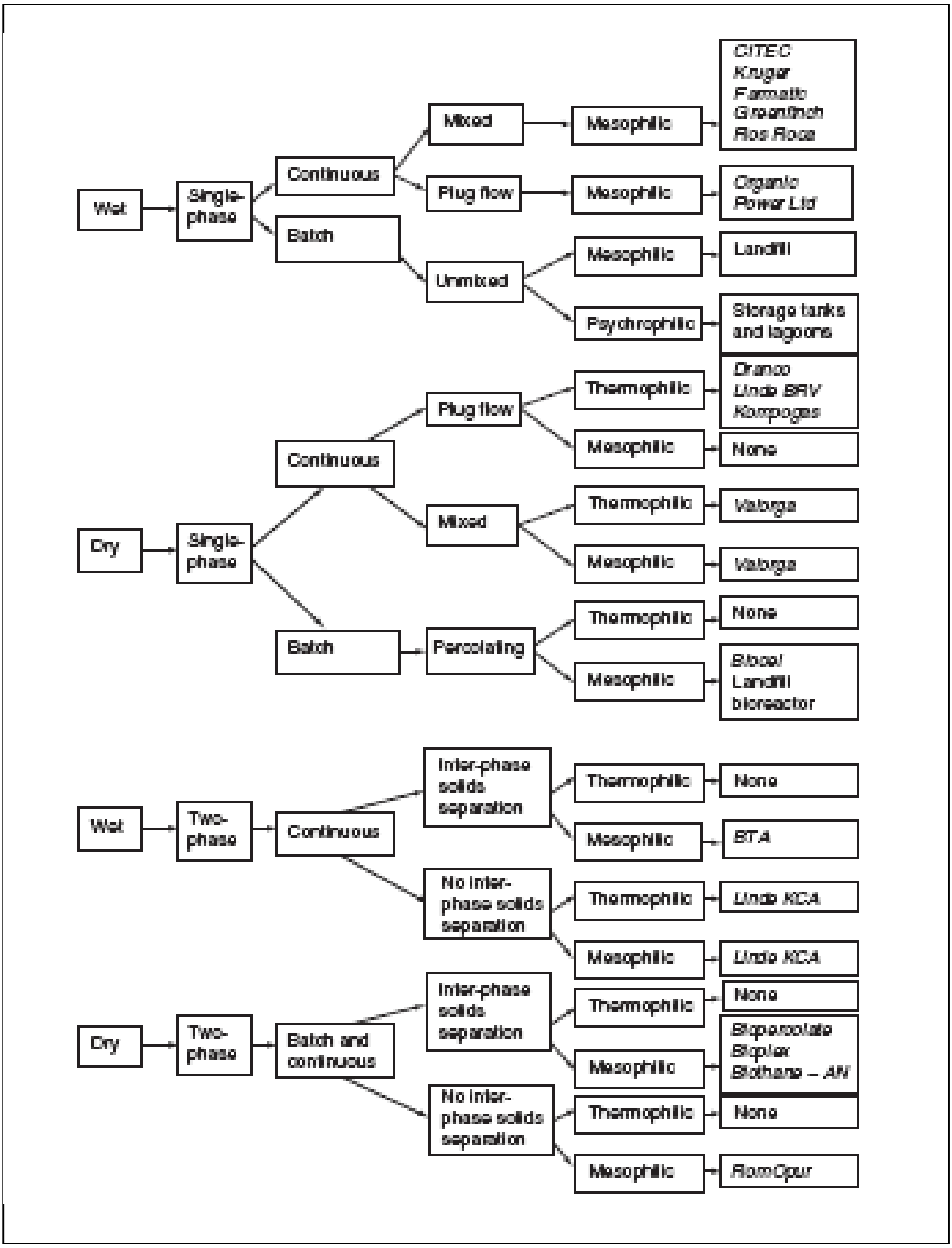


Figure 2.2 Classification of process alternatives for anaerobic digestion (Banks and Stentiford, 2007)

2.2.2 Thermal conversions

2.2.2.1 Incineration

Incineration with energy recovery is the combustion of solid waste with excess amounts of air or oxygen. Incineration can process MSW or RDF. In the UK there are 13 incinerators or energy recovery facilities (ERF) for MSW and two for RDF with a total capacity of 900 tonnes/year. Incinerators are classified by the way the waste is moved through the combustion zone: 1. Moving grate, 2. Rotary kiln and 3. Fluidised bed (Biffaward, 2003).

Moving grate is a conventional type of incinerator. Typically for mass fired incineration, MSW from collection trucks is unloaded into a storage pit where a crane picks up the waste and puts it into the feeding chute. From the chute the wastes enter the furnace and fall on the moving grate to be fired. Air can be added from under the grate or over the grate. Various gases and small particles rise up to the combustion chamber and burn at higher temperatures. The heat in the combustion chamber heats up the water in the tubes lining walls of the chamber and combined with a boiler in the chamber the water turns to steam and is converted to electricity by a turbine generator. Pollution control equipment removes NO_x, SO_2 and small particles. The ash falls from the grate into the residue hopper for further disposal (Tchobanoglous et al. 1993).

The rotary kiln has an inclined rotating drum. The wastes move down the incline along the length of the drum as it turns (Biffaward, 2003).

The fluidised bed combustion (FBC) system is a vertical cylinder with a sand bed. The FBC uses air to force up the sand particles to promote mixing and transfer heat to the feedstock. A start-up fuel is needed to heat the bed but it does not require any additional fuel during operation. The feedstock is then fed into the reactor below or above the level of the fluidised bed (Tchobanoglous et al. 1993). The hot gases pass through a cyclone to remove sand and particles and enter a waste heat boiler for steam to generate electricity. Then the gases pass through pollution control equipment before release to the environment. The FBC is more versatile than the conventional combustion system with various feedstocks, has better heat recovery than rotary or moving grate kilns and releases minimum emissions of SO_2, however the feedstock for a FBC should have similar sizes of less than 400 mm^3 to ensure better combustion (Biffaward, 2003).

From Table 2.6 the overall efficiency values for Energy from Waste plants efficiency ranges from 14-30%. A study by Murer et al. (2011) reported that the efficiency of The HoogRendement Centrale block of Afval Energie Dedrijf Amsterdam was 30% in December 2010. This was achieved by having high steam temperatures of up to 480ºC. The plant was designed for high energy output from the beginning which is different from past ERF facilities that focused on disposal of waste (Murer et al., 2011).

Table 2.6 Efficiency values for incinerator/ERF

		Biffaward, 2003	CIWM, 2003	EU, 2006	Ryu et al, 2007	Defra, 2007	Murer et al., 2011	Drummond, 2012 (calculated)	Smith, 2012 (calculated)
Overall efficiency	%	25.4	22-25	20	25	14-27	30	*29.31*	
with CHP	%		85						*36.98*

Table 2.7 presents a list of ERF in the UK ranked in order of capacity. SELCHP (South East London Combined Heat and Power) is formed from a consortium of the London boroughs of Southwark, Lewisham and Greenwich. The plant was officially opened in 1994 and is the first energy-from-waste plant in UK to meet the new EU directives at that time. The feedstock is MSW and commercial waste in the Lewisham, Greenwich, Westminster and Bromley area. The steam temperature is 395°C at a pressure of 46 bar which directly enters a single 35 MW steam turbine generator (SELCHP, 2009).

Sheffield has been recovering energy from waste since the 1970s for electricity and district heating. The plant was upgraded by 2007 to meet the emission standard of 1996 and the EU waste incineration directive 2005. It provides heat to over 140 buildings in the district energy network such as homes, universities, leisure centres and offices (Veolia Environmental Services, 2011). In 2011 Sheffield processed 207,000 tonnes of waste with an average reported heating value of 9.71 MJ/kg. The electricity produced in 2011 was 110,556 MWh and the thermal energy produced was 95,938 MWh (Smith, 2012). Therefore the calculated efficiency for this plant in 2011 is 36.98%.

Table 2.7 ERF in the UK ranked in order of capacity

ERF Plant [a]	capacity (tpa) [a]	Energy recovery [a]	Year [a]
Edmonton	500,000	Electricity 32MW	1975
SELCHP	420,000	Electricity, 32MW	1994
Lakeside- Colnbrook [c]	410,000	Electricity, 37MW	2010
Tyseley Birmingham	350,000	Electricity, 25MW	1996
Cleveland	245,000	Electricity, 20MW	1998
Coventry	240,000	Electricity, 17.7MW & Heat	1975
Sheffield[b]	225,000	Electricity, 19MW (max) & 60 MW Heat (max)	2006
Stoke	200,000	Electricity, 12.5MW	1997
Marchwood	165,000	Electricity, 14MW	2004
Portsmouth	165,000	Electricity, 14MW	2005
Nottingham	150,000	Electricity & Heat (max 20MW heat)	1973
Kirklees	136,000	Electricity, 9W	2002
Dundee	120,000	Electricity, 8.3MW	2000
Wolverhampton	105,000	Electricity, 7MW	1998
Dudley	90,000	Electricity, 7MW	1998
Chineham	90,000	Electricity, 7MW	2003
Douglas (Isle of Man)	60,000	Electricity, 6MW	2004
North East Lincolnshire	56,000	Electricity, 3MW & Heat, 3MW	2004
Shetland	23,000	Heat	2000
Isles of Scilly	3,700	No energy recovery	1987

a (Defra, 2007)
b (Veolia Environmental Services, 2010)
c (Grundon, 2010)

The Lakeside energy-from-waste plant at Colnbrook is operated by Viridor/Grundon Waste Management ltd. The feedstock includes MSW and nonhazardous commercial and industrial waste (Grundon, 2010). It is one of the newer plants commissioned. In 2012 Drummond (2012) reported in a Resource Efficiency and Waste Management Solutions presentation that the Lakeside ERF processed 410,000 tonnes/year of waste and generated 37 MW electricity (Drummond, 2012). Assuming the same heating value for waste as Sheffield the calculated energy efficiency is 29.31%.

The plant in Cleveland operated since 1998 by SITA UK in a joint venture with the Teesside local authorities of Stockton, Middlesbrough, Redcar and Cleveland, and Hartlepool. This was extended to a three stream plant in 2009 under contract with Northumberland County Council with a capacity of 390,000 tonnes/year of MSW. The feedstock is MSW and confidential waste (SITA, 2011)

The Marchwood, Portsmouth and Chineham facilities (Figures 2.3 and 2.4) are part of Project Integra, applying an integrated waste management approach in Hampshire County. The feedstock is household waste after recycling. Kerbside recycling includes paper, magazines, cardboard, junk mail, food and drinks cans and plastic bottles which are sorted at a MRF. Other materials such as glass, clothes and books are recycled at bring banks and household waste recycling centres (HWRC). Green garden waste is collected separately to be processed into a soil conditioner product (Veolia Environmental Services, 2010).

Figure 2.3 The Marchwood Energy Recovery Facility near Southampton, UK

The Douglas - Isle of Man facility has two incinerators. The primary incinerator which can process up to 60,000 tonnes/year, uses a water-cooled grate and incinerates old tyres with MSW and commercial waste (SITA Isle of Man, 2008). There is also a bulky waste shredder for large furniture. The secondary incinerator can process 5,000 tonnes of clinical, animal and oil waste. In 2008, the Isle of Man facility processed 57,000 tonnes of waste and 14,000 MWh electricity entered grid of the Manx electricity Authority that year, although the turbine temporarily failed to operate (SITA Isle of Man, 2008).

Figure 2.4 Model of Chineham Energy Recovery Facility near Basingstoke, UK

2.2.2.2 Gasification

Gasification is the partial combustion of solid waste by limiting the available air or oxygen to generate syngas containing carbon monoxide, hydrogen and gaseous hydrocarbons. Most gasification plants use material recovered waste or RDF with a low moisture content of 6-7% to produce syngas (Biffaward, 2003). The syngas can be burnt at 850°C to provide exhaust gas containing all the energy of the original fuel (Biffaward, 2003). Different types of gasification technology include updraught, downdraught, bubbling fluidised bed, circulation fluidised bed and rotary kiln reactors. The three modes of operation are partial oxidation with air, partial oxidation with oxygen and gasification with steam (Biffaward, 2003).

An example of using gasification for the treatment of MSW is the Clean Hill Homan facility in Fukuoka Prefecture Japan. The furnace type is a high temperature gasification direct melting furnace. The processing capacity is 250 tonnes/day divided into two furnaces of 125 tonnes/day (Ishibashi, 2013). Householders separate recyclable plastic, metal, and glass as well as bulky waste from the main MSW. This MSW residue is the feedstock of the high temperature gasification furnace. Auxiliary fuel is required to raise the furnace temperature. The amount of fuel used is 60 kg of coke per tonne of MSW (Ishibashi, 2013). The maximum temperature reached is 1600 ºC but 950 ºC is the average minimum operating temperature in order to ensure no formation of dioxin (Ishibashi, 2013). The syngas is burnt in the combustion chamber and heat is utilised for electricity generation (4,990 kW) and for operation of the facility. There are three types of waste from the process. The slag is recycled into road construction aggregate, the melted metals are sent to a metal smelter and the fly ash is sent to another company to recover more metals. The energy efficiency is about 15% (Ishibashi, 2013).

2.2.2.3 Pyrolysis

Pyrolysis is the thermal processing of waste in the complete absence of oxygen (Tchobanoglous et al., 1993). Pyrolysis technology is in commercial use in the metal industry and in the plastic recovery industry in converting polymers back to petrochemical feedstocks (Biffaward, 2003). Pyrolysis for MSW in commercial practice includes technologies by Nexus and Thide Environnement technologies. The Nexus process utilises unsorted MSW as the feedstock and pyrolyses at 500°C (Biffaward, 2003). Applications of pyrolysis are predominantly in Germany and Japan.

2.3 **Energy Assessment**

Energy assessment is often used to study the energy balance of a process or system. The Energy Footprinting approach is a method to assess the energy efficiency in terms of mass and energy balance. A study of the energy footprint of waste management in Southampton was conducted by Dacombe et al. (2004). In this study the boundary starts at the household and ends at disposal or reprocessing. The study showed the mass and energy flow for different scenarios in collection and recycling schemes as well as waste treatment options (Dacombe et al., 2004). For example in the study of glass waste, the major source of energy savings is from recycling for making new glass and not for aggregate replacement. Also it was determined that collection at kerbside performed better than bring-your-own sites (Powrie and Dacombe, 2006).

2.4 Life Cycle Assessment (LCA)

LCA is an environmental management tool that evaluates inputs, outputs and potential environmental impacts of a product or service or system for the whole life cycle (Mcdougall et al., 2001). The international standard ISO 14040:2006 describes the principles and framework for LCA as: definition of the goal and scope, the life cycle inventory analysis, the life cycle impact assessment, interpretation, reporting and critical review of the LCA. The first step, Goal and Scope, also includes the system boundary and details of the study. The second step is Life Cycle Inventory analysis (LCI). This phase is an inventory of the input and output to the system of the LCA study. Next is the Life Cycle Impact Assessment (LCIA) phase which assesses the environmental impacts associated with each input and output to the system. In the final step, Interpretation, the results are summarised for conclusions or recommendations to decision-making depending on the goals of the study (ISO, 2006a).

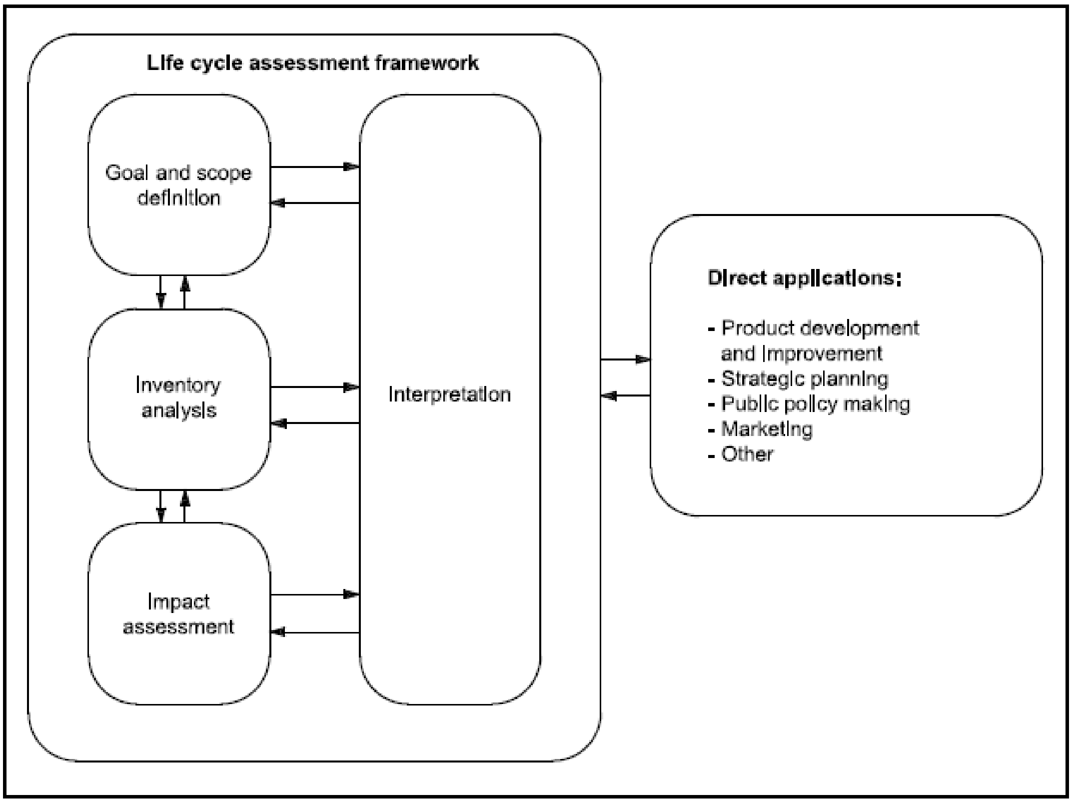


Figure 2.5 Life Cycle Assessment Framework (ISO, 2006a)

2.4.1 LCA software models

Initially LCA studies were focused on product analysis and design. Different teams in different countries gathered their own data for their own projects. A large amount of data was required yet between the different studies there were differences as well as repetition of data. LCA software models were developed to aid in the calculations and compiling of LCI. General LCA software widely used for product LCA includes SimaPro (PRe Consultants, 2014) and GaBi (PE International, 2014). Then LCA became a tool to determine the environmental impacts of systems. LCA studies of integrated waste management systems became useful for national policies, waste management options, technology development and optimisation. Examples of LCA software models for waste management systems include EASEWASTE, DST, ORWARE, WIZARD, WRATE (Christensen, 2009).

2.4.2 WRATE

Waste and Resources Assessment Tool for the Environment (WRATE) is an LCA software model from the Environment Agency in UK, developed jointly by Golder Associates (UK) Ltd and ERM, which compares the environmental impacts of different municipal waste management systems. WRATE utilises the concept of life cycle assessment to include the resource consumption including energy and material use, waste transportation and operation of waste management processes with their environmental costs and benefits. WRATE version 2.0.1.4 includes the Life Cycle Inventory (LCI) database ecoinvent version 2.1 (Environment Agency, 2012).

2.4.2.1 WRATE modelling system

The functional unit in WRATE is a given mass of MSW. The system includes components in an integrated waste management system including waste collection, waste transport, waste transfer, pre-treatment, waste treatment and recovery, materials recycling and disposal.

The system boundaries include all the processes in waste management from the point where the waste is discarded to its recovery or disposal. The inputs to the systems are

1) waste input from where waste leaves the household;
2) energy input from the extraction of fuel for each process; and
3) materials input from the extraction of virgin and secondary materials for each process.

The outputs of the system are:

1) energy output from the energy recovery processes in the form of heat and electricity;
2) recovered materials output from the processes;
3) compost output from biological treatment plant;
4) air emissions output from each process of waste management;
5) water emissions output from each process; and
6) residual solid waste output in the landfill at the end of biologically active period.

The model takes into account the first level (operational), second level (infrastructure) and avoided burdens from materials and energy displacement but does not take into account the energy and material burdens of the waste materials (zero waste burden approach).

The main allocation rule for waste management processes is based on the incoming waste. For thermal treatment and organic processes it is based on biodegradable carbon content and calorific value. For MRF and MBT it is based on incoming waste fractions.
For landfill gas emissions and leachate emissions it is based on the chemical composition of the waste calculated in GasSim and LandSim model respectively.

The main assumptions in WRATE are 1) electricity generation is offset against marginal national grid energy mix, although the values in the marginal national grid energy mix can be adjusted; 2) heat generation is offset against gas combustion with thermal efficiency of 85 %; 3) avoided material is offset against virgin material; 4) substituted virgin material is offset against virgin material; 5) recovered or recycled material incorporated in new product is not taken into account; and 6) compost is offset against inorganic fertilisers, peat, topsoil, soil conditioner.

WRATE is for modelling municipal solid waste and not for products. The data are limited to existing scientific knowledge. The chemical analysis for each waste category is provided by the Environment Agency’s waste analysis research programme. Financial and social costs are not included in the model. WRATE does not take into account the decrease in operational performance with time (Coleman et al., 2006).

2.4.2.2 Comparisons of WRATE to other LCA software for waste management

According to Gentil et al. (2010) the generic abilities of LCA model are as follows:

- Able to model environmental performance from variable fractional waste composition.
- Able to model emissions related to elemental composition of waste.
- Able to model emissions responding to operating processes.
- Able to model emission offsets to reflect substitution.
- Flexible system boundaries.
- Determination of LCI of integrated waste management system (Gentil et al., 2010).

The software models that fit the criteria above and were reviewed by Gentil et al. (2010) are as follows:

- EASEWASTE, Denmark
- EPIC/CSR, Canada
- IWM2, UK
- LCA-IWM, EU
- MSW-DST, USA
- ORWARE, Sweden
- SSWMSS, Japan
- WISARD, UK
- WRATE, UK

A summary of advantages and disadvantages of WRATE compared to other waste management LCA software is presented in Table 2.8 based on Gentil et al. (2010) and RTI International (2007). One advantage is that WRATE is very comprehensive and offers a large selection of options. For example WRATE has one of the most environmental impact indicators reported, with a total of 12, waste composition fractions, with a total of 67, waste containers, with a total of 34 and a variety of technology both thermal and biological treatment. The software includes LCI data of upstream materials for operating the facilities and also considers the lifetime impact of the facilities by including impact during construction, maintenance and decommissioning. WRATE is also flexible. For example user defined process can be created, the energy source and ratio can be modified by the user, and the energy generated can offset different or user defined energy mix. Disadvantages include the lack of phosphorus data in elemental composition of waste fractions, the model is not sensitive to an increase in fraction separation, it generates generic ash composition that does not change with varied waste composition, and landfill technology can not be modified (Gentil et al., 2010 and RTI International, 2007).

Table 2.8 Advantages and Disadvantages of WRATE compared to other software

Advantages	Disadvantages
One of the newer MSW LCA models - 2006 (EASEWASTE in 2008, SSWMSS in 2008)	
One of the most comprehensive	
One of the most Environmental impacts reported (12)	
Time horizon boundary - uses 20,000 years as infinite for modelling leachate emissions for 95%of potential emissions - life time considered for process, by including environmental emissions of construction, maintenance and decommissioning.	
Upstream boundary - includes LCI of upstream materials to operate the facilities	
Waste composition - one of the highest number of fractions (67)	- does not include phosphorus in elemental composition
Energy - default energy data forecasted until 2020 for many countries - energy source and ratio can be modified by user - a distinction between heat production and electricity production from different technology - energy generated can offset different or user defined energy mix	
Collection - comprehensive LCA information on waste containers (34)	
Transport Uses deterministic transport modelling – total distance and fuel consumption as input to calculate emissions	
Has 3 types of drive patterns (rural, urban, motorway)	
MRF - includes separation efficiency factors that considers amount and composition of rejected material - includes 26 recycling treatment facilities - default substitution ratio of 1:1 but can be changed - can model transportation of material from separation to actual reprocessing	- not sensitive to an increase in fraction separation
Thermal - includes newer technologies (pyrolysis/gasification) - includes disposal of air pollution control	- generates generic ash composition that does not change with varied waste composition

Advantages	Disadvantages
equipment	
LHV is calculated based on combining the LHV of the fractions using literature CV	
Biological - includes AD and composting - uses separate land-use model to model bio-treated materials - includes material/fertiliser substitution - can modify retention time	
Landfill - Uses GasSim to model landfill gas and LandSim to model emissions to groundwater - able to model complexity w/o slowing the LCA model - able to model leachate to groundwater due to liner failure	- requires 3rd party to model and transfer data and reassemble software - can not modify landfill technology - can not modify removal efficiency of leachate treatment plant
Carbon sequestration - 50% assumed	
Ease of use	- moderate to difficult to use w/o user manual

Based on (Gentil et al., 2010) and (RTI International, 2007)

2.4.3 Studies using WRATE

Tunesi (2011) used WRATE to conduct an LCA study of energy recovery from waste options in England. The three main strategies explored were 1) established combustion of residual waste; 2) pretreatment of residual waste; and 3) energy recovery from solid recovered fuel (SRF) in a dedicated plant. From nine scenarios the results showed that the scenario with established combustion plants/ ERF both new and with Combined heat and power (CHP) system performed better: if some recyclates were not exported to reprocessing but sent to ERF more energy would be recovered, although both scenarios result in the highest acidification impact values (Tunesi, 2011).

Burnley, Phillips and Coleman (2011) conducted an LCA study of energy recovery of organic fractions from MSW using WRATE. The waste fractions were paper, food, garden, wood, non recyclable mixed MSW and RDF. The results indicated that co-incineration of all waste fractions with cement manufacture was best for climate change and resource depletion impacts. Without the cement kiln then paper, garden and residual waste performed best in ERF, food waste in AD, wood waste in dedicated ERF and RDF in gasification (Burnley, Phillips and Coleman, 2011).

Watson et al (2009) used WRATE to conduct an LCA study of thermal treatment of residual waste. The study compared scenarios of combustion and gasification with the variation of energy recovery type (power or CHP), method of electrical generation and different conversion efficiencies for CHP. Climate change was the only impact assessment studied. The highest performance scenarios were scenarios with steam turbine and scenarios with highest efficiencies for CHP (Watson et al., 2009).

2.4.4 Comparisons of LCA studies

Each application of LCA to WtE conversions is different and unique to the local circumstances. The system boundaries, the method or software, and the environmental impact indicators vary according to each study. Studies of comparisons of waste management options and WtE technologies including LCA studies are assessed in Appendix B.

The system boundaries in the LCA studies by Rigamonti et al. (2009) and Zhao et al. (2009) start from the waste generation source, the households, and end at the disposal in landfill and emission and product exit points. The studies were conducted to find an optimum strategy for waste management for Italy and China respectively. These assessments take into account the collection transportation and recycling benefits (Rigamonti et al., 2009). Other studies such as those by Khoo (2009) or Chaya and Gheewala (2007) focused on comparing certain WtE processes and set up the system boundaries at receiving MSW or feedstock at the gate, thus not taking into account the collection impacts.

The method and software varies in each study. Finnveden et al. (2005), Moberg et al. (2005), Chaya and Gheewala (2007), Rigamonti et al. (2009) and Zaman (2010) used SimaPro. Khoo (2009) and Wittmaier et al. (2009) used GaBi. Manfredi and Christensen (2008) used EASEWASTE. Zhao et al. (2009) used CMLCA. Rodriguez-Iglesias et al, (2003) used IWM-1. Feo and Malvano (2009) used WIZARD. Tunesi (2010) and Burnley (2011) used WRATE.

Based on a survey of recent studies, the most popular environmental impact indicator is global warming potential. LCA studies focussing on one environmental impact indicator that chose global warming potential include those by Zhao et al. (2009), Liamsanguan and Gheewala (2008) and Zsigraiova et al. (2009). Other environmental impact indicators such as acidification, nutrient enrichment, eutrophication, stratospheric ozone depletion, photo-oxidant formation, heavy metals, solid waste to landfill, energy resources, toxicity are used in addition to global warming potential but none of the studies have focussed on just one of these indicators.

Rodriguez-Iglesias et al, (2003) applied the largest number of scenarios (19) to conduct an LCA study of the waste options in the Principality of Asturias, as well as using a cost analysis. The main scenarios were: 1) landfilling; 2) combustible fraction to ERF and residual to landfill; 3) recycling and ERF; and 4) compost, recycling and landfilling. The other scenarios were variations in amount of MSW, distance to treatment facilities and price of compost. Results indicated that scenarios with biological treatments showed the greatest cost benefit ratio although they had higher CO_2, NO_x and SO_2 emissions. Scenarios with ERF performed best at energy recovery but had higher dioxins, furans and heavy metal emissions (Rodriguez-Iglesias et al., 2003).

2.4.5 Comparisons with AD

Chaya and Gheewala (2007) conducted an LCA study comparing MSW to energy schemes as follows: 1) Incineration of unsorted MSW and 2) Anaerobic digestion of the organic waste fraction and landfill of residue; both schemes would generate electricity but not recover heat. Although actual data for AD were not available, as the AD plant was under construction at the time of study, the environmental impact indicators showed that the AD scheme was better than incineration due to the high organic waste content (Chaya and Gheewala, 2007).

An LCA study by Zhao et al. (2009) focused on GHG emissions of seven MSW management options. The best was the integrated system option where about half of the MSW is incinerated with energy recovery and the other half enters a MRF. Metals, glass, paper and plastics are recycled, kitchen waste is treated in AD, and the residue is disposed of in a landfill with gas recovery. Another interesting result in this study was that in terms of GHG emission, the option of Composting is similar to the AD option. The reason given is that AD consumes more external energy, though it also produces electricity from biogas so the net effect is almost zero. The LCA method for this study used economic partitioning and substitution (Zhao et al., 2009).

The benefits of an integrated system with AD are further confirmed by Cherubini et al. (2008) in a LCA study of urban waste management. The study compared 4 scenarios as follows: 1) MSW to landfill; 2) Landfill gas recovery; 3) MSW sorted at landfill for recycling of ferrous metals, organic fractions to AD producing biogas, electricity and compost, inorganic fraction to RDF for combustion to produce electricity and residues to landfill; 4) MSW to incinerator to produce electricity. The study focused on material flow accounting, gross energy requirement and emissions and the results showed that the third scenario which was an integrated system was the best waste management option. The reason given was that the option utilises both the organic and inorganic fraction for energy recovery (Cherubini et al., 2008).

2.4.6 Comparisons with Landfill gas

Wanichpongpan and Gheewala (2007) conducted a study using LCA to compare large-scale landfill with landfill gas recovery to produce electricity and smaller-scale landfills with no energy recovery. The waste management recommendation in Thailand is to encourage one centralised waste disposal site for one province rather than many small-scale landfills, which is the current situation. A review of energy efficiency, GHG emissions and economics shows that the larger landfill with landfill gas recovery is the better option. Sensitivity analysis also showed that global warming potential was sensitive to gas collection efficiency and methane oxidation rate (Wanichpongpan and Gheewala, 2007). The size of the province and the distance from each local authority to the centralised landfill could counter the benefits from the energy gained from the large scale landfill with gas recovery.

An LCA modelling study by Manfredi and Christensen (2009) compared 6 landfilling technologies as follows: 1) open dump; 2) conventional landfill with flares; 3) conventional landfill with energy recovery; 4) standard bioreactor landfill; 5) flushing bioreactor landfill;

and 6) semi-aerobic landfill. With normalised environmental impacts for the time period of 0-15 years options 4–6, bioreactors and semi-aerobic technologies showed less environmental impact. This was due to rapid degradation by enhancing leachate recirculation for methane generation and energy recovery (Manfredi and Christensen, 2009).

2.4.7 Comparisons with Incineration

Energy balance and LCA studies have shown that larger-scale incinerators of MSW with CHP systems are more efficient and have a lesser impact on the environment than smaller-scale incinerators (Rigamonti et al., 2009) or landfill without gas recovery (Liamsanguan and Gheewala, 2008). The composition and calorific values of the feedstock determine the energy output. Light MBT of MSW to reduce the moisture content by removing the organic waste fraction improves the energy output, but a more intensive treatment to produce RDF or SRF incinerated in the same combustion system decreases the energy efficiency (Consonni et al., 2005) and increases environmental impacts, such as the global warming potential (Consonni et al., 2005). The GHG emissions could also be higher for the option of MBT of MSW to separate out the organic fraction for composting and landfill disposal of the residue than for incineration of MSW with CHP (Knox and Robinson, 2007).

SRF or RDF which has high calorific value would be more suitably used in WtE processes rather than composting or disposal in a landfill. The energy balance would improve if there is a market for SRF or RDF from MBT or MHT processes to co-combust in the industry, such as at power plants and cement kilns (Papageorgiou et al., 2009). A study by Garg et al. (2009) investigated the co-combustion of SRF in 1) a coal fired thermal power plant; 2) a MSW incinerator; 3) a biomass combustion system using woodchips; and 4) a cement kiln using coal. After a heat and mass balance, an environmental impacts assessment and a risk analysis the co-combustion of SRF in cement kiln was the preferred option since no changes to the existing equipment were necessary. The MSW incinerator would need further emission control due to increased gaseous emissions (Garg et al., 2009).

2.4.8 Comparisons with Gasification and Pyrolysis

Khoo (2009) conducted an LCA study of pyrolysis and gasification options as follows: 1) Two-stage pyrolysis-gasification of MSW; 2) Pyrolysis of MSW; 3) Thermal cracking gasification of granulated MSW; 4) Combined pyrolysis, gasification and oxidation of MSW; 5) Steam gasification of wood; 6) Circulating fluidised bed gasification of organic wastes; 7) Gasification of RDF; and 8) Gasification of scrap tyres. The normalised and weighted environmental impact indicators results show that the optimum WtE option is the two-stage pyrolysis-gasification of MSW followed by steam gasification of wood (Khoo, 2009).

Giugliano et al. (2008) conducted a study to compare alternative strategies for energy recovery from MSW as follows: 1) Combustion of MR residue in grate combustor, Rankine steam cycle for electricity and district heating; 2) Aerobic bio-stabilisation of MR residue and combustion in grate combustor, Rankine steam cycle for electricity and district heating; and 3) aerobic bio-stabilisation of MR residue, mechanical refining RDF production, gasification plant, syngas co-combusted in natural gas combined cycle power plant. Energy balance results showed that the gasification of RDF produces higher electrical energy. The reduction in environmental impact is not as significant as for the combustion of MR residue, however, since for gasification the syngas displaces natural gas, while for combustion the MR residue displaces coal or oil and gas mix (Giugliano et al., 2008).

2.5 Review Conclusions

Most of the studies on waste management LCA have been carried out within the past ten years with many of the more recent studies using LCA software models recently. There is, however, a gap in the literature for a focused study on incineration/ERF and AD and their combinations as part of integrated waste management. A few studies of the different treatment process scenarios have variations of other factors such as waste composition, waste amount and distances. All of the studies are geographically restricted to a certain area. Therefore an LCA study using WRATE to find suitable combinations of incineration/ERF and AD with variations of factors for different conditions to create a simplified decision making tool would be a different and novel approach to previous studies.

Chapter 3

Research Methodology

In order to achieve the overall aim, the research adopted an objective methodology approach in which a series of objectives were specified and methods for achieving them were identified.

3.1 Assemble data and information on Incineration and Anaerobic Digestion and other related waste management process

This process adopted an iterative approach consisting of data collection, identifying and mapping flow diagrams of the relevant waste management processes for Incineration/ERF and AD, and identifying the requirements of the each process for modelling in WRATE.

The waste management processes was identified as starting from MSW generation from households, followed by collection of MSW, intermediate facilities such as transfer station, pre-treatment or materials recovery facility, WtE treatment process, reprocessing and disposal.

The requirements of each waste management process include the waste input or feedstock characteristics, capacity, energy conversion, pollution control and other relevant technical requirements. The feedstock characteristics include composition, moisture content, biodegradable content and/or heat values. The capacity requirements include the size of the processing unit and the amount of waste processed in a year. The energy conversion unit requirements include the type and capacity, such as a steam turbine or a CHP unit. The pollution control requirements include the regulations and the type and capacity. These data were obtained from literature, case studies, government agencies, websites, manufacturer information and including building on previous work at University of Southampton.

3.2 Plan and develop possible combinations of Incineration and Anaerobic Digestion waste management schemes

Phase One

The purpose of phase one was to collate the data gathered at that point in time, enter it into the WRATE model, and identify additional data collection needs. Therefore in phase one, potential options and combinations of Incineration/Energy Recovery Facility and Anaerobic Digestion and waste management processes were selected from the data identified in 3.1. Several potential scenarios for MSW management options were drafted. The scenarios started from the generation of wastes and collection from households, to wastes segregation, to any pre-treatment required prior to entering the WtE treatment processes, to the WtE treatment processes and to the disposal of residues. For incineration scenarios if any recycling scheme was selected, the residual waste was sent to the incinerator/ERF. Ash from incinerator/ERF was sent to landfill. For AD scenarios, if any recycling scheme was selected, the residual waste was sent to landfill. Although AD-only scenarios would have more residual waste entering the landfill, and the predicted overall impacts were therefore expected to be greater than the incinerator/ERF scenarios or combination scenarios, including these scenarios are important since the majority of local authorities in less economically developed communities are not able to establish an ERF. This research also studied the different recycling schemes for each WtE method. The scenarios were methodically developed to vary the WtE treatment process with the collection and recycling schemes. Fifty two possible scenarios were planned and a full list of these is given in chapter 4.

The recycling schemes considered were: 1) no recycling; 2) post process recycling; 3) post collection recycling; and 4) source segregation. Post collection recycling scenarios included a MRF, in this case a 'dirty' MRF, to separate recyclates from MSW. Source segregation scenarios included different bins for the households to separate their rubbish and a 'clean' MRF to separate recyclates from comingled recycle waste. For the model in phase one, a theoretical maximum was assumed and the recycling materials capture rate is set at 100%. This means that for source segregation scenarios, all the recyclates in the household waste are assumed to be separated into the comingled recycled waste bin.

3.3 Map each of the scenarios of Incineration and Anaerobic Digestion and their combinations in WRATE

For phase one only 21 scenarios out of 52 scenarios were able to be mapped in WRATE as some processes were not available or had configurations that were not practical. In the process of mapping the scenarios all the user data was entered in each of the selected processes. These data included decisions such as the type of process, the capacity, the waste distribution, the type of collection vessels, the distances, the road type ratio, the energy recovery type, the flue gas cleaning method, the landfill lining. Full details of the selections are given in chapter 4.

3.4 Conduct Life Cycle Assessment using WRATE and interpret the results

For phase one the study was set in a hypothetical city with details shown in chapter 4. The data derived from 3.1 was selected for use in the 52 scenarios developed in 3.2 and modelled in WRATE to determine the life cycle impact assessment (LCIA) of each scenario, including the energy recovered. Further data was gathered and tasks in 3.1 to 3.3 were repeated to complete all the scenarios in WRATE as far as possible.

3.4.1 Life Cycle Inventory

WRATE includes the Life Cycle Inventory (LCI) database ecoinvent version 2.1. The ecoinvent Centre (originally the Swiss Centre for Life Cycle Inventories) is a Competence Centre of the Swiss Federal Institute of Technology Zürich (ETH Zurich) and Lausanne (EPF Lausanne), the Paul Scherrer Institute (PSI), the Swiss Federal Laboratories for Materials Testing and Research (Empa), and the Swiss Federal Research Station Agroscope Reckenholz-Tänikon (ART). The Ecoinvent LCI database is constructed from studies and measurements of the energy and resource use and emissions to the environment from the processes and the materials involved. The LCI database is included in various LCA software for products LCA and waste management LCA, and is used in LCA studies by industry and authorities and for other areas such as Integrated Product Policy (IPP), Technology Assessment (TA) and Design for the Environment (DfE) (Frischknecht et al, 2007).

3.4.2 Life Cycle Impact Assessment

The scenarios were mapped and data input into WRATE for modelling. WRATE provides headline results as follows:

1) Biodegradable waste landfilled
2) Energy recovered
3) Land take
4) Waste composted
5) Waste landfilled
6) Waste recovered
7) Waste recycled.

Within WRATE several LCIA (Life Cycle Impact Assessment) methods included in the software such as Problem Oriented Approach, Damage Oriented Approach, ECOINDICATOR 99, IMPACT 2002, EDIP and more. The method used for the default impact assessments is a Problem Oriented Approach methodology which is also called CML 2001 since it was developed by CML centre (Centre of Environmental Science of Leiden University) in 2001 (Hischier, R. et al., 2009). This research used the default LCIA method. The six default environmental impact assessment categories deemed as significant and portraying a wide range of environmental problems by the UK Environment Agency are as follows:

1) Climate change: GWP (Global Warming Potential) 100a
2) Acidification potential: average European
3) Eutrophication potential:generic
4) Freshwater aquatic ecotoxicity potential:FAETP infinte
5) Human toxicity potential: HTP infinite
6) Resources: depletion of abiotic resources

Although these six environmental impact assessment categories do not cover all of the environmental problems that may occur , for example water shortage or marine pollution, they are representative of the major problems that could be caused by waste management. For this research they represent the main possible problems that are associated with household waste management system by AD and incineration. Climate change or global warming potential is concerned with the GHG released from the use of energy in and released directly from the waste management process itself. Acidification potential is concerned with the pollutants released from the combustion process which could result in acid precipitation. Eutrophication potential is concerned with pollutants high in plant nutrients from the waste management process, such as truck washing and release from landfill or AD, which may enter the water system, causing excess growth of plant and algae, resulting in lack of oxygen and aquatic animal death. Freshwater aquatic ecotoxicity potential is concerned with toxic substances from the waste management process impacting the freshwater ecosystem. Human toxicity potential is concerned with toxic substances from the waste management process impacting the biological human system. Resources or depletion of abiotic resources is concerned with the use of non renewable resources such as minerals and fossil fuel. These environmental impact assessment categories are therefore selected as they represent the key issues associated with incineration and AD.

3.4.3 Interpretation

The environmental impact assessment and energy recovered data resulting from the WRATE model in 3.4.2 were analysed and interpreted. The data and results are presented in chapter 5.

WRATE gives the result in characterisation impact assessment and normalisation impact assessment. The CML 2001 equivalence unit and normalisation factor stored in the WRATE database for each impact assessment are shown in Table 3.1. Each characterisation impact assessment has the equivalence unit relating to the particular impact, such as kg CO2-Eq for global warming potential. Normalisation, an optional step for an LCA study, is a method to compare all 6 different environmental problems at an equal level. Each impact assessment has a normalisation factor to calculate in order to achieve the normalised value in units of European person equivalent (Eur.person.eq.). WRATE also provides further results as normalisation per person, in units of Eur.person.eq. per person, the results are divided by the population number in each group. For the purposes of this research these equivalence unit and normalization factors were adopted.

Table 3.1 Equivalence unit and normalisation factor

Impact assessments	equivalence unit	normalisation factor
Climate change	kg CO2-Eq	12924.28
Acidification	kg SO2-Eq	71.54
Eutrophication	kg PO4-Eq	33.42
Fresh water aquatic ecotoxicity	kg 1,4-DCB-Eq	1318.53
Human toxicity	kg 1,4-DCB-Eq	19765.01
Resources depletion	kg antimony-Eq	38.64

3.5 Comparing the scenarios with examples encountered in practice

The results from the initial 21 scenarios out of the 52 planned scenarios were reviewed to exclude scenarios that were not possible or were impractical as well as to identify modified scenarios for inclusion in phase two.

3.6 Modify the scenarios to better represent existing waste management in practice

Phase two

After reviewing the results and practical examples, 18 scenarios were planned for Incineration, 17 for AD and 72 for combinations of both for a country/ population density group. Four country/ population density groups were chosen: UK urban, UK rural, Thailand urban and Thailand rural. Full details of the scenarios are shown in chapter 6.

3.7 Conduct life cycle assessments of the scenarios with the different parameters and analyse the results

LCA were conducted on all four groups (UK urban, UK rural, Thailand urban and Thailand rural). The parameters to investigate are designed into the scenario organisation by varying the WtE technology, the energy recovery type, the recycling scheme and the recycling rate. By conducting LCA for urban and rural the population density parameter is compared. The waste composition parameter is compared by the two countries. In order to focus the research on a specific source, the household waste fraction, was chosen to align the data from the UK and Thailand and exclude other waste sources in the area such as commercial waste, street and park waste, civil amenities site waste. Household waste is defined as waste from residential dwellings and in some data sources is identified as kerbside collected household waste.The results are presented in chapter 7.

3.8 Establish a method to determine the comparison of energy performance and life cycle impact assessment in order to rank the scenarios

A ranking method was established to rank the scenarios by each impact assessment, then as combined LCIA. Then the energy recovered ranking was combined with the combined LCIA ranking. A single impact assessment, climate change was ranked and combined with the energy recovered ranking. The results are shown in chapter 7.

3.9 Compiling the scenarios according to the energy performance and life cycle impact assessment ranking of the scenarios

The scenarios were compiled in an excel worksheet according to the energy performance and life cycle impact assessment ranking of the scenarios.

3.10 Construct a decision-making matrix of suitable scenarios

A decision making matrix for local authorities was constructed by using the environmental impacts and energy recovered from the LCA results in WRATE and the ranking to identify the scenarios with suitable options of ERF and AD or any combinations of both as part of an integrated waste management system for different locations and conditions. For example, combinations of ERF and AD in urban locations in developed nations and developing nations, rural locations in developed nations and developing nations.

3.11 Identify case studies and the relevant national and local policies

Phuket province in Thailand was chosen as a case study for consideration of plans for future waste management involving WtE .

3.12 Applying the rapid screening method for decision making of waste to energy schemes for the case study

The decision-making matrix was applied to the Phuket waste management issues and the resulting suitable scenarios were given.

3.13 Utilise the results to improve the policies related to the case study

The resulting suitable scenarios for Phuket waste management were identified from the decision making matrix and improvements were discussed.

Chapter 4

Phase One Scenario Design

The goal of this LCA is to compare scenarios of MSW management with different collection and recycling schemes using WtE conversion treatment process i.e. Incineration/ERF and AD and the combinations thereof. The purpose of Phase One was to collate the data gathered at that point in time, enter it into the WRATE model, and identify additional data collection needs. This chapter explains the design of the scenario for Phase One.

4.1 Scenario names

The 52 possible scenarios are shown in Table 4.1. The scenarios were organised into three waste treatment process groups: 1) AD only; 2) Incineration only; and 3) combination of AD and Incineration. Within each group the scenarios were organised into recycling schemes. The recycling schemes were: 1) no recycling; 2) post process recycling; 3) post collection recycling; and 4) source segregation. Within each recycling scheme the scenarios were further organised into energy recovery type: 1) electricity; 2) heat; 3) heat and electricity; and 4) vehicle fuel (for scenarios with AD). Therefore the names of the scenario are in the format of number of scenario + process + energy recovery type + recycling scheme. An example is 'scenario 7 Incineration for electricity post collection recycling'.

4.2 Recycling schemes

As noted above, the recycling schemes are: 1) no recycling; 2) post process recycling; 3) post collection recycling; and 4) source segregation. No recycling scenarios Post collection recycling scenarios include a Material Recovery Facility (MRF), in this case a 'dirty' MRF, to separate recyclates from MSW. Source segregation scenarios include different bins for the households to separate their rubbish and include a 'clean' MRF to separate recyclates from comingled recycled waste. For the purposes of phase one of this study, a theoretical maximum was assumed and the recyclable materials capture rate was assumed to be 100%.

Table 4.1 Possible scenarios for phase one

Scenario	WtE technology combinations	Recycling methods			
		No recycling	Post process recycling	Post collection recycling-mrf	Source segregation
1	Incineration for electricity	✓			
2	Incineration for heat	✓			
3	Incineration for heat and electricity	✓			
4	Incineration for electricity		✓		
5	Incineration for heat		✓		
6	Incineration for heat and electricity		✓		
7	Incineration for electricity			✓	
8	Incineration for heat			✓	
9	Incineration for heat and electricity			✓	
10	Incineration for electricity				✓
11	Incineration for heat				✓
12	Incineration for heat and electricity				✓
13	Anaerobic Digestion for electricity	✓			
14	Anaerobic Digestion for heat	✓			
15	Anaerobic Digestion for vehicle fuel	✓			
16	Anaerobic Digestion for heat, electricity and vehicle fuel	✓			
17	Anaerobic Digestion for electricity		✓		
18	Anaerobic Digestion for heat		✓		
19	Anaerobic Digestion for vehicle fuel		✓		
20	Anaerobic Digestion for heat, electricity and vehicle fuel		✓		
21	Anaerobic Digestion for electricity			✓	
22	Anaerobic Digestion for heat			✓	
23	Anaerobic Digestion for vehicle fuel			✓	
24	Anaerobic Digestion for heat, electricity and vehicle fuel			✓	
25	Anaerobic Digestion for electricity				✓
26	Anaerobic Digestion for heat				✓
27	Anaerobic Digestion for vehicle fuel				✓
28	Anaerobic Digestion for heat, electricity and vehicle fuel				✓
29	Incineration for heat and Anaerobic Digestion for electricity			✓	
30	Incineration for heat and Anaerobic Digestion for heat			✓	
31	Incineration for heat and Anaerobic Digestion for			✓	

Scenario	WtE technology combinations	Recycling methods			
		No recycling	Post process recycling	Post collection recycling-mrf	Source segregation
	vehicle fuel				
32	Incineration for heat and Anaerobic Digestion for heat, electricity and vehicle fuel			✓	
33	Incineration for heat and Anaerobic Digestion for electricity				✓
34	Incineration for heat and Anaerobic Digestion for heat				✓
35	Incineration for heat and Anaerobic Digestion for vehicle fuel				✓
36	Incineration for heat and Anaerobic Digestion for heat, electricity and vehicle fuel				✓
37	Incineration for electricity and Anaerobic Digestion for electricity			✓	
38	Incineration for electricity and Anaerobic Digestion for heat			✓	
39	Incineration for electricity and Anaerobic Digestion for vehicle fuel			✓	
40	Incineration for electricity and Anaerobic Digestion for heat, electricity and vehicle fuel			✓	
41	Incineration for electricity and Anaerobic Digestion for electricity				✓
42	Incineration for electricity and Anaerobic Digestion for heat				✓
43	Incineration for electricity and Anaerobic Digestion for vehicle fuel				✓
44	Incineration for electricity and Anaerobic Digestion for heat, electricity and vehicle fuel				✓
45	Incineration for heat and electricity and Anaerobic Digestion for electricity			✓	
46	Incineration for heat and electricity and Anaerobic Digestion for heat			✓	
47	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel			✓	
48	Incineration for heat and electricity and Anaerobic Digestion for heat, electricity and vehicle fuel			✓	
49	Incineration for heat and electricity and Anaerobic Digestion for electricity				✓
50	Incineration for heat and				✓

Scenario	WtE technology combinations	Recycling methods			
		No recycling	Post process recycling	Post collection recycling-mrf	Source segregation
	electricity and Anaerobic Digestion for heat				
51	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel				✓
52	Incineration for heat and electricity and Anaerobic Digestion for heat, electricity and vehicle fuel				✓

4.3 Scope and Boundary

The hypothetical city has a population of 200,000 and 80,000 households. The city area is 50 km^2 and population density of 4,000/km^2. The municipal solid waste (MSW) arising is 95,000 tonnes/year with a waste arising rate of 475 kg/person-year.

The scope of the LCA study is the waste management with combinations of Incineration/ERF and AD and recycling schemes of 95,000 tonnes/year of waste in a hypothetical city. The functional unit therefore is 95,000 tonnes/year of MSW.

The boundary is from MSW generation from households, collection of MSW, intermediate facilities such as transfer station, pre-treatment or materials recovery facility, WtE treatment process, reprocessing and disposal.

4.4 Electricity mix

Table 4.2 Electricity Mix

Baseline Fuel mix (%)	Generating Efficiencies (%)	Energy Source	Marginal Fuel Mix (%)
100		Total	100
34.6	35.7	Coal	46.6
1.1	33.1	Oil	0.8
3.4	34.9	Gas	3.3
39.6	47.6	Gas CCGT	49.3
15.3	38.6	Nuclear	0
0.2	20.6	Waste	0
0.8	18.7	Thermal other	0
2.3	25.8	Renewables thermal	0
0	15.5	Solar PV	0
1.4	25	Wind	0
0	82	Tidal	0

Baseline Fuel mix (%)	Generating Efficiencies (%)	Energy Source	Marginal Fuel Mix (%)
0	82	Wave	0
1.3	82	Hydro	0
0	82	Geothermal	0
0	82	Renewable other	0

The electricity mix data chosen from those available in WRATE, is from the year 2007 for the UK to correspond with the waste composition data. The details are given in Table 4.3. The marginal fuel mix for the UK was available in WRATE to reflect changing the use of fossil fuels. The LCIA results are offset against this component of the fuel mix. Therefore in the scenarios where electricity is produced from waste, the fossil fuel amount is replaced and the impacts associated with it are reduced. Fossil fuels are set as the marginal fuel mix because fossil fuel use are related to the increase of GHG and it is targeted as the fuel to be replaced.

4.5 Waste composition

The waste composition chosen from the default data available in WRATE was municipal waste from England in 2007 based on WR0119 - Municipal Waste Composition: A Review of Municipal Waste Component Analyses (Defra, 2008). Details of the waste composition are given in Table 4.2.

Table 4.3 Waste composition

Waste Fraction	**%**	**Quantity [tonnes]**
Paper and card		
Unspecified paper	0	0
Newspapers	7.10	6745.0
Magazines	3.25	3087.5
Recyclable paper	3.80	3610.0
Other paper	3.26	3097.0
Card packaging	6.26	5947.0
Other card	0.32	304.0
Plastic film		
Unspecified plastic film	0	0
Bags	1.17	1111.5
Packaging film	2.64	2508.0
Other film plastic	0	0
Dense plastic		
Unspecified dense plastic	0	0
Drinks bottles	1.91	1814.5
Other bottles	0	0
Other packaging	2.36	2242.0
Other dense plastic	1.90	1805.0
Textiles		
Unspecified textiles	0	0

Waste Fraction	%	Quantity [tonnes]
Artificial textiles	1.41	1339.5
Natural textiles	1.38	1311.0
Absorbent hygiene products		
Unspecified absorbent hygiene products	0	0
Disposable nappies	2.16	2052.0
Other (sanpro and dressings)	0.18	171.0
Wood		
Unspecified wood	3.60	3420.0
Wood packaging	0	0
Non-packaging wood	0	0
Combustibles		
Unspecified combustibles	0	0
Shoes	0.68	646.0
Carpet/underlay	0.43	408.5
Furniture	1.76	1672.0
Other combustibles	3.22	3059.0
Non-combustibles		
Unspecified non-combustibles	0.96	912.0
Bricks, blocks, plaster	1.40	1330.0
Soil	0.12	114.0
Inorganic pet litter	0	0
Other non-combustibles	0.18	171.0
Glass		
Unspecified glass	0	0
Packaging	0	0
Non-packaging glass	0	0
Green bottles	0.43	408.5
Clear bottles	3.15	2992.5
Brown bottles	3.49	3315.5
Jars	0.82	779.0
Organic		
Unspecified organic	0	0
Garden waste	12.22	11609.0
Food waste	17.40	16530.0
Organic pet bedding/litter	0	0
Other organics	1.97	1871.5
Ferrous metal		
Unspecified ferrous metal	0	0
Steel food and drink cans	3.03	2878.5
Other ferrous metal	0.03	28.5
Non-ferrous metal		
Unspecified non-ferrous metal	0	0
Aluminium drinks cans	0.47	446.5
Foil	0.26	247.0
Other non-ferrous metal	0.59	560.5
Fine material <10mm		
Unspecified fine material	1.98	1881.0
Waste electrical and electronic equipment		
Unspecified WEEE	2.23	2118.5
White goods	0	0
Large electronic goods (excluding CRT TVs and monitors)	0	0
CRT TVs and monitors	0	0
Other WEEE	0	0
Specific hazardous household		
Unspecified hazardous household waste items	0.48	456.0
Batteries	0	0

Waste Fraction	%	Quantity [tonnes]
Clinical waste	0	0
Paint/varnish	0	0
Oil	0	0
Garden herbicides & pesticides	0	0

4.6 Processes selected for use in the study

To create a scenario in WRATE, waste management processes are selected for each step of the waste management procedure from collection to disposal. The various user-entered values are input for each process (such as waste distribution, numbers of bins, distances for vehicles, type of MRF, energy recovery type for incineration, capacity of AD and type of landfill lining). Capacities for processes must be above the incoming waste amount, therefore the values entered for each process in each scenario are individualised. Table 4.4 gives a summary of process parameters selected. The properties of the transportation used for each travel component is given in Table 4.5.

Table 4.4 Summary of processes selected for phase one

Processes name and code in WRATE	Reasons
Wheeled bins 12276	The 140 L bin is typically used and has the capacity to hold the weekly household waste. 80,000 bins selected for residual waste and another 80,000 bins for scenarios with source segregated recycling.
Kitchen Caddy 12222	An unvented kitchen caddy was selected to minimise attraction of pest from vented odours which is a normal occurrence in a hot climate.
Garden Bag 12064	The kerbside reusable bag made from polypropylene was typical to hold garden waste in UK.
6x4 Refuse Collection Vehicle (RCV) Fleet Euro 4 Diesel V2 12115	A typical refuse collection vehicle of 12.8 T capacity with a low sulphur emission was selected for household waste and organic waste.
Kerbside multi-compartment 12027	A multi-compartment collection vehicle of 5.5 T capacity was selected for segregated organic waste.
Articulated Truck 8.026 T	A truck to represent the bulk haulage from transfer stations to the various treatment plants, landfill and reprocessing plants.
Transfer station (road) 12246	A transfer station for road transport was selected for all scenarios with a varying capacity for each
MRF 11130	A twin streamer high mechanisation MRF for mixed waste was selected for scenarios with post collection recycling (dirty MRF)
MRF 12248	A source separated waste MRF with infrared plastic separation was

Processes name and code in WRATE	**Reasons**
	selected for scenarios with source segregation
Incinerator: Flexible (based on the Chineham ERF) 21849	95,000 tonnes/year.A flexible incinerator with options for energy recovery including electricity, heat, and heat and electricity. Flue gas cleaning type is dry. The NOx reduction type is SNCR. A theoretical maximum is selected. For electricity a maximum efficiency of 29% is selected. For heat a maximum efficiency of 90% is selected. The heating fuel to offset is gas. For heat and electricity, a maximum electricity efficiency of 25% and a maximum heat efficiency of 90% were selected.
AD electricity	An AD plant based on the Biogen Greenfinch plant with electricity recovery only. The capacity was increased to 22,500 tpa.
Landfill 12161	A landfill with HDPE liner and cap was selected as it would be required for APC residues.
IBA recycling 12028	An incineration bottom ash recycling with ferrous and non ferrous recycling was selected for post process recycling scenarios.
Ferrous metal 12287	Ferrous metal recycling was selected for post process recycling, post collection, and source segregation scenarios.
Non ferrous scrap metal 11123	Non ferrous metal recycling was selected for post process recycling, post collection, and source segregation scenarios.
Plastic-Film 12302	Plastic-film recycling was selected for source segregation scenarios.
Plastic-Dense 12304	Plastic-dense recycling was selected for post process recycling, post collection, and source segregation scenarios.
Glass-Aggregate 12252	Glass aggregate recycling was selected for post process recycling, post collection, and source segregation scenarios for mixed glass.
Glass-Clear 21129	Glass-Clear recycling was selected for source segregation scenarios.
Glass-Brown 11319	Glass-Brown recycling was selected for source segregation scenarios.
Glass-Green 12291	Glass-Green recycling was selected for source segregation scenarios.
Paper- 12124	Glass- Paper recycling was selected for source segregation scenarios.

Table 4.5 Properties of the transportation used in the scenarios

vehicle	vehicle capacity	Fuel type	Distance A to B	Ratio urban %	Ratio rural %	Ratio motorway %
Household to Waste transfer station						
6x4 Refuse Collection Vehicle (RCV) Fleet	12.842 T	Diesel	12 km	80	20	0

vehicle	vehicle capacity	Fuel type	Distance A to B	Ratio urban %	Ratio rural %	Ratio motorway %
Household to AD						
Kerbside multi-compartment 12027	5.5 T	ULS diesel	20 km	70	20	10
Waste transfer station to Incinerator/ERF						
Articulated Truck	8.026 T		10 km	10	45	45
Waste transfer station to Landfill						
Articulated Truck	8.026 T		10 km	10	40	50
MRF to Recycling						
Articulated Truck	8.026 T		20 km	33	33	34
MRF to Landfill						
Articulated Truck	8.026 T		10 km	10	40	50
MRF to Incinerator						
Articulated Truck	8.026 T		5 km	10	45	45
MRF to AD						
Articulated Truck	8.026 T		5 km	10	45	45
Incinerator to Recycling						
Articulated Truck	8.026 T		20 km	33	33	34
Incinerator to Landfill and IBA						
Articulated Truck	8.026 T		10 km	10	40	50

4.7 Scenario maps

From the 52 possible scenarios, 21 scenarios were mapped successfully in WRATE, with the rest of the scenarios requiring additional data and/or user-defined processes. The 21 scenarios were 1-13, 21, 25, 29, 33, 37, 41, 45 and 49. Descriptions of the waste flow and corresponding scenario maps are given below.

Scenario 1 Incineration for electricity /

Scenario 2 Incineration for heat /

Scenario 3 Incineration for heat and electricity

The scenario maps for these three scenarios are the same with the exception of the energy recovery option. The energy recovery type for scenario 2 and 3 are heat for district heating, and heat for district heating and electricity, respectively. The map is shown in Figure 4.1

- Household waste is collected from wheeled bins.
- The collection trucks deliver the waste to the transfer station where it is compacted and transferred by articulated trucks to the ERF.
- At the ERF, no metals are recovered.
- Articulated trucks transfer all ash waste to the landfill.

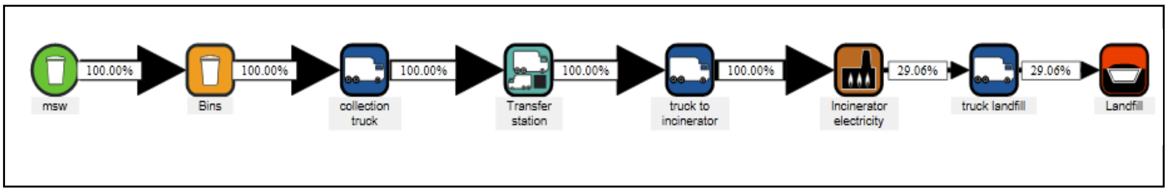


Figure 4.1 Scenario 1 map

Scenario 4 Incineration for electricity post process recycling /
Scenario 5 Incineration for heat post process recycling/
Scenario 6 Incineration for heat and electricity post process recycling

The scenario maps for these three scenarios are the same with the exception of energy recovery option. The energy recovery type for scenario 5 and 6 are heat for district heating, and heat for district heating and electricity, respectively. The map is shown in Figure 4.2.

- The household waste is collected from wheeled bins.
- The collection trucks deliver the waste to the transfer station where it is compacted and transferred to the ERF.
- Articulated trucks deliver the compacted waste to the ERF. At the ERF the ferrous metal recovery is 100% and aluminium recovery is 50%. The processed waste are separated into 4 types, incineration bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).
- Articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- Articulated trucks transfer the APC residue to the landfill.

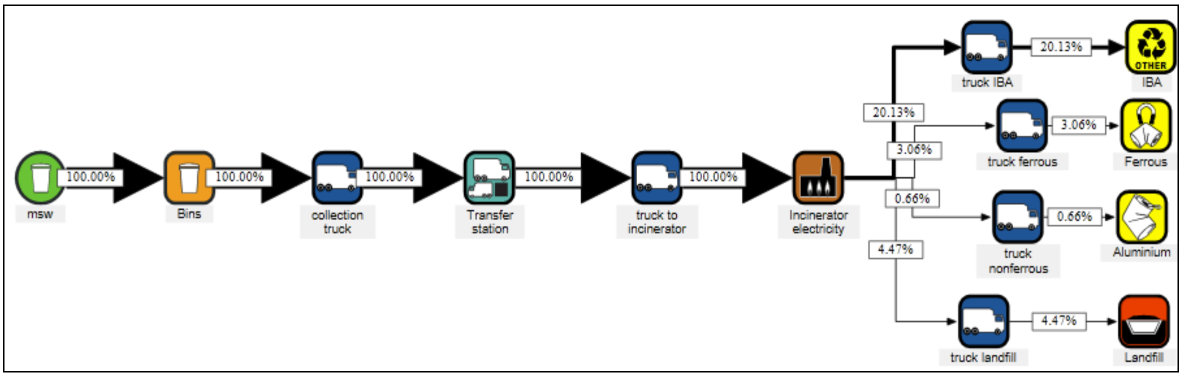


Figure 4.2 Scenario 4 map

Scenario 7 Incineration for electricity post collection recycling /

Scenario 8 Incineration for heat post collection recycling /

Scenario 9 Incineration for heat and electricity post collection recycling

The scenario maps for these 3 scenarios are the same with the exception of energy recovery option. The energy recovery type for scenario 8 and 9 are heat for district heating, and heat for district heating and electricity, respectively. The map is shown in Figure 4.3

- The household waste is collected from wheeled bins.
- The collection trucks delivers the waste to the MRF where mixed waste is sorted and the recycle components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, dense plastic, and mix glass. The articulated truck delivers to the different recycling facilities.
- The articulated truck delivers waste residue to ERF. Ferrous metal recovery is 100% and aluminium recovery is 50%. The processed waste are separated into 4 types, incinerator bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).
- The articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- The articulated truck transfers the APC residue to the landfill.

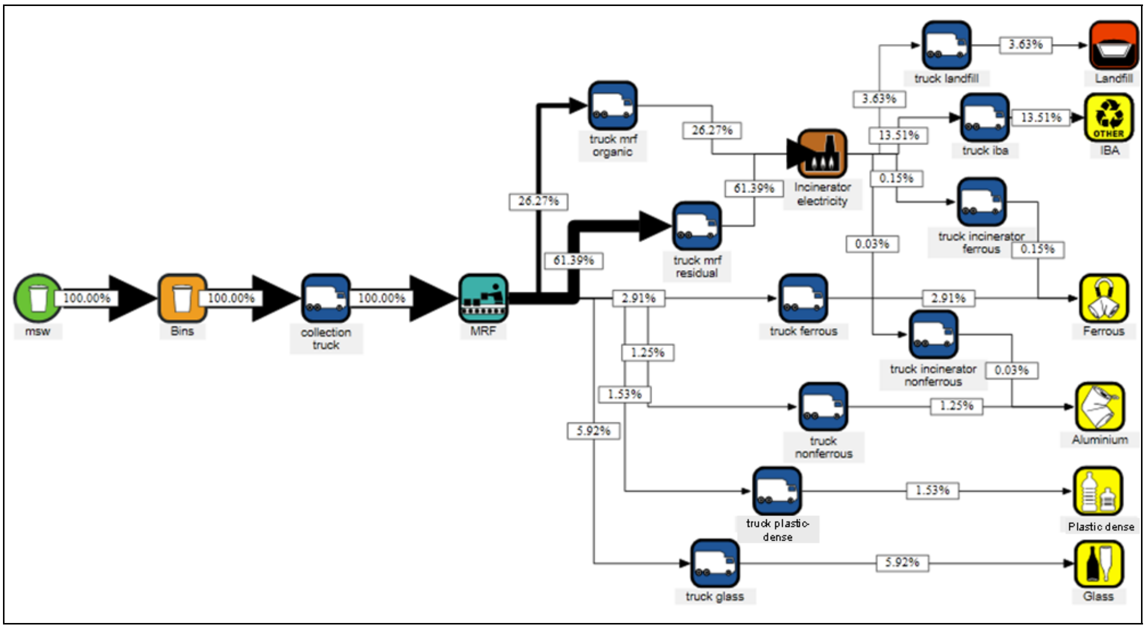


Figure 4.3 Scenario 7 map

Scenario 10 Incineration for electricity source segregate/

Scenario 11 Incineration for heat source segregated/

Scenario 12 Incineration for heat and electricity source segregated

The scenario maps for these 3 scenarios are the same with the exception of energy recovery option. For scenario 11 and 12, the energy recovery type is heat for district heating, and heat for district heating and electricity, respectively. The map is shown in Figure 4.4

- The MSW is segregated at the source. The household has 2 wheeled bins, one for mix recyclables and the other for the residual waste.
- The recycling trucks deliver the mix recyclables to the MRF where it is sorted and the various recycle components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, plastic dense, plastic film, clear glass, green glass, brown glass and paper. Articulated trucks deliver different recyclates to the various recycling facilities. The residual waste is sent to the ERF.
- The collection trucks deliver residual waste from households to the ERF and articulated trucks deliver the residual waste from the MRF to the ERF. At the ERF ferrous metal recovery is 100% and aluminium recovery is 50%. The processed

waste are separated into 4 types, incinerator bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).

- Articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- The Articulated truck transfers the APC residue to the landfill.

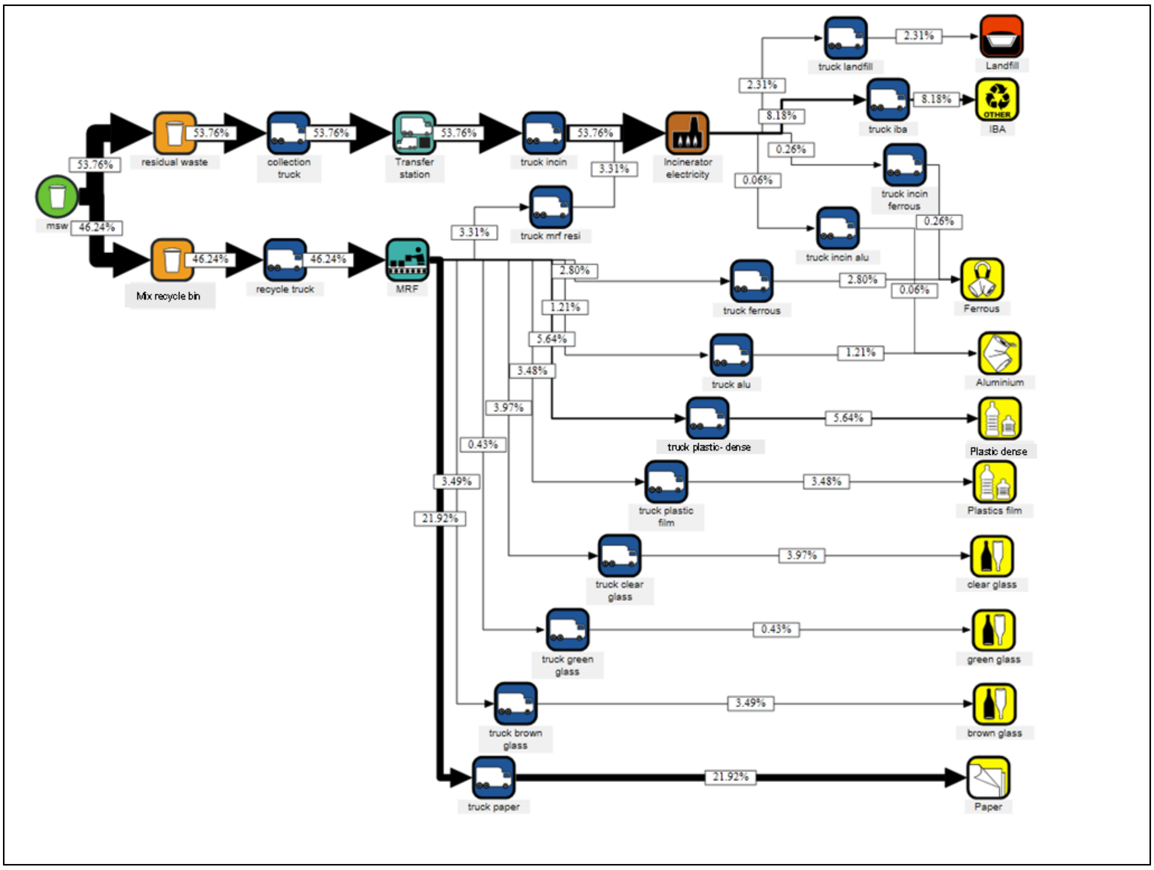


Figure 4.4 Scenario 10 map

Scenario 13 Landfill (Anaerobic Digestion) for electricity

In this scenario landfill is chosen to represent the process of anaerobic digestion of waste without any recycling and the methane produced is collected as landfill gas which generates electricity shown in Figure 4.5.

- The household waste is collected from wheeled bins.
- The collection truck delivers the MSW to the transfer station where it is compacted.
- Articulated trucks transfer the compacted MSW to the landfill site.

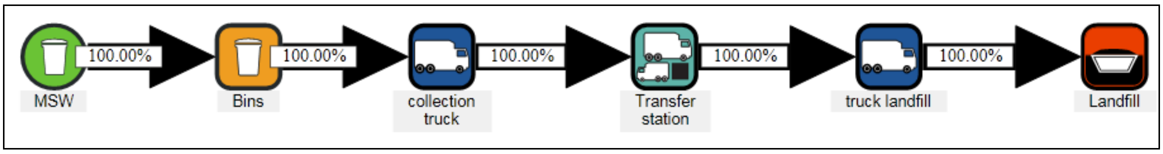


Figure 4.5 Scenario 13 map

Scenario 21 Anaerobic Digestion for electricity post collection recycling

In Figure 4.6 the scenario map for scenario 21 is shown.

- The household waste is collected from wheeled bins.
- The collection truck delivers the waste to the MRF where mixed waste is sorted into recyclable components, residual waste and organic fraction. The recyclable components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, dense plastic, and mix glass. Articulated trucks deliver different recyclates to the various the recycling facilities.
- The organic waste fraction is sent to the Anaerobic Digestion plant. Articulated trucks deliver the organic waste fraction to the Anaerobic Digestion plant.
- Articulated trucks transfer residual waste to the landfill site.

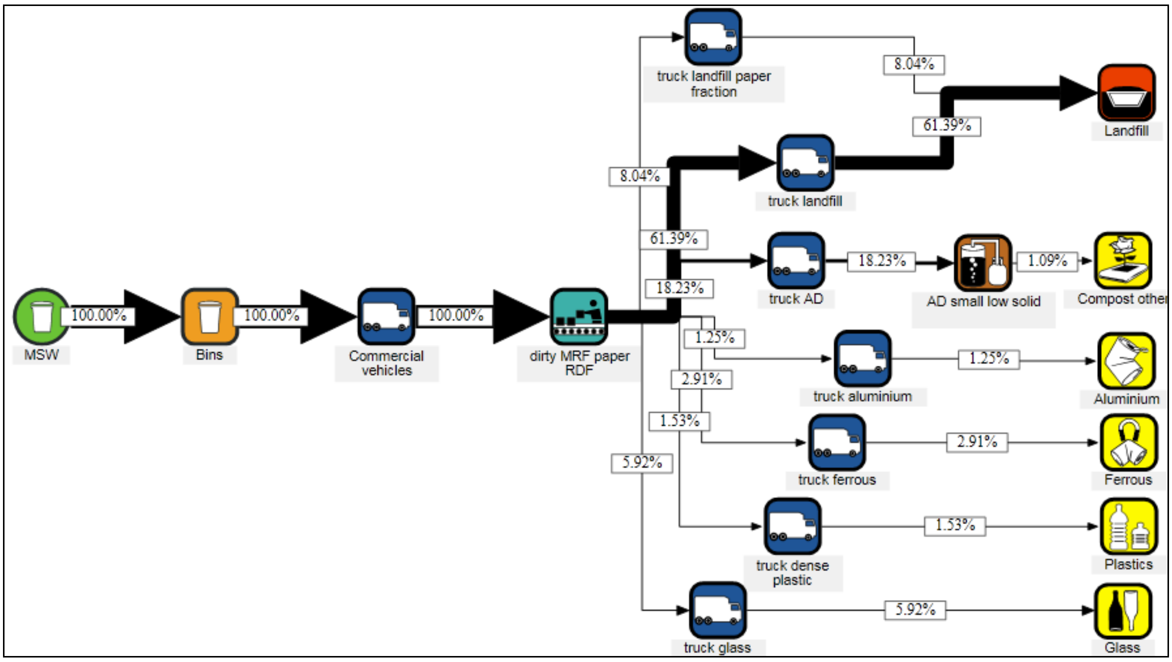


Figure 4.6 Scenario 21 map

Scenario 25 Anaerobic Digestion for electricity source segregate

In Figure 4.7 the scenario map for scenario 25 is shown.

- The household waste is segregated at the source. The household has a bag for garden waste, a kitchen caddy for organic kitchen waste and 2 wheeled bins, one for mix recyclables and the other for the residual waste. The garden waste and the kitchen waste collection truck is the Kerbside vehicle multi- compartment using diesel.
- The collection trucks deliver the residual waste to the transfer station where it is compacted and transferred to the landfill site.
- The collection truck delivers the mixed recycle waste to the MRF where mixed recyclables is sorted and the various recycle components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, plastic dense, plastic film, clear glass, green glass, brown glass and paper. The residual waste is sent to the landfill site. Articulated trucks deliver different recyclates to the various the recycling facilities.

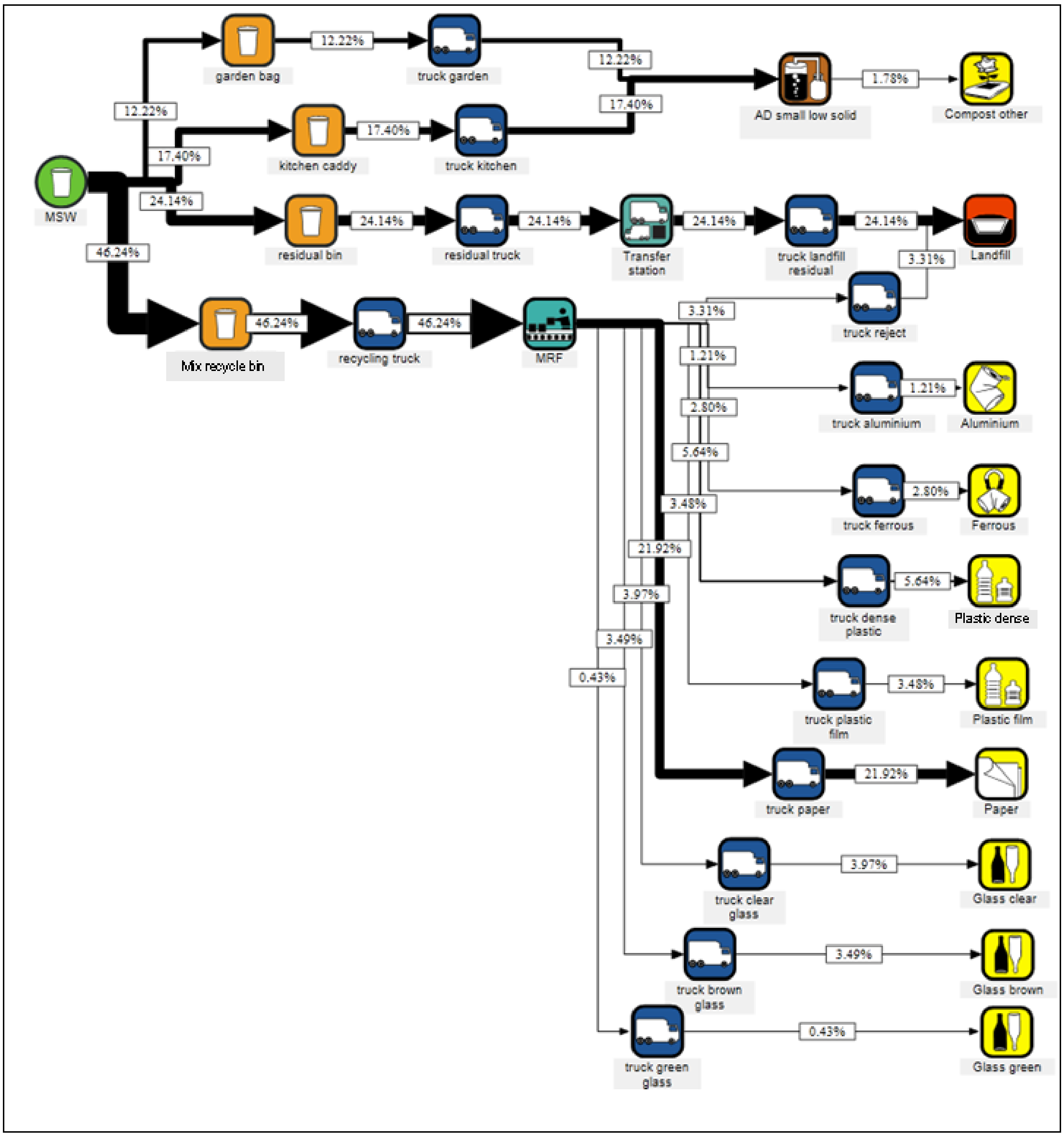


Figure 4.7 Scenario 25 map

Scenario 29 Incineration for heat and Anaerobic Digestion for electricity post collection recycling/

Scenario 37 Incineration for electricity and Anaerobic Digestion for electricity post collection recycling/

Scenario 45 Incineration for heat and electricity and Anaerobic Digestion for electricity post collection recycling

The scenario maps for these 3 scenarios are the same with the exception of energy recovery option. For scenario 37 the energy recovery type is electricity, for scenario 45 the energy recovery type is heat for district heating and electricity. The map is shown in Figure 4.8

- The household waste is collected from wheeled bins.
- The collection trucks delivers the waste to the MRF where mixed waste is sorted and the recycle components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, dense plastic, and mix glass. Articulated trucks deliver the different recyclates to the various recycling facilities
- The Articulated truck delivers to the AD plant.
- The residual waste is sent to the ERF. Articulated trucks deliver residual waste to ERF. Ferrous metal recovery is 100% and aluminium recovery is 50%. The processed waste are separated into 4 types, incinerator bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).
- Articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- Articulated trucks transfer the APC residue to the landfill.

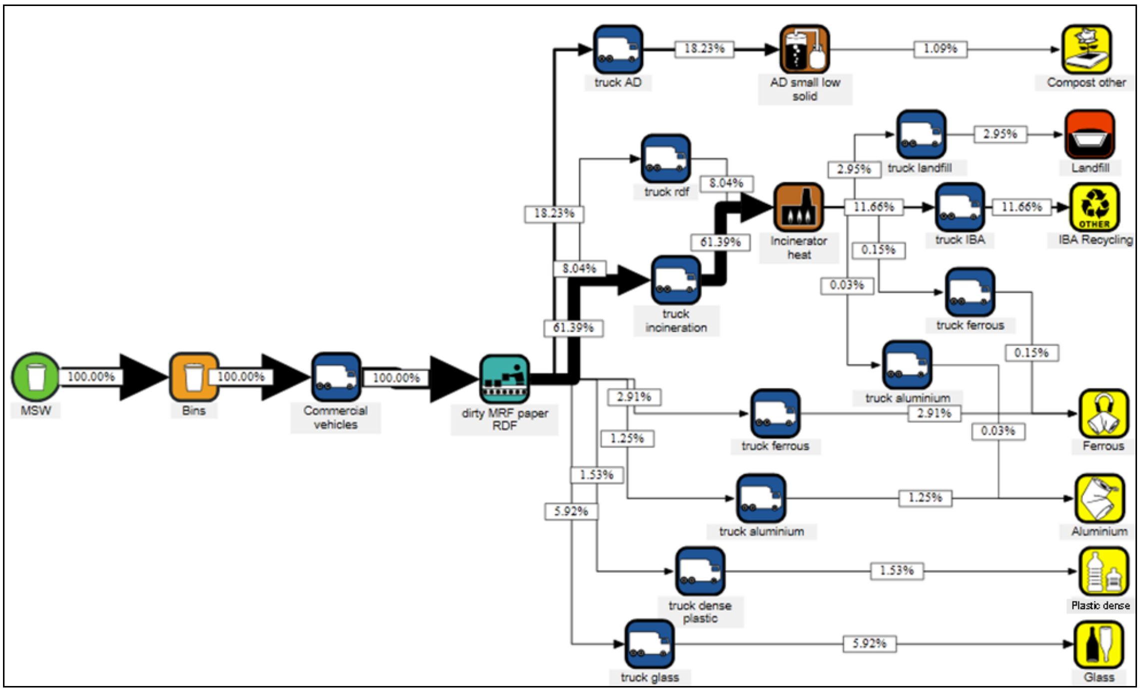


Figure 4.8 Scenario 29 map

Scenario 33 Incineration for heat and Anaerobic Digestion for electricity source segregate/

Scenario 41 Incineration for electricity and Anaerobic Digestion for electricity source segregation/

Scenario 49 Incineration for heat and electricity and Anaerobic Digestion for electricity source segregation

The scenario maps for these 3 scenarios are the same with the exception of energy recovery option. For scenario 41 the energy recovery type is electricity, for scenario 49 the energy recovery type is heat for district heating and electricity. The map is shown in Figure 4.9.

- The household waste is segregated at the source. The household has a bag for garden waste, a kitchen caddy for organic kitchen waste and 2 wheeled bins, one for mix recyclables and the other for the residual waste. The garden waste and the kitchen waste collection truck is the Kerbside vehicle multi- compartment using diesel.
- The collection trucks deliver the residual waste to the transfer station where it is compacted and transferred to the landfill site.
- The recycling trucks delivers the recyclables to the MRF where mixed recyclables is sorted and the recycle components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, dense plastic, plastic film, clear glass, green glass, brown glass and paper. Articulated trucks deliver the different recyclates to the various recycling facilities.
- The residual waste is sent to the ERF. Articulated trucks deliver residual waste to ERF. Ferrous metal recovery is 100% and aluminium recovery is 50%. The processed waste are separated into 4 types, incinerator bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).
- The Articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- The Articulated truck transfers the APC residue to the landfill.

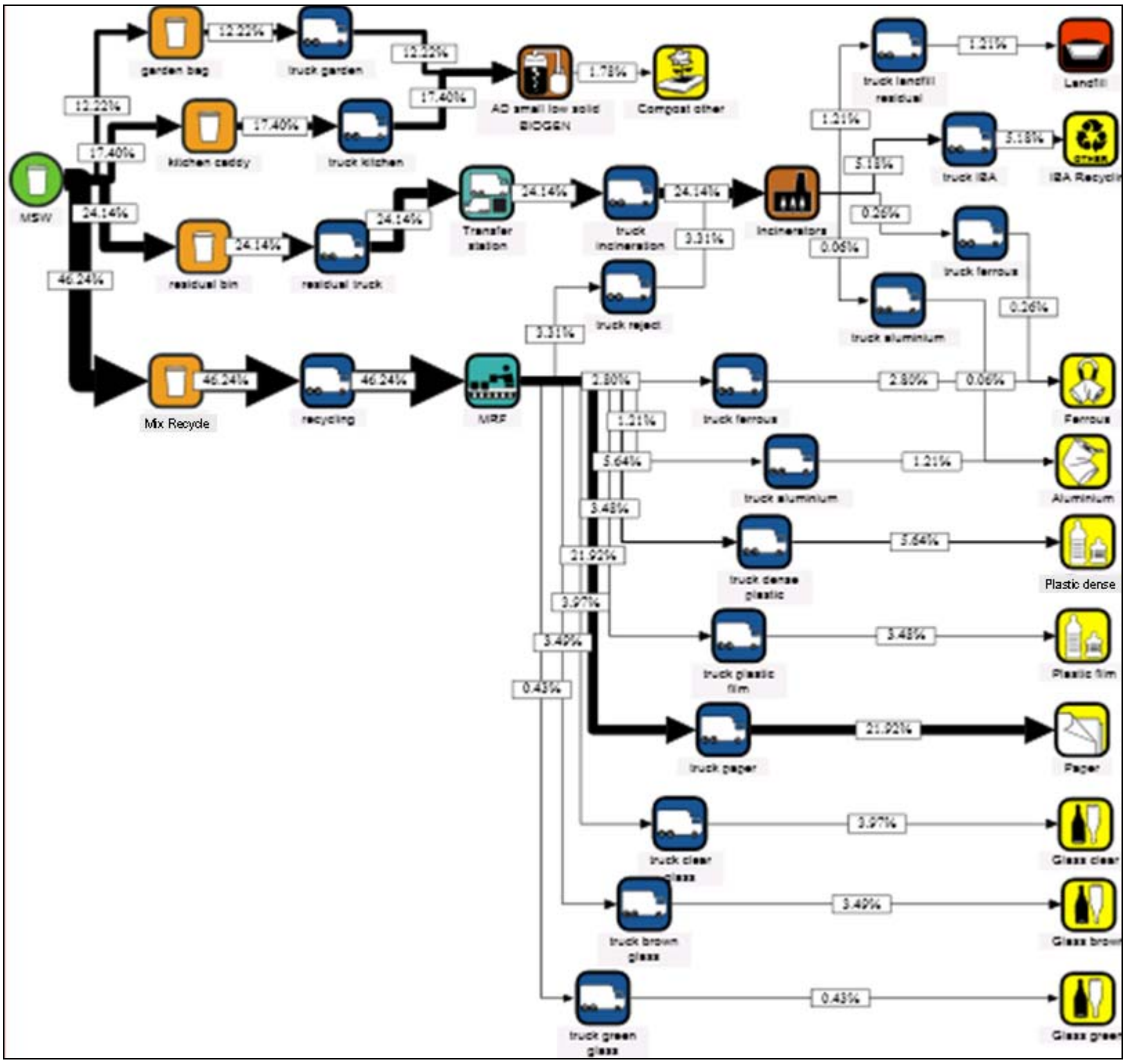


Figure 4.9 Scenario 33 map

Chapter 5
Phase one results

From the 52 possible scenarios, 21 were modelled initially in WRATE with the available processes built in the program. The 21 scenarios are 1-13, 21, 25, 29, 33, 37, 41, 45 and 49. The other scenarios required the application of user defined function to create processes that are unique to the project and not available in WRATE.

Although not all of the 52 scenarios for phase 1 have been modelled in WRATE, the results from the 21 scenarios were informative and observations were made.

5.1 Headline Values

The first results from WRATE were the headline values shown in table 5.1. They are not LCA indicators but they provide information about the waste flow and land use. They composed of the amount of 1) biodegradable waste landfilled, 2) energy recovered, 3) land take 4) waste composted, 5) waste landfilled, 6) waste recovered and 7) waste recycled. These values were calculated from the data input of the waste flow e.g. the amount of each waste fraction and where they were distributed to and the relevant data in the database of the software. A clear example shown in scenario 13 where all the waste was sent to the landfill therefore the amount of Waste Landfilled was equal to the total project waste of 95,000 tonnes. Energy Recovered values were calculated from the amount of each waste category, the respective calorific values in the default database and the energy conversion of each WtE treatment process. Land take values were from data of the area required for the facilities of each process.

Table 5.1 Headline values

scenario	Biodegrade-able Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
1	0	215,449,201	0.296	0	27,605	95,000	0
2	0	705,837,307	0.296	0	27,605	95,000	0
3	0	311,918,992	0.296	0	27,605	95,000	0
4	0	215,449,201	0.231	0	5,201	95,000	3,534
5	0	705,837,307	0.231	0	5,201	95,000	3,534
6	0	311,918,992	0.231	0	5,201	95,000	3,534

scenario	Biodegrade-able Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
7	0	212,511,298	0.166	0	4,456	83,285	11,208
8	0	696,212,385	0.166	0	4,456	83,285	11,208
9	0	307,665,610	0.166	0	4,456	83,285	11,208
10	0	100,557,732	0.37	0	4,925	54,216	41,089
11	0	329,439,136	0.37	0	4,925	54,216	41,089
12	0	145,583,582	0.37	0	4,925	54,216	41,089
13	63,603	50,852,450	0.495	0	95,000	0	0
21	45,596	63,277,631	0.363	17,322	66,500	0	11,031
25	14,640	54,321,252	0.419	28,139	28,698	0	40,784
29	0	660,946,780	0.172	17,322	3,898	65,963	11,208
33	0	272,840,187	0.345	28,139	4,017	26,077	41,089
37	0	217,651,524	0.172	17,322	3,898	65,963	11,208
41	0	108,660,074	0.345	28,139	4,017	26,077	41,089
45	0	304,857,148	0.172	17,322	3,898	65,963	11,208
49	0	140,957,801	0.345	28,139	4,017	26,077	41,089

5.1.1 Biodegradable waste to landfill

The only 3 scenarios that had biodegradable waste disposed in the landfill scenarios 13, 21 and 25. These scenarios did not combine AD with incineration so residuals that were unsuitable for AD were sent to the landfill. The amount decreases with the increasing efforts in recycling. Scenario 13- AD for electricity with no recycling was basically all waste sent to the landfill with gas collection so the waste disposed in the landfill was the most of all scenarios at 63,603 tonnes. Scenario 21- AD for electricity post process recycling disposed of 45,596 tonnes. Scenario 25- AD for electricity source segregation disposed 14,640 tonnes.

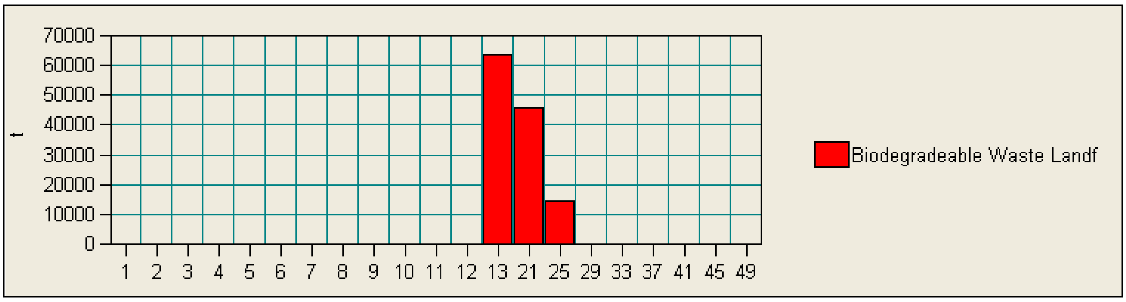


Figure 5.1 Amount of Biodegradable Waste in Landfill

5.1.2 Energy Recovered

The scenarios that recovered more energy are the scenarios with incineration/ERF or combined with incineration/ERF. The most significant are the 4 scenarios using mainly incineration/ERF for heat as the efficiency was higher as follows.

- Scenario 2 Incineration for heat with no recycling
- Scenario 5 Incineration for heat post process recycling
- Scenario 8 Incineration for heat post collection recycling
- Scenario 29 Incineration for heat AD for electricity post collection recycling

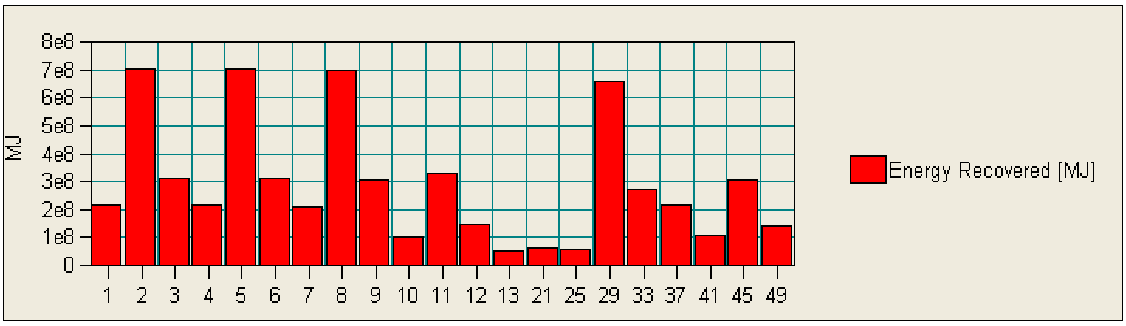


Figure 5.2 Amount of Energy Recovered

5.1.3 Land take

Land take values for scenarios 10-12 were higher than scenarios 1-9 although more efforts in recycling increased, due to the addition of MRF and transfer station, this could be misleading because a transfer station could have been included in 7-9. Further study would be needed to establish the reason.

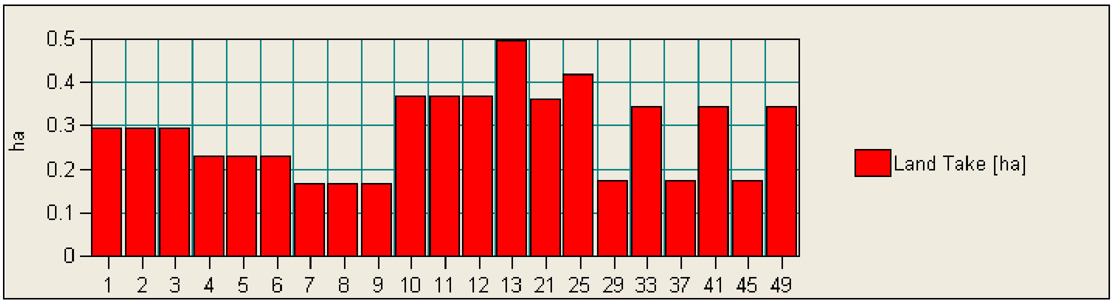


Figure 5.3 Amount of Land Take

5.1.4 Waste Composted

WRATE identifies digestate from AD as compost therefore the scenarios with AD (21, 25, 29, 33, 37, 41, 45 and 49) would have amounts of waste composted allocated to them.

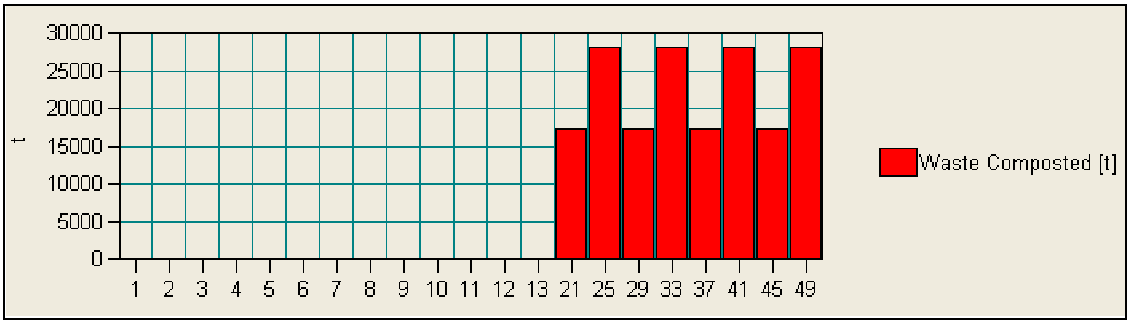


Figure 5.4 Amount of Waste Composted

5.1.5 Waste Landfilled

Scenario 13- AD for electricity with no recycling was basically all waste sent to the landfill with gas collection so the waste disposed in the landfill was the most of all scenarios at 63,603 tonnes. Scenario 21 and 25 had increased recycling and less waste was sent to landfill. The rest of the scenarios included ERF and minimised the amount of waste to landfill with the exception of scenario 1 to 3 where no recycling takes place.

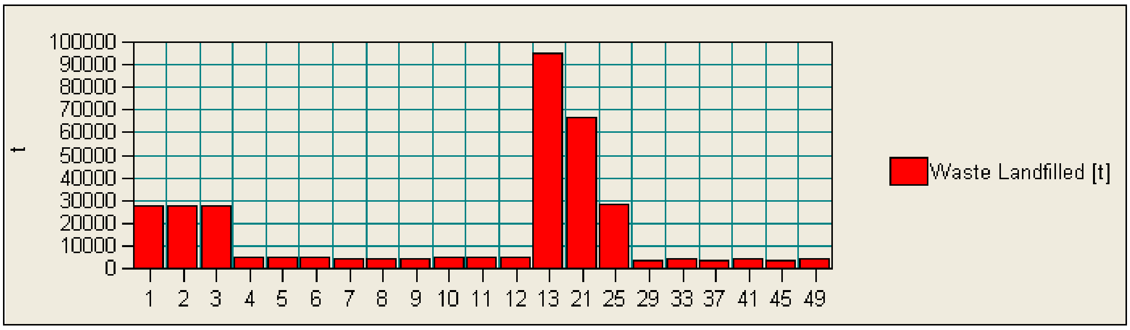


Figure 5.5 Amount of Waste Landfilled

5.1.6 Waste Recovered

For WRATE waste recovered is waste recovered as energy, therefore the scenarios with ERF have high values of waste recovered and decreases with increasing recycling efforts.

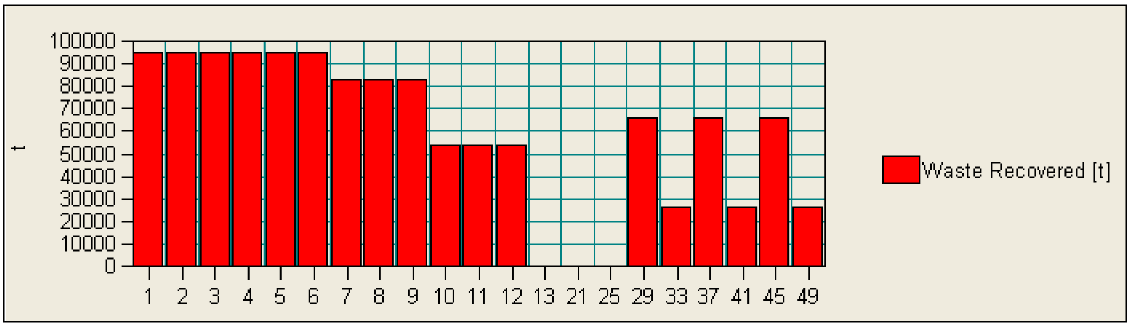


Figure 5.6 Amount of Waste Recovered

5.1.7 Waste Recycled

As more recycling increases in the scenarios more waste is recycled as expected. Four levels are clearly seen which correlates to the design of the scenarios which set four different recycling schemes. The recycling schemes are 1) no recycling 2) post process recycling 3) post collection recycling and 4) source segregation.

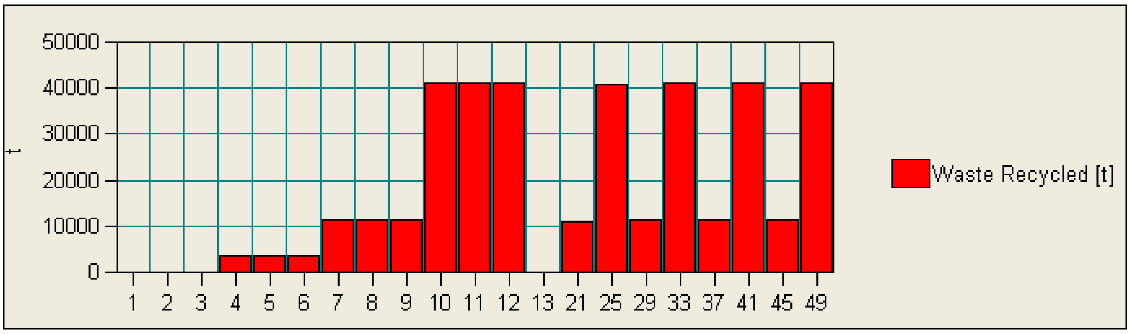


Figure 5.7 Amount of Waste Recycled

5.2 Life Cycle Impact Assessments

The default environmental impact assessments in WRATE are 1) Climate change, GWP (Global Warming Potential), 2) Acidification potential, 3) Eutrophication potential, 4) Fresh water aquatic ecotoxicity, 5) Human toxicity and 6)Resources depletion of abiotic resources.

5.2.1 Climate change, GWP (Global Warming Potential)

Scenario 13- AD for electricity with no recycling which actually was the total amount of waste sent to the landfill had the highest global warming potential due to waste continuing to degrade in the landfill. The rest of the scenarios have negative values which indicates better performance in GHG emissions. As recycling increases GWP decreases. ERF with heat and ERF with CHP also perform slightly better than ERF electricity.

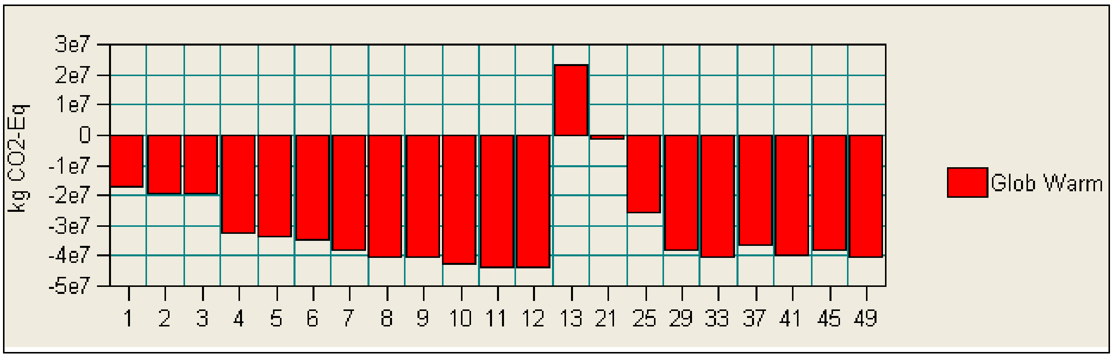


Figure 5.8 Climate change, GWP (Global Warming Potential)

5.2.2 Acidification potential

Scenario 2 and 13 had the highest acidification potential. The rest of the scenarios have negative values which indicates better performance in acidification potential. As recycling increases acidification decreases. ERF with electricity and CHP performs better than ERF heat.

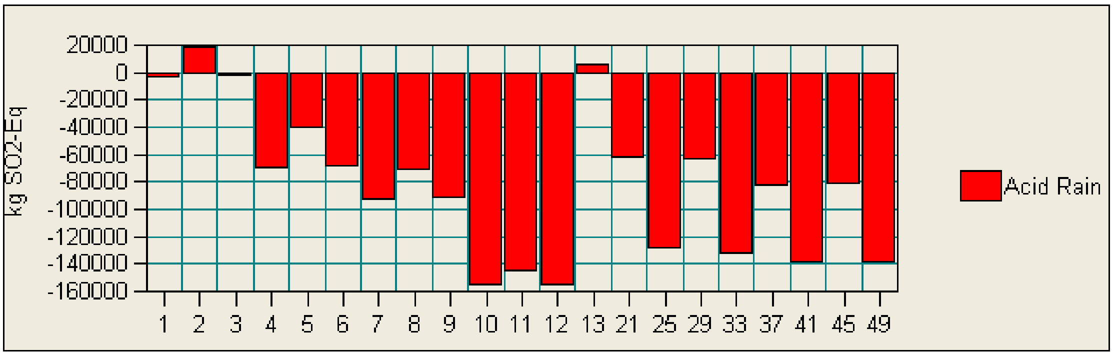


Figure 5.9 Acidification potential

5.2.3 Eutrophication potential

Scenario 13 and 21 has a large amount of waste sent to landfill so it has the corresponding high eutrophication potential. However further investigation is needed to see why scenario 21 is higher than 13. As a recurring trend the eutrophication potential decreases as recycling increases. Within the same recycling scheme it can be observed that ERF with heat has a higher impact than ERF with electricity and ERF with CHP. Combinations of ERF and AD performs better than either technology alone.

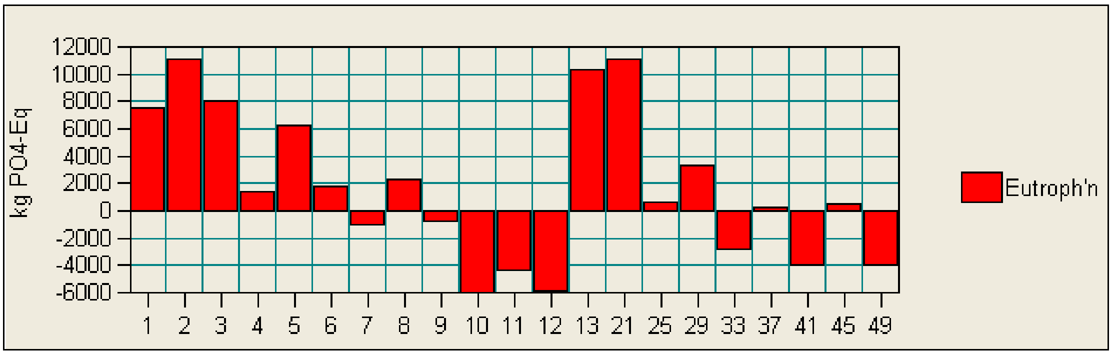


Figure 5.10 Eutrophication potential

5.2.4 Fresh water aquatic ecotoxicity

The scenarios 1-3, ERFs with no recycling, and 13 , landfill, have significantly more aquatic ecotoxicity impacts than the rest of the scenarios, with scenario 2, ERF heat with no recycling and scenario 13 , landfill, actually having an environmental burden.

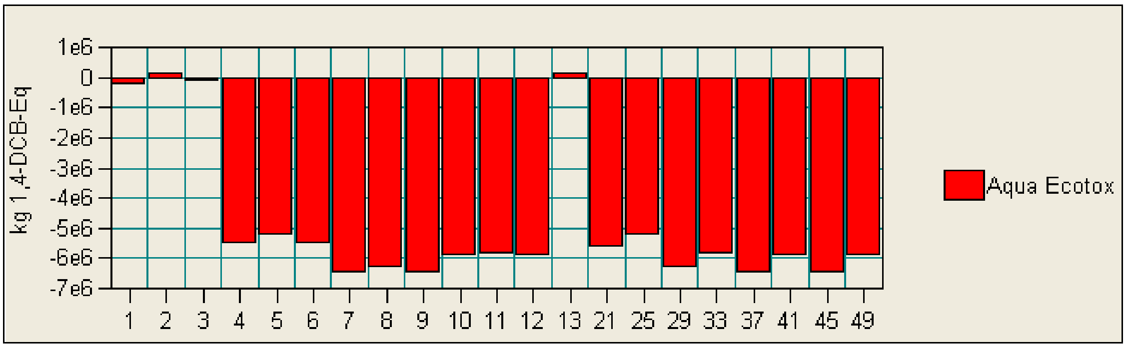


Figure 5.11 Fresh water aquatic ecotoxicity

5.2.5 Human toxicity

Similarly the scenarios 1-3, ERFs with no recycling and scenario 13, landfill, have significantly more human toxicity impacts than the rest of the scenarios, with scenario 13, landfill, actually having an environmental burden.

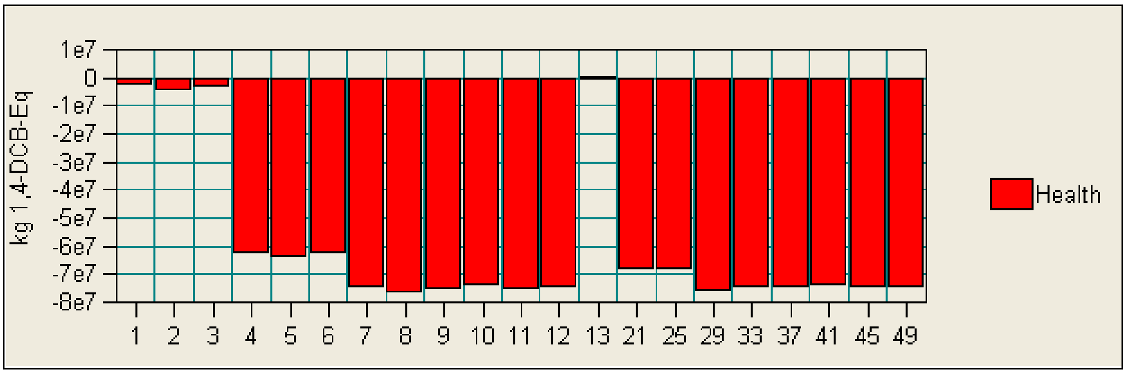


Figure 5.12 Human toxicity

5.2.6 Resources depletion of abiotic resources

As a recurring trend the resource depletion decreases as recycling increases. Combinations of ERF and AD with post collection recycling and source segregation are similar to ERF with post collection recycling and source segregation.

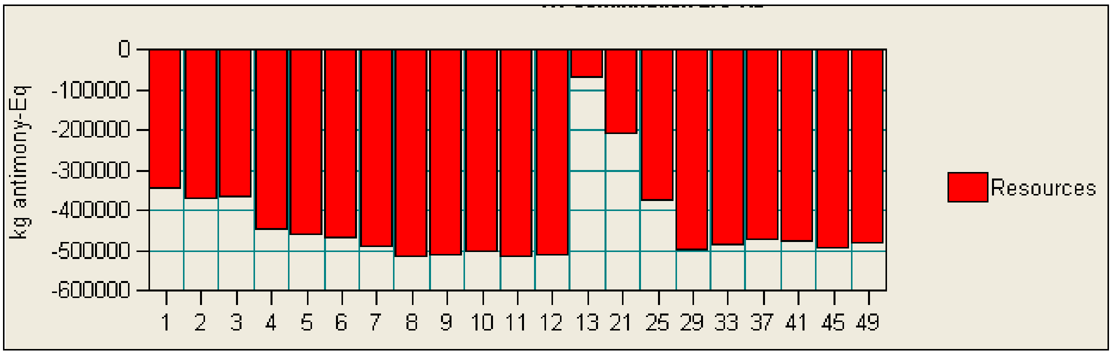


Figure 5.13 Resources depletion of abiotic resources

5.2.7 Multiple impact assessments

The results in the multiple impact assessments normalised the values of each impact category and uses the unit of European Person Equivalent to compare all six impact categories shown in Figure 5.14. High negative values for resource depletion for all scenarios are interpreted as positive impacts to the environment as resources are recovered or recycled.

Scenario 13, predominantly using landfill, stands out as having the highest environmental burden in the global warming potential impact. For most of the scenarios there are small burdens shown in eutrophication potential impact category. Scenarios with incineration only perform better than scenarios with AD only. Scenarios with incineration and AD combination perform better than scenarios with AD only but not as well as scenarios with incineration only. The recycling schemes scenarios show a trend of improving the environmental impact in all categories as the level of waste segregation increases.

Resources depletion impact assessment has values that are 4 times more than the other impact assessments. All the impacts are negative indicating benefits to the environment from offsets.

Fresh water aqua ecotoxicity and human toxicity impact assessments have similar results. There are more burdens for scenarios with incineration no recycling and AD with no recycling (landfill) than the other scenarios. The other scenarios all have benefits to the environment.

Eutrophication potential impact assessments have very small burdens and offsets in comparison to the other five impact assessments. There are more burdens for scenarios with no recycling.

The highest acidification potential impacts are from scenario 2 and 13. The other scenarios have negative values which indicate better performance in acidification potential such as avoided emissions.

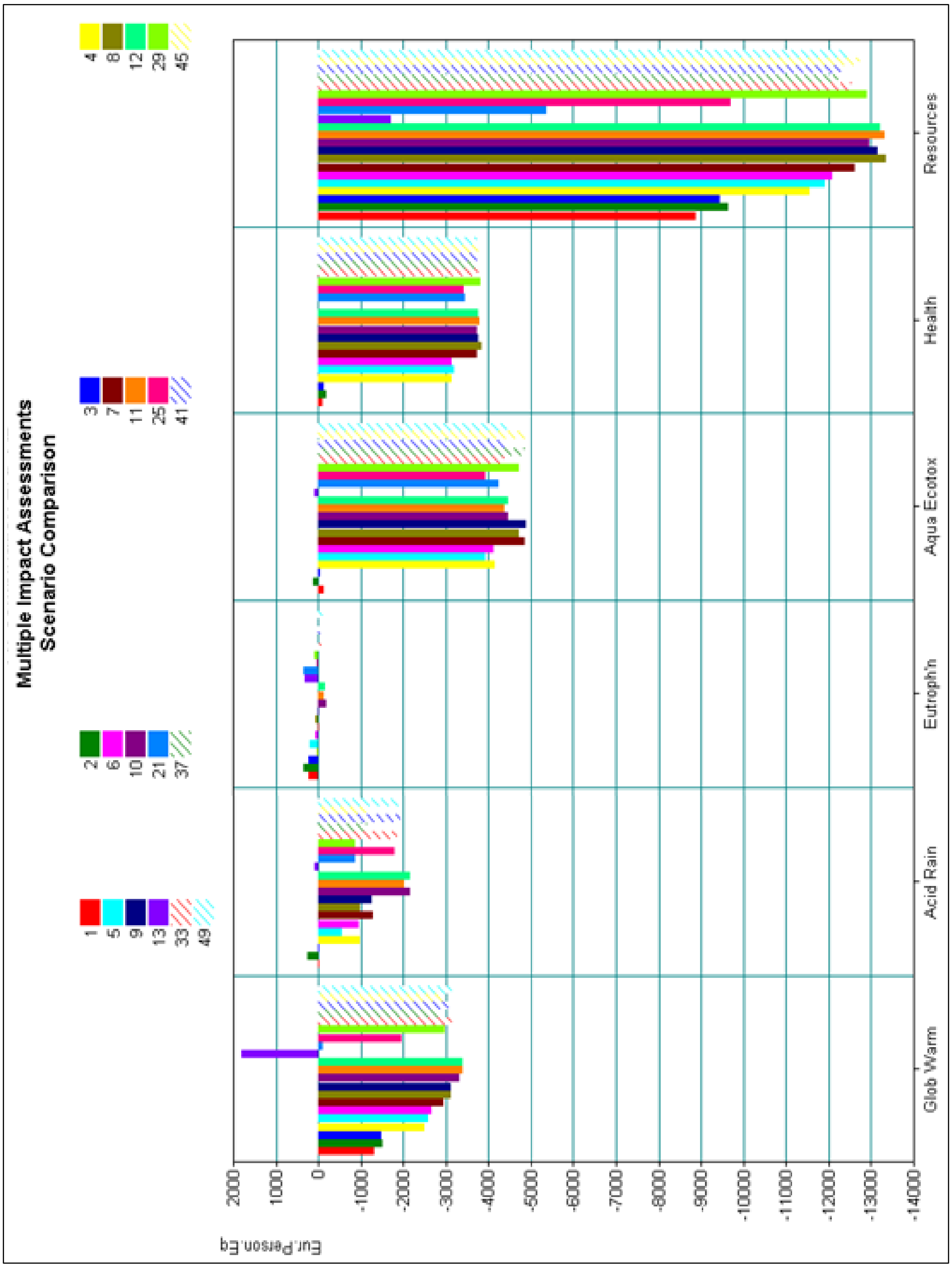


Figure 5.14 Multiple impact assessments

5.3 Comparison of selected group of scenarios

5.3.1 Comparison of key scenarios with source segregation of waste

The scenarios with source segregation of waste are compared and shown in figure 5.15. The scenarios are scenario 10 Incineration for electricity, scenario 25 AD for electricity, and scenario 41 - Incineration for electricity and AD for electricity. It can also be seen that the scenario with AD consistently have slightly more burdens than scenarios Incineration for electricity and the combination of Incineration for electricity and AD for electricity.

There is a large difference between the environmental impacts for resources depletion and the other impact categories due to the recycling scheme of source segregation. The impacts for eutrophication potential are near the zero mark signifying the positive and negative burdens balance each other out.

The results could be focused down further to consider the resources depletion impacts of the different steps in waste management; collection, transportation, intermediate facilities, recycling, treatment and recovery and landfill. Figures 5.16 and 5.17 shows the significant difference in impacts of the 3 scenarios is in the actual treatment and recovery (blue) step and the largest contribution to the negative burden is recycling (yellow) step, as expected.

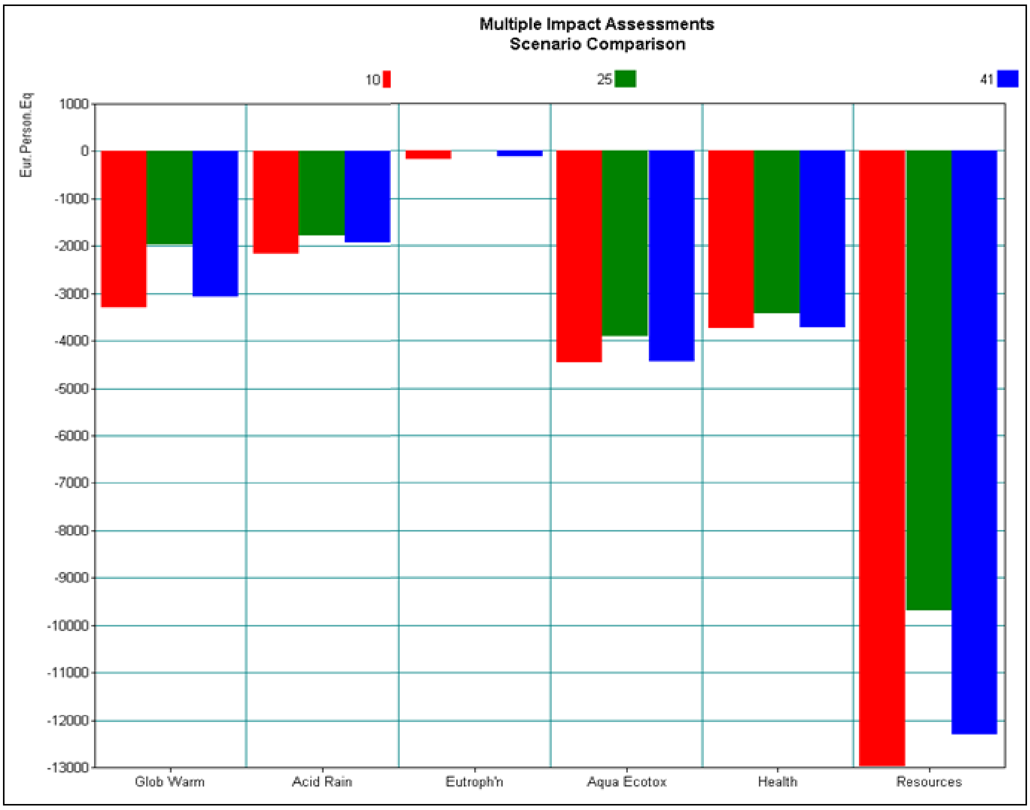


Figure 5.15 Comparison of 3 source segregation scenarios

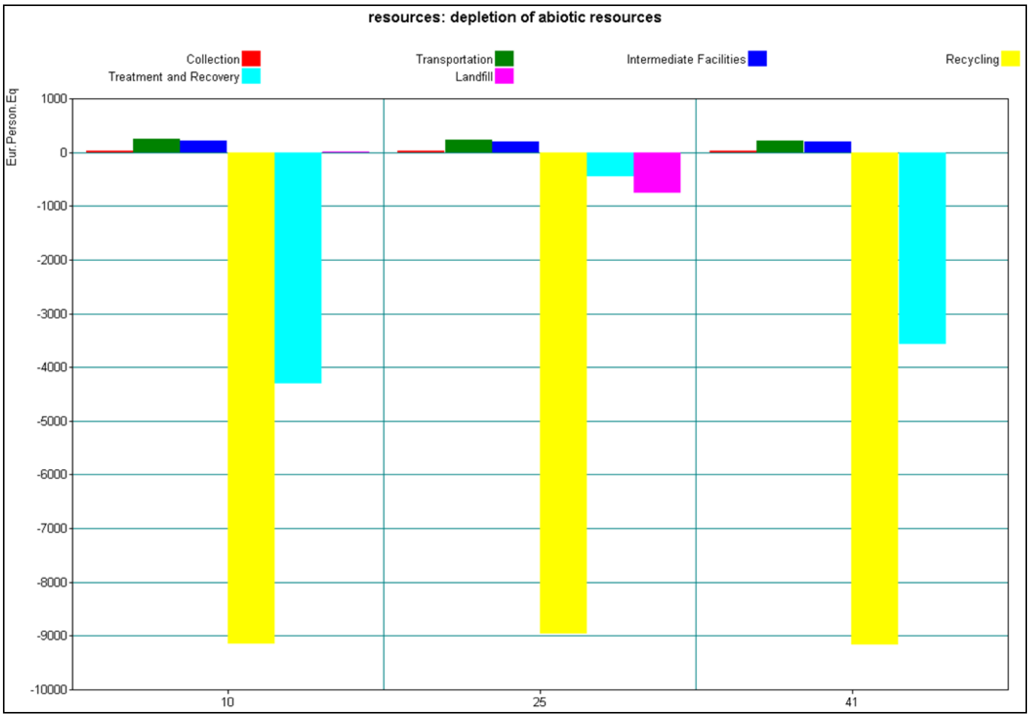


Figure 5.16 Resources depletion of 3 source segregation scenarios

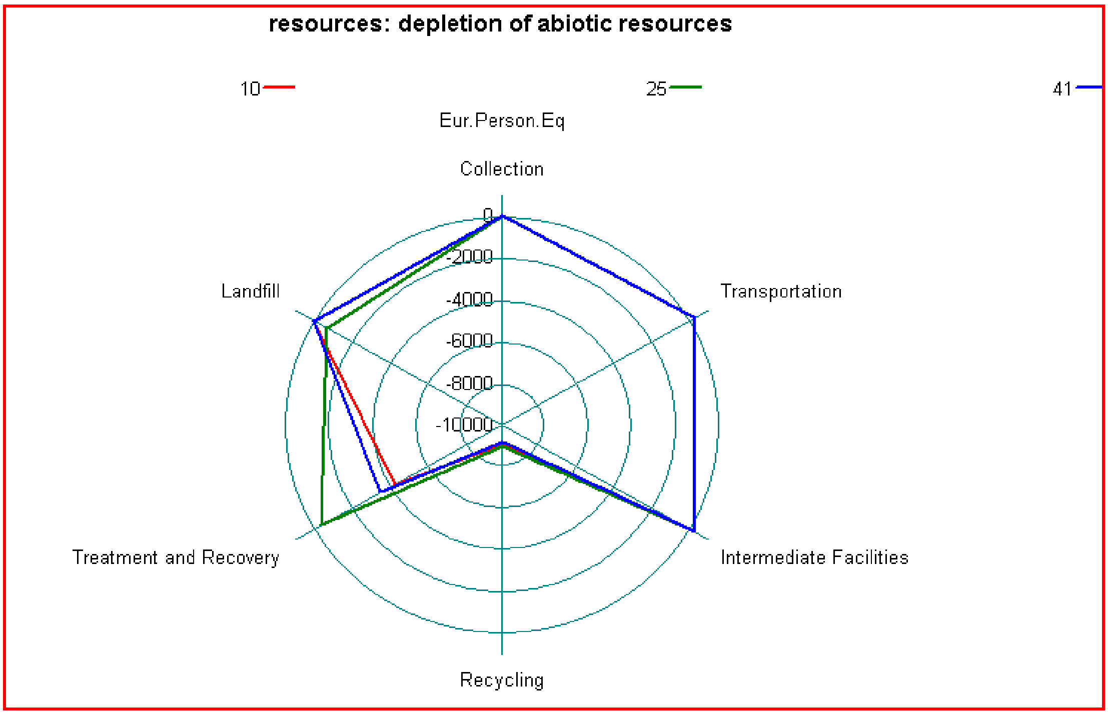


Figure 5.17 Resources depletion of 3 source segregation scenarios, web chart

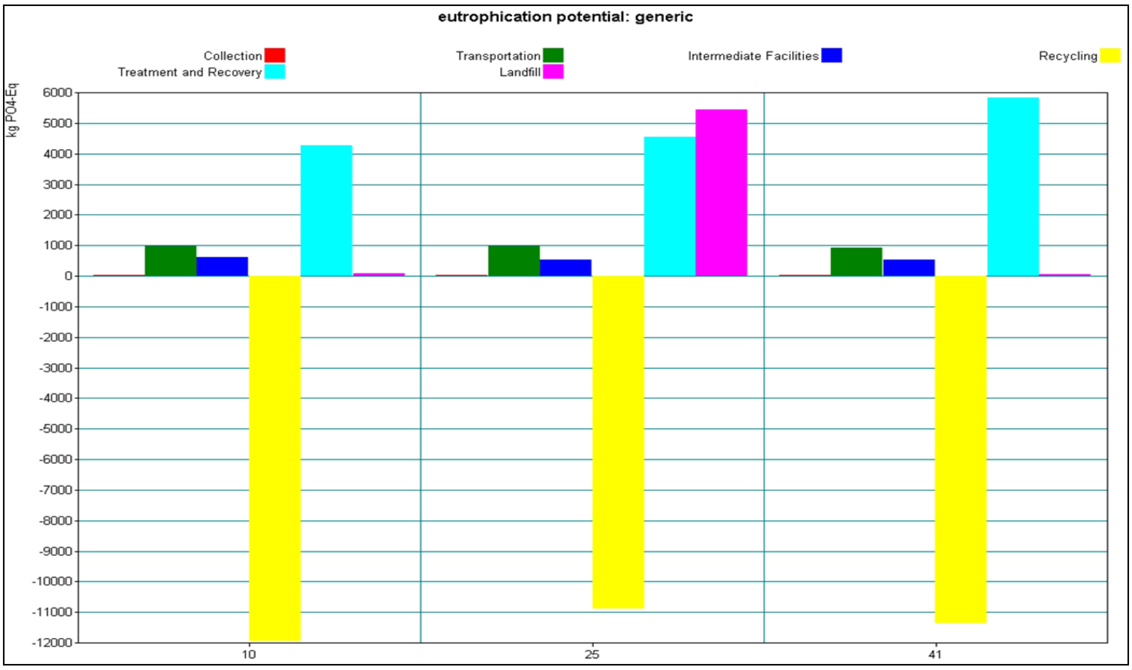


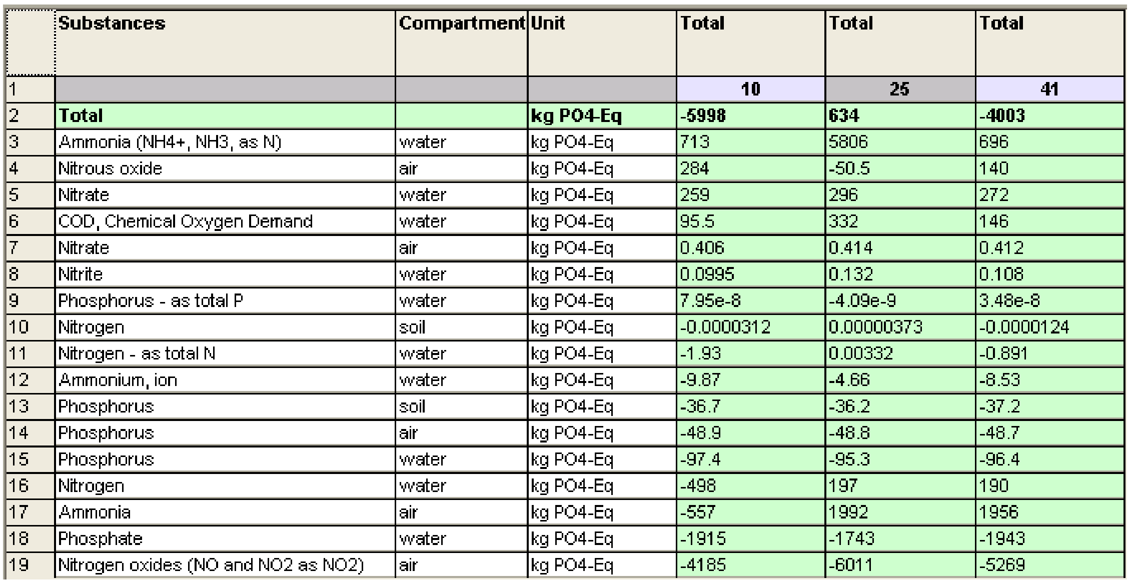
Figure 5.18 Eutrophication potential of 3 source segregation scenarios

When focused on to the eutrophication potential impact category, the 2 steps that contribute to the burden are treatment and recovery (blue) and landfill (pink) shown in figure 5.18.

Scenario 25 has more waste sent to the landfill than scenario 10 and 41 where the residuals were sent to ERF.

In table 5.2, the emissions contributing to the eutrophication potential in each scenario are shown. The main emissions contributing to in scenario 10 are ammonia to water, nitrous oxide to air and nitrate to water. The main emissions contributing to in scenario 25 are ammonia to water, ammonia to air and COD to water. The main emissions contributing to in scenario 41 are ammonia to air, ammonia to water, and nitrate to water.

Table 5.2 Details of emissions contributing to eutrophication potential



	Substances	Compartment	Unit	Total	Total	Total
1				10	25	41
2	**Total**		**kg PO4-Eq**	**-5998**	**634**	**-4003**
3	Ammonia (NH4+, NH3, as N)	water	kg PO4-Eq	713	5806	696
4	Nitrous oxide	air	kg PO4-Eq	284	-50.5	140
5	Nitrate	water	kg PO4-Eq	259	296	272
6	COD, Chemical Oxygen Demand	water	kg PO4-Eq	95.5	332	146
7	Nitrate	air	kg PO4-Eq	0.406	0.414	0.412
8	Nitrite	water	kg PO4-Eq	0.0995	0.132	0.108
9	Phosphorus - as total P	water	kg PO4-Eq	7.95e-8	-4.09e-9	3.48e-8
10	Nitrogen	soil	kg PO4-Eq	-0.0000312	0.00000373	-0.0000124
11	Nitrogen - as total N	water	kg PO4-Eq	-1.93	0.00332	-0.891
12	Ammonium, ion	water	kg PO4-Eq	-9.87	-4.66	-8.53
13	Phosphorus	soil	kg PO4-Eq	-36.7	-36.2	-37.2
14	Phosphorus	air	kg PO4-Eq	-48.9	-48.8	-48.7
15	Phosphorus	water	kg PO4-Eq	-97.4	-95.3	-96.4
16	Nitrogen	water	kg PO4-Eq	-498	197	190
17	Ammonia	air	kg PO4-Eq	-557	1992	1956
18	Phosphate	water	kg PO4-Eq	-1915	-1743	-1943
19	Nitrogen oxides (NO and NO2 as NO2)	air	kg PO4-Eq	-4185	-6011	-5269

5.3.2 Comparison of incineration/ERF and AD

In general scenarios with incineration/ERF only have lesser environmental burdens and more energy recovery than the scenarios with AD only.

Scenarios with no recycling

The 2 scenarios with no recycling compared are scenario 1 Incineration for electricity and scenario 13 Anaerobic digestion for electricity. The energy recovery for scenario 1 is 215,449,201 MJ and for scenario 13 is 50,852,450 MJ. The multiple impacts displayed in figure 5.19 shows that scenario 1 generally has less environmental impacts than scenario 13 with significant differences in Climate change impact and Resources depletion. Figures

5.20 and 5.21 shows that the treatment process in scenario 1, incineration, has positive effects in both climate change and resources depletion impact assessments while scenario 13 has an impact in climate change and a lesser positive effect in resources depletion.

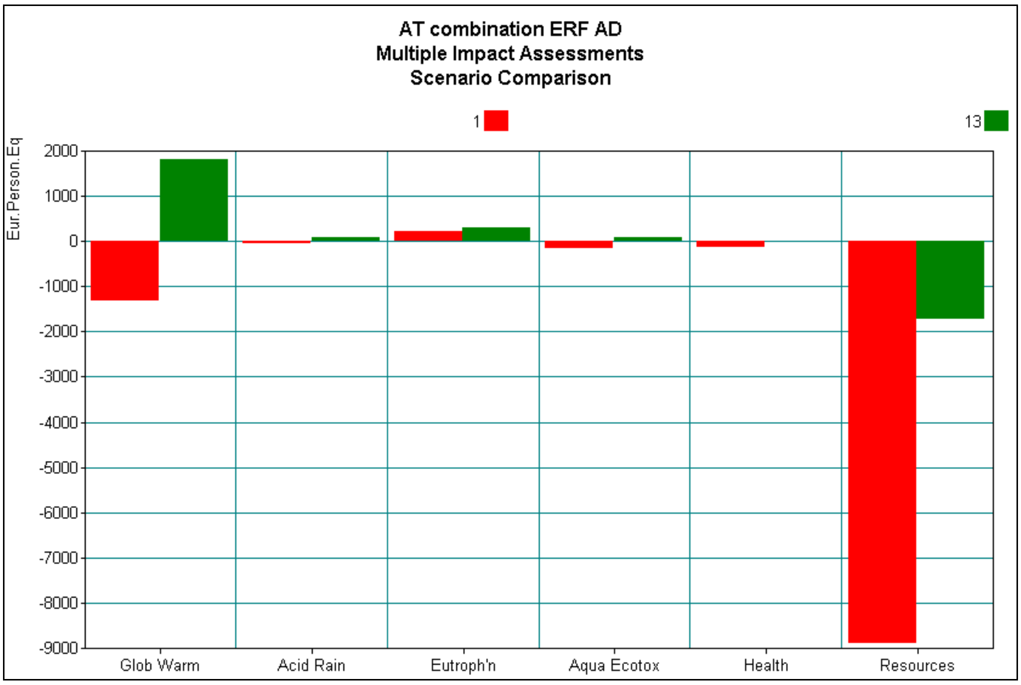


Figure 5.19 Incineration and AD with no recycling

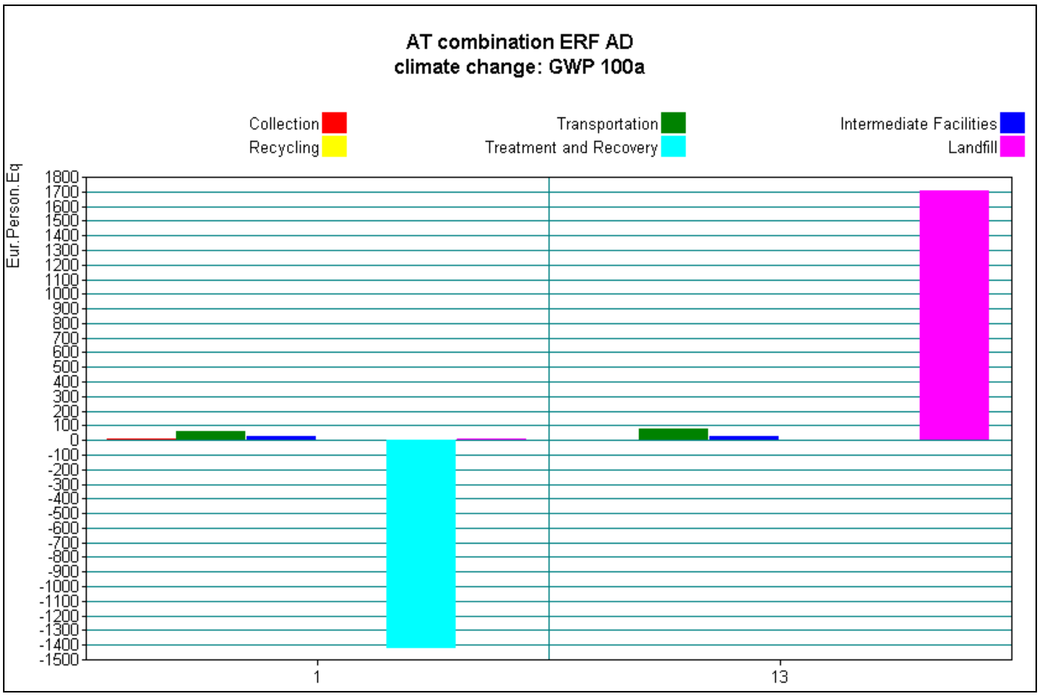


Figure 5.20 Climate change for Incineration and AD with no recycling

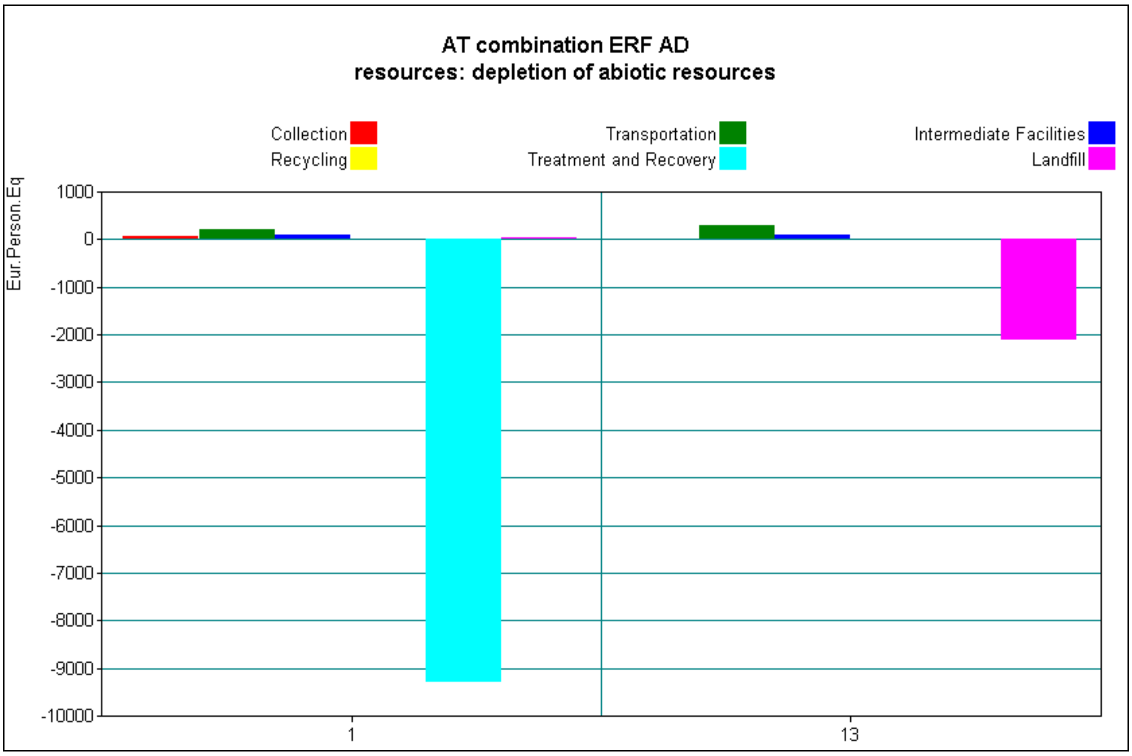


Figure 5.21 Resources depletion for Incineration and AD with no recycling

Scenarios with post collection recycling

The 2 scenarios with post collection recycling compared are scenario 7 Incineration for electricity post collection recycling and scenario 21 Anaerobic digestion for electricity post collection recycling. The energy recovery for scenario 7 is 212,511,298 MJ and for scenario 21 is 63,277,631 MJ. The multiple impacts displayed in figure 5.22 shows that scenario 7 generally has less environmental impacts than scenario 21 with significant differences in Climate change impact and Resources depletion. Figures 5.23 and 5.24 shows that the treatment process in scenario 7, incineration, has positive effects in both climate change and resources depletion impact assessments while scenario 21 has an impact in climate change and a lesser positive effect in resources depletion.

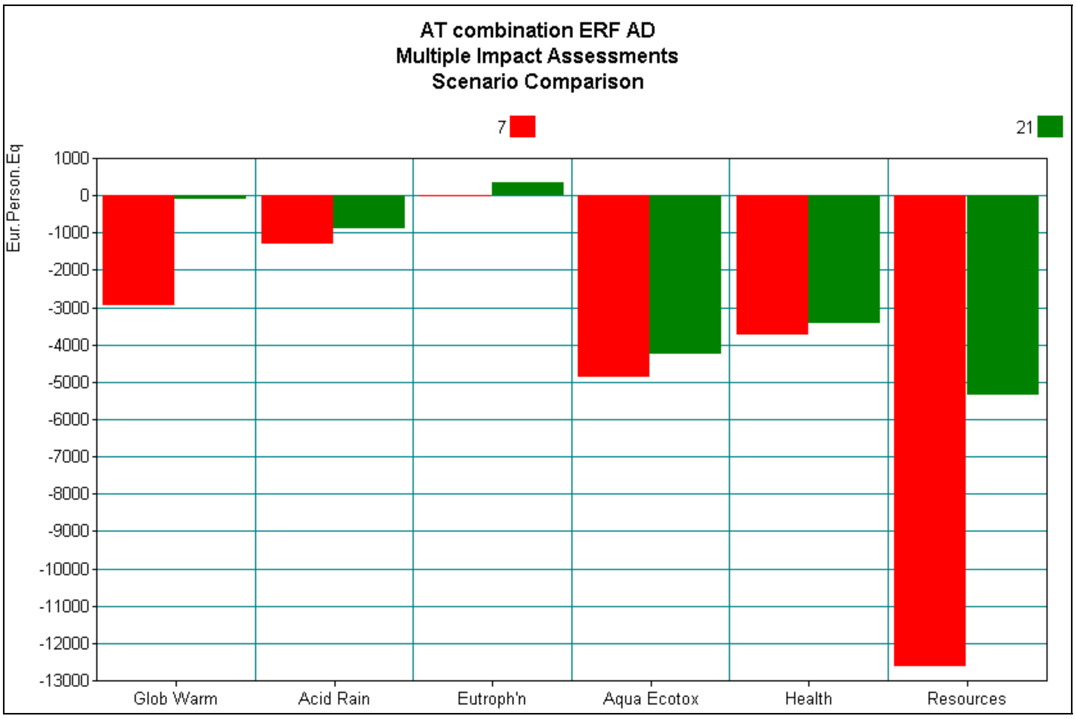


Figure 5.22 Incineration and AD with post collection recycling

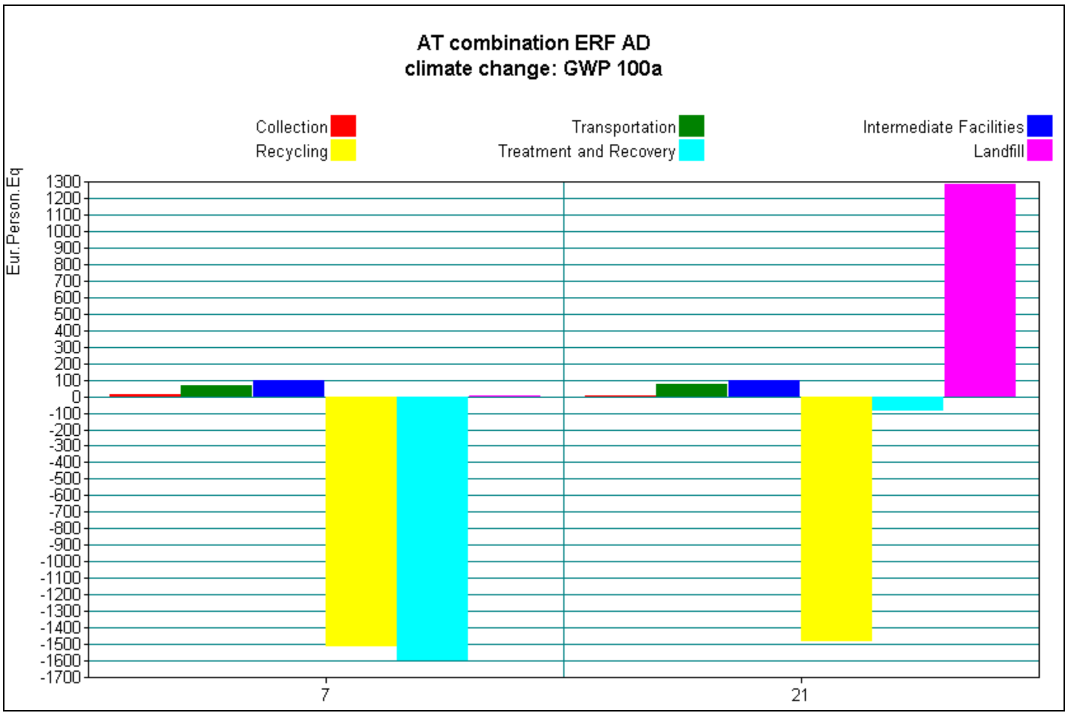


Figure 5.23 Climate change for Incineration and AD with post collection recycling

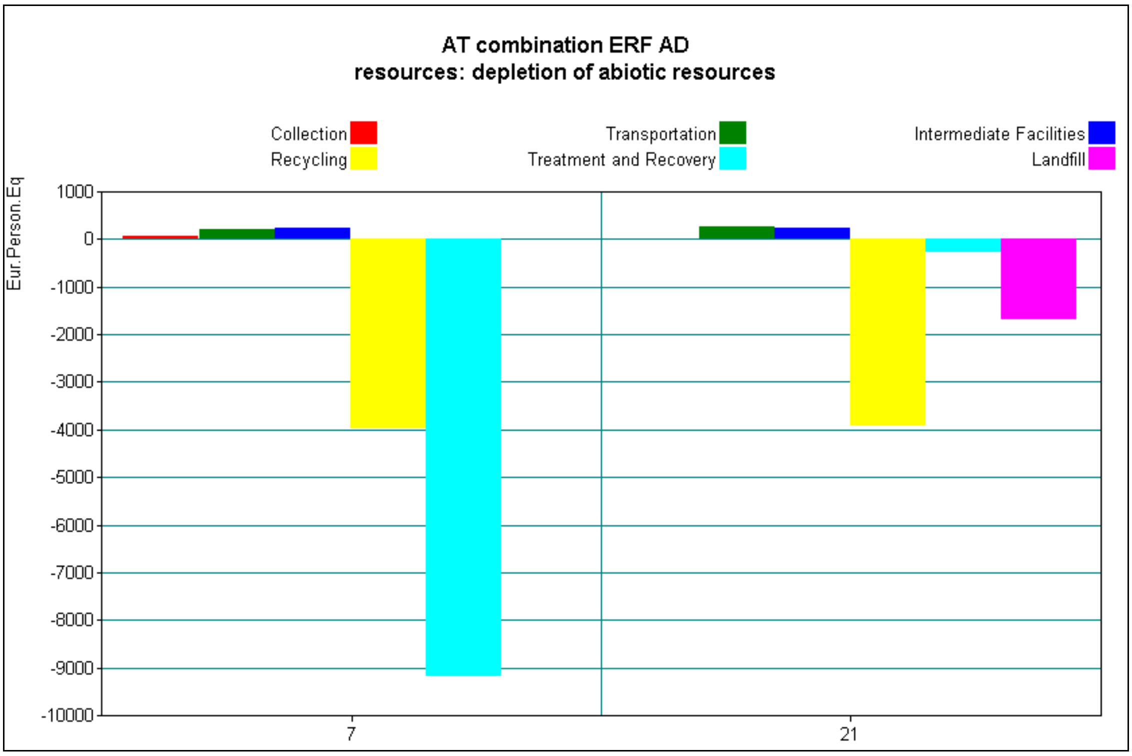


Figure 5.24 Resources depletion for Incineration and AD with post collection recycling

Scenarios with source segregation

The 2 scenarios with source segregation compared are scenario 10 Incineration for electricity source segregation and scenario 25 Anaerobic digestion for source segregation. The energy recovery for scenario 10 is 100,557,732 MJ and for scenario 25 is 54,321,252 MJ. The multiple impacts displayed in figure 5.25 shows that scenario 10 generally has less environmental impacts than scenario 25 with significant differences in Climate change impact and Resources depletion. Figures 5.26 and 5.27 shows that the treatment process in scenario 10, incineration, has positive effects in both climate change and resources depletion impact assessments while scenario 25 has an impact in climate change and a lesser positive effect in resources depletion.

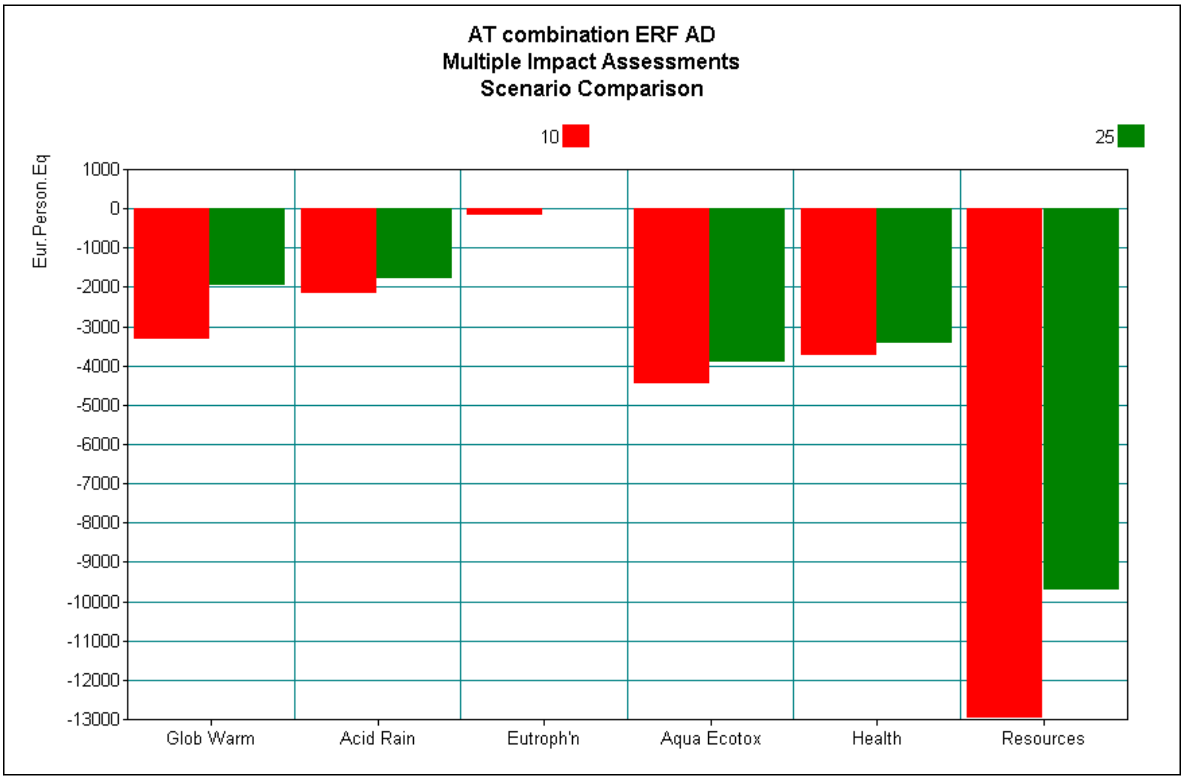


Figure 5.25 Incineration and AD with source segregation

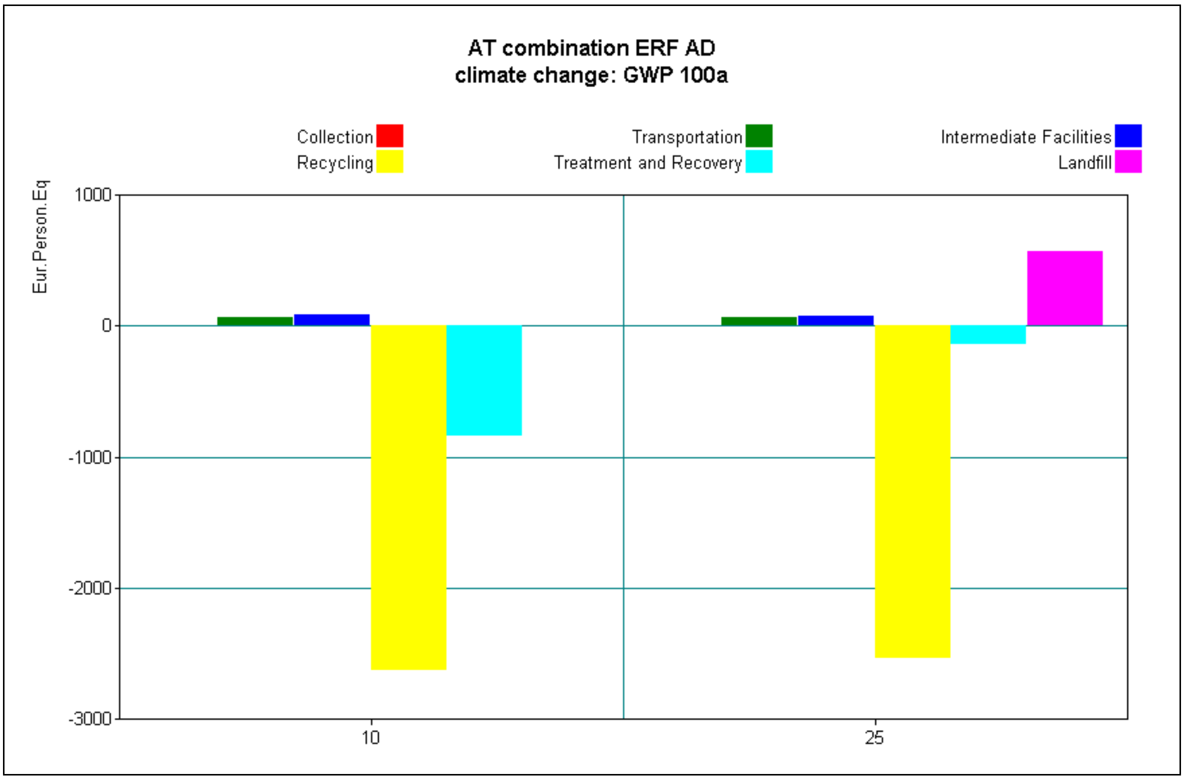


Figure 5.26 Climate change for Incineration and AD with source segregation

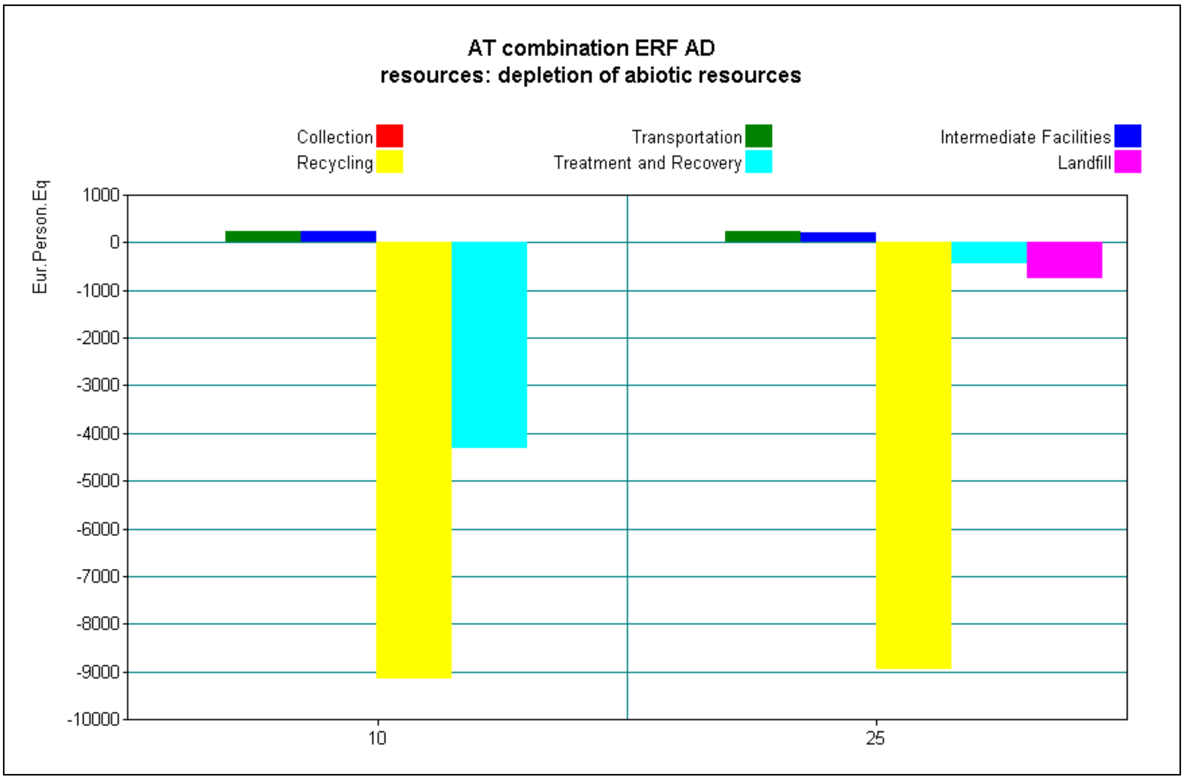


Figure 5.27 Resources depletion for Incineration and AD with source segregation

5.3.3 Comparison of energy recovery type: electricity, heat and combined heat and electricity

In general energy recovery in the form of heat recovers more energy than electricity and combined heat and electricity. Scenarios with heat have comparable impacts with electricity and combined heat and electricity but more impacts in Acidification potential, Eutrophication potential and Aqua ecotoxicity. The environmental impacts improve with more recycling but the difference between post collection recycling and source segregation is very small while the energy recovery is more in the post collection recycling than source segregation.

Scenarios with no recycling

The 3 scenarios with no recycling compared are scenario 1 Incineration for electricity and scenario 2 Incineration for heat and scenario 3 Incineration for heat and electricity. The energy recovery for scenario 1 is 215,449,201 MJ, for scenario 2 is 705,837,307 MJ and for scenario 3 is 311,918,992 MJ. The multiple impacts displayed in figure 5.28 shows that scenario 2 and 3 has less environmental impacts than scenario 1 in Climate change and Resources depletion. However scenario 2 has slightly more impact in Acidification potential, Eutrophication potential and Aqua ecotoxicity. Figure 5.29 displays the Acidification potential impacts associated with each process stage for the treatment (incineration) category. Scenario 2 has a lesser positive burden in the energy output stage than scenarios 1 and 3. This is also the case with Eutrophication potential and Aqua ecotoxicity impact assessment. In table 5.3 the emissions contributing to the higher acidification impacts for scenario 2 are ammonia to air and nitrogen oxides to air.

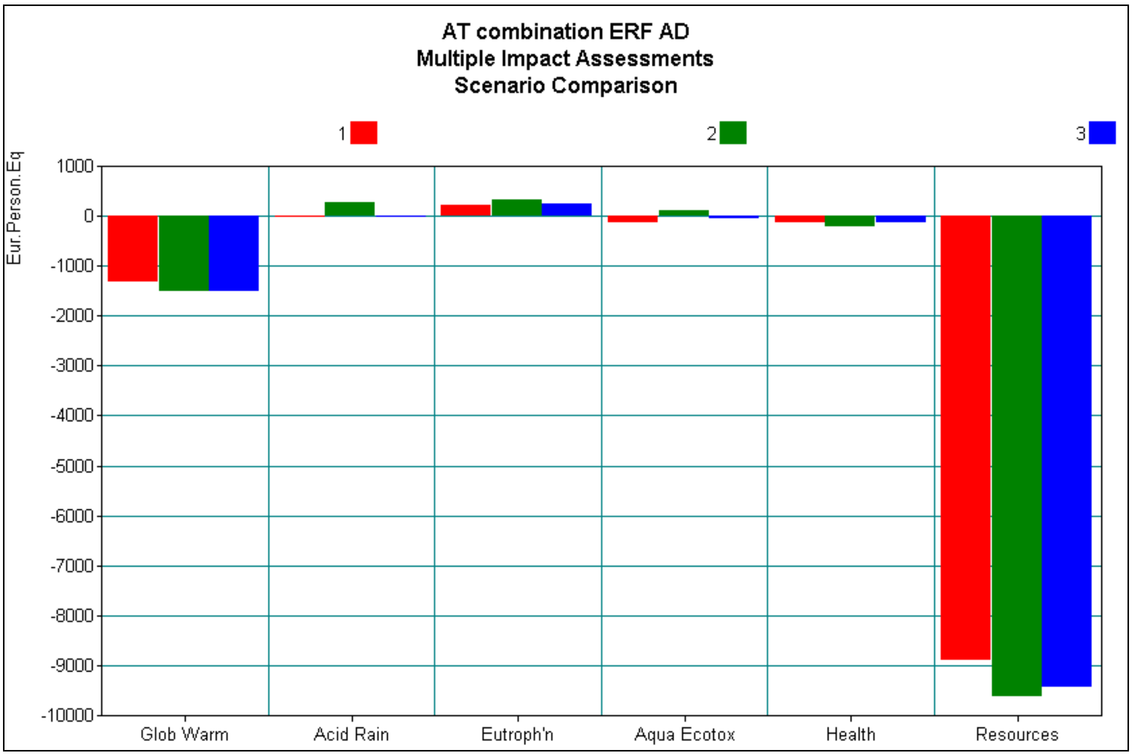


Figure 5.28 Energy recovery type with no recycling

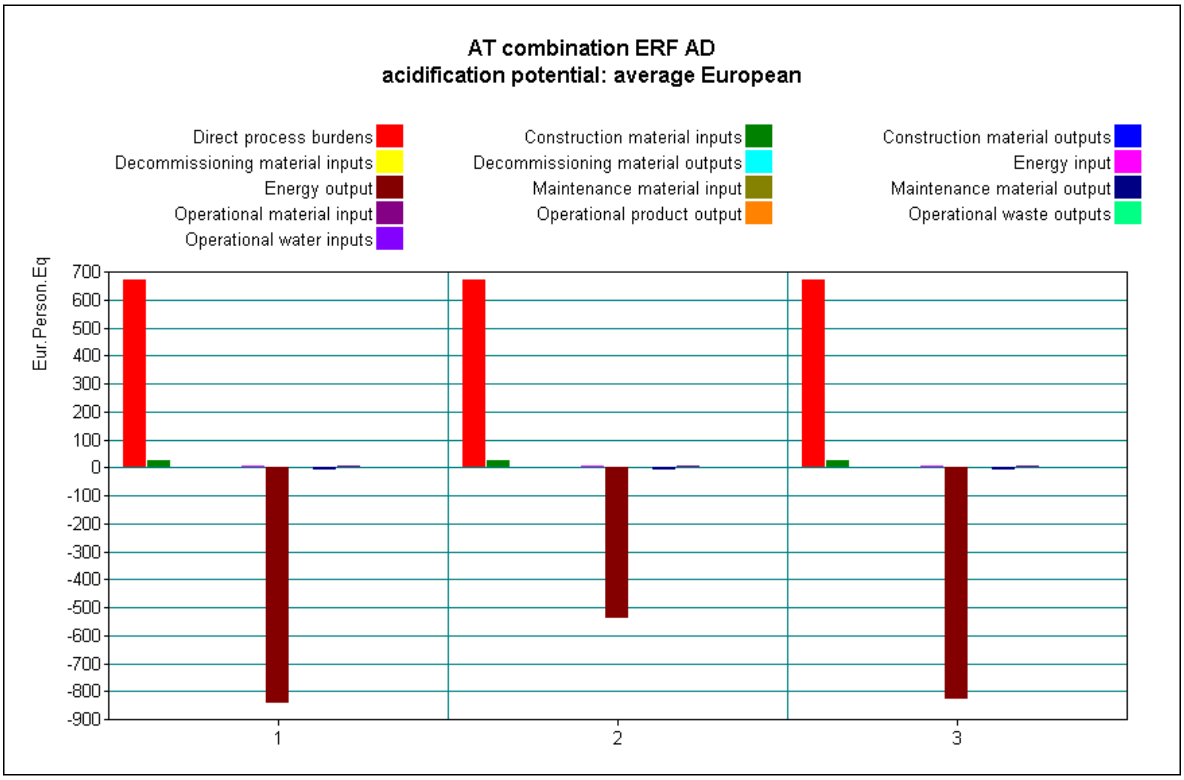
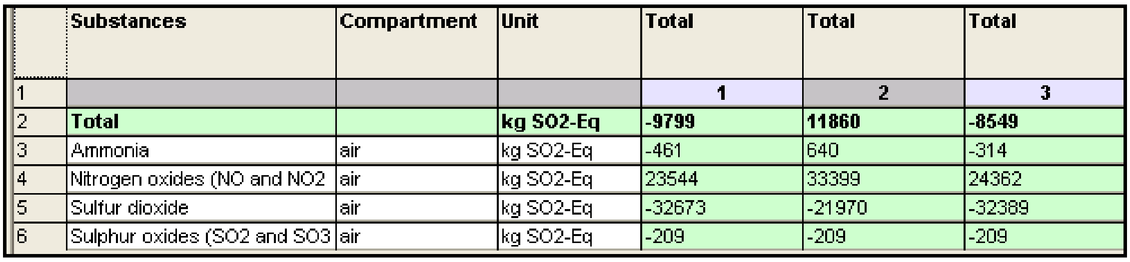


Figure 5.29 Acidification potential by process stage

Table 5.3 Details of emissions contributing to acidification potential scenario 1-3



	Substances	Compartment	Unit	Total	Total	Total
1				1	2	3
2	**Total**		**kg SO2-Eq**	**-9799**	**11860**	**-8549**
3	Ammonia	air	kg SO2-Eq	-461	640	-314
4	Nitrogen oxides (NO and NO2	air	kg SO2-Eq	23544	33399	24362
5	Sulfur dioxide	air	kg SO2-Eq	-32673	-21970	-32389
6	Sulphur oxides (SO2 and SO3	air	kg SO2-Eq	-209	-209	-209

Scenarios with post process recycling

The 3 scenarios with post process recycling compared are scenario 4 Incineration for electricity post process recycling and scenario 5 Incineration for heat post process recycling and scenario 6 Incineration for heat and electricity post process recycling. The energy recovery for scenario 4 is 215,449,201 MJ, for scenario 5 is 705,837,307 MJ and for scenario 6 is 311,918,992 MJ. The multiple impacts displayed in figure 5.30 shows that scenario 6 has less environmental impacts than scenarios 5 and 4, in that order, in Climate change and Resources depletion. Scenario 5 has slightly more impact in Acidification potential, Eutrophication potential and Aqua ecotoxicity. Figure 5.31 displays the

Acidification potential impacts associated with each process stage for the treatment (incineration) category. Scenario 5 has a less positive burden in the energy output stage than scenarios 4 and 6. This is also the case with Eutrophication potential and Aqua ecotoxicity impact assessment. In table 5.4 the emissions contributing to the higher acidification impacts for scenario 5 are ammonia to air and nitrogen oxides to air.

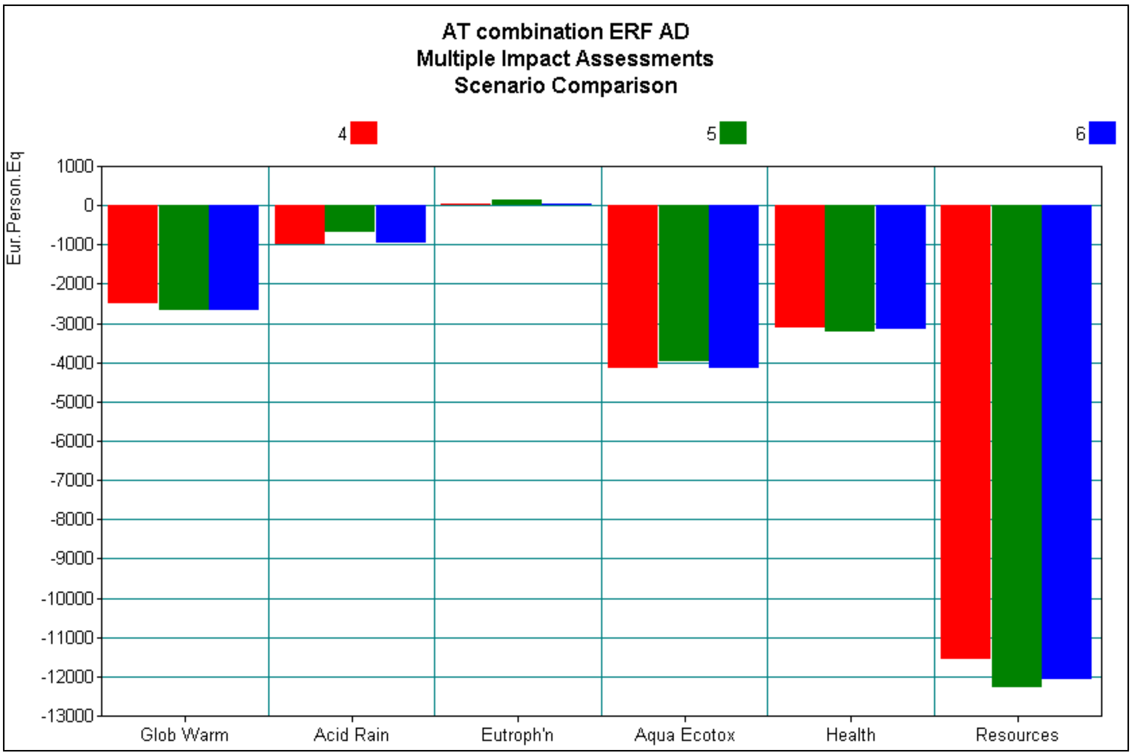


Figure 5.30 Energy recovery type with post process recycling

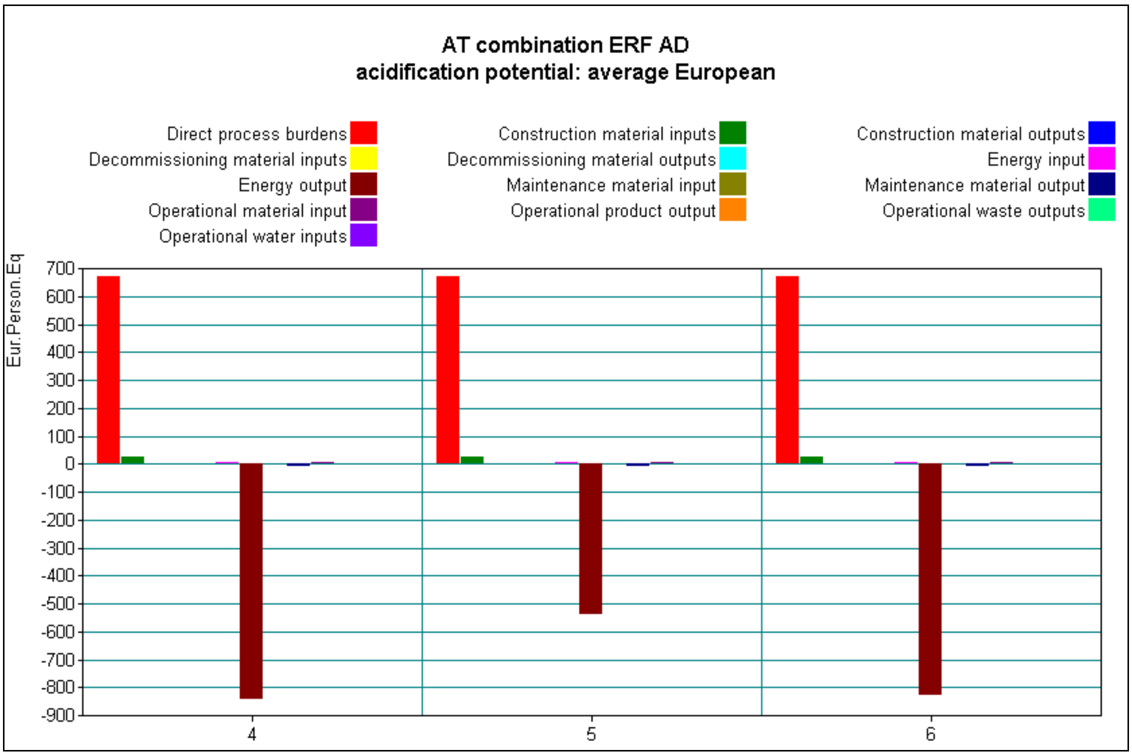
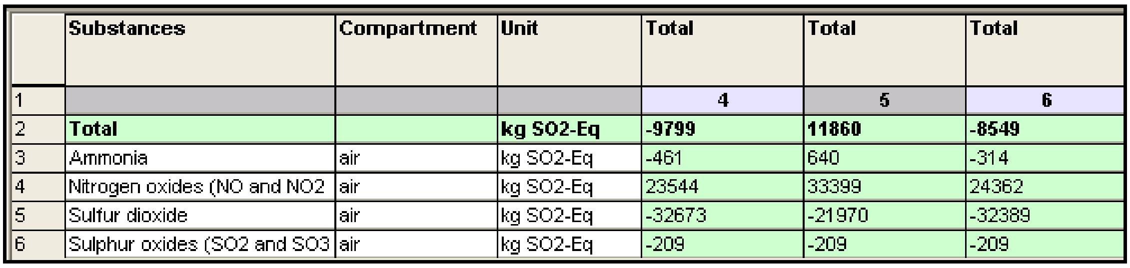


Figure 5.31 Acidification potential by process stage

Table 5.4 Details of emissions contributing to acidification potential scenario 4-6



	Substances	Compartment	Unit	Total	Total	Total
1				4	5	6
2	**Total**		**kg SO2-Eq**	**-9799**	**11860**	**-8549**
3	Ammonia	air	kg SO2-Eq	-461	640	-314
4	Nitrogen oxides (NO and NO2	air	kg SO2-Eq	23544	33399	24362
5	Sulfur dioxide	air	kg SO2-Eq	-32673	-21970	-32389
6	Sulphur oxides (SO2 and SO3	air	kg SO2-Eq	-209	-209	-209

Scenarios with post collection recycling

The 3 scenarios with post collection recycling compared are scenario 7 Incineration for electricity post collection recycling and scenario 8 Incineration for heat post collection recycling and scenario 9 Incineration for heat and electricity post collection recycling. The energy recovery for scenario 7 is 212,511,298 MJ, for scenario 8 is 696,212,385 MJ and for scenario 9 is 307,665,610 MJ. The multiple impacts displayed in figure 5.32 shows that scenario 8 and 9 has slightly lesser environmental impacts than scenarios 7 in Climate change and Resources depletion. Similar to 5.3.3.1, scenario 8 has slightly more impact in Acidification potential, Eutrophication potential and Aqua ecotoxicity. Figure 5.33

displays the Acidification potential impacts associated with each process stage for the treatment (incineration) category. Scenario 8 has a lesser positive burden in the energy output stage than scenarios 7 and 9. This is also the case with Eutrophication potential and Aqua ecotoxicity impact assessment. In table 5.5 the emissions contributing to the higher acidification impacts for scenario 8 are ammonia to air and nitrogen oxides to air.

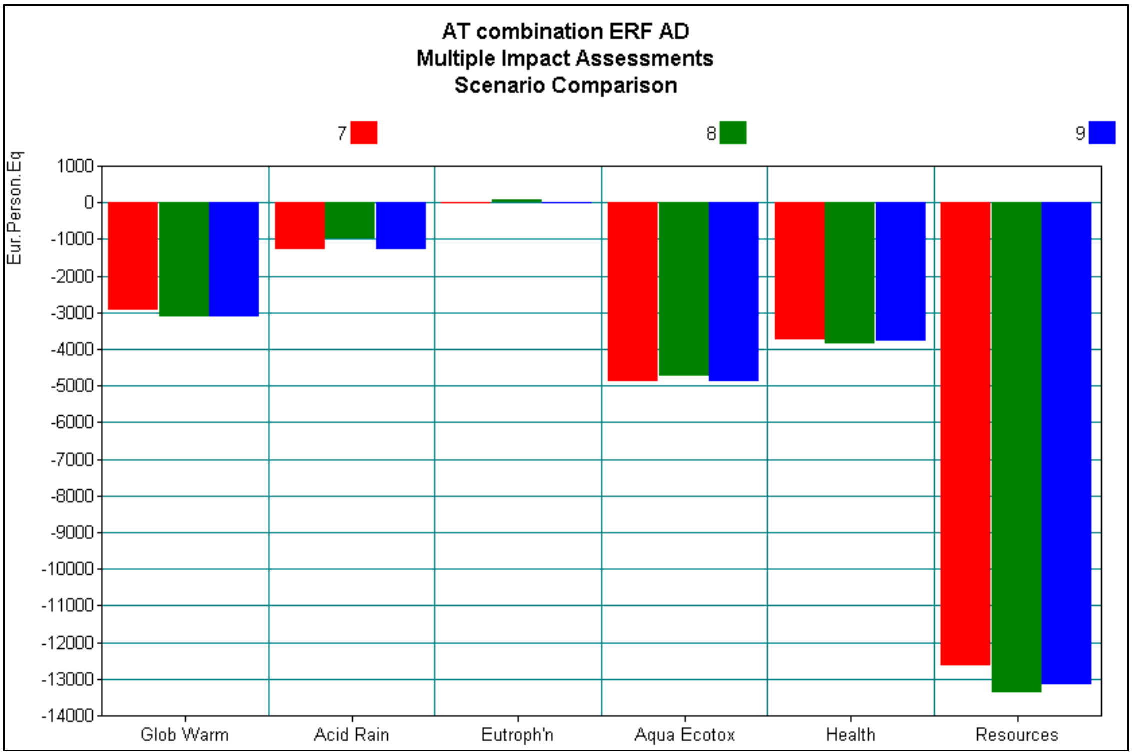


Figure 5.32 Energy recovery type with post collection recycling

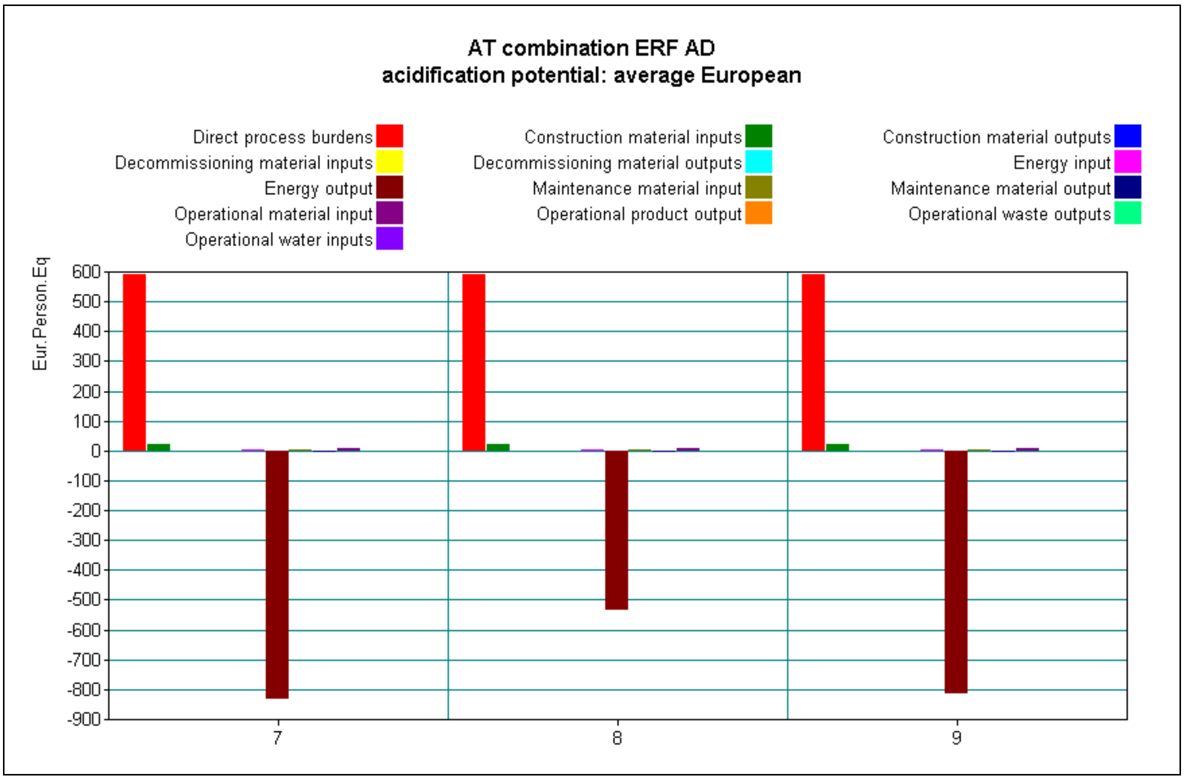
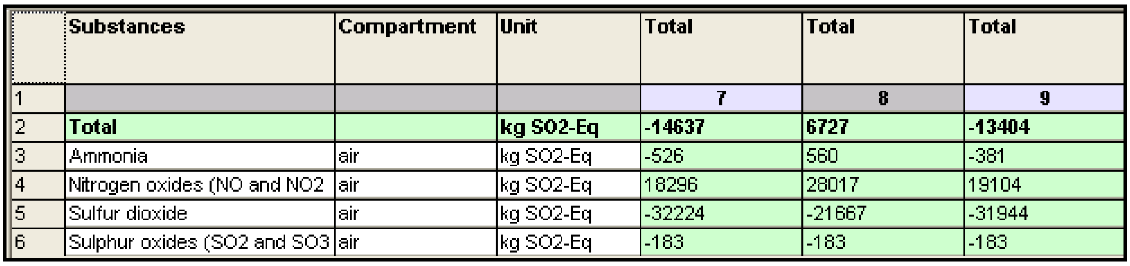


Figure 5.33 Acidification potential by process stage

Table 5.5 Details of emissions contributing to acidification potential scenario 7-9



	Substances	Compartment	Unit	Total	Total	Total
1				7	8	9
2	**Total**		**kg SO2-Eq**	**-14637**	**6727**	**-13404**
3	Ammonia	air	kg SO2-Eq	-526	560	-381
4	Nitrogen oxides (NO and NO2	air	kg SO2-Eq	18296	28017	19104
5	Sulfur dioxide	air	kg SO2-Eq	-32224	-21667	-31944
6	Sulphur oxides (SO2 and SO3	air	kg SO2-Eq	-183	-183	-183

Scenarios with source segregation

The 3 scenarios with source segregation compared are scenario 10 Incineration for electricity source segregation and scenario 11 Incineration for heat source segregation and scenario 12 Incineration for heat and electricity source segregation. The energy recovery for scenario 10 is 100,557,732 MJ, for scenario 11 is 329,439,136 MJ and for scenario 12 is 145,583,582 MJ. The multiple impacts displayed in figure 5.34 shows that overall the three scenarios have similar environmental impacts with scenario 11 and 12 has very slightly less environmental impacts than scenarios 10 in Climate change and Resources depletion.

Similar to 5.3.3.1, scenario 11 has slightly more impact in Acidification potential, Eutrophication potential and Aqua ecotoxicity. Figure 5.35 displays the Acidification potential impacts associated with each process stage for the treatment (incineration) category. Scenario 11 has a lesser positive burden in the energy output stage than scenarios 10 and 12. This is also the case with Eutrophication potential and Aqua ecotoxicity impact assessment. In table 5.6 the emissions contributing to the higher acidification impacts for scenario 11 are ammonia to air and nitrogen oxides to air.

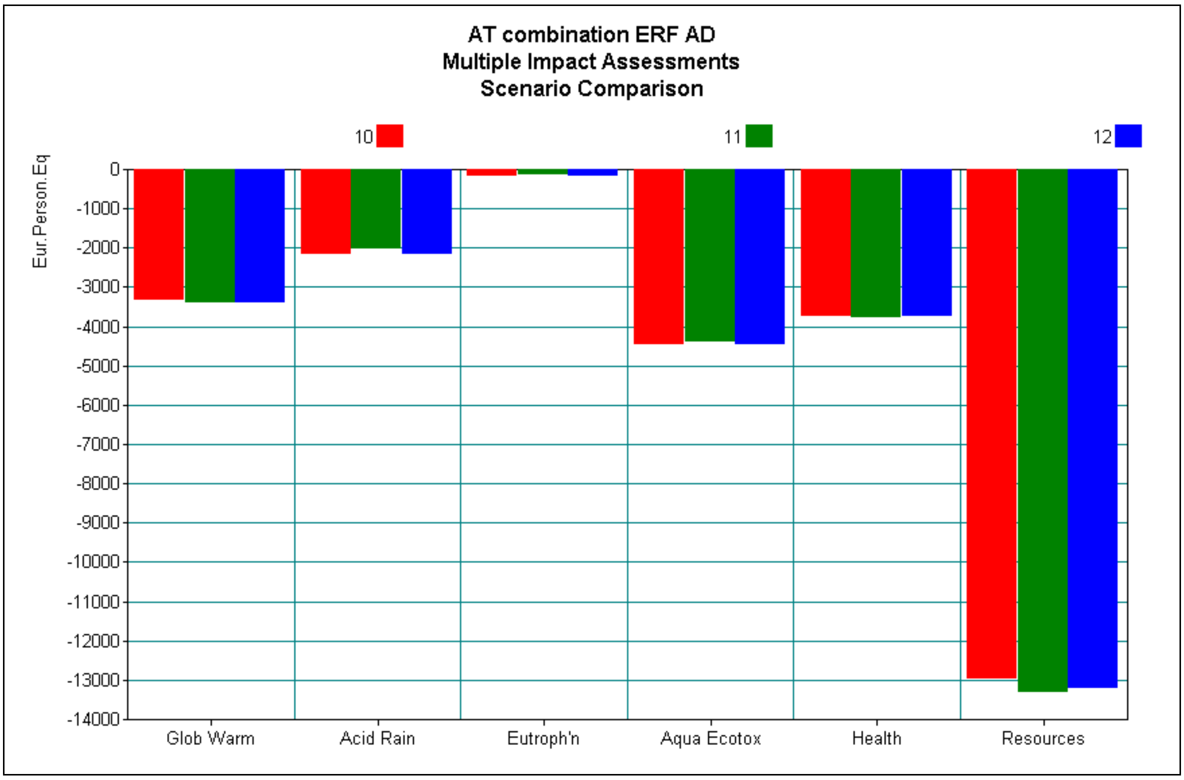


Figure 5.34 Energy recovery type with source segregation

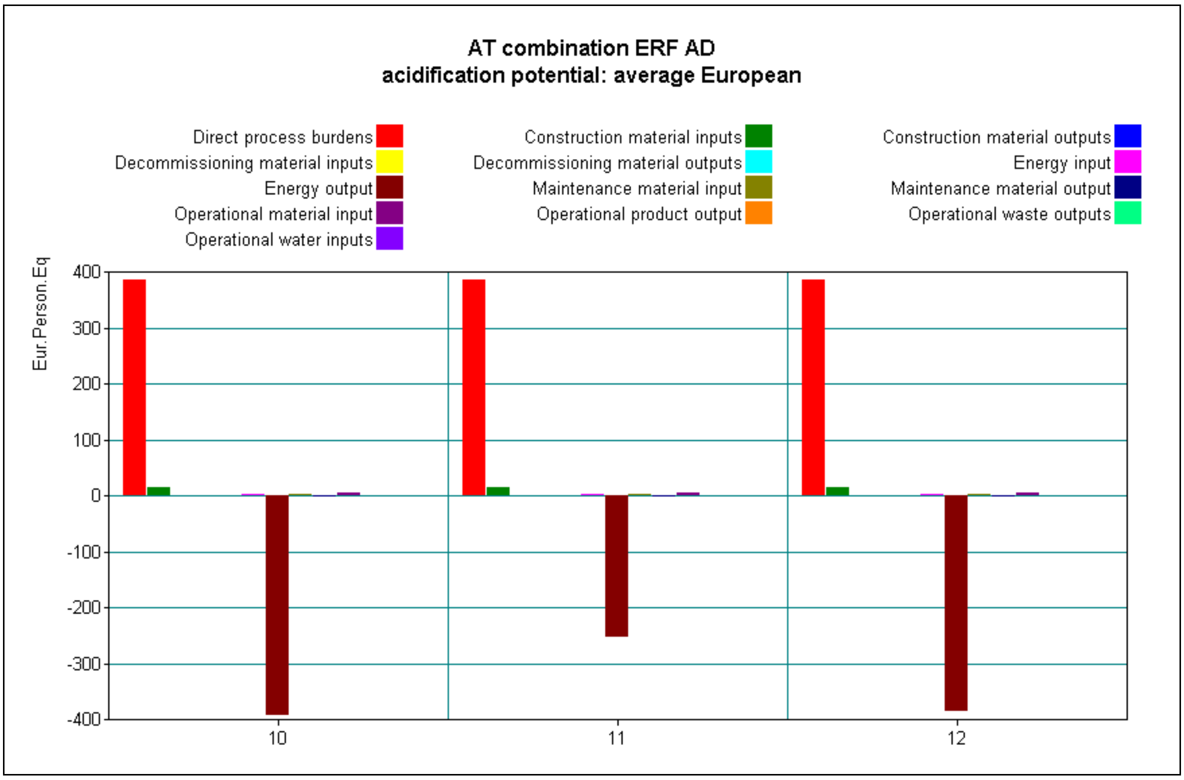
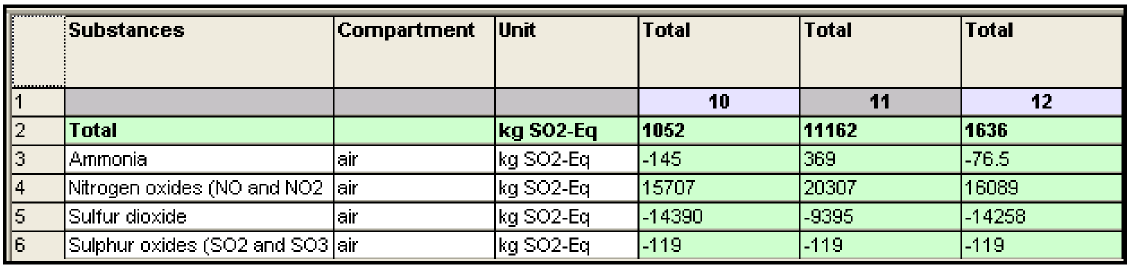


Figure 5.35 Acidification potential by process stage

Table 5.6 Details of emissions contributing to acidification potential scenario 10-12



	Substances	Compartment	Unit	Total	Total	Total
1				10	11	12
2	**Total**		**kg SO2-Eq**	**1052**	**11162**	**1636**
3	Ammonia	air	kg SO2-Eq	-145	369	-76.5
4	Nitrogen oxides (NO and NO2	air	kg SO2-Eq	15707	20307	16089
5	Sulfur dioxide	air	kg SO2-Eq	-14390	-9395	-14258
6	Sulphur oxides (SO2 and SO3	air	kg SO2-Eq	-119	-119	-119

Scenarios with combination incineration/ERF and AD post collection recycling

The 3 scenarios with post collection recycling compared are scenario 29 Incineration for heat and AD for electricity post collection recycling and scenario 37 Incineration for electricity and AD for electricity post collection recycling and scenario 45 Incineration for heat and electricity and AD for electricity post collection recycling. The energy recovery for scenario 29 is 660,946,780 MJ, for scenario 37 is 217,651,524 MJ and for scenario 45 is 304,857,148 MJ. The multiple impacts displayed in figure 5.36 shows that scenario 29 and 45 has slightly lesser environmental impacts than scenario 37 in Climate change and

Resources depletion. Similar to 5.3.3.1, scenario 29 has slightly more impact in Acidification potential, Eutrophication potential and Aqua ecotoxicity. Figure 5.37 displays the Acidification potential impacts associated with each process stage for the treatment (incineration) category. Scenario 29 has a lesser positive burden in the energy output stage than scenarios 37 and 45. This is also the case with Eutrophication potential and Aqua ecotoxicity impact assessment. In table 5.6 the emissions contributing to the higher acidification impacts for scenario 29 are ammonia to air and nitrogen oxides to air.

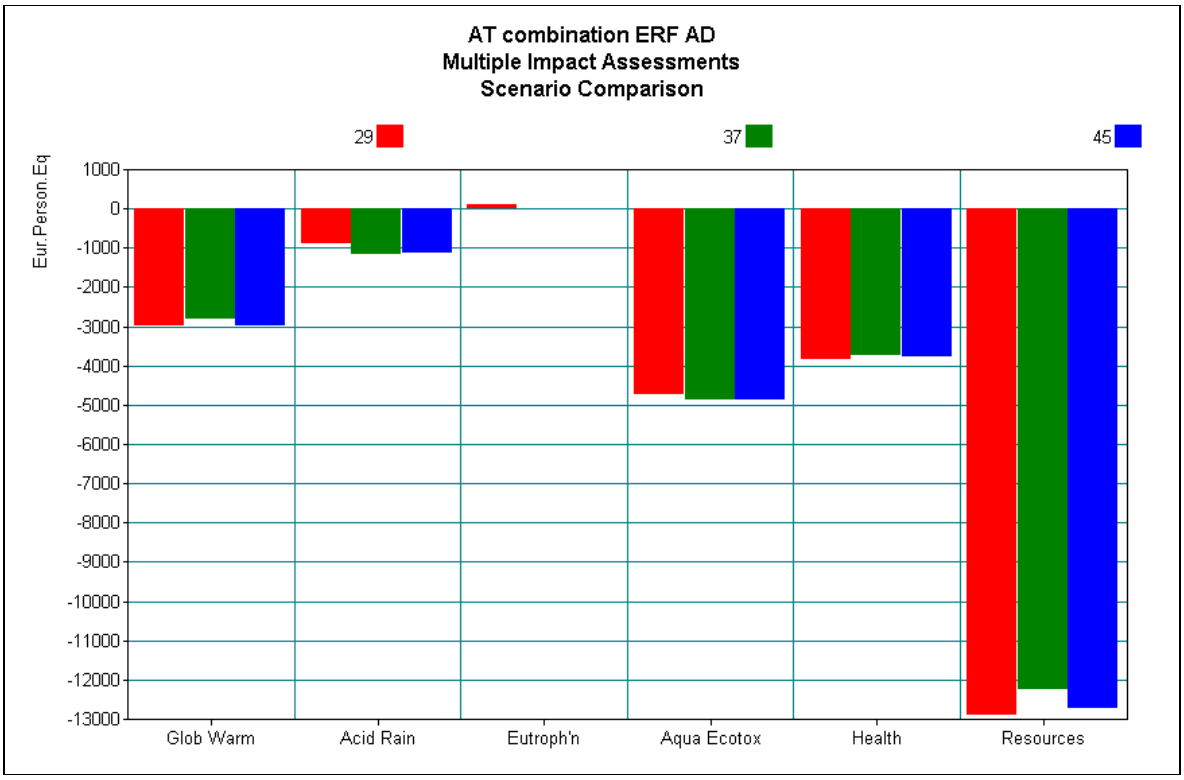


Figure 5.36 Energy recovery type with combination ERF and AD post collection recycling

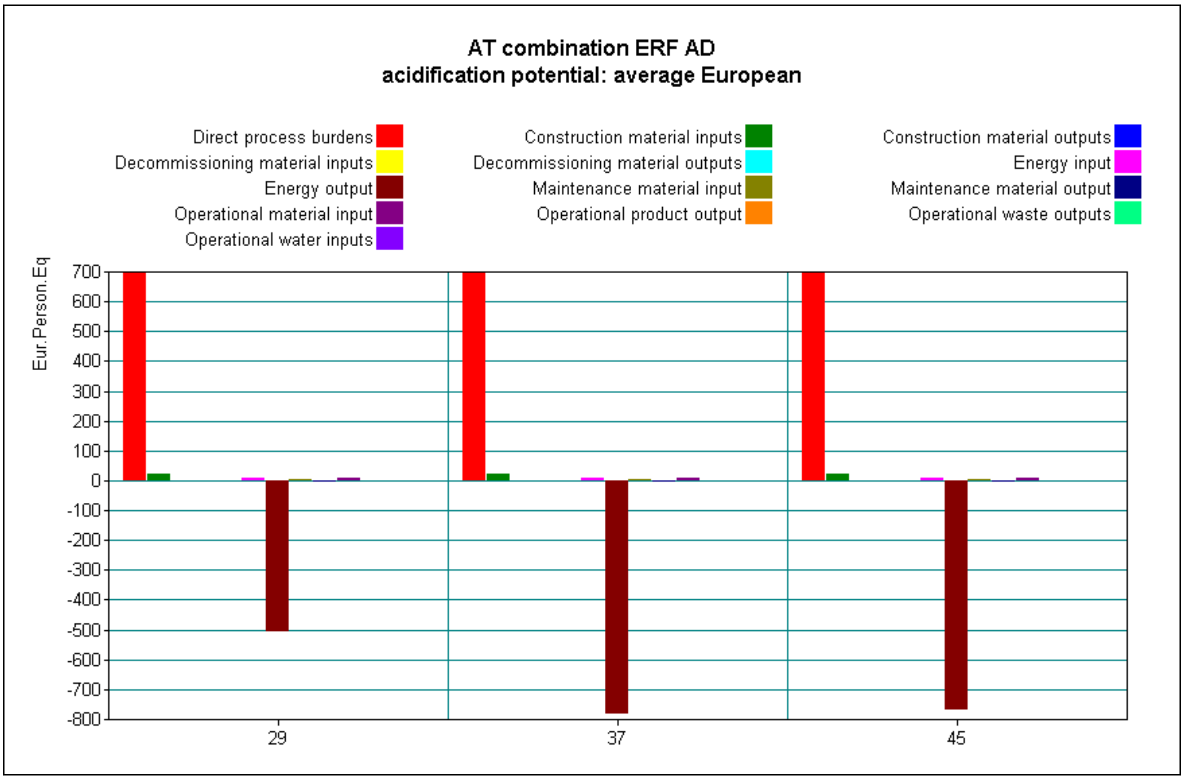
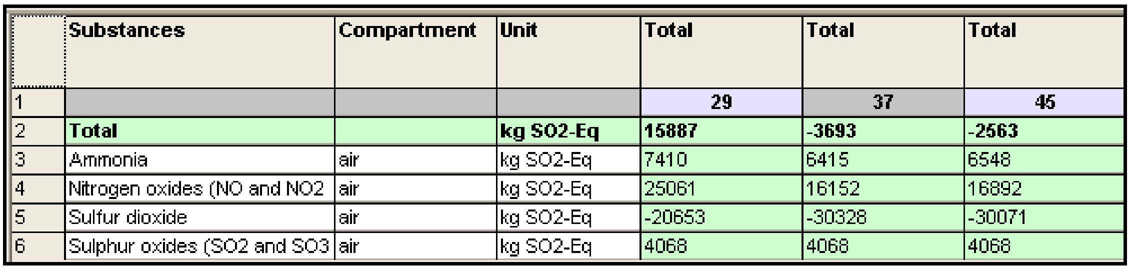


Figure 5.37 Acidification potential by process stage

Table 5.7 Details of emissions contributing to acidification potential scenario 29, 37, 45



	Substances	Compartment	Unit	Total	Total	Total
1				29	37	45
2	**Total**		**kg SO2-Eq**	**15887**	**-3693**	**-2563**
3	Ammonia	air	kg SO2-Eq	7410	6415	6548
4	Nitrogen oxides (NO and NO2	air	kg SO2-Eq	25061	16152	16892
5	Sulfur dioxide	air	kg SO2-Eq	-20653	-30328	-30071
6	Sulphur oxides (SO2 and SO3	air	kg SO2-Eq	4068	4068	4068

Scenarios with combination incineration/ERF and AD source segregation

The 3 scenarios with source segregation compared are scenario 33 Incineration for heat and AD for electricity source segregation and scenario 41 Incineration for electricity and AD for electricity source segregation and scenario 49 Incineration for heat and electricity and AD for electricity source segregation. The energy recovery for scenario 33 is 272,840,187 MJ, for scenario 41 is 108,660,074 MJ and for scenario 49 is 140,957,801 MJ. The multiple impacts displayed in figure 5.38 shows that overall the three scenarios have similar environmental impacts with scenario 33 and 49 has very slightly lesser environmental impacts than scenarios 41 in Climate change and Resources depletion. Similar to 5.3.3.1, scenario 33 has slightly more impact in Acidification potential, Eutrophication potential and Aqua ecotoxicity. Figure 5.39 displays the Acidification potential impacts associated with each process stage for the treatment (incineration) category. Scenario 33 has a lesser positive burden in the energy output stage than scenarios 41 and 49. This is also the case with Eutrophication potential and Aqua ecotoxicity impact assessment. In table 5.8 the emissions contributing to the higher acidification impacts for scenario 33 are ammonia to air and nitrogen oxides to air.

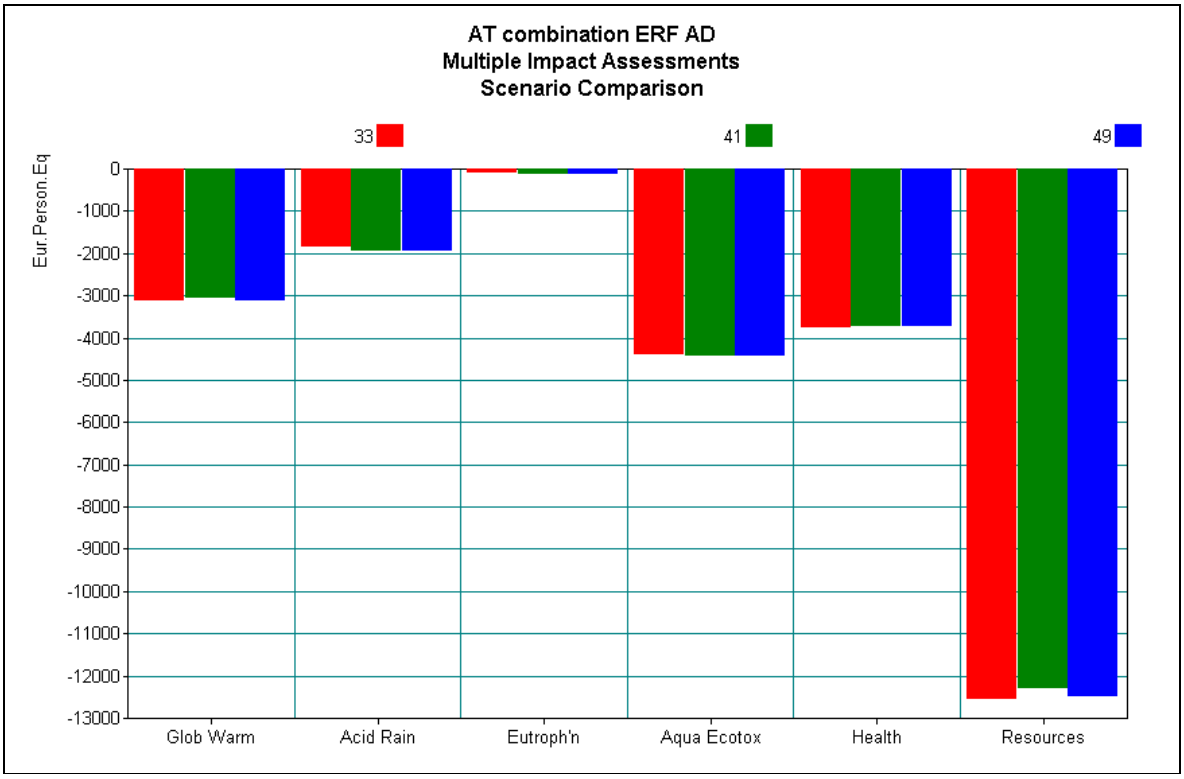


Figure 5.38 Energy recovery type with combination ERF and AD source segregation

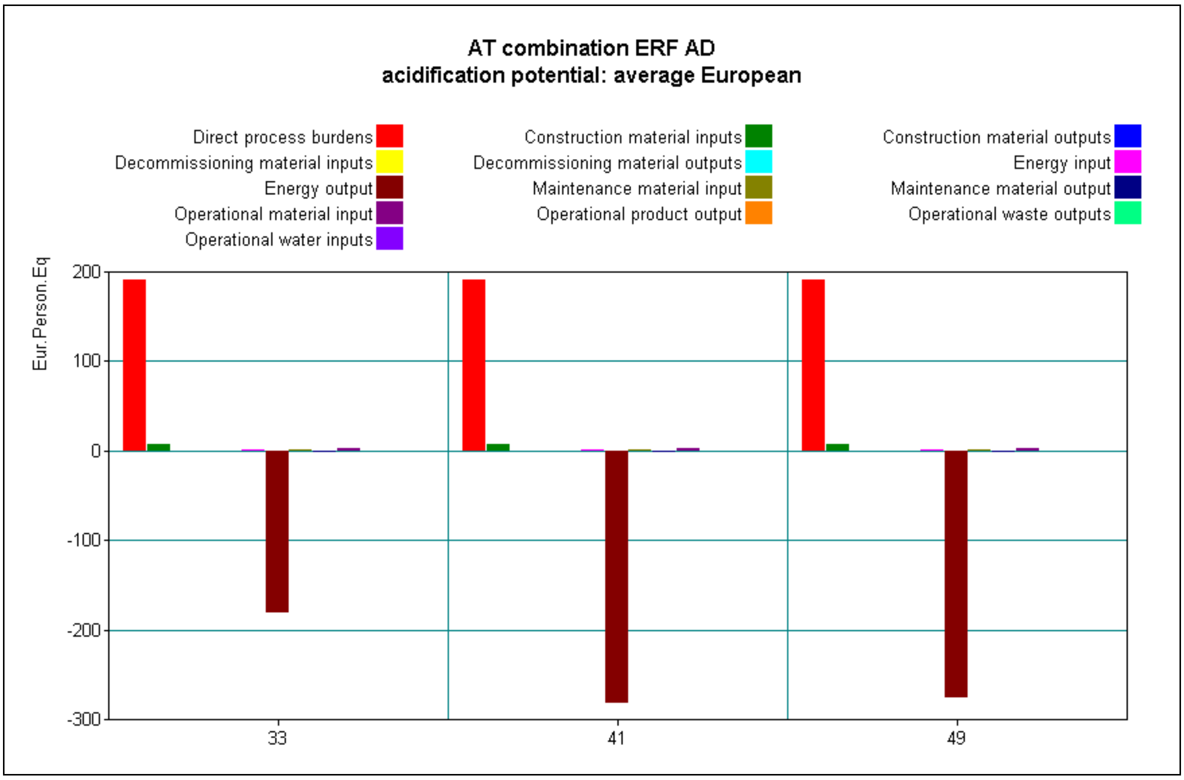
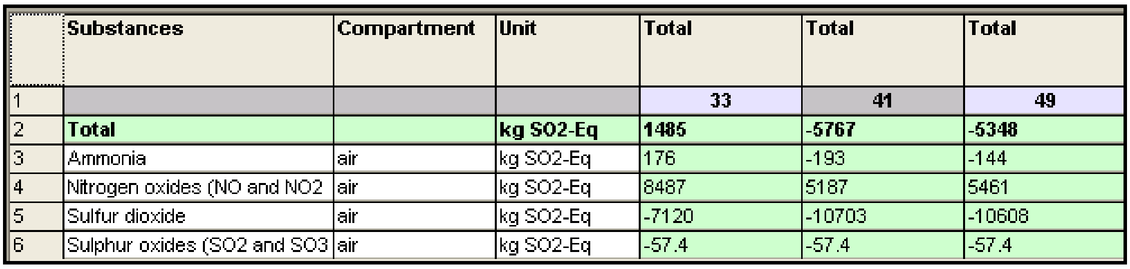


Figure 5.39 Acidification potential by process stage

Table 5.8 Details of emissions contributing to acidification potential scenario 33, 41, 49



	Substances	Compartment	Unit	Total	Total	Total
1				33	41	49
2	**Total**		**kg SO2-Eq**	**1485**	**-5767**	**-5348**
3	Ammonia	air	kg SO2-Eq	176	-193	-144
4	Nitrogen oxides (NO and NO2	air	kg SO2-Eq	8487	5187	5461
5	Sulfur dioxide	air	kg SO2-Eq	-7120	-10703	-10608
6	Sulphur oxides (SO2 and SO3	air	kg SO2-Eq	-57.4	-57.4	-57.4

5.4 Improvements for phase two

There were a few obstacles in modelling all the planned scenarios in WRATE using available processes. It was apparent that user defined functions were required for AD with heat recovery, AD with electricity and heat recovery, AD with vehicle fuel, and for Articulated trucks 8.026 tonnes changed to 44 tonnes.

Chapter 6

Phase two scenario design

For phase two the earlier results in phase one were taken into consideration and scenarios were modified and reorganized. The boundary remains the same; starting from MSW generation from households, collection of MSW, intermediate facilities such as transfer station, pre-treatment or materials recovery facility, WtE treatment process, reprocessing and disposal.

6.1 Scenario names and codes

Two reference countries were selected to represent a location in a developed country and a developing country in order to explore and compare the different effects of waste composition and electricity mix on the outcome of the scenarios as well as provide alternatives for the subsequent decision making matrix. United Kingdom was selected to represent the developed country and Thailand was selected to represent the developing country. The coding for United Kingdom is UK and for Thailand is TH. In each country two different population densities were selected, urban and rural, since the collection transportation would be different. The coding for urban is UR and for rural is RU. A summary of coding for the scenarios is shown in table 6.1.

Table 6.1 Coding for country and density type

Country	Population Density type	Code
United Kingdom	Urban	UKUR
United Kingdom	Rural	UKRU
Thailand	Urban	THUR
Thailand	Rural	THRU

The scenarios are organised in layers of intervention parameters which comprises of WtE technology option, energy recovery type, recycling scheme and selected recycling rate. The WtE technology options are;

1. Incineration with energy recovery
2. Anaerobic digestion (AD)
3. Combinations of Incineration and AD.

The energy recovery type includes;

1. Electricity
2. Heat
3. Combined heat and electricity
4. For AD an extra energy recovery type is vehicle fuel.

The recycling schemes comprises of;

1. No recycling
2. Post process recycling
3. Post collection recycling
4. Source segregation.

The recycling rate (RR) are;

1. 25 % which is the average recycling rate in Thailand for the year 2011(Pollution Control Department, 2012)
2. 43% which is the average recycling rate in England for the year 2011/12 (Department for Environment Food and Rural Affairs, 2012)
3. 50% which is the target recycling rate in England for the year 2020 (Department for Environment Food and Rural Affairs, 2012)

Each country and density group such as UK urban (UKUR) have 18 incineration scenarios, 17 AD scenarios and 72 combination scenarios. Altogether for 4 country and density group there were 428 maximum planned scenarios. The code IN is for incineration with energy recovery, AD is for anaerobic digestion and C1 is for the combination of incineration and anaerobic digestion. The codes for the modified scenarios are shown in tables 6.2 to 6.4.

Table 6.2 Incineration scenarios – 1-18 IN

Scenario code	**Scenario name**	**Recycling methods**			
		No recycling	**Post process recycling**	**Post collection recyclingMRF**	**Source segregation**
1 IN	Incineration for electricity	✓			
2 IN	Incineration for heat	✓			
3 IN	Incineration for heat and electricity	✓			
4 IN	Incineration for electricity		✓		
5 IN	Incineration for heat		✓		
6 IN	Incineration for heat and electricity		✓		
7 IN	Incineration for electricity			✓	

Scenario code	Scenario name	Recycling methods			
		No recycling	Post process recycling	Post collection recyclingMRF	Source segregation
8 IN	Incineration for heat			✓	
9 IN	Incineration for heat and electricity			✓	
10 IN	Incineration for electricity 25% RR				✓
11 IN	Incineration for heat 25% RR				✓
12 IN	Incineration for heat and electricity 25% RR				✓
13 IN	Incineration for electricity 43% RR				✓
14 IN	Incineration for heat 43% RR				✓
15 IN	Incineration for heat and electricity 43% RR				✓
16 IN	Incineration for electricity 50% RR				✓
17 IN	Incineration for heat 50% RR				✓
18 IN	Incineration for heat and electricity 50% RR				✓

Table 6.3 Anaerobic digestion scenarios – 1-17 AD

Scenario code	Scenario name	Recycling methods			
		No recycling	Post process recycling	Post collection recycling	Source segregation
1 AD	Anaerobic Digestion for electricity (landfill option to represent this scenario)	✓			
2 AD	Anaerobic Digestion for electricity			✓	
3 AD	Anaerobic Digestion for heat			✓	
4 AD	Anaerobic Digestion for heat and electricity			✓	
5 AD	Anaerobic Digestion for vehicle fuel			✓	
6 AD	Anaerobic Digestion for electricity 25% RR				✓
7 AD	Anaerobic Digestion for heat 25% RR				✓
8 AD	Anaerobic Digestion for heat and electricity 25% RR				✓
9 AD	Anaerobic Digestion for vehicle fuel 25% RR				✓
10 AD	Anaerobic Digestion for electricity 43% RR				✓
11 AD	Anaerobic Digestion for heat 43% RR				✓
12 AD	Anaerobic Digestion for heat and electricity 43% RR				✓
13 AD	Anaerobic Digestion for vehicle fuel 43% RR				✓
14 AD	Anaerobic Digestion for electricity 50% RR				✓
15 AD	Anaerobic Digestion for heat 50% RR				✓
16 AD	Anaerobic Digestion for heat and electricity 50% RR				✓
17 AD	Anaerobic Digestion for vehicle fuel 50% RR				✓

Scenarios with post process recycling were eliminated due to technology process not available on WRATE and a user defined process was not created for it.

Table 6.4 Combination 1 scenarios – 1-72 C1 Organic waste (food and garden) to AD, Residuals to ERF, recycling to MRF

Scenario code	**Scenario name**	**Recycling methods**			
		No recycling	**Post process recycling**	**Post collection recycling-MRF**	**Source segregation**
	Incineration for electricity				
1 C1	Incineration for electricity and Anaerobic Digestion for electricity	✓			
2 C1	Incineration for electricity and Anaerobic Digestion for heat	✓			
3 C1	Incineration for electricity and Anaerobic Digestion for heat and electricity	✓			
4 C1	Incineration for electricity and Anaerobic Digestion for vehicle fuel	✓			
5 C1	Incineration for electricity and Anaerobic Digestion for electricity		✓		
6 C1	Incineration for electricity and Anaerobic Digestion for heat		✓		
7 C1	Incineration for electricity and Anaerobic Digestion for heat and electricity		✓		
8 C1	Incineration for electricity and Anaerobic Digestion for vehicle fuel		✓		
9 C1	Incineration for electricity and Anaerobic Digestion for electricity			✓	
10 C1	Incineration for electricity and Anaerobic Digestion for heat			✓	
11 C1	Incineration for electricity and Anaerobic Digestion for heat and electricity			✓	
12 C1	Incineration for electricity and Anaerobic Digestion for vehicle fuel			✓	
13 C1	Incineration for electricity and Anaerobic Digestion for electricity 25% RR				✓
14 C1	Incineration for electricity and Anaerobic Digestion for heat 20% RR				✓
15 C1	Incineration for electricity and Anaerobic Digestion for heat and electricity 25% RR				✓
16 C1	Incineration for electricity and Anaerobic Digestion for vehicle fuel 25% RR				✓
17 C1	Incineration for electricity and Anaerobic Digestion for electricity 43% RR				✓
18 C1	Incineration for electricity and Anaerobic Digestion for heat 43% RR				✓
19 C1	Incineration for electricity and Anaerobic Digestion for heat and electricity 43% RR				✓
20 C1	Incineration for electricity and Anaerobic Digestion for vehicle fuel 43% RR				✓
21 C1	Incineration for electricity and Anaerobic Digestion for electricity 50% RR				✓
22 C1	Incineration for electricity and Anaerobic Digestion for heat 50% RR				✓
23 C1	Incineration for electricity and Anaerobic Digestion for heat and electricity 50% RR				✓

Scenario code	Scenario name	Recycling methods			
		No recycling	Post process recycling	Post collection recycling-MRF	Source segregation
24 C1	Incineration for electricity and Anaerobic Digestion for vehicle fuel 50% RR				✓
	Incineration for heat				
25 C1	Incineration for heat and Anaerobic Digestion for electricity	✓			
26 C1	Incineration for heat and Anaerobic Digestion for heat	✓			
27 C1	Incineration for heat and Anaerobic Digestion for heat and electricity	✓			
28 C1	Incineration for heat and Anaerobic Digestion for vehicle fuel	✓			
29 C1	Incineration for heat and Anaerobic Digestion for electricity		✓		
30 C1	Incineration for heat and Anaerobic Digestion for heat		✓		
31 C1	Incineration for heat and Anaerobic Digestion for heat and electricity		✓		
32 C1	Incineration for heat and Anaerobic Digestion for vehicle fuel		✓		
33 C1	Incineration for heat and Anaerobic Digestion for electricity			✓	
34 C1	Incineration for heat and Anaerobic Digestion for heat			✓	
35 C1	Incineration for heat and Anaerobic Digestion for heat and electricity			✓	
36 C1	Incineration for heat and Anaerobic Digestion for vehicle fuel			✓	
37 C1	Incineration for heat and Anaerobic Digestion for electricity 25% RR				✓
38 C1	Incineration for heat and Anaerobic Digestion for heat 25% RR				✓
39 C1	Incineration for heat and Anaerobic Digestion for heat and electricity 25% RR				✓
40 C1	Incineration for heat and Anaerobic Digestion for vehicle fuel 25% RR				✓
41 C1	Incineration for heat and Anaerobic Digestion for electricity 43% RR				✓
42 C1	Incineration for heat and Anaerobic Digestion for heat 43% RR				✓
43 C1	Incineration for heat and Anaerobic Digestion for heat and electricity 43% RR				✓
44 C1	Incineration for heat and Anaerobic Digestion for vehicle fuel 43% RR				✓
45 C1	Incineration for heat and Anaerobic Digestion for electricity 50% RR				✓
46 C1	Incineration for heat and Anaerobic Digestion for heat 50% RR				✓
47 C1	Incineration for heat and Anaerobic Digestion for heat and electricity 50% RR				✓

Scenario code	Scenario name	Recycling methods			
		No recycling	Post process recycling	Post collection recycling-MRF	Source segregation
48 C1	Incineration for heat and Anaerobic Digestion for vehicle fuel 50% RR				✓
	Incineration for heat and electricity				
49 C1	Incineration for heat and electricity and Anaerobic Digestion for electricity	✓			
50 C1	Incineration for heat and electricity and Anaerobic Digestion for heat	✓			
51 C1	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity	✓			
52 C1	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel	✓			
53 C1	Incineration for heat and electricity and Anaerobic Digestion for electricity		✓		
54 C1	Incineration for heat and electricity and Anaerobic Digestion for heat		✓		
55 C1	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity		✓		
56 C1	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel		✓		
57 C1	Incineration for heat and electricity and Anaerobic Digestion for electricity			✓	
58 C1	Incineration for heat and electricity and Anaerobic Digestion for heat			✓	
59 C1	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity			✓	
60 C1	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel			✓	
61 C1	Incineration for heat and electricity and Anaerobic Digestion for electricity 25% RR				✓
62 C1	Incineration for heat and electricity and Anaerobic Digestion for heat 25% RR				✓
63 C1	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity 25% RR				✓
64 C1	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel 25% RR				✓
65 C1	Incineration for heat and electricity and Anaerobic Digestion for electricity 43% RR				✓
66 C1	Incineration for heat and electricity and Anaerobic Digestion for heat 43% RR				✓
67 C1	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity 43% RR				✓
68 C1	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel 43% RR				✓
69 C1	Incineration for heat and electricity and Anaerobic Digestion for electricity 50% RR				✓
70 C1	Incineration for heat and electricity and Anaerobic Digestion for heat 50% RR				✓
71 C1	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity 50% RR				✓

Scenario code	Scenario name	Recycling methods			
		No recycling	Post process recycling	Post collection recycling-MRF	Source segregation
72 C1	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel 50% RR				✓

Many scenarios were designed in order to represent as many situations as possible with the different configurations of WtE technology, energy recovery type, recycling schemes. The results will be used to create a simplified decision making tool.

6.2 Recycling Material Capture Rates

In order to create the scenarios with the stated recycling rate, the recycling material capture rates for each country/density group had to be established and entered into the waste distribution table in WRATE for each scenario. An assumption is made that all different fractions of the recycling materials have the same recycling material capture rate within that scenario. The recycling material capture rate is determined from the proportion of recycling amount (%) against the residual amount (%). The recycling amount include the fractions of papers, plastics, glass, metals, IBA sent from aggregate, and organic waste sent to AD. According to the waste statistics for England (Department for Environment Food and Rural Affairs, 2012) the recycling rate is the proportion of the amount of waste sent for reuse, recycling and composting to the total waste arising. Therefore any waste sent to AD is included in the calculation of recycling rate. A summary of the recycling material capture rate is shown in table 6.5.

Table 6.5 Recycling Material Capture Rate

Recycling rate	**25%**	**43%**	**50%**
Scenario code	Recycling Material Capture Rate (recycling amount (%) : residual amount (%))		
IN UKUR	10:90	75:25	95:5
AD UKUR	32:68	55:45	63:37
C1 UKUR	5:95	35:65	45:55
IN UKRU	11:89	74:26	97:3
AD UKRU	32:68	54:46	63:37
C1 UKRU	6:94	35:65	46:54
IN THUR	50:50	100:0 (34% RR)	-

Recycling rate	25%	43%	50%
AD THUR	27:73	46:54	54:46
C1 THUR	12:88	35:65	45:55
IN THRU	51:49	100:0 (34% RR)	-
AD THRU	27:73	46:54	54:46
C1 THRU	12:88	35:65	45:55

6.3 Background Information

For an urban location Southampton was selected as the amount of household waste is near the average household waste arising for unitary local authorities. Unitary local authorities are urban authorities. Winchester was selected for a rural location as it also has a household waste arising near the average value for collection authorities. Collection authorities are more rural in nature. Once the population density values for UK have been establish locations in Thailand were selected based on the similar population density in order to apply the same collection distances for locations with the same population density. Chiang Mai was selected to represent an urban location for Thailand and Nakorn Ratchasima was selected as the rural location. Details are shown in table 6.6.

Table 6.6 Background Information

Country	Density type	Population (person)	Area (km^2)	number of household	density (person/ km^2)	waste generation [c] (Tonne/year)	Reference City
UK [a]	Urban	236,900	51.8	98,300	4,572.5	86,518	Southampton
UK [b]	Rural	116,600	661.0	46,900	176.4	37,231	Winchester
Thailand [d]	Urban	174,235	40.2	67,010	4,334.2	96,725	Chiang Mai
Thailand [d]	Rural	174,057	633.0	31,569	274.9	64,240	Nakorn Ratchasima

a :population statistics (Southampton City Council, 2012)
b: population statistics (Winchester City Council, 2012)
c: waste data(Department for Environment Food and Rural Affairs, 2012)
d: population statistics and waste data (Pollution Control Department, 2003)

6.4 Electricity mix

The electricity mix in WRATE is different for each country. The outcome will vary as the calculations of energy offset are calculated according to the individual country's electricity mix. The UK electricity mix is available in WRATE software. The Thai electricity mix is calculated from data given in appendix 5 of the National Power Development Plan 2010, Third Revision

(Energy Policy and Planning Office, 2012) and an estimate of generating efficiencies by Wangjiraniran, Nidhiritdhikrai and Eua-Arporn (2012). Details are shown in table 6.7.

Table 6.7 Electricity Mix

UK electricity mix 2012 [a]			
Energy source	**Baseline fuel mix %**	**Generating efficiencies %**	**Marginal fuel mix %**
Total	100		100
Coal	33.4	35.7	50.5
Oil	0.3	33.1	0
Gas	3.4	34.9	3.1
Gas CCGT	35.4	47.6	46.4
Nuclear	16	38.6	0
Waste	0.2	20.6	0
Thermal other	0.8	18.7	0
Renewables thermal	2.3	25.8	0
Solar PV	0.1	15.5	0
Wind	6.6	25	0
Tidal	0.1	82	0
Wave	0.1	82	0
Hydro	1.3	82	0
Geothermal	0	82	0
Renewable other	0	82	0
Thailand electricity mix 2012			
Energy source	**Baseline fuel mix %** [b]	**Generating efficiencies %** [c]	**Marginal fuel mix %**
Total	100.000		100
Coal	19.045	35	22.8
Oil	1.185	35	0.0
Gas	64.665	35	77.2
Gas CCGT	0.000	45	0
Nuclear	0.000	35	0
Waste	0.013	30	0
Thermal other	0.000	18.7	0
Renewables thermal-biomass	0.587	35	0
Solar PV	0.173	15	0
Wind	0.143	15	0
Tidal	0.000	82	0
Wave	0.000	82	0
Hydro	14.127	38	0
Geothermal	0.000	82	0
Renewable other-biogas	0.063	30	0

a: UK electricity mix in the database within the software WRATE V2.0.1 (2010)

b: Thai baseline fuel mix adapted from National Power Development Plan 2010. Third Revision (Energy Policy and Planning Office, 2012)

c: Thai generating efficiencies adapted from Wangjiraniran, Nidhiritdhikrai and Eua-Arporn (2012)

6.5 Waste Composition

The details of each waste fraction used in this study are shown in table 6.8. The UK waste composition is selected from the database within WRATE which is household waste from England in 2007 from the document by Department for Environment Food and Rural Affairs - WR0119 - Municipal Waste Composition: A Review of Municipal Waste Component Analyses (Department for Environment Food and Rural Affairs, 2008). However the glass fraction has been adapted by calculating from values given in annex 4 of the above document to reflect the different coloured glass in the waste stream. The household waste composition for Thailand is an average of two household waste compositions sampled in two seasons in Thailand (Pollution Control Department, 2003).

Table 6.8 Waste composition

Waste Fraction	**UK** [a]	**Thailand** [b]
Total	**100**	**100**
Paper and card		
Unspecified paper	0	1.31
Newspapers	7.17	1.73
Magazines	2.88	2.26
Recyclable paper	2.17	0.875
Other paper	4.97	0
Card packaging	6.51	0.48
Other card	1.62	0
Plastic film		
Unspecified plastic film	0	0
Bags	2.09	10.655
Packaging film	2.03	0.29
Other film plastic	0.24	0
Dense plastic		
Unspecified dense plastic	0	0
Drinks bottles	1.08	0.51
Other bottles	1.62	1.195
Other packaging	2.31	2.935
Other dense plastic	1.66	0.655
Textiles		
Unspecified textiles	2.89	1.405
Artificial textiles	0	0
Natural textiles	0	0
Absorbent hygiene products		
Unspecified absorbent hygiene products	3.52	2.45
Disposable nappies	0	0

Waste Fraction	**UK [a]**	**Thailand [b]**
Other (sanpro and dressings)	0	0
Wood		
Unspecified wood	0.85	0.84
Wood packaging	0	0
Non-packaging wood	0	0
Combustibles		
Unspecified combustibles	1.21	0
Shoes	0.33	0
Carpet/underlay	0.43	0
Furniture	0.03	0
Other combustibles	0	0
Non-combustibles		
Unspecified non-combustibles	2.37	0
Bricks, blocks, plaster	0	0
Soil	0	0
Inorganic pet litter	0	0
Other non-combustibles	0	0
Glass		
Unspecified glass	4.77	0
Packaging	0	0
Non-packaging glass	0	0
Green bottles	0.92	0.11
Clear bottles	0.67	0.995
Brown bottles	0.16	1.345
Jars	0	0
Organic		
Unspecified organic		0
Garden waste	11.94	0
Food waste	24.78	66.295
Organic pet bedding/litter	0	0
Other organics	2.53	0
Ferrous metal		
Unspecified ferrous metal		1.51
Steel food and drink cans	1.82	0
Other ferrous metal	0.76	0
Non-ferrous metal		
Unspecified non-ferrous metal		0
Aluminium drinks cans	0.37	1.865
Foil	0	0
Other non-ferrous metal	0.38	0.06
Fine material <10mm		
Unspecified fine material	1.55	0
Waste electrical and electronic equipment		
Unspecified WEEE		0
White goods	0.11	0
Large electronic goods (excluding CRT TVs and	0.12	0

Waste Fraction	UK [a]	Thailand [b]
CRT TVs and monitors	0.01	0
Other WEEE	0.75	0
Specific hazardous household		
Unspecified hazardous household waste items		0.055
Batteries	0.07	0.19
Clinical waste	0.13	0
Paint/varnish	0.08	0
Oil	0.02	0
Garden herbicides & pesticides	0.08	0

a: adapted from household waste composition (Department for Environment Food and Rural Affairs, 2008)
b: adapted from household waste composition (Pollution Control Department, 2003)

6.6 Other waste properties

Default values of proximate, ultimate analysis and heat values are given in WRATE from the document by Department for Environment Food and Rural Affairs (2008)- WR0119 - Municipal Waste Composition: A Review of Municipal Waste Component Analyses. The table cannot be downloaded out from the software. A summary of the net heat values in WRATE are compared to the literature values in appendix A4 are shown in table 6.9. Most of the waste fractions have heat values similar and within range of the heat values in appendix A4. The heat value for garden waste of 4.2 MJ/kg is slightly lower than the range of 5-20 MJ/kg and so is the paper heat value of 10.7 MJ/kg is slightly lower than the range of 11-26 MJ/kg. The heat values for glass and metals has a slightly wider range from 0-1.6 MJ/kg compared to values in appendix A4 of 0.1-0.7 MJ/kg. The RDF values have a much wider range from 0-29.7 MJ/kg compared to values in appendix A4 of MJ/kg but this is due to the RDF heat values in WRATE are listed according to the RDF of each waste fraction while the RDF heat values are for the whole mixture of RDF. The total heat values of household waste given in WRATE of 9.6 MJ/kg is within the range compared to values in appendix A4 of 5-13 MJ/kg as well as within the range encountered at Marchwood Energy Recovery Facility of 7.5 – 11.5 MJ/kg (Campbell, 2010).

Table 6.9 Heat values of MSW

LHV in MJ kg^{-1}	Appendix A4	WRATE
Food waste (excluding meat and fat)	2 – 7	3.5
Garden waste	5 – 20	4.2
Paper	11 – 26	10.7
Plastics	21 – 40	19.9-29.6
Textiles, rubber and leather	9 – 26	14.3
Glass and metal	0.1 – 0.7	0-1.6

LHV in MJ kg^{-1}	**Appendix A4**	**WRATE**
Total MSW	5 – 13	9.6
RDF	13 – 24	0-29.7

6.7 Processes selected for use in study

To create a scenario in WRATE processes of waste management are selected for each step of waste management from collection to disposal. The various user entered values are input into each process such as waste distribution, numbers of bins, distances for vehicles, type of MRF, energy recovery type for incineration, capacity of AD and type of landfill lining. Capacities for processes must be above the incoming waste amount therefore the values entered for each process in each scenario are individualised. The full detail of user entered values for each process and scenario along with the details of user defined processes are tabulated in appendix C. Below in table 6.10 is a summary of processes selected.

Table 6.10 Summary of processes selected

Processes name and code in WRATE	**Reasons**
Wheeled bins 12276	The 140 L bin is typically used and has the capacity to hold the weekly household waste.
Kitchen Caddy 12222	An unvented kitchen caddy was selected to minimise attraction of pest from vented odours which is a normal occurrence in a hot climate.
Garden Bag 12064	The kerbside reusable bag made from polypropylene was typical to hold garden waste in UK.
Kerbside box w/lid 12018	The 55 L box was selected for recyclables especially paper as a lid would prevent rain water entering the box. A wheeled bin is too big and would not facilitate source segregation.
Kerbside box w/o lid 12277	The 55 L box was selected for recyclables to be stacked under the box w/lid. A wheeled bin is too big and would not facilitate source segregation.
6x4 Refuse Collection Vehicle (RCV) Fleet Euro 4 Diesel V2 12115	A typical refuse collection vehicle of 12.8 T capacity with a low sulphur emission was selected for household waste and organic waste.
Kerbside multi-compartment 12027	A multi-compartment collection vehicle of 5.5 T capacity was selected for segregated recyclable materials.
6x4 Refuse Collection Vehicle (RCV) Fleet CNG 12113	A typical refuse collection vehicle of 12.8 T capacity using CNG was selected for household waste and organic waste for scenarios using

Processes name and code in WRATE	**Reasons**
	biomethane as vehicle fuel.
Articulated Truck 44 T 11068	A user defined truck to represent the bulk haulage from transfer stations to the various treatment plants, landfill and reprocessing plants.
Transfer station (road) 12246	A transfer station for road transport was selected for all scenarios with a varying capacity for each
MRF 11130	A twin streamer high mechanisation MRF for mixed waste was selected for scenarios with post collection recycling (dirty MRF)
MRF 12248	A source separated waste MRF with infrared plastic separation was selected for scenarios with source segregation
Incinerator: Flexible (based on the Chineham ERF) 21849	A flexible incinerator with options for energy recovery including electricity, heat, and heat and electricity. Options for flue gas cleaning, NOx reduction and metals recovery are available.
AD heat and electricity 11369	A user defined process based on an updated version on WRATE
AD heat 11370	A user defined process based on an updated version on WRATE and adapted to reflect heat recovery only
AD electricity 11371	A user defined process based on an updated version on WRATE and adapted to reflect electricity recovery only
AD vehicle fuel 11377	A user defined process based on an updated version on WRATE and a biogas upgrade version developed by Huiu (2012) with further calculations by the user adapted to reflect vehicle fuel.
Landfill 12161	A landfill with HDPE liner and cap was selected as it would be required for APC residues.
IBA recycling 12028	An incineration bottom ash recycling with ferrous and non ferrous recycling was selected for post process recycling scenarios.
Ferrous metal 12287	Ferrous metal recycling was selected for post process recycling, post collection, and source segregation scenarios.
Non ferrous scrap metal 11123	Non ferrous metal recycling was selected for post process recycling, post collection, and source segregation scenarios.
Plastic-Film 12302	Plastic-film recycling was selected for source segregation scenarios.
Plastic-Dense 12304	Plastic-dense recycling was selected for post process recycling, post collection, and source segregation scenarios.
Glass-Aggregate 12252	Glass aggregate recycling was selected for post process recycling, post collection, and source segregation scenarios for mixed glass.
Glass-Clear 21129	Glass-Clear recycling was selected for source segregation scenarios.
Glass-Brown 11319	Glass-Brown recycling was selected for source segregation scenarios.
Glass-Green 12291	Glass-Green recycling was selected for source segregation scenarios.

Processes name and code in WRATE	**Reasons**
Paper- 12124	Glass- Paper recycling was selected for source segregation scenarios.

6.8 Scenario maps

There were 422 scenarios created with 422 individual scenario maps. There were only 15 IN THUR and 15 IN THRU because for source segregated scenarios, 100% recycling material capture rate only yielded a 34% recycling rate for the scenario. Therefore source segregated scenarios with 43% recycling rate were changed to 34% and no scenarios could be built for 50% recycling rate. A selected sample of scenario maps are shown in figures 6.1 to 6.11 to portray the 11 main different layouts of the scenarios. These include 4 scenario maps for IN scenarios to represent 4 recycling schemes, 3 scenario maps for AD scenarios to represent 3 recycling schemes and 4 scenario maps for C1 scenarios to represent 4 recycling schemes. The variations in energy recovery type and recycling rate are selected and individualised within the properties table of each process therefore the scenario map layouts are the same. The icons with a question mark symbol are user defined processes.

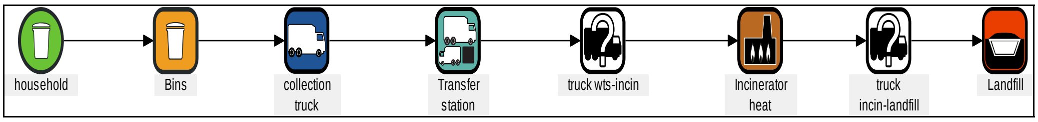


Figure 6.1 Scenario map 01 IN THUR Incineration for heat

The scenario maps for scenarios with incineration only and no recycling (1-3 IN) are the same with the exception of the energy recovery option. The energy recovery types are electricity, heat for district heating, and heat for district heating and electricity. The map is shown in Figure 6.1

- Household waste is collected from wheeled bins.
- The collection trucks deliver the waste to the transfer station where it is compacted and transferred by articulated trucks to the ERF.
- At the ERF, no metals are recovered.
- Articulated trucks transfer all ash waste to the landfill.

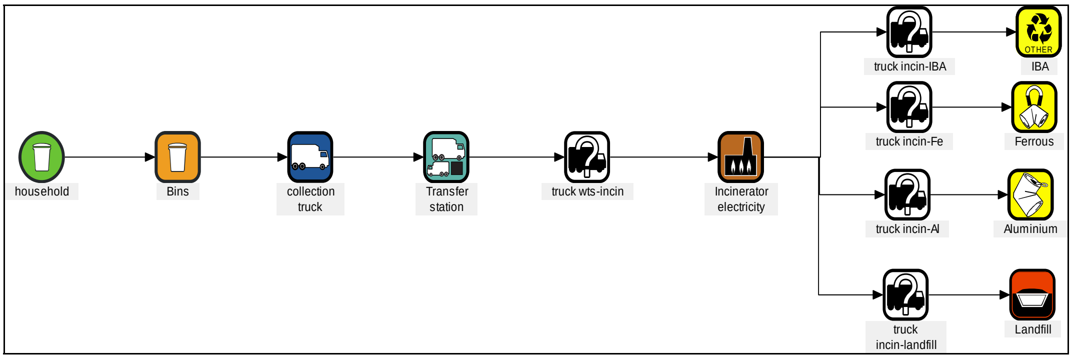


Figure 6.2 Scenario map 04 IN THUR Incineration for electricity post process recycling

The scenario maps for the scenarios with incineration for electricity post process recycling (4-6 IN) are the same with the exception of energy recovery option. The energy recovery types are electricity, heat for district heating, and heat for district heating and electricity. The map is shown in Figure 6.2.

- The household waste is collected from wheeled bins.
- The collection trucks deliver the waste to the transfer station where it is compacted and transferred to the ERF.
- Articulated trucks deliver the compacted waste to the ERF. At the ERF the ferrous metal recovery is 100% and aluminium recovery is 50%. The processed waste are separated into 4 types, incineration bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).
- Articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- Articulated trucks transfer the APC residue to the landfill.

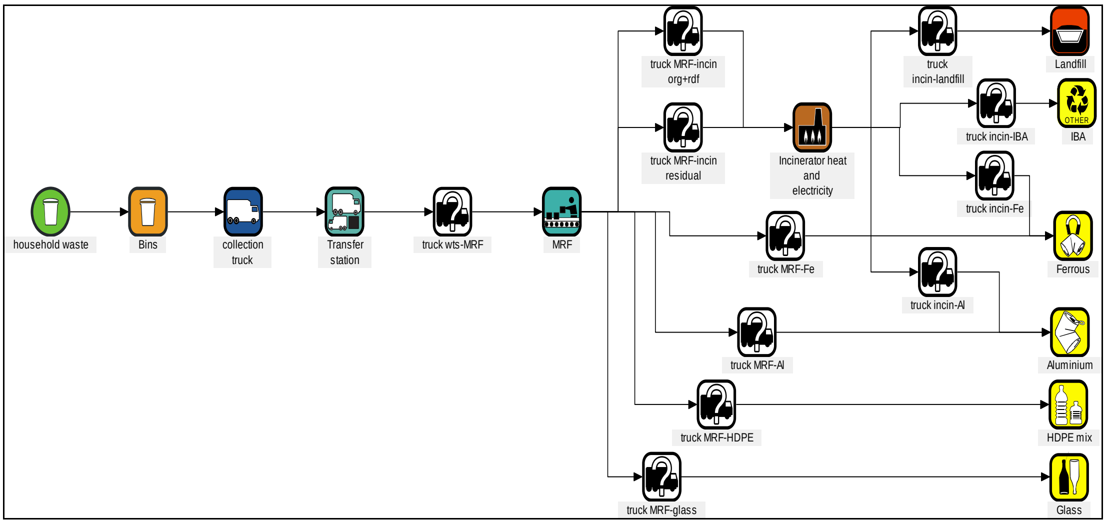


Figure 6.3 Scenario map 09 IN UKUR Incineration for heat and electricity post collection recycling

The scenario maps for the scenarios with incineration for electricity post collection recycling (7-9 IN) are the same with the exception of energy recovery option. The energy recovery types are electricity, heat for district heating, and heat for district heating and electricity. The map is shown in Figure 6.3.

- The household waste is collected from wheeled bins.
- The collection trucks deliver the waste to the transfer station where it is compacted and transferred to the MRF.
- The articulated trucks delivers the waste to the MRF where mixed waste is sorted and the recycle components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, dense plastic, and mix glass. The articulated truck delivers to the different recycling facilities.
- The articulated truck delivers waste residue to ERF. Ferrous metal recovery is 100% and aluminium recovery is 50%. The processed waste are separated into 4 types, incinerator bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).
- The articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- The articulated truck transfers the APC residue to the landfill.

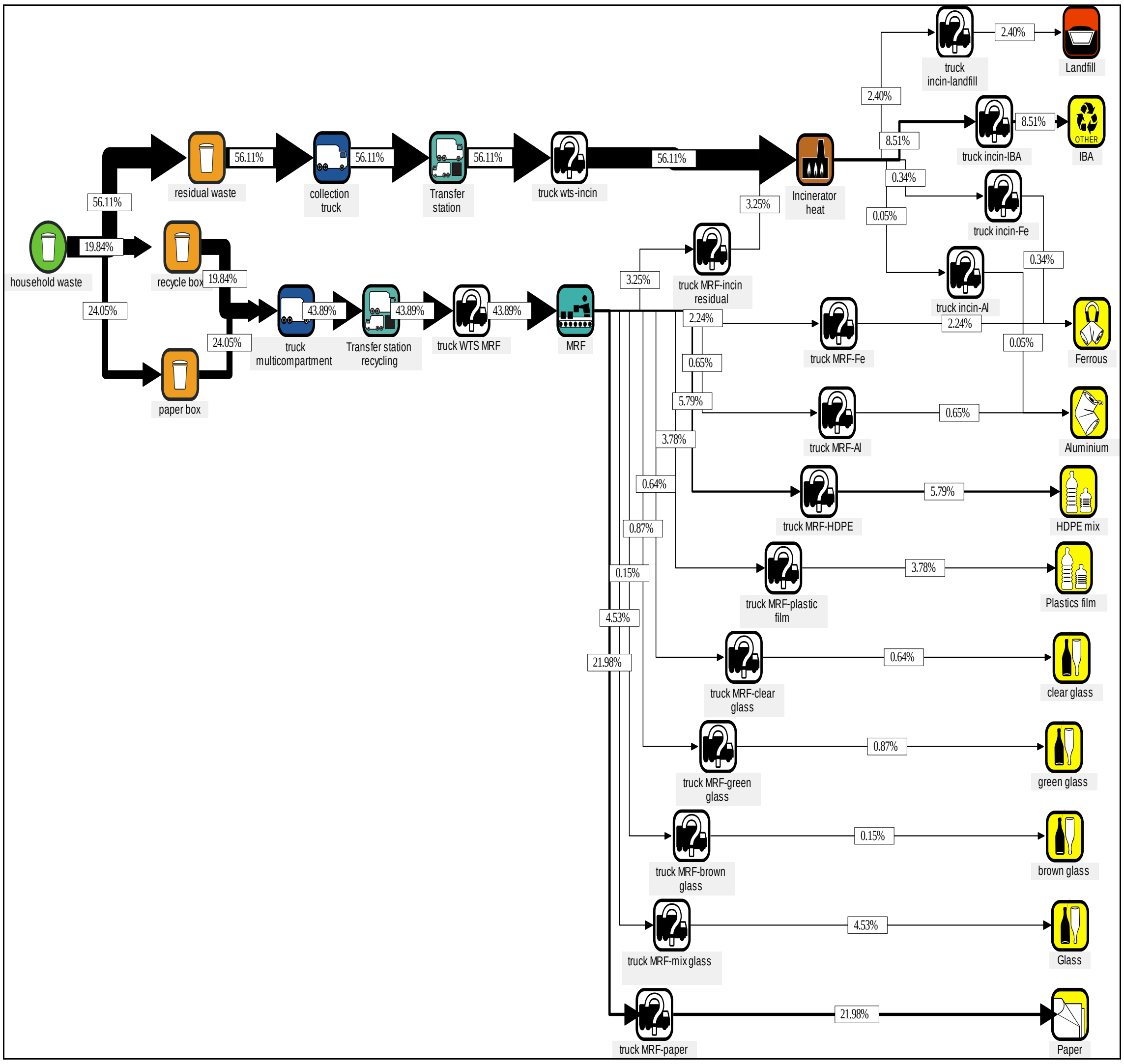


Figure 6.4 Scenario map 17 IN UKUR Incineration for heat source segregation 50% RR

The scenario maps for the scenarios with incineration for electricity source segregation (10-18 IN) are the same with the exception of energy recovery option and recycling rate. The energy recovery types are electricity, heat for district heating, and heat for district heating and electricity. The recycling rates are; 25%, 43%, 50% for UK and 25% and 34% for Thailand. The map is shown in Figure 6.4.

- The MSW is segregated at the source. The household has one wheeled bin for residual waste, and two recycling boxes one for mix recyclables and the other for the recycle paper.

- The multi compartment recycling trucks deliver the mix recyclables to the transfer station.
- The articulated trucks deliver the mix recyclables to the MRF where it is sorted and the various recycle components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, plastic dense, plastic film, clear glass, green glass, brown glass and paper. Articulated trucks deliver different recyclates to the various recycling facilities. The residual waste is sent to the ERF.
- The collection trucks deliver residual waste from households to the transfer station where the waste is compacted and sent to the ERF
- Articulated trucks deliver the residual waste from the MRF and transfer station to the ERF. At the ERF ferrous metal recovery is 100% and aluminium recovery is 50%. The processed waste are separated into 4 types, incinerator bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).
- Articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- The Articulated truck transfers the APC residue to the landfill.
-

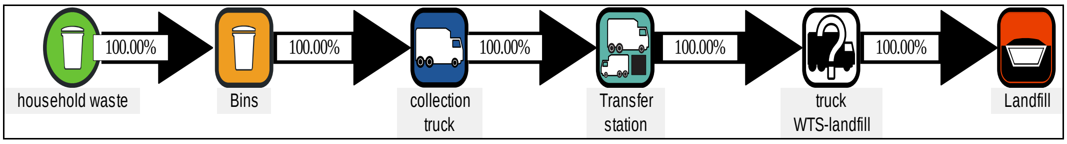


Figure 6.5 Scenario map 01 AD UKUR Anaerobic Digestion (landfill) for electricity

In this scenario landfill is chosen to represent the process of anaerobic digestion of waste without any recycling (01 AD) and the methane produced is collected as landfill gas which generates electricity shown in Figure 6.5.

- The household waste is collected from wheeled bins.
- The collection truck delivers the MSW to the transfer station where it is compacted.
- Articulated trucks transfer the compacted MSW to the landfill site.

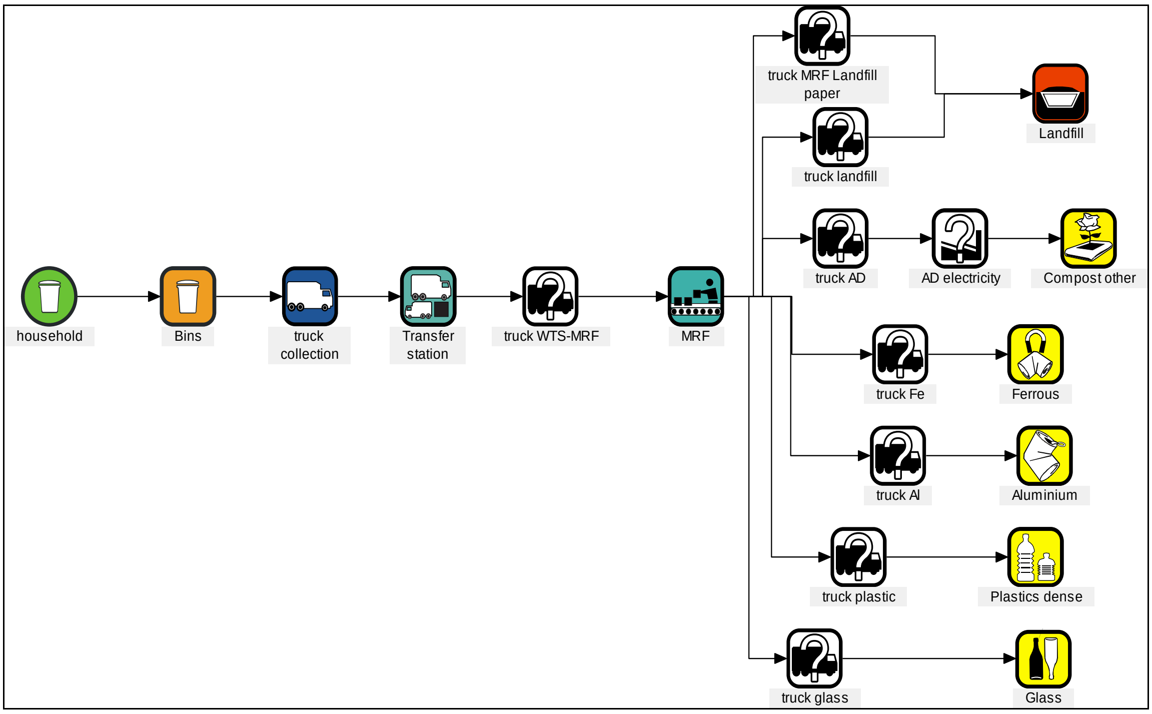


Figure 6.6 Scenario map 02 AD THUR AD electricity post collection recycling

The scenario maps for the scenarios with AD post collection (2-5 AD) are the same with the exception of energy recovery option. The energy recovery types are electricity, heat for district heating, heat for district heating and electricity, and vehicle fuel. The map is shown in Figure 6.6.

- The household waste is collected from wheeled bins.
- The collection truck delivers the waste to the transfer station where it is compacted.
- Articulated trucks deliver the waste to the MRF where mixed waste is sorted into recyclable components, residual waste and organic fraction. The recyclable components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, dense plastic, and mix glass. Articulated trucks deliver different recyclates to the various the recycling facilities.
- The organic waste fraction is sent to the Anaerobic Digestion plant. Articulated trucks deliver the organic waste fraction to the Anaerobic Digestion plant.
- Articulated trucks transfer residual waste to the landfill site.

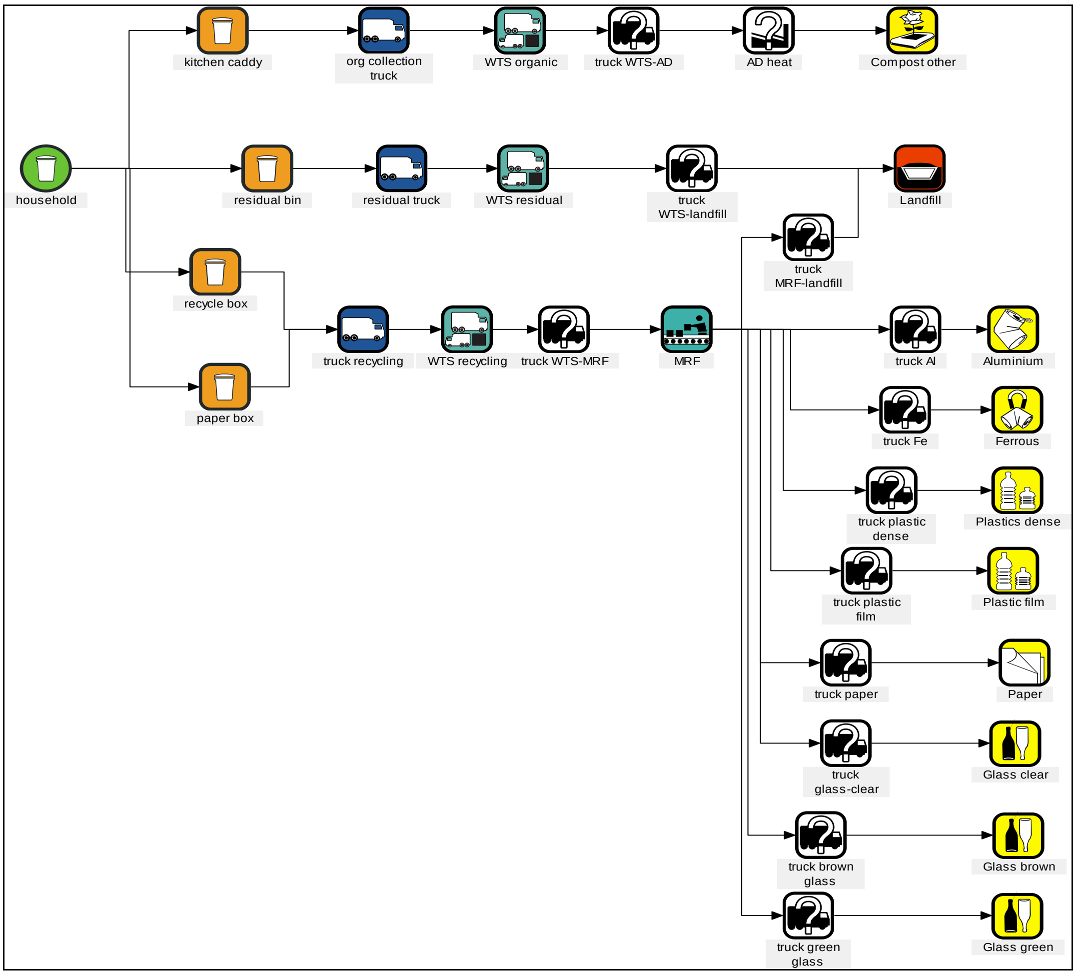


Figure 6.7 Scenario map 07 AD THUR AD heat source segregation 25% RR

The scenario maps for the scenarios with AD source segregation (6-17 AD) are the same with the exception of energy recovery option and recycling rates. The energy recovery types are electricity, heat for district heating, heat for district heating and electricity, and vehicle fuel. The recycling rates are 25%, 43% and 50%. The map is shown in Figure 6.7.

- The household waste is segregated at the source. The household has a kitchen caddy for organic kitchen waste and one wheeled bin for residual waste, two recycling boxes, one for mix recyclables and the other for paper. The recycling truck is the Kerbside vehicle multi-compartment.
- The organic waste collection trucks deliver the organic waste to the transfer station then articulated trucks delivers to the AD facility.
- The collection trucks deliver the residual waste to the transfer station where it is compacted and transferred to the landfill site.

- The multi compartment truck delivers the mixed recycle waste to the MRF where mixed recyclables is sorted and the various recycle components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, plastic dense, plastic film, clear glass, green glass, brown glass and paper. The residual waste is sent to the landfill site. Articulated trucks deliver different recyclates to the various the recycling facilities.

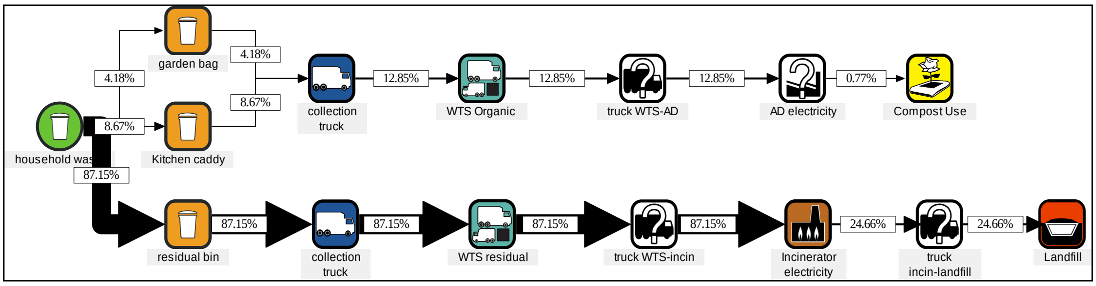


Figure 6.8 Scenario map 01 C1UKUR Incineration electricity AD electricity

The scenario maps for the scenarios with incineration and AD electricity no recycling (1-4, 25-28, 49-52 C1) are the same with the exception of energy recovery option. The energy recovery types are electricity, heat for district heating, heat for district heating and electricity, and vehicle fuel. The map is shown in Figure 6.8.

- The household waste is separated into one wheeled bin for residual waste, one garden bag and one kitchen caddy for organic food waste.
- The collection trucks deliver the waste to the transfer station where it is compacted.
- The organic waste collection trucks collects waste from the garden bag and kitchen caddy and deliver to the transfer station.
- The Articulated truck delivers the organic waste to the AD facility.
- Articulated trucks deliver the compacted residual waste to ERF. No metal is recovered.
- Articulated trucks transfer the APC residue to the landfill.

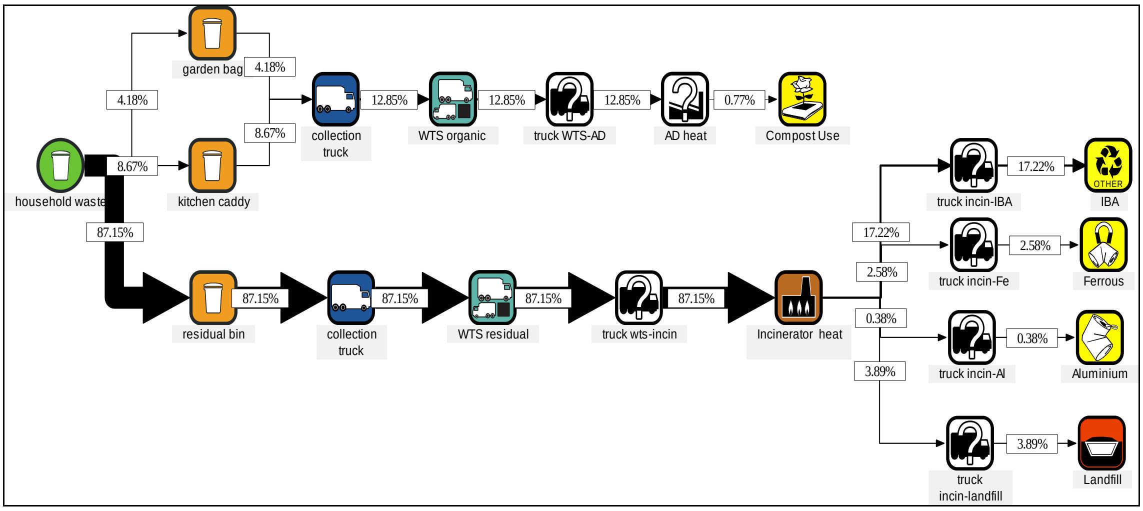


Figure 6.9 Scenario map 30 C1UKUR Incineration heat AD heat post process recycling

The scenario maps for the scenarios with incineration and AD electricity post process recycling (5-8, 29-32, 53-56 C1) are the same with the exception of energy recovery option. The energy recovery types are electricity, heat for district heating, heat for district heating and electricity, and vehicle fuel. The map is shown in Figure 6.9.

- The household waste is separated into one wheeled bin for residual waste, one garden bag and one kitchen caddy for organic food waste.
- The collection trucks deliver the waste to the transfer station where it is compacted.
- The organic waste collection trucks collects waste from the garden bag and kitchen caddy and deliver to the transfer station.
- The Articulated truck delivers the organic waste to the AD facility.
- Articulated trucks deliver the compacted residual waste to ERF. Ferrous metal recovery is 100% and aluminium recovery is 50%. The processed waste are separated into 4 types, incinerator bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).
- Articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- Articulated trucks transfer the APC residue to the landfill.

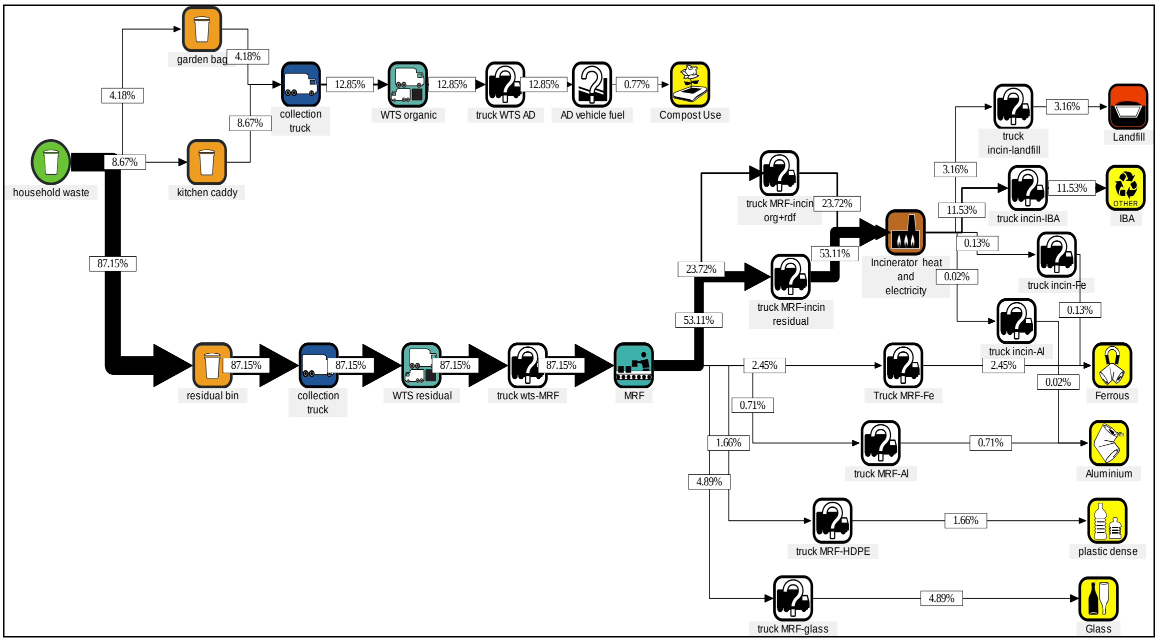


Figure 6.10 Scenario map 60 C1UKUR Incineration heat and electricity AD vehicle fuel post collection recycling

The scenario maps for the scenarios with incineration and AD electricity post collection recycling (9-12, 33-36, 57-60 C1) are the same with the exception of energy recovery option. The energy recovery types are electricity, heat for district heating, heat for district heating and electricity, and vehicle fuel. The map is shown in Figure 6.10.

- The household waste is separated into one wheeled bin for residual waste, one garden bag and one kitchen caddy for organic food waste.
- The collection trucks deliver the waste to the transfer station where it is compacted.
- The organic waste collection trucks collects waste from the garden bag and kitchen caddy and deliver to the transfer station.
- The Articulated truck delivers the organic waste to the AD facility.
- Articulated trucks deliver the compacted waste to the MRF where mixed waste is sorted into recyclable components, residual waste and organic fraction. The recyclable components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, dense plastic, and mix glass. Articulated trucks deliver different recyclates to the various the recycling facilities.
- Articulated trucks deliver the residual waste to ERF. Ferrous metal recovery is 100% and aluminium recovery is 50%. The processed waste are separated into 4

types, incinerator bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).

- Articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- Articulated trucks transfer the APC residue to the landfill.

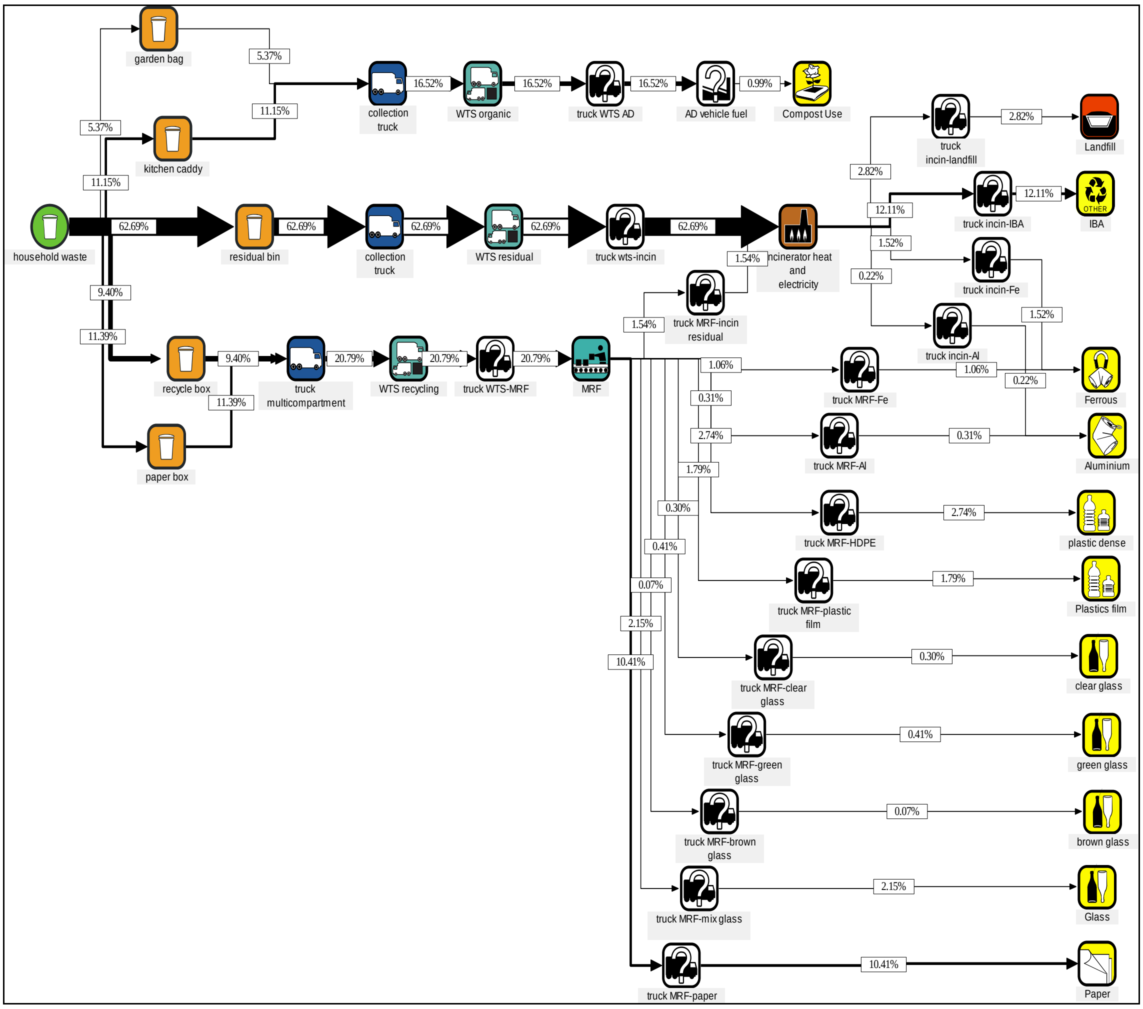


Figure 6.11 Scenario map 72 C1UKUR Incineration heat and electricity AD vehicle fuel source segregation 50% RR

The scenario maps for the scenarios with incineration and AD electricity post collection recycling (13-24, 37-48, 61-72 C1) are the same with the exception of energy recovery option. The energy recovery types are electricity, heat for district heating, heat for district heating and electricity, and vehicle fuel. The map is shown in Figure 6.10.

- The household waste is separated into one wheeled bin for residual waste, one garden bag, one kitchen caddy for organic food waste and two recycling boxes, one for mixed recyclables and one for paper.
- The collection trucks deliver the residual waste to the transfer station where it is compacted.
- The organic waste collection trucks collects waste from the garden bag and kitchen caddy and deliver to the transfer station.
- The multi compartment truck delivers the mixed recycle waste to the transfer station.
- The Articulated truck delivers the organic waste to the AD facility.
- The Articulated truck delivers the mixed recycle waste to the MRF where mixed recyclables is sorted and the various recycle components are baled, ready for transfer to the recycling facilities for ferrous metal, aluminium, plastic dense, plastic film, clear glass, green glass, brown glass and paper. The residual waste is sent to the ERF. Articulated trucks deliver different recyclates to the various the recycling facilities.
- Articulated trucks deliver the residual waste to ERF. Ferrous metal recovery is 100% and aluminium recovery is 50%. The processed waste are separated into 4 types, incinerator bottom ash (IBA), ferrous metals, aluminium and air pollution control residue (APC).
- Articulated trucks transfer the processed waste to the IBA, ferrous and aluminium recycling facilities.
- Articulated trucks transfer the APC residue to the landfill.

Chapter 7

Phase two Results and Ranking

7.1 Results

The full results from WRATE are shown in appendix D. Within the tables they are arranged in the country/population density group code of UKUR, UKRU, THUR and THRU. Each group table has 5 types of results as follow;

1. Headline values. The category of interest in this research is energy recovered (MJ)
2. Characterisation Impact assessment
3. Characterisation per person Impact assessment
4. Normalisation Impact assessment
5. Normalisation per person Impact assessment

7.1.1 Life Cycle Impact Assessment (LCIA) results

Due to the large number of scenarios, WRATE was not able to display all 107 scenarios within a country/population density group code which included UKUR, UKRU, THUR and THRU. Therefore the results are presented in this research by using charts created in Excel. The positive values for impact assessment are interpreted as burdens or emissions to the environment while negative values are interpreted as benefits achieved from various offsets and by avoiding emissions.

Multi LCIA Results

For this study the LCIA results presented in this part are expressed as normalisation per person. Normalisation is an optional step in an LCA study (ISO, 2006b).Normalisation is a method to compare all six different environmental problem indicators at an equal level. Each impact assessment has a normalisation factor to multiply to achieve the normalised result in units of European person equivalent (Eur.person.eq.). The results are further specified as normalisation per person, in units of Eur.person.eq. per person, divided by the population number in each group, for example UKUR is divided by 236,900. This enables the comparison between each country/population density group equally preventing the different population size becoming an issue.

The trends in the multi LCIA results for all four country/population density group code of UKUR, UKRU, THUR and THRU are similar to each other with a few differences seen in figures 7.1 to 7.4. The magnitude of values for LCIA for THUR is higher than the other three groups and the urban groups have larger values than the rural groups. Among the six impact assessments for all four country/population density groups, the magnitude of the values for ‘resources depletion’ impact assessments are about four times larger than values of the human toxicity, freshwater aquatic ecotoxicity and climate change impact assessments and about 40 times larger than values of the eutrophication and acidification impact assessments. This signifies that the main impact to the environment for waste management is resource use and depletion. Indeed, it is the underlying theme to the whole study in finding the best method to recover and use all the different materials in the waste stream sustainably.

For ‘resources depletion’ impact assessments, all scenarios give a negative value which indicates offsets. The resources saved from recycling activities are offset against resources required for producing the same amount of virgin material. This trend is expected since most of the scenarios have recycling activities. For the scenarios that do not have recycling activities, there were other processes which reduced the use of resources. For example in the lowest performing scenario, ‘01 AD for electricity no recycling (landfill)’, energy was recovered from landfill gas which offsets the use of fossil fuels.

Most scenarios in ‘human toxicity’ and ‘freshwater aquatic ecotoxicity’ impact assessment have negative values with only a few scenarios such as ‘01 AD for electricity no recycling (landfill)’ showing small net environmental burdens.

Most of the scenarios in ‘eutrophication’ impact assessment have very small positive values indicating small burdens to the environment with decreasing trends as a higher amount of waste is recycled. Both AD and incineration have emissions contributing to the eutrophication problem. In the AD scenarios the contribution is mainly from landfill of residual waste with direct process burdens to the air in the form of NOx emissions and to the water in the form of ammonia and phosphate. In the incineration scenarios the contribution is direct process burdens to the air in the form of ammonia, NOx and N_2O emissions.

Only the scenarios without recycling show a net burden to the environment in ‘acidification’ impact assessments and the offsets increases (negative impact values) with increasing recycling amounts.

Most of the scenarios in ‘climate change’ impact assessment have negative values and the trend also becomes more negative with increasing recycling amounts. However the AD scenarios with no recycling scheme, scenarios with post collection recycling, and scenarios with source segregation 25% RR, show burdens to the environment, especially ‘01 AD for electricity no recycling (landfill)’. More in-depth results on climate change LCIA is discussed in 7.1.2.

In general from the graphs in Figures 7.1 to 7.4, the scenarios with AD have more environmental burdens than the scenarios with incineration or the combination of incineration and AD due to sending residual waste to the landfill. Some incineration scenarios perform better than the combination scenarios. The WtE technology type is the largest factor that contributes significantly to the LCIA results. The second largest factor that contributes significantly to the LCIA results is the different recycling schemes and to a certain extent each different recycling rates can be reclassified as another recycling scheme. In other words the amounts of materials that are recycled are the second largest factor that affects the result. The energy recovery type is the third factor that contributes to the result. Heat and electricity tends to perform better for incineration and combination scenarios while vehicle fuel performs better for AD scenarios.

From the overall result of multi LCIA, the expected result that the combination scenario of ‘72 C1 Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR’ would perform the best did not occur. In many cases the scenarios with post collection performed better. With some investigation it was found that a larger amount of material is recycled via sorting at the ‘dirty’ MRF than the scenarios of 50% source segregation which had a lower recycling material capture rate than the MRF.

Therefore extra scenarios were added to UKRU and THRU with 100% materials capture rate. These scenarios are:

1. ‘73 C1 UKRU Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation’ with a maximum recycling rate achieved at 80%;
2. ‘73 C1 THRU Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation’ with a maximum recycling rate achieved at 93% ;
3. ‘18 AD THRU Anaerobic Digestion for vehicle fuel Source segregation’ with a maximum recycling rate achieved at 93%’.

The graphs in Figures 7.2 and 7.4 show that although the ‘73 C1’ scenarios perform better than ‘72 C1’ scenarios, in many impact assessments they are still have more burdens than scenarios of the post collection scenarios in UKRU and the scenarios of IN source segregation (34% RR) which also have 100% material capture rate in THRU.

The recycling material capture rates from Table 6.5 and the results from 73 C1 UKRU and 73 C1 THRU and 18 AD THRU gives information about the maximum recycling rate that can be achieved. If everyone participates and recycle only the dry recyclates (paper, plastic, glass and metals) the maximum recycling rate possible would be slightly above 50% in the UK and only 34% in Thailand. If organic waste is utilised whether by composting or AD, in addition to recycling dry recyclates the maximum recycling rate possible would be 80% in the UK and 93% in Thailand.

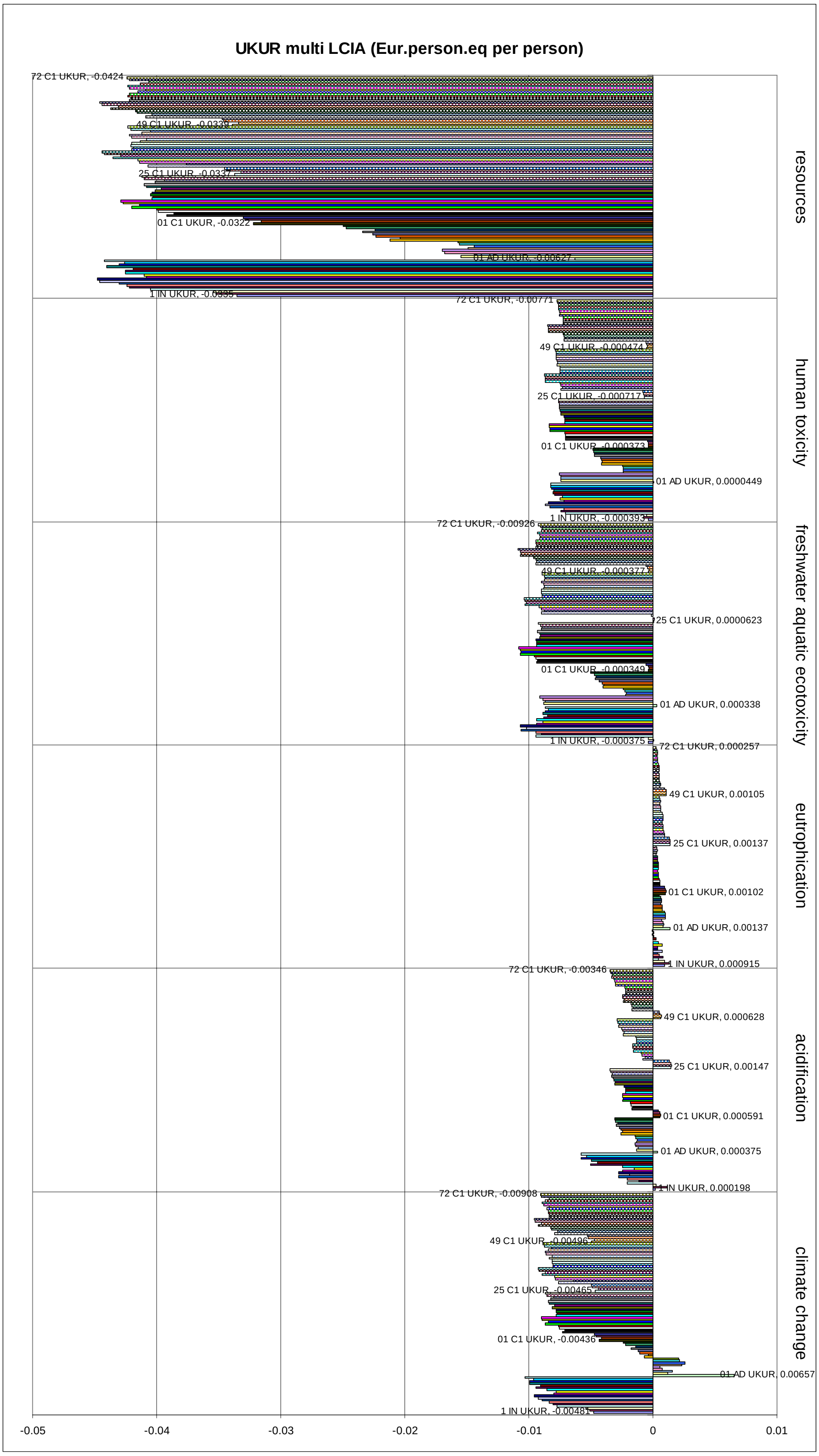


Figure 7.1 UKUR multi LCIA normalisation per person

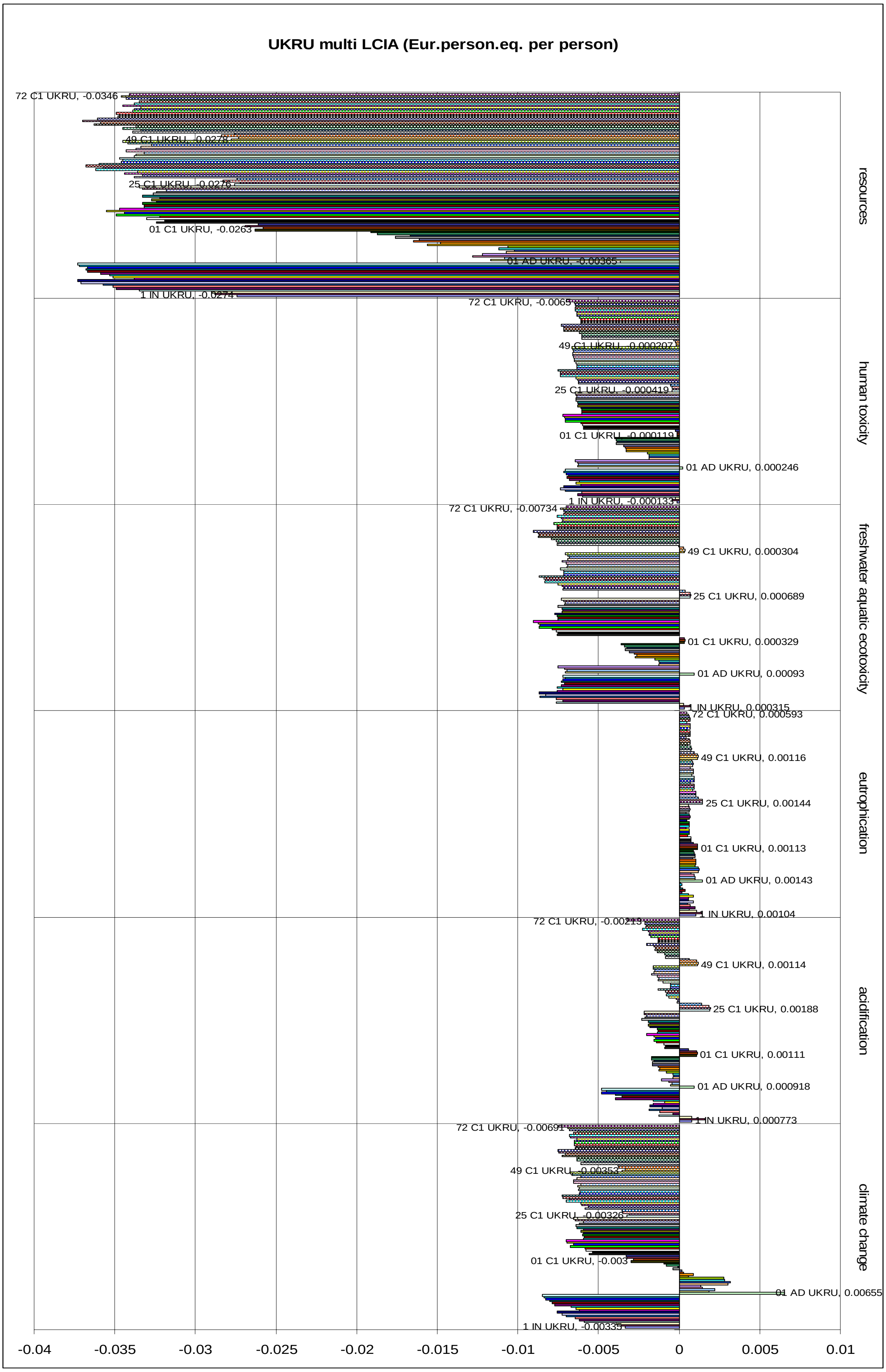


Figure 7.2 UKRU multi LCIA normalisation per person

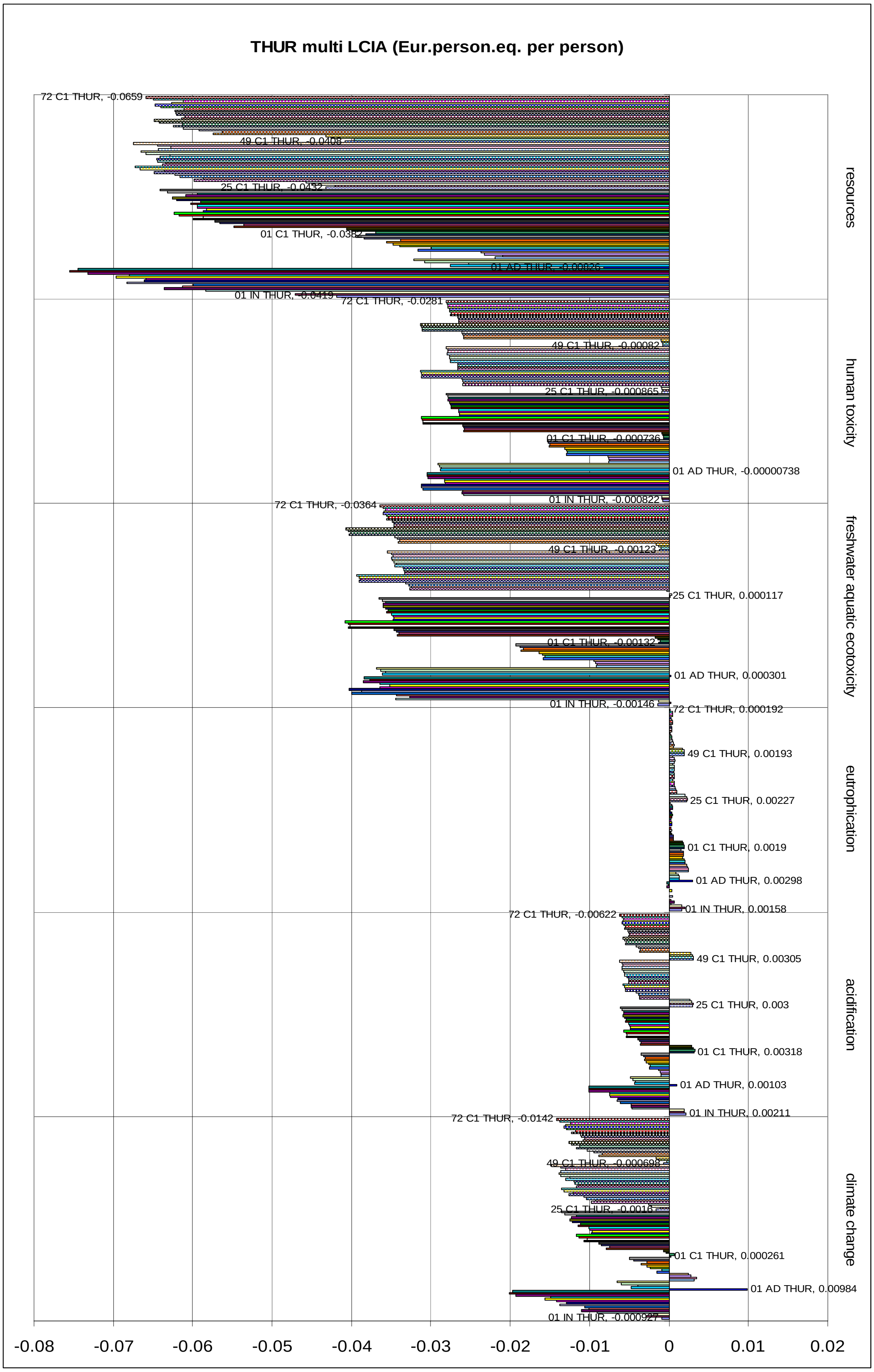


Figure 7.3 THUR multi LCIA normalisation per person

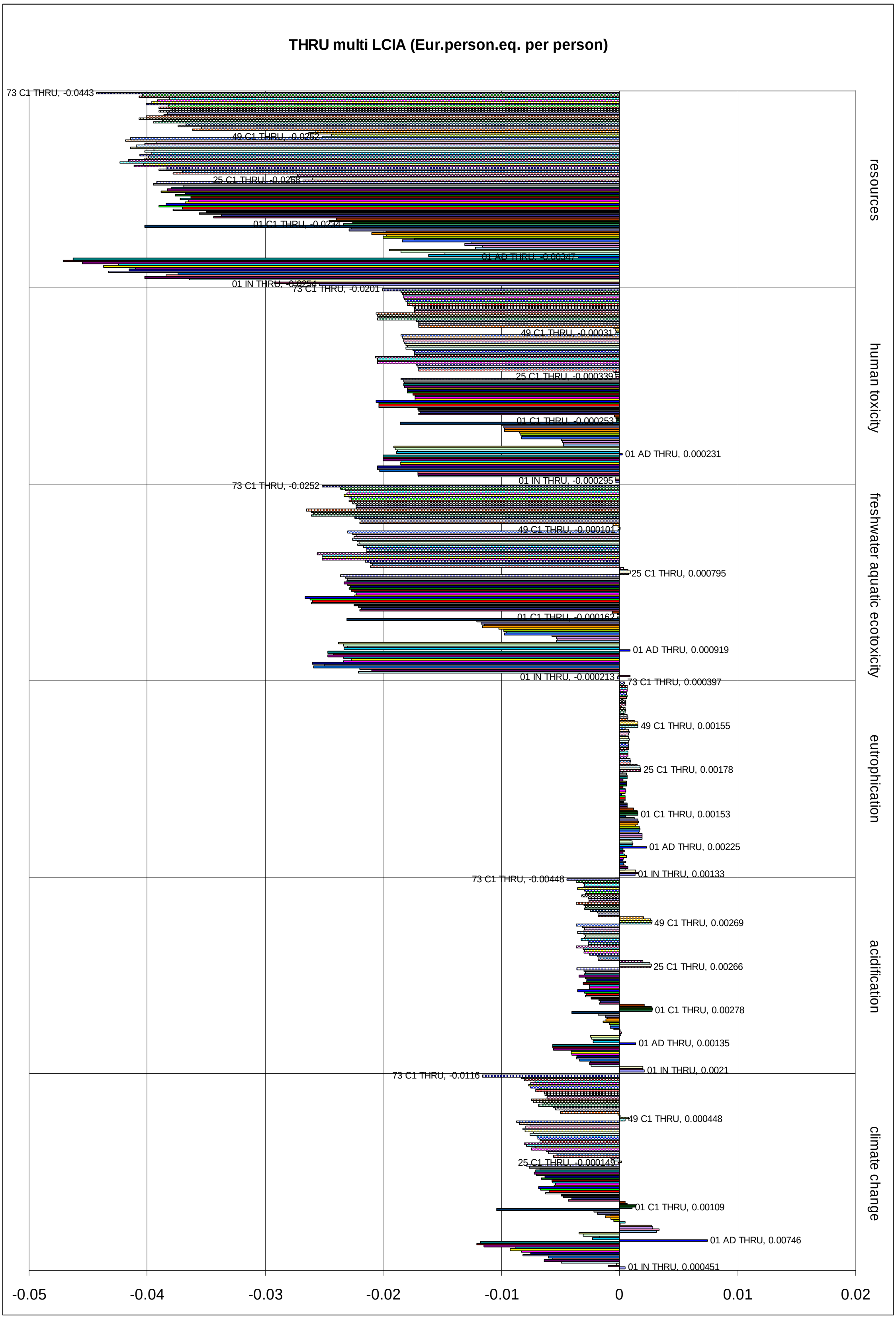


Figure 7.4 THRU multi LCIA normalisation per person

7.1.2 Climate change/GWP LCIA results

Climate change/GWP is an important issue and is discussed in further detail in this section. The results for Climate change/GWP LCIA are shown in Figures 7.5 to 7.8. The Climate change LCIA results for scenarios with incineration, and scenarios with combination of incineration and AD, except for scenarios 01-02 C1 THUR, 01-04, 26 and 49-51 C1 THRU, and 1 IN THRU; are all negative values which indicates that the scenarios have processes with GWP offsets. The WRATE model assumes that the GHG emissions associated with the incineration of waste with biogenic carbon content is not counted as GHG contributing to GWP since the biogenic carbon would be released to the environment naturally. Therefore the GHG emissions related to the energy gained from the incineration of waste with biogenic carbon content is offset against the GHG emission related to the same amount of energy produced from fossil fuel.

In all four country/population density group code of UKUR, UKRU, THUR and THRU scenarios with no recycling scheme have more GHG emissions than all the other scenarios. However the scenarios 01-02 C1 THUR, 01-04, 26 and 49-51 C1 THRU, and 1 IN THRU have positive values which indicates that in these scenarios, the offsets are less than the GHG emissions. The Thai waste composition has a larger organic waste fraction (66%) and a smaller combustible and recyclable waste fractions compared to the waste composition of the UK (39% organic waste fraction). In the above scenarios the amount of combustible waste entering the incineration is too low to generate enough energy to offset the GHG emissions from all the activities. Also with no recycling there are no offsets that comes from the reducing the use of energy in producing virgin materials. When comparing the scenario 1 IN THRU (all waste entering the incineration) to the scenario 01 C1 THRU (divert organic waste to AD and the rest entering the incineration) there are more burdens in 01 C1 THRU than 1 IN THRU. The benefits of diverting organic waste to AD is not enough to offset the impacts from the additional activities of collecting organic waste separately in a rural town with a large and low population density area in Thailand.

For AD scenarios, the scenarios with no recycling (01 AD), scenarios with post collection recycling (02-05 AD), and scenarios with source segregation 25% RR (06-09AD), show burdens to the environment. The scenario ‘01 AD for electricity no recycling (landfill)’ has the most burdens in all four country/population density group code of UKUR, UKRU, THUR and THRU. Scenarios with source segregation 25% RR have more GHG emissions than scenarios with post collection recycling because the ‘dirty MRF’ in these scenarios can capture more recycling materials than the scenarios with source segregation 25% RR.

The best performing scenarios are 18 IN UKUR incineration for heat and electricity 50% RR, 18 IN UKRU incineration for heat and electricity 50% RR, 14 IN THUR incineration for heat 34% RR, 14 IN THRU incineration for heat 34% RR. The additional scenarios of 73 C1 UKRU incineration for heat and electricity and AD for vehicle fuel 80% RR,73 C1 THRU incineration for heat and electricity and AD for vehicle fuel 93% RR, and 18 AD THRU AD for vehicle fuel 93% RR also have very low climate change impacts.

Further analysis of climate change impacts for categories for scenario 18 IN UKUR is shown in Figure 7.9. The categories with the largest offsets are the recycling process and the treatment and recovery process. The collection process and intermediate facilities have low burdens by comparison to the other processes. The transportation process has slightly more burdens and varies with the different waste separation. Scenario 18 IN UKUR has the highest offset for recycling and when combined with the offset from the energy recovered during treatment and recovery, the scenario is the best performing for UKUR. Figure 7.10 shows the climate change impacts for stages for scenario 18 IN UKUR. The stages with the largest impacts are direct process burdens, energy output and operational output. Scenario 18 IN UKUR has high offsets from combined energy output and operational output impacts and low direct process burdens.

As for the scenario with the most burden 01 AD for electricity no recycling (landfill) further analysis of climate change impacts for categories for scenario 01 AD UKUR is shown in Figure 7.11. The categories with the largest offsets are the recycling process and the landfill process. The collection process and intermediate facilities have low burdens by comparison to the other processes. The transportation process has slightly more burdens and varies with the different waste separation. The AD treatment and recovery process has low offsets. Scenario 1AD UKUR has no recycling offsets and has the highest burden from the landfill category since all of the waste enters the landfill and decays anaerobically producing methane, a GHG. Therefore this scenario has the most environmental impact. Figure 7.12 shows the climate change impacts of stages for scenario 1AD UKUR. The stages with the largest impacts are direct process burdens, energy output and operational output. Scenario 1AD UKUR has high direct process burdens and low energy outputs to offset the burdens.

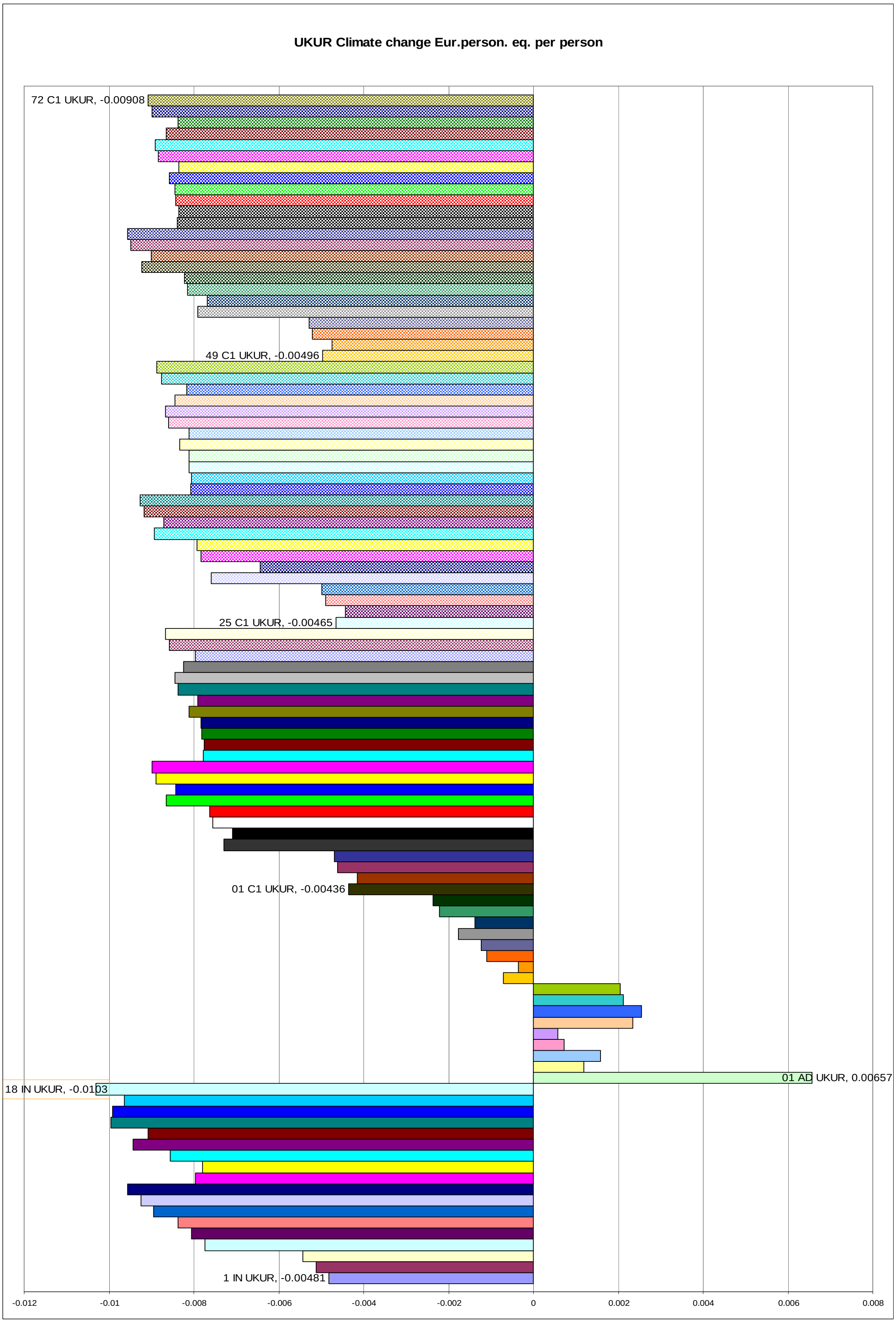


Figure 7.5 UKUR Climate Change LCIA normalisation per person

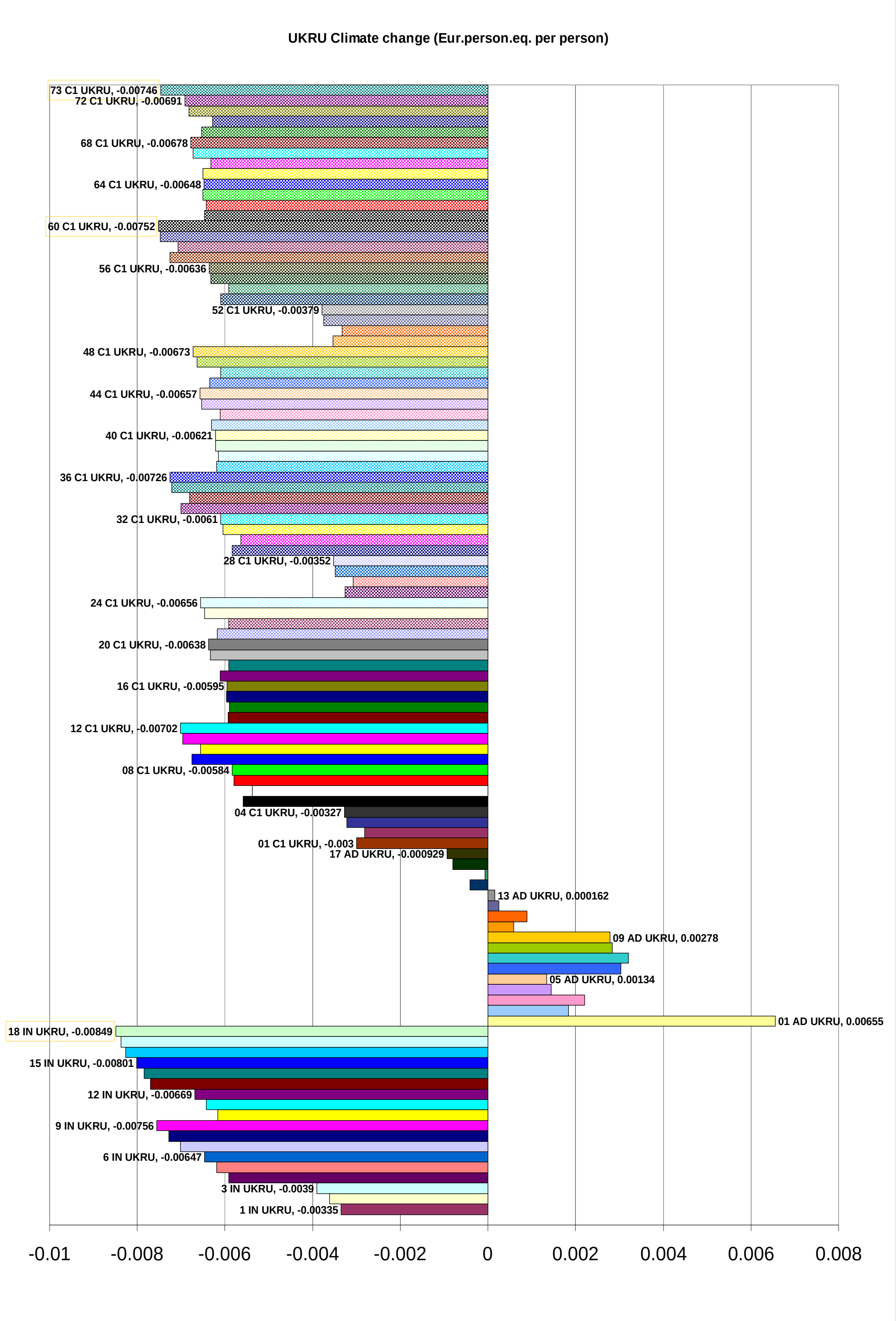


Figure 7.6 UKRU Climate Change LCIA normalisation per person

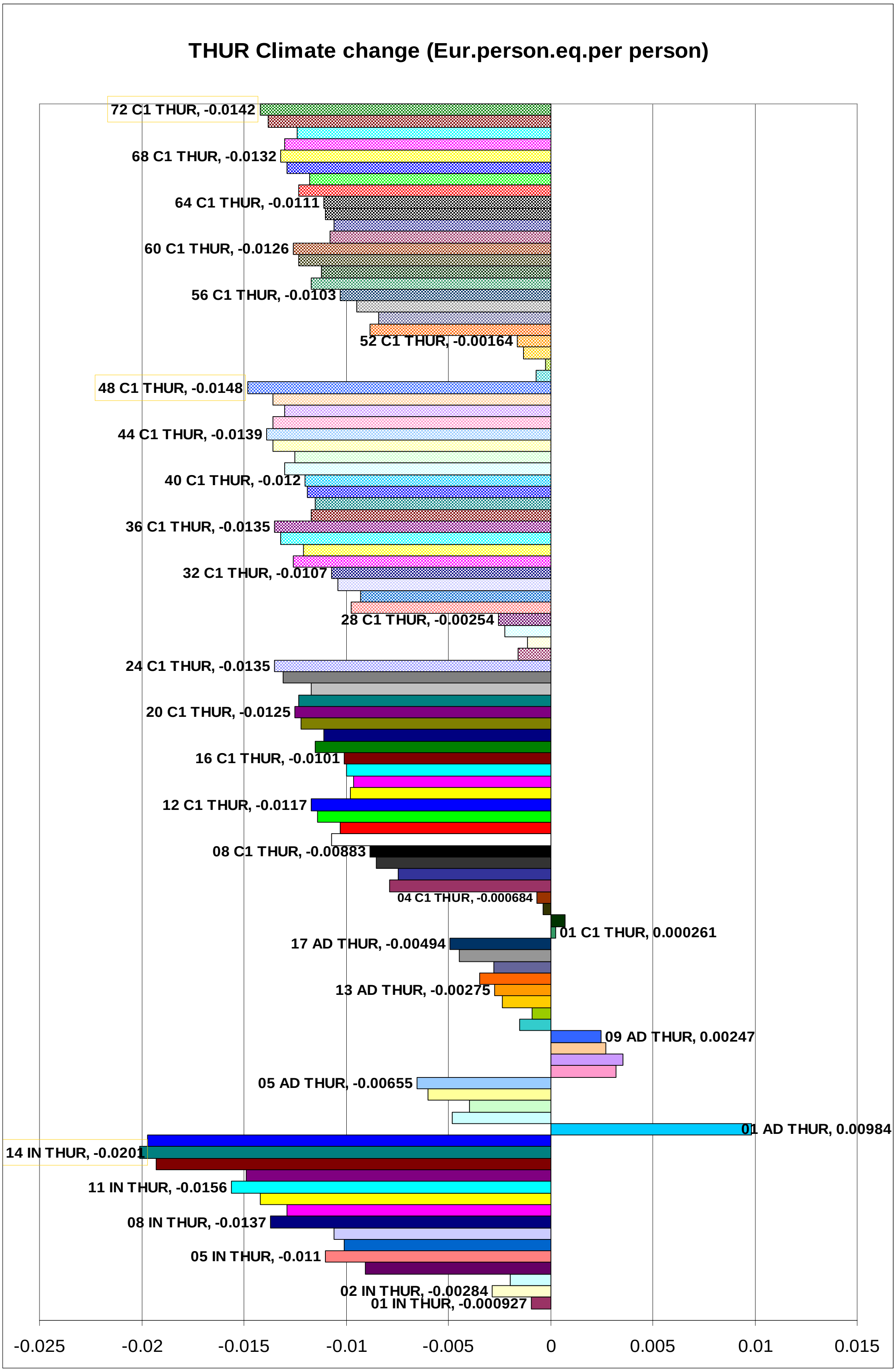


Figure 7.7 THUR Climate Change LCIA normalisation per person

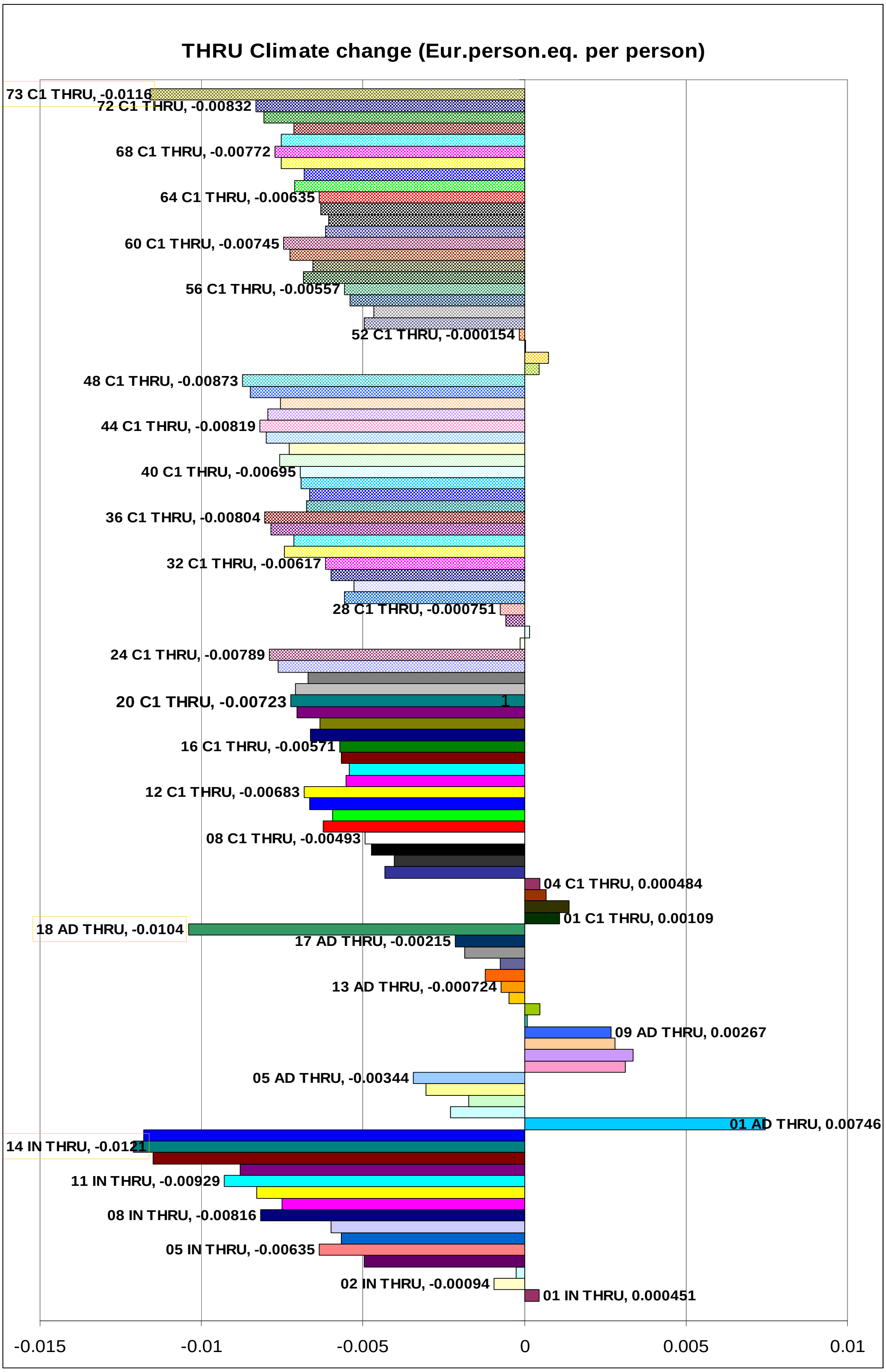


Figure 7.8 THRU Climate Change LCIA normalisation per person

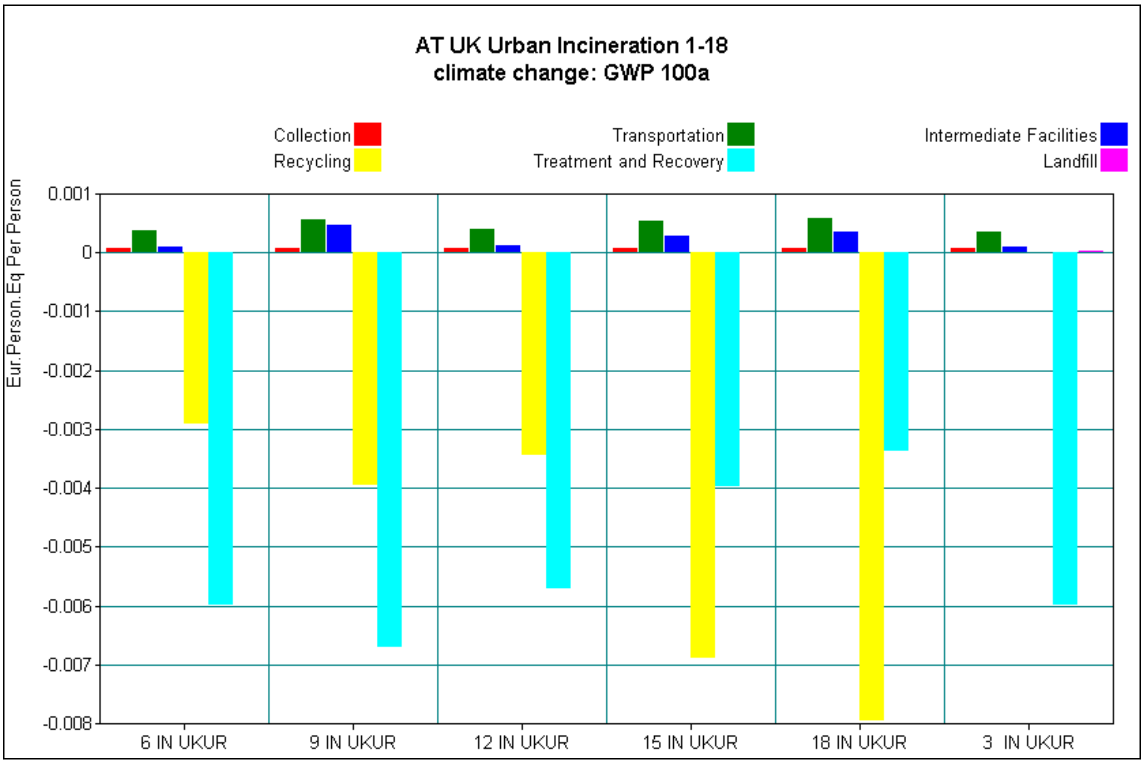


Figure 7.9 Climate change impacts for process categories -IN UKUR

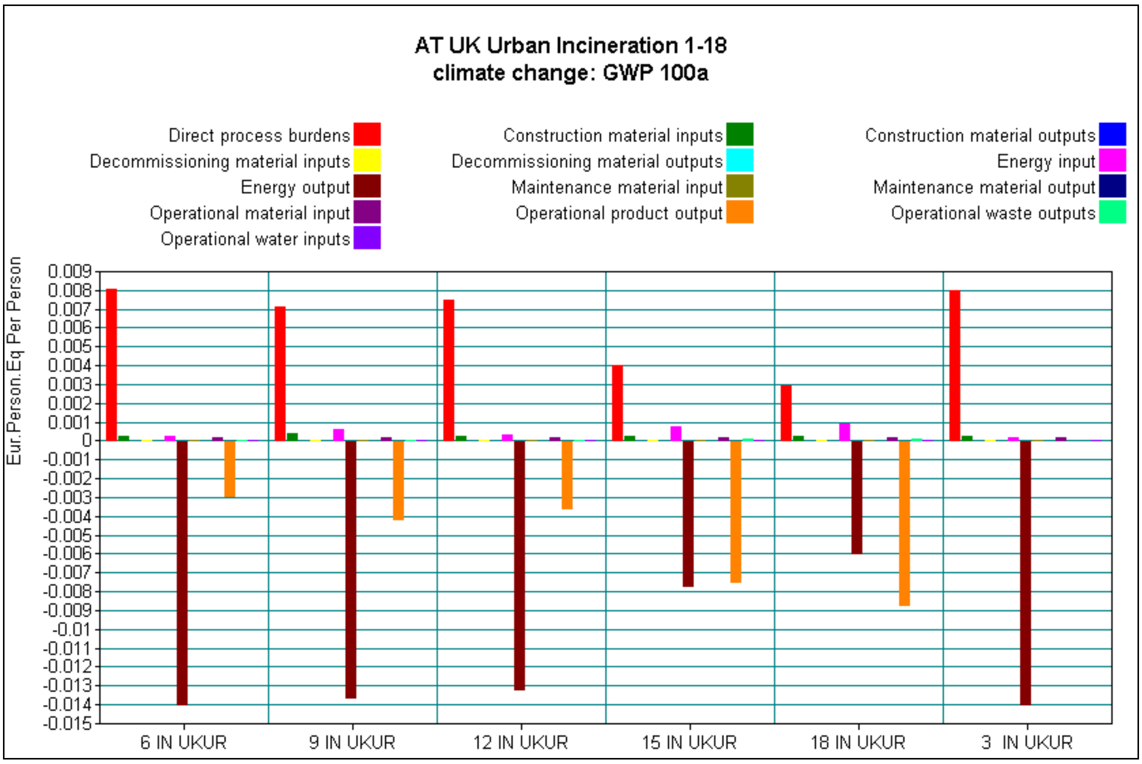


Figure 7.10 Climate change impacts for process stages -IN UKUR

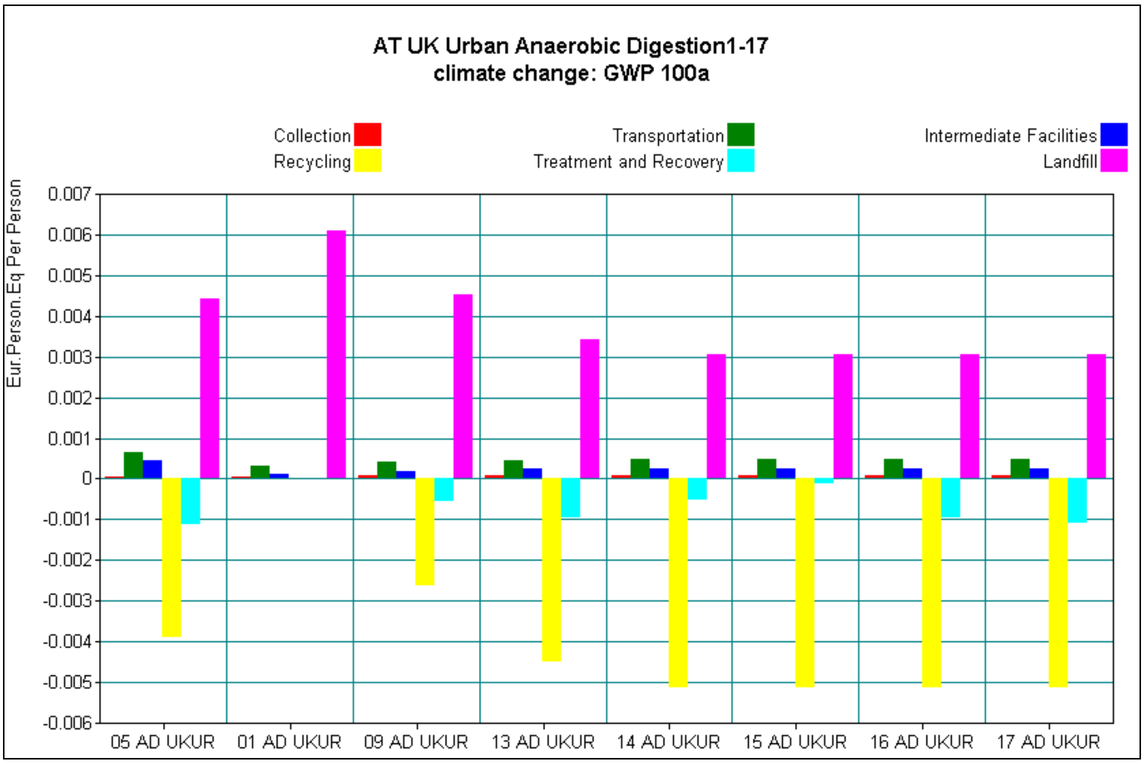


Figure 7.11 Climate change impacts for process categories -AD UKUR

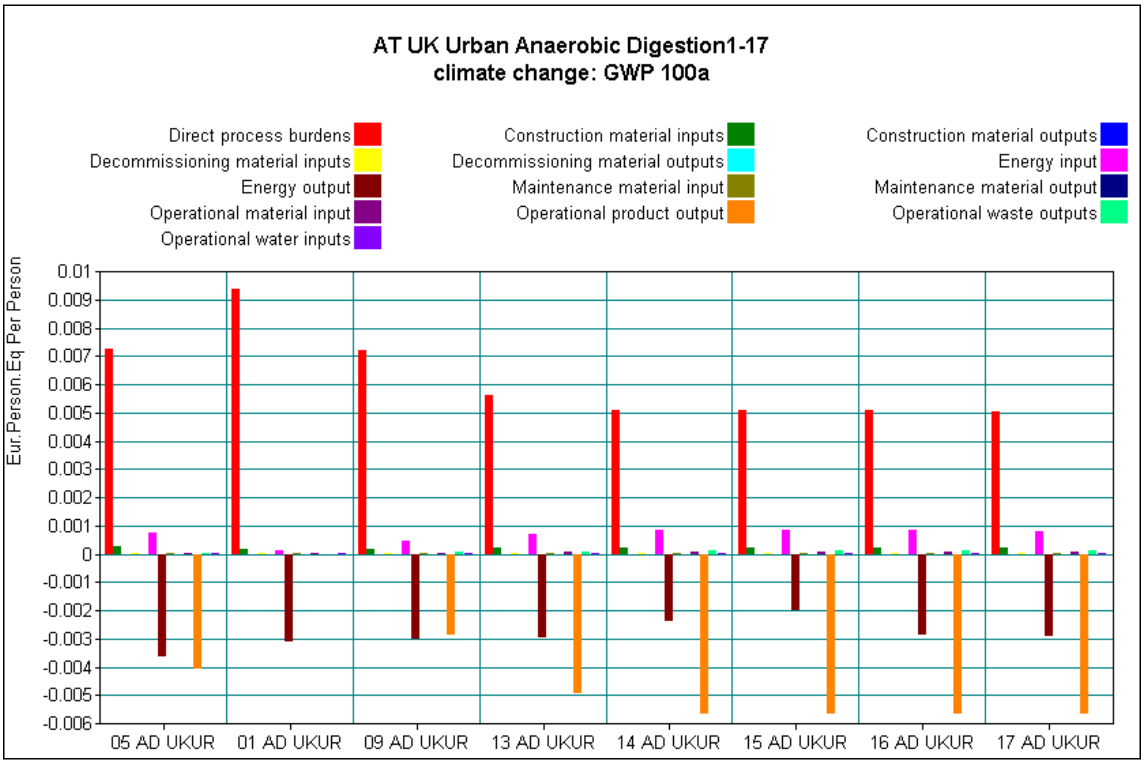


Figure 7.12 Climate change impacts for process stages -AD UKUR

7.1.3 Energy recovery results

The energy recovery results are shown in Figures 7.13 to 7.16. The results are expressed in the unit of energy (MJ) recovered per person for the period selected which is one year. The trends of the energy recovery for all four groups; UKUR, UKRU, THUR, and THRU, are very similar. The largest contributing factor is the energy recovery type for incineration. The highest amount of energy recovered is by using the heat only as the energy recovery type. From the graphs in Figures 7.10 to 7.13, the scenarios with heat only recovery, have higher energy recovery values than the others in the same recycling scheme subgroup. This is due to the selected conversion efficiency for heat recovery (90%) is much higher than that of electricity only (29%) and heat and electricity (41%). The maximum conversion efficiency values were selected in order to investigate the outcomes for the best case scenarios.

The second largest contributing factor is the recycling scheme. The subgroups of 'No recycling' and 'Post process recycling' have the same values. They both have similar amounts of energy recovery as all of the waste collected enters the incinerator therefore maximising the energy recovery amount. The rest of the recycling scheme subgroups have decreasing energy recovery amount in order of the amount of material removed from the residual waste for recycling which are post collection recycling, 25% source segregation, 43% source segregation and 50% source segregation.

The third largest contributing factor is the energy recovery type for AD for vehicle fuel. This is due to the energy recovery was from the methane produced and injected into the gas grid so there is no loss due to conversion efficiencies. The energy required for scrubbing the biogas from AD has already been accounted for. In these scenarios, the refuse collection vehicles delivering to the AD plant were using compressed natural gas (CNG) in order to account for the emissions from using methane in vehicles.

The trends are the same whether comparing between urban and rural areas or comparing between an economically developed country and a lesser economically developed country. The scenarios having the highest energy recovery for all four groups, UKUR, UKRU, THUR and THRU are '28 C1 Incineration for heat and Anaerobic Digestion for vehicle fuel with no recycling' and '32 C1 Incineration for heat and Anaerobic Digestion for vehicle fuel with post process recycling'. The energy recovered per person for the rural areas in both countries are close at 2,291.2 MJ for scenario 28 C1 UKRU and 2,337.5 MJ for scenario 28 C1 THRU. However the energy recovered per person for the urban areas in Thailand is much higher than in UK at 3,515.3 MJ for scenario 28 C1 THUR and 2,620 MJ for scenario 28 C1 UKUR.

From these results local authorities decide on their energy recovery options. If the priority for a local authority is only to generate the most energy as possible then scenarios with the energy recovery type for incineration for heat only would be selected. These local authorities would need to have a constant demand for heat throughout the year to maximise the benefit of generating the most energy such as district heating and use in local industry. It is noted that district heating in urban areas with cold climate regions would not require the same amount of heat energy throughout the year. For regions with tropical climates, district heating is not required rather district cooling using absorption refrigerator would be more appropriate. Utilising the heat in the local industry which demands a constant supply of heat would be beneficial. The second best option of energy recovery type is incineration for heat and electricity, and the third best is incineration for electricity.

Also sending as much combustible waste as possible to the incinerator to recover energy from these materials would maximise the energy recovered. The local authority would also have to convert the methane from the AD process to vehicle fuel and utilise the methane in the vehicles in their area.

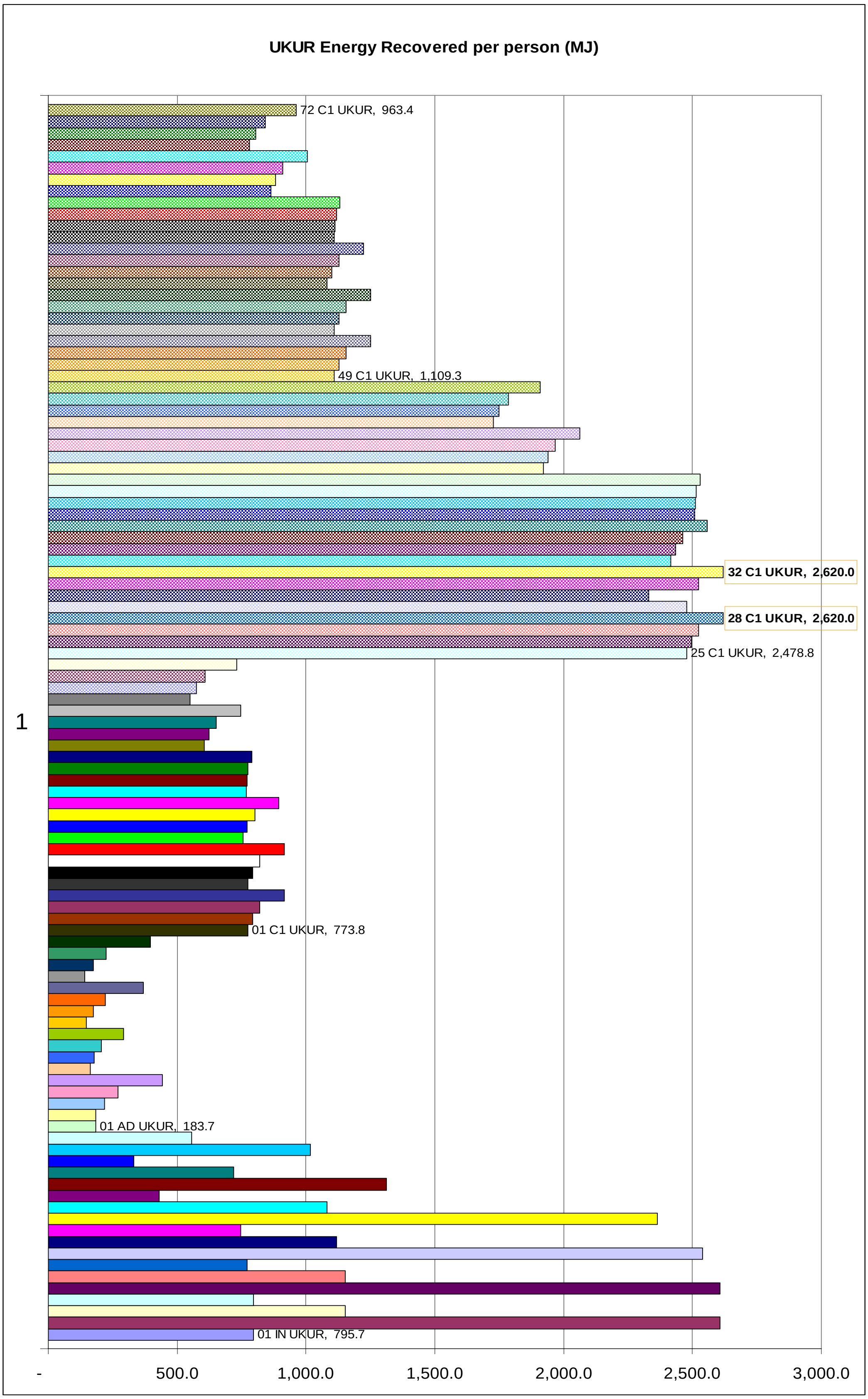


Figure 7.13 UKUR Energy Recovered per person

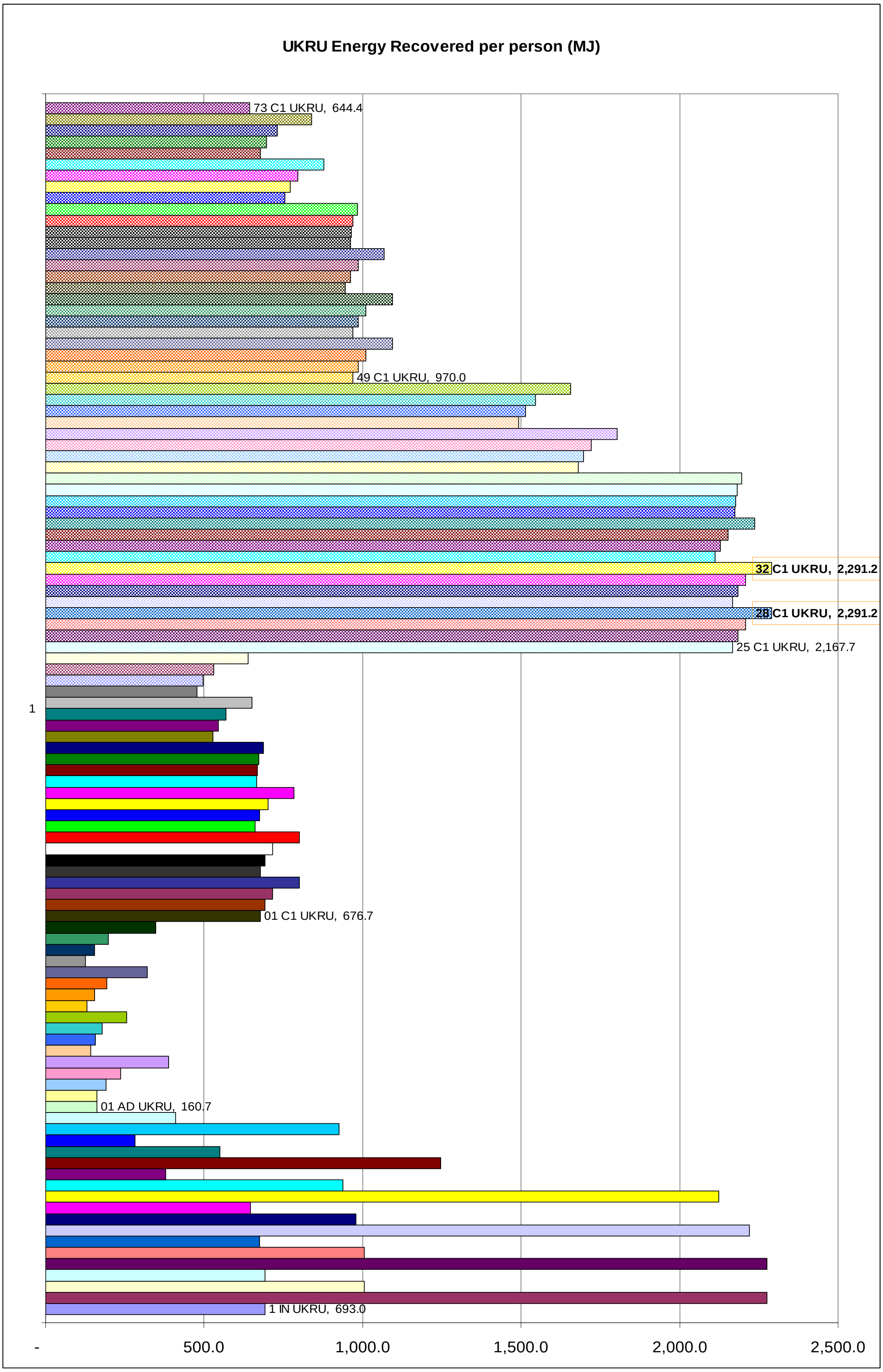


Figure 7.14 UKRU Energy Recovered per person

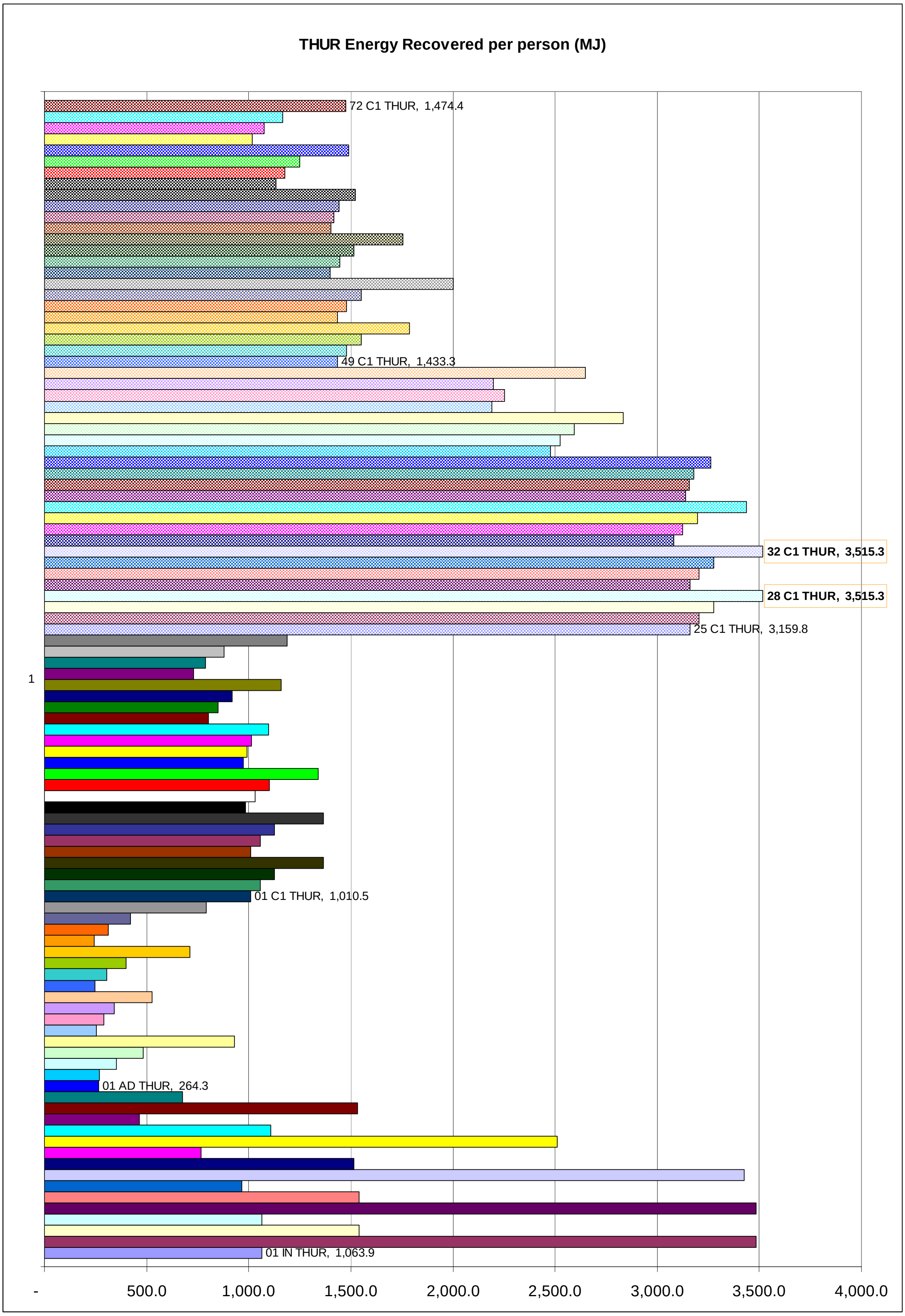


Figure 7.15 THUR Energy Recovered per person

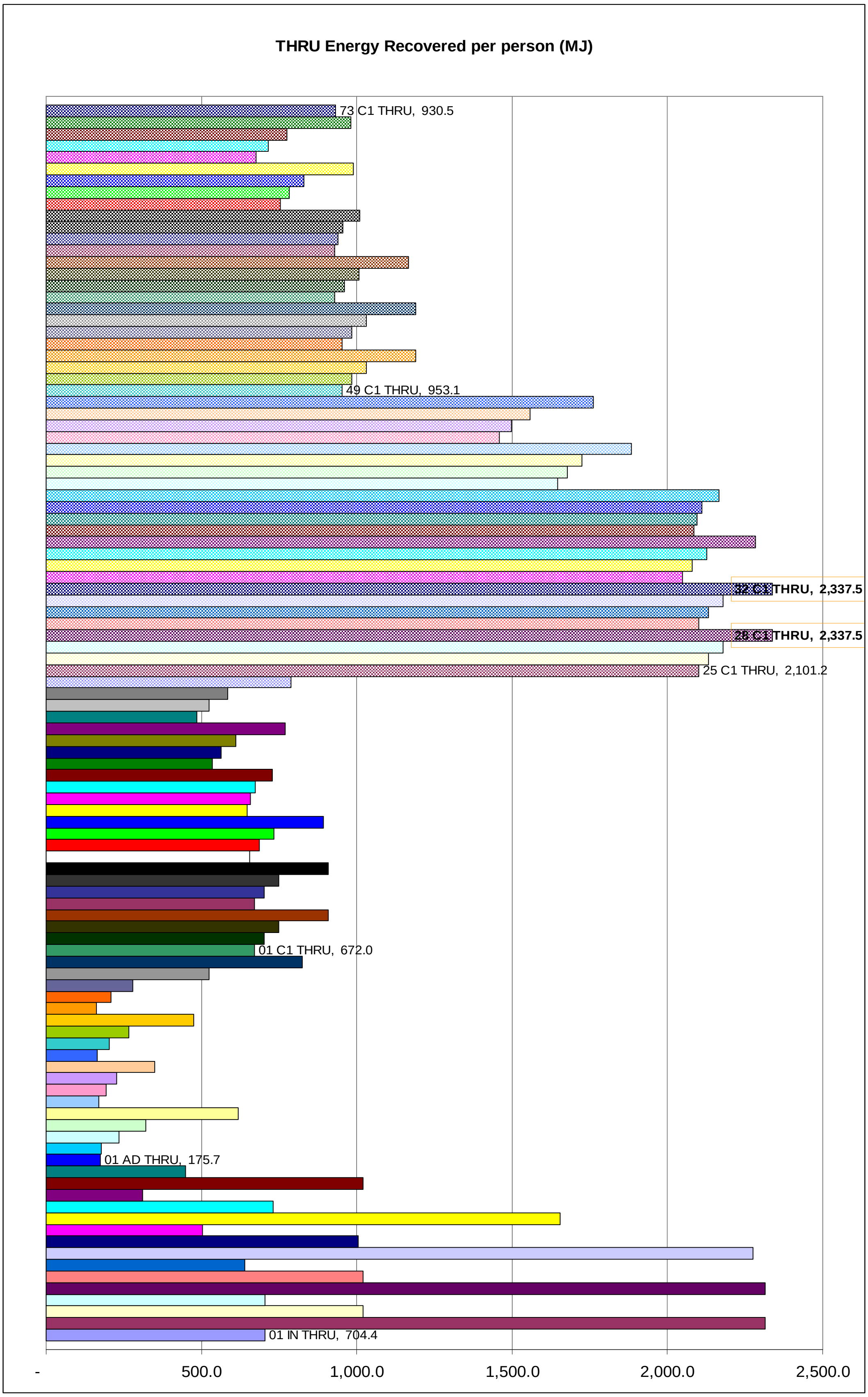


Figure 7.16 THRU Energy Recovered per person

7.2 Ranking

For an LCA study, according to ISO 14044: Environmental Management-Life Cycle Assessment-Requirements and Guidelines, optional LCIA elements include normalisation, grouping, weighting and data quality analysis (ISO, 2006b). The steps for weighting and grouping are based on value choices where different organization and societies may have different preferences and the weighting results may be different based on the same LCIA characterisation results. Therefore the application of these elements must provide transparent methods and calculations. Only LCA studies used in comparative assertions intended to be disclosed to the public shall not use weighting (ISO, 2006b).

This research is a theoretical exercise based on hypothetical locations in order to explore the environmental impacts and energy generated by different WtE technology and to design a simple decision-making tool. This research is not intended to be disclosed to the public as a comparative assertion of a specific location or specific technology. The ranking method proposed in this research uses a weighting method, an optional step in LCA, to provide a ranking of scenarios for the simple decision-making tool.

7.2.1 Ranking method

The method to prioritise the LCIA results of the scenarios in each of the country/population density group is by ranking. Table 7.1 shows an example of the ranking calculations. For each group all the scenarios (V,W,X,Y,Z) are listed together with the values for the impact assessments such as impact assessment 1 (column A) and impact assessment 2 (column C). The scenarios are ranked according to the best performance which is represented by having the most negative value for each impact assessment. Column B is the ranking for impact assessment 1 and column D is the ranking for impact assessment 2. Then the ranking for all impact assessments are averaged in column E and a combined LCIA ranking in column F was determined from the average in column E by ranking from the smallest number to the largest number. For this example scenario Z has a combined ranking of 1. Table 7.2 shows the top 3 rankings of the combined LCIA. A full list of ranking results is given in Appendix E.

Table 7.1 Example of ranking calculations

scenarios	**A** **Impact assessment 1**	**B** **Ranking for impact assessment 1**	**C** **Impact assessment 2 value**	**D** **Ranking for impact assessment 2**	**E** **Average ranking (B+D/number of impact assessments)**	**F** **Combined Ranking (rank E in order from small to large number)**
V	*-20*	2	*-3*	3	2.5	**3**
W	*-15*	3	*-8*	1	2	**2**
X	*-3*	5	*3*	5	5	**5**
Y	*-10*	4	*-2*	4	4	**4**
Z	*-30*	1	*-5*	2	1.5	**1**

By using this method, all six environmental problems have the same weight, thus giving importance to all problems equally. The advantage is that the resulting ranking will show the scenario which is an 'all rounder', a scenario that performs well in all impact assessments. The disadvantage is that it disregards the magnitude of the impact between impact assessments. If this ranking method was not applied then in this research the LCIA values for 'resource depletion' impact assessments would dominate (four - twenty times larger than other impact assessments) and the best performing scenario in 'resource depletion' impact assessment would be prioritised as number one. If any local authority wants to only select three out of six impact assessments then the average ranking is calculated by dividing by three.

7.2.2 Combined LCIA ranking

The high ranking scenario for UKUR is 09 IN and for UKRU is 60 C1. Both scenarios have the same energy recovery type (heat and electricity) and the same recycling scheme (post collection recycling). For THUR and THRU the high ranking scenarios are both 14 IN which have 100% recycling materials capture rate. The additional scenario 73 C1, ranked third, also has 100% recycling materials capture rate. For source segregation scenarios to rank higher than post collection recycling scenarios the capture rate must be very high to almost approaching 100% so that the amount of materials recycled can offset the burdens in transportation and sorting or the efficiency of the MRF is lower.

Table 7.2 Top 3 Ranking of combined LCIA

scenario code	**scenario name**	climate change	acidification	eutrophication	freshwater aquatic ecotoxicity	human toxicity	resources	average	combined
UKUR									
09 IN UKUR	Incineration for heat and electricity Post collection recycling	5	31	24	7	8	1	12.67	1
60 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	6	41	28	1	6	2	14.00	2
07 IN UKUR	Incineration for electricity Post collection recycling	18	29	17	9	14	13	16.67	3
UKRU									
60 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	8	18	8	1	6	12	8.83	1
09 IN UKRU	Incineration for heat and electricity Post collection recycling	7	27	19	7	9	2	11.83	2
18 IN UKRU	Incineration for heat and electricity Source segregation 50% RR	1	2	2	52	16	1	12.33	3
THUR									
14 IN THUR	Incineration for heat Source segregation 34% RR	1	1	3	18	16	1	6.667	1
15 IN THUR	Incineration for heat and electricity Source segregation 34% RR	2	2	2	17	17	2	7.000	2
13 IN THUR	Incineration for electricity Source segregation 34% RR	3	3	1	16	18	3	7.333	3
THRU									
14 IN THRU	Incineration for heat Source segregation 34% RR	1	1	1	19	17	1	6.67	1
15 IN THRU	Incineration for heat and electricity Source segregation 34% RR	2	2	2	18	18	2	7.33	2

scenario code	scenario name	climate change	acidification	eutrophication	freshwater aquatic ecotoxicity	human toxicity	resources	average	combined
73 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 93% RR 100 % capture rate	3	4	4	13	16	4	7.33	2
13 IN THRU	Incineration for electricity Source segregation 34% RR	4	3	3	17	19	3	8.17	4

7.2.3 Combined LCIA and energy recovered ranking

The decision for WTE management options sometimes is to balance between the most energy recovered and the least environmental impacts. In order to consider equally the energy recovered and the impacts on the environment of each scenario a combined LCIA and energy recovered ranking is required. The energy recovered values for the scenarios in each of the country/population density group is ranked with the highest amount of energy recovered ranked as number 1. Then this ranking is averaged with the combined LCIA ranking to determine the combined LCIA and energy recovered ranking. This method gives energy recovered ranking the same weight as all six environmental problems together. However with a reverse point of view, a single impact assessment is worth only 1/6 in weight compared to the energy recovered. Table 7.3 shows the top 3 ranking of the combined LCIA and energy recovered.

The high ranking scenarios for UKUR and UKRU are similar with scenarios 08 IN, 36 C1, and 60 C1 for UKUR and scenarios 36 C1, 08 IN, and 60 C1 for UKRU. These scenarios have the same energy recovery type (heat for incineration and vehicle fuel for AD) and the same recycling scheme (post collection recycling). For THUR and THRU the high ranking scenarios are also similar with scenarios 08 IN, 35C1, and 36 C1 for THUR and scenarios 35C1, 08 IN, and 36 C1 for THRU. These scenarios have the same energy recovery type (heat for incineration and vehicle fuel for AD) and the same recycling scheme (post collection recycling).

Table 7.3 Top 3 Ranking of combined LCIA and energy recovered for UKUR

scenario code	**scenario name**	Energy Ranking	combined LCIA ranking	average	combined energy and LCIA ranking
UKUR					
08 IN UKUR	Incineration for heat Post collection recycling	6	17	11.5	1
36 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	5	19	12	2
60 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	32	2	17	3
UKRU					
36 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	16	5	10.50	1
08 IN UKRU	Incineration for heat Post collection recycling	19	6	12.50	2
60 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	1	32	16.50	3
THUR					
08 IN THUR	Incineration for heat Post collection recycling	8	6	7.000	1
36 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	10	5	7.500	2
35 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	16	12	14.000	3
THRU					
36 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	5	5	5.00	1
08 IN THRU	Incineration for heat Post collection recycling	6	6	6.00	2
35 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	12	12	12.00	3

7.2.4 Climate change LCIA and energy recovered ranking

Different countries and local authorities may not give the same importance to all six environmental problems. A single impact assessment can be ranked and combined with the energy recovered ranking. Climate change is a global concern and many countries and local authorities have targets to reduce their carbon emissions. In this study, the climate change

LCIA and energy recovered ranking is presented. This particular ranking is determining the scenarios with the most energy recovered yet has the least climate change impact. The energy recovered values are the amount of energy generated by the processes in the scenario (MJ). The ranking will be prioritised by the higher the amount of energy. The climate change impact assessment is calculated from all the GHG emissions released or as offsets associated with the activities in the scenario, including energy use and produced. The ranking is prioritised by the most negative value of the impact assessment. This calculation is not double counting as it is concerned with different aspects of the energy issue. Table 7.4 shows the top 3 ranking of combined climate change and energy recovered.

Table 7.4 Top 3 Ranking of combined climate change and energy recovered for UKUR

scenario code	**scenario name**	Energy Ranking	Climate change ranking	average	combined energy and LCIA ranking
UKUR					
36 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	5	9	7	1
08 IN UKUR	Incineration for heat Post collection recycling	6	10	8	2
35 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	16	12	14	3
UKRU					
08 IN UKRU	Incineration for heat Post collection recycling	11	6	8.50	1
36 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	12	5	8.50	1
35 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	14	17	15.50	3
14 IN UKRU	Incineration for heat Source segregation 43% RR	5	29	17.00	4
THUR					
08 IN THUR	Incineration for heat Post collection recycling	11	6	8.500	1
36 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	16	5	10.500	2
48 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	6	21	13.500	3

THRU					
08 IN THRU	Incineration for heat Post collection recycling	13	6	9.50	1
36 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	15	5	10	2
48 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	8	21	14.50	3

The high ranking scenarios for UKUR and UKRU are similar with the scenarios 36 C1, 08 IN, and 35C1 for UKUR and scenarios 08 IN, 36 C1, and 35C1 for UKRU. These scenarios have the same energy recovery type (heat for incineration and vehicle fuel for AD) and the same recycling scheme (post collection recycling). For THUR and THRU the high ranking scenarios are the same with the scenarios 08 IN, 36 C1, and 48 C1. The have the same energy recovery type (heat for incineration and vehicle fuel for AD) and common recycling scheme (post collection recycling).

7.3 Phase two conclusions

7.3.1 LCIA conclusions

- Life Cycle Assessment with WRATE software of energy recovery from household solid waste through incineration and AD the parameters exerting the greatest influence in order are;

  1. WtE technology type.

  Among the WtE technology, Incineration only scenarios are comparable to combination of incineration and AD scenarios. AD only scenarios have the most burdens due to sending residual waste to the landfill.

  2. Recycling scheme with different recycling rate as a subset.

  For recycling schemes, scenarios with post collection recycling performs the best with source segregation sometimes have similar values if the recycling rate is high with a high recycling material capture rate.

  3. Energy Recovery type.

  For energy recovery type, scenarios with incineration for heat only perform the best for energy recovered related assessment and incineration for heat and electricity perform the best for LCIA. For AD scenarios with vehicle fuel performs the best.

  4. Population density also affects the outcome slightly by the magnitude of the values.

5. Electricity mix and waste composition is the main varying parameter that WRATE uses to calculate the LCIA thus both parameter greatly affect the results.

- The ‘resources depletion’ impact assessments have significantly higher impacts than the other impact assessments.
- For climate change impact assessments;
  - Most of scenarios have large negative values indicating offsets due to the large amount of recycling and energy recovered.
  - Many scenarios with no recycling in Thailand have net burdens to the environment due to the high amount of organic waste fraction. The benefits of diverting organic waste to AD is not enough to offset the impacts from the additional activities of collecting organic waste separately in a rural town with a large and low population density area in Thailand.
  - The best performing scenarios for climate change LCIA in each group are;
    - ❖ 18 IN UKUR incineration for heat and electricity 50% RR,
    - ❖ 18 IN UKRU incineration for heat and electricity 50% RR,
    - ❖ 14 IN THUR incineration for heat 34% RR,
    - ❖ 14 IN THRU incineration for heat 34% RR
- For energy recovery the largest contributing factors are energy recovery type and recycling scheme.
  - The scenarios having the highest energy recovery for all four groups, UKUR, UKRU, THUR and THRU are the same two scenarios; ‘28 C1 Incineration for heat and Anaerobic Digestion for vehicle fuel with no recycling’ and ‘32 C1 Incineration for heat and Anaerobic Digestion for vehicle fuel with post process recycling’.

Further findings include;

- The discovery that for source segregation scenarios to perform better than post collection recycling scenarios the recycling materials capture rate must be very high to almost approaching 100% so that the amount of materials recycled can offset the burdens in transportation and sorting. Also if the efficiency of the ‘dirty’ MRF is lower in the post collection recycling scenarios then the offsets will be less than the source segregation scenarios recycling offsets.

- With full participation, the maximum recycling rate possible would be slightly above 50% in the UK and only 34% in Thailand by recycling only the dry recyclates (paper, plastic, glass and metals). If organic waste is utilised whether by composting or AD in addition to recycling dry recyclates the maximum recycling rate possible would be 80% in the UK and 93% in Thailand.

7.3.2 Ranking conclusions

The ranking method proposed in this research uses a weighting method, an optional step in LCA, to provide a ranking of scenarios for the simple decision-making tool.

The highest ranking scenarios for combined LCIA in each group are;

- 09 IN UKUR Incineration for heat and electricity Post collection recycling
- 60 C1UKRU Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling
- 14 IN THUR Incineration for heat Source segregation 34% RR
- 14 IN THRU Incineration for heat Source segregation 34% RR

The highest ranking scenarios for combined LCIA and energy recovered in each group are;

- 08 IN UKUR Incineration for heat Post collection recycling
- 36 C1 UKRU Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling
- 08 IN THUR Incineration for heat Post collection recycling
- 36 C1 THRU Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling

The highest ranking scenarios for climate change LCIA and energy recovered in each group are;

- 36 C1 UKUR Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling
- 08 IN UKRU Incineration for heat Post collection recycling
- 08 IN THUR Incineration for heat Post collection recycling
- 08 IN THRU Incineration for heat Post collection recycling

Chapter 8

Decision making matrix

8.1 Design of Decision making matrix based on LCIA

The results from the LCA study and the subsequent ranking is compiled into a database using Microsoft Excel worksheet. The full Decision making matrix is presented in Table F1, the background information is in Table F2, the energy mix is in Table F3 and F4 and the waste composition is in Table F5 shown in appendix F respectively.

8.1.1 Options for selection criteria

The first part of the Decision making matrix is the different options for selection criteria, shown in Figure 8.1. The data for each scenario in entered for the various criteria. An automatic filter function is applied to the headings of the columns of each criterion. A triangular button is shown for the user to click and select their options. By selecting from left to right the database is filtered until a single scenario or a set of scenarios are left for the user to study. Here the local authorities as intended users can select the options corresponding to their situation. The options for each selection criteria are as follows;

Country:

- UK
- Thailand

Population Density:

- Urban
- Rural

Combination of WtE:

- Incineration only
- Anaerobic Digestion only
- Incineration and Anaerobic Digestion

Energy type for Incineration:

- electricity
- heat
- heat and electricity

Energy type for Anaerobic Digestion:

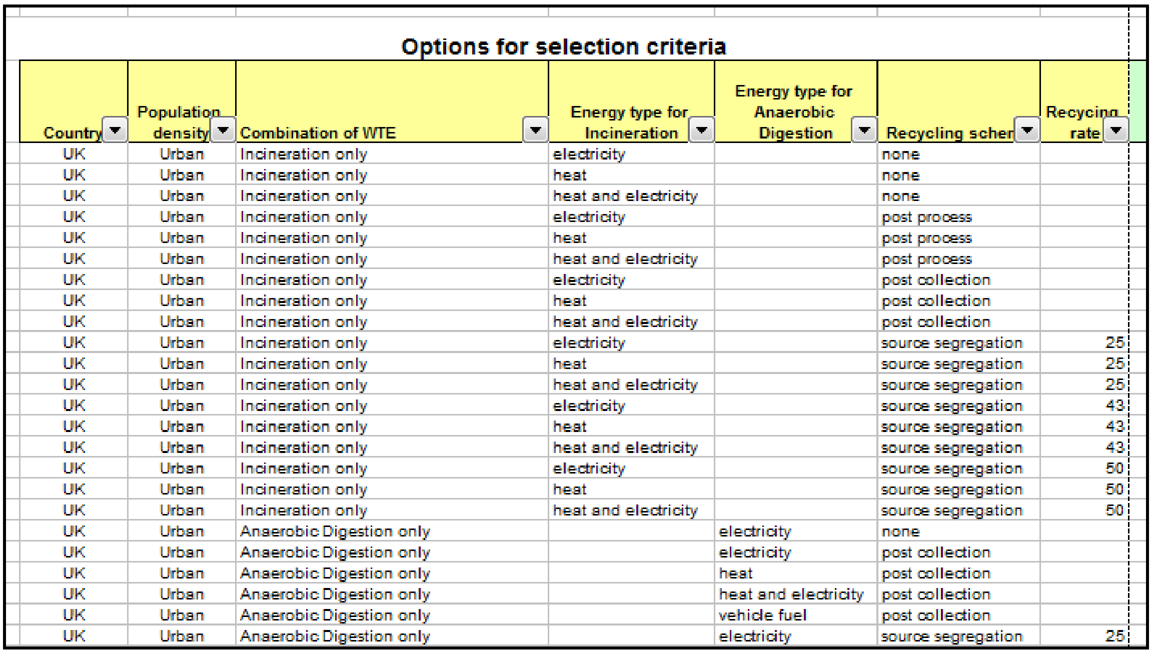
- electricity
- heat
- heat and electricity
- vehicle fuel

Recycling Scheme:

- No recycling
- Post process
- Post collection
- Source Segregation

Recycling Rate:

- 25%
- 43%
- 50%
- 80% (only for the scenario 73 C1 UKRU)
- 93%(only for the scenarios 18 AD THRU and 73 C1 THRU)



Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scher	Recycing rate
UK	Urban	Incineration only	electricity		none	
UK	Urban	Incineration only	heat		none	
UK	Urban	Incineration only	heat and electricity		none	
UK	Urban	Incineration only	electricity		post process	
UK	Urban	Incineration only	heat		post process	
UK	Urban	Incineration only	heat and electricity		post process	
UK	Urban	Incineration only	electricity		post collection	
UK	Urban	Incineration only	heat		post collection	
UK	Urban	Incineration only	heat and electricity		post collection	
UK	Urban	Incineration only	electricity		source segregation	25
UK	Urban	Incineration only	heat		source segregation	25
UK	Urban	Incineration only	heat and electricity		source segregation	25
UK	Urban	Incineration only	electricity		source segregation	43
UK	Urban	Incineration only	heat		source segregation	43
UK	Urban	Incineration only	heat and electricity		source segregation	43
UK	Urban	Incineration only	electricity		source segregation	50
UK	Urban	Incineration only	heat		source segregation	50
UK	Urban	Incineration only	heat and electricity		source segregation	50
UK	Urban	Anaerobic Digestion only		electricity	none	
UK	Urban	Anaerobic Digestion only		electricity	post collection	
UK	Urban	Anaerobic Digestion only		heat	post collection	
UK	Urban	Anaerobic Digestion only		heat and electricity	post collection	
UK	Urban	Anaerobic Digestion only		vehicle fuel	post collection	
UK	Urban	Anaerobic Digestion only		electricity	source segregation	25

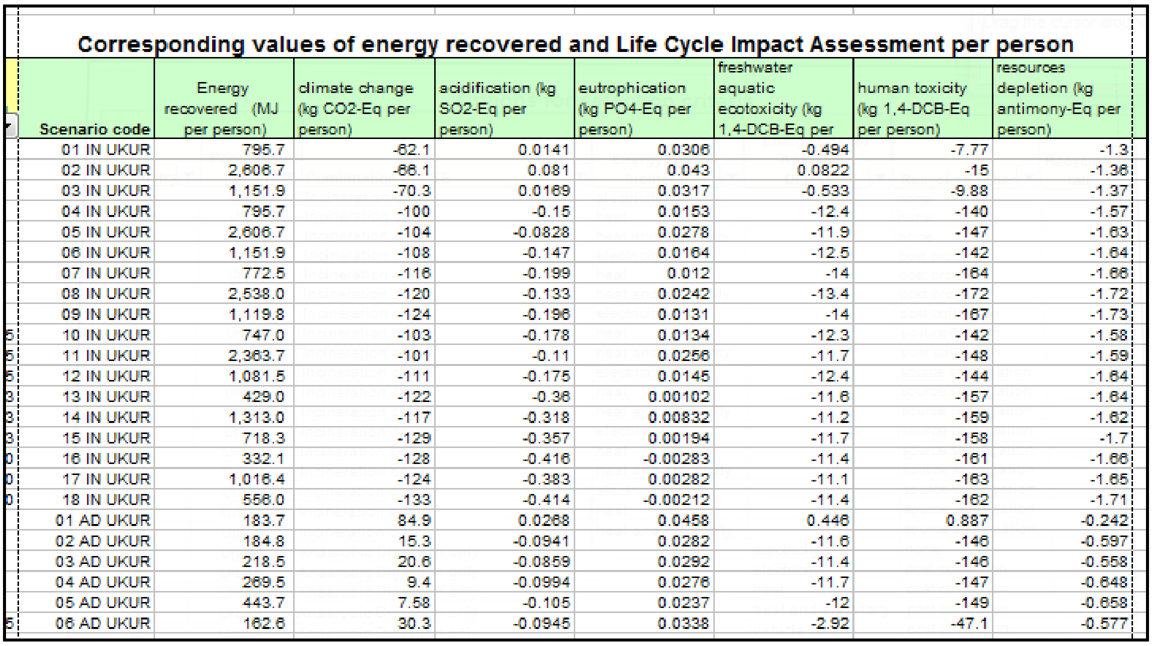
Figure 8.1 View of the Options for selection criteria

8.1.2 Values of Energy Recovered and Life Cycle Impact Assessment

The second part of the Decision making matrix is the corresponding values of the energy recovered and the 6 Life Cycle Impact Assessment (LCIA). The 6 LCIA are as follow;

1) Climate change, GWP (Global Warming Potential)
2) Acidification potential
3) Eutrophication potential
4) Fresh water aquatic ecotoxicity
5) Human toxicity
6) Resources depletion of abiotic resources

The values are in units of the LCIA relevant substance equivalents per person in order for the scenario data to be comparable between countries and population density types. Even though the values may not be the exact value for each individual local authority but the values will be useful for ranking if only one LCIA is prioritised such as climate change.



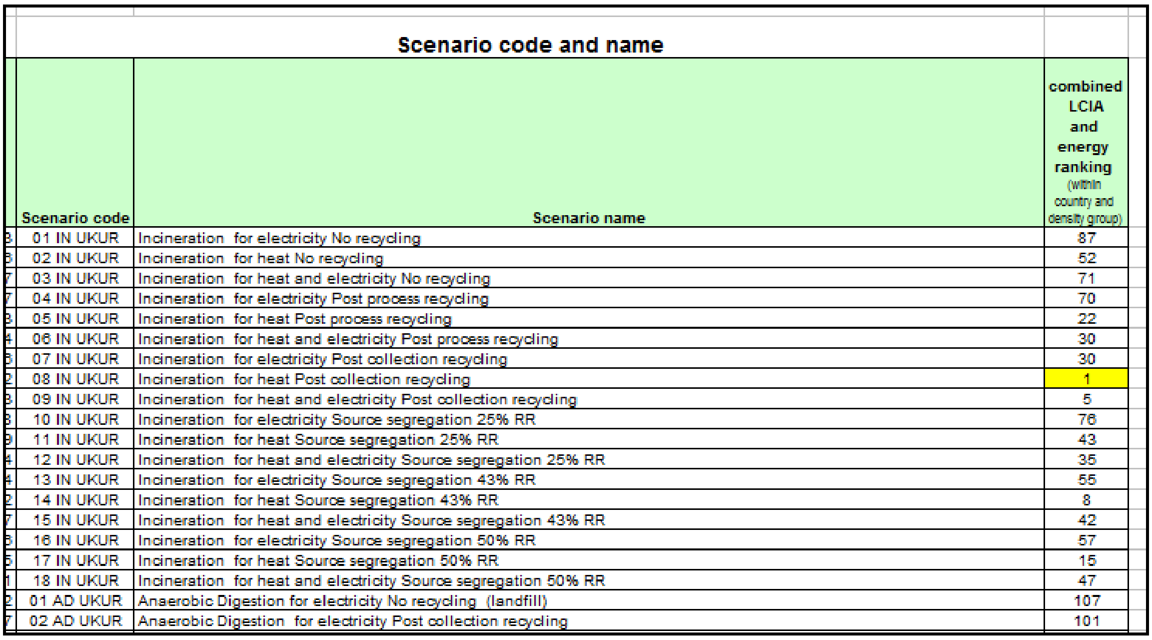
Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
01 IN UKUR	795.7	-62.1	0.0141	0.0306	-0.494	-7.77	-1.3
02 IN UKUR	2,606.7	-66.1	0.081	0.043	0.0822	-15	-1.36
03 IN UKUR	1,151.9	-70.3	0.0169	0.0317	-0.533	-9.88	-1.37
04 IN UKUR	795.7	-100	-0.15	0.0153	-12.4	-140	-1.57
05 IN UKUR	2,606.7	-104	-0.0828	0.0278	-11.9	-147	-1.63
06 IN UKUR	1,151.9	-108	-0.147	0.0164	-12.5	-142	-1.64
07 IN UKUR	772.5	-116	-0.199	0.012	-14	-164	-1.66
08 IN UKUR	2,538.0	-120	-0.133	0.0242	-13.4	-172	-1.72
09 IN UKUR	1,119.8	-124	-0.196	0.0131	-14	-167	-1.73
10 IN UKUR	747.0	-103	-0.178	0.0134	-12.3	-142	-1.58
11 IN UKUR	2,363.7	-101	-0.11	0.0256	-11.7	-148	-1.59
12 IN UKUR	1,081.5	-111	-0.175	0.0145	-12.4	-144	-1.64
13 IN UKUR	429.0	-122	-0.36	0.00102	-11.6	-157	-1.64
14 IN UKUR	1,313.0	-117	-0.318	0.00832	-11.2	-159	-1.62
15 IN UKUR	718.3	-129	-0.357	0.00194	-11.7	-158	-1.7
16 IN UKUR	332.1	-128	-0.416	-0.00283	-11.4	-161	-1.66
17 IN UKUR	1,016.4	-124	-0.383	0.00282	-11.1	-163	-1.65
18 IN UKUR	556.0	-133	-0.414	-0.00212	-11.4	-162	-1.71
01 AD UKUR	183.7	84.9	0.0268	0.0458	0.446	0.887	-0.242
02 AD UKUR	184.8	15.3	-0.0941	0.0282	-11.6	-146	-0.597
03 AD UKUR	218.5	20.6	-0.0859	0.0292	-11.4	-146	-0.558
04 AD UKUR	269.5	9.4	-0.0994	0.0276	-11.7	-147	-0.648
05 AD UKUR	443.7	7.58	-0.105	0.0237	-12	-149	-0.658
06 AD UKUR	162.6	30.3	-0.0945	0.0338	-2.92	-47.1	-0.577

Figure 8.2 View of the values of energy recovered and LCIA

8.1.3 Scenario code and name and combined ranking

The third part of the Decision making matrix is the associated scenario code and name and the corresponding combined ranking. The highest rank is number 1 and as the ranking number increases the priority decreases. A screen captured view is shown in Figure 8.3.



Scenario code and name

Scenario code	Scenario name	combined LCIA and energy ranking (within country and density group)
01 IN UKUR	Incineration for electricity No recycling	87
02 IN UKUR	Incineration for heat No recycling	52
03 IN UKUR	Incineration for heat and electricity No recycling	71
04 IN UKUR	Incineration for electricity Post process recycling	70
05 IN UKUR	Incineration for heat Post process recycling	22
06 IN UKUR	Incineration for heat and electricity Post process recycling	30
07 IN UKUR	Incineration for electricity Post collection recycling	30
08 IN UKUR	Incineration for heat Post collection recycling	1
09 IN UKUR	Incineration for heat and electricity Post collection recycling	5
10 IN UKUR	Incineration for electricity Source segregation 25% RR	76
11 IN UKUR	Incineration for heat Source segregation 25% RR	43
12 IN UKUR	Incineration for heat and electricity Source segregation 25% RR	35
13 IN UKUR	Incineration for electricity Source segregation 43% RR	55
14 IN UKUR	Incineration for heat Source segregation 43% RR	8
15 IN UKUR	Incineration for heat and electricity Source segregation 43% RR	42
16 IN UKUR	Incineration for electricity Source segregation 50% RR	57
17 IN UKUR	Incineration for heat Source segregation 50% RR	15
18 IN UKUR	Incineration for heat and electricity Source segregation 50% RR	47
01 AD UKUR	Anaerobic Digestion for electricity No recycling (landfill)	107
02 AD UKUR	Anaerobic Digestion for electricity Post collection recycling	101

Figure 8.3 View of the scenario code and name and combined ranking

8.2 Case Study: Phuket, Thailand

8.2.1 Background Information

Phuket province is situated in the southern region of Thailand. The province is an island in the Andaman Sea part of the Indian Ocean on the west coast of Thailand. The natural beauty of tropical forest hills, white sands and coral reefs are a great attraction for tourists from all around the world. Part of Phuket was also devastated in the 2004 Boxing day Tsunami. The main economic activities are tourism, agriculture, industry and some tin mining which was formerly the main economic activity.

The area of Phuket is 543 km^2. In 2011, the registered Thai population is 351,909 with an unregistered population estimated at 103,895. There is also a register for foreign workers population at 136,136 (Phuket Provincial Governor's Office, 2013). In 2008 the number of tourists visiting Phuket reached 5,000,653 with an average stay period of 5 days (Consultants of Technology, 2011). This could be calculated as an averaged tourist population of 68,502 per day (73 lots of 5 days stays) contributing to waste generation in Phuket. Altogether the waste generating population in Phuket can be estimated at 660,442. Thus for this study the population density is estimated at 1,216.3 person per km^2. The waste generation is estimated in 2009 at 519 tonnes per day or 187,435 tonnes per year with an estimated increase to 1000 tonnes per day in the next 10 years and 2000 tonnes per day in the next 20 years (Consultants of Technology, 2011).

The relevant Phuket provincial policies include promoting sustainable and eco-tourism and protecting the natural environment. The strategies include waste management to adequately support the growing population and the increasing tourism industry (Phuket Provincial Governor's Office, 2013). In the National Pollution Management Plan of 2011-2015 the strategies include supporting the realisation of the WtE projects as well as promoting integrated waste management and increasing the recycling rate to 30% (Pollution Control Department, 2011b). In the National Power Development Plan 2010 third Revision, there is a target to increase alternative energy sources, specifically to achieve 334.5 MW from WtE in the period of 2012-2021 (Energy Policy and Planning Office, 2012).

8.2.2 Phuket waste management plans

The Phuket Province has received a study which proposes the plan for municipal waste management. The plan include separating waste into 3 bins which are dry waste including recyclables and wet waste including organic waste and mixed waste where the 2 bins are not available. The dry waste will be further sorted at a MRF with the residuals and RDF fractions entering the incinerator. The wet waste will enter an AD plant with residual entering the incinerator. The mixed waste will enter the incinerator. The incinerator will have energy recovery in the form of electricity production feeding the national grid. The resulting ash will enter the landfill (Consultants of Technology, 2011).

However due to low participation and contaminants in the segregation bins as well as installing a new and larger incinerator there was a need for an interim plan to accommodate the municipal waste in Phuket. The interim plan comprises of four phases. Phase 1 is to build up the landfill containment dykes and dispose of the waste in the landfill while the new incinerator is being installed. Any organic fraction will decompose in the landfill thereby reducing the waste amount. Phase 2 is to put any new incoming waste into the incinerator while mining the landfill to bring old waste, with a lower amount of organic fraction, to the incinerator. In phase 3 the incoming waste amount would be higher than the incinerator capacity therefore a bioreactor landfill is proposed. The incoming waste would enter the landfill for 4 years with landfill gas capture for electricity generation then it will be removed and refined for the incinerator. Phase 4 would include building an additional waste management centre at another location as expansion is no longer possible at the present site (Consultants of Technology, 2011).

8.2.3 Application of Decision making matrix based on LCIA

For the case study of Phuket province there are three questions which can benefit from using the Decision making matrix.

1. What is the best balanced scenario in terms of energy recovery and LCIA for the waste management with energy recovery situation for Phuket Province?
2. How would the initial proposed plan of waste management for Phuket Province rank compare to the possible scenarios in the matrix?
3. How would the interim plan of waste management for Phuket Province rank compare to the other situations?

8.2.3.1 The best best balanced scenario in terms of energy recovery and LCIA for the waste management with energy recovery situation for Phuket Province.

For Phuket the following options for selection criteria are chosen;

Country: Thailand

Population Density: Urban (1,216.3 person per sq.km.)

Combination of WtE: Incineration and Anaerobic Digestion (Phuket already has a dry bin and wet bin system even if the quality of segregation is low)

Energy Type for Incineration: Electricity (Heat only is not practical as district heating is not essential in Thailand with a tropical climate. Heat and Electricity may be a low possibility if the heat can be used on site or used in a nearby industry)

Energy Type for Anaerobic Digestion: Vehicle Fuel (vehicles using natural gas are becoming popular as fuel price increases)

Recycling scheme: No option is selected as the recycling rate is low in Phuket.

Table 8.1 Result scenarios for Phuket Province

Scenario code	**Scenario name**	**combined LCIA and energy ranking** (within country and density group)
04 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	80

08 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	64
12 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	23
16 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	62
20 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	35
24 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	24

From the results the scenarios with the highest ranking for Phuket case study are 12 C1 THUR: Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling with a ranking of 23 and 24 C1 THUR: Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR with a ranking of 24. With the problem of low recycling participation the scenario of 12 C1 THUR: Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling with a ranking of 23 becomes suitable for Phuket. With the new incinerator being installed, the other facilities that are required are the MRF and the AD plant. Source Segregation is still suitable but only if the population understands and is willing to participate at a high enough level to reach a recycling rate of 50%. However is must be noted that an informal recycling sector is large in Thailand where recyclable waste are valuable to the lower income householder. Any recyclable waste that enter the informal sector and therefore are missing from the household waste collected by the local authorities are not documented and recorded in the statistics.

8.2.3.2 Initial proposed plan of waste management for Phuket Province

The Initial proposed plan of waste management for Phuket Province include separating waste into 3 bins which are dry waste, wet waste and mixed waste with facilities including a MRF, an AD plant and an incinerator.

For Phuket initial plan the following options for selection criteria are chosen;

Country: Thailand

Population Density: Urban (1,216.3 person per sq.km.)

Combination of WtE: Incineration and Anaerobic Digestion

Energy Type for Incineration: Electricity

Energy Type for Anaerobic Digestion: Electricity

Recycling scheme: No option is selected as the recycling rate is low in Phuket.

Table 8.2 Result scenarios for Phuket Province initial plan

Scenario code	Scenario name	combined LCIA and energy ranking (within country and density group)
01 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity No recycling	94
05 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	84
09 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	57
13 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 25% RR	77
17 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	72
21 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	69

From this set of scenarios the highest ranking of 57 is the scenario 09 C1 THUR: Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling. Controversially, source segregation may not be the best option. Also with a low recycling rate putting the waste through a MRF would yield a better result for energy recovery and environmental impacts. However it is noted that the if the efficiency for the 'dirty MRF' is lower than used in this study then the offsets associated with this post collection recycling scenario will be lower than source segregation scenarios. Therefore the next highest ranking of 69 is the scenario 21 C1 THUR Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR. The local authorities in Phuket will have to decide between investing in a highly efficient MRF or local outreach programmes to encourage citizens and tourists to separate their waste at the source.

8.2.3.3 Interim plan of waste management for Phuket Province

The interim plan of waste management for Phuket Province includes an incinerator and a bioreactor landfill. There are existing small composting sites which are assumed to be included in this interim plan. However a MRF is not included therefore the recycling scheme is determined to be post process. For this particular plan the decision making matrix may not truly reflect the situation as a bioreactor landfill and landfill mining in this configuration is not included.

For Phuket's interim plan the following options for selection criteria are chosen;

Country: Thailand

Population Density: Urban (1,216.3 person per sq.km.)

Combination of WtE: Incineration

Energy Type for Incineration: Electricity

Recycling scheme: Post process

Table 8.3 Result scenarios for Phuket Province interim plan

Scenario code	**Scenario name**	**combined LCIA and energy ranking** (within country and density group)
04 IN THUR	Incineration for electricity Post process recycling	74
07 IN THUR	*Incineration for electricity Post collection recycling*	*48*

From this situation the closest scenario is 04 IN THUR: Incineration for electricity Post process recycling with a ranking of 74 which is lower than the initial plan ranked at 57. However if a MRF is included, the ranking could improve to 48 ranking with a post collection recycling scheme. The energy recovered from the bioreactor could also improve the ranking.

Chapter 9

Conclusions

The aims of this research are;

1. to determine which parameters are likely to exert the greatest influence on energy performance and environmental impacts for strategic decision-making and policy formulation of energy recovery from municipal solid waste through thermal and biological processing, by applying a comprehensive scenario analysis using Life Cycle Assessment with WRATE software.

2. to use this enhanced understanding as the basis to create a simplified assessment and screening methodology.

9.1 Using LCA to assess WtE technology

By applying comprehensive scenario analysis using Life Cycle Assessment with WRATE software of energy recovery from municipal solid waste through incineration and AD the parameters exerting the greatest influence is WtE technology followed by Recycling scheme with Recycling rate as a subset then Energy Recovery type. Population density also affects the outcome slightly by the magnitude of the values. Electricity mix and waste composition is the main varying parameter that WRATE uses to calculate the LCIA thus both parameter greatly affect the results.

- Among the WtE technology, Incineration only scenarios are comparable to combination of incineration and AD scenarios. AD only scenarios have the most burdens due to sending residual waste to the landfill.
- For recycling schemes, scenarios with post collection recycling performs the best with source segregation sometimes performing similar if the recycling rate is high with a high recycling material capture rate.
- For energy recovery type, scenarios with incineration for heat only perform the best for energy recovered related assessment and incineration for heat and electricity perform the best for LCIA. For AD energy recovery type, scenarios with vehicle fuel perform the best.

For climate change LCIA, most of scenarios have large negative values indicating offsets due to the large amount of recycling and energy recovered.

  - Many scenarios with no recycling in Thailand have net burdens to the environment due to large organic waste fraction in the waste composition. In combination with incineration, without recycling, the benefits of diverting organic waste to AD is not enough to offset the impacts from the additional activities of collecting organic waste separately in a rural town with a large and low population density area in Thailand.
  - The best performing scenarios for climate change LCIA in UKUR and UKRU are the same scenario 18 IN incineration for heat and electricity 50% RR;
  - The best performing scenarios for climate change LCIA in THUR and THRU are the same scenario 14 IN incineration for heat 34% RR. The recycling materials capture rate is 100%.

For energy recovery the largest contributing factors are energy recovery type and recycling scheme.

  - The scenarios having the highest energy recovery for all four groups, UKUR, UKRU, THUR and THRU are the same two scenarios; '28 C1 Incineration for heat and Anaerobic Digestion for vehicle fuel with no recycling' and '32 C1 Incineration for heat and Anaerobic Digestion for vehicle fuel with post process recycling'.

Further findings include the discovery that for source segregation scenarios to rank higher than post collection recycling scenarios the capture rate must be very high to almost approaching 100% so that the amount of materials recycled can offset the burdens in transportation and sorting.

- With full participation, the maximum recycling rate possible would be slightly above 50% in the UK and only 34% in Thailand by recycling only the dry recyclates (paper, plastic, glass and metals). If organic waste is utilised whether by composting or AD in addition to recycling dry recyclates the maximum recycling rate possible would be 80% in the UK and 93% in Thailand.

The ranking method proposed in this research uses a weighting method, an optional step in LCA, to provide a ranking of scenarios for the simple decision-making tool.

The highest ranking scenarios for combined LCIA in each group are;

- 09 IN UKUR Incineration for heat and electricity Post collection recycling
- 60 C1UKRU Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling
- 14 IN THUR Incineration for heat Source segregation 34% RR
- 14 IN THRU Incineration for heat Source segregation 34% RR

The highest ranking scenarios for combined LCIA and energy recovered in each group are;

- 08 IN UKUR Incineration for heat Post collection recycling
- 36 C1 UKRU Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling
- 08 IN THUR Incineration for heat Post collection recycling
- 36 C1 THRU Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling

The highest ranking scenarios for climate change LCIA and energy recovered in each group are;

- 36 C1 UKUR Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling
- 08 IN UKRU Incineration for heat Post collection recycling
- 08 IN THUR Incineration for heat Post collection recycling
- 08 IN THRU Incineration for heat Post collection recycling

The assumptions and process options used in this study was maximised for the theoretical maximum. The actual emissions and offsets in the LCIA will depend on the particular local facilities. A general guideline from the trends presented in this study can be used to support the decision making of WtE technology and scenario selection.

Recommendation to the national policy

As a recommendation to the national policy of Thailand, a general guideline to support the decision making of WtE technology and scenario selection is presented as follows;

- As a policy for protecting the environment, WtE management scenarios with incineration for heat and the highest recycling rate is recommended. As a policy for generating energy, WtE management scenarios with the combination of incineration for heat and AD for vehicle fuel with either no recycling or post process recycling is recommended.
- As a policy to balance both protecting the environment and generating energy, WtE management scenarios with incineration for heat and post collection recycling is recommended.
- However for all the above recommendations, there must be a constant heat utilisation outlet such as district cooling or local industry. The incineration energy recovery as heat and electricity would be second choice and energy recovery as electricity would be third choice.
- AD only scenarios are not recommended, although it will be an improvement from some current waste management practice in some areas of normal landfill or even open dumping.
- Combinations of incineration and AD would have to ensure that the separate collection distance is not too far for the burdens to outweigh the offsets gained from the amount of organic waste converted to energy; as well as ensuring the highest amount of recycling rate. In rural towns, household organic waste may be better treated by using household composting or household scale AD.
- With full participation, the maximum recycling rate possible would be only 34% in Thailand by recycling only the dry recyclates (paper, plastic, glass and metals). If organic waste is utilised whether by composting or AD in addition to recycling dry recyclates the maximum recycling rate possible would be 93% in Thailand.

9.2 Decision making matrix

The LCA scenario analysis results were then used to create a simplified assessment and screening methodology in a form of Decision making matrix for local authorities to select the WtE technology and waste management scenario suitable to their particular location.

The application of the Decision making matrix for local authorities can be useful to a certain degree. For situations where WtE technology has not been chosen or if they include incineration and AD then the Decision making matrix can yield results suitable for those situations. However if the case study are considering technology or processes which are not included in the Decision making matrix then the results will not reflect the actual situation.

For countries where LCA data and software may not be readily available or a system is not in place for an LCA study for each waste management plan the approach in building the Decision making matrix for local authorities is quite comprehensive but will provide the user with simplified solutions where they can further conduct other relevant criteria such as economic feasibility and public perceptions. However further work is required. More scenarios with more WtE technology processes in various configurations will be necessary to apply to a wider range of case studies.

9.3 Further work

In order to improve upon this research, further work includes;

- Exploring the minimum assumptions and process options used for the theoretical minimum situation.
- Conducting a sensitivity analysis for this LCA study using WRATE.
- More scenarios with more WtE technology processes in various configurations to apply to a wider range of situations.
- A study applying the LIME method for Thailand (Rewlay-ngoen et al., 2013) is a promising method of using LCIA results, such as human health, to group the damage on the environmental endpoint then quantifying the damage to a chosen unit such as in monetary terms. Although this method is considered an optional step in LCA study, LIME is very comprehensive and useful in the step of interpretation of results. Applying this method to the LCIA results from this research work would enhance the decision making process for local authorities in waste management.

References

Arena, U., Mastellone, M.L. and Perugini, F., 2003. The environmental performance of alternative solid waste management options: a life cycle assessment study. *Chemical Engineering Journal,* 96**,** pp. 207-222.

Banks, C.J. and Stentiford, E.I., 2007. Biodegradable municipal solid waste: biotreatment options. *Waste and Resource Management,* 160**,** pp. 11-18**.**

Banks, C.J., Chesshire, M., Heaven, S. and Arnold, R., 2011. Anaerobic digestion of source-segregated domestic food waste: Performance assessment by mass and energy balance. *Bioresource Technology,* 102**,** pp. 612-620.

Baumann, H. and Tillman, A., 2004. The Hitch Hiker's Guide to LCA. An orientation in life cycle assessment methodology and application. Lund: Studentlitteratur.

Biffaward, 2003. Thermal methods of municipal waste treatment: Biffaward programme on sustainable resource use. Chester: Biffaward

Brooks, D. and Powrie, W., 2007. Briefing: Defra's new technologies demonstrator programme. *Waste and Resource Management,* 160**,** pp. 5-10.

Burnley, S.J., Phillips, R. and Coleman, T., 2011 A life cycle assessment of recovering energy from the organic fractions of municipal waste. *Proceedings Sardinia 2011, Thirteenth International Waste Management and Landfill Symposium,* Santa Margherita di Pula, Italy 3-7 October 2011. CISA, Italy.

Burnley, S.J., Phillips, R., Coleman, T. and Rampling, T., 2011. Energy implications of thermal recovery of biodegradable municipal waste materials in the United Kingdom. *Waste Management*, 31(9-10), pp. 1949-1959.

Buswell, A.M. and Mueller J.F., 1952. Mechanism of Methane Fermentation. *Industrial and Engineering Chemistry*. 44(3), pp.550-552

Campbell, M., 2010. *Overview of Marchwood Energy Recovery Facility*. [Conversation] (Personal communication, 16 September 2010).

CEWEP, 2007. Map European waste to energy plants in 2007. [Online] Available at <http://www.cewep.com.data.studies.art145,138.html> [accessed 27 November 2009]

Chaya, W. and Gheewala, S. H., 2007. Life cycle assessment of MSW-to-energy schemes in Thailand. *Journal of Cleaner Production*, 15**,** pp.1463-1468.

Cherubini, F., Bargigli, S. and Ulgiati, S., 2009. Life cycle assessment (LCA) of waste management strategies: Landfilling, sorting plant and incineration. *Energy,* 34**,** pp. 2116-2123.

Cherubini, F., Bargigli, S. and Ulgiati, S., 2008. Life cycle assessment of urban waste management: Energy performances and environmental impacts. The case of Rome, Italy. *Waste Management*, 28**,** pp. 2552-2564.

Christensen, T. H., 2009. LCA-modeling in waste management: Key assumptions, variations and uncertainties. 24-25 November 2009. ISWA conference; WTE Beacon. Malmo

Coleman, T., Thomas, B., Shiels, S., Lythgo, K., Gottberg, A., Aumonier, S., Collins, M., Laenen, P.P., Garrett, P., Hall, D., Gentil, E., Haslam, I., Brown, A., Turnbull, R. and Plimmer, B., 2006. *WRATE user manual v1.1*. Environment Agency

Consonni, S., Giugliano, M. and Grosso, M., 2005. Alternative strategies for energy recovery from municipal solid waste: Part A: Mass and energy balances. *Waste Management,* 25**,** pp.123-135.

Consultants of Technology, 2011. Final Report of the Twenty Year Feasibility Study of Municipal Waste Management for Phuket Province. Phuket. PJT Technology. (in Thai)

Council of the European Union. Council Directive 1999/31/EC on the landfill of waste. *Official Journal of the European Communities*, 1999, 16/7/1999.

Council of the European Union. Council Directive 2000/76/EC on the incineration of waste. *Official Journal of the European Communities*, 2000, 4/12/2000.

Council of the European Union. Council Directive 2008/98/EC on waste. *Official Journal of the European Communities*, 2008, 19/11/2008.

Council of the European Union. Council Directive 2009/28/EC on the promotion of the use of energy from renewable sources. *Official Journal of the European Communities*, 2009, 23/04/2009.

Dacombe, P., Krivtsov, V., Banks, C. J. and Heaven, S., 2004. An energy and materials flow model for evaluation of alternatives for processing domestic and commercial wastes - A case study of Southampton, Research Paper. Southampton, University of Southampton.

De Baere, L., 2006. Will anaerobic digestion of solid waste survive in the future? *Water Science and Technology,* 53**,** pp.187-194.

Department for Energy and Climate Change, 2009. The UK Renewable Energy Strategy (Cm 7686). Norwich: Department for Energy and Climate Change.

Department for Environment Food and Rural Affairs, 2007. Incineration of Municipal Solid Waste. [pdf] Available at : <http://www.defra.gov.uk/environment/waste/residual/newtech/documents/incineration.pdf> [accessed 1 June 2010]

Department for Environment Food and Rural Affairs, (2007) Waste Strategy for England 2007 (Cm 7086). In Department for Environment Food and Rural Affairs (Ed.). Norwich: TSO (The Stationery Office).

Department for Environment Food and Rural Affairs, 2008. Municipal waste composition: Review of Municipal Waste Component Analyses - WR0119. [Online] Available at: <http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=15133> [accessed 29 June 2011]

Department for Environment Food and Rural Affairs, (2009a) Statistical Release Ref: 257/09 Municipal waste management statistics for England 2008/09. In Department for Environment Food and Rural Affairs (Ed.). London, Department for Environment Food and Rural Affairs.

Department for Environment Food and Rural Affairs, 2009b. New technologies demonstrator programme. Department for Environment Food and Rural Affairs. [Online] Available at: <http://www.defra.gov.uk/environment/waste/residual/newtech/demo/index.htm> [accessed 7 November 2009]

Department for Environment Food and Rural Affairs, 2011a. Anaerobic Digestion Strategy and Action Plan. [pdf] Available at: < https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69400/anaerobic-digestion-strat-action-plan.pdf> [accessed 16 June 2011]

Department for Environment Food and Rural Affairs, 2011b. Government Review of Waste Policy in England 2011. [pdf] Available at: < https:// www.gov.uk/government/uploads/system/uploads/attachment_data/file/69401/pb13540-waste-policy-review110614.pdf> [accessed 14 December 2013]

Department for Environment Food and Rural Affairs, 2012a. Local Authority Collected Waste Statistics - Local Authority data. [Online] Available at: <http://www.defra.gov.uk/statistics/environment/waste/wrfg23-wrmsannual/> [accessed 8 November 2012]

Department for Environment Food and Rural Affairs, 2012b. Local Authority Collected Waste Management Statistics for England-Final Annual results 2011/12. [pdf] Available at: < http://www.defra.gov.uk/statistics/files/mwb201112_statsrelease.pdf > [accessed 10 November 2012]

Drummond, C., 2012.Waste as a Source of Renewable Energy: A Vital Contribution to UK Energy Security and Carbon Reduction. [pdf] Available at: <http://www.rwm exhibition.com/files/colindrummond.pdf> [accessed 17 December 2013]

Ecoinvent, 2012. Ecoinvent Centre. [Online] Available at: <http://www.ecoinvent.org/home> [accessed 25 January 2012]

Energy Policy and Planning Office, 2012. National Power Development Plan 2010. Third Revision. Bangkok: Energy Policy and Planning Office (In Thai)

Environment Agency, 2012. WRATE. [Online] Available at: <http://www.environment-agency.gov.uk/research/commercial/102922.aspx> [accessed 25 January 2012]

European Commission, 2011. Generation and treatment of municipal waste. [Online] Available at: <http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-11-031/EN/KS-SF-11-031-EN.PDF> [accessed 13 November 2013]

European Commission, 2013. Climate Change, EU greenhouse gas emissions and targets. [Online] Available at: <http://ec.europa.eu/clima/policies/g-gas/index_en.htm> [accessed 10 November 2013]

Feo, G. D. and Malvano, C., 2009. The use of LCA in selecting the best MSW management system. *Waste Management,* 29**,** pp. 901-1915.

Frischknecht, R., Jungbluth N., Althaus H.-J., Doka G., Dones R., Hischier R., Hellweg S., Nemecek T., Rebitzer G. and Spielmann M., 2007. Overview and Methodology. Final report ecoinvent data v2.0, No. 1. Swiss Centre for Life Cycle Inventories, Dübendorf, CH

Finnveden, G., Johansson, J., Lind, P. and Moberg, Å. 2005. Life cycle assessment of energy from solid waste—part 1: general methodology and results. *Journal of Cleaner Production,* 13**,** pp. 213-229.

Garg, A., Smith, R., Hill, D., Longhurst, P. J., Pollard, S. J. T. and Simms, N. J., 2009. An integrated appraisal of energy recovery options in the United Kingdom using solid recovered fuel derived from municipal solid waste. *Waste Management,* 29**,** pp. 2289-2297.

Gentil, E. C., Damgaard, A., Hauschild, M., Finnveden, G., Eriksson, O., Thorneloe, S., Kaplan, P. O., Barlaz, M., Muller, O., Matsui, Y., II, R. and Christensen, T. H. 2010. Models for waste life cycle assessment: Review of technical assumptions. *Waste Management*, 30**,** pp. 2636-2648.

Giugliano, M., Grosso, M. and Rigamonti, L., 2008. Energy recovery from municipal waste: A case study for a middle-sized Italian district. *Waste Management,* 28**,** pp. 39-50.

Gomez, A., Zubizarreta, J., Rodrigues, M., Dopazo, C. and Fueyo, N., 2010. Potential and cost of electricity generation from human and animal waste in Spain. *Renewable Energy,* 35(2)**,** pp. 498-505.

Grundon, 2010. Energy from Waste. [Online] Available at: <http://www.grundon.com /how/energyFromWaste.htm> [accessed 1 June 2010]

Hartmann, H. and Ahring, B. K., 2006. Strategies for the anaerobic digestion of the organic fraction of municipal solid waste: an overview. *Water Science and Technology,* 53**,** pp. 7-22.

Hischier, R., Weidema, B., Althaus, H., Bauer, C., Doka, G., Dones, R., Frischknecht, R., Hellweg, S., Humbert, S., Jungbluth, N., Köllner, T., Loerincik, Y., Margni, M. and Nemecek, T., 2009. *Implementation of Life Cycle Impact Assessment Methods in Ecoinvent v2.1*. St. Gallen: Ecoinvent

Huiu, B., 2012. *Ludlow plant with biogas upgrade module in WRATE.* [Email] (Personal communication, 4 September 2012)

Ishibashi, H., 2013. *Overview of Clean Hill Homan Recycling Center and Heat Recovery Facility*. [Conversation] (Personal communication, 15 November 2013).

ISO, 2006a. ISO 14040: Environmental Management-Life Cycle Assessment-Principles and Framework. International Organization for Standardization

ISO, 2006b. ISO 14044: Environmental Management-Life Cycle Assessment-Requirements and Guidelines. International Organization for Standardization

Khoo, H. H., 2009. Life cycle impact assessment of various waste conversion technologies. *Waste Management*, 29**,** pp.1892-1900.

Kiely, G., 1998. *Environmental Engineering,* Singapore, Irwin/McGraw-Hill.

Knipe, A.D., 2007. *Comparison of Greenhouse gas emissions from the centralised and household treatments of food waste, ERC/07/001*. Environmental Research and Consultancy.

Knox, K. and Robinson, H., 2007. MBT and thermal treatment of MSW residues: a comparative study of energy balance and long-term pollution potential of leachates in *Proceedings Sardinia 2007, Eleventh International Waste Management and Landfill Symposium*, Cagliari, Italy 1-5 October 2007. CISA, Italy.

Liamsanguan, C. and Gheewala, S. H., 2008. LCA: A decision support tool for environmental assessment of MSW management systems. *Journal of Environmental Management,* 87**,** pp.132-138.

Lightowler, P., 2012. Will gasification finally take off? Waste Planning, DCServices. [Online] Available at <http://www.dcservices.co.uk/news/1163564/> [Accessed 25 October 2013]

Lisney, R., 2001. Project Integra a personal history, Winchester:Hampshire County Council

Lisney, B., Riley, K. and Banks, C., 2003. *From waste to resource management,* Discussion paper, Hampshire Natural Resources Initiative.

Manfredi, S. and Chirstensen, T. H., 2009. Environmental assessment of solid waste landfilling technologies by means of LCA-modeling. *Waste Management,* 29**,** pp. 32-43.

Mata-Alvarez, J. (Ed.), 2003. *Biomethanization of the organic fraction of municipal solid wastes,* London: IWA Publishing.

Mcdougall, F.R., White, P.R., Franke, M. and Hindle, P., 2001. *Integrated Solid Waste Management: a Life Cycle Inventory.* 2nd ed. Oxford: Blackwell Science.

Menikpura, S. N. M. and Basnayake, B. F. A. (2009) New applications of [`]Hess Law' and comparisons with models for determining calorific values of municipal solid wastes in the Sri Lankan context. *Renewable Energy,* 34**,** pp. 1587-1594.

Moberg, Å., Finnveden, G., Johansson, J. Lind, P., 2005. Life cycle assessment of energy from solid waste—part 2: landfilling compared to other treatment methods. *Journal of Cleaner Production,* 13**,** pp. 231-240.

Murer, M.J., Spliethoff, H., de Waal, C.M.W., Wilpshaar, S., Berkhout, B., van Berlo, M.A.J., Gohlke, O., Martin, J.J.E., 2011. High efficient waste-to-energy in Amsterdam: getting ready for the next steps. *Waste Management and Research,* 29(10), pp. 20-29.

Oakdene Hollins, 2005. Quantification of the potential energy from residuals (EfR) in the UK. London: The Institution of Civil Engineers and The Renewable Power Association.

Open University, 2008. The open university household waste study: Key findings from 2008 for Defra. Milton Keynes: Open University

Papageorgiou, A., Barton, J. R. and Karagiannidis, A., 2009. Assessment of the greenhouse effect impact of technologies used for energy recovery from municipal waste: A case for England. *Journal of Environmental Management,* 90**,** pp. 2999-3012.

Parfitt, J. 2002. Analysis of household waste composition and factors driving waste increase. WRAP

Parfitt, J. P. and Bridgewater, E., 2009. A review of municipal waste compositional data in the United Kingdom and the development of a new approach to national estimates. *Proceedings Sardinia 2009 Twelfth International Waste Management and Landfill Symposium* S. Margherita di Pula, Cagliari, Italy 5-9 October 2009, CISA.

Patumsawad, S. and Cliffe, K. R., 2002. Experimental study on fluidised bed combustion of high moisture municipal solid waste. *Energy Conversion and Management,* 43**,** pp. 2329-2340.

Peavy, H. S., Rowe, D. R. and Tchobanoglous, G., 1985. *Environmental Engineering,* Singapore, McGraw-Hill, Inc.

PE International, 2014. GaBi Software. [Online] Available at: <http://www.gabi-software.com> [accessed 25 January 2014]

Phuket Provincial Governor’s Office, 2013. Province Introduction. [Online] Available at: <http://www.phuket.go.th/webpk/contents.php?str=intropk> [accessed 17 Jan 2013]

Pollution Control Department, 2003. National Municipal Waste Composition Survey and Analysis. Bangkok: Pollution Control Department (in Thai)

Pollution Control Department, 2011a. Summary of the State of Pollution in Thailand 2011. Bangkok: Pollution Control Department (in Thai)

Pollution Control Department, 2011b. Pollution Management Plan 2011-2015. Bangkok: Pollution Control Department (in Thai)

Pollution Control Department, 2012. State of Pollution in Thailand 2011. Bangkok: Pollution Control Department (in Thai)

Powrie, W. and Dacombe, P., 2006. Sustainable waste management - what and how? *Waste and Resource Management,* 159**,** pp.101-116.

PRe Consultants, 2014. LCA Software SimaPro. [Online] Available at: <http:// www.pre-sustainability.com> [accessed 25 January 2014]

Rapport, J., Zhang, R., Jenkins, B. and Williams, R., 2008. Current anaerobic digestion technologies used for treatment of municipal organic solid waste. Sacramento, California Integrated Waste Management Board.

Rewlay-ngoen, C., Papong, S., Kubo, T., Itsubo, N., Malakul, P., and Sampattgul, S. 2013. Characterization Factors for Human Health and Biodiversity Damage of Chemical Substances in Life Cycle Impact Assessment. *International Journal of American Journal of Environmental Protection.* 2(6) 154-160.

Rigamonti, L., Grosso, M. and Giugliano, M., 2009. Life cycle assessment for optimising the level of separated collection in integrated MSW management systems. *Waste Management,* 29**,** 934-944.

Rodriguez-Iglesias, J., Maranon, E., Castrillon, L., Riestra, P., and Sastre, H., 2003. Life cycle analysis of municipal solid waste management possibilities in Asturias, Spain. *Waste Management and Research*, 21, 535-548.

RTI International, 2007. Evaluation of Existing Municipal Solid Waste/ Life Cycle Assessment Tools. California: RTI International

Salter, A., 2009, *Design of full scale reactors.* 13 August 2009. [Class handout] Jyvaskyla: University of Jyvaskyla Summer School.

SELCHP, 2009. Using waste to provide energy for the community. South East London Combined Heat and Power. London.

SITA Isle of Man, 2008. Annual public report 2008. Energy from waste facility, Douglas.

SITA, 2011. Teesside. [Online] Available at: <http://www.sita.co.uk/what-we-do/local-authority-services/public-private-partnerships/teesside> [accessed 29 June 2011]

Shropshire Newsroom, 2013., Local charity sparks new life into Ludlow green energy facility [Online] Available at: < http://shropshire.gov.uk/news/2013/08/local-charity-sparks-new-life-into-ludlow-green-energy-facility/> [accessed 9 October 2013]

Smith, A., 2012. Annual Performance Report 2011. Sheffield Energy Recovery Facility. [pdf] Available at: < http://ukwin.org.uk/files/pdf/sheffield2011.pdf> [accessed 16 December 2013]

Southampton City Council, 2012. 2011 Census. [Online] Available at :http://www.southampton.gov.uk/living/statsresearch/2011census/default.aspx> [accessed 8 November 2012]

Southampton City Council, 2014. What can go in my recycling bin?. [Online] Available at :http://www.southampton.gov.uk/s-environment/householdwaste/what_can_go_in_my_recycling_bin.aspx> [accessed 15 January 2014]

Tchobanoglous, G., Theisen, H. and Vigil, S., 1993. *Integrated Solid Waste Management:Engineering Principles and Management Issues,* Singapore: McGraw-Hill.

Tunesi, S. 2011. LCA of local strategies for energy recovery from waste in England, applied to a large municipal flow. *Waste Management,* 31**,** pp.561-571.

United Nations, 2013. United Nations Conference on Sustainable Development, Rio+20. [Online] Available at:http://sustainabledevelopment.un.org/rio20.html [accessed 10 November 2013]

United Nations, 2013. United Nations Framework Convention on Climate Change, Kyoto Protocol. [Online] Available at: http://unfccc.int/kyoto_protocol/items/2830.php [accessed 10 November 2013]

U.S. EPA, 2013. Municipal solid waste generation, recycling and disposal in the United States: facts and figures for 2011. Washington DC: U.S. EPA.

VEOLIA Environmental Services, 2010. *Integra North. Energy Recovery Facility,* Otterbourne: Veolia Environmental Services.

VEOLIA Environmental Services, 2011. *Sheffield's. Energy Recovery Facility: Transforming our rubbish into energy,* Sheffield: Veolia Environmental Services.

Vesilind, P.A., Worrel, W.A. and Reinhart, D.R., 2002. *Solid Waste Engineering* Pacific Grove: Brooks/Cole.

Wangjiraniran, W., Nidhiritdhikrai, R. and Eua-Arporn, B., 2012. Scenarios on Power Generation in Thailand. *Proceedings 2012 International Conference on Future Environment and Energy. IPCBEE 28(2012)*, Singapore 26-28 February 2012. IACSIT Press.

Wanichpongpan, W. and Gheewala, S. H., 2007. Life cycle assessment as a decision support tool for landfill gas-to energy projects. *Journal of Cleaner Production,* 15**,** pp. 1819-1826.

Watson M., Hoy, C., Mkushi, G. and Williams, M., 2009. *Modelling of Impacts for selected residual waste plant options using WRATE*. AEA Technology report ED46665, Harwell: AEA Technology.

Whiting, J., 2008. Pyrolysis and Gasification of Solid Waste. 8 July 2008. [powerpoint] Southampton: University of Southampton.

Williams, P. T., 2005. *Waste Treatment and Disposal 2nd ed.,* Chichester: John Wiley & Sons Ltd.

Winchester City Council, 2012. Census 2011. [Online] Avaialble at : <http://www.winchester.gov.uk/data/census/census-2011/> [accessed 8 November 2012]

Wittmaier, M., Langer, S. and Sawilla, B., 2009. Possibilities and limitations of life cycle assessment (LCA) in the development of waste utilization systems - Applied examples for a region in Northern Germany. *Waste Management,* 29**,** pp. 1732-1738.

World Commission on Environment and Development, 1987. Report of the World Commission on Environment and Development: Our common future. UN Documents: Gathering a Body of Global Agreements.

Yamaura, T. 2013. *Fukuoka Prefecture's efforts in the Environmental Field.*[Conversation] (Personal communication, 13 November 2013).

Young, G. C. 2010. Municipal Solid Waste to Energy Conversion Processes : Economic, Technical, and Renewable Comparisons. Hoboken, NJ, USA: Wiley. [Online] Available at http://site.ebrary.com/lib/soton/Doc?id=10387096&ppg=168 [accessed 9 December 2013]

Zaman, A. U., 2010. Comparative study of municipal solid waste treatment technologies using life cycle assessment method. International Journal of Environment Science and Technology, 7 (2), pp.225-234.

Zhao, W., Der Voet, E. V., Zhang, Y. and Huppes, G., 2009. Life cycle assessment of municipal solid waste management with regard to greenhouse gas emissions: Case study of Tianjin, China. *Science of the Total Environment,* 407**,** pp.1517-1526.

Zsigraiova, Z., Tavares, G., Semiao, V. and Carvalho, M. D. G., 2009. Integrated waste-to-energy conversion and waste transportation within island communities. *Energy,* 34**,** pp. 623-635.

Appendix A

Table A1 Municipal Solid Waste and Household Waste Composition (% wet weight) from Different Countries

	* selected for model							Williams, 2005	Coggins, 2009
	adapted from Defra, 2008 (each glass colour fraction)	Parfitt and Bridgwater, 2009 (same study defra, 2008)		Parfitt, 2002	Papageorgiou et al., 2009 ("Bin data" from Parfitt, 2002)		Open University 2008	Warrington (NHWAP survey, 1994)	EA,2006
Category	Household-Englan	Kerb England	HWRC Engla	England	Wet MSW	Dry MSW	England	Dry weight,%	British
Organic	***40.1***	***40.1***	***40.6***	***42***	***37.5***	***23.1***	***41.5***	***21.7***	***30.52***
Food waste	24.78	24.8	1.9	17	22.2	13	19.3	18.1	
Slaughter house									
Garden waste	11.94	11.9	23.5	20	15.3	10.1	22.2	3.6	
Other organics	2.53	2.5	0.5						
Wood	0.85	0.9	14.7	5					2.8
Paper/board	***25.32***	***25.4***	***8.4***	***18***	***22.7***	***26.8***	***6***	***27.4***	***21***
Unspecified paper									
Newspapers	7.17							8.6	
Magazines	2.88							4.3	
Recyclable paper	2.17								
Other paper	4.97	19.9	4.7				12	6.8	
Liquid cartons	6.51							0.6	
Card packaging	1.62	5.5	3.7					3.3	
Other card								3.8	
Plastic	***11.03***	***11***	***5.4***	***7***	***8.8***	***11.1***	***6.7***	***9.8***	***7.3***
Bags and film				3	4	4.4		3.8	2.8
Bags	2.09								
Packaging film	2.03								
Other film plastic	0.24								
Drinks bottles	1.08								
Other bottles	1.62							1.7	
Food packaging								1.6	
Other packaging	2.31								
PVC								1.5	
Other dense plastic	1.66			4	4.8	6.7	4.1	1.2	4.5
Misc. plastic							2.6		
Textiles	***2.89***	***2.9***	***2.8***	***3***	***3.2***	***2.9***	***2.5***	***1.9***	***1.8***
Leather									
Rubber									
Misc. combustibles	***5.49***	***4.5***		***3***	***6***	***6.1***	***12.1***	***10.3***	***9.3***
Disposible nappies/Sanitary	3.52	3.5		2			2.3	7.1	2.3
Unspecified combustibles	1.21								
Shoes	0.33								
Carpet/underlay	0.43								
Other		1		1			9.8	3.2	7
Fines	***1.55***	***1.5***	***0.4***	***3***	***5***	***4.7***	***0.6***	***6.8***	***5.2***
10 mm combustibles	1.55	1.5	0.4					3.4	
10 mm noncombustibles								3.4	
Glass	***6.52***	***6.5***	***2.4***	***7***	***8.4***	***12.6***	***9.4***	***9.7***	***5.8***
Unspecified glass	4.77								
Brown	0.16							0.4	
Green	0.92							1.5	
Clear	0.67							4	
Broken glass								3.8	
Metals	***3.44***	***3.3***	***9.1***	***8***	***6.3***	***9.5***	***5.5***	***7.8***	***5.47***
Unspecified ferrous metal				3					
Steel food and drink cans	1.82								
Fe Beverage cans					5.3	8	2.6	0.8	4.67
Fe Food cans								4.2	
Fe Other cans								0.3	
Other ferrous	0.76							0.8	
Scrap metal/white goods	0.11			5					
non Fe Beverage cans	0.37				1	1.5	1.2	0.4	0.8
Foil								0.5	
Other non-ferrous	0.38						1.7	0.8	
Misc. noncombustibles	***2.37***	***1.4***	***8.1***	***8***	***2.1***	***3.2***	***4.1***	***4.6***	***8***
Stone/ceramic									
Soil and other			8.1	8					
Furniture and Mattress	***0.03***		***5.9***						
WEEE		***1***	***5.8***						***2***
Large electronic goods	0.12								
CRT TV and monitors	0.01								
other WEEE	0.75								
Hazardous		***0.4***	***1.3***						***0.81***
Unspecified hazardous									
Batteries	0.07								
Clinical waste	0.13								
Paint/varnish	0.08								
Oil	0.02								
Garden herbicides&pesticide	0.08								
Other		***2***	***2***						

Appendix A

Table A1 Municipal Solid Waste and Household Waste Composition (% wet weight) from Different Countries

Category	Biffaward, 2003						Williams, 2005	
	DoE NHWAP (1992-1993)	Nuneaton&Bedworth March 1998	Nuneaton&Bedworth August 1998	Isle of Wight	Oakdene Hollins Ltd., 2005		2002, European commission 2004	Patumsawad and Cliffe, 2002
					Scotland	N. Ireland		UK
Organic	***20.2***	***38.3***	***36.6***	***21.5***	***16***	***44***	***20***	***25***
Food waste								25
Slaughter house								
Garden waste								
Other organics								
Wood								
Paper/board	***33.2***	***11.9***	***16***	***27.1***	***26***	***17***	***33***	***31***
Unspecified paper								
Newspapers								
Magazines								
Recyclable paper								
Other paper								31
Liquid cartons								
Card packaging								
Other card								
Plastic	***11.2***	***8.8***	***8.2***	***9.2***	***12***	***8***	***7***	***8***
Bags and film								
Bags								
Packaging film								
Other film plastic								
Drinks bottles								
Other bottles								
Food packaging								
Other packaging								
PVC								
Other dense plastic								
Misc. plastic								
Textiles	***2.1***	***3.2***	***3.4***	***3.2***	***4***	***1***	***4***	***5***
Leather								
Rubber								
Misc. combustibles	***8.1***	***6.8***	***6.5***	***3.5***	***17***	***8***		
Disposible nappies/Sanitary								
Unspecified combustibles								
Shoes								
Carpet/underlay								
Other								
Fines	***6.8***	***2.9***	***4.8***	***23.7***	***7***	***9***		
10 mm combustibles								
10 mm noncombustibles								
Glass	***9.3***	***3.8***	***5***	***4.2***	***9***	***7***	***10***	***10***
Unspecified glass								
Brown								
Green								
Clear								
Broken glass								
Metals	***7.3***	***4***	***4.1***	***5***	***7***	***4***	***8***	***8***
Unspecified ferrous metal								
Steel food and drink cans								
Fe Beverage cans								
Fe Food cans								
Fe Other cans								
Other ferrous								
Scrap metal/white goods								
non Fe Beverage cans								
Foil								
Other non-ferrous								
Misc. noncombustibles	***1.8***	***20.4***	***13.3***	-	***2***	***3***		
Stone/ceramic								
Soil and other								
Furniture and Mattress								
WEEE								
Large electronic goods								
CRT TV and monitors								
other WEEE								
Hazardous								
Unspecified hazardous								
Batteries								
Clinical waste								
Paint/varnish								
Oil								
Garden herbicides&pesticides								
Other							***18***	***13***

Appendix A

Table A1 Municipal Solid Waste and Household Waste Composition (% wet weight) from Different Countries

Category	Gomez et al., 2010	De Feo and Malvano, 2009	Cherubini et al, 2008	Murphy and McKeogh, 2004	Holmgren and Henning, 2004	Tchobanoglous et al, 1993	US.EPA, 2007	Qiu and Hayden, 2009
	Spain	Italy	Italy	Ireland 1998	Sweden reco	USA	USA	Canada
Organic	***48.9***	***42***	***50.8***	***32.9***	***45.2***	***29.5***	***30.89***	***29***
Food waste		30	49.5			9.0	12.5	
Slaughter house								
Garden waste		12				18.5	12.8	
Other organics								
Wood	0.6		1.3			2.0	5.6	
Paper/board	***20.5***	***30***	***18.8***	***19.5***	***20.1***	***40***	***32.7***	***27***
Unspecified paper								
Newspapers								
Magazines								
Recyclable paper								
Other paper	20.5		12			34.0		
Liquid cartons								
Card packaging								
Other card			6.8			6.0		
Plastic	***11.7***	***14***	***22.9***	***11.9***	***8.2***	***7.0***	***12.1***	***13***
Bags and film								
Bags								
Packaging film								
Other film plastic								
Drinks bottles								
Other bottles								
Food packaging								
Other packaging								
PVC								
Other dense plastic								
Misc. plastic								
Textiles	***3.7***	***2***	***2.4***	***2.9***	***3.2***	***2.0***	***4.7***	***5***
Leather			***0.3***			***0.5***	***2.9***	
Rubber			***0.3***			***0.5***		
Misc. combustibles					***14.1***			***14***
Disposible nappies/Sanitary								
Unspecified combustibles								
Shoes								
Carpet/underlay								
Other								
Fines		***1***						
10 mm combustibles								
10 mm noncombustibles								
Glass	***7.6***	***8***	***1.5***	***5.5***	***3.2***	***8.0***	***5.4***	***3***
Unspecified glass								
Brown								
Green								
Clear								
Broken glass								
Metals	***4.1***	***3***	***2.8***	***3.5***	***3.2***	***9.5***	***8.15***	***3***
Unspecified ferrous metal								
Steel food and drink cans								
Fe Beverage cans			1.9					
Fe Food cans						6.0		
Fe Other cans								
Other ferrous								
Scrap metal/white goods							6.1	
non Fe Beverage cans			0.9			0.5	1.3	
Foil								
Other non-ferrous						3.0	0.7	
Misc. noncombustibles					***2.6***	***3.0***	***1.5***	***6***
Stone/ceramic								
Soil and other								
Furniture and Mattress								
WEEE								
Large electronic goods								
CRT TV and monitors								
other WEEE								
Hazardous								
Unspecified hazardous								
Batteries								
Clinical waste								
Paint/varnish								
Oil								
Garden herbicides&pesticides								
Other	***2.9***		***0.2***	***23.8***			***1.7***	

Appendix A

Table A1 Municipal Solid Waste and Household Waste Composition (% wet weight) from Different Countries

Category				* selected for model				exacavated waste from landfill			
	Zhao et al, 2008	Zsigraiova et al, 2009	Menikpura and Basnayake, 2009	adapted from PCD, 2003, average two seasons	Chaya and Gheewala, 2007	Patumsawad and Cliffe, 2002	Liamsanguan and Gheewala, 2008	Chiemchaisri et al., 2009			
	Tianjin Chin	Santiago, Ca	Sri Lanka	Household-Tha	Thailand	Thailand	Phuket, Thaila	2 yr	5 yr	7 yr	10 yr
Organic	***56.88***	***27***	***71.30***	***67.14***	***41.92***	***39.00***	***31.77***	***7.66***	***3.42***	***9.77***	***1.2***
Food waste			56.57	66.295	35.94	39	18.12				
Slaughter house			2.34								
Garden waste			6.04		5.98		13.65				
Other organics											
Wood	1.93		6.35	0.84				7.66	3.42	9.77	1.2
Paper/board	***8.67***	***25***	***6.47***	***5.345***	***20.7***	***13***	***11.45***	***4.09***	***0***	***0***	***0***
Unspecified paper				1.31							
Newspapers				1.73							
Magazines				2.26							
Recyclable paper				0.875							
Other paper			2.71								
Liquid cartons											
Card packaging				0.48							
Other card			3.76								
Plastic	***12.12***	***23***	***5.9***	***16.24***	***15.88***	***10***	***27.71***	***36.8***	***24.6***	***44.8***	***35***
Bags and film			5.2					29.5	16.5	33.9	24
Bags				10.655							
Packaging film				0.29							
Other film plastic											
Drinks bottles				0.51							
Other bottles				1.195							
Food packaging								1.75	0.55	0.88	0.6
Other packaging				2.935							
PVC											
Other dense plastic			0.7	0.655							
Misc. plastic								7.2	8.2	10.9	11.4
Textiles	***2.47***		***1.75***	***1.405***	***2.5***	***23***	***3.06***	***11.5***	***7.45***	***10.2***	***1.8***
Leather			***1.4***								
Rubber			***2.8***		***2.44***		***1.85***	***0.6***	***0.83***	***1.18***	***0***
Misc. combustibles				***2.45***							
Disposible nappies/Sanitary				2.45							
Unspecified combustibles											
Shoes											
Carpet/underlay											
Other											
Fines											
10 mm combustibles											
10 mm noncombustibles											
Glass	***1.30***	***15***		***2.125***	***9.89***			***1.79***	***4.03***	***1.21***	***4.8***
Unspecified glass											
Brown				1.345							
Green				0.11							
Clear				0.67							
Broken glass											
Metals	***0.42***	***10***		***1.93***	***3.75***			***1.79***	***1.66***	***3.34***	***4.2***
Unspecified ferrous metal				1.51							
Steel food and drink cans											
Fe Beverage cans											
Fe Food cans											
Fe Other cans											
Other ferrous											
Scrap metal/white goods											
non Fe Beverage cans				1.865							
Foil											
Other non-ferrous				0.06							
Misc. noncombustibles	***16.21***				***1.62***		***15.44***	***34.1***	***57.4***	***28.6***	***52***
Stone/ceramic	16.21				1.62			1.19	0.83	0.73	2.99
Soil and other								32.9	56.6	27.9	49.1
Furniture and Mattress											
WEEE											
Large electronic goods											
CRT TV and monitors											
other WEEE											
Hazardous											
Unspecified hazardous				0.055							
Batteries				0.19							
Clinical waste											
Paint/varnish											
Oil											
Garden herbicides&pesticides											
Other					***1.02***	***15***	***8.71***				

Appendix A

Table A2 MSW proximate analysis % by wet weight

Type of waste	Moisture	Volatile matter	Fixed carbon	ash	reference
Food waste					
Organic (mixed)	70			5	Zsigraiova et al, 2009
Organic fraction	70	21		9	Consonni et al., 2005
Organic fraction (MR residue)	63.4	27.6		9.0	Giugliano et al., 2008
Food wastes-mixed	70.00	21.40	3.60	5.00	Tchobanoglous, 1993
Kitchen waste	70			5	Zhao et al, 2008
Kitchen waste	62.8	63.4	9.1	27.5	Papageorgiou et al., 2009
Kitchen garbage	70			5	Cherubini et al, 2008
Vegetable food waste	78.29	17.10	3.55	1.06	Williams, 2005
Fruit wastes	78.70	16.60	4.00	0.70	Tchobanoglous, 1993
Meat wastes	38.80	56.40	1.80	3.10	Tchobanoglous, 1993
Meat scraps (cooked)	38.74	56.34	1.81	3.11	Williams, 2005
Fats	2.00	95.30	2.50	0.20	Tchobanoglous, 1993
Fried fats	0.00	97.64	2.36	0.00	Williams, 2005
Garden waste					
Lawn grass	75.24	18.64	4.50	1.62	Williams, 2005
Evergreen shrubs	69.00	25.18	5.01	0.81	Williams, 2005
Flowering plants	53.94	35.64	8.08	2.34	Williams, 2005
Garden waste	58.0	65.1	12.2	22.7	Papageorgiou et al., 2009
Yard wastes	60.00	30.00	9.50	0.50	Tchobanoglous, 1993
Wood green timber	50.00	42.30	7.30	0.40	Tchobanoglous, 1993
Green Logs	50.00	42.25	7.25	0.50	Williams, 2005
Leaves	9.97	66.92	19.29	3.82	Williams, 2005
Hardwood	12.00	75.10	12.40	0.50	Tchobanoglous, 1993
Wood mixed	20.00	68.10	11.30		Tchobanoglous, 1993
Wood and bark	20.00	67.89	11.31	0.80	Williams, 2005
Wastewood	7.5	79.7	12.7	0.1	Yang et al, 2007
waste wood	6.9	71.7	18.5	2.9	Ryu et al, 2007b
Wood	1.5			2.4	Cherubini et al, 2008
Wood (MR residue)	10.4	88.1		1.5	Giugliano et al., 2008
Wood	22	76.5		1.5	Consonni et al., 2005
Wood	1.3			1.5	Zhao et al, 2008
Wood 2yr	45.3	91.4		8.6	Chiemchaisri et al., 2009
Wood 5 yr	31.9	37.7		62.3	Chiemchaisri et al., 2009
Wood 7 yr	49.8	84.1		15.9	Chiemchaisri et al., 2009
Wood 10 yr	10	84.3		15.7	Chiemchaisri et al., 2009
Paper products					
Cardboard	5.20	77.50	12.30	5.00	Tchobanoglous, 1993
Cardboard	5.2			5	Cherubini et al, 2008
Cardboard	2.7	80.4	11.2	5.7	Ryu et al, 2007b
Corrugated boxes	5.20	77.47	12.27	5.06	Williams, 2005
Magazines	4.10	66.40	7.00	22.50	Tchobanoglous, 1993
Newsprint	6.00	81.10	11.50	1.40	Tchobanoglous, 1993
Newsprint	5.97	81.12	11.48	1.43	Williams, 2005
Paper	10.2			6	Cherubini et al, 2008
Paper	10.2			6	Zhao et al, 2008
Paper & Card	25.2	78.1	9.5	12.4	Papageorgiou et al., 2009
Paper and cardboard	14	81		5	Consonni et al., 2005
Paper and cardboard (MR residue	24.2	70.8		5.0	Giugliano et al., 2008
Paper mixed	10.20	75.90	8.40	5.40	Tchobanoglous, 1993
Paper-mixed	10.24	75.94	8.44	5.38	Williams, 2005
Paper (mixed)	6			6	Zsigraiova et al, 2009
Plastic coated paper	4.71	84.20	8.45	2.64	Williams, 2005
Junk mail	4.56	73.32	9.03	13.09	Williams, 2005
Waxed cartons	3.40	90.90	4.50	1.20	Tchobanoglous, 1993
Waxed milk cartons	3.45	90.92	4.46	1.17	Williams, 2005
Paper 2yr	50.8	77.9		22.1	Chiemchaisri et al., 2009

Appendix A

Table A2 MSW proximate analysis % by wet weight

Type of waste	Moisture	matter	carbon	ash	reference
Plastics					
Plastics mixed	0.20	95.80	2.00	2.00	Tchobanoglous, 1993
Plastics (mixed)	2			10	Zsigraiova et al, 2009
Plastic (MR residue)	16.1	74.9		9.0	Giugliano et al., 2008
Plastics	0.2			10	Cherubini et al, 2008
Plastics	1.2			10	Zhao et al, 2008
Plastic	6	85		9	Consonni et al., 2005
Plastic film	29.8	83.1	2.7	14.2	Papageorgiou et al., 2009
Polyethylene	0.20	98.50	<.1	1.20	Tchobanoglous, 1993
Polystyrene	0.20	98.70	0.70	0.50	Tchobanoglous, 1993
Polystyrene	0.20	98.67	0.68	0.45	Williams, 2005
Polyurethane	0.20	87.10	8.30	4.40	Tchobanoglous, 1993
Plastic dense	11.0	87.0	6.4	6.6	Papageorgiou et al., 2009
Polyvinyl chloride	0.20	86.90	10.80	2.10	Tchobanoglous, 1993
PVC	0.20	86.89	10.85	2.06	Williams, 2005
Linoleum	2.10	64.50	6.60	26.80	Williams, 2005
Carry bags 2 yr	23.1	87.3		12.7	Chiemchaisri et al., 2009
Carry bags 5 yr	25	63.9		36.1	Chiemchaisri et al., 2009
Carry bags 7 yr	22.1	79.2		20.8	Chiemchaisri et al., 2009
Carry bags 10 yr	1.4	38.4		61.6	Chiemchaisri et al., 2009
Other bags 2 yr	4.6	93		7	Chiemchaisri et al., 2009
Other bags 5 yr	11.4	73		27	Chiemchaisri et al., 2009
Other bags 7 yr	14.1	78.2		21.8	Chiemchaisri et al., 2009
Other bags 10 yr	1.3	87.9		12.1	Chiemchaisri et al., 2009
Other plastic 2r	11.6	95.8		4.2	Chiemchaisri et al., 2009
Other plastic 5 yr	5	90.1		9.9	Chiemchaisri et al., 2009
Other plastic 7 yr	4.5	92.3		7.7	Chiemchaisri et al., 2009
Other plastic 10 yr	55.2	92.2		7.8	Chiemchaisri et al., 2009
Foam 2 yr	53.8	87.5		12.5	Chiemchaisri et al., 2009
Foam 5 yr	41.2	76.4		23.6	Chiemchaisri et al., 2009
Foam 7 yr	9.2	72.9		27.1	Chiemchaisri et al., 2009
Foam 10 yr	1	78.4		21.6	Chiemchaisri et al., 2009
Textile, Rubber, Leather					
Textile	10.00	66.00	17.50	6.50	Tchobanoglous, 1993
Textiles	10			2.5	Cherubini et al, 2008
Textiles	10			3.2	Zhao et al, 2008
Textile	3.6	89	6.9	0.5	Ryu et al, 2007b
Textiles	41.9	80.9	10.7	8.4	Papageorgiou et al., 2009
Upholstery	6.90	75.96	14.52	2.62	Williams, 2005
Rags	10.00	84.34	3.46	2.20	Williams, 2005
Clothes 2 yr	27.1	84		16	Chiemchaisri et al., 2009
Clothes 5 yr	33.3	88.9		11.1	Chiemchaisri et al., 2009
Clothes 7 yr	35.5	72.6		27.4	Chiemchaisri et al., 2009
Clothes 10 yr	3.1	46.8		53.2	Chiemchaisri et al., 2009
Rubber	1.20	83.90	4.90	9.90	Tchobanoglous, 1993
Rubber	1.20	83.98	4.94	9.88	Williams, 2005
Rubber 2yr	5.1	61.8		38.2	Chiemchaisri et al., 2009
Rubber 5 yr	6.3	63.4		39.6	Chiemchaisri et al., 2009
Rubber 7 yr	5.8	69.3		30.7	Chiemchaisri et al., 2009
Leather	10.00	68.50	12.50	9.00	Tchobanoglous, 1993
Leather shoe	7.46	57.12	14.26	21.16	Williams, 2005
Combustibles	35.9	75.1	11.3	13.6	Papageorgiou et al., 2009

Appendix A

Table A2 MSW proximate analysis % by wet weight

Type of waste	Moisture	matter	carbon	ash	reference
Glass					
Glass	2			98.9	Zsigraiova et al, 2009
Glass	2			98.9	Cherubini et al, 2008
Glass	2			98.9	Zhao et al, 2008
Glass	5.0	0.8	0.1	99.1	Papageorgiou et al., 2009
Glass and inert material (MR resid	0.0	5.0		95.0	Giugliano et al., 2008
Glass and inert material	2.5	2.5		95	Consonni et al., 2005
Glass and minerals	2.00	-	-	96-99+	Tchobanoglous, 1993
Glass 2 yr	0.1	0.2		99.8	Chiemchaisri et al., 2009
Glass 5 yr	0.1	0.2		99.8	Chiemchaisri et al., 2009
Glass 7 yr	0.5	0.1		99.9	Chiemchaisri et al., 2009
Glass 10 yr	0	0.1		99.9	Chiemchaisri et al., 2009
Metals					
Metals	3			90.5	Zsigraiova et al, 2009
Metals	2			90.5	Zhao et al, 2008
Metals	5	2.5		92.5	Consonni et al., 2005
Metals (MR residue)	0.0	7.5		92.5	Giugliano et al., 2008
Metal, Tin cans	5.00	-	-	94-99+	Tchobanoglous, 1993
Metal, Ferrous	2.00	-	-	96-99+	Tchobanoglous, 1993
Ferrous metals [a]	2			90.5	Cherubini et al, 2008
Ferrous metals	5.0	0.8	0.1	99.1	Papageorgiou et al., 2009
Non-ferrous Metals	5.0	0.8	0.1	99.1	Papageorgiou et al., 2009
Metal, Non ferrous	2.00	-	-	94-99+	Tchobanoglous, 1993
Aluminium[a]	2			90.5	Cherubini et al, 2008
Metal 2 yr	3.7	16.8		83.2	Chiemchaisri et al., 2009
Metal 5 yr	13.5	28.8		71.2	Chiemchaisri et al., 2009
Metal 7 yr	0.8	24.9		75.1	Chiemchaisri et al., 2009
Metal 10 yr	1.6	16		84	Chiemchaisri et al., 2009
Non combustibles					
Non-combustibles	5.0	0.8	0.1	99.1	Papageorgiou et al., 2009
Slag and ceramics	20			68	Zhao et al, 2008
Ceramic 2 yr	0.2	4.1		95.9	Chiemchaisri et al., 2009
Ceramic 5 yr	0.6	0.88		99.2	Chiemchaisri et al., 2009
Ceramic 7 yr	2.8	8.5		91.5	Chiemchaisri et al., 2009
Ceramic 10 yr	0.4	2.1		97.9	Chiemchaisri et al., 2009
Miscellaneous					
Office sweepings	3.20	20.50	6.30	70.00	Tchobanoglous, 1993
Vacuum cleaner dirt	5.47	55.68	8.51	30.34	Williams, 2005
Fines (MR residue)	47.0	18.0		35.0	Giugliano et al., 2008
Fines	41.0	31.9	4.2	63.9	Papageorgiou et al., 2009
Fines	30	35		35	Consonni et al., 2005
Soil 2 yr	24.7	48		52	Chiemchaisri et al., 2009
Soil 5 yr	16.6	25.4		74.6	Chiemchaisri et al., 2009
Soil 7 yr	23.7	19.3		80.7	Chiemchaisri et al., 2009
Soil 10 yr	3.9	24.6		75.4	Chiemchaisri et al., 2009
Other	3.2			68	Cherubini et al, 2008

Appendix A

Table A2 MSW proximate analysis % by wet weight

Type of waste	Moisture	matter	carbon	ash	reference
Residential MSW	21.00	52.00	7.00	20.00	Tchobanoglous, 1993
	15-40	40-60	4-15	10-30	Tchobanoglous, 1993
Commercial MSW	15.00	-			Tchobanoglous, 1993
	10-30				Tchobanoglous, 1993
MSW	20.00	-			Tchobanoglous, 1993
	10-30				Tchobanoglous, 1993
MSW England	31.56			25.12	Biffaward, 2003 (NHWAP survey, 1994)
MSW England	31.9			16.15	Williams, 2005 (NHWAP survey, 1994)
MSW	18.4	72.7		13.9	Cormos, 2009
MSW UK	32.43			22.3	Patumsawad and Cliffe, 2002
MSW UK	36.6	53.9	6.7	39.4	Papageorgiou et al., 2009
MSW	31.2	64.83		35.17	Garg et al., 2009
MSW Canada	31			23.4	Qiu and Hayden, 2009
MSW Thailand	58.4			13.4	Patumsawad and Cliffe, 2002
MSW Thailand	60	26	4	10	Suksankraisorn et al., 2004
MSW Thailand	40.4	31.31		28.29	Chaya and Gheewala, 2007
MSW Santiago	21.5			27.4	Zsigraiova et al, 2009
MSW Tianjin	44.39			17.37	Zhao et al, 2008
hydrothermally treated MSW	11.6	70.94	6.3	22.75	Muthuraman et al., 2009 online
sorted MSW	18.40	70.20		11.50	Grieco and Poggio, 2009
waste feedstock	28	40.8	7.2	24	Yang et al, 2007 c
Typical MSW	36	32	8.2	23.8	Yang and Swithenbank, 2008
MR residue UK	31.8	51.6		16.6	Consonni et al., 2005
MR residue Italy	29.1	53.8		17	Giugliano et al., 2008
Bio-stabilised MR residue	10.5	78.3		11.2	Giugliano et al., 2008
2 yr Excavated solid wastes	38.8	38.5		61.5	Chiemchaisri et al., 2009
5 yr Excavated solid wastes	50	57.2		42.8	Chiemchaisri et al., 2009
7 yr Excavated solid wastes	48.6	36.4		63.6	Chiemchaisri et al., 2009
10 yr Excavated solid wastes	34.7	40.8		59.2	Chiemchaisri et al., 2009
RDF					
RDF (plastic:cassava root) 1:0.8	2.95	84.30	1.20	14.50	Chiemchaisri et al., 2009
RDF (plastic:cassava root) 1:1	3.46	82.20	1.90	15.90	Chiemchaisri et al., 2009
RDF (plastic:cassava root) 1:1.2	3.64	85.2	1.2	13.6	Chiemchaisri et al., 2009
RDF (plastic:cassava root) 1:1.4	3.94	86.00	1.40	12.60	Chiemchaisri et al., 2009
RDF (plastic:cassava root) 1:1.6	5.50	88.80	0.90	10.30	Chiemchaisri et al., 2009
RDF 1(>16 mm)	3.7	67.6	9.8	18.9	Hernandez-Atonal et al. 2006
RDF 2 (8-16 mm)	1.7	73.6	7	17.7	Hernandez-Atonal et al. 2006
RDF 3 (< 8 mm)	19.7	49.1	10.8	20.4	Hernandez-Atonal et al. 2006
RDF	10.5	78.3		11.2	Giugliano et al., 2008
SRF	15.0	82.1		10.9	Garg et al., 2009

Appendix A

Table A3 MSW Ultimate analysis (% by weight - dry basis)

Ultimate analysis	**Percent by weight - dry basis**						
Type of waste	**Carbon**	**Hydrogen**	**Oxygen**	**Nitrogen**	**Sulfur**	**Ash**	**Reference**
Food waste							
Organic (mixed)	48	6.4	37.6	2.6	0.4	5	Zsigraiova et al, 2009
Kitchen waste	48(100)	6.4	37.6	2.6	0.4	5	Zhao et al, 2008
Kitchen garbage	48	6.4	37.6	2.6	0.4	5	Cherubini et al, 2008
Food wastes-mixed	48.0	6.4	37.6	2.6	0.4	5.0	Tchobanoglous, 1993
Vegetable food waste	49.06	6.62	37.55	1.68	0.20		Williams, 2005
Fruit wastes	48.5	6.2	39.5	1.4	0.2	4.2	Tchobanoglous, 1993
Meat scraps (cooked)	59.59	9.47	24.65	1.02	0.19		Williams, 2005
Meat wastes	59.6	9.4	24.7	1.2	0.2	4.9	Tchobanoglous, 1993
Fats	73.0	11.5	14.8	0.4	0.1	0.2	Tchobanoglous, 1993
Fried fats	73.14	11.54	14.82	0.43	0.07		Williams, 2005
Garden waste							Tchobanoglous, 1993
Lawn grass	46.18	5.96	36.43	4.46	0.42		Williams, 2005
Leaves	52.15	6.11	30.34	6.99	0.16		Williams, 2005
Green Logs	50.12	6.40	42.26	0.14	0.08		Williams, 2005
Evergreen shrubs	48.51	6.54	40.44	1.71	0.19		Williams, 2005
Flowering plants	46.65	6.61	40.18	1.21	0.26		Williams, 2005
Yard wastes	46.0	6.0	38.0	3.4	0.3	6.3	Tchobanoglous, 1993
Wood green timber	50.1	6.4	42.3	0.1	0.1	1.0	Tchobanoglous, 1993
Hardwood	49.6	6.1	43.2	0.1	<0.1	0.9	Tchobanoglous, 1993
Wood	49.4	5.7	42.3	0.2	0	2.4	Cherubini et al, 2008
Wood	49.6(100)	6	42.6	0.2	0.1	1.5	Zhao et al, 2008
Wastewood	47.9	6.2	38.3				Yang et al, 2007
Waste wood	44.9	6.7	38.6				Ryu et al, 2007 a
Wood and bark	50.46	5.97	42.37	0.15	0.05		Williams, 2005
Wood mixed	49.5	6.0	42.7	0.2	<0.1	1.5	Tchobanoglous, 1993
Wood chips mixed	48.1	5.8	45.5	0.1	<0.1	0.4	Tchobanoglous, 1993
Paper products							
Cardboard	43.0	5.9	44.8	0.3	0.2	5.0	Tchobanoglous, 1993
Cardboard	44	5.9	44.6	0.3	0.2	5	Cherubini et al, 2008
Cardboard	41.7	6.4	43.5				Ryu et al, 2007 a
Corrugated boxes	43.73	5.70	44.93	0.09	0.21		Williams, 2005
Magazines	32.9	5.0	38.6	0.1	0.1	23.3	Tchobanoglous, 1993
Newsprint	49.1	6.1	43.0	<0.1	0.2	1.5	Tchobanoglous, 1993
Newsprint	49.14	6.10	43.03	0.05	0.16		Williams, 2005
Paper	43.5	6	44	0.3	0.2	6	Cherubini et al, 2008
Paper	43.4(100)	5.8	44.3	0.3	0.2	6	Zhao et al, 2008
Paper mixed	43.4	5.8	44.3	0.3	0.2	6.0	Tchobanoglous, 1993
Paper-mixed	43.41	5.82	44.32	0.25	0.20		Williams, 2005
Paper (mixed)	43.5	6	44	0.3	0.2	6	Zsigraiova et al, 2009
Junk mail	37.87	5.41	42.74	0.17	0.09		Williams, 2005
Plastic coated paper	45.30	6.17	45.50	0.18	0.08		Williams, 2005
Waxed milk cartons	59.18	9.25	30.13	0.12	0.10		Williams, 2005
Waxed cartons	59.2	9.3	30.1	0.1	0.1	1.2	Tchobanoglous, 1993
Plastics							
Plastics	60	7.2	22.8	0	0	10	Cherubini et al, 2008
Plastics	60(0)	7.2	22.8	0	0	10	Zhao et al, 2008
Plastics mixed	60.0	7.2	22.8	-	-	10.0	Tchobanoglous, 1993
Plastics (mixed)	60	7.2	22.8	0	0	10	Zsigraiova et al, 2009
Polyethylene	85.2	14.2	-	<0.1	<0.1	0.4	Tchobanoglous, 1993
Polystyrene	87.1	8.4	4.0	0.2	-	0.3	Tchobanoglous, 1993
Polystyrene	87.10	8.45	3.96	0.21	0.02		Williams, 2005
Polyurethane	63.6	6.3	17.6	6.0	<0.1	4.3	Tchobanoglous, 1993
Polyvinyl chloride	45.2	5.6	1.6	0.1	0.1	2.0	Tchobanoglous, 1993
PVC	45.14	5.61	1.56	0.08	0.14		Williams, 2005
Linoleum	48.06	5.34	18.70	0.10	0.40		Williams, 2005

Appendix A

Table A3 MSW Ultimate analysis (% by weight - dry basis)

Type of waste	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash	Reference
Textile etc							Tchobanoglous, 1993
Textile	48.0	6.4	40.0	2.2	0.2	3.2	Tchobanoglous, 1993
Textiles	55	6.6	31.2	4.6	0.2	2.5	Cherubini et al, 2008
Textiles	48(80)	6.4	40	2.2	0.2	3.2	Zhao et al, 2008
Textile residue	43.3	6.2	46.4				Ryu et al, 2007 b
Rags	55.00	6.60	31.20	4.12	0.13		Williams, 2005
Upholstery	47.10	6.10	43.60	0.30	0.10		Williams, 2005
Rubber	69.7	8.7	-	-	1.6	20.0	Tchobanoglous, 1993
Rubber	77.65	10.35	-	-	2.00		Williams, 2005
Rubber	10	2	10	0	0	78	Cherubini et al, 2008
Leather	60.0	8.0	11.6	10.0	0.4	10.0	Tchobanoglous, 1993
Leather shoe	42.01	5.32	22.83	5.98	1.00		Williams, 2005
Leather	8	10	10	0.4	11.6	60	Cherubini et al, 2008
Glass							
Glass	0.5	0.1	0.4	0.1	0	98.9	Cherubini et al, 2008
Glass	0.5(0)	0.1	0.4	0.1	0	98.9	Zhao et al, 2008
Glass and minerals	0.5	0.1	0.4	<0.1	-	98.9	Tchobanoglous, 1993
Glass	0.5	0.1	0.4	0.1	0	98.9	Zsigraiova et al, 2009
Metals							
Metals	4.5	0.6	4.3	0.1	0	90.5	Zsigraiova et al, 2009
Metals	4.5(0)	0.6	4.3	0.1	0	90.5	Zhao et al, 2008
Metal, mixed	4.5	0.6	4.3	<0.1	-	90.5	Tchobanoglous, 1993
Ferrous metals	4.5	0.6	4.3	0.1	0	90.5	Cherubini et al, 2008
Aluminium	4.5	0.6	4.3	0.1	0	90.5	Cherubini et al, 2008
Other	26.3	3	2	0.5	0.2	68	Cherubini et al, 2008
Noncombustibles							
Slag and ceramics	24.3(0)	3	4	0.5	0.2	68	Zhao et al, 2008
Miscellaneous							
Office sweepings	24.3	3.0	4.0	0.5	0.2	68.0	Tchobanoglous, 1993
Oils, paints	66.9	9.6	5.2	2.0	-	16.3	Tchobanoglous, 1993
Vacuum cleaner dirt	35.69	4.73	20.08	6.26	1.15		Williams, 2005
MSW							
Household waste	18-31	2.5-8	20-40	0.3-0.8	.04-0.12		Biffaward, 2003 (NHWAP survey, 1994)
MSW	41.2	5.5	38.7	0.5	0.2	13.9	Cormos, 2009
MSW daf	50.2	5.8	42.3	0.97	0.73		Yang and Swithenbank, 2008
MSW	50.2	5.8	42.3	0.97	0.63		Yang et al, 2004
MSW	34.88	4.65	23.11	1.02	0.15		Garg et al., 2009
MSW USA	37.4	5.10	29.90	1.20	0.10	25.6	Young, 2010
MSW Canada	39	6.4	26	3.5	0.3	23.4	Qiu and Hayden, 2009
MSW Thailand	53.2	8.5	35.8	1.6	0.03		Suksankraisorn et al., 2004
MSW Thailand	37.14	5.41	24.93	0.22	0.09	32.21	tumsawad and Cliffe, 2002
MSW UK	35.81	4.82	24.43	0.78	0.41	33	tumsawad and Cliffe, 2002
MSW Santiago	28.1	3.6	19	0.3	0.1	27.4	Zsigraiova et al, 2009
MSW Tianjin	44.45(64)	5.78	30.47	1.65	0.28	17.37	Zhao et al, 2008
Waste feedstock	49.6	7.3	38.3	1.5	0.4		Yang et al, 2007
Hydrothermally MSW	39.14	2.93	3.07	0.895			Muthuraman et al., 2009 online
Sorted MSW	54.8	7.8	35.6	0.6	0.1	0.9	Grieco and Poggio, 2009
MR residue	27.6	3.5	19.7	0.2	0.1		Consonni et al., 2005
RDF							
RDF	44.7	6.2	38.4	0.7	<0.1	9.9	Tchobanoglous, 1993
RDF	55	7.3	35.9	0.6	0.3		Williams, 2005
RDF 1(>16 mm)	61.2	8.2	26.6	1.3	0.2		Hernandez-Atonal et al. 2006
RDF 2 (8-16 mm)	69.1	7.4	19.6	1.9	0.3		Hernandez-Atonal et al. 2006
RDF 3 (< 8 mm)	57.4	3.8	36.8	ND	0.2		Hernandez-Atonal et al. 2006
SRF	47.1	7.10	29.40	0.70	0.24		Garg et al., 2009
Bituminous Coal	73.8	4.9	9.1	1.4	0.8	9.8	Young, 2010

Appendix A

Table A4 Heating Values of MSW and Coal

	MJ/kg			
Type of waste	**LHV**	**HHV**	**Dry ash-free**	**Reference**
Putrescible				
Organic (mixed)	4.04			Zsigraiova et al, 2009
Organic matter	2.72			Gomez et al., 2009 online
Organic fraction	2.949			Giugliano et al., 2008
Organic fraction MR residue	1.719			Consonni et al., 2005
Wet putrescible	4.17			Biffaward, 2003 (NHWAP survey, 1994)
Putrescible	6.55			Oakdene Hollins Ltd., 2005
Kitchen waste		15.7		Papageorgiou et al., 2009
Kitchen waste residual MSW	4	5.9		Papageorgiou et al., 2009
Food waste		18.400		Menikpura and Basnayake, 2009
Food wastes-mixed	4.180	13.916	16.701	Tchobanoglous, 1993
Vegetable food waste	4.170	19.230	20.230	Williams, 2005
Fruit wastes	3.970	18.638	19.271	Tchobanoglous, 1993
Meat wastes	17.731	28.970	30.517	Tchobanoglous, 1993
Meat scraps (cooked)	17.730	28.940	30.490	Williams, 2005
Slaughter house		21.000		Menikpura and Basnayake, 2009
Fried fats	38.300	38.300	38.300	Williams, 2005
Fats	37.530	38.300	39.161	Tchobanoglous, 1993
Wood, Trees etc				
Garden trimmings		15.800		Menikpura and Basnayake, 2009
Garden waste		16.1		Papageorgiou et al., 2009
Garden waste residual MSW	4.9	6.8		Papageorgiou et al., 2009
Dry garden waste	18.49			Biffaward, 2003 (NHWAP survey, 1994)
Lawn grass	4.760	19.250	20.610	Williams, 2005
Leaves	18.490	20.540	21.460	Williams, 2005
Evergreen shrubs	6.270	20.230	20.750	Williams, 2005
Flowering plants	8.560	18.580	19.590	Williams, 2005
Yard wastes	6.050	15.126	15.317	Tchobanoglous, 1993
Green Logs	4.870	9.740	9.840	Williams, 2005
Wood green timber	4.885	9.769	9.848	Tchobanoglous, 1993
Hardwood	17.101	19.431	19.543	Tchobanoglous, 1993
Wood	13.58			Gomez et al., 2009 online
Wood		14.200		Menikpura and Basnayake, 2009
Wood	16.336			Giugliano et al., 2008
Wood MR residue	13.87			Consonni et al., 2005
Wood and bark	19.570	19.940	20.140	Williams, 2005
Wood mixed	15.445	19.343	19.499	Tchobanoglous, 1993
Waste wood		16		Ryu et al, 2006 a
Wastewood		16		Phan et al, 2007
Waste wood	16			Yang et al, 2007 a
Waste wood		16		Ryu et al, 2006 b
Paper products				
Paper/card	17.23			Oakdene Hollins Ltd., 2005
Paper and cardboard	11.267			Giugliano et al., 2008
Paper & Card		17.4		Papageorgiou et al., 2009
Paper and cardboard MR residue	13.22			Consonni et al., 2005
Paper & Card residual MSW	11.4	13		Papageorgiou et al., 2009
Corrugated boxes	16.380	17.280	18.260	Williams, 2005
Cardboard	16.380	17.278	18.240	Tchobanoglous, 1993
Cardboard		16.360		Menikpura and Basnayake, 2009
Cardboard		15.7		Ryu et al, 2006 a
Cardboard		15.7		Phan et al, 2007
Cardboard	15.7			Yang et al, 2007 a
Cardboard		15.7		Ryu et al, 2006 b
Card packaging	16.38			Biffaward, 2003 (NHWAP survey, 1994)
Other card	16.38			Biffaward, 2003 (NHWAP survey, 1994)
Magazines	12.221	12.742	16.647	Tchobanoglous, 1993
Magazines	17.07			Biffaward, 2003 (NHWAP survey, 1994)

Appendix A

Table A4 Heating Values of MSW and Coal

	MJ/kg			
Type of waste	**LHV**	**HHV**	**Dry ash-free**	**Reference**
Newspapers	18.55			Biffaward, 2003 (NHWAP survey, 1994)
Newsprint	18.550	19.734	20.032	Tchobanoglous, 1993
Newsprint	18.550	19.720	20.000	Williams, 2005
Paper	10.05			Gomez et al., 2009 online
Paper		15.000		Menikpura and Basnayake, 2009
Paper (mixed)	14.4			Zsigraiova et al, 2009
Paper mixed	15.814	17.610	18.738	Tchobanoglous, 1993
Paper-mixed	15.750	17.530	18.650	Williams, 2005
Other paper	15.75			Biffaward, 2003 (NHWAP survey, 1994)
Junk mail	14.160	14.830	17.210	Williams, 2005
Plastic coated paper	17.070	17.910	18.470	Williams, 2005
Waxed cartons	26.344	27.270	27.614	Tchobanoglous, 1993
Waxed milk cartons	26.350	27.290	27.660	Williams, 2005
Liquid cartons	26.35			Biffaward, 2003 (NHWAP survey, 1994)
Plastics				
Plastic	35.22			Gomez et al., 2009 online
Plastic	22.82			Giugliano et al., 2008
Plastic MR residue	26.18			Consonni et al., 2005
Plastics	34.51			Oakdene Hollins Ltd., 2005
Plastics 1		45.000		Menikpura and Basnayake, 2009
Plastics 2		33.300		Menikpura and Basnayake, 2009
Plastics mixed	32.799	33.471	37.272	Tchobanoglous, 1993
Plastics (mixed)	25			Zsigraiova et al, 2009
Plastic film		32.9		Papageorgiou et al., 2009
Plastic film residual MSW	21	23.1		Papageorgiou et al., 2009
Bags and film	41.5			Biffaward, 2003 (NHWAP survey, 1994)
Polyethylene	43.466	43.552	44.082	Tchobanoglous, 1993
Bottles	22			Biffaward, 2003 (NHWAP survey, 1994)
Food packaging	38			Biffaward, 2003 (NHWAP survey, 1994)
Polystyrene	38.191	38.265	38.216	Tchobanoglous, 1993
Polystyrene	38.020	38.090	38.230	Williams, 2005
Polyurethane	26.061	26.112	27.317	Tchobanoglous, 1993
Polyvinyl chloride	22.690	22.734	23.225	Tchobanoglous, 1993
PVC	22.590	22.640	23.160	Williams, 2005
PVC	22.59			Biffaward, 2003 (NHWAP survey, 1994)
Plastic dense		30		Papageorgiou et al., 2009
Plastic dense residual MSW	25	26.7		Papageorgiou et al., 2009
Other dense plastic	40.32			Biffaward, 2003 (NHWAP survey, 1994)
Linoleum	18.870	19.240	26.510	Williams, 2005
Textile, Rubber, Leather				
Textile	18.515	20.571	22.858	Tchobanoglous, 1993
Textile		16		Phan et al, 2007
Textile	16			Yang et al, 2007 a
Textile		16		Ryu et al, 2006 b
Textiles	14.35			Gomez et al., 2009 online
Textiles	16.12			Oakdene Hollins Ltd., 2005
Textiles	16.12			Biffaward, 2003 (NHWAP survey, 1994)
Textiles		17.000		Menikpura and Basnayake, 2009
Textiles		19.3		Papageorgiou et al., 2009
Textiles residual MSW	9.2	11.2		Papageorgiou et al., 2009
Upholstery	16.120	17.320	17.800	Williams, 2005
Rags	15.970	17.720	18.160	Williams, 2005
Rubber	25.330	25.637	28.494	Tchobanoglous, 1993
Rubber	25.930	26.230	29.180	Williams, 2005
Rubber		25.500		Menikpura and Basnayake, 2009
Leather		23.000		Menikpura and Basnayake, 2009
Leather	17.445	18.701	20.892	Tchobanoglous, 1993
Leather shoe	16.770	18.120	23.500	Williams, 2005

Table A4 Heating Values of MSW and Coal

	MJ/kg			
Type of waste	LHV	HHV	Dry ash-free	Reference
Miscellaneous				
Office sweepings	8.534	8.818	31.848	Tchobanoglous, 1993
Vacuum cleaner dirt	14.790	15.640	23.060	Williams, 2005
Fines	7.39			Oakdene Hollins Ltd., 2005
Fines	1.489			Giugliano et al., 2008
Fines		9		Papageorgiou et al., 2009
Fines residual MSW	3.9	5.3		Papageorgiou et al., 2009
Fines MR residue	4.395			Consonni et al., 2005
Combustibles				
Disposible nappies	4			Biffaward, 2003 (NHWAP survey, 1994)
10 mm combustibles	14.79			Biffaward, 2003 (NHWAP survey, 1994)
Combustibles		19.5		Papageorgiou et al., 2009
Combustibles residual MSW	10.7	12.5		Papageorgiou et al., 2009
Misc. combustible	9.25			Oakdene Hollins Ltd., 2005
Glass				
Glass and minerals	0.195	0.200	0.140	Tchobanoglous, 1993
Glass		0.2		Papageorgiou et al., 2009
Glass residual MSW	-0.1	0.2		Papageorgiou et al., 2009
Glass and inert material MR resi	-0.061			Consonni et al., 2005
Metals				
Metal, Tin cans	0.700	0.742	0.737	Tchobanoglous, 1993
Metals MR residue	-0.122			Consonni et al., 2005
Metal, Ferrous				
Ferrous metals		0.2		Papageorgiou et al., 2009
Ferrous metals residual MSW	-0.1	0.2		Papageorgiou et al., 2009
Metal, Non ferrous				
Non-ferrous Metals		0.2		Papageorgiou et al., 2009
Non-ferrous Metals residual MS	-0.1	0.2		Papageorgiou et al., 2009
Non-combustibles				
Non-combustibles		0.2		Papageorgiou et al., 2009
Non-combustibles residual MSW	-0.1	0.2		Papageorgiou et al., 2009
Other	20.14			Biffaward, 2003 (NHWAP survey, 1994)

Appendix A

Table A4 Heating Values of MSW and Coal

	MJ/kg			
Type of waste	**LHV**	**Dry=HHV=G**	**Dry ash-free**	**Reference**
MSW				
Residential MSW	11.63	14.5375	19.382558	Tchobanoglous, 1993
Commercial MSW	12.793	15.04922		Tchobanoglous, 1993
MSW	10.6996	13.3745		Tchobanoglous, 1993
MSW		10.93		Williams, 2005 (NHWAP survey, 1994)
MSW	15.21	16.43		Cormos, 2009
MSW		15.40		Garg et al., 2009
MSW	10.4			Zsigraiova et al, 2009
MSW	7.655			Yang et al, 2004
MSW		14		Papageorgiou et al., 2009
Waste feedstock	9.05			Yang et al, 2007 c
MSW USA	14.36	15.48		Young, 2010
MSW Canada	10.5			Qiu and Hayden, 2009
MSW UK	10.25	15.17		Patumsawad and Cliffe, 2002
MSW Thailand	6.49	15.59		Patumsawad and Cliffe, 2002
MSW Thailand	6.9			Suksankraisorn et al., 2004
MSW Thailand	5.163	6.121		Chaya and Gheewala, 2007
MSW Phuket	7.32			Liamsanguan and Gheewala, 2008
Sorted MSW	15.38			Grieco and Poggio, 2009
Hydrothermally treated MSW		17.84		Muthuraman et al., 2009 online
MR residue	9.871			Giugliano et al., 2008
Bio-stabilised MR residue	12.881			Giugliano et al., 2008
Residual MSW	7.06	8.63		Papageorgiou et al., 2009
MR residue	10.11			Consonni et al., 2005
RDF				
RDF	15.638			Giugliano et al., 2008
RDF (plastic:cassava root) 1:0.8	26			Chiemchaisri et al., 2009
RDF (plastic:cassava root) 1:1	23.8			Chiemchaisri et al., 2009
RDF (plastic:cassava root) 1:1.2	21.9			Chiemchaisri et al., 2009
RDF (plastic:cassava root) 1:1.4	22.8			Chiemchaisri et al., 2009
RDF (plastic:cassava root) 1:1.6	23.2			Chiemchaisri et al., 2009
RDF 1(>16 mm)	20.8	22.3		Hernandez-Atonal et al. 2006
RDF 2 (8-16 mm)	23.3	24.6		Hernandez-Atonal et al. 2006
RDF 3 (< 8 mm)	12.6	13.9		Hernandez-Atonal et al. 2006
Bituminous Coal	29.37	30.44		Young, 2010

Appendix B

Comparison of Waste Management LCA Studies

Author	Year	Location	LCA	software	inventory database	System boundary	Environmental Category	impact assessment method	treatment process
Knox and Robinson, 2007	2007	UK	No			In-after collection/Out-landfill / (exc- MR benefit / energy in compost)	CO2 emissions		landfill w biogas, incineration, compost
Garg et al., 2009	2009	UK	No			In-SRF fuel entry points/Out- product exit points	Global warming/Acidification/Winter smog		RDF, ERF elec
Zsigraiová et al., 2009	2009	Santiago, Cape Verde	No			In-waste gen	Global warming		
Arena et al, 2003	2003	Italy / Campania regione	Yes			collected waste-process-exit process	Energy consumption, Crude oil consumption, Water consumption, CO2 equiv., Air emission organic, Air emission dust, SO2 equiv., Water emission SS, Occupied landfill		RDF/SRF, landfill w biogas, ERF elec, compost
Rodriguez-Iglesias et al, 2003	2003	Spain / Asturias	Yes	IWM-1		In-becoming waste, losing value / Out-leave system or regain value	Greenhouse effect, Acidification, Eutrophication, Heavy Metals, Carcinogens, Winter Smog, Summer Smog		recycling, landfill w biogas, ERF elec, AD elec, compost
Consonni et al., 2005	2005	Italy	Yes			In-after recycling/Out-product exit points	Global warming, Human toxicity, Acidification, Photochemical ozone, Landfill volume		ERF: 1.Grate+CHP 2. Grate 3. Fluidised bed 4. Fluidised bed

Appendix B

Comparison of Waste Management LCA Studies

Author	Scenario amount	Scenario list	waste type	Composition	Results	Other notes
Knox and Robinson, 2007	2	1.MBT-compost/landfill 2. Incin/landfill	MSW	No	MBT compost consume energy/Less gas in landfill/ More CO2 emission	System boundary not clear
Garg et al., 2009	4		SRF from MSW	Yes / SRF, coal, MSW, woodchips	Cement kiln because no need to change equipment	Risk and financial analysis
Zsigraiová et al., 2009		1.MBI-steam turbine 2.MBI –steam turbine-elect/heat/drinking water	MSW/ No recycling	Yes	CHP best w MED dasalinate	Island/ Drinking water/ GIS
Arena et al, 2003	3	Landfill, RDF+combust, mass combust	MSW (restwaste), RDF	Yes	Mass burn combustion has more positive impacts	
Rodriguez-Iglesias et al, 2003	19		MSW	No	WtE- better energy use/ Compost+Biomethanisation less impact	economic cost analysis in model/ use term: biomethanisation = AD?
Consonni et al., 2005	4		1. recov MSW 2. recov MSW-org/landfill 3.RDF -sta org 4.RDF -org/ landfill	Yes/ Recovered MSW	Recovered MSW with cogen. District heating/ RDF not worth it unless co combust	Part a Detail energy balance (part b economic)

Appendix B

Comparison of Waste Management LCA Studies

Author	Year	Location	LCA	software	inventory database	System boundary	Environmental Category	impact assessment method	treatment process
Finnveden et al, 2005	2005	Sweden	Yes	Simapro 4.0	BUWAL 250, IDEMAT, Pre 4, FRANKLIN US LCI, IVAM 2		Energy use, Climate change GW, Acidification, Abiotic resource use, Eutrophication, Photochemical oxidation, Ozone layer depletion, Human toxicity, Ecotoxicity	Danish EDIP, Dutch USES-LCA, Ecoindicator 99	
Moberg et al, 2005	2005	Sweden	Yes	Simapro 4.0	BUWAL 250, IDEMAT, Pre 4, FRANKLIN US LCI, IVAM 2		Total energy, Non renewable energy, Abiotic resource, Non treated waste, Global Warming, Depletion of Stratospheric ozone, Photo-oxidant formation, SO x, NO x, Acidification (excluding SO x, NO x),Aquatic Eutrophication (excluding NO x), Eco toxicological impacts, Human toxicological impacts	Danish EDIP, Dutch USES-LCA, Ecoindicator 99	recycle, landfill, landfill w biogas, ERF heat
Wanichpongpan, 2007	2007	Thailand	Yes	?			GWP		landfill, landfill w biogas
Cherubini et al., 2008	2008	Italy	Yes			In-after collection/ Out-product exit points	Global warming, Acidification, Eutrophication, Dioxin		RDF/SRF,landfill, landfill w biogas, ERF CHP, AD elec, compost
Giugliano et al., 2008	2008	Italy	Yes	Not full		In –after recycling/ Out-product exit points/ Recycling benefit not inc	Global warming, Human toxicity, Photochemical ozone Acidification, Landfill volume		

Appendix B

Comparison of Waste Management LCA Studies

Author	Scenario amount	Scenario list	waste type	Composition	Results	Other notes
Finnveden et al, 2005	9 with 3 sub scenario	(sub. 1. AD and recycling 2. incin heat 3. landfill gas) 1. base 2.medium transport 3. long transport 4.medium transport plus passenger 5. natural gas 6. saved forest 7. surveyable time period 8. carbon sink 9. plastic palisade	fractions of MSW: food, paper, plastic	yes	In general Recycling better than Incineration which is better than landfill. But using passenger cars in source separation makes it worse. Food, AD or Incineration better than compost or landfill.	uses weighting by applying Swedish Ecotax 98
Moberg et al, 2005	9 with 3 sub scenario	(sub. 1. recycling 2. incin heat 3. landfill gas) 1. base 2.medium transport 3. long transport 4.medium transport plus passenger 5. natural gas 6. saved forest 7. surveyable time period 8. carbon sink 9. plastic palisade	fractions of MSW: paper, plastic		In general Recycling better than Incineration which is better than landfill. But using passenger cars in source separation makes it worse. But time boundary changes results, short term (100 yr) favour landfill over incineration in some scenario. Assumptions, boundaries, value choices ethical aspect are important	1.Same study as Finnveden et al, 2005 2.uses weighting by applying Swedish Ecotax 98
Wanichpongpan, 2007		1. Large landfill w biogas 2. Small landfill w/o biogas	MSW	No		
Cherubini et al., 2008	4	1.Landfill 2.Landfill gas-elect 3. recycle FE RDF combustOrg-AD-biogas/compost Landfill 4. incineration	MSW / Recov MSW	Yes/ MSW	Best energy and env.= recycle FE, RDF combust, Org-AD-biogas/compost, Landfill	Review methods/ Emery
Giugliano et al., 2008	3	1.combust-elec 2.aerobic sta, combust-elec 3. aerobic sta MR-RDF gasification syngas	MR /RDF	Yes / MR RDF	RDF gasification more energy output	Economic analysis

Appendix B

Comparison of Waste Management LCA Studies

Author	Year	Location	LCA	software	inventory database	System boundary	Environmental Category	impact assessment method	treatment process
Liamsanguan and Gheewala, 2008	2008	Thailand	Yes			In –after separation / Out- product exit points	Greenhouse gas		landfill w biogas, ERF elec
Cherubini et al, 2009	2009	Italy / Rome	Yes	multi method		MSW in Rome	Global warming, Acidification, Eutrophication, Material intensites, Gross energy requirement, ecological footprint		recycle, landfill, landfill w biogas, ERF elec, AD elec
Feo and Malvano, 2009	2009	Italy	Yes	Wizard		In-waste gen/ Out-product exit points	Renew. Energy, Non renew energy, Water, SS oxydable matters index, Mineral quarried, Greenhouse gas Eutrophication, Acidification, HW/non HW		
Khoo, 2009	2009	Singapore	Yes	EDIP / Gabi		In-after collection/ Out-product exit points	Global warming/ Eutrophication/ Photochemical ozone Acidification		pyrolysis, gasification
Papageorgiou et al., 2009	2009	England	Yes	approach		In-after kerbside collection/Out- product exit points	EF/CO2 equivalent		RDF
Rigamonti et al., 2009	2009	Italy	Yes	(simapro 7)		In-waste gen/Include replace mat./Out-product exit points	Global warming, Human toxicity, Acidification, Photochemical ozone		Incineration, ERF elec, ERF CHP

Appendix B

Comparison of Waste Management LCA Studies

Author	Scenario amount	Scenario list	waste type	Composition	Results	Other notes
Liamsanguan and Gheewala, 2008		1. landfill 2. WtE	MSW w/o metal/glass	Yes / MSW Not full	WtE better than landfill / But landfill w gas collection better	
Cherubini et al, 2009	4	Landfill/ Landfill with biogas/ Recycling,RDF to WtE, AD/ WtE	MSW, RDF	Yes	1.Recycling,RDF to WtE, AD 2. WtE 3. Landfill with biogas 4. Landfill	flow accounting MFA, Gross energy
Feo and Malvano, 2009	12	1-10. varied % source sep/ MRF/compost/RDF 11. no RDF 12. no MRF/RDF	MSW	Yes/ MSW	Option 11 best w/ 80% and RDF incineration	Detailed env impact
Khoo, 2009	8	1.pyrolysis-gasification 2. pyrolysis 3.thermal cracking gasification of granulated MSW 4.combine pyrol. Gasifi. Oxidation 5 Steam gasifi wood 6. FB gasification 7.gasification RDF 8 gasification tyres	MSW/ Scrapwood / Org waste/ RDF/ Tyres	No	For env. 1. pyrol –gasification MSW 2. steam gasifi. Wood / For cost 1. CFB gasifi. Org waste 2.pyrol-gasifi. Oxidation MSW	Cost analysis
Papageorgiou et al., 2009		1 MBI- no elec/ elec/ CHP 2 MBT-CHP/ powerplant/cement kiln 3 MHT-autoclave	1. MSW 2. SRF 3.SRF	Yes / MSW,Recovered MSW	MHT and MBT-if SRF with market in powerplant or cement kiln	Sensitivity analysis
Rigamonti et al., 2009			1. 35% Re MSW 2. 50% Re MSW 3. 60% Re MSW	No/ Only quantity	All option save energy/Large incinerator w CHP best	Sensitivity analysis/ Source separation calc.

Appendix B

Comparison of Waste Management LCA Studies

Author	Year	Location	LCA	software	inventory database	System boundary	Environmental Category	impact assessment method	treatment process
Wittmaier et al, 2009	2009	North Germany	Yes	Gabi 4.0			CO2 - GWP		landfill w biogas, ERF elec
Zhao et al., 2009	2009	China	Yes	CMLCA		In-waste gen/ Out-product exit points	Global warming		recycling, landfill w biogas, ERF elec, ERF CHP, AD elec, compost
Zaman, 2010	2010	Sweden/UK data	Yes	Simapro	CML2		Abiotic resource depletion, Acidification, Eutrophication, Global Warming 100yr, Ozone layer depletion, Human toxicity, Fresh water toxicity, Marine toxicity, Terrestial toxicity, Photochemical oxidation		landfill w biogas, ERF elec, pyrolysis, gasification
Tunesi, 2011	2011	England	Yes	WRATE	ecoinvent		Abiotic resource depletion, Global Warming 100yr, Acidification		recycling, landfill, landfill w biogas, ERF elec, ERF CHP, AD elec, compost
Burnley et al, 2011	2011	UK	Yes	WRATE	ecoinvent		Resource depletion, Eutrophication, Global Warming 100yr, Human toxicity, Aquatic eco-toxicity, Acidification		ERF elec, AD CHP,gasi, cement, dedicate combustion

Appendix B

Comparison of Waste Management LCA Studies

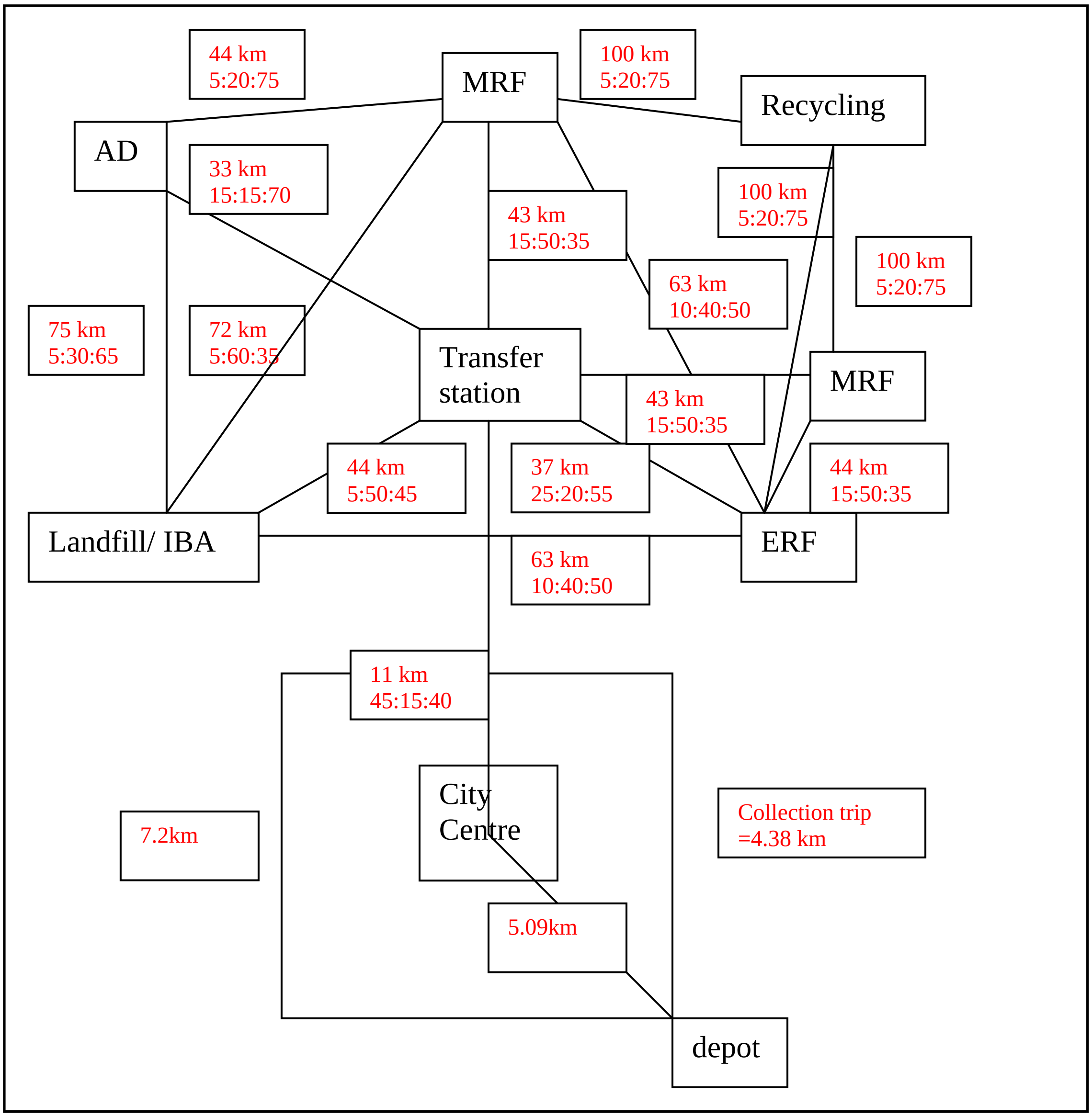
Author	Scenario amount	Scenario list	waste type	Composition	Results	Other notes
Wittmaier et al, 2009	3	1. Landfill 2.WtE 3. WtE optimized	MSW	No	WtE optimized	
Zhao et al., 2009	7	1. incin/landfill 2. landfill gas-elec 3.incin-elec 4.MRF incin-elec 5.50% compost/ incin-elec 6. 50% AD-biogas-elec/ incin-elec 7. MRF- AD-biogas-elec / incin-elec/ landfill gas-elec	MSW/ Recov MSW/ Dry MSW/Recov dry MSW	Yes/ MSW	Option 7 best but high investment at once	Sensitivity analysis
Zaman, 2010	3	1.landfill biogas 2.Incineration WtE 3. Pyrolysis-gasification	MSW	No	1. Landfill 2. Pyrolysis-gasification high energy efficiency 3. Incineration WtE	
Tunesi, 2011	9	variations of thermal treatment, pretreatment for SRF, FBG, cement kiln	MSW, SRF	Yes/ MSW=HW, NHWRC,street, fly	WtE- better than … FBG, MBT not worth it unless SRF for cement kiln, Not export recyclate but WtE better	WRATE does not account for biofuel
Burnley et al, 2011	4x6	AD, EfW, Gasification, Cement Kiln, Dedicated combustion	BMW; paper, food waste, garden waste, wood waste, residual waste, RDF	No/implied use default WRATE?	cement kiln : paper-EfW, food waste-AD, garden waste-EfW, wood waste-dedicated plant, residual waste-EfW, RDF-gasification	Sardinia 2011

Appendix C

Table C1 The properties of the collection vessels used in the scenarios

Scenario code	Collection type	Collection capacity	Amount of bins
1-18 IN UKUR	wheeled bins 12276	140 L / 36.4 kg	98,300
10-18 IN UKUR	Kerbside box w/lid 12018	55 L / 14.3 kg	98,300
10-18 IN UKUR	Kerbside box w/o lid 12277	55 L / 14.3 kg	98,300
1-17 AD UKUR	wheeled bins 12276	140 L / 36.4 kg	98,300
6-17 AD UKUR	Kitchen Caddy 12222	5 L / 1.9 kg	98,300
6-17 AD UKUR	Garden Bag 12064	30 L / 7.8 kg	98,300
6-17 AD UKUR	Kerbside box w/lid 12018	55 L / 14.3 kg	98,300
6-17 AD UKUR	Kerbside box w/o lid 12277	55 L / 14.3 kg	98,300
1-72 C1 UKUR	wheeled bins 12276	140 L / 36.4 kg	98,300
1-72 C1 UKUR	Kitchen Caddy 12222	5 L / 1.9 kg	98,300
1-72 C1 UKUR	Garden Bag 12064	30 L / 7.8 kg	98,300
13-24, 37-48, 61-72 C1 UKUR	Kerbside box w/lid 12018	55 L / 14.3 kg	98,300
	Kerbside box w/o lid 12277	55 L / 14.3 kg	98,300
1-18 IN UKRU	wheeled bins 12276	140 L / 36.4 kg	46,900
10-18 IN UKRU	Kerbside box w/lid 12018	55 L / 14.3 kg	46,900
10-18 IN UKRU	Kerbside box w/o lid 12277	55 L / 14.3 kg	46,900
1-17 AD UKRU	wheeled bins 12276	140 L / 36.4 kg	46,900
6-17 AD UKRU	Kitchen Caddy 12222	5 L / 1.9 kg	46,900
6-17 AD UKRU	Garden Bag 12064	30 L / 7.8 kg	46,900
6-17 AD UKRU	Kerbside box w/lid 12018	55 L / 14.3 kg	46,900
6-17 AD UKRU	Kerbside box w/o lid 12277	55 L / 14.3 kg	46,900
1-72 C1 UKRU	wheeled bins 12276	140 L / 36.4 kg	46,900
1-72 C1 UKRU	Kitchen Caddy 12222	5 L / 1.9 kg	46,900
1-72 C1 UKRU	Garden Bag 12064	30 L / 7.8 kg	46,900
13-24, 37-48, 61-72 C1 UKRU	Kerbside box w/lid 12018	55 L / 14.3 kg	46,900
	Kerbside box w/o lid 12277	55 L / 14.3 kg	46,900
1-15 IN THUR	wheeled bins 12276	140 L / 36.4 kg	67,010
10-15 IN THUR	Kerbside box w/lid 12018	55 L / 14.3 kg	67,010
10-15 IN THUR	Kerbside box w/o lid 12277	55 L / 14.3 kg	67,010
1-17 AD THUR	wheeled bins 12276	140 L / 36.4 kg	67,010
6-17 AD THUR	Kitchen Caddy 12222	5 L / 1.9 kg	67,010
6-17 AD THUR	Kerbside box w/lid 12018	55 L / 14.3 kg	67,010
6-17 AD THUR	Kerbside box w/o lid 12277	55 L / 14.3 kg	67,010
1-72 C1 THUR	wheeled bins 12276	140 L / 36.4 kg	67,010
1-72 C1 THUR	Kitchen Caddy 12222	5 L / 1.9 kg	67,010
13-24, 37-48, 61-72 C1 THUR	Kerbside box w/lid 12018	55 L / 14.3 kg	67,010
	Kerbside box w/o lid 12277	55 L / 14.3 kg	67,010
1-15 IN THRU	wheeled bins 12276	140 L / 36.4 kg	31,569
10-15 IN THRU	Kerbside box w/lid 12018	55 L / 14.3 kg	31,569
10-15 IN THRU	Kerbside box w/o lid 12277	55 L / 14.3 kg	31,569
1-17 AD THRU	wheeled bins 12276	140 L / 36.4 kg	31,569

Scenario code	**Collection type**	**Collection capacity**	**Amount of bins**
6-17 AD THRU	Kitchen Caddy 12222	5 L / 1.9 kg	31,569
6-17 AD THRU	Kerbside box w/lid 12018	55 L / 14.3 kg	31,569
6-17 AD THRU	Kerbside box w/o lid 12277	55 L / 14.3 kg	31,569
1-72 C1 THRU	wheeled bins 12276	140 L / 36.4 kg	31,569
1-72 C1 THRU	Kitchen Caddy 12222	5 L / 1.9 kg	31,569
13-24, 37-48, 61-72 C1 THRU	Kerbside box w/lid 12018	55 L / 14.3 kg	31,569
	Kerbside box w/o lid 12277	55 L / 14.3 kg	31,569



A diagram was created to represent the city area and the location of the various waste management processes. Distances between locations were based on the Hampshire facilities and the ratio of urban, rural and motorway were estimated on those locations and distances. The distance between houses for urban area was calculated at 5.8 m and for rural area was 100 m based on a similar study of refuse collection by Knipe (2007). The results are entered in Table C2.

Table C2 The properties of the transportation used in the scenarios

Scenario code	**vehicle**	vehicle capacity	Fuel type	Distance A to B	Ratio urban %	Ratio rural %	Ratio motorway %
Household to Waste transfer station							
1-18 IN UKUR 1-17 AD UKUR 1 -72 C1 UKUR 1-15 IN THUR 1-17 AD THUR 1 -72 C1 THUR	6x4 Refuse Collection Vehicle (RCV) Fleet Euro 4 Diesel V2 12115	12.842 T	Diesel	20 km	45	15	40
1-18 IN UKRU 1-17 AD UKRU 1 -72 C1 UKRU 1-15 IN THRU 1-17 AD THRU 1 -72 C1 THRU	6x4 Refuse Collection Vehicle (RCV) Fleet Euro 4 Diesel V2 12115	12.842 T	Diesel	128 km	40	50	10
10-18 IN UKUR 6-17 AD UKUR 13-24 C1 UKUR 37-48 C1 UKUR 61-72 C1 UKUR 10-15 IN THUR 6-17 AD THUR 13-24 C1 THUR 37-48 C1 THUR 61-72 C1 THUR	Kerbside multi-compartment 12027	5.5 T	ULS diesel	20 km	45	15	40
10-18 IN UKRU 6-17 AD UKRU 13 -24 C1 UKRU 37 -48 C1 UKRU 61 -72 C1 UKRU 10-18 IN THRU 6-17 AD THRU 13 -24 C1 THRU 37 -48 C1 THRU 61 -72 C1 THRU	Kerbside multi-compartment 12027	5.5 T	ULS diesel	128 km	40	50	10
5, 9, 13, 17 AD UKUR 4,8,12,16,20,24,28,32,36,40,44,48,52,56,60,64,68,72 C1 UKUR 5, 9, 13, 17 AD THUR 4,8,12,16,20,24,28,32,36,40,44,48,52,56,60,64,68,72 C1 THUR	6x4 Refuse Collection Vehicle (RCV) Fleet CNG 12113 (For organic and residual collection trucks)	12.842 T	CNG	20 km	45	15	40

Scenario code	**vehicle**	vehicle capacity	Fuel type	Distance A to B	Ratio urban %	Ratio rural %	Ratio motorway %
5, 9, 13, 17 AD UKRU 4,8,12,16,20,24,28,32,36,40,44,48,52,56,60,64,68,72 C1 UKRU 5, 9, 13, 17 AD THRU 4,8,12,16,20,24,28,32,36,40,44,48,52,56,60,64,68,72 C1 THRU	6x4 Refuse Collection Vehicle (RCV) Fleet CNG 12113 (For organic and residual collection trucks)	12.842 T	CNG	20 km	45	15	40
Waste transfer station to Incinerator/ERF							
1-18 IN UKUR, 1-72 C1 UKUR 1-18 IN UKRU 1-72 C1 UKRU 1-15 IN THUR 1-72 C1 THUR 1-15 IN THRU 1-72 C1 THRU	Articulated Truck 44 T 11068	26.9 T		37 km	25	20	55
Waste transfer station to MRF							
7-18 IN UKUR 2-17 AD UKUR 1-72 C1 UKUR 7-18 IN UKRU 2-17 AD UKRU 1-72 C1 UKRU 7-15 IN THUR 2-17 AD THUR 1-72 C1 THUR 7-15 IN THRU 2-17 AD THRU 1-72 C1 THRU	Articulated Truck 44 T 11068	26.9 T		43 km	15	50	35
Waste transfer station to AD							
2-17 AD UKUR 1-72 C1 UKUR 2-17 AD UKRU 1-72 C1 UKRU 2-17 AD THUR 1-72 C1 THUR 2-17 AD THRU 1-72 C1 THRU	Articulated Truck 44 T 11068	26.9 T		33 km	15	15	70
Waste transfer station to Landfill							
2-17 AD UKUR 2-17 AD UKRU 2-17 AD THUR 2-17 AD THRU	Articulated Truck 44 T 11068	26.9 T		44 km	5	50	45
MRF to Recycling							
7-18 IN UKUR 2-17 AD UKUR 9-24 C1 UKUR 33-48 C1 UKUR 57-72 C1 UKUR	Articulated Truck 44 T 11068	26.9 T		100 km	5	20	75

Scenario code	**vehicle**	vehicle capacity	Fuel type	Distance A to B	Ratio urban %	Ratio rural %	Ratio motorway %
7-18 IN UKRU 2-17 AD UKRU 9-24 C1 UKRU 33-48 C1 UKRU 57-72 C1 UKRU 7-15 IN THUR 2-17 AD THUR 9-24 C1 THUR 33-48 C1 THUR 57-72 C1 THUR 7-15 IN THRU 2-17 AD THRU 9-24 C1 THRU 33-48 C1 THRU 57-72 C1 THRU							
MRF to Landfill							
2-17 AD UKUR 9-24 C1 UKUR 33-48 C1 UKUR 57-72 C1 UKUR 2-17 AD UKRU 9-24 C1 UKRU 33-48 C1 UKRU 57-72 C1 UKRU 2-17 AD THUR 9-24 C1 THUR 33-48 C1 THUR 57-72 C1 THUR 2-17 AD THRU 9-24 C1 THRU 33-48 C1 THRU 57-72 C1 THRU	Articulated Truck 44 T 11068	26.9 T		72 km	5	60	35
MRF to Incinerator							
7-18 IN UKUR 9-24 C1 UKUR 33-48 C1 UKUR 57-72 C1 UKUR 7-18 IN UKRU 9-24 C1 UKRU 33-48 C1 UKRU 57-72 C1 UKRU 7-15 IN THUR 9-24 C1 THUR 33-48 C1 THUR 57-72 C1 THUR 7-15 IN THRU 9-24 C1 THRU 33-48 C1 THRU 57-72 C1 THRU	Articulated Truck 44 T 11068	26.9 T		44 km	15	50	35
MRF to AD							
2-17 AD UKUR 2-17 AD UKRU 2-17 AD THUR 2-17 AD THRU	Articulated Truck 44 T 11068	26.9 T		44 km	5	20	75

Scenario code	**vehicle**	vehicle capacity	Fuel type	Distance A to B	Ratio urban %	Ratio rural %	Ratio motorway %
Incinerator to Recycling							
4-18 IN UKUR 5-24 C1 UKUR 29-48 C1 UKUR 53-72 C1 UKUR 4-18 IN UKRU 5-24 C1 UKRU 29-48 C1 UKRU 53-72 C1 UKRU 4-15 IN THUR 5-24 C1 THUR 29-48 C1 THUR 53-72 C1 THUR 4-15 IN THRU 5-24 C1 THRU 29-48 C1 THRU 53-72 C1 THRU	Articulated Truck 44 T 11068	26.9 T		100 km	5	25	70
Incinerator to Landfill and IBA							
1-18 IN UKUR, 1-72 C1 UKUR 1-18 IN UKRU 1-72 C1 UKRU 1-15 IN THUR 1-72 C1 THUR 1-15 IN THRU 1-72 C1 THRU	Articulated Truck 44 T 11068	26.9 T		63 km	10	40	50

Table C3 The Waste Transfer Station

Scenario code	**Capacity (T)**	**User entered capacity-total (T) (Residual+ Recycling)**	**Residual (T)**	**recycling (T)**	**Organic (garden and kitchen)(T)**
1-9 IN UKUR	80,000	86,520			
10-12 IN UKUR	80,000	86,530	82,530	4,000	
13-15 IN UKUR	80,000	86,520	56,540	29,980	
16-18 IN UKUR	80,000	86,530	48,550	37,980	
1-5 AD UKUR	80,000	86,520			
6 - 9 AD UKUR	80,000	86,540	63,570	12,800	10,170
10 - 13 AD UKUR	80,000		47,070	21,990	17,480
14 - 17 AD UKUR	80,000		41,330	25,190	20,020
1-4 C1 UKUR	80,000		75,400		11,120
25-28 C1 UKUR	80,000				
49-52 C1 UKUR	80,000				
5-8 C1 UKUR	80,000		75,400		11,120
29-32 C1 UKUR	80,000				
53-56 C1 UKUR	80,000				
9-12 C1 UKUR	80,000		75,400		11,120
33-36 C1 UKUR	80,000				
57-60 C1 UKUR	80,000				
13-16 C1 UKUR	80,000		82,940	2,000	1,590
37-40 C1 UKUR	80,000				
61-64 C1 UKUR	80,000				
17-20 C1 UKUR	80,000		61,410	13,990	11,120
41-44 C1 UKUR	80,000				
65-68 C1 UKUR	80,000				
21-24 C1 UKUR	80,000		54,240	13,990	14,300
45-48 C1 UKUR	80,000				
69-72 C1 UKUR	80,000				
1-9 IN THUR	80,000		96,730		
10-12 IN THUR	80,000		82,810	13,920	
13-15 IN THUR	80,000		68,900	27,840	
16-18 IN THUR	80,000				
1-5 AD THUR	80,000		96,730		
6-9 AD THUR	80,000		71,900	7,520	17,320
10-13 AD THUR	80,000		54,430	12,810	29,500
14-17 AD THUR	80,000		47,080	15,030	34,630
1-4,25-28,49-52 C1 THUR	80,000		74,290		22,450
5-8,29-32,53-56 C1 THUR	80,000		74,290		22,450
9-12,33-36,57-60 C1 THUR	80,000		74,290		22,450
13-16,37-40,	80,000		85,700	3,340	7,700

Scenario code	Capacity (T)	User entered capacity-total (T) (Residual+ Recycling)	Residual (T)	recycling (T)	Organic (garden and kitchen)(T)
61-64 C1 THUR					
17-20,41-44, 65-68 C1 THUR	80,000		64,550	9,750	22,450
21-24,45-48, 69-72 C1 THUR	80,000		55,350	12,530	28,860
1-9 IN UKRU	80,000	110,570	37,240		
10-12 IN UKRU	80,000	110,570	35,350	1,900	
13-15 IN UKRU	80,000	110,580	24,510	12,740	
16-18 IN UKRU	80,000	110,570	20,560	16,690	
1-5 AD UKRU	80,000		37,240		
6-9 AD UKRU	80,000		27,360	5,510	4,380
10-13 AD UKRU	80,000		20,570	9,300	7,390
14-17 AD UKRU	80,000		17.790	10,840	8,620
1-4,25-28,49-52 C1 UKRU	80,000		32,460		4,790
5-8,29-32,53-56 C1 UKRU	80,000		32,460		4,790
9-12,33-36,57-60 C1 UKRU	80,000		32,460		4,790
13-16,37-40, 61-64 C1 UKRU	80,000		35,390	1,040	830
17-20,41-44, 65-68 C1 UKRU	80,000		26,640	6,030	4,790
21-24,45-48, 69-72 C1 UKRU	80,000		23,040	7,920	6,300
73 C1 UKRU	80,000		6,370	17,210	13,680
1-9 IN THRU	80,000	64,250			
10-12 IN THRU	80,000		54,820	9,430	
13-15 IN THRU	80,000		45,760	18,490	
16-18 IN THRU	80,000				
1-5 AD THRU	80,000		64,250		
6-9 AD THRU	80,000		47,760	5,000	11,500
10-13 AD THRU	80,000		36,150	8,510	19,590
14-17 AD THRU	80,000		31,270	10,000	23,000
18 AD THRU	80,000		3,180	18,490	42,590
1-4,25-28,49-52 C1 THRU	80,000		49,340		14,910
5-8,29-32,53-56 C1 THRU	80,000		49,340		14,910
9-12,33-36,57-60 C1 THRU	80,000		49,340		14,910
13-16,37-40, 61-64 C1 THUR	80,000		56,920	2,220	5,120
17-20,41-44, 65-68 C1 THRU	80,000		42,870	6,470	14,910
21-24,45-48, 69-72 C1 THRU	80,000		36,760	8,320	19,170
73 C1 THRU	80,000		3,180	18,490	42,590

Table C4 The Material Recovery Facilities

MRF type	**Dirty MRF 11130**	**Clean MRF 12248**
Capacity (T)	25,000	50,000
Scenario code	User entered capacity	
7-9 IN UKUR	86,520	
10-12 IN UKUR		4,000
13-15 IN UKUR		29,980
16-18 IN UKUR		37,980
2-5 AD UKUR	86,520	
6 - 9 AD UKUR		12,800
10 - 13 AD UKUR		21,990
14 - 17 AD UKUR		25,190
9-12,33-36,57-60 C1 UKUR	75,400	
13-16,37-40,61-64 C1 UKUR		2,000
17-20,41-44,65-68 C1 UKUR		13,990
21-24,45-48,69-72 C1 UKUR		17,990
Capacity (T)	25,000	50,000
Scenario code	User entered capacity	
7-9 IN THUR	96,730	
10-12 IN THUR		13,920
13-15 IN THUR		27,840
16-18 IN THUR		
2-5 AD THUR	96,730	
6 - 9 AD THUR		7,520
10 - 13 AD THUR		12,810
14 - 17 AD THUR		15,030
9-12,33-36,57-60 C1 THUR	74,290	
13-16,37-40,61-64 C1 THUR		3,340
17-20,41-44,65-68 C1 THUR		9,750
21-24,45-48,69-72 C1 THUR		12,530
Capacity (T)	25,000	50,000
Scenario code	User entered capacity	
7-9 IN UKRU	37,240	
10-12 IN UKRU		1,900
13-15 IN UKRU		12,740
16-18 IN UKRU		16,690
2-5 AD UKRU	37,240	
6 - 9 AD UKRU		5,510

MRF type	Dirty MRF 11130	Clean MRF 12248
10 - 13 AD UKRU		9,300
14 - 17 AD UKRU		10,840
9-12,33-36,57-60 C1 UKRU	32,460	
13-16,37-40,61-64 C1 UKRU		1,040
17-20,41-44,65-68 C1 UKRU		6,030
21-24,45-48,69-72 C1 UKRU		7,920
73 C1 UKRU		17,210
Capacity (T)	25,000	50,000
Scenario code	User entered capacity	
7-9 IN THRU	64,250	
10-12 IN THRU		9,430
13-15 IN THRU		
16-18 IN THRU		
2-5 AD THRU	64,250	
6 - 9 AD THRU		5,000
10 - 13 AD THRU		8,510
14 - 17 AD THRU		10,000
		18,490
9-12,33-36,57-60 C1 THRU		49,340
13-16,37-40,61-64 C1 THRU		2,220
17-20,41-44,65-68 C1 THRU		6,470
21-24,45-48,69-72 C1 THRU		8,320
73 C1 THRU		18,490

Table C5 The properties of the Incinerator used in the scenarios. Incinerator Flexible (based on the Chineham ERF)

Scenario code	Incinerator capacity (Tpa)	User entered capacity (Tpa)
1-6 IN UKUR	95,000	86,520
7-9 IN UKUR	95,000	77,350
10-12 IN UKUR	95,000	82,820
13-15 IN UKUR	95,000	58,770
16-18 IN UKUR	95,000	51,360
1-4,25-28,49-52 C1 UKUR	95,000	75,400
5-8,29-32,53-56 C1 UKUR	95,000	75,400
9-12,33-36,57-60 C1 UKUR	95,000	66,480
13-16,37-40, 61-64 C1 UKUR	95,000	83,080
17-20,41-44, 65-68 C1 UKUR	95,000	62,450
21-24,45-48, 69-72 C1 UKUR	95,000	55,570
1-6 IN THUR	95,000	96,730
7-9 IN THUR	95,000	89,070
10-12 IN THUR	95,000	83,910
13-15 IN THUR	95,000	
16-18 IN THUR	95,000	
1-4,25-28,49-52 C1 THUR	95,000	74,290
5-8,29-32,53-56 C1 THUR	95,000	74,290
9-12,33-36,57-60 C1 THUR	95,000	67,130
13-16,37-40,61-64 C1 THUR	95,000	85,960
17-20,41-44,65-68 C1 THUR	95,000	65,320
21-24,45-48,69-72 C1 THUR	95,000	56,340
1-6 IN UKRU	95,000	37,240
7-9 IN UKRU	95,000	33,290
10-12 IN UKRU	95,000	35,490
13-15 IN UKRU	95,000	25,460

Scenario code	Incinerator capacity (Tpa)	User entered capacity (Tpa)
16-18 IN UKRU	95,000	21,790
1-4,25-28,49-52 C1 UKRU	95,000	32,460
5-8,29-32,53-56 C1 UKRU	95,000	32,460
9-12,33-36,57-60 C1 UKRU	95,000	28,620
13-16,37-40,61-64 C1 UKRU	95,000	35,470
17-20,41-44,65-68 C1 UKRU	95,000	26,880
21-24,45-48,69-72 C1 UKRU	95,000	23,630
73 C1 UKRU	95,000	7,640
1-6 IN THRU	95,000	64,250
7-9 IN THRU	95,000	59,160
10-12 IN THRU	95,000	55,560
13-15 IN THRU	95,000	47,220
16-18 IN THRU	95,000	
1-4,25-28,49-52 C1 THRU	95,000	49,340
5-8,29-32,53-56 C1 THRU	95,000	49,340
9-12,33-36,57-60 C1 THRU	95,000	44,590
13-16,37-40,61-64 C1 THRU	95,000	57,090
17-20,41-44,65-68 C1 THRU	95,000	43,380
21-24,45-48,69-72 C1 THRU	95,000	37,420
73 C1 THRU	95,000	4,630

Table C6 Energy recovery and conversion efficiencies

Scenario code	**energy recovery type**	**electricity efficiency**	**Heat efficiency**	**Heating fuel offset**	**flue gas cleaning**	**NOx reduction**
1, 4,7,10,13,16 IN UKUR 1-24 C1 UKUR	electricity	29%	(30 %)		dry	SNCR
2,5,8 11,14,17 IN UKUR 25-48	heat	(15%)	90%	gas	dry	SNCR
3,6,9,12,15,18 IN UKUR 49-72	Heat and electricity	25%	16%	gas	dry	SNCR
1, 4,7,10,13,16 IN THUR 1-24 C1 THUR	electricity	29%	(30 %)	-	dry	SNCR
2,5,8 11,14,17 IN THUR 25-48	heat	(15%)	90%	gas	dry	SNCR
3,6,9,12,15,18 IN THUR 49-72	Heat and electricity	25%	16%	gas	dry	SNCR
1, 4,7,10,13,16 IN UKRU 1-24 C1 UKRU	electricity	29%	(30 %)	-	dry	SNCR
2,5,8 11,14,17 IN UKRU 25-48	heat	(15%)	90%	gas	dry	SNCR
3,6,9,12,15,18 IN UKRU 49-72	Heat and electricity	25%	16%	gas	dry	SNCR
1, 4,7,10,13,16 IN THUR 1-24 C1 THUR	electricity	29%	(30 %)	-	dry	SNCR
2,5,8 11,14,17 IN THUR 25-48	heat	(15%)	90%	gas	dry	SNCR
3,6,9,12,15,18 IN THUR 49-72	Heat and electricity	25%	16%	gas	dry	SNCR

Table C7 Metals recovery for incinerator

Scenario code	metals recovery
1-3 IN UKUR 1-4 C1 UKUR 25-28 C1 UKUR 49-52 C1 UKUR	None
4-18 IN UKUR 5-24 C1 UKUR 29-48 C1 UKUR 53-72 C1 UKUR	Fe 100% Non Fe 50%
1-3 IN THUR 1-4 C1 THUR 25-28 C1 THUR 49-52 C1 THUR	None
4-15 IN THUR 5-24 C1 THUR 29-48 C1 THUR 53-72 C1 THUR	Fe 100% Non Fe 50%
1-3 IN UKRU 1-4 C1 UKRU 25-28 C1 UKRU 49-52 C1 UKRU	None
4-18 IN UKRU 5-24 C1 UKRU 29-48 C1 UKRU 53-72 C1 UKRU	Fe 100% Non Fe 50%
1-3 IN THRU 1-4 C1 THRU 25-28 C1 THRU 49-52 C1 THRU	None
4-15 IN THRU 5-24 C1 THRU 29-48 C1 THRU 53-72 C1 THRU	Fe 100% Non Fe 50%

Table C8 The properties of the Anaerobic Digestion Plant used in the scenarios

Anaerobic Digestion type	**AD electricity 11371**	**AD Heat 11370**	**AD Heat and electricity 11369**	**AD Vehicle Fuel 11377**
Scenario code	2, 6, 10, 14 AD UKUR	3, 7, 11, 15 AD UKUR	4 , 8, 12, 16 AD UKUR	5, 9, 13, 17 AD UKUR
	1,5,9,13,17,21,25,29,33,37,41,45,49,53,57,61,65,69 C1 UKUR	2,6,10,14,18,22,26,30,34,38,42,46,50,54,58,62,66,70 C1 UKUR	3,7,11,15,19,23,27,31,35,39,43,47,51,55,59,63,67,71 C1 UKUR	4,8,12,16,20,24,28,32,36,40,44,48,52,56,60,64,68,72 C1 UKUR
Scenario code	2, 6, 10, 14 AD THUR	3, 7, 11, 15 AD THUR	4 , 8, 12, 16 AD THUR	5, 9, 13, 17 AD THUR
	1,5,9,13,17,21,25,29,33,37,41,45,49,53,57,61,65,69 C1 THUR	2,6,10,14,18,22,26,30,34,38,42,46,50,54,58,62,66,70 C1 THUR	3,7,11,15,19,23,27,31,35,39,43,47,51,55,59,63,67,71 C1 THUR	4,8,12,16,20,24,28,32,36,40,44,48,52,56,60,64,68,72 C1 THUR
Scenario code	2, 6, 10, 14 AD UKRU	3, 7, 11, 15 AD UKRU	4 , 8, 12, 16 AD UKRU	5, 9, 13, 17 AD UKRU
	1,5,9,13,17,21,25,29,33,37,41,45,49,53,57,61,65,69 C1 UKRU	2,6,10,14,18,22,26,30,34,38,42,46,50,54,58,62,66,70 C1 UKRU	3,7,11,15,19,23,27,31,35,39,43,47,51,55,59,63,67,71 C1 UKRU	4,8,12,16,20,24,28,32,36,40,44,48,52,56,60,64,68,72 C1 UKRU
Scenario code	2, 6, 10, 14 AD THRU	3, 7, 11, 15 AD THRU	4 , 8, 12, 16 AD THRU	5, 9, 13, 17 AD THRU
	1,5,9,13,17,21,25,29,33,37,41,45,49,53,57,61,65,69 C1 THRU	2,6,10,14,18,22,26,30,34,38,42,46,50,54,58,62,66,70 C1 THRU	3,7,11,15,19,23,27,31,35,39,43,47,51,55,59,63,67,71 C1 THRU	4,8,12,16,20,24,28,32,36,40,44,48,52,56,60,64,68,72 C1 THRU

Table C9 AD capacity

Scenario code	AD capacity (Tpa)	User entered capacity(Tpa)
2-5 AD UKUR	7,500	19,610
6-9 AD UKUR	7,500	10,170
10-13 AD UKUR	7,500	17,480
14-17 AD UKUR	7,500	43,190
1-4,25-28,49-52 C1 UKUR	7,500	11,120
5-8,29-32,53-56 C1 UKUR	7,500	11,120
9-12,33-36,57-60 C1 UKUR	7,500	11,120
13-16,37-40,61-64 C1 UKUR	7,500	1,590
17-20,41-44,65-68 C1 UKUR	7,500	11,120
21-24,45-48,69-72 C1 UKUR	7,500	14,300
2-5 AD THUR	7,500	37,020
6-9 AD THUR	7,500	17,320
10-13 AD THUR	7,500	29,500
14-17 AD THUR	7,500	34,630
1-4,25-28,49-52 C1 THUR	7,500	22,450
5-8,29-32,53-56 C1 THTUR	7,500	22,450
9-12,33-36,57-60 C1 THUR	7,500	22,450
13-16,37-40,61-64 C1 THUR	7,500	7,700
17-20,41-44,65-68 C1 THUR	7,500	22,450
21-24,45-48,69-72 C1 THUR	7,500	28,860
2-5 AD UKRU	7,500	8,440
6-9 AD UKRU	7,500	4,380
10-13 AD UKRU	7,500	7,390
14-17 AD UKRU	7,500	8,620
1-4,25-28,49-52 C1 UKRU	7,500	4,790
5-8,29-32,53-56 C1 UKRU	7,500	4,790
9-12,33-36,57-60 C1 UKRU	7,500	4,790
13-16,37-40,61-64 C1 UKRU	7,500	830
17-20,41-44,65-68 C1 UKRU	7,500	4,790
21-24,45-48,69-72 C1 UKRU	7,500	6,300
73 C1 UKRU	7,500	13,680
2-5 AD THRU	7,500	24,590
6-9 AD THRU	7,500	11,500
10-13 AD THRU	7,500	19,590
14-17 AD THRU	7,500	23,000
1-4,25-28,49-52 C1 THRU	7,500	14,910
5-8,29-32,53-56 C1 THRU	7,500	14,910
9-12,33-36,57-60 C1 THRU	7,500	14,910
13-16,37-40,61-64 C1 THRU	7,500	5,120
17-20,41-44,65-68 C1 THRU	7,500	14,910
21-24,45-48,69-72 C1 THRU	7,500	19,170
21-24,45-48,69-72 C1 THRU	7,500	42,590

Table C10 The properties of the landfill used in the scenarios

Landfill type	**HDPE liner and cap**	**12161**
Scenario code	**Landfill capacity (Tpa)**	**User entered annual capacity(Tpa)**
1-3 IN UKUR	250,000	22,875
4-6 IN UKUR	250,000	3,780
7-9 IN UKUR	250,000	3,140
10-12 IN UKUR	250,000	3,600
13-15 IN UKUR	250,000	2,440
16-18 IN UKUR	250,000	2,080
1 AD UKUR		
2-5 AD UKUR		57,750
6-9 AD UKUR		64,510
10-13 AD UKUR		48,700
14-17 AD UKUR		17,740
1-4,25-28,49-52 C1 UKUR		21,340
5-8,29-32,53-56 C1 UKUR		3,370
9-12,33-36,57-60 C1 UKUR		2,740
13-16,37-40,61-64 C1 UKUR		3,630
17-20,41-44,65-68 C1 UKUR		2,740
21-24,45-48,69-72 C1 UKUR		2,450
1-3 IN THUR	250,000	19,400
4-6 IN THUR	250,000	3,750
7-9 IN THUR	250,000	3,340
10-12 IN THUR	250,000	3,180
13-15 IN THUR	250,000	2,620
1 AD		96,730
2-5 AD THUR		52,050
6-9 AD THUR		72,500
10-13 AD THUR		55,440
14-17 AD THUR		48,260
1-4,25-28,49-52 C1 THUR		16,290
5-8,29-32,53-56 C1 THTUR		2,910
9-12,33-36,57-60 C1 THUR		2,520
13-16,37-40,61-64 C1 THUR		3,330
17-20,41-44,65-68 C1 THUR		2,520
21-24,45-48,69-72 C1 THUR		2,170
1-3 IN UKRU	250,000	9,850
4-6 IN UKRU	250,000	1,630
7-9 IN UKRU	250,000	1,350
10-12 IN UKRU	250,000	1,550
13-15 IN UKRU	250,000	1,060
16-18 IN UKRU	250,000	880

Landfill type	**HDPE liner and cap**	**12161**
Scenario code	**Landfill capacity (Tpa)**	**User entered annual capacity(Tpa)**
1 AD		37,240
2-5 AD UKRU		24,860
6-9 AD UKRU		27,7770
10-13 AD UKRU		21,260
14-17 AD UKRU		18,590
1-4,25-28,49-52 C1 UKRU		9,190
5-8,29-32,53-56 C1 UKRU		1,450
9-12,33-36,57-60 C1 UKRU		1,180
13-16,37-40,61-64 C1 UKRU		1,550
17-20,41-44,65-68 C1 UKRU		1,180
21-24,45-48,69-72 C1 UKRU		1,040
73 C1 UKRU		350
1-3 IN THRU		12,890
4-6 IN THRU		2,490
7-9 IN THRU		2,220
10-12 IN THRU		2,110
13-15 IN THRU		1,740
1 AD		64,250
2-5 AD THRU		34,580
6-9 AD THRU		48,150
10-13 AD THRU		36,820
14-17 AD THRU		32,060
18 AD		4,630
1-4,25-28,49-52 C1 THRU		10,810
5-8,29-32,53-56 C1 THTRU		1,940
9-12,33-36,57-60 C1 THRU		1,680
13-16,37-40,61-64 C1 THRU		2,210
17-20,41-44,65-68 C1 THRU		1,670
21-24,45-48,69-72 C1 THRU		1,440

Table C11 The capacity of the recycling facilities used in the scenarios

	IBA recycling Fe/non Fe 12028	Ferrous metal 12287	Non ferrous scrap metal 11123	Plastic film LLDPE 12302	Plastic dense HDPE 12304	Glass- aggregate 12252	Glass –clear 21129	Glass –brown 11319	Glass –green12291	Paper
Facility Capacity (Tpa)	90,000	1	1	1	1	75,000	1	1	1	1
Scenario code	User entered capacity (Tpa)									
4-6 IN UKUR	16,030	2,240	330							
7-9 IN UKUR	11,080	2,240	640		1,440	4,240				
10-12 IN UKUR	15,120	2,240	360	350	530	420	60	20	80	2,010
13-15 IN UKUR	9,190	2,240	550	2590	3960	3100	440	110	600	15,020
16-18 IN UKUR	7,370	2,240	610	3280	5010	3,930	560	140	760	19,020
2-5 AD UKUR		2,130	620		1,440	4,240				
6-9 AD UKUR	660		190	1,110	1,690	1,330	190	50	260	6,410
10-13 AD UKUR	1,130	1,940	350	1,900	2,910	2,220	320	80	440	12,020
14-17 AD UKUR		1,290	350	2,150	3,330	2,600	370	90	510	
5-8,29-32,53-56 C1 UKUR	14,910	2,240	330							
9-12,33-36,57-60 C1 UKUR	9,980	2,240	640		1,440	4,240				
13-16,37-40,61-64 C1 UKUR	1,5420	2,240	340	180	270	210	30	10	40	1,010
17-20,41-44,65-68 C1 UKUR	11,710	2,240	430	1,210	1,850	1,450	210	50	280	7,010
21-24,45-48,69-72 C1 UKUR	10,480	2,240	460	1,560	2,380	1,860	270	70	360	9,010
4-6 IN THUR	12,790	1,470	930							
7-9 IN THUR	9,430	1,470	1,824		1,280	1,780				
10-12 IN THUR	9,890	1,470	1,360	4,840	2,340		490	660	60	2,950

	IBA recycling Fe/non Fe 12028	Ferrous metal 12287	Non ferrous scrap metal 11123	Plastic film LLDPE 12302	Plastic dense HDPE 12304	Glass- aggregate 12252	Glass –clear 21129	Glass –brown 11319	Glass –green12291	Paper
13-15 IN THUR	6,980	1,470	1,780	9,680	4,680		970	1,310	110	5,890
2-5 AD THUR		1,390	1,770		1,280	1,790				
6-9 AD THUR		370	460	2,620	1,270		270	360	30	1,590
10-13 AD THUR		620	790	4,450	2,160		450	610	50	2,710
14-17 AD THUR		730	920	5,230	2,530		530	710	60	3,180
5-8,29-32,53-56 C1 THTUR	10510	1,470	930							
9-12,33-36,57-60 C1 THUR	7,200	1,470	1,820		1,280	1,790				
13-16,37-40,61-64 C1 THUR	1,1320	1,470	1,040	1,170	570		120	160	20	710
17-20,41-44,65-68 C1 THUR	8,470	1,470	1,230	3,390	1,640		340	460	40	2,060
21-24,45-48,69-72 C1 THUR	7,140	1,470	1,320	4,360	2,210		440	590	50	2,650
4-6 IN UKRU	6900	970	140							
7-9 IN UKRU	4770	970	280		620	1,830				
10-12 IN UKRU	6470	970	160	170	250	200	30	10	40	950
13-15 IN UKRU	4000	970	240	1,100	1680	1,320	190	50	260	6,380
16-18 IN UKRU	3100	970	270	1,440	2210	1,730	250	60	340	8,360
2-5 AD UKRU		920	270	1,830	620					
6-9 AD UKRU		290	90	480	730	570	80	20	110	2,760
10-13 AD UKRU		480	140	810	1,230	960	140	40	190	4,660
14-17 AD		560	170	940	1,430	1,120	160	40	220	5,430

	IBA recycling Fe/non Fe 12028	Ferrous metal 12287	Non ferrous scrap metal 11123	Plastic film LLDPE 12302	Plastic dense HDPE 12304	Glass- aggregate 12252	Glass –clear 21129	Glass –brown 11319	Glass –green12291	Paper
UKRU										
1-4,25-28,49-52 C1 UKRU	6,420	970	140							
5-8,29-32,53-56 C1 UKRU	4,300	970	280		620	1,830				
9-12,33-36,57-60 C1 UKRU	6,590	970	150	90	140	110	20	10	30	520
13-16,37-40,61-64 C1 UKRU	5,050	970	190	520	800	630	90	30	120	3,020
17-20,41-44,65-68 C1 UKRU	4,460	970	200	690	,1050	820	120	30	160	3,970
21-24,45-48,69-72 C1 UKRU	6,590	970	270	1,490	2,270	1,780	250	60	350	8,620
4-6 IN THRU	8,500	980	620							
7-9 IN THRU	6,260	980	1,210		850					
10-12 IN THRU	6,530	980	910	3,280	1,590		330	450	40	2,000
13-15 IN THRU	4,640	980	1190	6,430	3,110		640	870	80	3,910
2-5 AD THRU		930								
6-9 AD THRU		240								
10-13 AD THRU		410								
14-17 AD THRU		480								
18 AD		890								
1-4,25-28,49-52 C1 THRU	6,980	980	620							
5-8,29-32,53-56 C1 THTRU	4,780	980	1,210		850	1,190				
9-12,33-	7,510	980	690	780	380		80	110	10	470

	IBA recycling Fe/non Fe 12028	Ferrous metal 12287	Non ferrous scrap metal 11123	Plastic film LLDPE 12302	Plastic dense HDPE 12304	Glass- aggregate 12252	Glass –clear 21129	Glass –brown 11319	Glass –green12291	Paper
36,57-60 C1 THRU										
13-16,37-40,61-64 C1 THRU	5,630	980	820	2,250	1,090		230	310	30	1,370
17-20,41-44,65-68 C1 THRU	4,810	980	880	2,900	1,400		290	390	40	1,760
21-24,45-48,69-72 C1 THRU	300	980	1,190	6,430	3,110		640	870	80	3,910

User Defined Processes

Articulated Truck

44 tonnes

Anaerobic Digestion

Table C12 AD Heat

Original process in WRATE

AD small low solid BIOGEN GREENFINCH process- v2

11036

changed to

AT AD small low solid Heat only

11370

Using values from Banks et al.(2011) to update the allocation for process which was not operating fully at time of data collection.

Energy Recovered

original	([USER_TOTAL.CARBON-BIO]/[TYPICAL-TOTAL.CARBON-BIO])*[PROC_EN_PRODUCTS.ELECTRICITY-TO-THE-GRID]+[PROC_EN_PRODUCTS.EXTERNAL_HEAT]
new	**([USER_TOTAL.CARBON-BIO]/[TYPICAL-TOTAL.CARBON-BIO])*[PROC_EN_PRODUCTS.EXTERNAL_HEAT]**

Energy Inputs

original value	[PROC_ENERGY-INPUTS.GRID.PROCESS]	417,600.00	MJ	
				source
	= total electrical parasitic	270,422.00	kWh	table 5

	kWh x 3600 MJ/kWh	973,519.20	MJ	
	waste processed in study	3936.504	Tonnes	table 2
original value	waste processed by original AD	5050	Tonnes	
	=(total electrical parasitic) x (waste in original/waste in study)	1,248,892.92	MJ	
new value	**[PROC_ENERGY-INPUTS.GRID.PROCESS]**	**1,248,892.92**	**MJ**	
Process Energy Production				
External Heat				
	original value			
original value	[PROC_EN_PRODUCTS.EXTERNAL_HEAT]	6,127,200.00	MJ	
				source
	waste processed in study	3936.504	Tonnes	table 2
	Net energy output as heat	1027851	kWh	table 6
	heat per tonne feedstock	261.11	kWh/T	
original value	waste processed by original AD	5050	Tonnes	
	Heat	1,318,593.24	kWh	
new value	**[PROC_EN_PRODUCTS.EXTERNAL_HEAT]**	**4,746,935.65**	**MJ**	
Electricity to the Grid	delete			
original value	[PROC_EN_PRODUCTS.ELECTRICITY_TO_THE _GRID]	1,820,211.00	MJ	

Table C13 AD Electricity

Original process in WRATE **AD small low solid BIOGEN GREENFINCH process- v2** **11036** changed to **AT AD small low solid Electricity** **11371** Using values from Banks et al.(2011) to update the allocation for process which was not operating fully at time of data collection.	
Energy Recovered	
original	([USER_TOTAL.CARBON-BIO]/[TYPICAL-TOTAL.CARBON-BIO])*[PROC_EN_PRODUCTS.ELECTRICITY-TO-THE-GRID]+[PROC_EN_PRODUCTS.EXTERNAL_HEAT]
new	**([USER_TOTAL.CARBON-BIO]/[TYPICAL-TOTAL.CARBON-BIO])*[PROC_EN_PRODUCTS.ELECTRICITY-TO-THE-GRID]**

Energy Inputs				
original value	[PROC_ENERGY-INPUTS.GRID.PROCESS]	417,600.00	MJ	
				source
	= total electrical parasitic	270,422.00	kWh	table 5
	kWh x 3600 MJ/kWh	973,519.20	MJ	
	waste processed in study	3936.504	Tonnes	table 2
original value	waste processed by original AD	5050	Tonnes	
	=(total electrical parasitic) x (waste in original/waste in study)	1,248,892.92	MJ	
new value	**[PROC_ENERGY-INPUTS.GRID.PROCESS]**	**1,248,892.92**	**MJ**	
Process Energy Production				
External Heat	Delete			
original value	[PROC_EN_PRODUCTS.EXTERNAL_HEAT]	6,127,200.00	MJ	
new value				
Electricity to the Grid				
original value	[PROC_EN_PRODUCTS.ELECTRICITY_TO_THE _GRID]	1,820,211.00	MJ	
original value	Electricity per tonne feedstock	100.12	kWh/T	
				source
	Net energy output as electricity	619,652.00	kWh	table 6
	Electricity per tonne feedstock	157.41	kWh/T	
original value	waste processed by original AD	5050	Tonnes	
	Electricity	794,929.36	kWh	
new value	**[PROC_EN_PRODUCTS.ELECTRICITY_TO_THE _GRID]**	**2,861,745.69**	**MJ**	

Table C14 AD Vehicle fuel

inputs added

water	20l/Nm3		15,791,340	kg/y
electricity	0.2 kWh/Nm3		157,913	kWh
			568,488	**MJ**

Emission added due to scrubbing

CO2			362,854	kg/y
H2S			3,000	kg/y
water			15,791,340	kg/y

construction materials

concrete			13000	kg
steel			11000	kg
tarmac			230	kg

glass			5	kg
rubber			5	kg
Polyethylene			25	kg

Emission reduction due to removal of CHP unit 100kWe			
	100kWe	195kWe	for 5050 T
	kg/MJ $_{in}$	kg/MJ $_{in}$	emission in kg
CO2	5.58E-02	0.10881	1,890,081.24
CO	2.80E-05	0.0000546	948.43
N2O	1.00E-06	0.00000195	33.87
CH4	5.40E-06	0.00001053	182.91
NOX	3.20E-05	0.0000624	1,083.92
NMVOC	6.00E-07	0.00000117	20.32
Particulates, <2.5um	5.00E-07	9.75E-07	16.94
SO2	5.50E-07	1.0725E-06	18.63
	T	biogas m3	MJ
waste input	3936.504	615,472.00	13,540,384.00
waste input	5050	789,566.99	17,370,473.70

Wrate implementation of Gas upgrading unit into Ludlow AD plant

Reduced emmissions + added emmissions from scrubbing

			original kg	**New kg**
Nitrous oxide (N2O)	Process	Air	92.92	**59.05**
Methane, biogenic	Process	Air	171.02	**0.00**
Sulphur Dioxide (SO2)	Process	Air	1,100.00	**1,081.37**
Hydrogen sulphide (H2S)	Process	Air	0.00	**3,000.00**
Carbon dioxide - Biogenic	Process	Air	1,456,000.00	**0.00**
Carbon monoxide, biogenic	Process	Air	3,300.00	**2,351.57**
Nitrogen oxides	Process	Air	2,600.00	**1,516.08**
VOC, volatile organic compounds, unspecified origin	Process	Air	120.00	**99.68**
Water	Process	Sewer	3,922,740.00	**19,714,079.73**

Appendix D

Results from WRATE

Project **UK Urban area**

Project Headline Indicators

scenario code	Bio- degradeable Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
01 IN UKUR	-	188,493,664	0.260	-	22,874	86,518	-
02 IN UKUR	-	617,527,750	0.260	-	22,874	86,518	-
03 IN UKUR	-	272,893,812	0.260	-	22,874	86,518	-
04 IN UKUR	-	188,493,664	0.208	-	4,578	86,518	2,557
05 IN UKUR	-	617,527,750	0.208	-	4,578	86,518	2,557
06 IN UKUR	-	272,893,812	0.208	-	4,578	86,518	2,557
07 IN UKUR	-	183,002,760	0.258	-	4,023	77,343	8,529
08 IN UKUR	-	601,255,604	0.258	-	4,023	77,343	8,529
09 IN UKUR	-	265,282,008	0.258	-	4,023	77,343	8,529
10 IN UKUR	-	176,967,141	0.226	-	4,580	82,817	6,024
11 IN UKUR	-	559,955,730	0.226	-	4,580	82,817	6,024
12 IN UKUR	-	256,206,159	0.226	-	4,580	82,817	6,024
13 IN UKUR	-	101,625,902	0.345	-	4,592	58,762	28,561
14 IN UKUR	-	311,046,081	0.345	-	4,592	58,762	28,561
15 IN UKUR	-	170,163,415	0.345	-	4,592	58,762	28,561
16 IN UKUR	-	78,667,477	0.381	-	4,596	51,360	35,496
17 IN UKUR	-	240,777,301	0.381	-	4,596	51,360	35,496
18 IN UKUR	-	131,721,601	0.381	-	4,596	51,360	35,496
01 AD UKUR	62,431	43,529,312	0.451	-	86,518	-	-
02 AD UKUR	42,056	43,783,702	0.433	19,601	58,270	-	8,402
03 AD UKUR	42,056	51,753,706	0.433	19,601	58,270	-	8,402
04 AD UKUR	42,056	63,852,135	0.433	19,601	58,270	-	8,402
05 AD UKUR	42,056	105,121,750	0.433	19,601	58,270	-	8,402
06 AD UKUR	45,860	38,512,523	0.452	10,166	65,353	-	11,843
07 AD UKUR	45,860	42,485,050	0.452	10,166	65,353	-	11,843
08 AD UKUR	45,860	48,515,329	0.452	10,166	65,353	-	11,843
09 AD UKUR	45,860	69,085,544	0.452	10,166	65,353	-	11,843
10 AD UKUR	33,950	34,906,705	0.453	17,473	50,141	-	20,355
11 AD UKUR	33,950	41,734,487	0.453	17,473	50,141	-	20,355
12 AD UKUR	33,950	52,099,029	0.453	17,473	50,141	-	20,355
13 AD UKUR	33,950	87,454,085	0.453	17,473	50,141	-	20,355
14 AD UKUR	29,807	33,652,508	0.453	20,015	44,850	-	23,315
15 AD UKUR	29,807	41,473,422	0.453	20,015	44,850	-	23,315
16 AD UKUR	29,807	53,345,534	0.453	20,015	44,850	-	23,315
17 AD UKUR	29,807	93,843,143	0.453	20,015	44,850	-	23,315
01 C1 UKUR	-	183,323,485	0.261	11,119	21,443	75,399	-
02 C1 UKUR	-	187,668,437	0.261	11,119	21,443	75,399	-
03 C1 UKUR	-	194,264,055	0.261	11,119	21,443	75,399	-
04 C1 UKUR	-	216,762,727	0.261	11,119	21,443	75,399	-
05 C1 UKUR	-	183,323,485	0.212	11,119	4,219	75,399	2,557
06 C1 UKUR	-	187,668,437	0.212	11,119	4,219	75,399	2,557
07 C1 UKUR	-	194,264,055	0.212	11,119	4,219	75,399	2,557
08 C1 UKUR	-	216,762,727	0.212	11,119	4,219	75,399	2,557
09 C1 UKUR	-	178,784,587	0.254	11,119	3,675	66,477	8,529

scenario code	Bio- degradeable Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
10 C1 UKUR	-	183,129,540	0.254	11,119	3,675	66,477	8,529
11 C1 UKUR	-	189,725,157	0.254	11,119	3,675	66,477	8,529
12 C1 UKUR	-	212,223,829	0.254	11,119	3,675	66,477	8,529
13 C1 UKUR	-	182,095,858	0.217	1,588	4,528	83,079	4,290
14 C1 UKUR	-	182,716,565	0.217	1,588	4,528	83,079	4,290
15 C1 UKUR	-	183,658,796	0.217	1,588	4,528	83,079	4,290
16 C1 UKUR	-	186,872,892	0.217	1,588	4,528	83,079	4,290
17 C1 UKUR	-	143,146,241	0.275	11,119	4,226	62,446	14,692
18 C1 UKUR	-	147,491,193	0.275	11,119	4,226	62,446	14,692
19 C1 UKUR	-	154,086,811	0.275	11,119	4,226	62,446	14,692
20 C1 UKUR	-	176,585,483	0.275	11,119	4,226	62,446	14,692
21 C1 UKUR	-	130,410,883	0.295	14,296	4,125	55,568	18,159
22 C1 UKUR	-	135,997,250	0.295	14,296	4,125	55,568	18,159
23 C1 UKUR	-	144,477,330	0.295	14,296	4,125	55,568	18,159
24 C1 UKUR	-	173,404,193	0.295	14,296	4,125	55,568	18,159
25 C1 UKUR	-	587,235,059	0.261	11,119	21,443	75,399	-
26 C1 UKUR	-	591,580,011	0.261	11,119	21,443	75,399	-
27 C1 UKUR	-	598,175,629	0.261	11,119	21,443	75,399	-
28 C1 UKUR	-	620,674,301	0.261	11,119	21,443	75,399	-
29 C1 UKUR	-	587,235,059	0.212	11,119	4,219	75,399	2,557
30 C1 UKUR	-	551,851,004	0.212	11,119	4,219	75,399	2,557
31 C1 UKUR	-	598,175,629	0.212	11,119	4,219	75,399	2,557
32 C1 UKUR	-	620,674,301	0.212	11,119	4,219	75,399	2,557
33 C1 UKUR	-	572,322,510	0.254	11,119	3,675	66,477	8,529
34 C1 UKUR	-	576,667,463	0.254	11,119	3,675	66,477	8,529
35 C1 UKUR	-	583,263,080	0.254	11,119	3,675	66,477	8,529
36 C1 UKUR	-	605,761,752	0.254	11,119	3,675	66,477	8,529
37 C1 UKUR	-	594,423,142	0.217	1,588	4,528	83,079	4,290
38 C1 UKUR	-	595,043,849	0.217	1,588	4,528	83,079	4,290
39 C1 UKUR	-	595,986,081	0.217	1,588	4,528	83,079	4,290
40 C1 UKUR	-	599,200,176	0.217	1,588	4,528	83,079	4,290
41 C1 UKUR	-	455,232,717	0.275	11,119	4,226	62,446	14,692
42 C1 UKUR	-	459,577,669	0.275	11,119	4,226	62,446	14,692
43 C1 UKUR	-	466,173,286	0.275	11,119	4,226	62,446	14,692
44 C1 UKUR	-	488,671,958	0.275	11,119	4,226	62,446	14,692
45 C1 UKUR	-	409,083,755	0.295	14,296	4,125	55,568	18,159
46 C1 UKUR	-	414,670,122	0.295	14,296	4,125	55,568	18,159
47 C1 UKUR	-	423,150,202	0.295	14,296	4,125	55,568	18,159
48 C1 UKUR	-	452,077,066	0.295	14,296	4,125	55,568	18,159
49 C1 UKUR	-	262,781,500	0.261	11,119	21,443	75,399	-
50 C1 UKUR	-	267,126,452	0.261	11,119	21,443	75,399	-
51 C1 UKUR	-	273,722,070	0.261	11,119	21,443	75,399	-
52 C1 UKUR	-	296,220,741	0.261	11,119	21,443	75,399	-
53 C1 UKUR	-	262,781,500	0.212	11,119	4,219	75,399	2,557
54 C1 UKUR	-	267,126,452	0.212	11,119	4,219	75,399	2,557
55 C1 UKUR	-	273,722,070	0.212	11,119	4,219	75,399	2,557
56 C1 UKUR	-	296,220,741	0.212	11,119	4,219	75,399	2,557

scenario code	Bio- degradeable Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
57 C1 UKUR	-	256,201,884	0.254	11,119	3,675	66,477	8,529
58 C1 UKUR	-	260,546,836	0.254	11,119	3,675	66,477	8,529
59 C1 UKUR	-	267,142,454	0.254	11,119	3,675	66,477	8,529
60 C1 UKUR	-	289,641,126	0.254	11,119	3,675	66,477	8,529
61 C1 UKUR	-	263,209,422	0.217	1,588	4,528	83,079	4,290
62 C1 UKUR	-	263,830,129	0.217	1,588	4,528	83,079	4,290
63 C1 UKUR	-	264,772,360	0.217	1,588	4,528	83,079	4,290
64 C1 UKUR	-	267,986,456	0.217	1,588	4,528	83,079	4,290
65 C1 UKUR	-	204,540,302	0.275	11,119	4,226	62,446	14,692
66 C1 UKUR	-	208,885,254	0.275	11,119	4,226	62,446	14,692
67 C1 UKUR	-	215,480,872	0.275	11,119	4,226	62,446	14,692
68 C1 UKUR	-	237,979,544	0.275	11,119	4,226	62,446	14,692
69 C1 UKUR	-	185,231,776	0.295	14,296	4,125	55,568	18,159
70 C1 UKUR	-	190,818,143	0.295	14,296	4,125	55,568	18,159
71 C1 UKUR	-	199,298,223	0.295	14,296	4,125	55,568	18,159
72 C1 UKUR	-	228,225,086	0.295	14,296	4,125	55,568	18,159

Appendix D
Results from WRATE

Project **UK Urban area**

Characterisation Impact assessment

scenario code	climate change: GWP 100a (kg CO2-Eq)	acidification potential: average European (kg SO2-Eq)	eutrophication potential: generic (kg PO4-Eq)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq)	human toxicity: HTP infinite (kg 1,4-DCB-Eq)	resources: depletion of abiotic resources (kg antimony-Eq)
01 IN UKUR	- 14,716,464	3,351	7,241	- 116,999	- 1,841,054	- 306,950
02 IN UKUR	- 15,665,513	19,185	10,196	19,480	- 3,548,529	- 322,007
03 IN UKUR	- 16,661,517	4,015	7,507	- 126,263	- 2,340,605	- 323,904
04 IN UKUR	- 23,702,442	- 35,455	3,630	- 2,947,012	- 33,098,478	- 370,876
05 IN UKUR	- 24,651,491	- 19,621	6,585	- 2,810,533	- 34,805,953	- 385,933
06 IN UKUR	- 25,647,495	- 34,791	3,896	- 2,956,275	- 33,598,029	- 387,830
07 IN UKUR	- 27,397,966	- 47,054	2,849	- 3,318,097	- 38,964,327	- 393,194
08 IN UKUR	- 28,323,166	- 31,618	5,730	- 3,185,048	- 40,628,895	- 407,872
09 IN UKUR	- 29,294,142	- 46,407	3,108	- 3,327,128	- 39,451,324	- 409,721
10 IN UKUR	- 24,389,209	- 42,053	3,184	- 2,921,007	- 33,624,979	- 373,188
11 IN UKUR	- 23,855,420	- 25,994	6,070	- 2,770,813	- 35,020,671	- 375,640
12 IN UKUR	- 26,215,321	- 41,430	3,434	- 2,929,704	- 34,093,982	- 389,105
13 IN UKUR	- 28,914,842	- 85,206	243	- 2,754,130	- 37,075,120	- 388,861
14 IN UKUR	- 27,785,456	- 75,257	1,971	- 2,654,803	- 37,760,343	- 383,538
15 IN UKUR	- 30,494,330	- 84,667	459	- 2,761,653	- 37,480,782	- 402,629
16 IN UKUR	- 30,355,816	- 98,541	- 670	- 2,703,687	- 38,142,000	- 394,074
17 IN UKUR	- 29,481,572	- 90,840	668	- 2,626,800	- 38,672,423	- 389,953
18 IN UKUR	- 31,578,481	- 98,124	- 502	- 2,709,510	- 38,456,018	- 404,731
01 AD UKUR	20,115,764	6,354	10,847	105,651	210,164	- 57,425
02 AD UKUR	3,632,624	- 22,294	6,682	- 2,743,772	- 34,694,535	- 141,486
03 AD UKUR	4,870,266	- 20,354	6,927	- 2,712,000	- 34,595,505	- 132,163
04 AD UKUR	2,226,027	- 23,555	6,541	- 2,761,908	- 34,887,268	- 153,416
05 AD UKUR	1,795,031	- 24,924	5,613	- 2,850,739	- 35,283,664	- 155,962
06 AD UKUR	7,188,002	- 22,388	8,017	- 690,751	- 11,148,449	- 136,743
07 AD UKUR	7,804,886	- 21,421	8,139	- 674,915	- 11,099,089	- 132,096
08 AD UKUR	6,486,905	- 23,017	7,947	- 699,791	- 11,244,514	- 142,689
09 AD UKUR	6,270,456	- 24,179	7,395	- 746,939	- 11,461,139	- 143,495
10 AD UKUR	- 2,148,345	- 43,203	5,961	- 1,263,841	- 19,317,652	- 194,364
11 AD UKUR	- 1,088,076	- 41,541	6,170	- 1,236,622	- 19,232,814	- 186,377
12 AD UKUR	- 3,353,355	- 44,284	5,840	- 1,279,378	- 19,482,764	- 204,584
13 AD UKUR	- 3,731,081	- 45,404	5,046	- 1,354,659	- 19,816,946	- 206,958
14 AD UKUR	- 5,397,433	- 50,447	5,245	- 1,463,229	- 22,159,528	- 214,420
15 AD UKUR	- 4,182,943	- 48,543	5,485	- 1,432,052	- 22,062,350	- 205,271
16 AD UKUR	- 6,777,717	- 51,685	5,106	- 1,481,026	- 22,348,655	- 226,126
17 AD UKUR	- 7,211,539	- 52,790	4,229	- 1,566,093	- 22,723,727	- 229,046
01 C1 UKUR	- 13,351,521	10,018	8,088	- 109,039	- 1,747,419	- 294,452
02 C1 UKUR	- 12,676,804	11,076	8,221	- 91,719	- 1,693,431	- 289,370
03 C1 UKUR	- 14,118,345	9,330	8,011	- 118,927	- 1,852,490	- 300,956
04 C1 UKUR	- 14,354,548	7,976	7,392	- 171,039	- 2,093,028	- 301,744
05 C1 UKUR	- 22,358,143	- 28,851	4,467	- 2,930,110	- 32,989,818	- 358,509
06 C1 UKUR	- 21,683,427	- 27,794	4,601	- 2,912,789	- 32,935,830	- 353,426
07 C1 UKUR	- 23,124,968	- 29,539	4,391	- 2,939,997	- 33,094,889	- 365,012
08 C1 UKUR	- 23,361,171	- 30,893	3,772	- 2,992,109	- 33,335,427	- 365,800
09 C1 UKUR	- 26,471,247	- 41,242	3,574	- 3,333,390	- 38,975,049	- 384,165

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq)	acidification potential: average European (kg SO2-Eq)	eutrophication potential: generic (kg PO4-Eq)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq)	human toxicity: HTP infinite (kg 1,4-DCB-Eq)	resources: depletion of abiotic resources (kg antimony-Eq)
10 C1 UKUR	- 25,796,531	- 40,184	3,707	- 3,316,069	- 38,921,061	- 379,083
11 C1 UKUR	- 27,238,072	- 41,930	3,497	- 3,343,277	- 39,080,119	- 390,669
12 C1 UKUR	- 27,482,209	- 42,063	3,094	- 3,387,383	- 39,267,592	- 392,833
13 C1 UKUR	- 23,823,517	- 37,658	3,549	- 2,931,197	- 33,342,575	- 369,728
14 C1 UKUR	- 23,727,129	- 37,507	3,568	- 2,928,722	- 33,334,863	- 369,002
15 C1 UKUR	- 23,933,063	- 37,756	3,538	- 2,932,609	- 33,357,585	- 370,657
16 C1 UKUR	- 23,960,189	- 38,967	3,270	- 2,946,731	- 33,436,204	- 369,622
17 C1 UKUR	- 24,856,709	- 52,132	2,880	- 2,841,254	- 34,851,095	- 367,420
18 C1 UKUR	- 24,181,992	- 51,074	3,014	- 2,823,933	- 34,797,108	- 362,337
19 C1 UKUR	- 25,623,534	- 52,820	2,804	- 2,851,141	- 34,956,166	- 373,924
20 C1 UKUR	- 25,861,020	- 53,976	2,220	- 2,901,958	- 35,188,120	- 374,934
21 C1 UKUR	- 25,254,246	- 57,018	2,650	- 2,812,237	- 35,359,610	- 367,078
22 C1 UKUR	- 24,386,753	- 55,658	2,822	- 2,789,968	- 35,290,198	- 360,543
23 C1 UKUR	- 26,240,164	- 57,902	2,552	- 2,824,949	- 35,494,702	- 375,439
24 C1 UKUR	- 26,547,768	- 59,040	1,863	- 2,888,000	- 35,777,778	- 377,132
25 C1 UKUR	- 14,244,997	24,925	10,870	19,448	- 3,354,911	- 308,628
26 C1 UKUR	- 13,570,280	25,983	11,004	36,768	- 3,300,923	- 303,545
27 C1 UKUR	- 15,011,821	24,237	10,794	9,561	- 3,459,982	- 315,131
28 C1 UKUR	- 15,248,024	22,883	10,175	- 42,552	- 3,700,520	- 315,919
29 C1 UKUR	- 23,251,619	- 13,944	7,250	- 2,801,623	- 34,597,310	- 372,684
30 C1 UKUR	- 19,719,421	- 10,493	7,606	- 2,740,060	- 34,127,435	- 344,169
31 C1 UKUR	- 24,018,444	- 14,632	7,173	- 2,811,510	- 34,702,381	- 379,188
32 C1 UKUR	- 24,254,647	- 15,986	6,555	- 2,863,622	- 34,942,919	- 379,976
33 C1 UKUR	- 27,341,776	- 26,718	6,285	- 3,208,202	- 40,541,255	- 397,976
34 C1 UKUR	- 26,667,059	- 25,660	6,418	- 3,190,882	- 40,487,268	- 392,894
35 C1 UKUR	- 28,108,601	- 27,406	6,208	- 3,218,090	- 40,646,326	- 404,480
36 C1 UKUR	- 28,352,738	- 27,539	5,806	- 3,262,195	- 40,833,799	- 406,644
37 C1 UKUR	- 24,735,609	- 22,440	6,390	- 2,800,032	- 34,983,560	- 384,199
38 C1 UKUR	- 24,639,221	- 22,289	6,409	- 2,797,558	- 34,975,848	- 383,472
39 C1 UKUR	- 24,845,155	- 22,538	6,379	- 2,801,445	- 34,998,570	- 385,128
40 C1 UKUR	- 24,872,281	- 23,749	6,111	- 2,815,567	- 35,077,189	- 384,093
41 C1 UKUR	- 25,547,063	- 40,614	5,031	- 2,741,977	- 36,093,141	- 378,373
42 C1 UKUR	- 24,872,346	- 39,556	5,164	- 2,724,656	- 36,039,153	- 373,290
43 C1 UKUR	- 26,313,887	- 41,302	4,954	- 2,751,864	- 36,198,212	- 384,876
44 C1 UKUR	- 26,551,373	- 42,458	4,370	- 2,802,681	- 36,430,166	- 385,887
45 C1 UKUR	- 25,870,687	- 46,733	4,570	- 2,723,589	- 36,468,676	- 376,858
46 C1 UKUR	- 25,003,194	- 45,373	4,742	- 2,701,320	- 36,399,263	- 370,323
47 C1 UKUR	- 26,856,604	- 47,617	4,472	- 2,736,301	- 36,603,767	- 385,219
48 C1 UKUR	- 27,164,209	- 48,755	3,783	- 2,799,352	- 36,886,843	- 386,912
49 C1 UKUR	- 15,182,679	10,643	8,338	- 117,761	- 2,217,718	- 310,413
50 C1 UKUR	- 14,507,962	11,701	8,472	- 100,440	- 2,163,730	- 305,331
51 C1 UKUR	- 15,949,504	9,955	8,262	- 127,648	- 2,322,789	- 316,917
52 C1 UKUR	- 16,185,706	8,602	7,643	- 179,760	- 2,563,327	- 317,705
53 C1 UKUR	- 24,189,302	- 28,226	4,718	- 2,938,831	- 33,460,116	- 374,470
54 C1 UKUR	- 23,514,585	- 27,168	4,852	- 2,921,511	- 33,406,129	- 369,387
55 C1 UKUR	- 24,956,126	- 28,914	4,641	- 2,948,718	- 33,565,187	- 380,973
56 C1 UKUR	- 25,192,329	- 30,268	4,023	- 3,000,831	- 33,805,726	- 381,761

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq)	acidification potential: average European (kg SO2-Eq)	eutrophication potential: generic (kg PO4-Eq)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq)	human toxicity: HTP infinite (kg 1,4-DCB-Eq)	resources: depletion of abiotic resources (kg antimony-Eq)
57 C1 UKUR	- 28,255,376	- 40,633	3,818	- 3,341,887	- 39,433,269	- 399,716
58 C1 UKUR	- 27,580,659	- 39,575	3,951	- 3,324,566	- 39,379,281	- 394,634
59 C1 UKUR	- 29,022,201	- 41,321	3,741	- 3,351,774	- 39,538,340	- 406,220
60 C1 UKUR	- 29,266,338	- 41,454	3,339	- 3,395,880	- 39,725,812	- 408,384
61 C1 UKUR	- 25,692,828	- 37,019	3,805	- 2,940,100	- 33,822,673	- 386,021
62 C1 UKUR	- 25,596,440	- 36,868	3,825	- 2,937,625	- 33,814,960	- 385,295
63 C1 UKUR	- 25,802,375	- 37,118	3,794	- 2,941,512	- 33,837,683	- 386,951
64 C1 UKUR	- 25,829,501	- 38,329	3,526	- 2,955,634	- 33,916,302	- 385,916
65 C1 UKUR	- 26,271,573	- 51,649	3,074	- 2,847,992	- 35,214,477	- 379,753
66 C1 UKUR	- 25,596,856	- 50,591	3,208	- 2,830,672	- 35,160,489	- 374,670
67 C1 UKUR	- 27,038,397	- 52,337	2,997	- 2,857,880	- 35,319,548	- 386,256
68 C1 UKUR	- 27,275,884	- 53,493	2,414	- 2,908,697	- 35,551,501	- 387,267
69 C1 UKUR	- 26,517,627	- 56,586	2,823	- 2,818,254	- 35,684,086	- 378,090
70 C1 UKUR	- 25,650,134	- 55,226	2,995	- 2,795,985	- 35,614,673	- 371,555
71 C1 UKUR	- 27,503,544	- 57,470	2,725	- 2,830,966	- 35,819,177	- 386,451
72 C1 UKUR	- 27,811,149	- 58,609	2,036	- 2,894,017	- 36,102,253	- 388,144

Appendix D

Results from WRATE

Project **UK Urban area**

Characterisation per person Impact assessment

scenario code	climate change: GWP 100a (kg CO2-Eq per person)	acidification potential: average European (kg SO2-Eq per person)	eutrophication potential: generic (kg PO4-Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq per person)	human toxicity: HTP infinite (kg 1,4-DCB-Eq per person)	resources: depletion of abiotic resources (kg antimony-Eq per person)
01 IN UKUR	-62.1	0.0141	0.0306	-0.494	-7.77	-1.3
02 IN UKUR	-66.1	0.081	0.043	0.0822	-15	-1.36
03 IN UKUR	-70.3	0.0169	0.0317	-0.533	-9.88	-1.37
04 IN UKUR	-100	-0.15	0.0153	-12.4	-140	-1.57
05 IN UKUR	-104	-0.0828	0.0278	-11.9	-147	-1.63
06 IN UKUR	-108	-0.147	0.0164	-12.5	-142	-1.64
07 IN UKUR	-116	-0.199	0.012	-14	-164	-1.66
08 IN UKUR	-120	-0.133	0.0242	-13.4	-172	-1.72
09 IN UKUR	-124	-0.196	0.0131	-14	-167	-1.73
10 IN UKUR	-103	-0.178	0.0134	-12.3	-142	-1.58
11 IN UKUR	-101	-0.11	0.0256	-11.7	-148	-1.59
12 IN UKUR	-111	-0.175	0.0145	-12.4	-144	-1.64
13 IN UKUR	-122	-0.36	0.00102	-11.6	-157	-1.64
14 IN UKUR	-117	-0.318	0.00832	-11.2	-159	-1.62
15 IN UKUR	-129	-0.357	0.00194	-11.7	-158	-1.7
16 IN UKUR	-128	-0.416	-0.00283	-11.4	-161	-1.66
17 IN UKUR	-124	-0.383	0.00282	-11.1	-163	-1.65
18 IN UKUR	-133	-0.414	-0.00212	-11.4	-162	-1.71
01 AD UKUR	84.9	0.0268	0.0458	0.446	0.887	-0.242
02 AD UKUR	15.3	-0.0941	0.0282	-11.6	-146	-0.597
03 AD UKUR	20.6	-0.0859	0.0292	-11.4	-146	-0.558
04 AD UKUR	9.4	-0.0994	0.0276	-11.7	-147	-0.648
05 AD UKUR	7.58	-0.105	0.0237	-12	-149	-0.658
06 AD UKUR	30.3	-0.0945	0.0338	-2.92	-47.1	-0.577
07 AD UKUR	32.9	-0.0904	0.0344	-2.85	-46.9	-0.558
08 AD UKUR	27.4	-0.0972	0.0335	-2.95	-47.5	-0.602
09 AD UKUR	26.5	-0.102	0.0312	-3.15	-48.4	-0.606
10 AD UKUR	-9.07	-0.182	0.0252	-5.33	-81.5	-0.82
11 AD UKUR	-4.59	-0.175	0.026	-5.22	-81.2	-0.787
12 AD UKUR	-14.2	-0.187	0.0247	-5.4	-82.2	-0.864
13 AD UKUR	-15.7	-0.192	0.0213	-5.72	-83.7	-0.874
14 AD UKUR	-22.8	-0.213	0.0221	-6.18	-93.5	-0.905
15 AD UKUR	-17.7	-0.205	0.0232	-6.04	-93.1	-0.866
16 AD UKUR	-28.6	-0.218	0.0216	-6.25	-94.3	-0.955
17 AD UKUR	-30.4	-0.223	0.0179	-6.61	-95.9	-0.967
01 C1 UKUR	-56.4	0.0423	0.0341	-0.46	-7.38	-1.24
02 C1 UKUR	-53.5	0.0468	0.0347	-0.387	-7.15	-1.22
03 C1 UKUR	-59.6	0.0394	0.0338	-0.502	-7.82	-1.27
04 C1 UKUR	-60.6	0.0337	0.0312	-0.722	-8.84	-1.27
05 C1 UKUR	-94.4	-0.122	0.0189	-12.4	-139	-1.51
06 C1 UKUR	-91.5	-0.117	0.0194	-12.3	-139	-1.49
07 C1 UKUR	-97.6	-0.125	0.0185	-12.4	-140	-1.54
08 C1 UKUR	-98.6	-0.13	0.0159	-12.6	-141	-1.54
09 C1 UKUR	-112	-0.174	0.0151	-14.1	-165	-1.62

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq per person)	acidification potential: average European (kg SO2-Eq per person)	eutrophication potential: generic (kg PO4-Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq per person)	human toxicity: HTP infinite (kg 1,4-DCB-Eq per person)	resources: depletion of abiotic resources (kg antimony-Eq per person)
10 C1 UKUR	-109	-0.17	0.0156	-14	-164	-1.6
11 C1 UKUR	-115	-0.177	0.0148	-14.1	-165	-1.65
12 C1 UKUR	-116	-0.178	0.0131	-14.3	-166	-1.66
13 C1 UKUR	-101	-0.159	0.015	-12.4	-141	-1.56
14 C1 UKUR	-100	-0.158	0.0151	-12.4	-141	-1.56
15 C1 UKUR	-101	-0.159	0.0149	-12.4	-141	-1.56
16 C1 UKUR	-101	-0.164	0.0138	-12.4	-141	-1.56
17 C1 UKUR	-105	-0.22	0.0122	-12	-147	-1.55
18 C1 UKUR	-102	-0.216	0.0127	-11.9	-147	-1.53
19 C1 UKUR	-108	-0.223	0.0118	-12	-148	-1.58
20 C1 UKUR	-109	-0.228	0.00937	-12.2	-149	-1.58
21 C1 UKUR	-107	-0.241	0.0112	-11.9	-149	-1.55
22 C1 UKUR	-103	-0.235	0.0119	-11.8	-149	-1.52
23 C1 UKUR	-111	-0.244	0.0108	-11.9	-150	-1.58
24 C1 UKUR	-112	-0.249	0.00786	-12.2	-151	-1.59
25 C1 UKUR	-60.1	0.105	0.0459	0.0821	-14.2	-1.3
26 C1 UKUR	-57.3	0.11	0.0464	0.155	-13.9	-1.28
27 C1 UKUR	-63.4	0.102	0.0456	0.0404	-14.6	-1.33
28 C1 UKUR	-64.4	0.0966	0.043	-0.18	-15.6	-1.33
29 C1 UKUR	-98.1	-0.0589	0.0306	-11.8	-146	-1.57
30 C1 UKUR	-83.2	-0.0443	0.0321	-11.6	-144	-1.45
31 C1 UKUR	-101	-0.0618	0.0303	-11.9	-146	-1.6
32 C1 UKUR	-102	-0.0675	0.0277	-12.1	-148	-1.6
33 C1 UKUR	-115	-0.113	0.0265	-13.5	-171	-1.68
34 C1 UKUR	-113	-0.108	0.0271	-13.5	-171	-1.66
35 C1 UKUR	-119	-0.116	0.0262	-13.6	-172	-1.71
36 C1 UKUR	-120	-0.116	0.0245	-13.8	-172	-1.72
37 C1 UKUR	-104	-0.0947	0.027	-11.8	-148	-1.62
38 C1 UKUR	-104	-0.0941	0.0271	-11.8	-148	-1.62
39 C1 UKUR	-105	-0.0951	0.0269	-11.8	-148	-1.63
40 C1 UKUR	-105	-0.1	0.0258	-11.9	-148	-1.62
41 C1 UKUR	-108	-0.171	0.0212	-11.6	-152	-1.6
42 C1 UKUR	-105	-0.167	0.0218	-11.5	-152	-1.58
43 C1 UKUR	-111	-0.174	0.0209	-11.6	-153	-1.62
44 C1 UKUR	-112	-0.179	0.0184	-11.8	-154	-1.63
45 C1 UKUR	-109	-0.197	0.0193	-11.5	-154	-1.59
46 C1 UKUR	-106	-0.192	0.02	-11.4	-154	-1.56
47 C1 UKUR	-113	-0.201	0.0189	-11.6	-155	-1.63
48 C1 UKUR	-115	-0.206	0.016	-11.8	-156	-1.63
49 C1 UKUR	-64.1	0.0449	0.0352	-0.497	-9.36	-1.31
50 C1 UKUR	-61.2	0.0494	0.0358	-0.424	-9.13	-1.29
51 C1 UKUR	-67.3	0.042	0.0349	-0.539	-9.8	-1.34
52 C1 UKUR	-68.3	0.0363	0.0323	-0.759	-10.8	-1.34
53 C1 UKUR	-102	-0.119	0.0199	-12.4	-141	-1.58
54 C1 UKUR	-99.3	-0.115	0.0205	-12.3	-141	-1.56
55 C1 UKUR	-105	-0.122	0.0196	-12.4	-142	-1.61
56 C1 UKUR	-106	-0.128	0.017	-12.7	-143	-1.61

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq per person)	acidification potential: average European (kg SO2-Eq per person)	eutrophication potential: generic (kg PO4-Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq per person)	human toxicity: HTP infinite (kg 1,4-DCB-Eq per person)	resources: depletion of abiotic resources (kg antimony-Eq per person)
57 C1 UKUR	-119	-0.172	0.0161	-14.1	-166	-1.69
58 C1 UKUR	-116	-0.167	0.0167	-14	-166	-1.67
59 C1 UKUR	-123	-0.174	0.0158	-14.1	-167	-1.71
60 C1 UKUR	-124	-0.175	0.0141	-14.3	-168	-1.72
61 C1 UKUR	-108	-0.156	0.0161	-12.4	-143	-1.63
62 C1 UKUR	-108	-0.156	0.0161	-12.4	-143	-1.63
63 C1 UKUR	-109	-0.157	0.016	-12.4	-143	-1.63
64 C1 UKUR	-109	-0.162	0.0149	-12.5	-143	-1.63
65 C1 UKUR	-111	-0.218	0.013	-12	-149	-1.6
66 C1 UKUR	-108	-0.214	0.0135	-11.9	-148	-1.58
67 C1 UKUR	-114	-0.221	0.0127	-12.1	-149	-1.63
68 C1 UKUR	-115	-0.226	0.0102	-12.3	-150	-1.63
69 C1 UKUR	-112	-0.239	0.0119	-11.9	-151	-1.6
70 C1 UKUR	-108	-0.233	0.0126	-11.8	-150	-1.57
71 C1 UKUR	-116	-0.243	0.0115	-12	-151	-1.63
72 C1 UKUR	-117	-0.247	0.00859	-12.2	-152	-1.64

Project **UK Urban area**

Normalisation Impact assessment

scenario code	climate change: GWP 100a (Eur.Person.Eq)	acidification potential: average European (Eur.Person.Eq)	eutrophication potential: generic (Eur.Person.Eq)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq)	human toxicity: HTP infinite (Eur.Person.Eq)	resources: depletion of abiotic resources (Eur.Person.Eq)
01 IN UKUR	-1139	46.8	217	-88.7	-93.1	-7943
02 IN UKUR	-1212	268	305	14.8	-180	-8333
03 IN UKUR	-1289	56.1	225	-95.8	-118	-8382
04 IN UKUR	-1834	-496	109	-2235	-1675	-9598
05 IN UKUR	-1907	-274	197	-2132	-1761	-9987
06 IN UKUR	-1984	-486	117	-2242	-1700	-10036
07 IN UKUR	-2120	-658	85.2	-2516	-1971	-10175
08 IN UKUR	-2191	-442	171	-2416	-2056	-10555
09 IN UKUR	-2267	-649	93	-2523	-1996	-10603
10 IN UKUR	-1887	-588	95.3	-2215	-1701	-9657
11 IN UKUR	-1846	-363	182	-2101	-1772	-9721
12 IN UKUR	-2028	-579	103	-2222	-1725	-10069
13 IN UKUR	-2237	-1191	7.26	-2089	-1876	-10063
14 IN UKUR	-2150	-1052	59	-2013	-1910	-9925
15 IN UKUR	-2359	-1183	13.7	-2094	-1896	-10419
16 IN UKUR	-2349	-1377	-20	-2051	-1930	-10198
17 IN UKUR	-2281	-1270	20	-1992	-1957	-10091
18 IN UKUR	-2443	-1372	-15	-2055	-1946	-10474
01 AD UKUR	1556	88.8	325	80.1	10.6	-1486
02 AD UKUR	281	-312	200	-2081	-1755	-3661
03 AD UKUR	377	-285	207	-2057	-1750	-3420
04 AD UKUR	172	-329	196	-2095	-1765	-3970
05 AD UKUR	139	-348	168	-2162	-1785	-4036
06 AD UKUR	556	-313	240	-524	-564	-3539
07 AD UKUR	604	-299	244	-512	-562	-3418
08 AD UKUR	502	-322	238	-531	-569	-3693
09 AD UKUR	485	-338	221	-566	-580	-3713
10 AD UKUR	-166	-604	178	-959	-977	-5030
11 AD UKUR	-84.2	-581	185	-938	-973	-4823
12 AD UKUR	-259	-619	175	-970	-986	-5294
13 AD UKUR	-289	-635	151	-1027	-1003	-5356
14 AD UKUR	-418	-705	157	-1110	-1121	-5549
15 AD UKUR	-324	-679	164	-1086	-1116	-5312
16 AD UKUR	-524	-722	153	-1123	-1131	-5852
17 AD UKUR	-558	-738	127	-1188	-1150	-5927
01 C1 UKUR	-1033	140	242	-82.7	-88.4	-7620
02 C1 UKUR	-981	155	246	-69.6	-85.7	-7488
03 C1 UKUR	-1092	130	240	-90.2	-93.7	-7788
04 C1 UKUR	-1111	111	221	-130	-106	-7809
05 C1 UKUR	-1730	-403	134	-2222	-1669	-9278
06 C1 UKUR	-1678	-389	138	-2209	-1666	-9146
07 C1 UKUR	-1789	-413	131	-2230	-1674	-9446
08 C1 UKUR	-1808	-432	113	-2269	-1687	-9466
09 C1 UKUR	-2048	-576	107	-2528	-1972	-9942

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (Eur.Person.Eq)	acidification potential: average European (Eur.Person.Eq)	eutrophication potential: generic (Eur.Person.Eq)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq)	human toxicity: HTP infinite (Eur.Person.Eq)	resources: depletion of abiotic resources (Eur.Person.Eq)
10 C1 UKUR	-1996	-562	111	-2515	-1969	-9810
11 C1 UKUR	-2108	-586	105	-2536	-1977	-10110
12 C1 UKUR	-2126	-588	92.6	-2569	-1987	-10166
13 C1 UKUR	-1843	-526	106	-2223	-1687	-9568
14 C1 UKUR	-1836	-524	107	-2221	-1687	-9549
15 C1 UKUR	-1852	-528	106	-2224	-1688	-9592
16 C1 UKUR	-1854	-545	97.8	-2235	-1692	-9565
17 C1 UKUR	-1923	-729	86.2	-2155	-1763	-9508
18 C1 UKUR	-1871	-714	90.2	-2142	-1761	-9377
19 C1 UKUR	-1983	-738	83.9	-2162	-1769	-9677
20 C1 UKUR	-2001	-754	66.4	-2201	-1780	-9703
21 C1 UKUR	-1954	-797	79.3	-2133	-1789	-9499
22 C1 UKUR	-1887	-778	84.4	-2116	-1785	-9330
23 C1 UKUR	-2030	-809	76.4	-2142	-1796	-9716
24 C1 UKUR	-2054	-825	55.7	-2190	-1810	-9760
25 C1 UKUR	-1102	348	325	14.7	-170	-7987
26 C1 UKUR	-1050	363	329	27.9	-167	-7855
27 C1 UKUR	-1162	339	323	7.25	-175	-8155
28 C1 UKUR	-1180	320	304	-32.3	-187	-8175
29 C1 UKUR	-1799	-195	217	-2125	-1750	-9644
30 C1 UKUR	-1526	-147	228	-2078	-1727	-8907
31 C1 UKUR	-1858	-205	215	-2132	-1756	-9813
32 C1 UKUR	-1877	-223	196	-2172	-1768	-9833
33 C1 UKUR	-2116	-373	188	-2433	-2051	-10299
34 C1 UKUR	-2063	-359	192	-2420	-2048	-10167
35 C1 UKUR	-2175	-383	186	-2441	-2056	-10467
36 C1 UKUR	-2194	-385	174	-2474	-2066	-10523
37 C1 UKUR	-1914	-314	191	-2124	-1770	-9942
38 C1 UKUR	-1906	-312	192	-2122	-1770	-9924
39 C1 UKUR	-1922	-315	191	-2125	-1771	-9966
40 C1 UKUR	-1924	-332	183	-2135	-1775	-9940
41 C1 UKUR	-1977	-568	151	-2080	-1826	-9792
42 C1 UKUR	-1924	-553	155	-2066	-1823	-9660
43 C1 UKUR	-2036	-577	148	-2087	-1831	-9960
44 C1 UKUR	-2054	-593	131	-2126	-1843	-9986
45 C1 UKUR	-2002	-653	137	-2066	-1845	-9752
46 C1 UKUR	-1935	-634	142	-2049	-1842	-9583
47 C1 UKUR	-2078	-666	134	-2075	-1852	-9969
48 C1 UKUR	-2102	-682	113	-2123	-1866	-10013
49 C1 UKUR	-1175	149	249	-89.3	-112	-8033
50 C1 UKUR	-1123	164	253	-76.2	-109	-7901
51 C1 UKUR	-1234	139	247	-96.8	-118	-8201
52 C1 UKUR	-1252	120	229	-136	-130	-8222
53 C1 UKUR	-1872	-395	141	-2229	-1693	-9691
54 C1 UKUR	-1819	-380	145	-2216	-1690	-9559
55 C1 UKUR	-1931	-404	139	-2236	-1698	-9859
56 C1 UKUR	-1949	-423	120	-2276	-1710	-9879

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (Eur.Person.Eq)	acidification potential: average European (Eur.Person.Eq)	eutrophication potential: generic (Eur.Person.Eq)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq)	human toxicity: HTP infinite (Eur.Person.Eq)	resources: depletion of abiotic resources (Eur.Person.Eq)
57 C1 UKUR	-2186	-568	114	-2535	-1995	-10344
58 C1 UKUR	-2134	-553	118	-2521	-1992	-10212
59 C1 UKUR	-2246	-578	112	-2542	-2000	-10512
60 C1 UKUR	-2264	-579	99.9	-2575	-2010	-10568
61 C1 UKUR	-1988	-517	114	-2230	-1711	-9990
62 C1 UKUR	-1980	-515	114	-2228	-1711	-9971
63 C1 UKUR	-1996	-519	114	-2231	-1712	-10014
64 C1 UKUR	-1999	-536	106	-2242	-1716	-9987
65 C1 UKUR	-2033	-722	92	-2160	-1782	-9827
66 C1 UKUR	-1981	-707	96	-2147	-1779	-9696
67 C1 UKUR	-2092	-732	89.7	-2167	-1787	-9996
68 C1 UKUR	-2110	-748	72.2	-2206	-1799	-10022
69 C1 UKUR	-2052	-791	84.5	-2137	-1805	-9784
70 C1 UKUR	-1985	-772	89.6	-2121	-1802	-9615
71 C1 UKUR	-2128	-803	81.5	-2147	-1812	-10001
72 C1 UKUR	-2152	-819	60.9	-2195	-1827	-10045

Project **UK Urban area**

Normalisation per person Impact assessment

scenario code	climate change: GWP 100a (Eur.Person.Eq per person)	acidification potential: average European (Eur.Person.Eq per person)	eutrophication potential: generic (Eur.Person.Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq per person)	human toxicity: HTP infinite (Eur.Person.Eq per person)	resources: depletion of abiotic resources (Eur.Person.Eq per person)
01 IN UKUR	-0.00481	0.000198	0.000915	-0.000375	-0.000393	-0.0335
02 IN UKUR	-0.00512	0.00113	0.00129	0.0000624	-0.000758	-0.0352
03 IN UKUR	-0.00544	0.000237	0.000948	-0.000404	-0.0005	-0.0354
04 IN UKUR	-0.00774	-0.00209	0.000458	-0.00943	-0.00707	-0.0405
05 IN UKUR	-0.00805	-0.00116	0.000832	-0.009	-0.00743	-0.0422
06 IN UKUR	-0.00838	-0.00205	0.000492	-0.00946	-0.00718	-0.0424
07 IN UKUR	-0.00895	-0.00278	0.00036	-0.0106	-0.00832	-0.043
08 IN UKUR	-0.00925	-0.00187	0.000724	-0.0102	-0.00868	-0.0446
09 IN UKUR	-0.00957	-0.00274	0.000393	-0.0107	-0.00843	-0.0448
10 IN UKUR	-0.00797	-0.00248	0.000402	-0.00935	-0.00718	-0.0408
11 IN UKUR	-0.00779	-0.00153	0.000767	-0.00887	-0.00748	-0.041
12 IN UKUR	-0.00856	-0.00244	0.000434	-0.00938	-0.00728	-0.0425
13 IN UKUR	-0.00944	-0.00503	0.0000306	-0.00882	-0.00792	-0.0425
14 IN UKUR	-0.00907	-0.00444	0.000249	-0.0085	-0.00806	-0.0419
15 IN UKUR	-0.00996	-0.005	0.000058	-0.00884	-0.008	-0.044
16 IN UKUR	-0.00991	-0.00581	-0.0000846	-0.00866	-0.00815	-0.043
17 IN UKUR	-0.00963	-0.00536	0.0000844	-0.00841	-0.00826	-0.0426
18 IN UKUR	-0.0103	-0.00579	-0.0000634	-0.00867	-0.00821	-0.0442
01 AD UKUR	0.00657	0.000375	0.00137	0.000338	0.0000449	-0.00627
02 AD UKUR	0.00119	-0.00132	0.000844	-0.00878	-0.00741	-0.0155
03 AD UKUR	0.00159	-0.0012	0.000875	-0.00868	-0.00739	-0.0144
04 AD UKUR	0.000727	-0.00139	0.000826	-0.00884	-0.00745	-0.0168
05 AD UKUR	0.000586	-0.00147	0.000709	-0.00913	-0.00754	-0.017
06 AD UKUR	0.00235	-0.00132	0.00101	-0.00221	-0.00238	-0.0149
07 AD UKUR	0.00255	-0.00126	0.00103	-0.00216	-0.00237	-0.0144
08 AD UKUR	0.00212	-0.00136	0.001	-0.00224	-0.0024	-0.0156
09 AD UKUR	0.00205	-0.00143	0.000934	-0.00239	-0.00245	-0.0157
10 AD UKUR	-0.000702	-0.00255	0.000753	-0.00405	-0.00413	-0.0212
11 AD UKUR	-0.000355	-0.00245	0.000779	-0.00396	-0.00411	-0.0204
12 AD UKUR	-0.0011	-0.00261	0.000738	-0.0041	-0.00416	-0.0223
13 AD UKUR	-0.00122	-0.00268	0.000637	-0.00434	-0.00423	-0.0226
14 AD UKUR	-0.00176	-0.00298	0.000662	-0.00468	-0.00473	-0.0234
15 AD UKUR	-0.00137	-0.00286	0.000693	-0.00458	-0.00471	-0.0224
16 AD UKUR	-0.00221	-0.00305	0.000645	-0.00474	-0.00477	-0.0247
17 AD UKUR	-0.00236	-0.00311	0.000534	-0.00501	-0.00485	-0.025
01 C1 UKUR	-0.00436	0.000591	0.00102	-0.000349	-0.000373	-0.0322
02 C1 UKUR	-0.00414	0.000654	0.00104	-0.000294	-0.000362	-0.0316
03 C1 UKUR	-0.00461	0.000551	0.00101	-0.000381	-0.000396	-0.0329
04 C1 UKUR	-0.00469	0.000471	0.000934	-0.000548	-0.000447	-0.033
05 C1 UKUR	-0.0073	-0.0017	0.000564	-0.00938	-0.00705	-0.0392
06 C1 UKUR	-0.00708	-0.00164	0.000581	-0.00933	-0.00703	-0.0386
07 C1 UKUR	-0.00755	-0.00174	0.000555	-0.00941	-0.00707	-0.0399
08 C1 UKUR	-0.00763	-0.00182	0.000476	-0.00958	-0.00712	-0.04
09 C1 UKUR	-0.00865	-0.00243	0.000451	-0.0107	-0.00832	-0.042

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (Eur.Person.Eq per person)	acidification potential: average European (Eur.Person.Eq per person)	eutrophication potential: generic (Eur.Person.Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq per person)	human toxicity: HTP infinite (Eur.Person.Eq per person)	resources: depletion of abiotic resources (Eur.Person.Eq per person)
10 C1 UKUR	-0.00843	-0.00237	0.000468	-0.0106	-0.00831	-0.0414
11 C1 UKUR	-0.0089	-0.00247	0.000442	-0.0107	-0.00835	-0.0427
12 C1 UKUR	-0.00898	-0.00248	0.000391	-0.0108	-0.00839	-0.0429
13 C1 UKUR	-0.00778	-0.00222	0.000448	-0.00938	-0.00712	-0.0404
14 C1 UKUR	-0.00775	-0.00221	0.000451	-0.00938	-0.00712	-0.0403
15 C1 UKUR	-0.00782	-0.00223	0.000447	-0.00939	-0.00712	-0.0405
16 C1 UKUR	-0.00783	-0.0023	0.000413	-0.00943	-0.00714	-0.0404
17 C1 UKUR	-0.00812	-0.00308	0.000364	-0.0091	-0.00744	-0.0401
18 C1 UKUR	-0.0079	-0.00301	0.000381	-0.00904	-0.00743	-0.0396
19 C1 UKUR	-0.00837	-0.00312	0.000354	-0.00913	-0.00747	-0.0408
20 C1 UKUR	-0.00845	-0.00318	0.00028	-0.00929	-0.00752	-0.041
21 C1 UKUR	-0.00825	-0.00336	0.000335	-0.009	-0.00755	-0.0401
22 C1 UKUR	-0.00796	-0.00328	0.000356	-0.00893	-0.00754	-0.0394
23 C1 UKUR	-0.00857	-0.00342	0.000322	-0.00904	-0.00758	-0.041
24 C1 UKUR	-0.00867	-0.00348	0.000235	-0.00925	-0.00764	-0.0412
25 C1 UKUR	-0.00465	0.00147	0.00137	0.0000623	-0.000717	-0.0337
26 C1 UKUR	-0.00443	0.00153	0.00139	0.000118	-0.000705	-0.0332
27 C1 UKUR	-0.0049	0.00143	0.00136	0.0000306	-0.000739	-0.0344
28 C1 UKUR	-0.00498	0.00135	0.00129	-0.000136	-0.00079	-0.0345
29 C1 UKUR	-0.00759	-0.000823	0.000916	-0.00897	-0.00739	-0.0407
30 C1 UKUR	-0.00644	-0.000619	0.000961	-0.00877	-0.00729	-0.0376
31 C1 UKUR	-0.00784	-0.000863	0.000906	-0.009	-0.00741	-0.0414
32 C1 UKUR	-0.00792	-0.000943	0.000828	-0.00917	-0.00746	-0.0415
33 C1 UKUR	-0.00893	-0.00158	0.000794	-0.0103	-0.00866	-0.0435
34 C1 UKUR	-0.00871	-0.00151	0.000811	-0.0102	-0.00865	-0.0429
35 C1 UKUR	-0.00918	-0.00162	0.000784	-0.0103	-0.00868	-0.0442
36 C1 UKUR	-0.00926	-0.00162	0.000733	-0.0104	-0.00872	-0.0444
37 C1 UKUR	-0.00808	-0.00132	0.000807	-0.00896	-0.00747	-0.042
38 C1 UKUR	-0.00805	-0.00132	0.00081	-0.00896	-0.00747	-0.0419
39 C1 UKUR	-0.00811	-0.00133	0.000806	-0.00897	-0.00747	-0.0421
40 C1 UKUR	-0.00812	-0.0014	0.000772	-0.00901	-0.00749	-0.042
41 C1 UKUR	-0.00834	-0.0024	0.000635	-0.00878	-0.00771	-0.0413
42 C1 UKUR	-0.00812	-0.00233	0.000652	-0.00872	-0.0077	-0.0408
43 C1 UKUR	-0.00859	-0.00244	0.000626	-0.00881	-0.00773	-0.042
44 C1 UKUR	-0.00867	-0.00251	0.000552	-0.00897	-0.00778	-0.0422
45 C1 UKUR	-0.00845	-0.00276	0.000577	-0.00872	-0.00779	-0.0412
46 C1 UKUR	-0.00817	-0.00268	0.000599	-0.00865	-0.00777	-0.0405
47 C1 UKUR	-0.00877	-0.00281	0.000565	-0.00876	-0.00782	-0.0421
48 C1 UKUR	-0.00887	-0.00288	0.000478	-0.00896	-0.00788	-0.0423
49 C1 UKUR	-0.00496	0.000628	0.00105	-0.000377	-0.000474	-0.0339
50 C1 UKUR	-0.00474	0.00069	0.00107	-0.000322	-0.000462	-0.0334
51 C1 UKUR	-0.00521	0.000587	0.00104	-0.000409	-0.000496	-0.0346
52 C1 UKUR	-0.00529	0.000508	0.000965	-0.000575	-0.000547	-0.0347
53 C1 UKUR	-0.0079	-0.00167	0.000596	-0.00941	-0.00715	-0.0409
54 C1 UKUR	-0.00768	-0.0016	0.000613	-0.00935	-0.00713	-0.0404
55 C1 UKUR	-0.00815	-0.00171	0.000586	-0.00944	-0.00717	-0.0416
56 C1 UKUR	-0.00823	-0.00179	0.000508	-0.00961	-0.00722	-0.0417

scenario code	climate change: GWP 100a (Eur.Person.Eq per person)	acidification potential: average European (Eur.Person.Eq per person)	eutrophication potential: generic (Eur.Person.Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq per person)	human toxicity: HTP infinite (Eur.Person.Eq per person)	resources: depletion of abiotic resources (Eur.Person.Eq per person)
57 C1 UKUR	-0.00923	-0.0024	0.000482	-0.0107	-0.00842	-0.0437
58 C1 UKUR	-0.00901	-0.00234	0.000499	-0.0106	-0.00841	-0.0431
59 C1 UKUR	-0.00948	-0.00244	0.000473	-0.0107	-0.00844	-0.0444
60 C1 UKUR	-0.00956	-0.00245	0.000422	-0.0109	-0.00848	-0.0446
61 C1 UKUR	-0.00839	-0.00218	0.000481	-0.00941	-0.00722	-0.0422
62 C1 UKUR	-0.00836	-0.00218	0.000483	-0.0094	-0.00722	-0.0421
63 C1 UKUR	-0.00843	-0.00219	0.000479	-0.00942	-0.00723	-0.0423
64 C1 UKUR	-0.00844	-0.00226	0.000445	-0.00946	-0.00724	-0.0422
65 C1 UKUR	-0.00858	-0.00305	0.000388	-0.00912	-0.00752	-0.0415
66 C1 UKUR	-0.00836	-0.00299	0.000405	-0.00906	-0.00751	-0.0409
67 C1 UKUR	-0.00883	-0.00309	0.000379	-0.00915	-0.00754	-0.0422
68 C1 UKUR	-0.00891	-0.00316	0.000305	-0.00931	-0.00759	-0.0423
69 C1 UKUR	-0.00866	-0.00334	0.000357	-0.00902	-0.00762	-0.0413
70 C1 UKUR	-0.00838	-0.00326	0.000378	-0.00895	-0.00761	-0.0406
71 C1 UKUR	-0.00898	-0.00339	0.000344	-0.00906	-0.00765	-0.0422
72 C1 UKUR	-0.00908	-0.00346	0.000257	-0.00926	-0.00771	-0.0424

Appendix D

Results from WRATE

Project **UK Rural area**

Project Headline Indicators

scenario code	Bio- degradeable Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
1 IN UKRU	-	80,798,272	0.112		9,845	37,239	
2 IN UKRU	-	265,462,739	0.112		9,845	37,239	
3 IN UKRU	-	117,125,708	0.112		9,845	37,239	
4 IN UKRU	-	80,798,272	0.0895		1,970	37,239	1,100
5 IN UKRU	-	265,462,739	0.0895		1,970	37,239	1,100
6 IN UKRU	-	117,125,708	0.0895		1,970	37,239	1,100
7 IN UKRU	-	78,767,884	0.111		1,732	33,290	3,671
8 IN UKRU	-	258,791,898	0.111		1,732	33,290	3,671
9 IN UKRU	-	114,182,444	0.111		1,732	33,290	3,671
10 IN UKRU	-	75,363,313	0.0981		1,971	35,487	2,742
11 IN UKRU	-	247,606,178	0.0981		1,971	35,487	2,742
12 IN UKRU	-	109,247,155	0.0981		1,971	35,487	2,742
13 IN UKRU	-	44,235,817	0.148		1,976	25,451	12,144
14 IN UKRU	-	145,336,784	0.148		1,976	25,451	12,144
15 IN UKRU	-	64,124,532	0.148		1,976	25,451	12,144
16 IN UKRU	-	32,871,810	0.166		1,978	21,788	15,576
17 IN UKRU	-	108,000,339	0.166		1,978	21,788	15,576
18 IN UKRU	-	47,651,193	0.166		1,978	21,788	15,576
01 AD UKRU	26,872	18,735,848	0.194		37,239		
02 AD UKRU	18,102	18,845,342	0.186	8,437	25,080		3,616
03 AD UKRU	18,102	22,275,784	0.186	8,437	25,080		3,616
04 AD UKRU	18,102	27,483,179	0.186	8,437	25,080		3,616
05 AD UKRU	18,102	45,246,409	0.186	8,437	25,080		3,616
06 AD UKRU	19,739	16,576,525	0.195	4,376	28,129		5,097
07 AD UKRU	19,739	18,286,377	0.195	4,376	28,129		5,097
08 AD UKRU	19,739	20,881,925	0.195	4,376	28,129		5,097
09 AD UKRU	19,739	29,735,738	0.195	4,376	28,129		5,097
10 AD UKRU	14,835	15,091,992	0.195	7,384	21,867		8,602
11 AD UKRU	14,835	17,977,367	0.195	7,384	21,867		8,602
12 AD UKRU	14,835	22,357,353	0.195	7,384	21,867		8,602
13 AD UKRU	14,835	37,298,162	0.195	7,384	21,867		8,602
14 AD UKRU	12,829	14,484,682	0.195	8,615	19,304		10,035
15 AD UKRU	12,829	17,850,953	0.195	8,615	19,304		10,035
16 AD UKRU	12,829	22,960,937	0.195	8,615	19,304		10,035
17 AD UKRU	12,829	40,391,881	0.195	8,615	19,304		10,035
01 C1 UKRU	-	78,905,930	0.112	4,786	9,230	32,453	
02 C1 UKRU	-	80,776,081	0.112	4,786	9,230	32,453	
03 C1 UKRU	-	83,614,960	0.112	4,786	9,230	32,453	
04 C1 UKRU	-	93,298,819	0.112	4,786	9,230	32,453	
05 C1 UKRU	-	78,905,930	0.0911	4,786	1,816	32,453	1,100
06 C1 UKRU	-	80,776,081	0.0911	4,786	1,816	32,453	1,100
07 C1 UKRU	-	83,614,960	0.0911	4,786	1,816	32,453	1,100
08 C1 UKRU	-	93,298,819	0.0911	4,786	1,816	32,453	1,100
09 C1 UKRU	-	76,952,302	0.109	4,786	1,582	28,613	3,671

Appendix D

Results from WRATE

scenario code	Bio- degradeable Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
10 C1 UKRU	-	78,822,452	0.109	4,786	1,582	28,613	3,671
11 C1 UKRU	-	81,661,332	0.109	4,786	1,582	28,613	3,671
12 C1 UKRU	-	91,345,190	0.109	4,786	1,582	28,613	3,671
13 C1 UKRU	-	77,509,347	0.0944	820	1,944	35,463	1,996
14 C1 UKRU	-	77,829,945	0.0944	820	1,944	35,463	1,996
15 C1 UKRU	-	78,316,610	0.0944	820	1,944	35,463	1,996
16 C1 UKRU	-	79,976,700	0.0944	820	1,944	35,463	1,996
17 C1 UKRU	-	61,612,877	0.119	4,786	1,819	26,878	6,324
18 C1 UKRU	-	63,483,027	0.119	4,786	1,819	26,878	6,324
19 C1 UKRU	-	66,321,907	0.119	4,786	1,819	26,878	6,324
20 C1 UKRU	-	76,005,765	0.119	4,786	1,819	26,878	6,324
21 C1 UKRU	-	55,583,181	0.128	6,290	1,771	23,621	7,965
22 C1 UKRU	-	58,041,093	0.128	6,290	1,771	23,621	7,965
23 C1 UKRU	-	61,772,192	0.128	6,290	1,771	23,621	7,965
24 C1 UKRU	-	74,499,549	0.128	6,290	1,771	23,621	7,965
25 C1 UKRU	-	252,757,188	0.112	4,786	9,230	32,453	
26 C1 UKRU	-	254,627,338	0.112	4,786	9,230	32,453	
27 C1 UKRU	-	257,466,218	0.112	4,786	9,230	32,453	
28 C1 UKRU	-	267,150,076	0.112	4,786	9,230	32,453	
29 C1 UKRU	-	252,757,188	0.0911	4,786	1,816	32,453	1,100
30 C1 UKRU	-	254,627,338	0.0911	4,786	1,816	32,453	1,100
31 C1 UKRU	-	257,466,218	0.0911	4,786	1,816	32,453	1,100
32 C1 UKRU	-	267,150,076	0.0911	4,786	1,816	32,453	1,100
33 C1 UKRU	-	246,338,542	0.109	4,786	1,582	28,613	3,671
34 C1 UKRU	-	248,208,692	0.109	4,786	1,582	28,613	3,671
35 C1 UKRU	-	251,047,572	0.109	4,786	1,582	28,613	3,671
36 C1 UKRU	-	260,731,430	0.109	4,786	1,582	28,613	3,671
37 C1 UKRU	-	253,544,702	0.0944	820	1,944	35,463	1,996
38 C1 UKRU	-	253,865,299	0.0944	820	1,944	35,463	1,996
39 C1 UKRU	-	254,351,965	0.0944	820	1,944	35,463	1,996
40 C1 UKRU	-	256,012,054	0.0944	820	1,944	35,463	1,996
41 C1 UKRU	-	195,940,858	0.119	4,786	1,819	26,878	6,324
42 C1 UKRU	-	197,811,008	0.119	4,786	1,819	26,878	6,324
43 C1 UKRU	-	200,649,888	0.119	4,786	1,819	26,878	6,324
44 C1 UKRU	-	210,333,746	0.119	4,786	1,819	26,878	6,324
45 C1 UKRU	-	174,091,124	0.128	6,290	1,771	23,621	7,965
46 C1 UKRU	-	176,549,036	0.128	6,290	1,771	23,621	7,965
47 C1 UKRU	-	180,280,135	0.128	6,290	1,771	23,621	7,965
48 C1 UKRU	-	193,007,491	0.128	6,290	1,771	23,621	7,965
49 C1 UKRU	-	113,106,177	0.112	4,786	9,230	32,453	
50 C1 UKRU	-	114,976,328	0.112	4,786	9,230	32,453	
51 C1 UKRU	-	117,815,208	0.112	4,786	9,230	32,453	
52 C1 UKRU	-	127,499,066	0.112	4,786	9,230	32,453	
53 C1 UKRU	-	113,106,177	0.0911	4,786	1,816	32,453	1,100
54 C1 UKRU	-	114,976,328	0.0911	4,786	1,816	32,453	1,100
55 C1 UKRU	-	117,815,208	0.0911	4,786	1,816	32,453	1,100
56 C1 UKRU	-	127,499,066	0.0911	4,786	1,816	32,453	1,100

Appendix D

Results from WRATE

scenario code	Bio- degradeable Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
57 C1 UKRU	-	110,274,185	0.109	4,786	1,582	28,613	3,671
58 C1 UKRU	-	112,144,336	0.109	4,786	1,582	28,613	3,671
59 C1 UKRU	-	114,983,215	0.109	4,786	1,582	28,613	3,671
60 C1 UKRU	-	124,667,074	0.109	4,786	1,582	28,613	3,671
61 C1 UKRU	-	112,139,253	0.0944	820	1,944	35,463	1,996
62 C1 UKRU	-	112,459,850	0.0944	820	1,944	35,463	1,996
63 C1 UKRU	-	112,946,516	0.0944	820	1,944	35,463	1,996
64 C1 UKRU	-	114,606,606	0.0944	820	1,944	35,463	1,996
65 C1 UKRU	-	88,038,053	0.119	4,786	1,819	26,878	6,324
66 C1 UKRU	-	89,908,204	0.119	4,786	1,819	26,878	6,324
67 C1 UKRU	-	92,747,084	0.119	4,786	1,819	26,878	6,324
68 C1 UKRU	-	102,430,942	0.119	4,786	1,819	26,878	6,324
69 C1 UKRU	-	78,896,219	0.128	6,290	1,771	23,621	7,965
70 C1 UKRU	-	81,354,131	0.128	6,290	1,771	23,621	7,965
71 C1 UKRU	-	85,085,230	0.128	6,290	1,771	23,621	7,965
72 C1 UKRU	-	97,812,587	0.128	6,290	1,771	23,621	7,965
73 C1 UKRU	-	75,140,661	0.172	13,674	1,537	7,636	16,024

Appendix D

Results from WRATE

Project **UK Rural area**

Characterisation Impact assessment

scenario code	climate change: GWP 100a (kg CO2-Eq)	acidification potential: average European (kg SO2-Eq)	eutrophication potential: generic (kg PO4-Eq)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq)	human toxicity: HTP infinite (kg 1,4-DCB-Eq)	resources: depletion of abiotic resources (kg antimony-Eq)
01 IN UKRU	-5,044,866	6,450	4,047	48,452	-307,184	-123,262
02 IN UKRU	-5,453,354	13,265	5,320	107,195	-1,042,114	-129,743
03 IN UKRU	-5,882,054	6,736	4,162	44,464	-522,200	-130,559
04 IN UKRU	-8,912,424	-10,252	2,493	-1,169,630	-13,760,927	-150,776
05 IN UKRU	-9,320,912	-3,437	3,766	-1,110,887	-14,495,857	-157,256
06 IN UKRU	-9,749,612	-9,966	2,608	-1,173,618	-13,975,943	-158,073
07 IN UKRU	-10,575,566	-15,331	2,147	-1,330,712	-16,293,657	-160,964
08 IN UKRU	-10,973,790	-8,687	3,387	-1,273,445	-17,010,119	-167,282
09 IN UKRU	-11,391,717	-15,053	2,258	-1,334,599	-16,503,270	-168,078
10 IN UKRU	-9,301,111	-13,618	2,237	-1,162,178	-14,034,096	-152,299
11 IN UKRU	-9,682,123	-7,261	3,424	-1,107,386	-14,719,590	-158,344
12 IN UKRU	-10,081,985	-13,352	2,344	-1,165,897	-14,234,649	-159,106
13 IN UKRU	-11,607,423	-33,126	733	-1,122,008	-15,619,143	-161,740
14 IN UKRU	-11,831,064	-29,395	1,429	-1,089,847	-16,021,505	-165,288
15 IN UKRU	-12,065,770	-32,970	796	-1,124,191	-15,736,861	-165,735
16 IN UKRU	-12,449,446	-40,249	184	-1,107,344	-16,197,822	-165,187
17 IN UKRU	-12,615,635	-37,476	701	-1,083,445	-16,496,819	-167,823
18 IN UKRU	-12,790,046	-40,132	230	-1,108,966	-16,285,299	-168,156
01 AD UKRU	9,874,678	7,654	5,589	142,904	567,632	-16,448
02 AD UKRU	2,780,254	-4,676	3,796	-1,083,530	-14,455,952	-52,627
03 AD UKRU	3,312,959	-3,841	3,902	-1,069,855	-14,413,327	-48,614
04 AD UKRU	2,174,828	-5,219	3,736	-1,091,336	-14,538,908	-57,762
05 AD UKRU	2,023,599	-9,125	2,759	-1,152,153	-14,860,639	-54,830
06 AD UKRU	4,562,532	-3,107	4,691	-188,701	-4,264,505	-48,113
07 AD UKRU	4,828,050	-2,690	4,743	-181,885	-4,243,260	-46,112
08 AD UKRU	4,260,766	-3,377	4,661	-192,592	-4,305,853	-50,672
09 AD UKRU	4,196,824	-6,705	3,931	-232,136	-4,527,910	-47,585
10 AD UKRU	886,705	-10,585	4,061	-417,130	-7,589,893	-70,188
11 AD UKRU	1,334,768	-9,883	4,150	-405,628	-7,554,041	-66,813
12 AD UKRU	377,476	-11,042	4,010	-423,696	-7,659,668	-74,507
13 AD UKRU	243,648	-14,015	3,240	-472,525	-7,914,750	-72,475
14 AD UKRU	-616,946	-13,645	3,804	-510,580	-8,950,279	-79,218
15 AD UKRU	-94,206	-12,825	3,907	-497,161	-8,908,451	-75,281
16 AD UKRU	-1,211,047	-14,178	3,744	-518,240	-9,031,683	-84,257
17 AD UKRU	-1,400,193	-14,281	3,433	-552,412	-9,176,928	-85,934
01 C1 UKRU	-4,527,583	9,241	4,403	50,563	-274,590	-118,432
02 C1 UKRU	-4,237,172	9,696	4,460	58,019	-251,353	-116,245
03 C1 UKRU	-4,857,639	8,945	4,370	46,308	-319,814	-121,232
04 C1 UKRU	-4,925,012	5,044	3,526	1,286	-574,521	-117,541
05 C1 UKRU	-8,403,922	-7,488	2,845	-1,163,664	-13,721,836	-146,001
06 C1 UKRU	-8,113,511	-7,033	2,902	-1,156,209	-13,698,599	-143,814
07 C1 UKRU	-8,733,978	-7,784	2,812	-1,167,920	-13,767,060	-148,800
08 C1 UKRU	-8,801,351	-11,685	1,968	-1,212,942	-14,021,767	-145,109
09 C1 UKRU	-10,174,186	-12,821	2,460	-1,337,238	-16,297,967	-157,043

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq)	acidification potential: average European (kg SO2-Eq)	eutrophication potential: generic (kg PO4-Eq)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq)	human toxicity: HTP infinite (kg 1,4-DCB-Eq)	resources: depletion of abiotic resources (kg antimony-Eq)
10 C1 UKRU	-9,883,775	-12,365	2,518	-1,329,783	-16,274,730	-154,856
11 C1 UKRU	-10,504,242	-13,117	2,427	-1,341,494	-16,343,192	-159,843
12 C1 UKRU	-10,571,615	-17,018	1,583	-1,386,516	-16,597,899	-156,152
13 C1 UKRU	-8,933,764	-11,100	2,510	-1,159,443	-13,876,957	-149,784
14 C1 UKRU	-8,883,979	-11,022	2,520	-1,158,165	-13,872,973	-149,409
15 C1 UKRU	-8,990,345	-11,150	2,505	-1,160,173	-13,884,709	-150,264
16 C1 UKRU	-8,971,703	-14,897	1,823	-1,188,738	-14,067,699	-145,930
17 C1 UKRU	-9,206,293	-15,757	2,510	-1,113,251	-14,461,148	-147,168
18 C1 UKRU	-8,915,882	-15,302	2,567	-1,105,796	-14,437,910	-144,981
19 C1 UKRU	-9,536,349	-16,053	2,477	-1,117,507	-14,506,372	-149,968
20 C1 UKRU	-9,609,818	-19,333	1,742	-1,158,319	-14,732,946	-147,024
21 C1 UKRU	-9,310,390	-17,527	2,509	-1,095,780	-14,682,987	-146,181
22 C1 UKRU	-8,928,707	-16,928	2,585	-1,085,982	-14,652,447	-143,306
23 C1 UKRU	-9,744,178	-17,916	2,466	-1,101,373	-14,742,425	-149,860
24 C1 UKRU	-9,882,285	-17,991	2,238	-1,126,323	-14,848,477	-151,085
25 C1 UKRU	-4,912,152	15,657	5,600	105,867	-966,485	-124,534
26 C1 UKRU	-4,621,741	16,112	5,658	113,322	-943,248	-122,346
27 C1 UKRU	-5,242,208	15,361	5,567	101,611	-1,011,710	-127,333
28 C1 UKRU	-5,309,581	11,460	4,724	56,589	-1,266,417	-123,642
29 C1 UKRU	-8,788,491	-1,072	4,043	-1,108,361	-14,413,731	-152,103
30 C1 UKRU	-8,498,080	-616	4,100	-1,100,906	-14,390,494	-149,915
31 C1 UKRU	-9,118,547	-1,368	4,009	-1,112,616	-14,458,956	-154,902
32 C1 UKRU	-9,185,920	-5,269	3,166	-1,157,638	-14,713,663	-151,211
33 C1 UKRU	-10,548,879	-6,569	3,627	-1,283,355	-16,972,093	-162,988
34 C1 UKRU	-10,258,468	-6,114	3,685	-1,275,900	-16,948,855	-160,800
35 C1 UKRU	-10,878,935	-6,865	3,594	-1,287,611	-17,017,317	-165,787
36 C1 UKRU	-10,946,308	-10,766	2,750	-1,332,633	-17,272,024	-162,096
37 C1 UKRU	-9,323,164	-4,603	3,723	-1,103,445	-14,577,544	-155,962
38 C1 UKRU	-9,273,380	-4,525	3,733	-1,102,167	-14,573,561	-155,587
39 C1 UKRU	-9,379,745	-4,654	3,717	-1,104,175	-14,585,297	-156,442
40 C1 UKRU	-9,361,104	-8,400	3,036	-1,132,740	-14,768,286	-152,108
41 C1 UKRU	-9,503,434	-10,799	3,435	-1,070,520	-14,995,748	-151,883
42 C1 UKRU	-9,213,023	-10,344	3,493	-1,063,065	-14,972,510	-149,695
43 C1 UKRU	-9,833,490	-11,095	3,402	-1,074,776	-15,040,972	-154,682
44 C1 UKRU	-9,906,959	-14,375	2,667	-1,115,588	-15,267,546	-151,738
45 C1 UKRU	-9,572,537	-13,153	3,326	-1,058,082	-15,154,627	-150,340
46 C1 UKRU	-9,190,854	-12,555	3,401	-1,048,283	-15,124,086	-147,465
47 C1 UKRU	-10,006,325	-13,542	3,282	-1,063,675	-15,214,065	-154,019
48 C1 UKRU	-10,144,431	-13,617	3,055	-1,088,625	-15,320,117	-155,244
49 C1 UKRU	-5,315,749	9,510	4,511	46,810	-477,016	-125,302
50 C1 UKRU	-5,025,338	9,965	4,568	54,265	-453,778	-123,115
51 C1 UKRU	-5,645,805	9,214	4,478	42,554	-522,240	-128,102
52 C1 UKRU	-5,713,178	5,313	3,634	-2,468	-776,947	-124,411
53 C1 UKRU	-9,192,087	-7,219	2,953	-1,167,418	-13,924,262	-152,871
54 C1 UKRU	-8,901,676	-6,764	3,010	-1,159,963	-13,901,024	-150,683
55 C1 UKRU	-9,522,143	-7,515	2,920	-1,171,673	-13,969,486	-155,670
56 C1 UKRU	-9,589,516	-11,416	2,076	-1,216,695	-14,224,193	-151,979

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq)	acidification potential: average European (kg SO2-Eq)	eutrophication potential: generic (kg PO4-Eq)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq)	human toxicity: HTP infinite (kg 1,4-DCB-Eq)	resources: depletion of abiotic resources (kg antimony-Eq)
57 C1 UKRU	-10,942,109	-12,558	2,565	-1,340,896	-16,495,194	-163,737
58 C1 UKRU	-10,651,699	-12,103	2,623	-1,333,441	-16,471,957	-161,549
59 C1 UKRU	-11,272,165	-12,855	2,532	-1,345,151	-16,540,419	-166,536
60 C1 UKRU	-11,339,538	-16,756	1,688	-1,390,173	-16,795,126	-162,845
61 C1 UKRU	-9,731,831	-10,827	2,620	-1,163,244	-14,081,925	-156,741
62 C1 UKRU	-9,682,046	-10,749	2,629	-1,161,966	-14,077,942	-156,365
63 C1 UKRU	-9,788,412	-10,878	2,614	-1,163,974	-14,089,678	-157,220
64 C1 UKRU	-9,769,771	-14,624	1,932	-1,192,539	-14,272,667	-152,887
65 C1 UKRU	-9,815,277	-15,549	2,593	-1,116,151	-14,617,554	-152,476
66 C1 UKRU	-9,524,866	-15,094	2,651	-1,108,696	-14,594,317	-150,289
67 C1 UKRU	-10,145,333	-15,845	2,560	-1,120,407	-14,662,779	-155,276
68 C1 UKRU	-10,218,802	-19,125	1,825	-1,161,219	-14,889,353	-152,332
69 C1 UKRU	-9,847,653	-17,343	2,583	-1,098,339	-14,820,973	-150,864
70 C1 UKRU	-9,465,970	-16,745	2,658	-1,088,540	-14,790,433	-147,989
71 C1 UKRU	-10,281,441	-17,732	2,539	-1,103,932	-14,880,411	-154,543
72 C1 UKRU	-10,419,548	-17,808	2,312	-1,128,882	-14,986,463	-155,768
73 C1 UKRU	-11,246,385	-27,145	1,945	-1,077,056	-16,178,158	-153,584

Appendix D

Results from WRATE

Project **UK Rural area**

Characterisation per person Impact assessment

scenario code	climate change: GWP 100a (kg CO2-Eq per person)	acidification potential: average European (kg SO2-Eq per person)	eutrophication potential: generic (kg PO4-Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq per person)	human toxicity: HTP infinite (kg 1,4-DCB-Eq per person)	resources: depletion of abiotic resources (kg antimony-Eq per person)
1 IN UKRU	-43.3	0.0553	0.0347	0.416	-2.63	-1.06
2 IN UKRU	-46.8	0.114	0.0456	0.919	-8.94	-1.11
3 IN UKRU	-50.4	0.0578	0.0357	0.381	-4.48	-1.12
4 IN UKRU	-76.4	-0.0879	0.0214	-10	-118	-1.29
5 IN UKRU	-79.9	-0.0295	0.0323	-9.53	-124	-1.35
6 IN UKRU	-83.6	-0.0855	0.0224	-10.1	-120	-1.36
7 IN UKRU	-90.7	-0.131	0.0184	-11.4	-140	-1.38
8 IN UKRU	-94.1	-0.0745	0.029	-10.9	-146	-1.43
9 IN UKRU	-97.7	-0.129	0.0194	-11.4	-142	-1.44
10 IN UKRU	-79.8	-0.117	0.0192	-9.97	-120	-1.31
11 IN UKRU	-83	-0.0623	0.0294	-9.5	-126	-1.36
12 IN UKRU	-86.5	-0.115	0.0201	-10	-122	-1.36
13 IN UKRU	-99.5	-0.284	0.00629	-9.62	-134	-1.39
14 IN UKRU	-101	-0.252	0.0123	-9.35	-137	-1.42
15 IN UKRU	-103	-0.283	0.00682	-9.64	-135	-1.42
16 IN UKRU	-107	-0.345	0.00157	-9.5	-139	-1.42
17 IN UKRU	-108	-0.321	0.00601	-9.29	-141	-1.44
18 IN UKRU	-110	-0.344	0.00197	-9.51	-140	-1.44
01 AD UKRU	84.7	0.0656	0.0479	1.23	4.87	-0.141
02 AD UKRU	23.8	-0.0401	0.0326	-9.29	-124	-0.451
03 AD UKRU	28.4	-0.0329	0.0335	-9.18	-124	-0.417
04 AD UKRU	18.7	-0.0448	0.032	-9.36	-125	-0.495
05 AD UKRU	17.4	-0.0783	0.0237	-9.88	-127	-0.47
06 AD UKRU	39.1	-0.0266	0.0402	-1.62	-36.6	-0.413
07 AD UKRU	41.4	-0.0231	0.0407	-1.56	-36.4	-0.395
08 AD UKRU	36.5	-0.029	0.04	-1.65	-36.9	-0.435
09 AD UKRU	36	-0.0575	0.0337	-1.99	-38.8	-0.408
10 AD UKRU	7.6	-0.0908	0.0348	-3.58	-65.1	-0.602
11 AD UKRU	11.4	-0.0848	0.0356	-3.48	-64.8	-0.573
12 AD UKRU	3.24	-0.0947	0.0344	-3.63	-65.7	-0.639
13 AD UKRU	2.09	-0.12	0.0278	-4.05	-67.9	-0.622
14 AD UKRU	-5.29	-0.117	0.0326	-4.38	-76.8	-0.679
15 AD UKRU	-0.808	-0.11	0.0335	-4.26	-76.4	-0.646
16 AD UKRU	-10.4	-0.122	0.0321	-4.44	-77.5	-0.723
17 AD UKRU	-12	-0.122	0.0294	-4.74	-78.7	-0.737
01 C1 UKRU	-38.8	0.0793	0.0378	0.434	-2.35	-1.02
02 C1 UKRU	-36.3	0.0832	0.0383	0.498	-2.16	-0.997
03 C1 UKRU	-41.7	0.0767	0.0375	0.397	-2.74	-1.04
04 C1 UKRU	-42.2	0.0433	0.0302	0.011	-4.93	-1.01
05 C1 UKRU	-72.1	-0.0642	0.0244	-9.98	-118	-1.25
06 C1 UKRU	-69.6	-0.0603	0.0249	-9.92	-117	-1.23
07 C1 UKRU	-74.9	-0.0668	0.0241	-10	-118	-1.28
08 C1 UKRU	-75.5	-0.1	0.0169	-10.4	-120	-1.24
09 C1 UKRU	-87.3	-0.11	0.0211	-11.5	-140	-1.35

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq per person)	acidification potential: average European (kg SO2-Eq per person)	eutrophication potential: generic (kg PO4-Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq per person)	human toxicity: HTP infinite (kg 1,4-DCB-Eq per person)	resources: depletion of abiotic resources (kg antimony-Eq per person)
10 C1 UKRU	-84.8	-0.106	0.0216	-11.4	-140	-1.33
11 C1 UKRU	-90.1	-0.112	0.0208	-11.5	-140	-1.37
12 C1 UKRU	-90.7	-0.146	0.0136	-11.9	-142	-1.34
13 C1 UKRU	-76.6	-0.0952	0.0215	-9.94	-119	-1.28
14 C1 UKRU	-76.2	-0.0945	0.0216	-9.93	-119	-1.28
15 C1 UKRU	-77.1	-0.0956	0.0215	-9.95	-119	-1.29
16 C1 UKRU	-76.9	-0.128	0.0156	-10.2	-121	-1.25
17 C1 UKRU	-79	-0.135	0.0215	-9.55	-124	-1.26
18 C1 UKRU	-76.5	-0.131	0.022	-9.48	-124	-1.24
19 C1 UKRU	-81.8	-0.138	0.0212	-9.58	-124	-1.29
20 C1 UKRU	-82.4	-0.166	0.0149	-9.93	-126	-1.26
21 C1 UKRU	-79.8	-0.15	0.0215	-9.4	-126	-1.25
22 C1 UKRU	-76.6	-0.145	0.0222	-9.31	-126	-1.23
23 C1 UKRU	-83.6	-0.154	0.0211	-9.45	-126	-1.29
24 C1 UKRU	-84.8	-0.154	0.0192	-9.66	-127	-1.3
25 C1 UKRU	-42.1	0.134	0.048	0.908	-8.29	-1.07
26 C1 UKRU	-39.6	0.138	0.0485	0.972	-8.09	-1.05
27 C1 UKRU	-45	0.132	0.0477	0.871	-8.68	-1.09
28 C1 UKRU	-45.5	0.0983	0.0405	0.485	-10.9	-1.06
29 C1 UKRU	-75.4	-0.00919	0.0347	-9.51	-124	-1.3
30 C1 UKRU	-72.9	-0.00529	0.0352	-9.44	-123	-1.29
31 C1 UKRU	-78.2	-0.0117	0.0344	-9.54	-124	-1.33
32 C1 UKRU	-78.8	-0.0452	0.0271	-9.93	-126	-1.3
33 C1 UKRU	-90.5	-0.0563	0.0311	-11	-146	-1.4
34 C1 UKRU	-88	-0.0524	0.0316	-10.9	-145	-1.38
35 C1 UKRU	-93.3	-0.0589	0.0308	-11	-146	-1.42
36 C1 UKRU	-93.9	-0.0923	0.0236	-11.4	-148	-1.39
37 C1 UKRU	-80	-0.0395	0.0319	-9.46	-125	-1.34
38 C1 UKRU	-79.5	-0.0388	0.032	-9.45	-125	-1.33
39 C1 UKRU	-80.4	-0.0399	0.0319	-9.47	-125	-1.34
40 C1 UKRU	-80.3	-0.072	0.026	-9.71	-127	-1.3
41 C1 UKRU	-81.5	-0.0926	0.0295	-9.18	-129	-1.3
42 C1 UKRU	-79	-0.0887	0.03	-9.12	-128	-1.28
43 C1 UKRU	-84.3	-0.0952	0.0292	-9.22	-129	-1.33
44 C1 UKRU	-85	-0.123	0.0229	-9.57	-131	-1.3
45 C1 UKRU	-82.1	-0.113	0.0285	-9.07	-130	-1.29
46 C1 UKRU	-78.8	-0.108	0.0292	-8.99	-130	-1.26
47 C1 UKRU	-85.8	-0.116	0.0282	-9.12	-130	-1.32
48 C1 UKRU	-87	-0.117	0.0262	-9.34	-131	-1.33
49 C1 UKRU	-45.6	0.0816	0.0387	0.401	-4.09	-1.07
50 C1 UKRU	-43.1	0.0855	0.0392	0.465	-3.89	-1.06
51 C1 UKRU	-48.4	0.079	0.0384	0.365	-4.48	-1.1
52 C1 UKRU	-49	0.0456	0.0312	-0.0212	-6.66	-1.07
53 C1 UKRU	-78.8	-0.0619	0.0253	-10	-119	-1.31
54 C1 UKRU	-76.3	-0.058	0.0258	-9.95	-119	-1.29
55 C1 UKRU	-81.7	-0.0644	0.025	-10	-120	-1.34
56 C1 UKRU	-82.2	-0.0979	0.0178	-10.4	-122	-1.3

Appendix D
Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq per person)	acidification potential: average European (kg SO2-Eq per person)	eutrophication potential: generic (kg PO4-Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq per person)	human toxicity: HTP infinite (kg 1,4-DCB-Eq per person)	resources: depletion of abiotic resources (kg antimony-Eq per person)
57 C1 UKRU	-93.8	-0.108	0.022	-11.5	-141	-1.4
58 C1 UKRU	-91.4	-0.104	0.0225	-11.4	-141	-1.39
59 C1 UKRU	-96.7	-0.11	0.0217	-11.5	-142	-1.43
60 C1 UKRU	-97.3	-0.144	0.0145	-11.9	-144	-1.4
61 C1 UKRU	-83.5	-0.0929	0.0225	-9.98	-121	-1.34
62 C1 UKRU	-83	-0.0922	0.0226	-9.97	-121	-1.34
63 C1 UKRU	-83.9	-0.0933	0.0224	-9.98	-121	-1.35
64 C1 UKRU	-83.8	-0.125	0.0166	-10.2	-122	-1.31
65 C1 UKRU	-84.2	-0.133	0.0222	-9.57	-125	-1.31
66 C1 UKRU	-81.7	-0.129	0.0227	-9.51	-125	-1.29
67 C1 UKRU	-87	-0.136	0.022	-9.61	-126	-1.33
68 C1 UKRU	-87.6	-0.164	0.0157	-9.96	-128	-1.31
69 C1 UKRU	-84.5	-0.149	0.0222	-9.42	-127	-1.29
70 C1 UKRU	-81.2	-0.144	0.0228	-9.34	-127	-1.27
71 C1 UKRU	-88.2	-0.152	0.0218	-9.47	-128	-1.33
72 C1 UKRU	-89.4	-0.153	0.0198	-9.68	-129	-1.34
73 C1 UKRU	-96.5	-0.233	0.0167	-9.24	-139	-1.32

Appendix D

Results from WRATE

Project **UK Rural area**

Normalisation Impact assessment

scenario code	climate change: GWP 100a (Eur.Person.Eq)	acidification potential: average European (Eur.Person.Eq)	eutrophication potential: generic (Eur.Person.Eq)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq)	human toxicity: HTP infinite (Eur.Person.Eq)	resources: depletion of abiotic resources (Eur.Person.Eq)
1 IN UKRU	-390	90.2	121	36.7	-15.5	-3190
2 IN UKRU	-422	185	159	81.3	-52.7	-3358
3 IN UKRU	-455	94.2	125	33.7	-26.4	-3379
4 IN UKRU	-690	-143	74.6	-887	-696	-3902
5 IN UKRU	-721	-48	113	-843	-733	-4070
6 IN UKRU	-754	-139	78	-890	-707	-4091
7 IN UKRU	-818	-214	64.2	-1009	-824	-4165
8 IN UKRU	-849	-121	101	-966	-861	-4329
9 IN UKRU	-881	-210	67.6	-1012	-835	-4350
10 IN UKRU	-720	-190	66.9	-881	-710	-3941
11 IN UKRU	-749	-102	102	-840	-745	-4098
12 IN UKRU	-780	-187	70.1	-884	-720	-4117
13 IN UKRU	-898	-463	21.9	-851	-790	-4186
14 IN UKRU	-915	-411	42.8	-827	-811	-4277
15 IN UKRU	-934	-461	23.8	-853	-796	-4289
16 IN UKRU	-963	-563	5.49	-840	-820	-4275
17 IN UKRU	-976	-524	21	-822	-835	-4343
18 IN UKRU	-990	-561	6.89	-841	-824	-4352
01 AD UKRU	764	107	167	108	28.7	-426
02 AD UKRU	215	-65.4	114	-822	-731	-1362
03 AD UKRU	256	-53.7	117	-811	-729	-1258
04 AD UKRU	168	-72.9	112	-828	-736	-1495
05 AD UKRU	157	-128	82.5	-874	-752	-1419
06 AD UKRU	353	-43.4	140	-143	-216	-1245
07 AD UKRU	374	-37.6	142	-138	-215	-1193
08 AD UKRU	330	-47.2	139	-146	-218	-1311
09 AD UKRU	325	-93.7	118	-176	-229	-1231
10 AD UKRU	68.6	-148	122	-316	-384	-1816
11 AD UKRU	103	-138	124	-308	-382	-1729
12 AD UKRU	29.2	-154	120	-321	-388	-1928
13 AD UKRU	18.9	-196	96.9	-358	-400	-1876
14 AD UKRU	-47.7	-191	114	-387	-453	-2050
15 AD UKRU	-7.29	-179	117	-377	-451	-1948
16 AD UKRU	-93.7	-198	112	-393	-457	-2180
17 AD UKRU	-108	-200	103	-419	-464	-2224
01 C1 UKRU	-350	129	132	38.3	-13.9	-3065
02 C1 UKRU	-328	136	133	44	-12.7	-3008
03 C1 UKRU	-376	125	131	35.1	-16.2	-3137
04 C1 UKRU	-381	70.5	105	0.975	-29.1	-3042
05 C1 UKRU	-650	-105	85.1	-883	-694	-3778
06 C1 UKRU	-628	-98.3	86.8	-877	-693	-3722
07 C1 UKRU	-676	-109	84.1	-886	-697	-3851
08 C1 UKRU	-681	-163	58.9	-920	-709	-3755
09 C1 UKRU	-787	-179	73.6	-1014	-825	-4064

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (Eur.Person.Eq)	acidification potential: average European (Eur.Person.Eq)	eutrophication potential: generic (Eur.Person.Eq)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq)	human toxicity: HTP infinite (Eur.Person.Eq)	resources: depletion of abiotic resources (Eur.Person.Eq)
10 C1 UKRU	-765	-173	75.3	-1009	-823	-4007
11 C1 UKRU	-813	-183	72.6	-1017	-827	-4136
12 C1 UKRU	-818	-238	47.4	-1052	-840	-4041
13 C1 UKRU	-691	-155	75.1	-879	-702	-3876
14 C1 UKRU	-687	-154	75.4	-878	-702	-3866
15 C1 UKRU	-696	-156	74.9	-880	-702	-3889
16 C1 UKRU	-694	-208	54.5	-902	-712	-3776
17 C1 UKRU	-712	-220	75.1	-844	-732	-3808
18 C1 UKRU	-690	-214	76.8	-839	-730	-3752
19 C1 UKRU	-738	-224	74.1	-848	-734	-3881
20 C1 UKRU	-744	-270	52.1	-878	-745	-3805
21 C1 UKRU	-720	-245	75.1	-831	-743	-3783
22 C1 UKRU	-691	-237	77.3	-824	-741	-3709
23 C1 UKRU	-754	-250	73.8	-835	-746	-3878
24 C1 UKRU	-765	-251	67	-854	-751	-3910
25 C1 UKRU	-380	219	168	80.3	-48.9	-3223
26 C1 UKRU	-358	225	169	85.9	-47.7	-3166
27 C1 UKRU	-406	215	167	77.1	-51.2	-3295
28 C1 UKRU	-411	160	141	42.9	-64.1	-3200
29 C1 UKRU	-680	-15	121	-841	-729	-3936
30 C1 UKRU	-658	-8.62	123	-835	-728	-3880
31 C1 UKRU	-706	-19.1	120	-844	-732	-4009
32 C1 UKRU	-711	-73.6	94.7	-878	-744	-3913
33 C1 UKRU	-816	-91.8	109	-973	-859	-4218
34 C1 UKRU	-794	-85.5	110	-968	-858	-4161
35 C1 UKRU	-842	-96	108	-977	-861	-4290
36 C1 UKRU	-847	-150	82.3	-1011	-874	-4195
37 C1 UKRU	-721	-64.3	111	-837	-738	-4036
38 C1 UKRU	-718	-63.2	112	-836	-737	-4026
39 C1 UKRU	-726	-65	111	-837	-738	-4048
40 C1 UKRU	-724	-117	90.8	-859	-747	-3936
41 C1 UKRU	-735	-151	103	-812	-759	-3930
42 C1 UKRU	-713	-145	105	-806	-758	-3874
43 C1 UKRU	-761	-155	102	-815	-761	-4003
44 C1 UKRU	-767	-201	79.8	-846	-772	-3927
45 C1 UKRU	-741	-184	99.5	-802	-767	-3891
46 C1 UKRU	-711	-175	102	-795	-765	-3816
47 C1 UKRU	-774	-189	98.2	-807	-770	-3986
48 C1 UKRU	-785	-190	91.4	-826	-775	-4017
49 C1 UKRU	-411	133	135	35.5	-24.1	-3243
50 C1 UKRU	-389	139	137	41.2	-23	-3186
51 C1 UKRU	-437	129	134	32.3	-26.4	-3315
52 C1 UKRU	-442	74.3	109	-1.87	-39.3	-3220
53 C1 UKRU	-711	-101	88.3	-885	-704	-3956
54 C1 UKRU	-689	-94.5	90.1	-880	-703	-3899
55 C1 UKRU	-737	-105	87.4	-889	-707	-4028
56 C1 UKRU	-742	-160	62.1	-923	-720	-3933

Appendix D
Results from WRATE

scenario code	climate change: GWP 100a (Eur.Person.Eq)	acidification potential: average European (Eur.Person.Eq)	eutrophication potential: generic (Eur.Person.Eq)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq)	human toxicity: HTP infinite (Eur.Person.Eq)	resources: depletion of abiotic resources (Eur.Person.Eq)
57 C1 UKRU	-847	-176	76.8	-1017	-835	-4237
58 C1 UKRU	-824	-169	78.5	-1011	-833	-4181
59 C1 UKRU	-872	-180	75.8	-1020	-837	-4310
60 C1 UKRU	-877	-234	50.5	-1054	-850	-4214
61 C1 UKRU	-753	-151	78.4	-882	-712	-4056
62 C1 UKRU	-749	-150	78.7	-881	-712	-4046
63 C1 UKRU	-757	-152	78.2	-883	-713	-4069
64 C1 UKRU	-756	-204	57.8	-904	-722	-3956
65 C1 UKRU	-759	-217	77.6	-847	-740	-3946
66 C1 UKRU	-737	-211	79.3	-841	-738	-3889
67 C1 UKRU	-785	-221	76.6	-850	-742	-4018
68 C1 UKRU	-791	-267	54.6	-881	-753	-3942
69 C1 UKRU	-762	-242	77.3	-833	-750	-3904
70 C1 UKRU	-732	-234	79.5	-826	-748	-3830
71 C1 UKRU	-796	-248	76	-837	-753	-3999
72 C1 UKRU	-806	-249	69.2	-856	-758	-4031
73 C1 UKRU	-870	-379	58.2	-817	-819	-3975

Appendix D

Results from WRATE

Project **UK Rural area**

Normalisation per person Impact assessment

scenario code	climate change: GWP 100a (Eur.Person.Eq per person)	acidification potential: average European (Eur.Person.Eq per person)	eutrophication potential: generic (Eur.Person.Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq per person)	human toxicity: HTP infinite (Eur.Person.Eq per person)	resources: depletion of abiotic resources (Eur.Person.Eq per person)
1 IN UKRU	-0.00335	0.000773	0.00104	0.000315	-0.000133	-0.0274
2 IN UKRU	-0.00362	0.00159	0.00137	0.000697	-0.000452	-0.0288
3 IN UKRU	-0.0039	0.000808	0.00107	0.000289	-0.000227	-0.029
4 IN UKRU	-0.00591	-0.00123	0.00064	-0.00761	-0.00597	-0.0335
5 IN UKRU	-0.00619	-0.000412	0.000966	-0.00723	-0.00629	-0.0349
6 IN UKRU	-0.00647	-0.00119	0.000669	-0.00763	-0.00606	-0.0351
7 IN UKRU	-0.00702	-0.00184	0.000551	-0.00866	-0.00707	-0.0357
8 IN UKRU	-0.00728	-0.00104	0.000869	-0.00828	-0.00738	-0.0371
9 IN UKRU	-0.00756	-0.0018	0.00058	-0.00868	-0.00716	-0.0373
10 IN UKRU	-0.00617	-0.00163	0.000574	-0.00756	-0.00609	-0.0338
11 IN UKRU	-0.00642	-0.000871	0.000879	-0.0072	-0.00639	-0.0351
12 IN UKRU	-0.00669	-0.0016	0.000602	-0.00758	-0.00618	-0.0353
13 IN UKRU	-0.0077	-0.00397	0.000188	-0.0073	-0.00678	-0.0359
14 IN UKRU	-0.00785	-0.00352	0.000367	-0.00709	-0.00695	-0.0367
15 IN UKRU	-0.00801	-0.00395	0.000204	-0.00731	-0.00683	-0.0368
16 IN UKRU	-0.00826	-0.00483	0.0000471	-0.0072	-0.00703	-0.0367
17 IN UKRU	-0.00837	-0.00449	0.00018	-0.00705	-0.00716	-0.0372
18 IN UKRU	-0.00849	-0.00481	0.0000591	-0.00721	-0.00707	-0.0373
01 AD UKRU	0.00655	0.000918	0.00143	0.00093	0.000246	-0.00365
02 AD UKRU	0.00184	-0.000561	0.000974	-0.00705	-0.00627	-0.0117
03 AD UKRU	0.0022	-0.00046	0.001	-0.00696	-0.00625	-0.0108
04 AD UKRU	0.00144	-0.000626	0.000959	-0.0071	-0.00631	-0.0128
05 AD UKRU	0.00134	-0.00109	0.000708	-0.00749	-0.00645	-0.0122
06 AD UKRU	0.00303	-0.000372	0.0012	-0.00123	-0.00185	-0.0107
07 AD UKRU	0.0032	-0.000323	0.00122	-0.00118	-0.00184	-0.0102
08 AD UKRU	0.00283	-0.000405	0.0012	-0.00125	-0.00187	-0.0112
09 AD UKRU	0.00278	-0.000804	0.00101	-0.00151	-0.00196	-0.0106
10 AD UKRU	0.000588	-0.00127	0.00104	-0.00271	-0.00329	-0.0156
11 AD UKRU	0.000886	-0.00118	0.00106	-0.00264	-0.00328	-0.0148
12 AD UKRU	0.00025	-0.00132	0.00103	-0.00276	-0.00332	-0.0165
13 AD UKRU	0.000162	-0.00168	0.000831	-0.00307	-0.00343	-0.0161
14 AD UKRU	-0.000409	-0.00164	0.000976	-0.00332	-0.00388	-0.0176
15 AD UKRU	-0.0000625	-0.00154	0.001	-0.00323	-0.00387	-0.0167
16 AD UKRU	-0.000804	-0.0017	0.000961	-0.00337	-0.00392	-0.0187
17 AD UKRU	-0.000929	-0.00171	0.000881	-0.00359	-0.00398	-0.0191
01 C1 UKRU	-0.003	0.00111	0.00113	0.000329	-0.000119	-0.0263
02 C1 UKRU	-0.00281	0.00116	0.00114	0.000377	-0.000109	-0.0258
03 C1 UKRU	-0.00322	0.00107	0.00112	0.000301	-0.000139	-0.0269
04 C1 UKRU	-0.00327	0.000605	0.000905	8.36E-06	-0.000249	-0.0261
05 C1 UKRU	-0.00558	-0.000898	0.00073	-0.00757	-0.00595	-0.0324
06 C1 UKRU	-0.00538	-0.000843	0.000745	-0.00752	-0.00594	-0.0319
07 C1 UKRU	-0.0058	-0.000933	0.000722	-0.0076	-0.00597	-0.033
08 C1 UKRU	-0.00584	-0.0014	0.000505	-0.00789	-0.00608	-0.0322
09 C1 UKRU	-0.00675	-0.00154	0.000631	-0.0087	-0.00707	-0.0349

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (Eur.Person.Eq per person)	acidification potential: average European (Eur.Person.Eq per person)	eutrophication potential: generic (Eur.Person.Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq per person)	human toxicity: HTP infinite (Eur.Person.Eq per person)	resources: depletion of abiotic resources (Eur.Person.Eq per person)
10 C1 UKRU	-0.00656	-0.00148	0.000646	-0.00865	-0.00706	-0.0344
11 C1 UKRU	-0.00697	-0.00157	0.000623	-0.00873	-0.00709	-0.0355
12 C1 UKRU	-0.00702	-0.00204	0.000406	-0.00902	-0.0072	-0.0347
13 C1 UKRU	-0.00593	-0.00133	0.000644	-0.00754	-0.00602	-0.0332
14 C1 UKRU	-0.0059	-0.00132	0.000647	-0.00753	-0.00602	-0.0332
15 C1 UKRU	-0.00597	-0.00134	0.000643	-0.00755	-0.00602	-0.0333
16 C1 UKRU	-0.00595	-0.00179	0.000468	-0.00773	-0.0061	-0.0324
17 C1 UKRU	-0.00611	-0.00189	0.000644	-0.00724	-0.00627	-0.0327
18 C1 UKRU	-0.00592	-0.00183	0.000659	-0.00719	-0.00626	-0.0322
19 C1 UKRU	-0.00633	-0.00192	0.000636	-0.00727	-0.00629	-0.0333
20 C1 UKRU	-0.00638	-0.00232	0.000447	-0.00753	-0.00639	-0.0326
21 C1 UKRU	-0.00618	-0.0021	0.000644	-0.00713	-0.00637	-0.0324
22 C1 UKRU	-0.00592	-0.00203	0.000663	-0.00706	-0.00636	-0.0318
23 C1 UKRU	-0.00647	-0.00215	0.000633	-0.00716	-0.0064	-0.0333
24 C1 UKRU	-0.00656	-0.00216	0.000574	-0.00733	-0.00644	-0.0335
25 C1 UKRU	-0.00326	0.00188	0.00144	0.000689	-0.000419	-0.0276
26 C1 UKRU	-0.00307	0.00193	0.00145	0.000737	-0.000409	-0.0272
27 C1 UKRU	-0.00348	0.00184	0.00143	0.000661	-0.000439	-0.0283
28 C1 UKRU	-0.00352	0.00137	0.00121	0.000368	-0.00055	-0.0274
29 C1 UKRU	-0.00583	-0.000128	0.00104	-0.00721	-0.00625	-0.0338
30 C1 UKRU	-0.00564	-0.0000739	0.00105	-0.00716	-0.00624	-0.0333
31 C1 UKRU	-0.00605	-0.000164	0.00103	-0.00724	-0.00627	-0.0344
32 C1 UKRU	-0.0061	-0.000632	0.000812	-0.00753	-0.00638	-0.0336
33 C1 UKRU	-0.007	-0.000788	0.000931	-0.00835	-0.00736	-0.0362
34 C1 UKRU	-0.00681	-0.000733	0.000946	-0.0083	-0.00735	-0.0357
35 C1 UKRU	-0.00722	-0.000823	0.000922	-0.00838	-0.00738	-0.0368
36 C1 UKRU	-0.00726	-0.00129	0.000706	-0.00867	-0.00749	-0.036
37 C1 UKRU	-0.00619	-0.000552	0.000955	-0.00718	-0.00633	-0.0346
38 C1 UKRU	-0.00615	-0.000542	0.000958	-0.00717	-0.00632	-0.0345
39 C1 UKRU	-0.00622	-0.000558	0.000954	-0.00718	-0.00633	-0.0347
40 C1 UKRU	-0.00621	-0.00101	0.000779	-0.00737	-0.00641	-0.0338
41 C1 UKRU	-0.00631	-0.00129	0.000882	-0.00696	-0.00651	-0.0337
42 C1 UKRU	-0.00611	-0.00124	0.000896	-0.00691	-0.0065	-0.0332
43 C1 UKRU	-0.00653	-0.00133	0.000873	-0.00699	-0.00653	-0.0343
44 C1 UKRU	-0.00657	-0.00172	0.000684	-0.00726	-0.00662	-0.0337
45 C1 UKRU	-0.00635	-0.00158	0.000853	-0.00688	-0.00658	-0.0334
46 C1 UKRU	-0.0061	-0.00151	0.000873	-0.00682	-0.00656	-0.0327
47 C1 UKRU	-0.00664	-0.00162	0.000842	-0.00692	-0.0066	-0.0342
48 C1 UKRU	-0.00673	-0.00163	0.000784	-0.00708	-0.00665	-0.0345
49 C1 UKRU	-0.00353	0.00114	0.00116	0.000304	-0.000207	-0.0278
50 C1 UKRU	-0.00333	0.00119	0.00117	0.000353	-0.000197	-0.0273
51 C1 UKRU	-0.00375	0.0011	0.00115	0.000277	-0.000227	-0.0284
52 C1 UKRU	-0.00379	0.000637	0.000932	-0.0000161	-0.000337	-0.0276
53 C1 UKRU	-0.0061	-0.000865	0.000758	-0.00759	-0.00604	-0.0339
54 C1 UKRU	-0.00591	-0.000811	0.000772	-0.00754	-0.00603	-0.0334
55 C1 UKRU	-0.00632	-0.000901	0.000749	-0.00762	-0.00606	-0.0345
56 C1 UKRU	-0.00636	-0.00137	0.000533	-0.00791	-0.00617	-0.0337

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (Eur.Person.Eq per person)	acidification potential: average European (Eur.Person.Eq per person)	eutrophication potential: generic (Eur.Person.Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq per person)	human toxicity: HTP infinite (Eur.Person.Eq per person)	resources: depletion of abiotic resources (Eur.Person.Eq per person)
57 C1 UKRU	-0.00726	-0.00151	0.000658	-0.00872	-0.00716	-0.0363
58 C1 UKRU	-0.00707	-0.00145	0.000673	-0.00867	-0.00715	-0.0359
59 C1 UKRU	-0.00748	-0.00154	0.00065	-0.00875	-0.00718	-0.037
60 C1 UKRU	-0.00752	-0.00201	0.000433	-0.00904	-0.00729	-0.0361
61 C1 UKRU	-0.00646	-0.0013	0.000672	-0.00757	-0.00611	-0.0348
62 C1 UKRU	-0.00642	-0.00129	0.000675	-0.00756	-0.00611	-0.0347
63 C1 UKRU	-0.0065	-0.0013	0.000671	-0.00757	-0.00611	-0.0349
64 C1 UKRU	-0.00648	-0.00175	0.000496	-0.00776	-0.00619	-0.0339
65 C1 UKRU	-0.00651	-0.00186	0.000666	-0.00726	-0.00634	-0.0338
66 C1 UKRU	-0.00632	-0.00181	0.00068	-0.00721	-0.00633	-0.0334
67 C1 UKRU	-0.00673	-0.0019	0.000657	-0.00729	-0.00636	-0.0345
68 C1 UKRU	-0.00678	-0.00229	0.000468	-0.00755	-0.00646	-0.0338
69 C1 UKRU	-0.00653	-0.00208	0.000663	-0.00714	-0.00643	-0.0335
70 C1 UKRU	-0.00628	-0.00201	0.000682	-0.00708	-0.00642	-0.0328
71 C1 UKRU	-0.00682	-0.00213	0.000652	-0.00718	-0.00646	-0.0343
72 C1 UKRU	-0.00691	-0.00213	0.000593	-0.00734	-0.0065	-0.0346
73 C1 UKRU	-0.00746	-0.00325	0.000499	-0.00701	-0.00702	-0.0341

Appendix D

Results from WRATE

Project **Thailand Urban area**

Project Headline Indicators

scenario code	Bio- degradeable Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
01 IN THUR	-	185,373,422	0.266		19,393	96,725	
02 IN THUR	-	607,305,465	0.266		19,393	96,725	
03 IN THUR	-	268,376,447	0.266		19,393	96,725	
04 IN THUR	-	185,373,422	0.22		4,382	96,725	2,389
05 IN THUR	-	607,305,465	0.22		4,382	96,725	2,389
06 IN THUR	-	268,376,447	0.22		4,382	96,725	2,389
07 IN THUR	-	168,637,323	0.278		4,061	89,062	6,321
08 IN THUR	-	597,030,522	0.278		4,061	89,062	6,321
09 IN THUR	-	263,835,811	0.278		4,061	89,062	6,321
10 IN THUR	-	133,508,174	0.267		5,810	83,907	14,115
11 IN THUR	-	437,388,718	0.267		5,810	83,907	14,115
12 IN THUR	-	193,287,953	0.267		5,810	83,907	14,115
13 IN THUR	-	81,307,824	0.315		7,238	71,090	25,841
14 IN THUR	-	267,136,870	0.315		7,238	71,090	25,841
15 IN THUR	-	117,864,357	0.315		7,238	71,090	25,841
01 AD THUR	74,413	46,053,489	0.504		96,725		
02 AD THUR	35,942	46,533,819	0.446	37,010	52,669		6,209
03 AD THUR	35,942	61,582,525	0.446	37,010	52,669		6,209
04 AD THUR	35,942	84,426,393	0.446	37,010	52,669		6,209
05 AD THUR	35,942	162,350,357	0.446	37,010	52,669		6,209
06 AD THUR	55,514	44,140,151	0.465	17,312	73,817		6,922
07 AD THUR	55,514	50,347,695	0.465	17,312	73,817		6,922
08 AD THUR	55,514	59,770,717	0.465	17,312	73,817		6,922
09 AD THUR	55,514	91,914,102	0.465	17,312	73,817		6,922
10 AD THUR	42,215	42,793,729	0.437	29,495	57,697		11,793
11 AD THUR	42,215	53,369,543	0.437	29,495	57,697		11,793
12 AD THUR	42,215	69,423,580	0.437	29,495	57,697		11,793
13 AD THUR	42,215	124,186,385	0.437	29,495	57,697		11,793
14 AD THUR	36,615	42,226,814	0.425	34,624	50,910		13,843
15 AD THUR	36,615	54,641,900	0.425	34,624	50,910		13,843
16 AD THUR	36,615	73,487,944	0.425	34,624	50,910		13,843
17 AD THUR	36,615	137,774,714	0.425	34,624	50,910		13,843
01 C1 THUR	-	176,067,097	0.267	22,442	16,504	74,283	
02 C1 THUR	-	184,113,912	0.267	22,442	16,504	74,283	
03 C1 THUR	-	196,328,941	0.267	22,442	16,504	74,283	
04 C1 THUR	-	237,996,292	0.267	22,442	16,504	74,283	
05 C1 THUR	-	176,067,097	0.227	22,442	3,657	74,283	2,389
06 C1 THUR	-	184,113,912	0.227	22,442	3,657	74,283	2,389
07 C1 THUR	-	196,328,941	0.227	22,442	3,657	74,283	2,389
08 C1 THUR	-	237,996,292	0.227	22,442	3,657	74,283	2,389
09 C1 THUR	-	171,836,826	0.27	22,442	3,358	67,125	6,328
10 C1 THUR	-	179,883,641	0.27	22,442	3,358	67,125	6,328
11 C1 THUR	-	192,098,670	0.27	22,442	3,358	67,125	6,328

Appendix D

Results from WRATE

scenario code	Bio- degradeable Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
12 C1 THUR	-	233,766,021	0.27	22,442	3,358	67,125	6,328
13 C1 THUR	-	169,946,590	0.234	7,694	4,477	85,954	5,203
14 C1 THUR	-	172,705,498	0.234	7,694	4,477	85,954	5,203
15 C1 THUR	-	176,893,507	0.234	7,694	4,477	85,954	5,203
16 C1 THUR	-	191,179,456	0.234	7,694	4,477	85,954	5,203
17 C1 THUR	-	139,921,855	0.26	22,442	4,656	65,311	10,598
18 C1 THUR	-	147,968,670	0.26	22,442	4,656	65,311	10,598
19 C1 THUR	-	160,183,698	0.26	22,442	4,656	65,311	10,598
20 C1 THUR	-	201,851,049	0.26	22,442	4,656	65,311	10,598
21 C1 THUR	-	127,163,427	0.272	28,854	4,734	56,335	12,943
22 C1 THUR	-	137,509,333	0.272	28,854	4,734	56,335	12,943
23 C1 THUR	-	153,214,369	0.272	28,854	4,734	56,335	12,943
24 C1 THUR	-	206,786,678	0.272	28,854	4,734	56,335	12,943
25 C1 THUR	-	550,551,031	0.267	22,442	16,504	74,283	
26 C1 THUR	-	558,597,846	0.267	22,442	16,504	74,283	
27 C1 THUR	-	570,812,874	0.267	22,442	16,504	74,283	
28 C1 THUR	-	612,480,226	0.267	22,442	16,504	74,283	
29 C1 THUR	-	550,551,031	0.227	22,442	3,657	74,283	2,389
30 C1 THUR	-	558,597,846	0.227	22,442	3,657	74,283	2,389
31 C1 THUR	-	570,812,874	0.227	22,442	3,657	74,283	2,389
32 C1 THUR	-	612,480,226	0.227	22,442	3,657	74,283	2,389
33 C1 THUR	-	536,652,474	0.27	22,442	3,358	67,125	6,328
34 C1 THUR	-	544,699,289	0.27	22,442	3,358	67,125	6,328
35 C1 THUR	-	556,914,317	0.27	22,442	3,358	67,125	6,328
36 C1 THUR	-	598,581,668	0.27	22,442	3,358	67,125	6,328
37 C1 THUR	-	547,232,909	0.234	7,694	4,477	85,954	5,203
38 C1 THUR	-	549,991,817	0.234	7,694	4,477	85,954	5,203
39 C1 THUR	-	554,179,827	0.234	7,694	4,477	85,954	5,203
40 C1 THUR	-	568,465,776	0.234	7,694	4,477	85,954	5,203
41 C1 THUR	-	431,795,830	0.26	22,442	4,656	65,311	10,598
42 C1 THUR	-	439,842,645	0.26	22,442	4,656	65,311	10,598
43 C1 THUR	-	452,057,673	0.26	22,442	4,656	65,311	10,598
44 C1 THUR	-	493,725,024	0.26	22,442	4,656	65,311	10,598
45 C1 THUR	-	381,901,600	0.272	28,854	4,734	56,335	12,943
46 C1 THUR	-	392,247,506	0.272	28,854	4,734	56,335	12,943
47 C1 THUR	-	382,896,329	0.272	28,854	4,734	56,335	12,943
48 C1 THUR	-	461,524,851	0.272	28,854	4,734	56,335	12,943
49 C1 THUR	-	249,736,068	0.267	22,442	16,504	74,283	
50 C1 THUR	-	257,782,883	0.267	22,442	16,504	74,283	
51 C1 THUR	-	269,997,911	0.267	22,442	16,504	74,283	
52 C1 THUR	-	311,665,263	0.267	22,442	16,504	74,283	
53 C1 THUR	-	249,736,068	0.227	22,442	3,657	74,283	2,389
54 C1 THUR	-	257,782,883	0.227	22,442	3,657	74,283	2,389
55 C1 THUR	-	269,997,911	0.227	22,442	3,657	74,283	2,389
56 C1 THUR	-	348,499,748	0.227	22,442	3,657	74,283	2,389
57 C1 THUR	-	243,603,838	0.27	22,442	3,358	67,125	6,328

Appendix D

Results from WRATE

scenario code	Bio- degradeable Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
58 C1 THUR	-	251,650,654	0.27	22,442	3,358	67,125	6,328
59 C1 THUR	-	263,865,682	0.27	22,442	3,358	67,125	6,328
60 C1 THUR	-	305,533,033	0.27	22,442	3,358	67,125	6,328
61 C1 THUR	-	244,166,849	0.234	7,694	4,477	85,954	5,203
62 C1 THUR	-	246,925,757	0.234	7,694	4,477	85,954	5,203
63 C1 THUR	-	251,113,767	0.234	7,694	4,477	85,954	5,203
64 C1 THUR	-	265,399,716	0.234	7,694	4,477	85,954	5,203
65 C1 THUR	-	197,339,686	0.26	22,442	4,656	65,311	10,598
66 C1 THUR	-	205,386,501	0.26	22,442	4,656	65,311	10,598
67 C1 THUR	-	217,601,529	0.26	22,442	4,656	65,311	10,598
68 C1 THUR	-	259,268,881	0.26	22,442	4,656	65,311	10,598
69 C1 THUR	-	177,275,855	0.272	28,854	4,734	56,335	12,943
70 C1 THUR	-	187,621,760	0.272	28,854	4,734	56,335	12,943
71 C1 THUR	-	203,326,797	0.272	28,854	4,734	56,335	12,943
72 C1 THUR	-	256,899,105	0.272	28,854	4,734	56,335	12,943

Appendix D
Results from WRATE

Project **Thailand Urban area**

Characterisation Impact assessment

scenario code	climate change: GWP 100a (kg CO2-Eq)	acidification potential: average European (kg SO2-Eq)	eutrophication potential: generic (kg PO4-Eq)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq)	human toxicity: HTP infinite (kg 1,4-DCB-Eq)	resources: depletion of abiotic resources (kg antimony-Eq)
01 IN THUR	- 2,088,257	26,286	9,184	- 335,901	- 2,830,057	- 282,016
02 IN THUR	- 6,395,265	24,043	11,671	47,645	- 3,271,601	- 316,842
03 IN THUR	- 4,466,446	24,482	9,388	- 310,621	- 3,150,626	- 301,450
04 IN THUR	- 20,398,145	- 57,760	1,507	- 7,904,014	- 89,350,085	- 393,478
05 IN THUR	- 24,705,153	- 60,003	3,994	- 7,520,469	- 89,791,629	- 428,303
06 IN THUR	- 22,776,334	- 59,564	1,711	- 7,878,735	- 89,670,653	- 412,912
07 IN THUR	- 23,855,344	- 76,531	430	- 9,198,833	- 106,638,830	- 403,245
08 IN THUR	- 30,833,128	- 81,127	2,469	- 8,894,781	- 107,484,785	- 460,014
09 IN THUR	- 28,936,942	- 80,696	225	- 9,246,986	- 107,365,857	- 444,883
10 IN THUR	- 31,945,791	- 91,731	- 2	- 8,372,745	- 97,111,965	- 444,000
11 IN THUR	- 35,047,750	- 93,346	1,789	- 8,096,511	- 97,429,970	- 469,082
12 IN THUR	- 33,658,591	- 93,030	145	- 8,354,539	- 97,342,843	- 457,997
13 IN THUR	- 43,378,555	- 125,462	- 1,487	- 8,835,420	- 104,852,221	- 493,092
14 IN THUR	- 45,275,466	- 126,450	- 392	- 8,666,497	- 105,046,687	- 508,430
15 IN THUR	- 44,425,967	- 126,256	- 1,397	- 8,824,287	- 104,993,407	- 501,651
01 AD THUR	22169068	12823	17354	69163	-25415	-55584
02 AD THUR	-10818883	-54711	7281	-8295875	-99169181	-184936
03 AD THUR	-8912297	-53116	7688	-8208717	-98848164	-169991
04 AD THUR	-13474774	-57093	7015	-8330119	-99533094	-207461
05 AD THUR	-14745791	-60774	5372	-8464812	-100117651	-216212
06 AD THUR	7191293	-12540	13961	-2107280	-25995611	-147304
07 AD THUR	7977754	-11882	14129	-2071328	-25863192	-141138
08 AD THUR	6095747	-13522	13852	-2121406	-26145724	-156595
09 AD THUR	5551947	-15982	12985	-2181750	-26419135	-159554
10 AD THUR	-3392465	-30536	11554	-3639574	-44276732	-212464
11 AD THUR	-2052569	-29416	11841	-3578322	-44051130	-201961
12 AD THUR	-5258952	-32210	11367	-3663640	-44532479	-228294
13 AD THUR	-6191668	-35442	10060	-3760150	-44956540	-234417
14 AD THUR	-7844243	-38097	10543	-4284678	-51973573	-239830
15 AD THUR	-6271321	-36782	10879	-4212774	-51708736	-227500
16 AD THUR	-10035336	-40062	10323	-4312929	-52273798	-258413
17 AD THUR	-11131806	-43618	8831	-4424667	-52761294	-265869
01 C1 THUR	587380	39642	11039	-304031	-2533024	-257327
02 C1 THUR	1606866	40495	11257	-257427	-2361370	-249335
03 C1 THUR	-832773	38368	10896	-322342	-2727614	-269371
04 C1 THUR	-1539434	35446	9820	-398816	-3070431	-273508
05 C1 THUR	-17767047	-44528	3343	-7854126	-89023740	-369079
06 C1 THUR	-16747561	-43676	3561	-7807521	-88852086	-361088
07 C1 THUR	-19187200	-45802	3201	-7872437	-89218330	-381124
08 C1 THUR	-19893860	-48724	2125	-7948910	-89561147	-385260
09 C1 THUR	-24196554	-66559	1722	-9273860	-106896329	-403216
10 C1 THUR	-23177068	-65706	1940	-9227255	-106724675	-395224
11 C1 THUR	-25616707	-67832	1580	-9292171	-107090920	-415260

Appendix D
Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq)	acidification potential: average European (kg SO2-Eq)	eutrophication potential: generic (kg PO4-Eq)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq)	human toxicity: HTP infinite (kg 1,4-DCB-Eq)	resources: depletion of abiotic resources (kg antimony-Eq)
12 C1 THUR	-26323368	-70755	504	-9368644	-107433736	-419397
13 C1 THUR	-22073162	-61142	1812	-7994327	-91070809	-395478
14 C1 THUR	-21723624	-60850	1886	-7978348	-91011956	-392738
15 C1 THUR	-22560071	-61579	1763	-8000605	-91137526	-399608
16 C1 THUR	-22796832	-63431	1243	-8032398	-91292002	-400068
17 C1 THUR	-25954344	-68392	2272	-8185213	-94472996	-405303
18 C1 THUR	-24934858	-67540	2490	-8138609	-94301342	-397311
19 C1 THUR	-27374497	-69666	2130	-8203524	-94667586	-417347
20 C1 THUR	-28082052	-72451	1078	-8279096	-95004425	-421639
21 C1 THUR	-27700623	-71594	2464	-8269765	-95961002	-410057
22 C1 THUR	-26389855	-70498	2744	-8209845	-95740305	-399782
23 C1 THUR	-29526534	-73232	2281	-8293308	-96211190	-425543
24 C1 THUR	-30438782	-76423	997	-8387914	-96627317	-431500
25 C1 THUR	-3594454	37338	13193	26826	-2978833	-291186
26 C1 THUR	-2574968	38191	13411	73431	-2807179	-283194
27 C1 THUR	-5014607	36064	13050	8515	-3173423	-303230
28 C1 THUR	-5721268	33142	11974	-67959	-3516240	-307367
29 C1 THUR	-21948881	-46832	5497	-7523268	-89469549	-402938
30 C1 THUR	-20929394	-45980	5715	-7476664	-89297896	-394947
31 C1 THUR	-23369033	-48106	5355	-7541579	-89664140	-414983
32 C1 THUR	-24075694	-51028	4279	-7618053	-90006956	-419119
33 C1 THUR	-28270423	-68803	3821	-8951544	-107330629	-436201
34 C1 THUR	-27250937	-67951	4039	-8904940	-107158975	-428209
35 C1 THUR	-29690576	-70077	3679	-8969855	-107525219	-448245
36 C1 THUR	-30397237	-72999	2602	-9046329	-107868036	-452382
37 C1 THUR	-26286290	-63464	3982	-7660994	-91519955	-429591
38 C1 THUR	-25936752	-63171	4056	-7645015	-91461102	-426850
39 C1 THUR	-26773199	-63900	3933	-7667272	-91586671	-433720
40 C1 THUR	-27009960	-65752	3413	-7699065	-91741147	-434180
41 C1 THUR	-29213679	-70188	3951	-7927342	-94820461	-431693
42 C1 THUR	-28194193	-69335	4169	-7880737	-94648807	-423701
43 C1 THUR	-30633832	-71462	3809	-7945653	-95015052	-443737
44 C1 THUR	-31341387	-74246	2757	-8021225	-95351890	-448028
45 C1 THUR	-30545265	-73162	3929	-8044703	-96264259	-433090
46 C1 THUR	-29234497	-72066	4209	-7984783	-96043561	-422815
47 C1 THUR	-30569025	-73290	3887	-8040343	-96252156	-433797
48 C1 THUR	-33283424	-77990	2462	-8162852	-96930573	-454532
49 C1 THUR	-1572912	37998	11212	-282913	-2824980	-274983
50 C1 THUR	-553426	38850	11430	-236308	-2653326	-266991
51 C1 THUR	-2993065	36724	11070	-301224	-3019571	-287027
52 C1 THUR	-3699726	33802	9994	-377698	-3362387	-291163
53 C1 THUR	-19927338	-46173	3517	-7833007	-89315696	-386735
54 C1 THUR	-18907852	-45320	3735	-7786403	-89144043	-378743
55 C1 THUR	-21347491	-47447	3375	-7851318	-89510287	-398779
56 C1 THUR	-23134298	-51191	2385	-7917233	-89999081	-411743
57 C1 THUR	-26301072	-68161	1892	-9253287	-107180748	-420416

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq)	acidification potential: average European (kg SO2-Eq)	eutrophication potential: generic (kg PO4-Eq)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq)	human toxicity: HTP infinite (kg 1,4-DCB-Eq)	resources: depletion of abiotic resources (kg antimony-Eq)
58 C1 THUR	-25281586	-67308	2110	-9206682	-107009094	-412424
59 C1 THUR	-27721225	-69434	1749	-9271598	-107375338	-432460
60 C1 THUR	-28427886	-72357	673	-9348071	-107718155	-436596
61 C1 THUR	-24249620	-62799	1987	-7973051	-91364950	-413266
62 C1 THUR	-23900082	-62507	2061	-7957072	-91306098	-410526
63 C1 THUR	-24736529	-63236	1938	-7979329	-91431667	-417395
64 C1 THUR	-24973290	-65087	1418	-8011122	-91586143	-417856
65 C1 THUR	-27638083	-69674	2408	-8168754	-94700548	-419064
66 C1 THUR	-26618597	-68821	2625	-8122149	-94528894	-411072
67 C1 THUR	-29058236	-70948	2265	-8187065	-94895138	-431108
68 C1 THUR	-29765790	-73732	1213	-8262636	-95231977	-435399
69 C1 THUR	-29170135	-72713	2582	-8255399	-96159602	-422067
70 C1 THUR	-27859368	-71617	2862	-8195479	-95938905	-411792
71 C1 THUR	-30996046	-74351	2399	-8278942	-96409790	-437553
72 C1 THUR	-31908294	-77541	1115	-8373548	-96825917	-443510

Appendix D

Results from WRATE

Project **Thailand Urban area**

Characterisation per person Impact assessment

scenario code	climate change: GWP 100a (kg CO2-Eq per person)	acidification potential: average European (kg SO2-Eq per person)	eutrophication potential: generic (kg PO4-Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq per person)	human toxicity: HTP infinite (kg 1,4-DCB-Eq per person)	resources: depletion of abiotic resources (kg antimony-Eq per person)
01 IN THUR	-12	0.151	0.0527	-1.93	-16.2	-1.62
02 IN THUR	-36.7	0.138	0.067	0.273	-18.8	-1.82
03 IN THUR	-25.6	0.141	0.0539	-1.78	-18.1	-1.73
04 IN THUR	-117	-0.332	0.00865	-45.4	-513	-2.26
05 IN THUR	-142	-0.344	0.0229	-43.2	-515	-2.46
06 IN THUR	-131	-0.342	0.00982	-45.2	-515	-2.37
07 IN THUR	-137	-0.439	0.00247	-52.8	-612	-2.31
08 IN THUR	-177	-0.466	0.0142	-51.1	-617	-2.64
09 IN THUR	-166	-0.463	0.00129	-53.1	-616	-2.55
10 IN THUR	-183	-0.526	-0.0000112	-48.1	-557	-2.55
11 IN THUR	-201	-0.536	0.0103	-46.5	-559	-2.69
12 IN THUR	-193	-0.534	0.000832	-47.9	-559	-2.63
13 IN THUR	-249	-0.72	-0.00853	-50.7	-602	-2.83
14 IN THUR	-260	-0.726	-0.00225	-49.7	-603	-2.92
15 IN THUR	-255	-0.725	-0.00802	-50.6	-603	-2.88
01 AD THUR	127	0.0736	0.0996	0.397	-0.146	-0.319
02 AD THUR	-62.1	-0.314	0.0418	-47.6	-569	-1.06
03 AD THUR	-51.2	-0.305	0.0441	-47.1	-567	-0.976
04 AD THUR	-77.3	-0.328	0.0403	-47.8	-571	-1.19
05 AD THUR	-84.6	-0.349	0.0308	-48.6	-575	-1.24
06 AD THUR	41.3	-0.072	0.0801	-12.1	-149	-0.845
07 AD THUR	45.8	-0.0682	0.0811	-11.9	-148	-0.81
08 AD THUR	35	-0.0776	0.0795	-12.2	-150	-0.899
09 AD THUR	31.9	-0.0917	0.0745	-12.5	-152	-0.916
10 AD THUR	-19.5	-0.175	0.0663	-20.9	-254	-1.22
11 AD THUR	-11.8	-0.169	0.068	-20.5	-253	-1.16
12 AD THUR	-30.2	-0.185	0.0652	-21	-256	-1.31
13 AD THUR	-35.5	-0.203	0.0577	-21.6	-258	-1.35
14 AD THUR	-45	-0.219	0.0605	-24.6	-298	-1.38
15 AD THUR	-36	-0.211	0.0624	-24.2	-297	-1.31
16 AD THUR	-57.6	-0.23	0.0593	-24.8	-300	-1.48
17 AD THUR	-63.9	-0.25	0.0507	-25.4	-303	-1.53
01 C1 THUR	3.37	0.228	0.0634	-1.74	-14.5	-1.48
02 C1 THUR	9.22	0.232	0.0646	-1.48	-13.6	-1.43
03 C1 THUR	-4.78	0.22	0.0625	-1.85	-15.7	-1.55
04 C1 THUR	-8.84	0.203	0.0564	-2.29	-17.6	-1.57
05 C1 THUR	-102	-0.256	0.0192	-45.1	-511	-2.12
06 C1 THUR	-96.1	-0.251	0.0204	-44.8	-510	-2.07
07 C1 THUR	-110	-0.263	0.0184	-45.2	-512	-2.19
08 C1 THUR	-114	-0.28	0.0122	-45.6	-514	-2.21
09 C1 THUR	-139	-0.382	0.00989	-53.2	-614	-2.31
10 C1 THUR	-133	-0.377	0.0111	-53	-613	-2.27
11 C1 THUR	-147	-0.389	0.00907	-53.3	-615	-2.38

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq per person)	acidification potential: average European (kg SO2-Eq per person)	eutrophication potential: generic (kg PO4-Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq per person)	human toxicity: HTP infinite (kg 1,4-DCB-Eq per person)	resources: depletion of abiotic resources (kg antimony-Eq per person)
12 C1 THUR	-151	-0.406	0.00289	-53.8	-617	-2.41
13 C1 THUR	-127	-0.351	0.0104	-45.9	-523	-2.27
14 C1 THUR	-125	-0.349	0.0108	-45.8	-522	-2.25
15 C1 THUR	-129	-0.353	0.0101	-45.9	-523	-2.29
16 C1 THUR	-131	-0.364	0.00714	-46.1	-524	-2.3
17 C1 THUR	-149	-0.393	0.013	-47	-542	-2.33
18 C1 THUR	-143	-0.388	0.0143	-46.7	-541	-2.28
19 C1 THUR	-157	-0.4	0.0122	-47.1	-543	-2.4
20 C1 THUR	-161	-0.416	0.00619	-47.5	-545	-2.42
21 C1 THUR	-159	-0.411	0.0141	-47.5	-551	-2.35
22 C1 THUR	-151	-0.405	0.0157	-47.1	-549	-2.29
23 C1 THUR	-169	-0.42	0.0131	-47.6	-552	-2.44
24 C1 THUR	-175	-0.439	0.00572	-48.1	-555	-2.48
25 C1 THUR	-20.6	0.214	0.0757	0.154	-17.1	-1.67
26 C1 THUR	-14.8	0.219	0.077	0.421	-16.1	-1.63
27 C1 THUR	-28.8	0.207	0.0749	0.0489	-18.2	-1.74
28 C1 THUR	-32.8	0.19	0.0687	-0.39	-20.2	-1.76
29 C1 THUR	-126	-0.269	0.0316	-43.2	-513	-2.31
30 C1 THUR	-120	-0.264	0.0328	-42.9	-513	-2.27
31 C1 THUR	-134	-0.276	0.0307	-43.3	-515	-2.38
32 C1 THUR	-138	-0.293	0.0246	-43.7	-517	-2.41
33 C1 THUR	-162	-0.395	0.0219	-51.4	-616	-2.5
34 C1 THUR	-156	-0.39	0.0232	-51.1	-615	-2.46
35 C1 THUR	-170	-0.402	0.0211	-51.5	-617	-2.57
36 C1 THUR	-174	-0.419	0.0149	-51.9	-619	-2.6
37 C1 THUR	-151	-0.364	0.0229	-44	-525	-2.47
38 C1 THUR	-149	-0.363	0.0233	-43.9	-525	-2.45
39 C1 THUR	-154	-0.367	0.0226	-44	-526	-2.49
40 C1 THUR	-155	-0.377	0.0196	-44.2	-527	-2.49
41 C1 THUR	-168	-0.403	0.0227	-45.5	-544	-2.48
42 C1 THUR	-162	-0.398	0.0239	-45.2	-543	-2.43
43 C1 THUR	-176	-0.41	0.0219	-45.6	-545	-2.55
44 C1 THUR	-180	-0.426	0.0158	-46	-547	-2.57
45 C1 THUR	-175	-0.42	0.0226	-46.2	-552	-2.49
46 C1 THUR	-168	-0.414	0.0242	-45.8	-551	-2.43
47 C1 THUR	-175	-0.421	0.0223	-46.1	-552	-2.49
48 C1 THUR	-191	-0.448	0.0141	-46.8	-556	-2.61
49 C1 THUR	-9.03	0.218	0.0644	-1.62	-16.2	-1.58
50 C1 THUR	-3.18	0.223	0.0656	-1.36	-15.2	-1.53
51 C1 THUR	-17.2	0.211	0.0635	-1.73	-17.3	-1.65
52 C1 THUR	-21.2	0.194	0.0574	-2.17	-19.3	-1.67
53 C1 THUR	-114	-0.265	0.0202	-45	-513	-2.22
54 C1 THUR	-109	-0.26	0.0214	-44.7	-512	-2.17
55 C1 THUR	-123	-0.272	0.0194	-45.1	-514	-2.29
56 C1 THUR	-133	-0.294	0.0137	-45.4	-517	-2.36
57 C1 THUR	-151	-0.391	0.0109	-53.1	-615	-2.41

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (kg CO2-Eq per person)	acidification potential: average European (kg SO2-Eq per person)	eutrophication potential: generic (kg PO4-Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq per person)	human toxicity: HTP infinite (kg 1,4-DCB-Eq per person)	resources: depletion of abiotic resources (kg antimony-Eq per person)
58 C1 THUR	-145	-0.386	0.0121	-52.8	-614	-2.37
59 C1 THUR	-159	-0.399	0.01	-53.2	-616	-2.48
60 C1 THUR	-163	-0.415	0.00386	-53.7	-618	-2.51
61 C1 THUR	-139	-0.36	0.0114	-45.8	-524	-2.37
62 C1 THUR	-137	-0.359	0.0118	-45.7	-524	-2.36
63 C1 THUR	-142	-0.363	0.0111	-45.8	-525	-2.4
64 C1 THUR	-143	-0.374	0.00814	-46	-526	-2.4
65 C1 THUR	-159	-0.4	0.0138	-46.9	-544	-2.41
66 C1 THUR	-153	-0.395	0.0151	-46.6	-543	-2.36
67 C1 THUR	-167	-0.407	0.013	-47	-545	-2.47
68 C1 THUR	-171	-0.423	0.00696	-47.4	-547	-2.5
69 C1 THUR	-167	-0.417	0.0148	-47.4	-552	-2.42
70 C1 THUR	-160	-0.411	0.0164	-47	-551	-2.36
71 C1 THUR	-178	-0.427	0.0138	-47.5	-553	-2.51
72 C1 THUR	-183	-0.445	0.0064	-48.1	-556	-2.55

Appendix D

Results from WRATE

Project **Thailand Urban area**

Normalisation Impact assessment

scenario code	climate change: GWP 100a (Eur.Person.Eq)	acidification potential: average European (Eur.Person.Eq)	eutrophication potential: generic (Eur.Person.Eq)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq)	human toxicity: HTP infinite (Eur.Person.Eq)	resources: depletion of abiotic resources (Eur.Person.Eq)
01 IN THUR	-162	367	275	-255	-143	-7298
02 IN THUR	-495	336	349	36.1	-166	-8199
03 IN THUR	-346	342	281	-236	-159	-7801
04 IN THUR	-1578	-807	45.1	-5995	-4521	-10183
05 IN THUR	-1912	-839	120	-5704	-4543	-11084
06 IN THUR	-1762	-833	51.2	-5975	-4537	-10685
07 IN THUR	-1846	-1070	12.9	-6977	-5395	-10435
08 IN THUR	-2386	-1134	73.9	-6746	-5438	-11904
09 IN THUR	-2239	-1128	6.74	-7013	-5432	-11513
10 IN THUR	-2472	-1282	-0.0583	-6350	-4913	-11490
11 IN THUR	-2712	-1305	53.5	-6141	-4929	-12139
12 IN THUR	-2604	-1300	4.34	-6336	-4925	-11852
13 IN THUR	-3356	-1754	-44.5	-6701	-5305	-12760
14 IN THUR	-3503	-1768	-11.7	-6573	-5315	-13157
15 IN THUR	-3437	-1765	-41.8	-6692	-5312	-12982
01 AD THUR	1715	179	519	52.5	-1.29	-1438
02 AD THUR	-837	-765	218	-6292	-5017	-4786
03 AD THUR	-690	-742	230	-6226	-5001	-4399
04 AD THUR	-1043	-798	210	-6318	-5036	-5369
05 AD THUR	-1141	-850	161	-6420	-5065	-5595
06 AD THUR	556	-175	418	-1598	-1315	-3812
07 AD THUR	617	-166	423	-1571	-1309	-3652
08 AD THUR	472	-189	414	-1609	-1323	-4052
09 AD THUR	430	-223	389	-1655	-1337	-4129
10 AD THUR	-262	-427	346	-2760	-2240	-5498
11 AD THUR	-159	-411	354	-2714	-2229	-5226
12 AD THUR	-407	-450	340	-2779	-2253	-5908
13 AD THUR	-479	-495	301	-2852	-2275	-6066
14 AD THUR	-607	-533	315	-3250	-2630	-6206
15 AD THUR	-485	-514	326	-3195	-2616	-5887
16 AD THUR	-776	-560	309	-3271	-2645	-6687
17 AD THUR	-861	-610	264	-3356	-2669	-6880
01 C1 THUR	45.4	554	330	-231	-128	-6659
02 C1 THUR	124	566	337	-195	-119	-6452
03 C1 THUR	-64.4	536	326	-244	-138	-6971
04 C1 THUR	-119	495	294	-302	-155	-7078
05 C1 THUR	-1375	-622	100	-5957	-4504	-9551
06 C1 THUR	-1296	-611	107	-5921	-4495	-9344
07 C1 THUR	-1485	-640	95.8	-5971	-4514	-9863
08 C1 THUR	-1539	-681	63.6	-6029	-4531	-9970
09 C1 THUR	-1872	-930	51.5	-7033	-5408	-10435
10 C1 THUR	-1793	-918	58.1	-6998	-5400	-10228
11 C1 THUR	-1982	-948	47.3	-7047	-5418	-10746

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (Eur.Person.Eq)	acidification potential: average European (Eur.Person.Eq)	eutrophication potential: generic (Eur.Person.Eq)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq)	human toxicity: HTP infinite (Eur.Person.Eq)	resources: depletion of abiotic resources (Eur.Person.Eq)
12 C1 THUR	-2037	-989	15.1	-7105	-5436	-10853
13 C1 THUR	-1708	-855	54.2	-6063	-4608	-10234
14 C1 THUR	-1681	-851	56.4	-6051	-4605	-10163
15 C1 THUR	-1746	-861	52.7	-6068	-4611	-10341
16 C1 THUR	-1764	-887	37.2	-6092	-4619	-10353
17 C1 THUR	-2008	-956	68	-6208	-4780	-10489
18 C1 THUR	-1929	-944	74.5	-6172	-4771	-10282
19 C1 THUR	-2118	-974	63.7	-6222	-4790	-10800
20 C1 THUR	-2173	-1013	32.2	-6279	-4807	-10911
21 C1 THUR	-2143	-1001	73.7	-6272	-4855	-10612
22 C1 THUR	-2042	-985	82.1	-6226	-4844	-10346
23 C1 THUR	-2285	-1024	68.3	-6290	-4868	-11012
24 C1 THUR	-2355	-1068	29.8	-6362	-4889	-11167
25 C1 THUR	-278	522	395	20.3	-151	-7535
26 C1 THUR	-199	534	401	55.7	-142	-7329
27 C1 THUR	-388	504	390	6.46	-161	-7847
28 C1 THUR	-443	463	358	-51.5	-178	-7954
29 C1 THUR	-1698	-655	164	-5706	-4527	-10427
30 C1 THUR	-1619	-643	171	-5670	-4518	-10221
31 C1 THUR	-1808	-672	160	-5720	-4537	-10739
32 C1 THUR	-1863	-713	128	-5778	-4554	-10846
33 C1 THUR	-2187	-962	114	-6789	-5430	-11288
34 C1 THUR	-2109	-950	121	-6754	-5422	-11081
35 C1 THUR	-2297	-980	110	-6803	-5440	-11600
36 C1 THUR	-2352	-1020	77.9	-6861	-5458	-11707
37 C1 THUR	-2034	-887	119	-5810	-4630	-11117
38 C1 THUR	-2007	-883	121	-5798	-4627	-11046
39 C1 THUR	-2072	-893	118	-5815	-4634	-11224
40 C1 THUR	-2090	-919	102	-5839	-4642	-11236
41 C1 THUR	-2260	-981	118	-6012	-4797	-11172
42 C1 THUR	-2181	-969	125	-5977	-4789	-10965
43 C1 THUR	-2370	-999	114	-6026	-4807	-11483
44 C1 THUR	-2425	-1038	82.5	-6083	-4824	-11594
45 C1 THUR	-2363	-1023	118	-6101	-4870	-11208
46 C1 THUR	-2262	-1007	126	-6056	-4859	-10942
47 C1 THUR	-2365	-1024	116	-6098	-4870	-11226
48 C1 THUR	-2575	-1090	73.7	-6191	-4904	-11763
49 C1 THUR	-122	531	335	-215	-143	-7116
50 C1 THUR	-42.8	543	342	-179	-134	-6909
51 C1 THUR	-232	513	331	-228	-153	-7428
52 C1 THUR	-286	472	299	-286	-170	-7535
53 C1 THUR	-1542	-645	105	-5941	-4519	-10008
54 C1 THUR	-1463	-633	112	-5905	-4510	-9801
55 C1 THUR	-1652	-663	101	-5955	-4529	-10320
56 C1 THUR	-1790	-716	71.4	-6005	-4553	-10655
57 C1 THUR	-2035	-953	56.6	-7018	-5423	-10880

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (Eur.Person.Eq)	acidification potential: average European (Eur.Person.Eq)	eutrophication potential: generic (Eur.Person.Eq)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq)	human toxicity: HTP infinite (Eur.Person.Eq)	resources: depletion of abiotic resources (Eur.Person.Eq)
58 C1 THUR	-1956	-941	63.1	-6982	-5414	-10673
59 C1 THUR	-2145	-971	52.3	-7032	-5433	-11191
60 C1 THUR	-2200	-1011	20.1	-7090	-5450	-11298
61 C1 THUR	-1876	-878	59.4	-6047	-4623	-10695
62 C1 THUR	-1849	-874	61.7	-6035	-4620	-10624
63 C1 THUR	-1914	-884	58	-6052	-4626	-10802
64 C1 THUR	-1932	-910	42.4	-6076	-4634	-10813
65 C1 THUR	-2138	-974	72	-6195	-4791	-10845
66 C1 THUR	-2060	-962	78.6	-6160	-4783	-10638
67 C1 THUR	-2248	-992	67.8	-6209	-4801	-11156
68 C1 THUR	-2303	-1031	36.3	-6267	-4818	-11267
69 C1 THUR	-2257	-1016	77.3	-6261	-4865	-10922
70 C1 THUR	-2156	-1001	85.6	-6216	-4854	-10657
71 C1 THUR	-2398	-1039	71.8	-6279	-4878	-11323
72 C1 THUR	-2469	-1084	33.4	-6351	-4899	-11477

Appendix D

Results from WRATE

Project **Thailand Urban area**

Normalisation per person Impact assessment

scenario code	climate change: GWP 100a (Eur.Person.Eq per person)	acidification potential: average European (Eur.Person.Eq per person)	eutrophication potential: generic (Eur.Person.Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq per person)	human toxicity: HTP infinite (Eur.Person.Eq per person)	resources: depletion of abiotic resources (Eur.Person.Eq per person)
01 IN THUR	-0.000927	0.00211	0.00158	-0.00146	-0.000822	-0.0419
02 IN THUR	-0.00284	0.00193	0.002	0.000207	-0.00095	-0.0471
03 IN THUR	-0.00198	0.00196	0.00161	-0.00135	-0.000915	-0.0448
04 IN THUR	-0.00906	-0.00463	0.000259	-0.0344	-0.0259	-0.0584
05 IN THUR	-0.011	-0.00481	0.000686	-0.0327	-0.0261	-0.0636
06 IN THUR	-0.0101	-0.00478	0.000294	-0.0343	-0.026	-0.0613
07 IN THUR	-0.0106	-0.00614	7.38E-05	-0.04	-0.031	-0.0599
08 IN THUR	-0.0137	-0.00651	0.000424	-0.0387	-0.0312	-0.0683
09 IN THUR	-0.0129	-0.00647	3.87E-05	-0.0403	-0.0312	-0.0661
10 IN THUR	-0.0142	-0.00736	-3.34E-07	-0.0364	-0.0282	-0.0659
11 IN THUR	-0.0156	-0.00749	0.000307	-0.0352	-0.0283	-0.0697
12 IN THUR	-0.0149	-0.00746	2.49E-05	-0.0364	-0.0283	-0.068
13 IN THUR	-0.0193	-0.0101	-0.000255	-0.0385	-0.0304	-0.0732
14 IN THUR	-0.0201	-0.0101	-6.73E-05	-0.0377	-0.0305	-0.0755
15 IN THUR	-0.0197	-0.0101	-0.00024	-0.0384	-0.0305	-0.0745
01 AD THUR	0.00984	0.00103	0.00298	0.000301	-7.38E-06	-0.00826
02 AD THUR	-0.0048	-0.00439	0.00125	-0.0361	-0.0288	-0.0275
03 AD THUR	-0.00396	-0.00426	0.00132	-0.0357	-0.0287	-0.0252
04 AD THUR	-0.00598	-0.00458	0.0012	-0.0363	-0.0289	-0.0308
05 AD THUR	-0.00655	-0.00488	0.000923	-0.0368	-0.0291	-0.0321
06 AD THUR	0.00319	-0.00101	0.0024	-0.00917	-0.00755	-0.0219
07 AD THUR	0.00354	-0.000953	0.00243	-0.00902	-0.00751	-0.021
08 AD THUR	0.00271	-0.00108	0.00238	-0.00923	-0.00759	-0.0233
09 AD THUR	0.00247	-0.00128	0.00223	-0.0095	-0.00767	-0.0237
10 AD THUR	-0.00151	-0.00245	0.00198	-0.0158	-0.0129	-0.0316
11 AD THUR	-0.000911	-0.00236	0.00203	-0.0156	-0.0128	-0.03
12 AD THUR	-0.00234	-0.00258	0.00195	-0.0159	-0.0129	-0.0339
13 AD THUR	-0.00275	-0.00284	0.00173	-0.0164	-0.0131	-0.0348
14 AD THUR	-0.00348	-0.00306	0.00181	-0.0187	-0.0151	-0.0356
15 AD THUR	-0.00278	-0.00295	0.00187	-0.0183	-0.015	-0.0338
16 AD THUR	-0.00446	-0.00321	0.00177	-0.0188	-0.0152	-0.0384
17 AD THUR	-0.00494	-0.0035	0.00152	-0.0193	-0.0153	-0.0395
01 C1 THUR	0.000261	0.00318	0.0019	-0.00132	-0.000736	-0.0382
02 C1 THUR	0.000714	0.00325	0.00193	-0.00112	-0.000686	-0.037
03 C1 THUR	-0.00037	0.00308	0.00187	-0.0014	-0.000792	-0.04
04 C1 THUR	-0.000684	0.00284	0.00169	-0.00174	-0.000892	-0.0406
05 C1 THUR	-0.00789	-0.00357	0.000574	-0.0342	-0.0259	-0.0548
06 C1 THUR	-0.00744	-0.0035	0.000612	-0.034	-0.0258	-0.0536
07 C1 THUR	-0.00852	-0.00367	0.00055	-0.0343	-0.0259	-0.0566
08 C1 THUR	-0.00883	-0.00391	0.000365	-0.0346	-0.026	-0.0572
09 C1 THUR	-0.0107	-0.00534	0.000296	-0.0404	-0.031	-0.0599
10 C1 THUR	-0.0103	-0.00527	0.000333	-0.0402	-0.031	-0.0587
11 C1 THUR	-0.0114	-0.00544	0.000271	-0.0404	-0.0311	-0.0617

Appendix D

Results from WRATE

scenario code	climate change: GWP 100a (Eur.Person.Eq per person)	acidification potential: average European (Eur.Person.Eq per person)	eutrophication potential: generic (Eur.Person.Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq per person)	human toxicity: HTP infinite (Eur.Person.Eq per person)	resources: depletion of abiotic resources (Eur.Person.Eq per person)
12 C1 THUR	-0.0117	-0.00568	8.65E-05	-0.0408	-0.0312	-0.0623
13 C1 THUR	-0.0098	-0.00491	0.000311	-0.0348	-0.0264	-0.0587
14 C1 THUR	-0.00965	-0.00488	0.000324	-0.0347	-0.0264	-0.0583
15 C1 THUR	-0.01	-0.00494	0.000303	-0.0348	-0.0265	-0.0594
16 C1 THUR	-0.0101	-0.00509	0.000213	-0.035	-0.0265	-0.0594
17 C1 THUR	-0.0115	-0.00549	0.00039	-0.0356	-0.0274	-0.0602
18 C1 THUR	-0.0111	-0.00542	0.000428	-0.0354	-0.0274	-0.059
19 C1 THUR	-0.0122	-0.00559	0.000366	-0.0357	-0.0275	-0.062
20 C1 THUR	-0.0125	-0.00581	0.000185	-0.036	-0.0276	-0.0626
21 C1 THUR	-0.0123	-0.00574	0.000423	-0.036	-0.0279	-0.0609
22 C1 THUR	-0.0117	-0.00566	0.000471	-0.0357	-0.0278	-0.0594
23 C1 THUR	-0.0131	-0.00588	0.000392	-0.0361	-0.0279	-0.0632
24 C1 THUR	-0.0135	-0.00613	0.000171	-0.0365	-0.0281	-0.0641
25 C1 THUR	-0.0016	0.003	0.00227	0.000117	-0.000865	-0.0432
26 C1 THUR	-0.00114	0.00306	0.0023	0.00032	-0.000815	-0.0421
27 C1 THUR	-0.00223	0.00289	0.00224	3.71E-05	-0.000922	-0.045
28 C1 THUR	-0.00254	0.00266	0.00206	-0.000296	-0.00102	-0.0457
29 C1 THUR	-0.00975	-0.00376	0.000944	-0.0327	-0.026	-0.0598
30 C1 THUR	-0.00929	-0.00369	0.000982	-0.0325	-0.0259	-0.0587
31 C1 THUR	-0.0104	-0.00386	0.00092	-0.0328	-0.026	-0.0616
32 C1 THUR	-0.0107	-0.00409	0.000735	-0.0332	-0.0261	-0.0622
33 C1 THUR	-0.0126	-0.00552	0.000656	-0.039	-0.0312	-0.0648
34 C1 THUR	-0.0121	-0.00545	0.000694	-0.0388	-0.0311	-0.0636
35 C1 THUR	-0.0132	-0.00562	0.000632	-0.039	-0.0312	-0.0666
36 C1 THUR	-0.0135	-0.00586	0.000447	-0.0394	-0.0313	-0.0672
37 C1 THUR	-0.0117	-0.00509	0.000684	-0.0333	-0.0266	-0.0638
38 C1 THUR	-0.0115	-0.00507	0.000697	-0.0333	-0.0266	-0.0634
39 C1 THUR	-0.0119	-0.00513	0.000675	-0.0334	-0.0266	-0.0644
40 C1 THUR	-0.012	-0.00527	0.000586	-0.0335	-0.0266	-0.0645
41 C1 THUR	-0.013	-0.00563	0.000679	-0.0345	-0.0275	-0.0641
42 C1 THUR	-0.0125	-0.00556	0.000716	-0.0343	-0.0275	-0.0629
43 C1 THUR	-0.0136	-0.00573	0.000654	-0.0346	-0.0276	-0.0659
44 C1 THUR	-0.0139	-0.00596	0.000473	-0.0349	-0.0277	-0.0665
45 C1 THUR	-0.0136	-0.00587	0.000675	-0.035	-0.028	-0.0643
46 C1 THUR	-0.013	-0.00578	0.000723	-0.0348	-0.0279	-0.0628
47 C1 THUR	-0.0136	-0.00588	0.000667	-0.035	-0.0279	-0.0644
48 C1 THUR	-0.0148	-0.00626	0.000423	-0.0355	-0.0281	-0.0675
49 C1 THUR	-0.000698	0.00305	0.00193	-0.00123	-0.00082	-0.0408
50 C1 THUR	-0.000246	0.00312	0.00196	-0.00103	-0.00077	-0.0397
51 C1 THUR	-0.00133	0.00295	0.0019	-0.00131	-0.000877	-0.0426
52 C1 THUR	-0.00164	0.00271	0.00172	-0.00164	-0.000976	-0.0432
53 C1 THUR	-0.00885	-0.0037	0.000604	-0.0341	-0.0259	-0.0574
54 C1 THUR	-0.0084	-0.00364	0.000641	-0.0339	-0.0259	-0.0563
55 C1 THUR	-0.00948	-0.00381	0.00058	-0.0342	-0.026	-0.0592
56 C1 THUR	-0.0103	-0.00411	0.00041	-0.0345	-0.0261	-0.0612
57 C1 THUR	-0.0117	-0.00547	0.000325	-0.0403	-0.0311	-0.0624

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scenario code	climate change: GWP 100a (Eur.Person.Eq per person)	acidification potential: average European (Eur.Person.Eq per person)	eutrophication potential: generic (Eur.Person.Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq per person)	human toxicity: HTP infinite (Eur.Person.Eq per person)	resources: depletion of abiotic resources (Eur.Person.Eq per person)
58 C1 THUR	-0.0112	-0.0054	0.000362	-0.0401	-0.0311	-0.0613
59 C1 THUR	-0.0123	-0.00557	0.0003	-0.0404	-0.0312	-0.0642
60 C1 THUR	-0.0126	-0.0058	0.000116	-0.0407	-0.0313	-0.0648
61 C1 THUR	-0.0108	-0.00504	0.000341	-0.0347	-0.0265	-0.0614
62 C1 THUR	-0.0106	-0.00501	0.000354	-0.0346	-0.0265	-0.061
63 C1 THUR	-0.011	-0.00507	0.000333	-0.0347	-0.0265	-0.062
64 C1 THUR	-0.0111	-0.00522	0.000244	-0.0349	-0.0266	-0.0621
65 C1 THUR	-0.0123	-0.00559	0.000413	-0.0356	-0.0275	-0.0622
66 C1 THUR	-0.0118	-0.00552	0.000451	-0.0354	-0.0274	-0.0611
67 C1 THUR	-0.0129	-0.00569	0.000389	-0.0356	-0.0276	-0.064
68 C1 THUR	-0.0132	-0.00592	0.000208	-0.036	-0.0277	-0.0647
69 C1 THUR	-0.013	-0.00583	0.000443	-0.0359	-0.0279	-0.0627
70 C1 THUR	-0.0124	-0.00575	0.000492	-0.0357	-0.0279	-0.0612
71 C1 THUR	-0.0138	-0.00596	0.000412	-0.036	-0.028	-0.065
72 C1 THUR	-0.0142	-0.00622	0.000192	-0.0364	-0.0281	-0.0659

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Project **Thailand Rural area**

Project Headline Indicators

scenario code	Bio- degradeable Waste Landfilled [t]	Energy Recovered [MJ]	Land Take [ha]	Waste Composted [t]	Waste Landfilled [t]	Waste Recovered [t]	Waste Recycled [t]
01 IN THRU	-	122,610,607	0.177		12,880	64,240	
02 IN THRU	-	402,837,171	0.177		12,880	64,240	
03 IN THRU	-	177,737,144	0.177		12,880	64,240	
04 IN THRU	-	122,610,607	0.146		2,910	64,240	1,587
05 IN THRU	-	402,837,171	0.146		2,910	64,240	1,587
06 IN THRU	-	177,737,144	0.146		2,910	64,240	1,587
07 IN THRU	-	111,503,860	0.184		2,697	59,151	4,198
08 IN THRU	-	396,021,607	0.184		2,697	59,151	4,198
09 IN THRU	-	174,730,026	0.184		2,697	59,151	4,198
10 IN THRU	-	87,619,538	0.178		3,878	55,557	9,530
11 IN THRU	-	287,874,008	0.178		3,878	55,557	9,530
12 IN THRU	-	127,013,860	0.178		3,878	55,557	9,530
13 IN THRU	-	54,000,668	0.209		4,807	47,214	17,163
14 IN THRU	-	177,419,204	0.209		4,807	47,214	17,163
15 IN THRU	-	78,279,724	0.209		4,807	47,214	17,163
01 AD THRU	49,425	30,589,045	0.335		64,240		
02 AD THRU	23,874	30,908,056	0.296	24,580	34,985		4,119
03 AD THRU	23,874	40,902,669	0.296	24,580	34,985		4,119
04 AD THRU	23,874	56,074,445	0.296	24,580	34,985		4,119
05 AD THRU	23,874	107,827,719	0.296	24,580	34,985		4,119
06 AD THRU	36,872	29,317,664	0.309	11,498	49,026		4,597
07 AD THRU	36,872	33,440,410	0.309	11,498	49,026		4,597
08 AD THRU	36,872	39,698,719	0.309	11,498	49,026		4,597
09 AD THRU	36,872	61,046,778	0.309	11,498	49,026		4,597
10 AD THRU	28,039	28,422,989	0.29	19,589	38,320		7,832
11 AD THRU	28,039	35,446,926	0.29	19,589	38,320		7,832
12 AD THRU	28,039	46,109,230	0.29	19,589	38,320		7,832
13 AD THRU	28,039	82,479,998	0.29	19,589	38,320		7,832
14 AD THRU	24,320	28,046,283	0.282	22,996	33,813		9,194
15 AD THRU	24,320	36,291,775	0.282	22,996	33,813		9,194
16 AD THRU	24,320	48,808,393	0.282	22,996	33,813		9,194
17 AD THRU	24,320	91,504,512	0.282	22,996	33,813		9,194
18 AD THRU	2,934	143,395,465	0.237	42,585	7,893		17,026
01 C1 THRU	-	116,959,179	0.178	14,905	10,955	49,335	
02 C1 THRU	-	122,303,478	0.178	14,905	10,955	49,335	
03 C1 THRU	-	130,416,101	0.178	14,905	10,955	49,335	
04 C1 THRU	-	158,089,512	0.178	14,905	10,955	49,335	
05 C1 THRU	-	116,959,179	0.151	14,905	2,428	49,335	1,587
06 C1 THRU	-	122,303,478	0.151	14,905	2,428	49,335	1,587
07 C1 THRU	-	130,416,101	0.151	14,905	2,428	49,335	1,587
08 C1 THRU	-	158,089,512	0.151	14,905	2,428	49,335	1,587
09 C1 THRU	-	114,153,654	0.179	14,905	2,230	44,586	4,198
10 C1 THRU	-	119,497,954	0.179	14,905	2,230	44,586	4,198

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11 C1 THRU	-	127,610,576	0.179	14,905	2,230	44,586	4,198
12 C1 THRU	-	155,283,987	0.179	14,905	2,230	44,586	4,198
13 C1 THRU	-	112,439,781	0.155	5,110	2,973	57,087	3,456
14 C1 THRU	-	114,272,113	0.155	5,110	2,973	57,087	3,456
15 C1 THRU	-	117,053,584	0.155	5,110	2,973	57,087	3,456
16 C1 THRU	-	126,541,610	0.155	5,110	2,973	57,087	3,456
17 C1 THRU	-	92,945,700	0.173	14,905	3,092	43,376	7,038
18 C1 THRU	-	98,290,000	0.173	14,905	3,092	43,376	7,038
19 C1 THRU	-	106,402,623	0.173	14,905	3,092	43,376	7,038
20 C1 THRU	-	134,076,033	0.173	14,905	3,092	43,376	7,038
21 C1 THRU	-	84,470,012	0.181	19,163	3,144	37,415	8,596
22 C1 THRU	-	91,341,255	0.181	19,163	3,144	37,415	8,596
23 C1 THRU	-	101,771,770	0.181	19,163	3,144	37,415	8,596
24 C1 THRU	-	137,351,869	0.181	19,163	3,144	37,415	8,596
25 C1 THRU	-	365,728,002	0.178	14,905	10,955	49,335	
26 C1 THRU	-	371,072,302	0.178	14,905	10,955	49,335	
27 C1 THRU	-	379,184,925	0.178	14,905	10,955	49,335	
28 C1 THRU	-	406,858,335	0.178	14,905	10,955	49,335	
29 C1 THRU	-	365,728,002	0.151	14,905	2,428	49,335	1,587
30 C1 THRU	-	371,072,302	0.151	14,905	2,428	49,335	1,587
31 C1 THRU	-	379,184,925	0.151	14,905	2,428	49,335	1,587
32 C1 THRU	-	406,858,335	0.151	14,905	2,428	49,335	1,587
33 C1 THRU	-	356,510,450	0.179	14,905	2,230	44,586	4,198
34 C1 THRU	-	361,854,750	0.179	14,905	2,230	44,586	4,198
35 C1 THRU	-	369,967,373	0.179	14,905	2,230	44,586	4,198
36 C1 THRU	-	397,640,784	0.179	14,905	2,230	44,586	4,198
37 C1 THRU	-	363,063,871	0.155	5,110	2,973	57,087	3,456
38 C1 THRU	-	364,896,203	0.155	5,110	2,973	57,087	3,456
39 C1 THRU	-	367,677,674	0.155	5,110	2,973	57,087	3,456
40 C1 THRU	-	377,165,700	0.155	5,110	2,973	57,087	3,456
41 C1 THRU	-	286,831,714	0.173	14,905	3,092	43,376	7,038
42 C1 THRU	-	292,176,014	0.173	14,905	3,092	43,376	7,038
43 C1 THRU	-	300,288,636	0.173	14,905	3,092	43,376	7,038
44 C1 THRU	-	327,962,047	0.173	14,905	3,092	43,376	7,038
45 C1 THRU	-	253,687,297	0.181	19,163	3,144	37,415	8,596
46 C1 THRU	-	260,558,540	0.181	19,163	3,144	37,415	8,596
47 C1 THRU	-	270,989,055	0.181	19,163	3,144	37,415	8,596
48 C1 THRU	-	306,569,154	0.181	19,163	3,144	37,415	8,596
49 C1 THRU	-	165,897,308	0.178	14,905	10,955	49,335	
50 C1 THRU	-	171,241,608	0.178	14,905	10,955	49,335	
51 C1 THRU	-	179,354,230	0.178	14,905	10,955	49,335	
52 C1 THRU	-	207,027,641	0.178	14,905	10,955	49,335	
53 C1 THRU	-	165,897,308	0.151	14,905	2,428	49,335	1,587
54 C1 THRU	-	171,241,608	0.151	14,905	2,428	49,335	1,587
55 C1 THRU	-	179,354,230	0.151	14,905	2,428	49,335	1,587
56 C1 THRU	-	207,027,641	0.151	14,905	2,428	49,335	1,587
57 C1 THRU	-	161,830,401	0.179	14,905	2,230	44,586	4,198
58 C1 THRU	-	167,174,701	0.179	14,905	2,230	44,586	4,198
59 C1 THRU	-	175,287,323	0.179	14,905	2,230	44,586	4,198
60 C1 THRU	-	202,960,734	0.179	14,905	2,230	44,586	4,198
61 C1 THRU	-	161,742,881	0.155	5,110	2,973	57,087	3,456
62 C1 THRU	-	163,575,213	0.155	5,110	2,973	57,087	3,456
63 C1 THRU	-	166,356,683	0.155	5,110	2,973	57,087	3,456
64 C1 THRU	-	175,844,710	0.155	5,110	2,973	57,087	3,456
65 C1 THRU	-	131,087,211	0.173	14,905	3,092	43,376	7,038
66 C1 THRU	-	136,431,511	0.173	14,905	3,092	43,376	7,038

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67 C1 THRU	-	144,544,133	0.173	14,905	3,092	43,376	7,038
68 C1 THRU	-	172,217,544	0.173	14,905	3,092	43,376	7,038
69 C1 THRU	-	117,758,659	0.181	19,163	3,144	37,415	8,596
70 C1 THRU	-	124,629,901	0.181	19,163	3,144	37,415	8,596
71 C1 THRU	-	135,060,416	0.181	19,163	3,144	37,415	8,596
72 C1 THRU	-	170,640,515	0.181	19,163	3,144	37,415	8,596
73 C1 THRU	-	161,966,859	0.223	42,585	3,430	4,630	17,163

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Results from WRATE

Project **Thailand Rural area**

Characterisation Impact assessment

scenario code	climate change: GWP 100a (kg CO2-Eq)	acidification potential: average European (kg SO2-Eq)	eutrophication potential: generic (kg PO4-Eq)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq)	human toxicity: HTP infinite (kg 1,4-DCB-Eq)	resources: depletion of abiotic resources (kg antimony-Eq)
01 IN THRU	1,015,601	26,096	7,724	- 48,934	- 1,014,865	- 170,876
02 IN THRU	- 2,113,667	24,372	9,336	198,647	- 1,348,465	- 196,213
03 IN THRU	- 600,946	24,865	7,854	- 33,131	- 1,233,336	- 184,088
04 IN THRU	- 11,146,180	- 29,726	2,625	- 5,075,344	- 58,477,445	- 244,913
05 IN THRU	- 14,275,449	- 31,450	4,237	- 4,827,763	- 58,811,044	- 270,250
06 IN THRU	- 12,762,728	- 30,956	2,755	- 5,059,541	- 58,695,916	- 258,125
07 IN THRU	- 13,473,181	- 42,217	1,905	- 5,936,098	- 69,964,309	- 251,654
08 IN THRU	- 18,353,479	- 45,484	3,224	- 5,740,707	- 70,563,080	- 291,377
09 IN THRU	- 16,866,351	- 44,999	1,767	- 5,968,564	- 70,449,900	- 279,457
10 IN THRU	- 18,653,708	- 50,106	2,130	- 5,376,828	- 63,656,265	- 275,887
11 IN THRU	- 20,889,934	- 51,338	3,282	- 5,199,903	- 63,894,661	- 293,993
12 IN THRU	- 19,808,919	- 50,985	2,223	- 5,365,535	- 63,812,388	- 285,329
13 IN THRU	- 25,876,744	- 69,718	1,648	- 5,666,848	- 68,634,681	- 305,736
14 IN THRU	- 27,254,950	- 70,478	2,358	- 5,557,807	- 68,781,606	- 316,895
15 IN THRU	- 26,588,711	- 70,260	1,706	- 5,659,888	- 68,730,901	- 311,555
01 AD THRU	16780884	16853	13099	210868	795823	-23340
02 AD THRU	-5127338	-27996	6409	-5344737	-65050382	-109242
03 AD THRU	-3861077	-26937	6680	-5286851	-64837178	-99316
04 AD THRU	-6891250	-29578	6233	-5367480	-65292075	-124202
05 AD THRU	-7741287	-31117	5302	-5450992	-65640913	-131036
06 AD THRU	7045002	1413	11129	-1224672	-16402650	-82255
07 AD THRU	7567331	1849	11240	-1200794	-16314704	-78160
08 AD THRU	6317394	760	11056	-1234053	-16502347	-88426
09 AD THRU	6010782	-6153	9561	-1310070	-16924420	-83980
10 AD THRU	179548	-9501	9735	-2235204	-28507807	-123890
11 AD THRU	1069441	-8756	9925	-2194523	-28357973	-116914
12 AD THRU	-1060081	-10612	9611	-2251187	-28677661	-134403
13 AD THRU	-1628231	-17724	7879	-2349089	-29185508	-132439
14 AD THRU	-2711413	-14097	9148	-2660703	-33604770	-141423
15 AD THRU	-1666756	-13224	9371	-2612947	-33428879	-133234
16 AD THRU	-4166630	-15402	9002	-2679466	-33804165	-153764
17 AD THRU	-4844896	-22598	7170	-2786585	-34348149	-152845
18 AD THRU	-23338794	-50612	3097	-5302074	-64032748	-270163
01 C1 THRU	2443044	34645	8902	-37242	-870886	-157430
02 C1 THRU	3120136	35211	9046	-6290	-756882	-152123
03 C1 THRU	1499848	33799	8807	-49404	-1000124	-165430
04 C1 THRU	1089658	26136	7096	-139153	-1488506	-161227
05 C1 THRU	-9747384	-21258	3791	-5051609	-58313757	-231653
06 C1 THRU	-9070291	-20692	3935	-5020656	-58199753	-226345
07 C1 THRU	-10690580	-22104	3696	-5063770	-58442995	-239652
08 C1 THRU	-11100770	-29767	1985	-5153519	-58931377	-235449
09 C1 THRU	-14017468	-35883	2716	-5994457	-70183527	-254322
10 C1 THRU	-13340375	-35317	2860	-5963504	-70069523	-249014

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11 C1 THRU	-14960663	-36729	2621	-6006618	-70312765	-262321
12 C1 THRU	-15370853	-44392	910	-6096367	-70801147	-258118
13 C1 THRU	-12419438	-31573	2914	-5137848	-59637508	-247486
14 C1 THRU	-12187292	-31379	2964	-5127236	-59598421	-245667
15 C1 THRU	-12742820	-31863	2882	-5142018	-59681818	-250229
16 C1 THRU	-12842970	-38618	1575	-5200745	-60036097	-243825
17 C1 THRU	-14897193	-35238	3452	-5258446	-61867243	-252887
18 C1 THRU	-14220101	-34672	3597	-5227494	-61753239	-247579
19 C1 THRU	-15840389	-36084	3357	-5270608	-61996480	-260886
20 C1 THRU	-16257130	-43080	1763	-5355833	-62454630	-257486
21 C1 THRU	-15973382	-36827	3686	-5310810	-62836333	-255227
22 C1 THRU	-15102834	-36099	3872	-5271014	-62689756	-248402
23 C1 THRU	-17186062	-37914	3565	-5326446	-63002495	-265511
24 C1 THRU	-17740439	-45016	1845	-5423201	-63505862	-263416
25 C1 THRU	-334939	33115	10333	182545	-1167036	-179923
26 C1 THRU	342154	33681	10477	213498	-1053032	-174615
27 C1 THRU	-1278135	32269	10238	170384	-1296274	-187922
28 C1 THRU	-1688325	24605	8527	80635	-1784656	-183719
29 C1 THRU	-12525367	-22789	5222	-4831821	-58609907	-254146
30 C1 THRU	-11848274	-22222	5366	-4800868	-58495904	-248838
31 C1 THRU	-13468563	-23635	5127	-4843982	-58739145	-262145
32 C1 THRU	-13878752	-31298	3416	-4933732	-59227527	-257942
33 C1 THRU	-16723848	-37374	4110	-5780334	-70472044	-276235
34 C1 THRU	-16046755	-36808	4254	-5749381	-70358040	-270927
35 C1 THRU	-17667043	-38220	4015	-5792495	-70601282	-284234
36 C1 THRU	-18077233	-45883	2304	-5882244	-71089664	-280031
37 C1 THRU	-15218138	-33115	4356	-4916421	-59935867	-270147
38 C1 THRU	-14985992	-32921	4406	-4905809	-59896780	-268327
39 C1 THRU	-15541520	-33405	4324	-4920591	-59980177	-272889
40 C1 THRU	-15641671	-40159	3017	-4979318	-60334456	-266485
41 C1 THRU	-17062304	-36431	4567	-5087148	-62098057	-270417
42 C1 THRU	-16385211	-35865	4712	-5056195	-61984053	-265110
43 C1 THRU	-18005500	-37277	4473	-5099309	-62227294	-278416
44 C1 THRU	-18422241	-44272	2878	-5184535	-62685445	-275017
45 C1 THRU	-17863018	-37868	4660	-5161306	-63037780	-270526
46 C1 THRU	-16992471	-37140	4846	-5121510	-62891203	-263702
47 C1 THRU	-19075699	-38955	4538	-5176942	-63203942	-280811
48 C1 THRU	-19630076	-46057	2818	-5273697	-63707309	-278716
49 C1 THRU	1007967	33553	9017	-23214	-1064832	-169159
50 C1 THRU	1685059	34119	9162	7739	-950828	-163851
51 C1 THRU	64771	32707	8923	-35375	-1194070	-177158
52 C1 THRU	-345419	25043	7212	-125124	-1682452	-172955
53 C1 THRU	-11182461	-22350	3906	-5037580	-58507703	-243382
54 C1 THRU	-10505368	-21784	4051	-5006627	-58393699	-238074
55 C1 THRU	-12125657	-23196	3812	-5049741	-58636941	-251381
56 C1 THRU	-12535847	-30860	2101	-5139490	-59125323	-247178
57 C1 THRU	-15415555	-36947	2828	-5980789	-70372474	-265748
58 C1 THRU	-14738463	-36381	2973	-5949837	-70258470	-260440
59 C1 THRU	-16358751	-37793	2734	-5992951	-70501712	-273747
60 C1 THRU	-16768941	-45457	1023	-6082700	-70990094	-269544
61 C1 THRU	-13865218	-32674	3031	-5123714	-59832901	-259302
62 C1 THRU	-13633071	-32480	3080	-5113102	-59793814	-257483
63 C1 THRU	-14188599	-32964	2998	-5127884	-59877211	-262045
64 C1 THRU	-14288750	-39718	1692	-5186611	-60231489	-255641
65 C1 THRU	-16015667	-36089	3542	-5247513	-62018401	-262028
66 C1 THRU	-15338574	-35523	3687	-5216560	-61904397	-256720

67 C1 THRU	-16958863	-36935	3447	-5259674	-62147638	-270027
68 C1 THRU	-17375604	-43931	1853	-5344900	-62605788	-266627
69 C1 THRU	-16949548	-37570	3765	-5301267	-62968259	-263205
70 C1 THRU	-16079001	-36842	3951	-5261471	-62821682	-256380
71 C1 THRU	-18162229	-38657	3643	-5316903	-63134421	-273489
72 C1 THRU	-18716606	-45759	1924	-5413658	-63637788	-271394
73 C1 THRU	-26098665	-55835	2308	-5792203	-69315596	-297670

Appendix D

Results from WRATE

Project **Thailand Rural area**

Characterisation per person Impact assessment

scenario code	climate change: GWP 100a (kg CO2-Eq per person)	acidification potential: average European (kg SO2-Eq per person)	eutrophication potential: generic (kg PO4-Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (kg 1,4-DCB-Eq per person)	human toxicity: HTP infinite (kg 1,4-DCB-Eq per person)	resources: depletion of abiotic resources (kg antimony-Eq per person)
01 IN THRU	5.83	0.15	0.0444	-0.281	-5.83	-0.982
02 IN THRU	-12.1	0.14	0.0536	1.14	-7.75	-1.13
03 IN THRU	-3.45	0.143	0.0451	-0.19	-7.09	-1.06
04 IN THRU	-64	-0.171	0.0151	-29.2	-336	-1.41
05 IN THRU	-82	-0.181	0.0243	-27.7	-338	-1.55
06 IN THRU	-73.3	-0.178	0.0158	-29.1	-337	-1.48
07 IN THRU	-77.4	-0.243	0.0109	-34.1	-402	-1.45
08 IN THRU	-105	-0.261	0.0185	-33	-405	-1.67
09 IN THRU	-96.9	-0.259	0.0102	-34.3	-405	-1.61
10 IN THRU	-107	-0.288	0.0122	-30.9	-366	-1.59
11 IN THRU	-120	-0.295	0.0189	-29.9	-367	-1.69
12 IN THRU	-114	-0.293	0.0128	-30.8	-367	-1.64
13 IN THRU	-149	-0.401	0.00947	-32.6	-394	-1.76
14 IN THRU	-157	-0.405	0.0135	-31.9	-395	-1.82
15 IN THRU	-153	-0.404	0.0098	-32.5	-395	-1.79
01 AD THRU	96.4	0.0968	0.0753	1.21	4.57	-0.134
02 AD THRU	-29.5	-0.161	0.0368	-30.7	-374	-0.628
03 AD THRU	-22.2	-0.155	0.0384	-30.4	-373	-0.571
04 AD THRU	-39.6	-0.17	0.0358	-30.8	-375	-0.714
05 AD THRU	-44.5	-0.179	0.0305	-31.3	-377	-0.753
06 AD THRU	40.5	0.00812	0.0639	-7.04	-94.2	-0.473
07 AD THRU	43.5	0.0106	0.0646	-6.9	-93.7	-0.449
08 AD THRU	36.3	0.00437	0.0635	-7.09	-94.8	-0.508
09 AD THRU	34.5	-0.0353	0.0549	-7.53	-97.2	-0.482
10 AD THRU	1.03	-0.0546	0.0559	-12.8	-164	-0.712
11 AD THRU	6.14	-0.0503	0.057	-12.6	-163	-0.672
12 AD THRU	-6.09	-0.061	0.0552	-12.9	-165	-0.772
13 AD THRU	-9.35	-0.102	0.0453	-13.5	-168	-0.761
14 AD THRU	-15.6	-0.081	0.0526	-15.3	-193	-0.813
15 AD THRU	-9.58	-0.076	0.0538	-15	-192	-0.765
16 AD THRU	-23.9	-0.0885	0.0517	-15.4	-194	-0.883
17 AD THRU	-27.8	-0.13	0.0412	-16	-197	-0.878
18 AD THRU	-134	-0.291	0.0178	-30.5	-368	-1.55
01 C1 THRU	14	0.199	0.0511	-0.214	-5	-0.904
02 C1 THRU	17.9	0.202	0.052	-0.0361	-4.35	-0.874
03 C1 THRU	8.62	0.194	0.0506	-0.284	-5.75	-0.95
04 C1 THRU	6.26	0.15	0.0408	-0.799	-8.55	-0.926
05 C1 THRU	-56	-0.122	0.0218	-29	-335	-1.33
06 C1 THRU	-52.1	-0.119	0.0226	-28.8	-334	-1.3
07 C1 THRU	-61.4	-0.127	0.0212	-29.1	-336	-1.38
08 C1 THRU	-63.8	-0.171	0.0114	-29.6	-339	-1.35
09 C1 THRU	-80.5	-0.206	0.0156	-34.4	-403	-1.46
10 C1 THRU	-76.6	-0.203	0.0164	-34.3	-403	-1.43

Appendix D

Results from WRATE

11 C1 THRU	-86	-0.211	0.0151	-34.5	-404	-1.51
12 C1 THRU	-88.3	-0.255	0.00523	-35	-407	-1.48
13 C1 THRU	-71.4	-0.181	0.0167	-29.5	-343	-1.42
14 C1 THRU	-70	-0.18	0.017	-29.5	-342	-1.41
15 C1 THRU	-73.2	-0.183	0.0166	-29.5	-343	-1.44
16 C1 THRU	-73.8	-0.222	0.00905	-29.9	-345	-1.4
17 C1 THRU	-85.6	-0.202	0.0198	-30.2	-355	-1.45
18 C1 THRU	-81.7	-0.199	0.0207	-30	-355	-1.42
19 C1 THRU	-91	-0.207	0.0193	-30.3	-356	-1.5
20 C1 THRU	-93.4	-0.248	0.0101	-30.8	-359	-1.48
21 C1 THRU	-91.8	-0.212	0.0212	-30.5	-361	-1.47
22 C1 THRU	-86.8	-0.207	0.0222	-30.3	-360	-1.43
23 C1 THRU	-98.7	-0.218	0.0205	-30.6	-362	-1.53
24 C1 THRU	-102	-0.259	0.0106	-31.2	-365	-1.51
25 C1 THRU	-1.92	0.19	0.0594	1.05	-6.7	-1.03
26 C1 THRU	1.97	0.194	0.0602	1.23	-6.05	-1
27 C1 THRU	-7.34	0.185	0.0588	0.979	-7.45	-1.08
28 C1 THRU	-9.7	0.141	0.049	0.463	-10.3	-1.06
29 C1 THRU	-72	-0.131	0.03	-27.8	-337	-1.46
30 C1 THRU	-68.1	-0.128	0.0308	-27.6	-336	-1.43
31 C1 THRU	-77.4	-0.136	0.0295	-27.8	-337	-1.51
32 C1 THRU	-79.7	-0.18	0.0196	-28.3	-340	-1.48
33 C1 THRU	-96.1	-0.215	0.0236	-33.2	-405	-1.59
34 C1 THRU	-92.2	-0.211	0.0244	-33	-404	-1.56
35 C1 THRU	-102	-0.22	0.0231	-33.3	-406	-1.63
36 C1 THRU	-104	-0.264	0.0132	-33.8	-408	-1.61
37 C1 THRU	-87.4	-0.19	0.025	-28.2	-344	-1.55
38 C1 THRU	-86.1	-0.189	0.0253	-28.2	-344	-1.54
39 C1 THRU	-89.3	-0.192	0.0248	-28.3	-345	-1.57
40 C1 THRU	-89.9	-0.231	0.0173	-28.6	-347	-1.53
41 C1 THRU	-98	-0.209	0.0262	-29.2	-357	-1.55
42 C1 THRU	-94.1	-0.206	0.0271	-29	-356	-1.52
43 C1 THRU	-103	-0.214	0.0257	-29.3	-358	-1.6
44 C1 THRU	-106	-0.254	0.0165	-29.8	-360	-1.58
45 C1 THRU	-103	-0.218	0.0268	-29.7	-362	-1.55
46 C1 THRU	-97.6	-0.213	0.0278	-29.4	-361	-1.52
47 C1 THRU	-110	-0.224	0.0261	-29.7	-363	-1.61
48 C1 THRU	-113	-0.265	0.0162	-30.3	-366	-1.6
49 C1 THRU	5.79	0.193	0.0518	-0.133	-6.12	-0.972
50 C1 THRU	9.68	0.196	0.0526	0.0445	-5.46	-0.941
51 C1 THRU	0.372	0.188	0.0513	-0.203	-6.86	-1.02
52 C1 THRU	-1.98	0.144	0.0414	-0.719	-9.67	-0.994
53 C1 THRU	-64.2	-0.128	0.0224	-28.9	-336	-1.4
54 C1 THRU	-60.4	-0.125	0.0233	-28.8	-335	-1.37
55 C1 THRU	-69.7	-0.133	0.0219	-29	-337	-1.44
56 C1 THRU	-72	-0.177	0.0121	-29.5	-340	-1.42
57 C1 THRU	-88.6	-0.212	0.0162	-34.4	-404	-1.53
58 C1 THRU	-84.7	-0.209	0.0171	-34.2	-404	-1.5
59 C1 THRU	-94	-0.217	0.0157	-34.4	-405	-1.57
60 C1 THRU	-96.3	-0.261	0.00587	-34.9	-408	-1.55
61 C1 THRU	-79.7	-0.188	0.0174	-29.4	-344	-1.49
62 C1 THRU	-78.3	-0.187	0.0177	-29.4	-344	-1.48
63 C1 THRU	-81.5	-0.189	0.0172	-29.5	-344	-1.51
64 C1 THRU	-82.1	-0.228	0.00972	-29.8	-346	-1.47
65 C1 THRU	-92	-0.207	0.0203	-30.1	-356	-1.51
66 C1 THRU	-88.1	-0.204	0.0212	-30	-356	-1.47

Appendix D

Results from WRATE

67 C1 THRU	-97.4	-0.212	0.0198	-30.2	-357	-1.55
68 C1 THRU	-99.8	-0.252	0.0106	-30.7	-360	-1.53
69 C1 THRU	-97.4	-0.216	0.0216	-30.5	-362	-1.51
70 C1 THRU	-92.4	-0.212	0.0227	-30.2	-361	-1.47
71 C1 THRU	-104	-0.222	0.0209	-30.5	-363	-1.57
72 C1 THRU	-108	-0.263	0.0111	-31.1	-366	-1.56
73 C1 THRU	-150	-0.321	0.0133	-33.3	-398	-1.71

Appendix D

Results from WRATE

Project **Thailand Rural area**

Normalisation Impact assessment

scenario code	climate change: GWP 100a (Eur.Person.Eq)	acidification potential: average European (Eur.Person.Eq)	eutrophication potential: generic (Eur.Person.Eq)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq)	human toxicity: HTP infinite (Eur.Person.Eq)	resources: depletion of abiotic resources (Eur.Person.Eq)
01 IN THRU	78.6	365	231	-37.1	-51.3	-4422
02 IN THRU	-164	341	279	151	-68.2	-5078
03 IN THRU	-46.5	348	235	-25.1	-62.4	-4764
04 IN THRU	-862	-416	78.5	-3849	-2959	-6338
05 IN THRU	-1105	-440	127	-3661	-2976	-6994
06 IN THRU	-987	-433	82.4	-3837	-2970	-6680
07 IN THRU	-1042	-590	57	-4502	-3540	-6512
08 IN THRU	-1420	-636	96.5	-4354	-3570	-7540
09 IN THRU	-1305	-629	52.9	-4527	-3564	-7232
10 IN THRU	-1443	-700	63.7	-4078	-3221	-7140
11 IN THRU	-1616	-718	98.2	-3944	-3233	-7608
12 IN THRU	-1533	-713	66.5	-4069	-3229	-7384
13 IN THRU	-2002	-975	49.3	-4298	-3473	-7912
14 IN THRU	-2109	-985	70.6	-4215	-3480	-8201
15 IN THRU	-2057	-982	51	-4293	-3477	-8063
01 AD THRU	1298	236	392	160	40.3	-604
02 AD THRU	-397	-391	192	-4054	-3291	-2827
03 AD THRU	-299	-377	200	-4010	-3280	-2570
04 AD THRU	-533	-413	186	-4071	-3303	-3214
05 AD THRU	-599	-435	159	-4134	-3321	-3391
06 AD THRU	545	19.7	333	-929	-830	-2129
07 AD THRU	586	25.8	336	-911	-825	-2023
08 AD THRU	489	10.6	331	-936	-835	-2288
09 AD THRU	465	-86	286	-994	-856	-2173
10 AD THRU	13.9	-133	291	-1695	-1442	-3206
11 AD THRU	82.7	-122	297	-1664	-1435	-3026
12 AD THRU	-82	-148	288	-1707	-1451	-3478
13 AD THRU	-126	-248	236	-1782	-1477	-3427
14 AD THRU	-210	-197	274	-2018	-1700	-3660
15 AD THRU	-129	-185	280	-1982	-1691	-3448
16 AD THRU	-322	-215	269	-2032	-1710	-3979
17 AD THRU	-375	-316	215	-2113	-1738	-3955
18 AD THRU	-1806	-707	92.7	-4021	-3240	-6991
01 C1 THRU	189	484	266	-28.2	-44.1	-4074
02 C1 THRU	241	492	271	-4.77	-38.3	-3937
03 C1 THRU	116	472	264	-37.5	-50.6	-4281
04 C1 THRU	84.3	365	212	-106	-75.3	-4172
05 C1 THRU	-754	-297	113	-3831	-2950	-5995
06 C1 THRU	-702	-289	118	-3808	-2945	-5857
07 C1 THRU	-827	-309	111	-3840	-2957	-6202
08 C1 THRU	-859	-416	59.4	-3909	-2982	-6093
09 C1 THRU	-1085	-502	81.3	-4546	-3551	-6581
10 C1 THRU	-1032	-494	85.6	-4523	-3545	-6444

Appendix D

Results from WRATE

11 C1 THRU	-1158	-513	78.4	-4556	-3557	-6788
12 C1 THRU	-1189	-621	27.2	-4624	-3582	-6680
13 C1 THRU	-961	-441	87.2	-3897	-3017	-6405
14 C1 THRU	-943	-439	88.7	-3889	-3015	-6357
15 C1 THRU	-986	-445	86.2	-3900	-3020	-6476
16 C1 THRU	-994	-540	47.1	-3944	-3037	-6310
17 C1 THRU	-1153	-493	103	-3988	-3130	-6544
18 C1 THRU	-1100	-485	108	-3965	-3124	-6407
19 C1 THRU	-1226	-504	100	-3997	-3137	-6751
20 C1 THRU	-1258	-602	52.7	-4062	-3160	-6663
21 C1 THRU	-1236	-515	110	-4028	-3179	-6605
22 C1 THRU	-1169	-505	116	-3998	-3172	-6428
23 C1 THRU	-1330	-530	107	-4040	-3188	-6871
24 C1 THRU	-1373	-629	55.2	-4113	-3213	-6817
25 C1 THRU	-25.9	463	309	138	-59	-4656
26 C1 THRU	26.5	471	314	162	-53.3	-4519
27 C1 THRU	-98.9	451	306	129	-65.6	-4863
28 C1 THRU	-131	344	255	61.2	-90.3	-4754
29 C1 THRU	-969	-319	156	-3665	-2965	-6577
30 C1 THRU	-917	-311	161	-3641	-2960	-6440
31 C1 THRU	-1042	-330	153	-3674	-2972	-6784
32 C1 THRU	-1074	-437	102	-3742	-2997	-6675
33 C1 THRU	-1294	-522	123	-4384	-3565	-7149
34 C1 THRU	-1242	-515	127	-4360	-3560	-7011
35 C1 THRU	-1367	-534	120	-4393	-3572	-7356
36 C1 THRU	-1399	-641	68.9	-4461	-3597	-7247
37 C1 THRU	-1177	-463	130	-3729	-3032	-6991
38 C1 THRU	-1160	-460	132	-3721	-3030	-6944
39 C1 THRU	-1203	-467	129	-3732	-3035	-7062
40 C1 THRU	-1210	-561	90.3	-3776	-3053	-6896
41 C1 THRU	-1320	-509	137	-3858	-3142	-6998
42 C1 THRU	-1268	-501	141	-3835	-3136	-6861
43 C1 THRU	-1393	-521	134	-3867	-3148	-7205
44 C1 THRU	-1425	-619	86.1	-3932	-3172	-7117
45 C1 THRU	-1382	-529	139	-3914	-3189	-7001
46 C1 THRU	-1315	-519	145	-3884	-3182	-6824
47 C1 THRU	-1476	-545	136	-3926	-3198	-7267
48 C1 THRU	-1519	-644	84.3	-4000	-3223	-7213
49 C1 THRU	78	469	270	-17.6	-53.9	-4378
50 C1 THRU	130	477	274	5.87	-48.1	-4240
51 C1 THRU	5.01	457	267	-26.8	-60.4	-4585
52 C1 THRU	-26.7	350	216	-94.9	-85.1	-4476
53 C1 THRU	-865	-312	117	-3821	-2960	-6298
54 C1 THRU	-813	-305	121	-3797	-2954	-6161
55 C1 THRU	-938	-324	114	-3830	-2967	-6505
56 C1 THRU	-970	-431	62.9	-3898	-2991	-6397
57 C1 THRU	-1193	-516	84.6	-4536	-3560	-6877
58 C1 THRU	-1140	-509	89	-4512	-3555	-6740
59 C1 THRU	-1266	-528	81.8	-4545	-3567	-7084
60 C1 THRU	-1297	-635	30.6	-4613	-3592	-6975
61 C1 THRU	-1073	-457	90.7	-3886	-3027	-6710
62 C1 THRU	-1055	-454	92.2	-3878	-3025	-6663
63 C1 THRU	-1098	-461	89.7	-3889	-3029	-6781
64 C1 THRU	-1106	-555	50.6	-3934	-3047	-6616
65 C1 THRU	-1239	-504	106	-3980	-3138	-6781
66 C1 THRU	-1187	-497	110	-3956	-3132	-6644

67 C1 THRU	-1312	-516	103	-3989	-3144	-6988
68 C1 THRU	-1344	-614	55.4	-4054	-3168	-6900
69 C1 THRU	-1311	-525	113	-4021	-3186	-6811
70 C1 THRU	-1244	-515	118	-3990	-3178	-6635
71 C1 THRU	-1405	-540	109	-4032	-3194	-7077
72 C1 THRU	-1448	-640	57.6	-4106	-3220	-7023
73 C1 THRU	-2019	-780	69.1	-4393	-3507	-7703

Appendix D

Results from WRATE

Project **Thailand Rural area**

Normalisation per person Impact assessment

scenario code	climate change: GWP 100a (Eur.Person.Eq per person)	acidification potential: average European (Eur.Person.Eq per person)	eutrophication potential: generic (Eur.Person.Eq per person)	freshwater aquatic ecotoxicity: FAETP infinite (Eur.Person.Eq per person)	human toxicity: HTP infinite (Eur.Person.Eq per person)	resources: depletion of abiotic resources (Eur.Person.Eq per person)
01 IN THRU	0.000451	0.0021	0.00133	-0.000213	-0.000295	-0.0254
02 IN THRU	-0.00094	0.00196	0.0016	0.000866	-0.000392	-0.0292
03 IN THRU	-0.000267	0.002	0.00135	-0.000144	-0.000359	-0.0274
04 IN THRU	-0.00495	-0.00239	0.000451	-0.0221	-0.017	-0.0364
05 IN THRU	-0.00635	-0.00253	0.000728	-0.021	-0.0171	-0.0402
06 IN THRU	-0.00567	-0.00249	0.000474	-0.022	-0.0171	-0.0384
07 IN THRU	-0.00599	-0.00339	0.000328	-0.0259	-0.0203	-0.0374
08 IN THRU	-0.00816	-0.00365	0.000554	-0.025	-0.0205	-0.0433
09 IN THRU	-0.0075	-0.00361	0.000304	-0.026	-0.0205	-0.0415
10 IN THRU	-0.00829	-0.00402	0.000366	-0.0234	-0.0185	-0.041
11 IN THRU	-0.00929	-0.00412	0.000564	-0.0227	-0.0186	-0.0437
12 IN THRU	-0.00881	-0.00409	0.000382	-0.0234	-0.0185	-0.0424
13 IN THRU	-0.0115	-0.0056	0.000283	-0.0247	-0.02	-0.0455
14 IN THRU	-0.0121	-0.00566	0.000405	-0.0242	-0.02	-0.0471
15 IN THRU	-0.0118	-0.00564	0.000293	-0.0247	-0.02	-0.0463
01 AD THRU	0.00746	0.00135	0.00225	0.000919	0.000231	-0.00347
02 AD THRU	-0.00228	-0.00225	0.0011	-0.0233	-0.0189	-0.0162
03 AD THRU	-0.00172	-0.00216	0.00115	-0.023	-0.0188	-0.0148
04 AD THRU	-0.00306	-0.00238	0.00107	-0.0234	-0.019	-0.0185
05 AD THRU	-0.00344	-0.0025	0.000912	-0.0238	-0.0191	-0.0195
06 AD THRU	0.00313	0.000113	0.00191	-0.00534	-0.00477	-0.0122
07 AD THRU	0.00336	0.000149	0.00193	-0.00523	-0.00474	-0.0116
08 AD THRU	0.00281	0.000061	0.0019	-0.00538	-0.0048	-0.0131
09 AD THRU	0.00267	-0.000494	0.00164	-0.00571	-0.00492	-0.0125
10 AD THRU	0.0000798	-0.000763	0.00167	-0.00974	-0.00829	-0.0184
11 AD THRU	0.000475	-0.000703	0.00171	-0.00956	-0.00824	-0.0174
12 AD THRU	-0.000471	-0.000852	0.00165	-0.00981	-0.00834	-0.02
13 AD THRU	-0.000724	-0.00142	0.00135	-0.0102	-0.00848	-0.0197
14 AD THRU	-0.00121	-0.00113	0.00157	-0.0116	-0.00977	-0.021
15 AD THRU	-0.000741	-0.00106	0.00161	-0.0114	-0.00972	-0.0198
16 AD THRU	-0.00185	-0.00124	0.00155	-0.0117	-0.00983	-0.0229
17 AD THRU	-0.00215	-0.00181	0.00123	-0.0121	-0.00998	-0.0227
18 AD THRU	-0.0104	-0.00406	0.000532	-0.0231	-0.0186	-0.0402
01 C1 THRU	0.00109	0.00278	0.00153	-0.000162	-0.000253	-0.0234
02 C1 THRU	0.00139	0.00283	0.00156	-0.0000274	-0.00022	-0.0226
03 C1 THRU	0.000667	0.00271	0.00151	-0.000215	-0.000291	-0.0246
04 C1 THRU	0.000484	0.0021	0.00122	-0.000606	-0.000433	-0.024
05 C1 THRU	-0.00433	-0.00171	0.000652	-0.022	-0.017	-0.0344
06 C1 THRU	-0.00403	-0.00166	0.000677	-0.0219	-0.0169	-0.0337
07 C1 THRU	-0.00475	-0.00178	0.000635	-0.0221	-0.017	-0.0356
08 C1 THRU	-0.00493	-0.00239	0.000341	-0.0225	-0.0171	-0.035
09 C1 THRU	-0.00623	-0.00288	0.000467	-0.0261	-0.0204	-0.0378
10 C1 THRU	-0.00593	-0.00284	0.000492	-0.026	-0.0204	-0.037

Appendix D

Results from WRATE

11 C1 THRU	-0.00665	-0.00295	0.000451	-0.0262	-0.0204	-0.039
12 C1 THRU	-0.00683	-0.00357	0.000156	-0.0266	-0.0206	-0.0384
13 C1 THRU	-0.00552	-0.00254	0.000501	-0.0224	-0.0173	-0.0368
14 C1 THRU	-0.00542	-0.00252	0.00051	-0.0223	-0.0173	-0.0365
15 C1 THRU	-0.00566	-0.00256	0.000495	-0.0224	-0.0173	-0.0372
16 C1 THRU	-0.00571	-0.0031	0.000271	-0.0227	-0.0175	-0.0363
17 C1 THRU	-0.00662	-0.00283	0.000593	-0.0229	-0.018	-0.0376
18 C1 THRU	-0.00632	-0.00278	0.000618	-0.0228	-0.018	-0.0368
19 C1 THRU	-0.00704	-0.0029	0.000577	-0.023	-0.018	-0.0388
20 C1 THRU	-0.00723	-0.00346	0.000303	-0.0233	-0.0182	-0.0383
21 C1 THRU	-0.0071	-0.00296	0.000634	-0.0231	-0.0183	-0.0379
22 C1 THRU	-0.00671	-0.0029	0.000666	-0.023	-0.0182	-0.0369
23 C1 THRU	-0.00764	-0.00304	0.000613	-0.0232	-0.0183	-0.0395
24 C1 THRU	-0.00789	-0.00362	0.000317	-0.0236	-0.0185	-0.0392
25 C1 THRU	-0.000149	0.00266	0.00178	0.000795	-0.000339	-0.0268
26 C1 THRU	0.000152	0.0027	0.0018	0.00093	-0.000306	-0.026
27 C1 THRU	-0.000568	0.00259	0.00176	0.000742	-0.000377	-0.0279
28 C1 THRU	-0.000751	0.00198	0.00147	0.000351	-0.000519	-0.0273
29 C1 THRU	-0.00557	-0.00183	0.000898	-0.0211	-0.017	-0.0378
30 C1 THRU	-0.00527	-0.00178	0.000923	-0.0209	-0.017	-0.037
31 C1 THRU	-0.00599	-0.0019	0.000881	-0.0211	-0.0171	-0.039
32 C1 THRU	-0.00617	-0.00251	0.000587	-0.0215	-0.0172	-0.0384
33 C1 THRU	-0.00743	-0.003	0.000706	-0.0252	-0.0205	-0.0411
34 C1 THRU	-0.00713	-0.00296	0.000731	-0.0251	-0.0205	-0.0403
35 C1 THRU	-0.00785	-0.00307	0.00069	-0.0252	-0.0205	-0.0423
36 C1 THRU	-0.00804	-0.00368	0.000396	-0.0256	-0.0207	-0.0416
37 C1 THRU	-0.00676	-0.00266	0.000749	-0.0214	-0.0174	-0.0402
38 C1 THRU	-0.00666	-0.00264	0.000757	-0.0214	-0.0174	-0.0399
39 C1 THRU	-0.00691	-0.00268	0.000743	-0.0214	-0.0174	-0.0406
40 C1 THRU	-0.00695	-0.00323	0.000519	-0.0217	-0.0175	-0.0396
41 C1 THRU	-0.00758	-0.00293	0.000785	-0.0222	-0.0181	-0.0402
42 C1 THRU	-0.00728	-0.00288	0.00081	-0.022	-0.018	-0.0394
43 C1 THRU	-0.008	-0.00299	0.000769	-0.0222	-0.0181	-0.0414
44 C1 THRU	-0.00819	-0.00356	0.000495	-0.0226	-0.0182	-0.0409
45 C1 THRU	-0.00794	-0.00304	0.000801	-0.0225	-0.0183	-0.0402
46 C1 THRU	-0.00755	-0.00298	0.000833	-0.0223	-0.0183	-0.0392
47 C1 THRU	-0.00848	-0.00313	0.00078	-0.0226	-0.0184	-0.0418
48 C1 THRU	-0.00873	-0.0037	0.000484	-0.023	-0.0185	-0.0414
49 C1 THRU	0.000448	0.00269	0.00155	-0.000101	-0.00031	-0.0252
50 C1 THRU	0.000749	0.00274	0.00158	0.0000337	-0.000276	-0.0244
51 C1 THRU	0.0000288	0.00263	0.00153	-0.000154	-0.000347	-0.0263
52 C1 THRU	-0.000154	0.00201	0.00124	-0.000545	-0.000489	-0.0257
53 C1 THRU	-0.00497	-0.00179	0.000671	-0.022	-0.017	-0.0362
54 C1 THRU	-0.00467	-0.00175	0.000696	-0.0218	-0.017	-0.0354
55 C1 THRU	-0.00539	-0.00186	0.000655	-0.022	-0.017	-0.0374
56 C1 THRU	-0.00557	-0.00248	0.000361	-0.0224	-0.0172	-0.0367
57 C1 THRU	-0.00685	-0.00297	0.000486	-0.0261	-0.0205	-0.0395
58 C1 THRU	-0.00655	-0.00292	0.000511	-0.0259	-0.0204	-0.0387
59 C1 THRU	-0.00727	-0.00304	0.00047	-0.0261	-0.0205	-0.0407
60 C1 THRU	-0.00745	-0.00365	0.000176	-0.0265	-0.0206	-0.0401
61 C1 THRU	-0.00616	-0.00262	0.000521	-0.0223	-0.0174	-0.0386
62 C1 THRU	-0.00606	-0.00261	0.00053	-0.0223	-0.0174	-0.0383
63 C1 THRU	-0.00631	-0.00265	0.000515	-0.0223	-0.0174	-0.039
64 C1 THRU	-0.00635	-0.00319	0.000291	-0.0226	-0.0175	-0.038
65 C1 THRU	-0.00712	-0.0029	0.000609	-0.0229	-0.018	-0.039
66 C1 THRU	-0.00682	-0.00285	0.000634	-0.0227	-0.018	-0.0382

67 C1 THRU	-0.00754	-0.00297	0.000593	-0.0229	-0.0181	-0.0401
68 C1 THRU	-0.00772	-0.00353	0.000319	-0.0233	-0.0182	-0.0396
69 C1 THRU	-0.00753	-0.00302	0.000647	-0.0231	-0.0183	-0.0391
70 C1 THRU	-0.00715	-0.00296	0.000679	-0.0229	-0.0183	-0.0381
71 C1 THRU	-0.00807	-0.0031	0.000626	-0.0232	-0.0184	-0.0407
72 C1 THRU	-0.00832	-0.00367	0.000331	-0.0236	-0.0185	-0.0404
73 C1 THRU	-0.0116	-0.00448	0.000397	-0.0252	-0.0201	-0.0443

Appendix E

LCIA Ranking of UKUR scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
09 IN UKUR	Incineration for heat and electricity Post collection recycling	5	31	24	7	8	1	12.67	1
60 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	6	41	28	1	6	2	14.00	2
07 IN UKUR	Incineration for electricity Post collection recycling	18	29	17	9	14	13	16.67	3
18 IN UKUR	Incineration for heat and electricity Source segregation 50% RR	1	2	2	75	17	6	17.17	4
59 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	7	43	38	3	7	5	17.17	4
15 IN UKUR	Incineration for heat and electricity Source segregation 43% RR	2	5	4	65	20	8	17.33	6
12 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	17	37	23	2	11	15	17.50	7
16 IN UKUR	Incineration for electricity Source segregation 50% RR	3	1	1	76	18	12	18.50	8
72 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	13	8	8	38	28	20	19.17	9
13 IN UKUR	Incineration for electricity Source segregation 43% RR	8	4	3	66	21	19	20.17	10
11 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	21	39	30	4	12	16	20.33	11
57 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	11	46	43	5	9	9	20.50	12
17 IN UKUR	Incineration for heat Source segregation 50% RR	4	3	5	79	16	17	20.67	13
58 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	15	49	46	8	10	11	23.17	14
68 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	20	16	10	36	35	22	23.17	14
71 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	16	10	13	46	31	25	23.50	16
08 IN UKUR	Incineration for heat Post collection recycling	10	61	67	15	3	3	26.50	17
24 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	27	7	6	39	32	48	26.50	17
14 IN UKUR	Incineration for heat Source segregation 43% RR	14	6	7	78	19	38	27.00	19
36 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	9	69	68	11	1	4	27.00	19
09 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	29	45	35	6	13	36	27.33	21
67 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	23	19	20	41	38	26	27.83	22
35 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	12	70	74	12	2	7	29.50	23

Appendix E

LCIA Ranking of UKUR scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
69 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	28	12	16	50	33	47	31.00	24
23 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	32	9	11	48	36	51	31.17	25
20 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	35	15	9	37	42	52	31.67	26
10 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	38	48	37	10	15	45	32.17	27
33 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	19	72	75	13	4	10	32.17	27
48 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	22	26	40	59	22	24	32.17	27
65 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	31	22	22	44	41	43	33.83	30
34 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	25	74	79	14	5	14	35.17	31
12 IN UKUR	Incineration for heat and electricity Source segregation 25% RR	33	42	29	31	60	18	35.50	32
19 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	42	17	14	42	49	55	36.50	33
44 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	26	36	49	55	25	30	36.83	34
21 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	46	11	12	52	37	68	37.67	35
70 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	40	14	19	61	34	59	37.83	36
64 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	36	52	31	19	61	29	38.00	37
47 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	24	28	52	71	23	32	38.33	38
66 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	43	24	26	47	43	53	39.33	39
63 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	37	56	41	23	62	23	40.33	40
06 IN UKUR	Incineration for heat and electricity Post process recycling	41	60	45	18	67	21	42.00	41
61 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 20% RR	39	57	42	24	63	27	42.00	41
17 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	52	20	18	45	52	67	42.33	43
22 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	58	13	15	62	39	72	43.17	44
43 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	30	44	59	67	27	34	43.50	45
45 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	34	30	53	73	24	49	43.83	46

Appendix E

LCIA Ranking of UKUR scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
62 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 20% RR	44	58	44	27	64	31	44.67	47
10 IN UKUR	Incineration for electricity Source segregation 25% RR	57	38	25	34	66	57	46.17	48
56 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	47	63	47	16	65	40	46.33	49
18 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	61	23	21	49	54	71	46.50	50
41 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	45	47	60	69	29	46	49.33	51
16 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	63	51	27	22	70	64	49.50	52
55 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	49	65	55	20	68	41	49.67	53
46 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation50% RR	48	33	57	77	26	62	50.50	54
15 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	64	53	32	28	72	61	51.67	55
13 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 20% RR	66	54	33	29	73	63	53.00	56
04 IN UKUR	Incineration for electricity Post process recycling	68	59	36	21	76	60	53.33	57
42 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	50	50	63	72	30	56	53.50	58
14 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 20% RR	67	55	34	32	75	66	54.83	59
08 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	70	62	39	17	74	69	55.17	60
40 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	51	77	72	51	44	37	55.33	61
53 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	60	67	56	26	69	54	55.33	61
39 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 20% RR	53	80	76	57	46	33	57.50	63
37 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 20% RR	54	81	77	58	47	35	58.67	64
07 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	72	64	50	25	77	70	59.67	65
05 IN UKUR	Incineration for heat Post process recycling	55	87	82	54	53	28	59.83	66
32 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	59	88	81	40	50	42	60.00	67
38 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 20% RR	56	84	78	60	48	39	60.83	68
11 IN UKUR	Incineration for heat Source segregation 25% RR	65	73	71	63	45	50	61.17	69

Appendix E

LCIA Ranking of UKUR scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
54 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	69	71	58	33	71	65	61.17	69
05 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	73	66	51	30	78	73	61.83	71
06 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	74	68	54	35	79	74	64.00	72
31 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	62	89	85	53	55	44	64.67	73
17 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	91	18	48	80	80	91	68.00	74
29 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	71	90	87	56	57	58	69.83	75
05 AD UKUR	Anaerobic Digestion for vehicle fuel Post collection recycling	99	75	66	43	40	99	70.33	76
16 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 50% RR	92	21	62	81	81	92	71.50	77
14 AD UKUR	Anaerobic Digestion for electricity Source segregation 50% RR	93	25	64	82	82	93	73.17	78
15 AD UKUR	Anaerobic Digestion for heat Source segregation 50% RR	94	27	65	83	83	95	74.50	79
13 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	95	32	61	84	84	94	75.00	80
30 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Post process recycling	75	91	91	70	59	75	76.83	81
12 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 43% RR	96	34	69	85	85	96	77.50	82
10 AD UKUR	Anaerobic Digestion for electricity Source segregation 43% RR	97	35	70	86	86	97	78.50	83
04 AD UKUR	Anaerobic Digestion for heat and electricity Post collection recycling	100	78	80	64	51	100	78.83	84
11 AD UKUR	Anaerobic Digestion for heat Source segregation 43% RR	98	40	73	87	87	98	80.50	85
02 AD UKUR	Anaerobic Digestion for electricity Post collection recycling	101	83	83	68	56	103	82.33	86
03 AD UKUR	Anaerobic Digestion for heat Post collection recycling	102	86	84	74	58	105	84.83	87
03 IN UKUR	Incineration for heat and electricity No recycling	76	93	90	95	98	76	88.00	88
52 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	77	96	92	92	97	78	88.67	89
09 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	103	76	89	88	88	101	90.83	90
01 IN UKUR	Incineration for electricity No recycling	83	92	86	98	104	84	91.17	91
51 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	78	98	99	94	99	79	91.17	91
04 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	85	95	88	93	102	87	91.67	93

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
08 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 25% RR	104	79	93	89	89	102	92.67	94
02 IN UKUR	Incineration for heat No recycling	79	103	103	105	93	77	93.33	95
28 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	80	104	102	102	92	80	93.33	95
49 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	81	100	100	97	100	82	93.33	95
03 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	87	97	94	96	103	88	94.17	98
06 AD UKUR	Anaerobic Digestion for electricity Source segregation 25% RR	105	82	95	90	90	104	94.33	99
27 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	82	105	104	103	94	81	94.83	100
50 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	84	102	101	100	101	85	95.50	101
07 AD UKUR	Anaerobic Digestion for heat Source segregation 25% RR	106	85	97	91	91	106	96.00	102
01 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity No recycling	89	99	96	99	105	89	96.17	103
25 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity No recycling	86	106	106	104	95	83	96.67	104
02 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat No recycling	90	101	98	101	106	90	97.67	105
26 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat No recycling	88	107	107	106	96	86	98.33	106
01 AD UKUR	Anaerobic Digestion for electricity No recycling (landfill)	107	94	105	107	107	107	104.50	107

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	Energy Ranking	combined LCIA ranking	average	combined LCIA and energy recovered ranking
08 IN UKUR	Incineration for heat Post collection recycling	6	17	11.5	1
36 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	5	19	12	2
60 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	32	2	17	3
35 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	16	23	19.5	4
09 IN UKUR	Incineration for heat and electricity Post collection recycling	41	1	21	5
59 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	38	4	21	5
33 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	18	27	22.5	7
14 IN UKUR	Incineration for heat Source segregation 43% RR	29	19	24	8
34 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	17	31	24	8
48 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	25	27	26	10
44 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	21	34	27.5	11
57 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	49	12	30.5	12
58 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	47	14	30.5	12
72 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	52	9	30.5	12
17 IN UKUR	Incineration for heat Source segregation 50% RR	50	13	31.5	15
12 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	56	7	31.5	15
47 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	26	38	32	17
68 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	51	14	32.5	18
43 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	22	45	33.5	19
32 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	1	67	34	20
40 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	7	61	34	20
05 IN UKUR	Incineration for heat Post process recycling	3	66	34.5	22
39 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 20% RR	10	63	36.5	23

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	Energy Ranking	combined LCIA ranking	average	combined LCIA and energy recovered ranking
11 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	63	11	37	24
45 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	28	46	37	24
64 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	37	37	37	24
41 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	24	51	37.5	27
71 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	59	16	37.5	27
37 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 20% RR	12	64	38	29
06 IN UKUR	Incineration for heat and electricity Post process recycling	36	41	38.5	30
07 IN UKUR	Incineration for electricity Post collection recycling	74	3	38.5	30
67 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	55	22	38.5	30
38 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 20% RR	11	68	39.5	33
56 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	30	49	39.5	33
12 IN UKUR	Incineration for heat and electricity Source segregation 25% RR	48	32	40	35
31 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	8	73	40.5	36
42 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	23	58	40.5	36
46 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation50% RR	27	54	40.5	36
63 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	42	40	41	39
61 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 20% RR	44	41	42.5	40
55 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	33	53	43	41
15 IN UKUR	Incineration for heat and electricity Source segregation 43% RR	81	6	43.5	42
11 IN UKUR	Incineration for heat Source segregation 25% RR	19	69	44	43
65 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	58	30	44	43
29 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	14	75	44.5	45
62 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 20% RR	43	47	45	46

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	Energy Ranking	combined LCIA ranking	average	combined LCIA and energy recovered ranking
18 IN UKUR	Incineration for heat and electricity Source segregation 50% RR	87	4	45.5	47
69 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	69	24	46.5	48
28 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	1	95	48	49
66 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	57	39	48	49
24 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	80	17	48.5	51
02 IN UKUR	Incineration for heat No recycling	3	95	49	52
09 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	77	21	49	52
70 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	62	36	49	52
13 IN UKUR	Incineration for electricity Source segregation 43% RR	90	10	50	55
10 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	73	27	50	55
16 IN UKUR	Incineration for electricity Source segregation 50% RR	93	8	50.5	57
30 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Post process recycling	20	81	50.5	57
20 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	79	26	52.5	59
53 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	45	61	53	60
27 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	8	100	54	61
54 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	39	69	54	61
23 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	84	25	54.5	63
08 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	53	60	56.5	64
19 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	82	33	57.5	65
25 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity No recycling	14	104	59	66
26 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat No recycling	13	106	59.5	67
52 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	30	89	59.5	67
16 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	68	52	60	69

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	Energy Ranking	combined LCIA ranking	average	combined LCIA and energy recovered ranking
04 IN UKUR	Incineration for electricity Post process recycling	64	57	60.5	70
03 IN UKUR	Incineration for heat and electricity No recycling	35	88	61.5	71
21 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	88	35	61.5	71
51 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	33	91	62	73
07 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	60	65	62.5	74
15 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	70	55	62.5	74
10 IN UKUR	Incineration for electricity Source segregation 25% RR	78	48	63	76
17 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	85	43	64	77
22 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	86	44	65	78
13 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 20% RR	76	56	66	79
18 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	83	50	66.5	80
14 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 20% RR	75	59	67	81
06 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	66	72	69	82
49 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	45	95	70	83
50 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	39	101	70	83
05 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	71	71	71	85
04 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	53	93	73	86
01 IN UKUR	Incineration for electricity No recycling	64	91	77.5	87
03 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	60	98	79	88
05 AD UKUR	Anaerobic Digestion for vehicle fuel Post collection recycling	89	76	82.5	89
17 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	91	74	82.5	90
02 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat No recycling	66	105	85.5	90
13 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	92	80	86	92
16 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 50% RR	96	77	86.5	93

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	Energy Ranking	combined LCIA ranking	average	combined LCIA and energy recovered ranking
01 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity No recycling	71	103	87	94
04 AD UKUR	Anaerobic Digestion for heat and electricity Post collection recycling	95	84	89.5	95
12 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 43% RR	97	82	89.5	95
15 AD UKUR	Anaerobic Digestion for heat Source segregation 50% RR	104	79	91.5	97
09 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	94	90	92	98
03 AD UKUR	Anaerobic Digestion for heat Post collection recycling	98	87	92.5	99
14 AD UKUR	Anaerobic Digestion for electricity Source segregation 50% RR	107	78	92.5	99
02 AD UKUR	Anaerobic Digestion for electricity Post collection recycling	100	86	93	101
11 AD UKUR	Anaerobic Digestion for heat Source segregation 43% RR	103	85	94	102
10 AD UKUR	Anaerobic Digestion for electricity Source segregation 43% RR	106	83	94.5	103
08 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 25% RR	99	94	96.5	104
06 AD UKUR	Anaerobic Digestion for electricity Source segregation 25% RR	105	99	102	105
07 AD UKUR	Anaerobic Digestion for heat Source segregation 25% RR	102	102	102	105
01 AD UKUR	Anaerobic Digestion for electricity No recycling (landfill)	101	107	104	107

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	Energy Ranking	climate change ranking	average	combined energy and climate change ranking
36 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	5	9	7	1
08 IN UKUR	Incineration for heat Post collection recycling	6	10	8	2
35 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	16	12	14	3
33 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	18	19	18.5	4
60 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	32	6	19	5
34 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	17	25	21	6
14 IN UKUR	Incineration for heat Source segregation 43% RR	29	14	21.5	7
59 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	38	7	22.5	8
09 IN UKUR	Incineration for heat and electricity Post collection recycling	41	5	23	9
44 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	21	26	23.5	10
48 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	25	22	23.5	10
47 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	26	24	25	12
43 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	22	30	26	13
17 IN UKUR	Incineration for heat Source segregation 50% RR	50	4	27	14
05 IN UKUR	Incineration for heat Post process recycling	3	55	29	15
40 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	7	51	29	15
32 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	1	59	30	17
57 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	49	11	30	17
45 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	28	34	31	19
58 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	47	15	31	19
39 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 20% RR	10	53	31.5	21
72 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	52	13	32.5	22
37 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 20% RR	12	54	33	23

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	Energy Ranking	climate change ranking	average	combined energy and climate change ranking
38 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 20% RR	11	56	33.5	24
41 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	24	45	34.5	25
31 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	8	62	35	26
68 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	51	20	35.5	27
12 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	56	17	36.5	28
42 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	23	50	36.5	28
64 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	37	36	36.5	30
46 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation50% RR	27	48	37.5	31
71 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	59	16	37.5	31
06 IN UKUR	Incineration for heat and electricity Post process recycling	36	41	38.5	33
56 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	30	47	38.5	34
67 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	55	23	39	35
63 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	42	37	39.5	36
12 IN UKUR	Incineration for heat and electricity Source segregation 25% RR	48	33	40.5	37
28 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	1	80	40.5	38
02 IN UKUR	Incineration for heat No recycling	3	79	41	39
55 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	33	49	41	39
15 IN UKUR	Incineration for heat and electricity Source segregation 43% RR	81	2	41.5	41
61 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 20% RR	44	39	41.5	41
11 IN UKUR	Incineration for heat Source segregation 25% RR	19	65	42	43
11 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	63	21	42	43
29 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	14	71	42.5	45
62 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 20% RR	43	44	43.5	46

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	Energy Ranking	climate change ranking	average	combined energy and climate change ranking
18 IN UKUR	Incineration for heat and electricity Source segregation 50% RR	87	1	44	47
65 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	58	31	44.5	48
27 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	8	82	45	49
07 IN UKUR	Incineration for electricity Post collection recycling	74	18	46	50
30 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Post process recycling	20	75	47.5	51
16 IN UKUR	Incineration for electricity Source segregation 50% RR	93	3	48	52
69 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	69	28	48.5	53
13 IN UKUR	Incineration for electricity Source segregation 43% RR	90	8	49	54
25 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity No recycling	14	86	50	55
66 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	57	43	50	55
26 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat No recycling	13	88	50.5	57
70 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	62	40	51	58
53 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	45	60	52.5	59
09 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	77	29	53	60
24 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	80	27	53.5	61
52 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	30	77	53.5	61
54 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	39	69	54	63
03 IN UKUR	Incineration for heat and electricity No recycling	35	76	55.5	64
10 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	73	38	55.5	64
51 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	33	78	55.5	64
20 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	79	35	57	67
23 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	84	32	58	68
08 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	53	70	61.5	69

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	Energy Ranking	climate change ranking	average	combined energy and climate change ranking
50 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	39	84	61.5	69
19 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	82	42	62	71
49 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	45	81	63	72
16 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	68	63	65.5	73
04 IN UKUR	Incineration for electricity Post process recycling	64	68	66	74
07 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	60	72	66	74
15 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	70	64	67	76
21 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	88	46	67	76
10 IN UKUR	Incineration for electricity Source segregation 25% RR	78	57	67.5	78
17 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	85	52	68.5	79
04 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	53	85	69	80
06 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	66	74	70	81
13 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 20% RR	76	66	71	82
14 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 20% RR	75	67	71	82
05 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	71	73	72	84
18 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	83	61	72	84
22 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	86	58	72	84
01 IN UKUR	Incineration for electricity No recycling	64	83	73.5	87
03 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	60	87	73.5	87
02 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat No recycling	66	90	78	89
01 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity No recycling	71	89	80	90
17 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	91	91	91	91
13 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	92	95	93.5	92
05 AD UKUR	Anaerobic Digestion for vehicle fuel Post collection recycling	89	99	94	93

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LCIA Ranking of UKUR scenarios

scenario code	scenario name	Energy Ranking	climate change ranking	average	combined energy and climate change ranking
16 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 50% RR	96	92	94	93
12 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 43% RR	97	96	96.5	95
04 AD UKUR	Anaerobic Digestion for heat and electricity Post collection recycling	95	100	97.5	96
09 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	94	103	98.5	97
15 AD UKUR	Anaerobic Digestion for heat Source segregation 50% RR	104	94	99	98
03 AD UKUR	Anaerobic Digestion for heat Post collection recycling	98	102	100	99
14 AD UKUR	Anaerobic Digestion for electricity Source segregation 50% RR	107	93	100	100
02 AD UKUR	Anaerobic Digestion for electricity Post collection recycling	100	101	100.5	101
11 AD UKUR	Anaerobic Digestion for heat Source segregation 43% RR	103	98	100.5	101
08 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 25% RR	99	104	101.5	103
10 AD UKUR	Anaerobic Digestion for electricity Source segregation 43% RR	106	97	101.5	103
01 AD UKUR	Anaerobic Digestion for electricity No recycling (landfill)	101	107	104	105
07 AD UKUR	Anaerobic Digestion for heat Source segregation 25% RR	102	106	104	105
06 AD UKUR	Anaerobic Digestion for electricity Source segregation 25% RR	105	105	105	107

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LCIA ranking of UKRU scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
60 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	8	18	8	1	6	12	8.83	1
09 IN UKRU	Incineration for heat and electricity Post collection recycling	7	27	19	7	9	2	11.83	2
18 IN UKRU	Incineration for heat and electricity Source segregation 50% RR	1	2	2	52	16	1	12.33	3
12 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	17	16	7	2	7	28	12.83	4
15 IN UKRU	Incineration for heat and electricity Source segregation 43% RR	4	5	5	43	21	7	14.17	5
16 IN UKRU	Incineration for electricity Source segregation 50% RR	3	1	1	56	18	9	14.67	6
17 IN UKRU	Incineration for heat Source segregation 50% RR	2	3	3	72	10	3	15.50	7
13 IN UKRU	Incineration for electricity Source segregation 43% RR	6	4	4	44	22	14	15.67	8
07 IN UKRU	Incineration for electricity Post collection recycling	16	24	16	10	15	16	16.17	9
59 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	9	41	33	3	8	5	16.50	10
14 IN UKRU	Incineration for heat Source segregation 43% RR	5	6	6	67	20	8	18.67	11
11 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	19	40	22	4	13	18	19.33	12
57 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	13	44	36	5	11	10	19.83	13
09 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	24	43	23	6	14	24	22.33	14
58 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	15	47	44	8	12	15	23.50	15
36 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	12	58	49	9	1	13	23.67	16
68 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	23	9	11	31	32	44	25.00	17
72 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	20	12	20	41	30	30	25.50	18
08 IN UKRU	Incineration for heat Post collection recycling	11	66	63	15	3	4	27.00	19
73 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 80% RR 100% capture rate	10	7	13	73	19	40	27.00	19
10 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	30	46	31	11	17	36	28.50	21

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LCIA ranking of UKRU scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
35 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	14	74	71	12	2	6	29.83	22
24 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	31	10	18	42	35	52	31.33	23
12 IN UKRU	Incineration for heat and electricity Source segregation 25% RR	27	38	21	25	62	19	32.00	24
33 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	18	77	72	13	4	11	32.50	25
64 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	36	29	12	18	61	41	32.83	26
71 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	21	13	34	59	33	38	33.00	27
20 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	42	8	9	35	40	69	33.83	28
67 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	25	21	35	45	44	33	33.83	30
34 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	22	78	74	14	5	17	35.00	30
44 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	29	30	48	48	24	50	38.17	31
65 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	34	23	40	47	46	43	38.83	32
56 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	43	49	15	16	63	48	39.00	33
23 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	38	11	24	62	39	61	39.17	34
69 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	32	15	38	64	36	53	39.67	35
48 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	26	36	58	68	23	34	40.83	36
63 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	35	55	42	26	64	23	40.83	36
19 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	45	20	25	46	52	59	41.17	38
10 IN UKRU	Incineration for electricity Source segregation 25% RR	55	35	17	29	68	45	41.50	39
06 IN UKRU	Incineration for heat and electricity Post process recycling	37	63	41	20	70	21	42.00	40
61 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 25% RR	39	56	43	28	65	25	42.67	41
16 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	64	28	10	19	67	72	43.33	42

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LCIA ranking of UKRU scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
47 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	28	37	61	77	25	39	44.50	43
62 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 25% RR	41	59	45	30	66	27	44.67	44
21 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	54	14	28	65	43	70	45.67	45
66 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	46	26	46	53	47	57	45.83	46
17 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	58	22	30	49	54	68	46.83	47
70 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	49	19	47	69	37	66	47.83	48
43 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	33	52	65	74	28	37	48.17	49
08 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	71	48	14	17	69	73	48.67	50
11 IN UKRU	Incineration for heat Source segregation 25% RR	40	71	66	55	41	20	48.83	51
55 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	47	69	54	21	71	31	48.83	51
40 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	51	67	57	40	38	46	49.83	53
15 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	63	50	27	32	74	58	50.67	54
45 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	44	39	62	79	26	56	51.00	55
04 IN UKRU	Incineration for electricity Post process recycling	68	62	26	22	78	54	51.67	56
22 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	66	17	39	70	45	76	52.17	57
13 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 25% RR	65	51	29	34	75	62	52.67	58
18 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	67	25	37	57	57	74	52.83	59
53 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	59	72	55	24	72	42	54.00	60
41 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	48	57	68	75	29	49	54.33	61
32 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	61	79	59	37	42	51	54.83	62
14 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 25% RR	70	54	32	36	76	64	55.33	63

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LCIA ranking of UKRU scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
39 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 25% RR	50	82	75	58	48	26	56.50	64
46 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation50% RR	60	45	64	80	27	67	57.17	65
05 IN UKRU	Incineration for heat Post process recycling	53	86	80	51	53	22	57.50	66
37 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 25% RR	52	83	76	60	49	29	58.17	67
07 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	73	68	51	23	77	65	59.50	68
42 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	57	61	69	78	31	63	59.83	69
38 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 25% RR	56	84	77	61	50	32	60.00	70
54 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	69	75	56	33	73	55	60.17	71
05 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	75	70	52	27	79	71	62.33	72
31 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	62	90	86	50	55	35	63.00	73
05 AD UKRU	Anaerobic Digestion for vehicle fuel Post collection recycling	100	65	50	39	34	101	64.83	74
06 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	76	73	53	38	80	75	65.83	75
29 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	72	91	88	54	58	47	68.33	76
30 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Post process recycling	74	92	91	63	60	60	73.33	77
17 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	92	31	67	81	81	92	74.00	78
13 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	96	33	60	85	85	97	76.00	79
16 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 50% RR	93	32	79	82	82	93	76.83	80
14 AD UKRU	Anaerobic Digestion for electricity Source segregation 50% RR	94	34	82	83	83	94	78.33	81
04 AD UKRU	Anaerobic Digestion for heat and electricity Post collection recycling	101	80	78	66	51	100	79.33	82
15 AD UKRU	Anaerobic Digestion for heat Source segregation 50% RR	95	42	84	84	84	95	80.67	83
02 AD UKRU	Anaerobic Digestion for electricity Post collection recycling	102	81	81	71	56	102	82.17	84

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LCIA ranking of UKRU scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
12 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 43% RR	97	53	87	86	86	96	84.17	85
03 AD UKRU	Anaerobic Digestion for heat Post collection recycling	103	85	83	76	59	104	85.00	86
52 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	78	94	73	93	98	83	86.50	87
10 AD UKRU	Anaerobic Digestion for electricity Source segregation 43% RR	98	60	90	87	87	98	86.67	88
11 AD UKRU	Anaerobic Digestion for heat Source segregation 43% RR	99	64	92	88	88	99	88.33	89
04 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	86	93	70	94	99	90	88.67	90
03 IN UKRU	Incineration for heat and electricity No recycling	77	96	93	96	101	77	90.00	91
09 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	104	76	85	89	89	106	91.50	92
51 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	79	99	97	95	100	79	91.50	92
01 IN UKRU	Incineration for electricity No recycling	84	95	89	99	105	85	92.83	94
49 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	81	101	98	98	102	81	93.50	95
02 IN UKRU	Incineration for heat No recycling	80	105	104	106	94	78	94.50	96
28 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	82	104	102	102	93	84	94.50	96
03 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	88	98	94	97	104	88	94.83	98
27 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	83	106	105	104	95	80	95.50	99
08 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 25% RR	105	87	100	90	90	103	95.83	100
50 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	85	103	99	101	103	86	96.17	101
01 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity No recycling	90	100	95	100	106	89	96.67	102
06 AD UKRU	Anaerobic Digestion for electricity Source segregation 25% RR	106	88	101	91	91	105	97.00	103
25 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity No recycling	87	107	107	105	96	82	97.33	104
07 AD UKRU	Anaerobic Digestion for heat Source segregation 25% RR	107	89	103	92	92	107	98.33	105
02 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat No recycling	91	102	96	103	107	91	98.33	105
26 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat No recycling	89	108	108	107	97	87	99.33	107
01 AD UKRU	Anaerobic Digestion for electricity No recycling (landfill)	108	97	106	108	108	108	105.83	108

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LCIA ranking of UKRU scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking
36 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	16	5	10.50	1
08 IN UKRU	Incineration for heat Post collection recycling	19	6	12.50	2
60 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	1	32	16.50	3
35 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	22	17	19.50	4
14 IN UKRU	Incineration for heat Source segregation 43% RR	11	29	20.00	5
09 IN UKRU	Incineration for heat and electricity Post collection recycling	2	41	21.50	6
33 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	25	20	22.50	7
59 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	10	37	23.50	8
34 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	30	18	24.00	9
44 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	31	21	26.00	10
17 IN UKRU	Incineration for heat Source segregation 50% RR	7	50	28.50	11
12 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	4	56	30.00	12
48 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	36	25	30.50	13
57 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	13	48	30.50	13
58 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	15	46	30.50	13
40 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	53	9	31.00	16
32 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	62	1	31.50	17
56 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	33	30	31.50	17
64 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	26	40	33.00	19
68 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	17	51	34.00	20
05 IN UKRU	Incineration for heat Post process recycling	66	3	34.50	21

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LCIA ranking of UKRU scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking
47 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	43	26	34.50	21
11 IN UKRU	Incineration for heat Source segregation 25% RR	51	19	35.00	23
72 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	18	52	35.00	23
43 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	49	22	35.50	25
12 IN UKRU	Incineration for heat and electricity Source segregation 25% RR	24	49	36.50	26
11 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	12	62	37.00	27
06 IN UKRU	Incineration for heat and electricity Post process recycling	40	35	37.50	28
39 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 25% RR	64	12	38.00	29
31 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	73	7	40.00	30
63 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	36	44	40.00	30
37 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 25% RR	67	14	40.50	32
07 IN UKRU	Incineration for electricity Post collection recycling	9	73	41.00	33
38 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 25% RR	70	13	41.50	34
45 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	55	28	41.50	34
55 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	51	33	42.00	36
41 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	61	24	42.50	37
67 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	30	55	42.50	37
71 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	27	59	43.00	39
30 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Post process recycling	77	10	43.50	40
15 IN UKRU	Incineration for heat and electricity Source segregation 43% RR	5	83	44.00	41
61 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 25% RR	41	47	44.00	41

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LCIA ranking of UKRU scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking
62 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 25% RR	44	45	44.50	43
65 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	32	58	45.00	44
09 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	14	77	45.50	45
29 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	76	15	45.50	45
18 IN UKRU	Incineration for heat and electricity Source segregation 50% RR	3	89	46.00	47
42 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	69	23	46.00	47
46 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 50% RR	65	27	46.00	47
10 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	21	72	46.50	50
28 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	96	1	48.50	51
02 IN UKRU	Incineration for heat No recycling	96	3	49.50	52
13 IN UKRU	Incineration for electricity Source segregation 43% RR	8	91	49.50	52
73 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 80% RR 100% capture rate	19	80	49.50	52
16 IN UKRU	Incineration for electricity Source segregation 50% RR	6	94	50.00	55
53 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	60	42	51.00	56
66 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	46	57	51.50	57
08 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	50	54	52.00	58
24 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	23	81	52.00	58
20 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	28	78	53.00	60
27 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	99	7	53.00	60
69 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	35	71	53.00	60
54 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	71	38	54.50	63

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LCIA ranking of UKRU scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking
16 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	42	68	55.00	64
70 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	48	63	55.50	65
26 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat No recycling	107	10	58.50	66
52 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	87	30	58.50	66
10 IN UKRU	Incineration for electricity Source segregation 25% RR	39	79	59.00	68
23 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	34	85	59.50	69
25 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity No recycling	104	15	59.50	69
04 IN UKRU	Incineration for electricity Post process recycling	56	64	60.00	71
19 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	38	82	60.00	71
51 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	92	33	62.50	73
03 IN UKRU	Incineration for heat and electricity No recycling	91	35	63.00	74
07 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	68	60	64.00	75
15 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	54	74	64.00	75
17 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	47	86	66.50	77
21 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	45	88	66.50	77
13 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 25% RR	58	76	67.00	79
49 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	95	42	68.50	80
14 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 25% RR	63	75	69.00	81
50 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	101	38	69.50	82
05 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	72	69	70.50	83
06 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	75	66	70.50	83

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LCIA ranking of UKRU scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking
04 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	90	53	71.50	85
18 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	59	84	71.50	85
22 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	57	87	72.00	87
01 IN UKRU	Incineration for electricity No recycling	94	64	79.00	88
03 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	98	60	79.00	88
05 AD UKRU	Anaerobic Digestion for vehicle fuel Post collection recycling	74	96	85.00	90
01 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity No recycling	102	69	85.50	91
02 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat No recycling	105	66	85.50	91
02 AD UKRU	Anaerobic Digestion for electricity Post collection recycling	84	92	88.00	93
04 AD UKRU	Anaerobic Digestion for heat and electricity Post collection recycling	82	95	88.50	94
03 AD UKRU	Anaerobic Digestion for heat Post collection recycling	86	93	89.50	95
13 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	79	104	91.50	96
14 AD UKRU	Anaerobic Digestion for electricity Source segregation 50% RR	81	105	93.00	97
17 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	78	108	93.00	98
16 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 50% RR	80	107	93.50	99
12 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 43% RR	85	103	94.00	100
10 AD UKRU	Anaerobic Digestion for electricity Source segregation 43% RR	88	101	94.50	101
15 AD UKRU	Anaerobic Digestion for heat Source segregation 50% RR	83	106	94.50	101
11 AD UKRU	Anaerobic Digestion for heat Source segregation 43% RR	89	102	95.50	103
09 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	92	100	96.00	104
01 AD UKRU	Anaerobic Digestion for electricity No recycling (landfill)	108	90	99.00	105
08 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 25% RR	100	99	99.50	106
06 AD UKRU	Anaerobic Digestion for electricity Source segregation 25% RR	103	97	100.00	107
07 AD UKRU	Anaerobic Digestion for heat Source segregation 25% RR	105	98	101.50	108

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LCIA ranking of UKRU scenarios

scenario code	scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
08 IN UKRU	Incineration for heat Post collection recycling	11	6	8.50	1
36 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	12	5	8.50	1
35 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	14	17	15.50	3
14 IN UKRU	Incineration for heat Source segregation 43% RR	5	29	17.00	4
33 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	18	20	19.00	5
34 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	22	18	20.00	6
60 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	8	32	20.00	6
59 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	9	37	23.00	8
09 IN UKRU	Incineration for heat and electricity Post collection recycling	7	41	24.00	9
44 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	29	21	25.00	10
48 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	26	25	25.50	11
17 IN UKRU	Incineration for heat Source segregation 50% RR	2	50	26.00	12
47 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	28	26	27.00	13
43 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	33	22	27.50	14
05 IN UKRU	Incineration for heat Post process recycling	53	3	28.00	15
11 IN UKRU	Incineration for heat Source segregation 25% RR	40	19	29.50	16
40 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	51	9	30.00	17
57 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	13	48	30.50	18
58 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	15	46	30.50	18
32 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	61	1	31.00	20
39 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 25% RR	50	12	31.00	20

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LCIA ranking of UKRU scenarios

scenario code	scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
37 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation25% RR	52	14	33.00	22
31 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	62	7	34.50	23
38 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation25% RR	56	13	34.50	23
06 IN UKRU	Incineration for heat and electricity Post process recycling	37	35	36.00	25
41 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation43% RR	48	24	36.00	25
45 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation50% RR	44	28	36.00	25
72 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	20	52	36.00	25
12 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	17	56	36.50	29
56 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	43	30	36.50	29
68 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	23	51	37.00	31
12 IN UKRU	Incineration for heat and electricity Source segregation25% RR	27	49	38.00	32
64 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	36	40	38.00	32
63 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	35	44	39.50	34
42 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation43% RR	57	23	40.00	35
55 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	47	33	40.00	35
67 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	25	55	40.00	35
71 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	21	59	40.00	35
11 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	19	62	40.50	39
02 IN UKRU	Incineration for heat No recycling	80	3	41.50	40
28 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	82	1	41.50	40
30 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Post process recycling	74	10	42.00	42

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LCIA ranking of UKRU scenarios

scenario code	scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
61 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 25% RR	39	47	43.00	43
62 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 25% RR	41	45	43.00	43
15 IN UKRU	Incineration for heat and electricity Source segregation 43% RR	4	83	43.50	45
29 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	72	15	43.50	45
46 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 50% RR	60	27	43.50	45
07 IN UKRU	Incineration for electricity Post collection recycling	16	73	44.50	48
18 IN UKRU	Incineration for heat and electricity Source segregation 50% RR	1	89	45.00	49
27 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	83	7	45.00	49
73 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 80% RR 100% capture rate	10	80	45.00	49
65 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	34	58	46.00	52
13 IN UKRU	Incineration for electricity Source segregation 43% RR	6	91	48.50	53
16 IN UKRU	Incineration for electricity Source segregation 50% RR	3	94	48.50	53
26 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat No recycling	89	10	49.50	55
09 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	24	77	50.50	56
53 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	59	42	50.50	56
10 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	30	72	51.00	58
25 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity No recycling	87	15	51.00	58
66 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	46	57	51.50	60
69 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	32	71	51.50	60
54 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	69	38	53.50	62
52 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	78	30	54.00	63

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LCIA ranking of UKRU scenarios

scenario code	scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
03 IN UKRU	Incineration for heat and electricity No recycling	77	35	56.00	64
24 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	31	81	56.00	64
51 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	79	33	56.00	64
70 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	49	63	56.00	64
20 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	42	78	60.00	68
23 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	38	85	61.50	69
49 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	81	42	61.50	69
50 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	85	38	61.50	69
08 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	71	54	62.50	72
19 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	45	82	63.50	73
04 IN UKRU	Incineration for electricity Post process recycling	68	64	66.00	74
16 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	64	68	66.00	74
07 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	73	60	66.50	76
10 IN UKRU	Incineration for electricity Source segregation 25% RR	55	79	67.00	77
15 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	63	74	68.50	78
04 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	86	53	69.50	79
13 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 25% RR	65	76	70.50	80
06 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	76	66	71.00	81
21 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	54	88	71.00	81
05 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	75	69	72.00	83
17 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	58	86	72.00	83

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LCIA ranking of UKRU scenarios

scenario code	scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
14 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 25% RR	70	75	72.50	85
01 IN UKRU	Incineration for electricity No recycling	84	64	74.00	86
03 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	88	60	74.00	86
18 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	67	84	75.50	88
22 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	66	87	76.50	89
02 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat No recycling	91	66	78.50	90
01 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity No recycling	90	69	79.50	91
02 AD UKRU	Anaerobic Digestion for electricity Post collection recycling	102	92	97.00	92
03 AD UKRU	Anaerobic Digestion for heat Post collection recycling	103	93	98.00	93
04 AD UKRU	Anaerobic Digestion for heat and electricity Post collection recycling	101	95	98.00	93
05 AD UKRU	Anaerobic Digestion for vehicle fuel Post collection recycling	100	96	98.00	93
01 AD UKRU	Anaerobic Digestion for electricity No recycling (landfill)	108	90	99.00	96
10 AD UKRU	Anaerobic Digestion for electricity Source segregation 43% RR	98	101	99.50	97
14 AD UKRU	Anaerobic Digestion for electricity Source segregation 50% RR	94	105	99.50	97
12 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 43% RR	97	103	100.00	99
13 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	96	104	100.00	99
16 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 50% RR	93	107	100.00	99
17 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	92	108	100.00	99
11 AD UKRU	Anaerobic Digestion for heat Source segregation 43% RR	99	102	100.50	103
15 AD UKRU	Anaerobic Digestion for heat Source segregation 50% RR	95	106	100.50	103
06 AD UKRU	Anaerobic Digestion for electricity Source segregation 25% RR	106	97	101.50	105
08 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 25% RR	105	99	102.00	106
09 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	104	100	102.00	106
07 AD UKRU	Anaerobic Digestion for heat Source segregation 25% RR	107	98	102.50	108

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LCIA ranking for THUR scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
14 IN THUR	Incineration for heat Source segregation 34% RR	1	1	3	18	16	1	6.667	1
15 IN THUR	Incineration for heat and electricity Source segregation 34% RR	2	2	2	17	17	2	7.000	2
13 IN THUR	Incineration for electricity Source segregation 34% RR	3	3	1	16	18	3	7.333	3
09 IN THUR	Incineration for heat and electricity Post collection recycling	24	8	6	7	7	11	10.500	4
12 IN THUR	Incineration for heat and electricity Source segregation 25% RR	5	5	5	23	24	6	11.333	5
10 IN THUR	Incineration for electricity Source segregation 25% RR	7	6	4	22	25	12	12.667	6
60 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	25	22	9	2	2	16	12.667	6
08 IN THUR	Incineration for heat Post collection recycling	11	7	41	15	4	5	13.833	8
72 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	8	10	12	21	27	14	15.333	9
11 IN THUR	Incineration for heat Source segregation 25% RR	4	4	22	42	23	4	16.500	10
36 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	16	19	44	11	1	8	16.500	10
24 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	15	12	10	20	28	25	18.333	12
12 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	39	28	8	1	5	37	19.667	13
59 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	30	34	20	5	6	23	19.667	13
48 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	6	9	39	39	26	7	21.000	15
35 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	18	31	55	12	3	9	21.333	16
68 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	17	15	13	30	39	18	22.000	17
71 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	10	13	37	28	29	15	22.000	17
07 IN THUR	Incineration for electricity Post collection recycling	54	11	7	10	15	54	25.167	19
57 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	40	39	25	6	9	36	25.833	20
11 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	44	41	17	3	11	43	26.500	21
33 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	26	37	58	13	8	17	26.500	21

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LCIA ranking for THUR scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
23 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	19	17	35	26	32	31	26.667	23
20 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	28	21	11	27	41	35	27.167	24
44 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	9	14	47	46	38	10	27.333	25
47 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	13	16	59	44	31	20	30.500	26
69 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	22	20	43	31	33	34	30.500	26
09 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	51	44	19	4	13	55	31.000	28
58 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	45	43	30	9	12	47	31.000	28
45 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	14	18	60	43	30	22	31.167	30
67 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	23	27	33	36	42	26	31.167	30
34 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	34	40	65	14	10	29	32.000	32
43 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	12	26	57	56	40	13	34.000	33
21 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	31	25	40	29	35	52	35.333	34
10 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	56	46	27	8	14	63	35.667	35
19 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	33	33	32	34	45	42	36.500	36
70 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	29	24	48	35	36	48	36.667	37
65 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	32	32	38	38	44	39	37.167	38
46 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Source segregatior50% RR	20	23	68	50	34	33	38.000	39
41 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	21	30	62	57	43	24	39.500	40
22 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	38	29	46	32	37	58	40.000	41
64 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	46	47	15	47	52	40	41.167	42
17 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	42	38	34	37	48	53	42.000	43

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LCIA ranking for THUR scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
66 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	37	36	45	41	47	50	42.667	44
42 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	27	35	67	60	46	32	44.500	45
40 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	35	45	52	68	50	19	44.833	46
63 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	48	51	26	51	55	41	45.333	47
18 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	47	42	42	40	49	61	46.833	48
16 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	58	50	14	45	58	57	47.000	49
61 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 20% RR	50	53	28	53	56	45	47.500	50
39 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 20% RR	36	48	61	69	51	21	47.667	51
62 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 20% RR	53	54	29	54	57	51	49.667	52
15 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	60	55	21	48	59	59	50.333	53
37 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 20% RR	41	49	63	70	53	27	50.500	54
06 IN THUR	Incineration for heat and electricity Post process recycling	59	60	18	61	65	46	51.500	55
13 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 20% RR	61	56	23	49	60	62	51.833	56
38 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 20% RR	43	52	66	71	54	30	52.667	57
14 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 20% RR	63	57	24	52	61	66	53.833	58
56 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	57	65	36	58	63	49	54.667	59
05 AD THUR	Anaerobic Digestion for vehicle fuel Post collection recycling	73	58	71	19	19	94	55.667	60
04 IN THUR	Incineration for electricity Post process recycling	66	61	16	59	70	65	56.167	61
05 IN THUR	Incineration for heat Post process recycling	49	59	64	75	64	28	56.500	62
04 AD THUR	Anaerobic Digestion for heat and electricity Post collection recycling	74	62	74	24	20	96	58.333	63
08 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	68	67	31	55	67	68	59.333	64

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LCIA ranking for THUR scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
02 AD THUR	Anaerobic Digestion for electricity Post collection recycling	76	63	75	25	21	98	59.667	65
32 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	52	66	69	72	62	38	59.833	66
03 AD THUR	Anaerobic Digestion for heat Post collection recycling	78	64	76	33	22	99	62.000	67
31 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	55	68	70	73	66	44	62.667	68
55 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	64	69	51	64	68	60	62.667	68
53 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	67	71	53	65	71	67	65.667	70
07 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	69	73	49	62	73	69	65.833	71
29 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	62	70	72	74	69	56	67.167	72
05 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	71	75	50	63	75	71	67.500	73
54 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	70	74	56	67	74	70	68.500	74
06 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	72	76	54	66	76	72	69.333	75
30 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Post process recycling	65	72	73	76	72	64	70.333	76
17 AD THUR	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	75	77	77	77	77	86	78.167	77
16 AD THUR	Anaerobic Digestion for heat and electricity Source segregation 50% RR	77	78	83	78	78	87	80.167	78
14 AD THUR	Anaerobic Digestion for electricity Source segregation 50% RR	79	79	84	79	79	90	81.667	79
13 AD THUR	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	82	81	82	81	81	91	83.000	80
15 AD THUR	Anaerobic Digestion for heat Source segregation 50% RR	81	80	85	80	80	93	83.167	81
12 AD THUR	Anaerobic Digestion for heat and electricity Source segregation 43% RR	84	82	91	82	82	92	85.500	82
03 IN THUR	Incineration for heat and electricity No recycling	86	91	79	93	93	76	86.333	83
52 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	87	94	81	90	90	78	86.667	84
10 AD THUR	Anaerobic Digestion for electricity Source segregation 43% RR	89	83	93	83	83	95	87.667	85
02 IN THUR	Incineration for heat No recycling	80	90	94	102	91	73	88.333	86

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LCIA ranking for THUR scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
01 IN THUR	Incineration for electricity No recycling	92	92	78	91	97	81	88.500	87
28 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	83	93	96	99	89	74	89.000	88
04 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	95	95	80	89	94	83	89.333	89
11 AD THUR	Anaerobic Digestion for heat Source segregation 43% RR	93	84	95	84	84	97	89.500	90
51 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	90	97	88	95	95	79	90.667	91
27 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	85	96	98	100	92	75	91.000	92
09 AD THUR	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	100	85	97	85	85	100	92.000	93
49 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	94	99	89	96	98	82	93.000	94
03 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	96	101	86	92	100	84	93.167	95
25 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity No recycling	88	98	99	101	96	77	93.167	95
08 AD THUR	Anaerobic Digestion for heat and electricity Source segregation 25% RR	101	86	101	86	86	101	93.500	97
06 AD THUR	Anaerobic Digestion for electricity Source segregation 25% RR	102	87	102	87	87	102	94.500	98
01 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity No recycling	98	103	87	94	102	88	95.333	99
07 AD THUR	Anaerobic Digestion for heat Source segregation 25% RR	103	88	103	88	88	103	95.500	100
26 C1 THUR	Incineration for heat and Anaerobic Digestion for heat No recycling	91	100	100	104	99	80	95.667	101
50 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	97	102	92	98	101	85	95.833	102
02 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat No recycling	99	104	90	97	103	89	97.000	103
01 AD THUR	Anaerobic Digestion for electricity No recycling (landfill)	104	89	104	103	104	104	101.333	104

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LCIA ranking for THUR scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking	scenario code
08 IN THUR	Incineration for heat Post collection recycling	8	6	7.000	1	08 IN THUR
36 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	10	5	7.500	2	36 C1 THUR
35 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	16	12	14.000	3	48 C1 THUR
11 IN THUR	Incineration for heat Source segregation 25% RR	10	24	17.000	4	11 IN THUR
48 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	15	21	18.000	5	44 C1 THUR
14 IN THUR	Incineration for heat Source segregation 34% RR	1	36	18.500	6	35 C1 THUR
60 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	6	31	18.500	6	43 C1 THUR
33 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	21	19	20.000	8	14 IN THUR
09 IN THUR	Incineration for heat and electricity Post collection recycling	4	39	21.500	9	47 C1 THUR
44 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	25	20	22.500	10	45 C1 THUR
34 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	32	18	25.000	11	40 C1 THUR
59 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	13	38	25.500	12	33 C1 THUR
72 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	9	43	26.000	13	41 C1 THUR
47 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	26	27	26.500	14	46 C1 THUR
40 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	46	9	27.500	15	39 C1 THUR
43 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	33	22	27.500	15	42 C1 THUR
68 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	17	40	28.500	17	72 C1 THUR
45 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	30	28	29.000	18	05 IN THUR
39 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 20% RR	51	13	32.000	19	34 C1 THUR
05 IN THUR	Incineration for heat Post process recycling	62	3	32.500	20	32 C1 THUR
41 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	40	25	32.500	20	60 C1 THUR
46 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 50% RR	39	26	32.500	20	68 C1 THUR

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LCIA ranking for THUR scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking	scenario code
12 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	13	53	33.000	23	37 C1 THUR
12 IN THUR	Incineration for heat and electricity Source segregation 25% RR	5	62	33.500	24	38 C1 THUR
24 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	12	55	33.500	24	31 C1 THUR
32 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	66	1	33.500	24	09 IN THUR
42 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	45	23	34.000	27	12 IN THUR
57 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	20	50	35.000	28	71 C1 THUR
37 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 20% RR	54	17	35.500	29	59 C1 THUR
58 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	28	44	36.000	30	24 C1 THUR
38 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 20% RR	57	16	36.500	31	30 C1 THUR
71 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	17	57	37.000	32	29 C1 THUR
31 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	68	7	37.500	33	67 C1 THUR
64 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	42	37	39.500	34	02 IN THUR
20 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	24	58	41.000	35	64 C1 THUR
11 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	21	63	42.000	36	28 C1 THUR
67 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	30	54	42.000	36	20 C1 THUR
29 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	72	14	43.000	38	56 C1 THUR
30 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Post process recycling	76	10	43.000	39	58 C1 THUR
56 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	59	29	44.000	40	57 C1 THUR
02 IN THUR	Incineration for heat No recycling	86	3	44.500	41	15 IN THUR
06 IN THUR	Incineration for heat and electricity Post process recycling	55	34	44.500	41	65 C1 THUR
28 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	88	1	44.500	41	12 C1 THUR

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LCIA ranking for THUR scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking	scenario code
15 IN THUR	Incineration for heat and electricity Source segregation 34% RR	2	89	45.500	44	27 C1 THUR
10 IN THUR	Incineration for electricity Source segregation 25% RR	6	86	46.000	45	06 IN THUR
63 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	47	45	46.000	45	10 IN THUR
13 IN THUR	Incineration for electricity Source segregation 34% RR	3	92	47.500	47	63 C1 THUR
07 IN THUR	Incineration for electricity Post collection recycling	19	78	48.500	48	66 C1 THUR
65 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	38	59	48.500	48	69 C1 THUR
69 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	26	71	48.500	48	70 C1 THUR
27 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	92	7	49.500	51	13 IN THUR
61 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 20% RR	50	49	49.500	51	55 C1 THUR
55 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	68	32	50.000	53	61 C1 THUR
62 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 20% RR	52	48	50.000	53	23 C1 THUR
66 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	44	56	50.000	53	26 C1 THUR
70 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	37	65	51.000	56	62 C1 THUR
09 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	28	76	52.000	57	25 C1 THUR
23 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	23	81	52.000	57	11 C1 THUR
10 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	35	70	52.500	59	54 C1 THUR
25 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity No recycling	95	14	54.500	60	19 C1 THUR
26 C1 THUR	Incineration for heat and Anaerobic Digestion for heat No recycling	101	10	55.500	61	53 C1 THUR
16 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	49	64	56.500	62	52 C1 THUR
52 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	84	30	57.000	63	21 C1 THUR
08 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	64	51	57.500	64	08 C1 THUR

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LCIA ranking for THUR scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking	scenario code
54 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	74	41	57.500	64	03 IN THUR
19 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	36	80	58.000	66	16 C1 THUR
53 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	70	46	58.000	66	51 C1 THUR
03 IN THUR	Incineration for heat and electricity No recycling	83	34	58.500	68	22 C1 THUR
21 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	34	87	60.500	69	17 C1 THUR
51 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	91	32	61.500	70	10 C1 THUR
15 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	53	72	62.500	71	09 C1 THUR
17 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	43	83	63.000	72	07 C1 THUR
22 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	41	85	63.000	72	18 C1 THUR
04 IN THUR	Incineration for electricity Post process recycling	61	66	63.500	74	04 IN THUR
18 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	48	82	65.000	75	07 IN THUR
07 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	71	60	65.500	76	15 C1 THUR
13 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 20% RR	56	77	66.500	77	13 C1 THUR
14 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 20% RR	58	75	66.500	77	14 C1 THUR
05 AD THUR	Anaerobic Digestion for vehicle fuel Post collection recycling	60	79	69.500	79	50 C1 THUR
04 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	89	51	70.000	80	06 C1 THUR
49 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	94	46	70.000	80	49 C1 THUR
06 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	75	68	71.500	82	05 C1 THUR
50 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	102	41	71.500	82	04 C1 THUR
05 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	73	73	73.000	84	05 AD THUR
01 IN THUR	Incineration for electricity No recycling	87	66	76.500	85	03 C1 THUR
04 AD THUR	Anaerobic Digestion for heat and electricity Post collection recycling	63	91	77.000	86	01 IN THUR

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LCIA ranking for THUR scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking	scenario code
03 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	95	60	77.500	87	17 AD THUR
17 AD THUR	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	77	84	80.500	88	04 AD THUR
03 AD THUR	Anaerobic Digestion for heat Post collection recycling	67	95	81.000	89	02 C1 THUR
02 AD THUR	Anaerobic Digestion for electricity Post collection recycling	65	100	82.500	90	13 AD THUR
13 AD THUR	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	80	88	84.000	91	16 AD THUR
16 AD THUR	Anaerobic Digestion for heat and electricity Source segregation 50% RR	78	93	85.500	92	01 C1 THUR
02 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat No recycling	103	68	85.500	92	03 AD THUR
01 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity No recycling	99	73	86.000	94	02 AD THUR
12 AD THUR	Anaerobic Digestion for heat and electricity Source segregation 43% RR	82	94	88.000	95	12 AD THUR
15 AD THUR	Anaerobic Digestion for heat Source segregation 50% RR	81	97	89.000	96	15 AD THUR
09 AD THUR	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	93	90	91.500	97	14 AD THUR
14 AD THUR	Anaerobic Digestion for electricity Source segregation 50% RR	79	104	91.500	97	09 AD THUR
10 AD THUR	Anaerobic Digestion for electricity Source segregation 43% RR	85	103	94.000	99	11 AD THUR
11 AD THUR	Anaerobic Digestion for heat Source segregation 43% RR	90	98	94.000	99	10 AD THUR
08 AD THUR	Anaerobic Digestion for heat and electricity Source segregation 25% RR	97	96	96.500	101	08 AD THUR
07 AD THUR	Anaerobic Digestion for heat Source segregation 25% RR	100	99	99.500	102	07 AD THUR
06 AD THUR	Anaerobic Digestion for electricity Source segregation 25% RR	98	102	100.000	103	06 AD THUR
01 AD THUR	Anaerobic Digestion for electricity No recycling (landfill)	104	101	102.500	104	01 AD THUR

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LCIA ranking for THUR scenarios

scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
Incineration for heat Post collection recycling	11	6	8.500	1
Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	16	5	10.500	2
Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	6	21	13.500	3
Incineration for heat Source segregation 25% RR	4	24	14.000	4
Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	9	20	14.500	5
Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	18	12	15.000	6
Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	12	22	17.000	7
Incineration for heat Source segregation 34% RR	1	36	18.500	8
Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	13	27	20.000	9
Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	14	28	21.000	10
Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	35	9	22.000	11
Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	26	19	22.500	12
Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	21	25	23.000	13
Incineration for heat and Anaerobic Digestion for heat Source segregation 50% RR	20	26	23.000	13
Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 20% RR	36	13	24.500	15
Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	27	23	25.000	16
Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	8	43	25.500	17
Incineration for heat Post process recycling	49	3	26.000	18
Incineration for heat and Anaerobic Digestion for heat Post collection recycling	34	18	26.000	18
Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	52	1	26.500	20
Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	25	31	28.000	21
Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	17	40	28.500	22

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LCIA ranking for THUR scenarios

scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
Incineration for heat and Anaerobic Digestion for electricity Source segregation20% RR	41	17	29.000	23
Incineration for heat and Anaerobic Digestion for heat Source segregation20% RR	43	16	29.500	24
Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	55	7	31.000	25
Incineration for heat and electricity Post collection recycling	24	39	31.500	26
Incineration for heat and electricity Source segregation25% RR	5	62	33.500	27
Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	10	57	33.500	27
Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	30	38	34.000	29
Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation50% RR	15	55	35.000	30
Incineration for heat and Anaerobic Digestion for heat Post process recycling	65	10	37.500	31
Incineration for heat and Anaerobic Digestion for electricity Post process recycling	62	14	38.000	32
Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	23	54	38.500	33
Incineration for heat No recycling	80	3	41.500	34
Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 20% RR	46	37	41.500	34
Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	83	1	42.000	36
Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation43% RR	28	58	43.000	37
Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	57	29	43.000	37
Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	45	44	44.500	39
Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	40	50	45.000	40
Incineration for heat and electricity Source segregation34% RR	2	89	45.500	41
Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	32	59	45.500	41
Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	39	53	46.000	43

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LCIA ranking for THUR scenarios

scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	85	7	46.000	43
Incineration for heat and electricity Post process recycling	59	34	46.500	45
Incineration for electricity Source segregation 25% RR	7	86	46.500	45
Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	48	45	46.500	45
Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation43% RR	37	56	46.500	45
Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	22	71	46.500	45
Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation50% RR	29	65	47.000	50
Incineration for electricity Source segregation 34% RR	3	92	47.500	51
Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	64	32	48.000	52
Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 20% RR	50	49	49.500	53
Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	19	81	50.000	54
Incineration for heat and Anaerobic Digestion for heat No recycling	91	10	50.500	55
Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation20% RR	53	48	50.500	55
Incineration for heat and Anaerobic Digestion for electricity No recycling	88	14	51.000	57
Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	44	63	53.500	58
Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	70	41	55.500	59
Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	33	80	56.500	60
Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	67	46	56.500	60
Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	87	30	58.500	62
Incineration for electricity and Anaerobic Digestion for electricity Source segregation50% RR	31	87	59.000	63
Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	68	51	59.500	64

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LCIA ranking for THUR scenarios

scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
Incineration for heat and electricity No recycling	86	34	60.000	65
Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation20% RR	58	64	61.000	66
Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	90	32	61.000	66
Incineration for electricity and Anaerobic Digestion for heat Source segregation50% RR	38	85	61.500	68
Incineration for electricity and Anaerobic Digestion for electricity Source segregation43% RR	42	83	62.500	69
Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	56	70	63.000	70
Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	51	76	63.500	71
Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	69	60	64.500	72
Incineration for electricity and Anaerobic Digestion for heat Source segregation43% RR	47	82	64.500	72
Incineration for electricity Post process recycling	66	66	66.000	74
Incineration for electricity Post collection recycling	54	78	66.000	74
Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 20% RR	60	72	66.000	74
Incineration for electricity and Anaerobic Digestion for electricity Source segregation20% RR	61	77	69.000	77
Incineration for electricity and Anaerobic Digestion for heat Source segregation20% RR	63	75	69.000	77
Incineration for heat and electricity and Anaerobic Digestion for heat No recyclin	97	41	69.000	77
Incineration for electricity and Anaerobic Digestion for heat Post process recycling	72	68	70.000	80
Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	94	46	70.000	80
Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	71	73	72.000	82
Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	95	51	73.000	83
Anaerobic Digestion for vehicle fuel Post collection recycling	73	79	76.000	84
Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	96	60	78.000	85
Incineration for electricity No recyclin	92	66	79.000	86

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LCIA ranking for THUR scenarios

scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
Anaerobic Digestion for vehicle fuel Source segregation 50% RR	75	84	79.500	87
Anaerobic Digestion for heat and electricity Post collection recycling	74	91	82.500	88
Incineration for electricity and Anaerobic Digestion for heat No recycling	99	68	83.500	89
Anaerobic Digestion for vehicle fuel Source segregation 43% RR	82	88	85.000	90
Anaerobic Digestion for heat and electricity Source segregation 50% RR	77	93	85.000	91
Incineration for electricity and Anaerobic Digestion for electricity No recycling	98	73	85.500	92
Anaerobic Digestion for heat Post collection recycling	78	95	86.500	93
Anaerobic Digestion for electricity Post collection recycling	76	100	88.000	94
Anaerobic Digestion for heat and electricity Source segregation 43% RR	84	94	89.000	95
Anaerobic Digestion for heat Source segregation 50% RR	81	97	89.000	95
Anaerobic Digestion for electricity Source segregation 50% RR	79	104	91.500	97
Anaerobic Digestion for vehicle fuel Source segregation 25% RR	100	90	95.000	98
Anaerobic Digestion for heat Source segregation 43% RR	93	98	95.500	99
Anaerobic Digestion for electricity Source segregation 43% RR	89	103	96.000	100
Anaerobic Digestion for heat and electricity Source segregation 25% RR	101	96	98.500	101
Anaerobic Digestion for heat Source segregation 25% RR	103	99	101.000	102
Anaerobic Digestion for electricity Source segregation 25% RR	102	102	102.000	103
Anaerobic Digestion for electricity No recycling (landfill)	104	101	102.500	104

Appendix E

LCIA ranking for THRU scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
14 IN THRU	Incineration for heat Source segregation 34% RR	1	1	1	19	17	1	6.67	1
15 IN THRU	Incineration for heat and electricity Source segregation 34% RR	2	2	2	18	18	2	7.33	2
73 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 93% RR 100 % capture rate	3	4	4	13	16	4	7.33	2
13 IN THRU	Incineration for electricity Source segregation 34% RR	4	3	3	17	19	3	8.17	4
36 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	15	10	10	11	1	10	9.50	5
08 IN THRU	Incineration for heat Post collection recycling	13	12	12	16	5	6	10.67	6
12 IN THRU	Incineration for heat and electricity Source segregation 25% RR	7	6	6	25	26	7	12.83	7
09 IN THRU	Incineration for heat and electricity Post collection recycling	26	15	15	7	8	11	13.67	8
60 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	27	13	13	2	2	28	14.17	9
11 IN THRU	Incineration for heat Source segregation 25% RR	6	5	5	45	25	5	15.17	10
10 IN THRU	Incineration for electricity Source segregation 25% RR	11	8	8	23	28	15	15.50	11
35 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	19	26	26	12	4	8	15.83	12
18 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 93% RR 100% capture rate	5	7	7	32	24	25	16.67	13
48 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	8	9	9	35	27	12	16.67	13
72 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	10	11	11	22	29	20	17.17	15
59 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	30	29	29	5	6	17	19.33	16
12 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	40	16	16	1	3	46	20.33	17
33 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	28	31	31	14	7	14	20.83	18
24 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	18	14	14	21	30	36	22.17	19
71 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	14	24	24	30	32	18	23.67	20
47 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	9	23	23	48	31	9	23.83	21
44 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	12	17	17	47	40	16	24.83	22
57 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	39	34	34	6	9	32	25.67	23

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LCIA ranking for THRU scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
68 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	20	18	18	27	41	30	25.67	23
34 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	33	38	38	15	10	21	25.83	25
23 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	21	27	27	29	34	33	28.50	26
11 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	45	39	39	3	11	38	29.17	27
45 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	17	28	28	49	33	22	29.50	28
07 IN THRU	Incineration for electricity Post collection recycling	56	20	20	10	15	57	29.67	29
20 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	31	19	19	26	42	48	30.83	30
69 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	25	30	30	33	35	37	31.67	31
58 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	47	41	41	9	12	43	32.17	32
43 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	16	32	32	59	43	13	32.50	33
67 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	24	35	35	39	44	27	34.00	34
09 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	52	45	45	4	13	54	35.50	35
46 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation50% RR	23	33	33	57	36	35	36.17	36
21 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	35	37	37	31	37	53	38.33	37
41 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	22	40	40	60	45	23	38.33	37
70 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	32	36	36	38	38	51	38.50	39
40 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	37	21	21	70	52	31	38.67	40
10 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	58	48	48	8	14	60	39.33	41
64 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	48	22	22	46	53	52	40.50	42
65 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	34	43	43	41	46	41	41.33	43

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LCIA ranking for THRU scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
19 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	36	44	44	37	47	42	41.67	44
22 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	43	42	42	36	39	62	44.00	45
42 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	29	46	46	64	48	34	44.50	46
16 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	59	25	25	44	54	68	45.83	47
66 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	41	47	47	43	49	50	46.17	48
39 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 25% RR	38	51	51	72	55	19	47.67	49
17 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	46	49	49	40	50	56	48.33	50
37 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 25% RR	42	52	52	73	56	26	50.17	51
18 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	50	50	50	42	51	63	51.00	52
63 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	51	53	53	54	58	40	51.50	53
38 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 25% RR	44	54	54	74	57	29	52.00	54
61 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 25% RR	54	55	55	56	59	44	53.83	55
62 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 25% RR	55	56	56	58	60	49	55.67	56
05 IN THRU	Incineration for heat Post process recycling	49	59	59	77	67	24	55.83	57
05 AD THRU	Anaerobic Digestion for vehicle fuel Post collection recycling	75	62	62	20	20	96	55.83	57
15 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	61	57	57	51	61	59	57.67	59
04 AD THRU	Anaerobic Digestion for heat and electricity Post collection recycling	76	67	67	24	21	97	58.67	60
32 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	53	61	61	71	64	47	59.50	61
13 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 25% RR	64	58	58	53	62	64	59.83	62
06 IN THRU	Incineration for heat and electricity Post process recycling	60	63	63	63	69	45	60.50	63

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LCIA ranking for THRU scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
02 AD THRU	Anaerobic Digestion for electricity Post collection recycling	77	68	68	28	22	100	60.50	63
14 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 25% RR	65	60	60	55	63	66	61.50	65
56 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	62	64	64	52	65	65	62.00	66
03 AD THRU	Anaerobic Digestion for heat Post collection recycling	80	69	69	34	23	101	62.67	67
31 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	57	70	70	75	68	39	63.17	68
08 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	70	65	65	50	66	72	64.67	69
55 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	66	71	71	66	70	58	67.00	70
04 IN THRU	Incineration for electricity Post process recycling	69	66	66	61	74	67	67.17	71
29 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	63	72	72	76	71	55	68.17	72
53 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	68	74	74	67	72	69	70.67	73
30 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Post process recycling	67	75	75	78	73	61	71.50	74
07 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	71	76	76	62	75	70	71.67	75
54 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	72	77	77	69	76	71	73.67	76
05 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	73	78	78	65	77	73	74.00	77
06 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	74	79	79	68	78	74	75.33	78
17 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	78	73	73	79	79	90	78.67	79
16 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 50% RR	79	81	81	80	80	89	81.67	80
14 AD THRU	Anaerobic Digestion for electricity Source segregation 50% RR	81	82	82	81	81	92	83.17	81
13 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	85	80	80	83	83	95	84.33	82
15 AD THRU	Anaerobic Digestion for heat Source segregation 50% RR	84	83	83	82	82	94	84.67	83
12 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 43% RR	87	84	84	84	84	93	86.00	84
10 AD THRU	Anaerobic Digestion for electricity Source segregation 43% RR	92	85	85	85	85	98	88.33	85

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LCIA ranking for THRU scenarios

scenario code	scenario name	climate change ranking	acidification ranking	eutrophication ranking	freshwater aquatic ecotoxicity ranking	human toxicity ranking	resources ranking	average ranking	combined ranking
02 IN THRU	Incineration for heat No recycling	82	92	92	104	94	75	89.83	86
11 AD THRU	Anaerobic Digestion for heat Source segregation 43% RR	96	86	86	86	86	99	89.83	86
28 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	83	93	93	101	91	78	89.83	86
52 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	89	95	95	92	92	82	90.83	89
03 IN THRU	Incineration for heat and electricity No recycling	88	94	94	97	96	77	91.00	90
09 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	102	87	87	87	87	103	92.17	91
27 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	86	98	98	102	95	76	92.50	92
08 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 25% RR	103	88	88	88	88	102	92.83	93
04 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	97	97	97	91	93	87	93.67	94
51 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	91	99	99	96	97	80	93.67	94
06 AD THRU	Anaerobic Digestion for electricity Source segregation 25% RR	104	89	89	89	89	104	94.00	96
01 IN THRU	Incineration for electricity No recycling	95	96	96	94	101	83	94.17	97
07 AD THRU	Anaerobic Digestion for heat Source segregation 25% RR	105	90	90	90	90	105	95.00	98
25 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity No recycling	90	100	100	103	98	79	95.00	98
49 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	94	101	101	98	99	84	96.17	100
03 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	98	103	103	93	102	85	97.33	101
26 C1 THRU	Incineration for heat and Anaerobic Digestion for heat No recycling	93	102	102	106	100	81	97.33	101
50 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	99	104	104	100	103	86	99.33	103
01 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity No recycling	100	105	105	95	104	88	99.50	104
01 AD THRU	Anaerobic Digestion for electricity No recycling (landfill)	106	91	91	105	106	106	100.83	105
02 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat No recycling	101	106	106	99	105	91	101.33	106

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LCIA ranking for THRU scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking
36 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	5	5	5.00	1
08 IN THRU	Incineration for heat Post collection recycling	6	6	6.00	2
35 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	12	12	12.00	3
11 IN THRU	Incineration for heat Source segregation 25% RR	10	24	17.00	4
48 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation50% RR	13	21	17.00	4
14 IN THRU	Incineration for heat Source segregation 34% RR	1	36	18.50	6
33 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	18	19	18.50	6
60 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	9	31	20.00	8
44 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation43% RR	22	20	21.00	9
34 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	25	18	21.50	10
09 IN THRU	Incineration for heat and electricity Post collection recycling	8	39	23.50	11
47 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation50% RR	21	26	23.50	11
40 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation25% RR	40	9	24.50	13
73 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 93% RR 100 % capture rate	2	49	25.50	14
59 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	16	38	27.00	15
43 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation43% RR	33	22	27.50	16
45 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation50% RR	28	28	28.00	17
72 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	15	43	29.00	18
05 IN THRU	Incineration for heat Post process recycling	57	3	30.00	19
32 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	61	1	31.00	20
39 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation25% RR	49	13	31.00	20
41 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation43% RR	37	25	31.00	20
46 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation50% RR	36	27	31.50	23

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LCIA ranking for THRU scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking
68 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	23	40	31.50	23
37 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation25% RR	51	17	34.00	25
18 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 93% RR 100% capture rate	13	56	34.50	26
42 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation43% RR	46	23	34.50	26
38 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation25% RR	54	16	35.00	28
12 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	17	54	35.50	29
12 IN THRU	Incineration for heat and electricity Source segregation25% RR	7	65	36.00	30
57 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	23	50	36.50	31
31 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	68	7	37.50	32
24 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation50% RR	19	57	38.00	33
58 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	32	44	38.00	33
64 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	42	37	39.50	35
71 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	20	59	39.50	35
30 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Post process recycling	74	10	42.00	37
29 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	72	14	43.00	38
28 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	86	1	43.50	39
02 IN THRU	Incineration for heat No recycling	86	3	44.50	40
67 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	34	55	44.50	40
20 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation43% RR	30	60	45.00	42
11 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	27	64	45.50	43

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LCIA ranking for THRU scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking
15 IN THRU	Incineration for heat and electricity Source segregation 34% RR	2	91	46.50	44
56 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	66	29	47.50	45
06 IN THRU	Incineration for heat and electricity Post process recycling	63	34	48.50	46
13 IN THRU	Incineration for electricity Source segregation 34% RR	4	94	49.00	47
63 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	53	45	49.00	47
10 IN THRU	Incineration for electricity Source segregation 25% RR	11	88	49.50	49
27 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	92	7	49.50	49
55 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	70	32	51.00	51
62 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 25% RR	56	48	52.00	52
65 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	43	61	52.00	53
69 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	31	73	52.00	53
61 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 25% RR	55	51	53.00	55
66 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	48	58	53.00	55
70 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	39	67	53.00	55
07 IN THRU	Incineration for electricity Post collection recyclinc	29	80	54.50	58
23 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	26	83	54.50	58
26 C1 THRU	Incineration for heat and Anaerobic Digestion for heat No recycling	101	10	55.50	60
25 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity No recycling	98	14	56.00	61
09 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	35	78	56.50	62
10 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	41	72	56.50	62

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LCIA ranking for THRU scenarios

scenario code	**scenario name**	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking
16 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation25% RR	47	66	56.50	62
54 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	76	41	58.50	65
52 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	89	29	59.00	66
53 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	73	46	59.50	67
08 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	69	52	60.50	68
03 IN THRU	Incineration for heat and electricity No recycling	90	34	62.00	69
19 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation43% RR	44	82	63.00	70
21 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation50% RR	37	89	63.00	70
51 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	94	32	63.00	70
22 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation50% RR	45	87	66.00	73
15 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation25% RR	59	74	66.50	74
17 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation43% RR	50	85	67.50	75
18 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation43% RR	52	84	68.00	76
07 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	75	62	68.50	77
05 AD THRU	Anaerobic Digestion for vehicle fuel Post collection recycling	57	81	69.00	78
04 IN THRU	Incineration for electricity Post process recycling	71	68	69.50	79
13 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation25% RR	62	79	70.50	80
14 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation25% RR	65	77	71.00	81
50 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	103	41	72.00	82
04 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	94	52	73.00	83
49 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	100	46	73.00	83
06 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	78	70	74.00	85

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LCIA ranking for THRU scenarios

scenario code	scenario name	combined LCIA ranking	Energy recovered ranking	average	combined LCIA and energy recovered ranking
05 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	77	75	76.00	86
04 AD THRU	Anaerobic Digestion for heat and electricity Post collection recycling	60	93	76.50	87
03 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	101	62	81.50	88
03 AD THRU	Anaerobic Digestion for heat Post collection recycling	67	97	82.00	89
01 IN THRU	Incineration for electricity No recycling	97	68	82.50	90
02 AD THRU	Anaerobic Digestion for electricity Post collection recycling	63	102	82.50	90
17 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	79	86	82.50	90
13 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	82	90	86.00	93
16 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 50% RR	80	95	87.50	94
02 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat No recycling	106	70	88.00	95
01 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity No recycling	104	75	89.50	96
12 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 43% RR	84	96	90.00	97
15 AD THRU	Anaerobic Digestion for heat Source segregation 50% RR	83	99	91.00	98
09 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	91	92	91.50	99
11 AD THRU	Anaerobic Digestion for heat Source segregation 43% RR	86	100	93.00	100
14 AD THRU	Anaerobic Digestion for electricity Source segregation 50% RR	81	106	93.50	101
10 AD THRU	Anaerobic Digestion for electricity Source segregation 43% RR	85	105	95.00	102
08 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 25% RR	93	98	95.50	103
07 AD THRU	Anaerobic Digestion for heat Source segregation 25% RR	98	101	99.50	104
06 AD THRU	Anaerobic Digestion for electricity Source segregation 25% RR	96	104	100.00	105
01 AD THRU	Anaerobic Digestion for electricity No recycling (landfill)	105	103	104.00	106

Appendix E

LCIA ranking for THRU scenarios

scenario code	scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
08 IN THRU	Incineration for heat Post collection recycling	13	6	9.50	1
36 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	15	5	10	2
48 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	8	21	14.50	3
11 IN THRU	Incineration for heat Source segregation 25% RR	6	24	15.00	4
35 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	19	12	15.50	5
44 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	12	20	16.00	6
47 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	9	26	17.50	7
14 IN THRU	Incineration for heat Source segregation 34% RR	1	36	18.50	8
43 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	16	22	19.00	9
45 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	17	28	22.50	10
40 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	37	9	23.00	11
33 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	28	19	23.50	12
41 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	22	25	23.50	12
46 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 50% RR	23	27	25.00	14
34 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	33	18	25.50	15
39 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 25% RR	38	13	25.50	15
05 IN THRU	Incineration for heat Post process recycling	49	3	26.00	17
42 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	29	23	26.00	17
73 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 93% RR 100 % capture rate	3	49	26.00	17
72 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	10	43	26.50	20
32 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	53	1	27.00	21
60 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	27	31	29.00	22
37 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 25% RR	42	17	29.50	23

Appendix E

LCIA ranking for THRU scenarios

scenario code	scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
38 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation25% RR	44	16	30.00	24
68 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation43% RR	20	40	30.00	24
18 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 93% RR 100% capture rate	5	56	30.50	26
31 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	57	7	32.00	27
09 IN THRU	Incineration for heat and electricity Post collection recycling	26	39	32.50	28
59 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	30	38	34.00	29
12 IN THRU	Incineration for heat and electricity Source segregation 25% RR	7	65	36.00	30
71 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	14	59	36.50	31
24 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation50% RR	18	57	37.50	32
29 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	63	14	38.50	33
30 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Post process recycling	67	10	38.50	33
67 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	24	55	39.50	35
28 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	83	1	42.00	36
02 IN THRU	Incineration for heat No recycling	82	3	42.50	37
64 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation25% RR	48	37	42.50	37
57 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	39	50	44.50	39
20 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation43% RR	31	60	45.50	40
56 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	62	29	45.50	40
58 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	47	44	45.50	40
15 IN THRU	Incineration for heat and electricity Source segregation 34% RR	2	91	46.50	43

Appendix E

LCIA ranking for THRU scenarios

scenario code	scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
27 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	86	7	46.50	43
06 IN THRU	Incineration for heat and electricity Post process recycling	60	34	47.00	45
12 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	40	54	47.00	45
65 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation43% RR	34	61	47.50	47
63 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	51	45	48.00	48
13 IN THRU	Incineration for electricity Source segregation 34% RR	4	94	49.00	49
55 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	66	32	49.00	49
69 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation50% RR	25	73	49.00	49
10 IN THRU	Incineration for electricity Source segregation 25% RR	11	88	49.50	52
66 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation43% RR	41	58	49.50	52
70 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation50% RR	32	67	49.50	52
26 C1 THRU	Incineration for heat and Anaerobic Digestion for heat No recycling	93	10	51.50	55
62 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation25% RR	55	48	51.50	55
23 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation50% RR	21	83	52.00	57
25 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity No recycling	90	14	52.00	57
61 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation25% RR	54	51	52.50	59
11 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	45	64	54.50	60
54 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	72	41	56.50	61
53 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	68	46	57.00	62
19 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation43% RR	36	82	59.00	63

Appendix E

LCIA ranking for THRU scenarios

scenario code	scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
52 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	89	29	59.00	63
03 IN THRU	Incineration for heat and electricity No recycling	88	34	61.00	65
08 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	70	52	61.00	65
51 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	91	32	61.50	67
21 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation50% RR	35	89	62.00	68
16 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation25% RR	59	66	62.50	69
09 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	52	78	65.00	70
10 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	58	72	65.00	70
22 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation50% RR	43	87	65.00	70
17 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation43% RR	46	85	65.50	73
07 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	71	62	66.50	74
18 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation43% RR	50	84	67.00	75
15 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation25% RR	61	74	67.50	76
07 IN THRU	Incineration for electricity Post collection recycling	56	80	68.00	77
04 IN THRU	Incineration for electricity Post process recycling	69	68	68.50	78
49 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity No recyclin	94	46	70.00	79
50 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	99	41	70.00	79
14 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation25% RR	65	77	71.00	81
13 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation25% RR	64	79	71.50	82
06 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Post process recyclin	74	70	72.00	83
05 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	73	75	74.00	84
04 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recyclin	97	52	74.50	85

Appendix E

LCIA ranking for THRU scenarios

scenario code	scenario name	climate change ranking	Energy recovered ranking	average	combined energy and climate change ranking
05 AD THRU	Anaerobic Digestion for vehicle fuel Post collection recycling	75	81	78.00	86
03 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	98	62	80.00	87
01 IN THRU	Incineration for electricity No recycling	95	68	81.50	88
17 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	78	86	82.00	89
04 AD THRU	Anaerobic Digestion for heat and electricity Post collection recycling	76	93	84.50	90
02 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat No recycling	101	70	85.50	91
16 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 50% RR	79	95	87.00	92
13 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	85	90	87.50	93
01 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity No recycling	100	75	87.50	93
03 AD THRU	Anaerobic Digestion for heat Post collection recycling	80	97	88.50	95
02 AD THRU	Anaerobic Digestion for electricity Post collection recycling	77	102	89.50	96
12 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 43% RR	87	96	91.50	97
15 AD THRU	Anaerobic Digestion for heat Source segregation 50% RR	84	99	91.50	97
14 AD THRU	Anaerobic Digestion for electricity Source segregation 50% RR	81	106	93.50	99
09 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	102	92	97.00	100
11 AD THRU	Anaerobic Digestion for heat Source segregation 43% RR	96	100	98.00	101
10 AD THRU	Anaerobic Digestion for electricity Source segregation 43% RR	92	105	98.50	102
08 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 25% RR	103	98	100.50	103
07 AD THRU	Anaerobic Digestion for heat Source segregation 25% RR	105	101	103.00	104
06 AD THRU	Anaerobic Digestion for electricity Source segregation 25% RR	104	104	104.00	105
01 AD THRU	Anaerobic Digestion for electricity No recycling (landfill)	106	103	104.50	106

Appendix F

Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
UK	Urban	Incineration only	electricity		none	
UK	Urban	Incineration only	heat		none	
UK	Urban	Incineration only	heat and electricity		none	
UK	Urban	Incineration only	electricity		post process	
UK	Urban	Incineration only	heat		post process	
UK	Urban	Incineration only	heat and electricity		post process	
UK	Urban	Incineration only	electricity		post collection	
UK	Urban	Incineration only	heat		post collection	
UK	Urban	Incineration only	heat and electricity		post collection	
UK	Urban	Incineration only	electricity		source segregation	25
UK	Urban	Incineration only	heat		source segregation	25
UK	Urban	Incineration only	heat and electricity		source segregation	25
UK	Urban	Incineration only	electricity		source segregation	43
UK	Urban	Incineration only	heat		source segregation	43
UK	Urban	Incineration only	heat and electricity		source segregation	43
UK	Urban	Incineration only	electricity		source segregation	50
UK	Urban	Incineration only	heat		source segregation	50
UK	Urban	Incineration only	heat and electricity		source segregation	50
UK	Urban	Anaerobic Digestion only		electricity	none	
UK	Urban	Anaerobic Digestion only		electricity	post collection	
UK	Urban	Anaerobic Digestion only		heat	post collection	
UK	Urban	Anaerobic Digestion only		heat and electricity	post collection	
UK	Urban	Anaerobic Digestion only		vehicle fuel	post collection	
UK	Urban	Anaerobic Digestion only		electricity	source segregation	25
UK	Urban	Anaerobic Digestion only		heat	source segregation	25
UK	Urban	Anaerobic Digestion only		heat and electricity	source segregation	25

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
01 IN UKUR	795.7	-62.1	0.0141	0.0306	-0.494	-7.77	-1.3
02 IN UKUR	2,606.7	-66.1	0.081	0.043	0.0822	-15	-1.36
03 IN UKUR	1,151.9	-70.3	0.0169	0.0317	-0.533	-9.88	-1.37
04 IN UKUR	795.7	-100	-0.15	0.0153	-12.4	-140	-1.57
05 IN UKUR	2,606.7	-104	-0.0828	0.0278	-11.9	-147	-1.63
06 IN UKUR	1,151.9	-108	-0.147	0.0164	-12.5	-142	-1.64
07 IN UKUR	772.5	-116	-0.199	0.012	-14	-164	-1.66
08 IN UKUR	2,538.0	-120	-0.133	0.0242	-13.4	-172	-1.72
09 IN UKUR	1,119.8	-124	-0.196	0.0131	-14	-167	-1.73
10 IN UKUR	747.0	-103	-0.178	0.0134	-12.3	-142	-1.58
11 IN UKUR	2,363.7	-101	-0.11	0.0256	-11.7	-148	-1.59
12 IN UKUR	1,081.5	-111	-0.175	0.0145	-12.4	-144	-1.64
13 IN UKUR	429.0	-122	-0.36	0.00102	-11.6	-157	-1.64
14 IN UKUR	1,313.0	-117	-0.318	0.00832	-11.2	-159	-1.62
15 IN UKUR	718.3	-129	-0.357	0.00194	-11.7	-158	-1.7
16 IN UKUR	332.1	-128	-0.416	-0.00283	-11.4	-161	-1.66
17 IN UKUR	1,016.4	-124	-0.383	0.00282	-11.1	-163	-1.65
18 IN UKUR	556.0	-133	-0.414	-0.00212	-11.4	-162	-1.71
01 AD UKUR	183.7	84.9	0.0268	0.0458	0.446	0.887	-0.242
02 AD UKUR	184.8	15.3	-0.0941	0.0282	-11.6	-146	-0.597
03 AD UKUR	218.5	20.6	-0.0859	0.0292	-11.4	-146	-0.558
04 AD UKUR	269.5	9.4	-0.0994	0.0276	-11.7	-147	-0.648
05 AD UKUR	443.7	7.58	-0.105	0.0237	-12	-149	-0.658
06 AD UKUR	162.6	30.3	-0.0945	0.0338	-2.92	-47.1	-0.577
07 AD UKUR	179.3	32.9	-0.0904	0.0344	-2.85	-46.9	-0.558
08 AD UKUR	204.8	27.4	-0.0972	0.0335	-2.95	-47.5	-0.602

Appendix F

Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	combined LCIA and energy ranking (within country and density group)
01 IN UKUR	Incineration for electricity No recycling	87
02 IN UKUR	Incineration for heat No recycling	52
03 IN UKUR	Incineration for heat and electricity No recycling	71
04 IN UKUR	Incineration for electricity Post process recycling	70
05 IN UKUR	Incineration for heat Post process recycling	22
06 IN UKUR	Incineration for heat and electricity Post process recycling	30
07 IN UKUR	Incineration for electricity Post collection recycling	30
08 IN UKUR	Incineration for heat Post collection recycling	1
09 IN UKUR	Incineration for heat and electricity Post collection recycling	5
10 IN UKUR	Incineration for electricity Source segregation 25% RR	76
11 IN UKUR	Incineration for heat Source segregation 25% RR	43
12 IN UKUR	Incineration for heat and electricity Source segregation 25% RR	35
13 IN UKUR	Incineration for electricity Source segregation 43% RR	55
14 IN UKUR	Incineration for heat Source segregation 43% RR	8
15 IN UKUR	Incineration for heat and electricity Source segregation 43% RR	42
16 IN UKUR	Incineration for electricity Source segregation 50% RR	57
17 IN UKUR	Incineration for heat Source segregation 50% RR	15
18 IN UKUR	Incineration for heat and electricity Source segregation 50% RR	47
01 AD UKUR	Anaerobic Digestion for electricity No recycling (landfill)	107
02 AD UKUR	Anaerobic Digestion for electricity Post collection recycling	101
03 AD UKUR	Anaerobic Digestion for heat Post collection recycling	99
04 AD UKUR	Anaerobic Digestion for heat and electricity Post collection recycling	95
05 AD UKUR	Anaerobic Digestion for vehicle fuel Post collection recycling	89
06 AD UKUR	Anaerobic Digestion for electricity Source segregation 25% RR	105
07 AD UKUR	Anaerobic Digestion for heat Source segregation 25% RR	105
08 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 25% RR	104

Appendix F

Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
UK	Urban	Anaerobic Digestion only		vehicle fuel	source segregation	25
UK	Urban	Anaerobic Digestion only		electricity	source segregation	43
UK	Urban	Anaerobic Digestion only		heat	source segregation	43
UK	Urban	Anaerobic Digestion only		heat and electricity	source segregation	43
UK	Urban	Anaerobic Digestion only		vehicle fuel	source segregation	43
UK	Urban	Anaerobic Digestion only		electricity	source segregation	50
UK	Urban	Anaerobic Digestion only		heat	source segregation	50
UK	Urban	Anaerobic Digestion only		heat and electricity	source segregation	50
UK	Urban	Anaerobic Digestion only		vehicle fuel	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	electricity	electricity	none	
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat	none	
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	none	
UK	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	none	
UK	Urban	Incineration and Anaerobic Digestion	electricity	electricity	post process	
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat	post process	
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	post process	
UK	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	post process	
UK	Urban	Incineration and Anaerobic Digestion	electricity	electricity	post collection	
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat	post collection	
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	post collection	
UK	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	post collection	
UK	Urban	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat	source segregation	43

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
09 AD UKUR	291.6	26.5	-0.102	0.0312	-3.15	-48.4	-0.606
10 AD UKUR	147.3	-9.07	-0.182	0.0252	-5.33	-81.5	-0.82
11 AD UKUR	176.2	-4.59	-0.175	0.026	-5.22	-81.2	-0.787
12 AD UKUR	219.9	-14.2	-0.187	0.0247	-5.4	-82.2	-0.864
13 AD UKUR	369.2	-15.7	-0.192	0.0213	-5.72	-83.7	-0.874
14 AD UKUR	142.1	-22.8	-0.213	0.0221	-6.18	-93.5	-0.905
15 AD UKUR	175.1	-17.7	-0.205	0.0232	-6.04	-93.1	-0.866
16 AD UKUR	225.2	-28.6	-0.218	0.0216	-6.25	-94.3	-0.955
17 AD UKUR	396.1	-30.4	-0.223	0.0179	-6.61	-95.9	-0.967
01 C1 UKUR	773.8	-56.4	0.0423	0.0341	-0.46	-7.38	-1.24
02 C1 UKUR	792.2	-53.5	0.0468	0.0347	-0.387	-7.15	-1.22
03 C1 UKUR	820.0	-59.6	0.0394	0.0338	-0.502	-7.82	-1.27
04 C1 UKUR	915.0	-60.6	0.0337	0.0312	-0.722	-8.84	-1.27
05 C1 UKUR	773.8	-94.4	-0.122	0.0189	-12.4	-139	-1.51
06 C1 UKUR	792.2	-91.5	-0.117	0.0194	-12.3	-139	-1.49
07 C1 UKUR	820.0	-97.6	-0.125	0.0185	-12.4	-140	-1.54
08 C1 UKUR	915.0	-98.6	-0.13	0.0159	-12.6	-141	-1.54
09 C1 UKUR	754.7	-112	-0.174	0.0151	-14.1	-165	-1.62
10 C1 UKUR	773.0	-109	-0.17	0.0156	-14	-164	-1.6
11 C1 UKUR	800.9	-115	-0.177	0.0148	-14.1	-165	-1.65
12 C1 UKUR	895.8	-116	-0.178	0.0131	-14.3	-166	-1.66
13 C1 UKUR	768.7	-101	-0.159	0.015	-12.4	-141	-1.56
14 C1 UKUR	771.3	-100	-0.158	0.0151	-12.4	-141	-1.56
15 C1 UKUR	775.3	-101	-0.159	0.0149	-12.4	-141	-1.56
16 C1 UKUR	788.8	-101	-0.164	0.0138	-12.4	-141	-1.56
17 C1 UKUR	604.2	-105	-0.22	0.0122	-12	-147	-1.55
18 C1 UKUR	622.6	-102	-0.216	0.0127	-11.9	-147	-1.53

Appendix F

Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
09 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	98
10 AD UKUR	Anaerobic Digestion for electricity Source segregation 43% RR	103
11 AD UKUR	Anaerobic Digestion for heat Source segregation 43% RR	102
12 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 43% RR	95
13 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	92
14 AD UKUR	Anaerobic Digestion for electricity Source segregation 50% RR	99
15 AD UKUR	Anaerobic Digestion for heat Source segregation 50% RR	97
16 AD UKUR	Anaerobic Digestion for heat and electricity Source segregation 50% RR	93
17 AD UKUR	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	90
01 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity No recycling	94
02 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat No recycling	90
03 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	88
04 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	86
05 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	85
06 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	82
07 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	74
08 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	64
09 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	52
10 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	55
11 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	24
12 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	15
13 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 25% RR	79
14 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 25% RR	81
15 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	74
16 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	69
17 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	77
18 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	80

Appendix F

Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	heat	electricity	none	
UK	Urban	Incineration and Anaerobic Digestion	heat	heat	none	
UK	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	none	
UK	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	none	
UK	Urban	Incineration and Anaerobic Digestion	heat	electricity	post process	
UK	Urban	Incineration and Anaerobic Digestion	heat	heat	post process	
UK	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	post process	
UK	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	post process	
UK	Urban	Incineration and Anaerobic Digestion	heat	electricity	post collection	
UK	Urban	Incineration and Anaerobic Digestion	heat	heat	post collection	
UK	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	post collection	
UK	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	post collection	
UK	Urban	Incineration and Anaerobic Digestion	heat	electricity	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	heat	heat	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	heat	electricity	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	heat	heat	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	heat	electricity	source segregation	50

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
19 C1 UKUR	650.4	-108	-0.223	0.0118	-12	-148	-1.58
20 C1 UKUR	745.4	-109	-0.228	0.00937	-12.2	-149	-1.58
21 C1 UKUR	550.5	-107	-0.241	0.0112	-11.9	-149	-1.55
22 C1 UKUR	574.1	-103	-0.235	0.0119	-11.8	-149	-1.52
23 C1 UKUR	609.9	-111	-0.244	0.0108	-11.9	-150	-1.58
24 C1 UKUR	732.0	-112	-0.249	0.00786	-12.2	-151	-1.59
25 C1 UKUR	2,478.8	-60.1	0.105	0.0459	0.0821	-14.2	-1.3
26 C1 UKUR	2,497.2	-57.3	0.11	0.0464	0.155	-13.9	-1.28
27 C1 UKUR	2,525.0	-63.4	0.102	0.0456	0.0404	-14.6	-1.33
28 C1 UKUR	2,620.0	-64.4	0.0966	0.043	-0.18	-15.6	-1.33
29 C1 UKUR	2,478.8	-98.1	-0.0589	0.0306	-11.8	-146	-1.57
30 C1 UKUR	2,329.5	-83.2	-0.0443	0.0321	-11.6	-144	-1.45
31 C1 UKUR	2,525.0	-101	-0.0618	0.0303	-11.9	-146	-1.6
32 C1 UKUR	2,620.0	-102	-0.0675	0.0277	-12.1	-148	-1.6
33 C1 UKUR	2,415.9	-115	-0.113	0.0265	-13.5	-171	-1.68
34 C1 UKUR	2,434.2	-113	-0.108	0.0271	-13.5	-171	-1.66
35 C1 UKUR	2,462.1	-119	-0.116	0.0262	-13.6	-172	-1.71
36 C1 UKUR	2,557.0	-120	-0.116	0.0245	-13.8	-172	-1.72
37 C1 UKUR	2,509.2	-104	-0.0947	0.027	-11.8	-148	-1.62
38 C1 UKUR	2,511.8	-104	-0.0941	0.0271	-11.8	-148	-1.62
39 C1 UKUR	2,515.8	-105	-0.0951	0.0269	-11.8	-148	-1.63
40 C1 UKUR	2,529.3	-105	-0.1	0.0258	-11.9	-148	-1.62
41 C1 UKUR	1,921.6	-108	-0.171	0.0212	-11.6	-152	-1.6
42 C1 UKUR	1,940.0	-105	-0.167	0.0218	-11.5	-152	-1.58
43 C1 UKUR	1,967.8	-111	-0.174	0.0209	-11.6	-153	-1.62
44 C1 UKUR	2,062.8	-112	-0.179	0.0184	-11.8	-154	-1.63
45 C1 UKUR	1,726.8	-109	-0.197	0.0193	-11.5	-154	-1.59

Appendix F

Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	combined LCIA and energy ranking (within country and density group)
19 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	65
20 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	59
21 C1 UKUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	71
22 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	78
23 C1 UKUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	63
24 C1 UKUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	51
25 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity No recycling	66
26 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat No recycling	67
27 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	61
28 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	49
29 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	45
30 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Post process recycling	57
31 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	36
32 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	20
33 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	7
34 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	8
35 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	4
36 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	2
37 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 25% RR	29
38 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 25% RR	33
39 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 25% RR	23
40 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	20
41 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	27
42 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	36
43 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	19
44 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	11
45 C1 UKUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	24

Appendix F

Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
UK	Urban	Incineration and Anaerobic Digestion	heat	heat	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	none	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	none	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	none	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	none	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	post process	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	post process	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	post process	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	post process	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	post collection	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	post collection	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	post collection	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	post collection	
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	25
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	43
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	50
UK	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	50

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
46 C1 UKUR	1,750.4	-106	-0.192	0.02	-11.4	-154	-1.56
47 C1 UKUR	1,786.2	-113	-0.201	0.0189	-11.6	-155	-1.63
48 C1 UKUR	1,908.3	-115	-0.206	0.016	-11.8	-156	-1.63
49 C1 UKUR	1,109.3	-64.1	0.0449	0.0352	-0.497	-9.36	-1.31
50 C1 UKUR	1,127.6	-61.2	0.0494	0.0358	-0.424	-9.13	-1.29
51 C1 UKUR	1,155.4	-67.3	0.042	0.0349	-0.539	-9.8	-1.34
52 C1 UKUR	1,250.4	-68.3	0.0363	0.0323	-0.759	-10.8	-1.34
53 C1 UKUR	1,109.3	-102	-0.119	0.0199	-12.4	-141	-1.58
54 C1 UKUR	1,127.6	-99.3	-0.115	0.0205	-12.3	-141	-1.56
55 C1 UKUR	1,155.4	-105	-0.122	0.0196	-12.4	-142	-1.61
56 C1 UKUR	1,250.4	-106	-0.128	0.017	-12.7	-143	-1.61
57 C1 UKUR	1,081.5	-119	-0.172	0.0161	-14.1	-166	-1.69
58 C1 UKUR	1,099.8	-116	-0.167	0.0167	-14	-166	-1.67
59 C1 UKUR	1,127.7	-123	-0.174	0.0158	-14.1	-167	-1.71
60 C1 UKUR	1,222.6	-124	-0.175	0.0141	-14.3	-168	-1.72
61 C1 UKUR	1,111.1	-108	-0.156	0.0161	-12.4	-143	-1.63
62 C1 UKUR	1,113.7	-108	-0.156	0.0161	-12.4	-143	-1.63
63 C1 UKUR	1,117.7	-109	-0.157	0.016	-12.4	-143	-1.63
64 C1 UKUR	1,131.2	-109	-0.162	0.0149	-12.5	-143	-1.63
65 C1 UKUR	863.4	-111	-0.218	0.013	-12	-149	-1.6
66 C1 UKUR	881.7	-108	-0.214	0.0135	-11.9	-148	-1.58
67 C1 UKUR	909.6	-114	-0.221	0.0127	-12.1	-149	-1.63
68 C1 UKUR	1,004.6	-115	-0.226	0.0102	-12.3	-150	-1.63
69 C1 UKUR	781.9	-112	-0.239	0.0119	-11.9	-151	-1.6
70 C1 UKUR	805.5	-108	-0.233	0.0126	-11.8	-150	-1.57
71 C1 UKUR	841.3	-116	-0.243	0.0115	-12	-151	-1.63
72 C1 UKUR	963.4	-117	-0.247	0.00859	-12.2	-152	-1.64

Appendix F

Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
46 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat Source segregation50% RR	36
47 C1 UKUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	17
48 C1 UKUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	10
49 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	83
50 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	83
51 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	73
52 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	67
53 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	60
54 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	61
55 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	41
56 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	33
57 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	12
58 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	12
59 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	5
60 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	3
61 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 25% RR	40
62 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 25% RR	46
63 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	39
64 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	24
65 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	43
66 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	49
67 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	30
68 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	18
69 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	48
70 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	52
71 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	27
72 C1 UKUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	12

Appendix F

Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
UK	Rural	Incineration only	electricity		none	
UK	Rural	Incineration only	heat		none	
UK	Rural	Incineration only	heat and electricity		none	
UK	Rural	Incineration only	electricity		post process	
UK	Rural	Incineration only	heat		post process	
UK	Rural	Incineration only	heat and electricity		post process	
UK	Rural	Incineration only	electricity		post collection	
UK	Rural	Incineration only	heat		post collection	
UK	Rural	Incineration only	heat and electricity		post collection	
UK	Rural	Incineration only	electricity		source segregation	25
UK	Rural	Incineration only	heat		source segregation	25
UK	Rural	Incineration only	heat and electricity		source segregation	25
UK	Rural	Incineration only	electricity		source segregation	43
UK	Rural	Incineration only	heat		source segregation	43
UK	Rural	Incineration only	heat and electricity		source segregation	43
UK	Rural	Incineration only	electricity		source segregation	50
UK	Rural	Incineration only	heat		source segregation	50
UK	Rural	Incineration only	heat and electricity		source segregation	50
UK	Rural	Anaerobic Digestion only		electricity	none	
UK	Rural	Anaerobic Digestion only		electricity	post collection	
UK	Rural	Anaerobic Digestion only		heat	post collection	
UK	Rural	Anaerobic Digestion only		heat and electricity	post collection	
UK	Rural	Anaerobic Digestion only		vehicle fuel	post collection	
UK	Rural	Anaerobic Digestion only		electricity	source segregation	25
UK	Rural	Anaerobic Digestion only		heat	source segregation	25
UK	Rural	Anaerobic Digestion only		heat and electricity	source segregation	25
UK	Rural	Anaerobic Digestion only		vehicle fuel	source segregation	25

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
01 IN UKRU	693.0	-43.3	0.0553	0.0347	0.416	-2.63	-1.06
02 IN UKRU	2,276.7	-46.8	0.114	0.0456	0.919	-8.94	-1.11
03 IN UKRU	1,004.5	-50.4	0.0578	0.0357	0.381	-4.48	-1.12
04 IN UKRU	693.0	-76.4	-0.0879	0.0214	-10	-118	-1.29
05 IN UKRU	2,276.7	-79.9	-0.0295	0.0323	-9.53	-124	-1.35
06 IN UKRU	1,004.5	-83.6	-0.0855	0.0224	-10.1	-120	-1.36
07 IN UKRU	675.5	-90.7	-0.131	0.0184	-11.4	-140	-1.38
08 IN UKRU	2,219.5	-94.1	-0.0745	0.029	-10.9	-146	-1.43
09 IN UKRU	979.3	-97.7	-0.129	0.0194	-11.4	-142	-1.44
10 IN UKRU	646.3	-79.8	-0.117	0.0192	-9.97	-120	-1.31
11 IN UKRU	2,123.6	-83	-0.0623	0.0294	-9.5	-126	-1.36
12 IN UKRU	936.9	-86.5	-0.115	0.0201	-10	-122	-1.36
13 IN UKRU	379.4	-99.5	-0.284	0.00629	-9.62	-134	-1.39
14 IN UKRU	1,246.5	-101	-0.252	0.0123	-9.35	-137	-1.42
15 IN UKRU	550.0	-103	-0.283	0.00682	-9.64	-135	-1.42
16 IN UKRU	281.9	-107	-0.345	0.00157	-9.5	-139	-1.42
17 IN UKRU	926.2	-108	-0.321	0.00601	-9.29	-141	-1.44
18 IN UKRU	408.7	-110	-0.344	0.00197	-9.51	-140	-1.44
01 AD UKRU	160.7	84.7	0.0656	0.0479	1.23	4.87	-0.141
02 AD UKRU	161.6	23.8	-0.0401	0.0326	-9.29	-124	-0.451
03 AD UKRU	191.0	28.4	-0.0329	0.0335	-9.18	-124	-0.417
04 AD UKRU	235.7	18.7	-0.0448	0.032	-9.36	-125	-0.495
05 AD UKRU	388.0	17.4	-0.0783	0.0237	-9.88	-127	-0.47
06 AD UKRU	142.2	39.1	-0.0266	0.0402	-1.62	-36.6	-0.413
07 AD UKRU	156.8	41.4	-0.0231	0.0407	-1.56	-36.4	-0.395
08 AD UKRU	179.1	36.5	-0.029	0.04	-1.65	-36.9	-0.435
09 AD UKRU	255.0	36	-0.0575	0.0337	-1.99	-38.8	-0.408

Appendix F

Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
01 IN UKRU	Incineration for electricity No recycling	88
02 IN UKRU	Incineration for heat No recycling	52
03 IN UKRU	Incineration for heat and electricity No recycling	74
04 IN UKRU	Incineration for electricity Post process recycling	71
05 IN UKRU	Incineration for heat Post process recycling	21
06 IN UKRU	Incineration for heat and electricity Post process recycling	28
07 IN UKRU	Incineration for electricity Post collection recycling	33
08 IN UKRU	Incineration for heat Post collection recycling	2
09 IN UKRU	Incineration for heat and electricity Post collection recycling	6
10 IN UKRU	Incineration for electricity Source segregation 25% RR	68
11 IN UKRU	Incineration for heat Source segregation 25% RR	23
12 IN UKRU	Incineration for heat and electricity Source segregation 25% RR	26
13 IN UKRU	Incineration for electricity Source segregation 43% RR	52
14 IN UKRU	Incineration for heat Source segregation 43% RR	5
15 IN UKRU	Incineration for heat and electricity Source segregation 43% RR	41
16 IN UKRU	Incineration for electricity Source segregation 50% RR	55
17 IN UKRU	Incineration for heat Source segregation 50% RR	11
18 IN UKRU	Incineration for heat and electricity Source segregation 50% RR	47
01 AD UKRU	Anaerobic Digestion for electricity No recycling (landfill)	105
02 AD UKRU	Anaerobic Digestion for electricity Post collection recycling	93
03 AD UKRU	Anaerobic Digestion for heat Post collection recycling	95
04 AD UKRU	Anaerobic Digestion for heat and electricity Post collection recycling	94
05 AD UKRU	Anaerobic Digestion for vehicle fuel Post collection recycling	90
06 AD UKRU	Anaerobic Digestion for electricity Source segregation 25% RR	107
07 AD UKRU	Anaerobic Digestion for heat Source segregation 25% RR	108
08 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 25% RR	106
09 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	104

Appendix F

Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
UK	Rural	Anaerobic Digestion only		electricity	source segregation	43
UK	Rural	Anaerobic Digestion only		heat	source segregation	43
UK	Rural	Anaerobic Digestion only		heat and electricity	source segregation	43
UK	Rural	Anaerobic Digestion only		vehicle fuel	source segregation	43
UK	Rural	Anaerobic Digestion only		electricity	source segregation	50
UK	Rural	Anaerobic Digestion only		heat	source segregation	50
UK	Rural	Anaerobic Digestion only		heat and electricity	source segregation	50
UK	Rural	Anaerobic Digestion only		vehicle fuel	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	electricity	electricity	none	
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat	none	
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	none	
UK	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	none	
UK	Rural	Incineration and Anaerobic Digestion	electricity	electricity	post process	
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat	post process	
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	post process	
UK	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	post process	
UK	Rural	Incineration and Anaerobic Digestion	electricity	electricity	post collection	
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat	post collection	
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	post collection	
UK	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	post collection	
UK	Rural	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	43

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
10 AD UKRU	129.4	7.6	-0.0908	0.0348	-3.58	-65.1	-0.602
11 AD UKRU	154.2	11.4	-0.0848	0.0356	-3.48	-64.8	-0.573
12 AD UKRU	191.7	3.24	-0.0947	0.0344	-3.63	-65.7	-0.639
13 AD UKRU	319.9	2.09	-0.12	0.0278	-4.05	-67.9	-0.622
14 AD UKRU	124.2	-5.29	-0.117	0.0326	-4.38	-76.8	-0.679
15 AD UKRU	153.1	-0.808	-0.11	0.0335	-4.26	-76.4	-0.646
16 AD UKRU	196.9	-10.4	-0.122	0.0321	-4.44	-77.5	-0.723
17 AD UKRU	346.4	-12	-0.122	0.0294	-4.74	-78.7	-0.737
01 C1 UKRU	676.7	-38.8	0.0793	0.0378	0.434	-2.35	-1.02
02 C1 UKRU	692.8	-36.3	0.0832	0.0383	0.498	-2.16	-0.997
03 C1 UKRU	717.1	-41.7	0.0767	0.0375	0.397	-2.74	-1.04
04 C1 UKRU	800.2	-42.2	0.0433	0.0302	0.011	-4.93	-1.01
05 C1 UKRU	676.7	-72.1	-0.0642	0.0244	-9.98	-118	-1.25
06 C1 UKRU	692.8	-69.6	-0.0603	0.0249	-9.92	-117	-1.23
07 C1 UKRU	717.1	-74.9	-0.0668	0.0241	-10	-118	-1.28
08 C1 UKRU	800.2	-75.5	-0.1	0.0169	-10.4	-120	-1.24
09 C1 UKRU	660.0	-87.3	-0.11	0.0211	-11.5	-140	-1.35
10 C1 UKRU	676.0	-84.8	-0.106	0.0216	-11.4	-140	-1.33
11 C1 UKRU	700.4	-90.1	-0.112	0.0208	-11.5	-140	-1.37
12 C1 UKRU	783.4	-90.7	-0.146	0.0136	-11.9	-142	-1.34
13 C1 UKRU	664.7	-76.6	-0.0952	0.0215	-9.94	-119	-1.28
14 C1 UKRU	667.5	-76.2	-0.0945	0.0216	-9.93	-119	-1.28
15 C1 UKRU	671.7	-77.1	-0.0956	0.0215	-9.95	-119	-1.29
16 C1 UKRU	685.9	-76.9	-0.128	0.0156	-10.2	-121	-1.25
17 C1 UKRU	528.4	-79	-0.135	0.0215	-9.55	-124	-1.26
18 C1 UKRU	544.5	-76.5	-0.131	0.022	-9.48	-124	-1.24
19 C1 UKRU	568.8	-81.8	-0.138	0.0212	-9.58	-124	-1.29

Appendix F

Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
10 AD UKRU	Anaerobic Digestion for electricity Source segregation 43% RR	101
11 AD UKRU	Anaerobic Digestion for heat Source segregation 43% RR	103
12 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 43% RR	100
13 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	96
14 AD UKRU	Anaerobic Digestion for electricity Source segregation 50% RR	97
15 AD UKRU	Anaerobic Digestion for heat Source segregation 50% RR	101
16 AD UKRU	Anaerobic Digestion for heat and electricity Source segregation 50% RR	99
17 AD UKRU	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	98
01 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity No recycling	91
02 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat No recycling	91
03 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	88
04 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	85
05 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	83
06 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	83
07 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	75
08 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	58
09 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	45
10 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	50
11 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	27
12 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	12
13 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 25% RR	79
14 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 25% RR	81
15 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	75
16 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	64
17 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	77
18 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	85
19 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	71

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Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
UK	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	heat	electricity	none	
UK	Rural	Incineration and Anaerobic Digestion	heat	heat	none	
UK	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	none	
UK	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	none	
UK	Rural	Incineration and Anaerobic Digestion	heat	electricity	post process	
UK	Rural	Incineration and Anaerobic Digestion	heat	heat	post process	
UK	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	post process	
UK	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	post process	
UK	Rural	Incineration and Anaerobic Digestion	heat	electricity	post collection	
UK	Rural	Incineration and Anaerobic Digestion	heat	heat	post collection	
UK	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	post collection	
UK	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	post collection	
UK	Rural	Incineration and Anaerobic Digestion	heat	electricity	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	heat	heat	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	heat	electricity	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	heat	heat	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	heat	electricity	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	heat	heat	source segregation	50

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
20 C1 UKRU	651.9	-82.4	-0.166	0.0149	-9.93	-126	-1.26
21 C1 UKRU	476.7	-79.8	-0.15	0.0215	-9.4	-126	-1.25
22 C1 UKRU	497.8	-76.6	-0.145	0.0222	-9.31	-126	-1.23
23 C1 UKRU	529.8	-83.6	-0.154	0.0211	-9.45	-126	-1.29
24 C1 UKRU	638.9	-84.8	-0.154	0.0192	-9.66	-127	-1.3
25 C1 UKRU	2,167.7	-42.1	0.134	0.048	0.908	-8.29	-1.07
26 C1 UKRU	2,183.8	-39.6	0.138	0.0485	0.972	-8.09	-1.05
27 C1 UKRU	2,208.1	-45	0.132	0.0477	0.871	-8.68	-1.09
28 C1 UKRU	2,291.2	-45.5	0.0983	0.0405	0.485	-10.9	-1.06
29 C1 UKRU	2,167.7	-75.4	-0.00919	0.0347	-9.51	-124	-1.3
30 C1 UKRU	2,183.8	-72.9	-0.00529	0.0352	-9.44	-123	-1.29
31 C1 UKRU	2,208.1	-78.2	-0.0117	0.0344	-9.54	-124	-1.33
32 C1 UKRU	2,291.2	-78.8	-0.0452	0.0271	-9.93	-126	-1.3
33 C1 UKRU	2,112.7	-90.5	-0.0563	0.0311	-11	-146	-1.4
34 C1 UKRU	2,128.7	-88	-0.0524	0.0316	-10.9	-145	-1.38
35 C1 UKRU	2,153.1	-93.3	-0.0589	0.0308	-11	-146	-1.42
36 C1 UKRU	2,236.1	-93.9	-0.0923	0.0236	-11.4	-148	-1.39
37 C1 UKRU	2,174.5	-80	-0.0395	0.0319	-9.46	-125	-1.34
38 C1 UKRU	2,177.2	-79.5	-0.0388	0.032	-9.45	-125	-1.33
39 C1 UKRU	2,181.4	-80.4	-0.0399	0.0319	-9.47	-125	-1.34
40 C1 UKRU	2,195.6	-80.3	-0.072	0.026	-9.71	-127	-1.3
41 C1 UKRU	1,680.5	-81.5	-0.0926	0.0295	-9.18	-129	-1.3
42 C1 UKRU	1,696.5	-79	-0.0887	0.03	-9.12	-128	-1.28
43 C1 UKRU	1,720.8	-84.3	-0.0952	0.0292	-9.22	-129	-1.33
44 C1 UKRU	1,803.9	-85	-0.123	0.0229	-9.57	-131	-1.3
45 C1 UKRU	1,493.1	-82.1	-0.113	0.0285	-9.07	-130	-1.29
46 C1 UKRU	1,514.1	-78.8	-0.108	0.0292	-8.99	-130	-1.26

Appendix F

Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
20 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	60
21 C1 UKRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	77
22 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	87
23 C1 UKRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	69
24 C1 UKRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	58
25 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity No recycling	69
26 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat No recycling	66
27 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	60
28 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	51
29 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	45
30 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Post process recycling	40
31 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	30
32 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	17
33 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	7
34 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	9
35 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	4
36 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	1
37 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 25% RR	32
38 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 25% RR	34
39 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 25% RR	29
40 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	16
41 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	37
42 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	47
43 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	25
44 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	10
45 C1 UKRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	34
46 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat Source segregation50% RR	47

Appendix F

Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
UK	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	none	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	none	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	none	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	none	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	post process	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	post process	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	post process	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	post process	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	post collection	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	post collection	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	post collection	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	post collection	
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	25
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	43
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	50
UK	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	80

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
47 C1 UKRU	1,546.1	-85.8	-0.116	0.0282	-9.12	-130	-1.32
48 C1 UKRU	1,655.3	-87	-0.117	0.0262	-9.34	-131	-1.33
49 C1 UKRU	970.0	-45.6	0.0816	0.0387	0.401	-4.09	-1.07
50 C1 UKRU	986.1	-43.1	0.0855	0.0392	0.465	-3.89	-1.06
51 C1 UKRU	1,010.4	-48.4	0.079	0.0384	0.365	-4.48	-1.1
52 C1 UKRU	1,093.5	-49	0.0456	0.0312	-0.0212	-6.66	-1.07
53 C1 UKRU	970.0	-78.8	-0.0619	0.0253	-10	-119	-1.31
54 C1 UKRU	986.1	-76.3	-0.058	0.0258	-9.95	-119	-1.29
55 C1 UKRU	1,010.4	-81.7	-0.0644	0.025	-10	-120	-1.34
56 C1 UKRU	1,093.5	-82.2	-0.0979	0.0178	-10.4	-122	-1.3
57 C1 UKRU	945.7	-93.8	-0.108	0.022	-11.5	-141	-1.4
58 C1 UKRU	961.8	-91.4	-0.104	0.0225	-11.4	-141	-1.39
59 C1 UKRU	986.1	-96.7	-0.11	0.0217	-11.5	-142	-1.43
60 C1 UKRU	1,069.2	-97.3	-0.144	0.0145	-11.9	-144	-1.4
61 C1 UKRU	961.7	-83.5	-0.0929	0.0225	-9.98	-121	-1.34
62 C1 UKRU	964.5	-83	-0.0922	0.0226	-9.97	-121	-1.34
63 C1 UKRU	968.7	-83.9	-0.0933	0.0224	-9.98	-121	-1.35
64 C1 UKRU	982.9	-83.8	-0.125	0.0166	-10.2	-122	-1.31
65 C1 UKRU	755.0	-84.2	-0.133	0.0222	-9.57	-125	-1.31
66 C1 UKRU	771.1	-81.7	-0.129	0.0227	-9.51	-125	-1.29
67 C1 UKRU	795.4	-87	-0.136	0.022	-9.61	-126	-1.33
68 C1 UKRU	878.5	-87.6	-0.164	0.0157	-9.96	-128	-1.31
69 C1 UKRU	676.6	-84.5	-0.149	0.0222	-9.42	-127	-1.29
70 C1 UKRU	697.7	-81.2	-0.144	0.0228	-9.34	-127	-1.27
71 C1 UKRU	729.7	-88.2	-0.152	0.0218	-9.47	-128	-1.33
72 C1 UKRU	838.9	-89.4	-0.153	0.0198	-9.68	-129	-1.34
73 C1 UKRU	644.4	-96.5	-0.233	0.0167	-9.24	-139	-1.32

Appendix F

Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
47 C1 UKRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	21
48 C1 UKRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	13
49 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	80
50 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	82
51 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	73
52 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	66
53 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	56
54 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	63
55 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	36
56 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	17
57 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	13
58 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	13
59 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	8
60 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	3
61 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 25% RR	41
62 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 25% RR	43
63 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	30
64 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	19
65 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	44
66 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	57
67 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	37
68 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	20
69 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	60
70 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	65
71 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	39
72 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	23
73 C1 UKRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 80% RR 100% capture rate	52

Appendix F

Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
Thailand	Urban	Incineration only	electricity		none	
Thailand	Urban	Incineration only	heat		none	
Thailand	Urban	Incineration only	heat and electricity		none	
Thailand	Urban	Incineration only	electricity		post process	
Thailand	Urban	Incineration only	heat		post process	
Thailand	Urban	Incineration only	heat and electricity		post process	
Thailand	Urban	Incineration only	electricity		post collection	
Thailand	Urban	Incineration only	heat		post collection	
Thailand	Urban	Incineration only	heat and electricity		post collection	
Thailand	Urban	Incineration only	electricity		source segregation	25
Thailand	Urban	Incineration only	heat		source segregation	25
Thailand	Urban	Incineration only	heat and electricity		source segregation	25
Thailand	Urban	Incineration only	electricity		source segregation	34
Thailand	Urban	Incineration only	heat		source segregation	34
Thailand	Urban	Incineration only	heat and electricity		source segregation	34
Thailand	Urban	Anaerobic Digestion only		electricity	none	
Thailand	Urban	Anaerobic Digestion only		electricity	post collection	
Thailand	Urban	Anaerobic Digestion only		heat	post collection	
Thailand	Urban	Anaerobic Digestion only		heat and electricity	post collection	
Thailand	Urban	Anaerobic Digestion only		vehicle fuel	post collection	
Thailand	Urban	Anaerobic Digestion only		electricity	source segregation	25
Thailand	Urban	Anaerobic Digestion only		heat	source segregation	25
Thailand	Urban	Anaerobic Digestion only		heat and electricity	source segregation	25
Thailand	Urban	Anaerobic Digestion only		vehicle fuel	source segregation	25
Thailand	Urban	Anaerobic Digestion only		electricity	source segregation	43
Thailand	Urban	Anaerobic Digestion only		heat	source segregation	43
Thailand	Urban	Anaerobic Digestion only		heat and electricity	source segregation	43

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
01 IN THUR	1,063.9	-12	0.151	0.0527	-1.93	-16.2	-1.62
02 IN THUR	3,485.6	-36.7	0.138	0.067	0.273	-18.8	-1.82
03 IN THUR	1,540.3	-25.6	0.141	0.0539	-1.78	-18.1	-1.73
04 IN THUR	1,063.9	-117	-0.332	0.00865	-45.4	-513	-2.26
05 IN THUR	3,485.6	-142	-0.344	0.0229	-43.2	-515	-2.46
06 IN THUR	1,540.3	-131	-0.342	0.00982	-45.2	-515	-2.37
07 IN THUR	967.9	-137	-0.439	0.00247	-52.8	-612	-2.31
08 IN THUR	3,426.6	-177	-0.466	0.0142	-51.1	-617	-2.64
09 IN THUR	1,514.3	-166	-0.463	0.00129	-53.1	-616	-2.55
10 IN THUR	766.3	-183	-0.526	-0.0000112	-48.1	-557	-2.55
11 IN THUR	2,510.3	-201	-0.536	0.0103	-46.5	-559	-2.69
12 IN THUR	1,109.4	-193	-0.534	0.000832	-47.9	-559	-2.63
13 IN THUR	466.7	-249	-0.72	-0.00853	-50.7	-602	-2.83
14 IN THUR	1,533.2	-260	-0.726	-0.00225	-49.7	-603	-2.92
15 IN THUR	676.5	-255	-0.725	-0.00802	-50.6	-603	-2.88
01 AD THUR	264.3	127	0.0736	0.0996	0.397	-0.146	-0.319
02 AD THUR	267.1	-62.1	-0.314	0.0418	-47.6	-569	-1.06
03 AD THUR	353.4	-51.2	-0.305	0.0441	-47.1	-567	-0.976
04 AD THUR	484.6	-77.3	-0.328	0.0403	-47.8	-571	-1.19
05 AD THUR	931.8	-84.6	-0.349	0.0308	-48.6	-575	-1.24
06 AD THUR	253.3	41.3	-0.072	0.0801	-12.1	-149	-0.845
07 AD THUR	289.0	45.8	-0.0682	0.0811	-11.9	-148	-0.81
08 AD THUR	343.0	35	-0.0776	0.0795	-12.2	-150	-0.899
09 AD THUR	527.5	31.9	-0.0917	0.0745	-12.5	-152	-0.916
10 AD THUR	245.6	-19.5	-0.175	0.0663	-20.9	-254	-1.22
11 AD THUR	306.3	-11.8	-0.169	0.068	-20.5	-253	-1.16
12 AD THUR	398.4	-30.2	-0.185	0.0652	-21	-256	-1.31

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Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
01 IN THUR	Incineration for electricity No recycling	85
02 IN THUR	Incineration for heat No recycling	41
03 IN THUR	Incineration for heat and electricity No recycling	68
04 IN THUR	Incineration for electricity Post process recycling	74
05 IN THUR	Incineration for heat Post process recycling	20
06 IN THUR	Incineration for heat and electricity Post process recycling	41
07 IN THUR	Incineration for electricity Post collection recycling	48
08 IN THUR	Incineration for heat Post collection recycling	1
09 IN THUR	Incineration for heat and electricity Post collection recycling	9
10 IN THUR	Incineration for electricity Source segregation 25% RR	45
11 IN THUR	Incineration for heat Source segregation 25% RR	4
12 IN THUR	Incineration for heat and electricity Source segregation 25% RR	24
13 IN THUR	Incineration for electricity Source segregation 34% RR	47
14 IN THUR	Incineration for heat Source segregation 34% RR	6
15 IN THUR	Incineration for heat and electricity Source segregation 34% RR	44
01 AD THUR	Anaerobic Digestion for electricity No recycling (landfill)	104
02 AD THUR	Anaerobic Digestion for electricity Post collection recycling	90
03 AD THUR	Anaerobic Digestion for heat Post collection recycling	89
04 AD THUR	Anaerobic Digestion for heat and electricity Post collection recycling	86
05 AD THUR	Anaerobic Digestion for vehicle fuel Post collection recycling	79
06 AD THUR	Anaerobic Digestion for electricity Source segregation 25% RR	103
07 AD THUR	Anaerobic Digestion for heat Source segregation 25% RR	102
08 AD THUR	Anaerobic Digestion for heat and electricity Source segregation 25% RR	101
09 AD THUR	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	97
10 AD THUR	Anaerobic Digestion for electricity Source segregation 43% RR	99
11 AD THUR	Anaerobic Digestion for heat Source segregation 43% RR	99
12 AD THUR	Anaerobic Digestion for heat and electricity Source segregation 43% RR	95

Appendix F

Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
Thailand	Urban	Anaerobic Digestion only		vehicle fuel	source segregation	43
Thailand	Urban	Anaerobic Digestion only		electricity	source segregation	50
Thailand	Urban	Anaerobic Digestion only		heat	source segregation	50
Thailand	Urban	Anaerobic Digestion only		heat and electricity	source segregation	50
Thailand	Urban	Anaerobic Digestion only		vehicle fuel	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	electricity	none	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat	none	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	none	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	none	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	electricity	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	electricity	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat	source segregation	50

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
13 AD THUR	712.8	-35.5	-0.203	0.0577	-21.6	-258	-1.35
14 AD THUR	242.4	-45	-0.219	0.0605	-24.6	-298	-1.38
15 AD THUR	313.6	-36	-0.211	0.0624	-24.2	-297	-1.31
16 AD THUR	421.8	-57.6	-0.23	0.0593	-24.8	-300	-1.48
17 AD THUR	790.7	-63.9	-0.25	0.0507	-25.4	-303	-1.53
01 C1 THUR	1,010.5	3.37	0.228	0.0634	-1.74	-14.5	-1.48
02 C1 THUR	1,056.7	9.22	0.232	0.0646	-1.48	-13.6	-1.43
03 C1 THUR	1,126.8	-4.78	0.22	0.0625	-1.85	-15.7	-1.55
04 C1 THUR	1,365.9	-8.84	0.203	0.0564	-2.29	-17.6	-1.57
05 C1 THUR	1,010.5	-102	-0.256	0.0192	-45.1	-511	-2.12
06 C1 THUR	1,056.7	-96.1	-0.251	0.0204	-44.8	-510	-2.07
07 C1 THUR	1,126.8	-110	-0.263	0.0184	-45.2	-512	-2.19
08 C1 THUR	1,365.9	-114	-0.28	0.0122	-45.6	-514	-2.21
09 C1 THUR	986.2	-139	-0.382	0.00989	-53.2	-614	-2.31
10 C1 THUR	1,032.4	-133	-0.377	0.0111	-53	-613	-2.27
11 C1 THUR	1,102.5	-147	-0.389	0.00907	-53.3	-615	-2.38
12 C1 THUR	1,341.7	-151	-0.406	0.00289	-53.8	-617	-2.41
13 C1 THUR	975.4	-127	-0.351	0.0104	-45.9	-523	-2.27
14 C1 THUR	991.2	-125	-0.349	0.0108	-45.8	-522	-2.25
15 C1 THUR	1,015.3	-129	-0.353	0.0101	-45.9	-523	-2.29
16 C1 THUR	1,097.3	-131	-0.364	0.00714	-46.1	-524	-2.3
17 C1 THUR	803.1	-149	-0.393	0.013	-47	-542	-2.33
18 C1 THUR	849.2	-143	-0.388	0.0143	-46.7	-541	-2.28
19 C1 THUR	919.4	-157	-0.4	0.0122	-47.1	-543	-2.4
20 C1 THUR	1,158.5	-161	-0.416	0.00619	-47.5	-545	-2.42
21 C1 THUR	729.8	-159	-0.411	0.0141	-47.5	-551	-2.35
22 C1 THUR	789.2	-151	-0.405	0.0157	-47.1	-549	-2.29

Appendix F

Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
13 AD THUR	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	91
14 AD THUR	Anaerobic Digestion for electricity Source segregation 50% RR	97
15 AD THUR	Anaerobic Digestion for heat Source segregation 50% RR	96
16 AD THUR	Anaerobic Digestion for heat and electricity Source segregation 50% RR	92
17 AD THUR	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	88
01 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity No recycling	94
02 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat No recycling	92
03 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	87
04 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	80
05 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	84
06 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	82
07 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	76
08 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	64
09 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	57
10 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	59
11 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	36
12 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	23
13 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 25% RR	77
14 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 25% RR	77
15 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	71
16 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	62
17 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	72
18 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	75
19 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	66
20 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	35
21 C1 THUR	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	69
22 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	72

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Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	heat	electricity	none	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat	none	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	none	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	none	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	electricity	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	electricity	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	heat	electricity	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	heat	electricity	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	heat	electricity	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	none	

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
23 C1 THUR	879.4	-169	-0.42	0.0131	-47.6	-552	-2.44
24 C1 THUR	1,186.8	-175	-0.439	0.00572	-48.1	-555	-2.48
25 C1 THUR	3,159.8	-20.6	0.214	0.0757	0.154	-17.1	-1.67
26 C1 THUR	3,206.0	-14.8	0.219	0.077	0.421	-16.1	-1.63
27 C1 THUR	3,276.1	-28.8	0.207	0.0749	0.0489	-18.2	-1.74
28 C1 THUR	3,515.3	-32.8	0.19	0.0687	-0.39	-20.2	-1.76
29 C1 THUR	3,159.8	-126	-0.269	0.0316	-43.2	-513	-2.31
30 C1 THUR	3,206.0	-120	-0.264	0.0328	-42.9	-513	-2.27
31 C1 THUR	3,276.1	-134	-0.276	0.0307	-43.3	-515	-2.38
32 C1 THUR	3,515.3	-138	-0.293	0.0246	-43.7	-517	-2.41
33 C1 THUR	3,080.0	-162	-0.395	0.0219	-51.4	-616	-2.5
34 C1 THUR	3,126.2	-156	-0.39	0.0232	-51.1	-615	-2.46
35 C1 THUR	3,196.3	-170	-0.402	0.0211	-51.5	-617	-2.57
36 C1 THUR	3,435.5	-174	-0.419	0.0149	-51.9	-619	-2.6
37 C1 THUR	3,140.8	-151	-0.364	0.0229	-44	-525	-2.47
38 C1 THUR	3,156.6	-149	-0.363	0.0233	-43.9	-525	-2.45
39 C1 THUR	3,180.6	-154	-0.367	0.0226	-44	-526	-2.49
40 C1 THUR	3,262.6	-155	-0.377	0.0196	-44.2	-527	-2.49
41 C1 THUR	2,478.2	-168	-0.403	0.0227	-45.5	-544	-2.48
42 C1 THUR	2,524.4	-162	-0.398	0.0239	-45.2	-543	-2.43
43 C1 THUR	2,594.5	-176	-0.41	0.0219	-45.6	-545	-2.55
44 C1 THUR	2,833.7	-180	-0.426	0.0158	-46	-547	-2.57
45 C1 THUR	2,191.9	-175	-0.42	0.0226	-46.2	-552	-2.49
46 C1 THUR	2,251.3	-168	-0.414	0.0242	-45.8	-551	-2.43
47 C1 THUR	2,197.6	-175	-0.421	0.0223	-46.1	-552	-2.49
48 C1 THUR	2,648.9	-191	-0.448	0.0141	-46.8	-556	-2.61
49 C1 THUR	1,433.3	-9.03	0.218	0.0644	-1.62	-16.2	-1.58

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Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	combined LCIA and energy ranking (within country and density group)
23 C1 THUR	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	57
24 C1 THUR	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	24
25 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity No recycling	60
26 C1 THUR	Incineration for heat and Anaerobic Digestion for heat No recycling	61
27 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	51
28 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	41
29 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	38
30 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Post process recycling	39
31 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	33
32 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	24
33 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	8
34 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	11
35 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	3
36 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	2
37 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 25% RR	29
38 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 25% RR	31
39 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 25% RR	19
40 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	15
41 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	20
42 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	27
43 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	15
44 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	10
45 C1 THUR	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	18
46 C1 THUR	Incineration for heat and Anaerobic Digestion for heat Source segregation50% RR	20
47 C1 THUR	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	14
48 C1 THUR	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	5
49 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	80

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Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	none	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	none	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	none	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	post process	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	post collection	
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	25
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	43
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	50
Thailand	Urban	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	50
Thailand	Rural	Incineration only	electricity		none	
Thailand	Rural	Incineration only	heat		none	
Thailand	Rural	Incineration only	heat and electricity		none	
Thailand	Rural	Incineration only	electricity		post process	

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
50 C1 THUR	1,479.5	-3.18	0.223	0.0656	-1.36	-15.2	-1.53
51 C1 THUR	1,549.6	-17.2	0.211	0.0635	-1.73	-17.3	-1.65
52 C1 THUR	1,788.8	-21.2	0.194	0.0574	-2.17	-19.3	-1.67
53 C1 THUR	1,433.3	-114	-0.265	0.0202	-45	-513	-2.22
54 C1 THUR	1,479.5	-109	-0.26	0.0214	-44.7	-512	-2.17
55 C1 THUR	1,549.6	-123	-0.272	0.0194	-45.1	-514	-2.29
56 C1 THUR	2,000.2	-133	-0.294	0.0137	-45.4	-517	-2.36
57 C1 THUR	1,398.1	-151	-0.391	0.0109	-53.1	-615	-2.41
58 C1 THUR	1,444.3	-145	-0.386	0.0121	-52.8	-614	-2.37
59 C1 THUR	1,514.4	-159	-0.399	0.01	-53.2	-616	-2.48
60 C1 THUR	1,753.6	-163	-0.415	0.00386	-53.7	-618	-2.51
61 C1 THUR	1,401.4	-139	-0.36	0.0114	-45.8	-524	-2.37
62 C1 THUR	1,417.2	-137	-0.359	0.0118	-45.7	-524	-2.36
63 C1 THUR	1,441.2	-142	-0.363	0.0111	-45.8	-525	-2.4
64 C1 THUR	1,523.2	-143	-0.374	0.00814	-46	-526	-2.4
65 C1 THUR	1,132.6	-159	-0.4	0.0138	-46.9	-544	-2.41
66 C1 THUR	1,178.8	-153	-0.395	0.0151	-46.6	-543	-2.36
67 C1 THUR	1,248.9	-167	-0.407	0.013	-47	-545	-2.47
68 C1 THUR	1,488.0	-171	-0.423	0.00696	-47.4	-547	-2.5
69 C1 THUR	1,017.5	-167	-0.417	0.0148	-47.4	-552	-2.42
70 C1 THUR	1,076.8	-160	-0.411	0.0164	-47	-551	-2.36
71 C1 THUR	1,167.0	-178	-0.427	0.0138	-47.5	-553	-2.51
72 C1 THUR	1,474.4	-183	-0.445	0.0064	-48.1	-556	-2.55
01 IN THRU	704.4	5.83	0.15	0.0444	-0.281	-5.83	-0.982
02 IN THRU	2,314.4	-12.1	0.14	0.0536	1.14	-7.75	-1.13
03 IN THRU	1,021.1	-3.45	0.143	0.0451	-0.19	-7.09	-1.06
04 IN THRU	704.4	-64	-0.171	0.0151	-29.2	-336	-1.41

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Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
50 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	82
51 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	70
52 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	63
53 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	66
54 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	64
55 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	53
56 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	40
57 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	28
58 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	30
59 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	12
60 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	6
61 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 25% RR	51
62 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 25% RR	53
63 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	45
64 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	34
65 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	48
66 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	53
67 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	36
68 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	17
69 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	48
70 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	56
71 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	32
72 C1 THUR	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	13
01 IN THRU	Incineration for electricity No recycling	90
02 IN THRU	Incineration for heat No recycling	40
03 IN THRU	Incineration for heat and electricity No recycling	69
04 IN THRU	Incineration for electricity Post process recycling	79

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Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
Thailand	Rural	Incineration only	heat		post process	
Thailand	Rural	Incineration only	heat and electricity		post process	
Thailand	Rural	Incineration only	electricity		post collection	
Thailand	Rural	Incineration only	heat		post collection	
Thailand	Rural	Incineration only	heat and electricity		post collection	
Thailand	Rural	Incineration only	electricity		source segregation	25
Thailand	Rural	Incineration only	heat		source segregation	25
Thailand	Rural	Incineration only	heat and electricity		source segregation	25
Thailand	Rural	Incineration only	electricity		source segregation	34
Thailand	Rural	Incineration only	heat		source segregation	34
Thailand	Rural	Incineration only	heat and electricity		source segregation	34
Thailand	Rural	Anaerobic Digestion only		electricity	none	
Thailand	Rural	Anaerobic Digestion only		electricity	post collection	
Thailand	Rural	Anaerobic Digestion only		heat	post collection	
Thailand	Rural	Anaerobic Digestion only		heat and electricity	post collection	
Thailand	Rural	Anaerobic Digestion only		vehicle fuel	post collection	
Thailand	Rural	Anaerobic Digestion only		electricity	source segregation	25
Thailand	Rural	Anaerobic Digestion only		heat	source segregation	25
Thailand	Rural	Anaerobic Digestion only		heat and electricity	source segregation	25
Thailand	Rural	Anaerobic Digestion only		vehicle fuel	source segregation	25
Thailand	Rural	Anaerobic Digestion only		electricity	source segregation	43
Thailand	Rural	Anaerobic Digestion only		heat	source segregation	43
Thailand	Rural	Anaerobic Digestion only		heat and electricity	source segregation	43
Thailand	Rural	Anaerobic Digestion only		vehicle fuel	source segregation	43
Thailand	Rural	Anaerobic Digestion only		electricity	source segregation	50
Thailand	Rural	Anaerobic Digestion only		heat	source segregation	50
Thailand	Rural	Anaerobic Digestion only		heat and electricity	source segregation	50

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Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
05 IN THRU	2,314.4	-82	-0.181	0.0243	-27.7	-338	-1.55
06 IN THRU	1,021.1	-73.3	-0.178	0.0158	-29.1	-337	-1.48
07 IN THRU	640.6	-77.4	-0.243	0.0109	-34.1	-402	-1.45
08 IN THRU	2,275.2	-105	-0.261	0.0185	-33	-405	-1.67
09 IN THRU	1,003.9	-96.9	-0.259	0.0102	-34.3	-405	-1.61
10 IN THRU	503.4	-107	-0.288	0.0122	-30.9	-366	-1.59
11 IN THRU	1,653.9	-120	-0.295	0.0189	-29.9	-367	-1.69
12 IN THRU	729.7	-114	-0.293	0.0128	-30.8	-367	-1.64
13 IN THRU	310.2	-149	-0.401	0.00947	-32.6	-394	-1.76
14 IN THRU	1,019.3	-157	-0.405	0.0135	-31.9	-395	-1.82
15 IN THRU	449.7	-153	-0.404	0.0098	-32.5	-395	-1.79
01 AD THRU	175.7	96.4	0.0968	0.0753	1.21	4.57	-0.134
02 AD THRU	177.6	-29.5	-0.161	0.0368	-30.7	-374	-0.628
03 AD THRU	235.0	-22.2	-0.155	0.0384	-30.4	-373	-0.571
04 AD THRU	322.2	-39.6	-0.17	0.0358	-30.8	-375	-0.714
05 AD THRU	619.5	-44.5	-0.179	0.0305	-31.3	-377	-0.753
06 AD THRU	168.4	40.5	0.00812	0.0639	-7.04	-94.2	-0.473
07 AD THRU	192.1	43.5	0.0106	0.0646	-6.9	-93.7	-0.449
08 AD THRU	228.1	36.3	0.00437	0.0635	-7.09	-94.8	-0.508
09 AD THRU	350.7	34.5	-0.0353	0.0549	-7.53	-97.2	-0.482
10 AD THRU	163.3	1.03	-0.0546	0.0559	-12.8	-164	-0.712
11 AD THRU	203.7	6.14	-0.0503	0.057	-12.6	-163	-0.672
12 AD THRU	264.9	-6.09	-0.061	0.0552	-12.9	-165	-0.772
13 AD THRU	473.9	-9.35	-0.102	0.0453	-13.5	-168	-0.761
14 AD THRU	161.1	-15.6	-0.081	0.0526	-15.3	-193	-0.813
15 AD THRU	208.5	-9.58	-0.076	0.0538	-15	-192	-0.765
16 AD THRU	280.4	-23.9	-0.0885	0.0517	-15.4	-194	-0.883

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Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
05 IN THRU	Incineration for heat Post process recycling	19
06 IN THRU	Incineration for heat and electricity Post process recycling	46
07 IN THRU	Incineration for electricity Post collection recycling	58
08 IN THRU	Incineration for heat Post collection recycling	2
09 IN THRU	Incineration for heat and electricity Post collection recycling	11
10 IN THRU	Incineration for electricity Source segregation 25% RR	49
11 IN THRU	Incineration for heat Source segregation 25% RR	4
12 IN THRU	Incineration for heat and electricity Source segregation 25% RR	30
13 IN THRU	Incineration for electricity Source segregation 34% RR	47
14 IN THRU	Incineration for heat Source segregation 34% RR	6
15 IN THRU	Incineration for heat and electricity Source segregation 34% RR	44
01 AD THRU	Anaerobic Digestion for electricity No recycling (landfill)	106
02 AD THRU	Anaerobic Digestion for electricity Post collection recycling	90
03 AD THRU	Anaerobic Digestion for heat Post collection recycling	89
04 AD THRU	Anaerobic Digestion for heat and electricity Post collection recycling	87
05 AD THRU	Anaerobic Digestion for vehicle fuel Post collection recycling	78
06 AD THRU	Anaerobic Digestion for electricity Source segregation 25% RR	105
07 AD THRU	Anaerobic Digestion for heat Source segregation 25% RR	104
08 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 25% RR	103
09 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 25% RR	99
10 AD THRU	Anaerobic Digestion for electricity Source segregation 43% RR	102
11 AD THRU	Anaerobic Digestion for heat Source segregation 43% RR	100
12 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 43% RR	97
13 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 43% RR	93
14 AD THRU	Anaerobic Digestion for electricity Source segregation 50% RR	101
15 AD THRU	Anaerobic Digestion for heat Source segregation 50% RR	98
16 AD THRU	Anaerobic Digestion for heat and electricity Source segregation 50% RR	94

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Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
Thailand	Rural	Anaerobic Digestion only		vehicle fuel	source segregation	50
Thailand	Rural	Anaerobic Digestion only		vehicle fuel	source segregation	93
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	electricity	none	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat	none	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	none	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	none	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	electricity	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	electricity	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	electricity	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	heat and electricity	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	electricity	vehicle fuel	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	heat	electricity	none	

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
17 AD THRU	525.7	-27.8	-0.13	0.0412	-16	-197	-0.878
18 AD THRU	823.8	-134	-0.291	0.0178	-30.5	-368	-1.55
01 C1 THRU	672.0	14	0.199	0.0511	-0.214	-5	-0.904
02 C1 THRU	702.7	17.9	0.202	0.052	-0.0361	-4.35	-0.874
03 C1 THRU	749.3	8.62	0.194	0.0506	-0.284	-5.75	-0.95
04 C1 THRU	908.3	6.26	0.15	0.0408	-0.799	-8.55	-0.926
05 C1 THRU	672.0	-56	-0.122	0.0218	-29	-335	-1.33
06 C1 THRU	702.7	-52.1	-0.119	0.0226	-28.8	-334	-1.3
07 C1 THRU	749.3	-61.4	-0.127	0.0212	-29.1	-336	-1.38
08 C1 THRU	908.3	-63.8	-0.171	0.0114	-29.6	-339	-1.35
09 C1 THRU	655.8	-80.5	-0.206	0.0156	-34.4	-403	-1.46
10 C1 THRU	686.5	-76.6	-0.203	0.0164	-34.3	-403	-1.43
11 C1 THRU	733.2	-86	-0.211	0.0151	-34.5	-404	-1.51
12 C1 THRU	892.1	-88.3	-0.255	0.00523	-35	-407	-1.48
13 C1 THRU	646.0	-71.4	-0.181	0.0167	-29.5	-343	-1.42
14 C1 THRU	656.5	-70	-0.18	0.017	-29.5	-342	-1.41
15 C1 THRU	672.5	-73.2	-0.183	0.0166	-29.5	-343	-1.44
16 C1 THRU	727.0	-73.8	-0.222	0.00905	-29.9	-345	-1.4
17 C1 THRU	534.0	-85.6	-0.202	0.0198	-30.2	-355	-1.45
18 C1 THRU	564.7	-81.7	-0.199	0.0207	-30	-355	-1.42
19 C1 THRU	611.3	-91	-0.207	0.0193	-30.3	-356	-1.5
20 C1 THRU	770.3	-93.4	-0.248	0.0101	-30.8	-359	-1.48
21 C1 THRU	485.3	-91.8	-0.212	0.0212	-30.5	-361	-1.47
22 C1 THRU	524.8	-86.8	-0.207	0.0222	-30.3	-360	-1.43
23 C1 THRU	584.7	-98.7	-0.218	0.0205	-30.6	-362	-1.53
24 C1 THRU	789.1	-102	-0.259	0.0106	-31.2	-365	-1.51
25 C1 THRU	2,101.2	-1.92	0.19	0.0594	1.05	-6.7	-1.03

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Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
17 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 50% RR	90
18 AD THRU	Anaerobic Digestion for vehicle fuel Source segregation 93% RR 100% capture rate	26
01 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity No recycling	96
02 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat No recycling	95
03 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity No recycling	88
04 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel No recycling	83
05 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Post process recycling	86
06 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Post process recycling	85
07 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post process recycling	77
08 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post process recycling	68
09 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Post collection recycling	62
10 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Post collection recycling	62
11 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Post collection recycling	43
12 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	29
13 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 25% RR	80
14 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 25% RR	81
15 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	74
16 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	62
17 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 43% RR	75
18 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 43% RR	76
19 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	70
20 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	42
21 C1 THRU	Incineration for electricity and Anaerobic Digestion for electricity Source segregation 50% RR	70
22 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat Source segregation 50% RR	73
23 C1 THRU	Incineration for electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	58
24 C1 THRU	Incineration for electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	33
25 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity No recycling	61

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Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat	none	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	none	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	none	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	electricity	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	electricity	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	heat	electricity	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	heat	electricity	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	heat	electricity	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	heat	heat and electricity	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	heat	vehicle fuel	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	none	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	none	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	none	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	none	

Appendix F

Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
26 C1 THRU	2,131.9	1.97	0.194	0.0602	1.23	-6.05	-1
27 C1 THRU	2,178.5	-7.34	0.185	0.0588	0.979	-7.45	-1.08
28 C1 THRU	2,337.5	-9.7	0.141	0.049	0.463	-10.3	-1.06
29 C1 THRU	2,101.2	-72	-0.131	0.03	-27.8	-337	-1.46
30 C1 THRU	2,131.9	-68.1	-0.128	0.0308	-27.6	-336	-1.43
31 C1 THRU	2,178.5	-77.4	-0.136	0.0295	-27.8	-337	-1.51
32 C1 THRU	2,337.5	-79.7	-0.18	0.0196	-28.3	-340	-1.48
33 C1 THRU	2,048.2	-96.1	-0.215	0.0236	-33.2	-405	-1.59
34 C1 THRU	2,078.9	-92.2	-0.211	0.0244	-33	-404	-1.56
35 C1 THRU	2,125.6	-102	-0.22	0.0231	-33.3	-406	-1.63
36 C1 THRU	2,284.5	-104	-0.264	0.0132	-33.8	-408	-1.61
37 C1 THRU	2,085.9	-87.4	-0.19	0.025	-28.2	-344	-1.55
38 C1 THRU	2,096.4	-86.1	-0.189	0.0253	-28.2	-344	-1.54
39 C1 THRU	2,112.4	-89.3	-0.192	0.0248	-28.3	-345	-1.57
40 C1 THRU	2,166.9	-89.9	-0.231	0.0173	-28.6	-347	-1.53
41 C1 THRU	1,647.9	-98	-0.209	0.0262	-29.2	-357	-1.55
42 C1 THRU	1,678.6	-94.1	-0.206	0.0271	-29	-356	-1.52
43 C1 THRU	1,725.2	-103	-0.214	0.0257	-29.3	-358	-1.6
44 C1 THRU	1,884.2	-106	-0.254	0.0165	-29.8	-360	-1.58
45 C1 THRU	1,457.5	-103	-0.218	0.0268	-29.7	-362	-1.55
46 C1 THRU	1,497.0	-97.6	-0.213	0.0278	-29.4	-361	-1.52
47 C1 THRU	1,556.9	-110	-0.224	0.0261	-29.7	-363	-1.61
48 C1 THRU	1,761.3	-113	-0.265	0.0162	-30.3	-366	-1.6
49 C1 THRU	953.1	5.79	0.193	0.0518	-0.133	-6.12	-0.972
50 C1 THRU	983.8	9.68	0.196	0.0526	0.0445	-5.46	-0.941
51 C1 THRU	1,030.4	0.372	0.188	0.0513	-0.203	-6.86	-1.02
52 C1 THRU	1,189.4	-1.98	0.144	0.0414	-0.719	-9.67	-0.994

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Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
26 C1 THRU	Incineration for heat and Anaerobic Digestion for heat No recycling	60
27 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity No recycling	49
28 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel No recycling	39
29 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Post process recycling	38
30 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Post process recycling	37
31 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post process recycling	32
32 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post process recycling	20
33 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Post collection recycling	6
34 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Post collection recycling	10
35 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Post collection recycling	3
36 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Post collection recycling	1
37 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 25% RR	25
38 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 25% RR	28
39 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 25% RR	20
40 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	13
41 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 43% RR	20
42 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation 43% RR	26
43 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 43% RR	16
44 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	9
45 C1 THRU	Incineration for heat and Anaerobic Digestion for electricity Source segregation 50% RR	17
46 C1 THRU	Incineration for heat and Anaerobic Digestion for heat Source segregation50% RR	23
47 C1 THRU	Incineration for heat and Anaerobic Digestion for heat and electricity Source segregation 50% RR	11
48 C1 THRU	Incineration for heat and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	4
49 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity No recycling	83
50 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat No recycling	82
51 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity No recycling	70
52 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel No recycling	66

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Table F1 Decision-making Matrix

Options for selection criteria

Country	Population density	Combination of WTE	Energy type for Incineration	Energy type for Anaerobic Digestion	Recycling scheme	Recycing rate
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	post process	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	post collection	
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	25
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	43
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	electricity	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	heat and electricity	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	50
Thailand	Rural	Incineration and Anaerobic Digestion	heat and electricity	vehicle fuel	source segregation	93

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Table F1 Decision-making Matrix

Corresponding values of energy recovered and Life Cycle Impact Assessment per person

Scenario code	Energy recovered (MJ per person)	climate change (kg CO2-Eq per person)	acidification (kg SO2-Eq per person)	eutrophication (kg PO4-Eq per person)	freshwater aquatic ecotoxicity (kg 1,4-DCB-Eq per person)	human toxicity (kg 1,4-DCB-Eq per person)	resources depletion (kg antimony-Eq per person)
53 C1 THRU	953.1	-64.2	-0.128	0.0224	-28.9	-336	-1.4
54 C1 THRU	983.8	-60.4	-0.125	0.0233	-28.8	-335	-1.37
55 C1 THRU	1,030.4	-69.7	-0.133	0.0219	-29	-337	-1.44
56 C1 THRU	1,189.4	-72	-0.177	0.0121	-29.5	-340	-1.42
57 C1 THRU	929.8	-88.6	-0.212	0.0162	-34.4	-404	-1.53
58 C1 THRU	960.5	-84.7	-0.209	0.0171	-34.2	-404	-1.5
59 C1 THRU	1,007.1	-94	-0.217	0.0157	-34.4	-405	-1.57
60 C1 THRU	1,166.1	-96.3	-0.261	0.00587	-34.9	-408	-1.55
61 C1 THRU	929.3	-79.7	-0.188	0.0174	-29.4	-344	-1.49
62 C1 THRU	939.8	-78.3	-0.187	0.0177	-29.4	-344	-1.48
63 C1 THRU	955.8	-81.5	-0.189	0.0172	-29.5	-344	-1.51
64 C1 THRU	1,010.3	-82.1	-0.228	0.00972	-29.8	-346	-1.47
65 C1 THRU	753.1	-92	-0.207	0.0203	-30.1	-356	-1.51
66 C1 THRU	783.8	-88.1	-0.204	0.0212	-30	-356	-1.47
67 C1 THRU	830.4	-97.4	-0.212	0.0198	-30.2	-357	-1.55
68 C1 THRU	989.4	-99.8	-0.252	0.0106	-30.7	-360	-1.53
69 C1 THRU	676.6	-97.4	-0.216	0.0216	-30.5	-362	-1.51
70 C1 THRU	716.0	-92.4	-0.212	0.0227	-30.2	-361	-1.47
71 C1 THRU	776.0	-104	-0.222	0.0209	-30.5	-363	-1.57
72 C1 THRU	980.4	-108	-0.263	0.0111	-31.1	-366	-1.56
73 C1 THRU	930.5	-150	-0.321	0.0133	-33.3	-398	-1.71

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Table F1 Decision-making Matrix

Scenario code and name

Scenario code	Scenario name	**combined LCIA and energy ranking** (within country and density group)
53 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post process recycling	67
54 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post process recycling	65
55 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post process recycling	51
56 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post process recycling	45
57 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Post collection recycling	31
58 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Post collection recycling	33
59 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Post collection recycling	15
60 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Post collection recycling	8
61 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 25% RR	55
62 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 25% RR	52
63 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 25% RR	47
64 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 25% RR	35
65 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 43% RR	53
66 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 43% RR	55
67 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 43% RR	40
68 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 43% RR	23
69 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for electricity Source segregation 50% RR	53
70 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat Source segregation 50% RR	55
71 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for heat and electricity Source segregation 50% RR	35
72 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 50% RR	18
73 C1 THRU	Incineration for heat and electricity and Anaerobic Digestion for vehicle fuel Source segregation 93% RR 100 % capture rate	14

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Table F2 Background City Statistics

Country	Density type	Population (person)	Area (km^2)	number of household	density ($person/km^2$)	waste generation (Tonne/year)	Reference City
United Kingdom	Urban	236,900	51.8	98,300	4,572.5	86,518	Southampton
United Kingdom	Rural	116,600	661.0	46,900	176.4	37,231	Winchester
Thailand	Urban	174,235	40.2	67,010	4,334.2	96,725	Chiang Mai
Thailand	Rural	174,057	633.0	31,569	274.9	64,240	Nakorn Ratchasima

Table F3 UK energy mix 2012

Energy source	**Baseline fuel mix %**	**Generating efficiencies %**	**Marginal fuel mix %**
Total	100		100
Coal	33.4	35.7	50.5
Oil	0.3	33.1	0
Gas	3.4	34.9	3.1
Gas CCGT	35.4	47.6	46.4
Nuclear	16	38.6	0
Waste	0.2	20.6	0
Thermal other	0.8	18.7	0
Renewables thermal	2.3	25.8	0
Solar PV	0.1	15.5	0
Wind	6.6	25	0
Tidal	0.1	82	0
Wave	0.1	82	0
Hydro	1.3	82	0
Geothermal	0	82	0
Renewable other	0	82	0

Table F4 Thailand energy mix 2012

Energy source	**Baseline fuel mix %**	**Generating efficiencies %**	**Marginal fuel mix %**
Total	100.000		100
Coal	19.045	35	22.8
Oil	1.185	35	0.0
Gas	64.665	35	77.2
Gas CCGT	0.000	45	0
Nuclear	0.000	35	0
Waste	0.013	30	0
Thermal other	0.000	18.7	0
Renewables thermal-bi	0.587	35	0
Solar PV	0.173	15	0
Wind	0.143	15	0
Tidal	0.000	82	0
Wave	0.000	82	0
Hydro	14.127	38	0
Geothermal	0.000	82	0
Renewable other-bioga	0.063	30	0

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Table F5 Waste Composition

Waste Fraction	**UK**	**Thailand**
total	**100**	**100**
Paper and card		
Unspecified paper	0	1.31
Newspapers	7.17	1.73
Magazines	2.88	2.26
Recyclable paper	2.17	0.875
Other paper	4.97	0
Card packaging	6.51	0.48
Other card	1.62	0
Plastic film		
Unspecified plastic film	0	0
Bags	2.09	10.655
Packaging film	2.03	0.29
Other film plastic	0.24	0
Dense plastic		
Unspecified dense plastic	0	0
Drinks bottles	1.08	0.51
Other bottles	1.62	1.195
Other packaging	2.31	2.935
Other dense plastic	1.66	0.655
Textiles		
Unspecified textiles	2.89	1.405
Artificial textiles	0	0
Natural textiles	0	0
Absorbent hygiene products		
Unspecified absorbent hygiene products	3.52	2.45
Disposable nappies	0	0
Other (sanpro and dressings)	0	0
Wood		
Unspecified wood	0.85	0.84
Wood packaging	0	0
Non-packaging wood	0	0
Combustibles		
Unspecified combustibles	1.21	0
Shoes	0.33	0
Carpet/underlay	0.43	0
Furniture	0.03	0
Other combustibles	0	0
Non-combustibles		
Unspecified non-combustibles	2.37	0
Bricks, blocks, plaster	0	0
Soil	0	0
Inorganic pet litter	0	0
Other non-combustibles	0	0
Glass		
Unspecified glass	4.77	0
Packaging	0	0

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Waste Fraction	**UK**	**Thailand**
Non-packaging glass	0	0
Green bottles	0.92	0.11
Clear bottles	0.67	0.995
Brown bottles	0.16	1.345
Jars	0	0
Organic		
Unspecified organic	11.94	0
Garden waste	24.78	0
Food waste	0	66.295
Organic pet bedding/litter	2.53	0
Other organics		0
Ferrous metal		
Unspecified ferrous metal	1.82	1.51
Steel food and drink cans	0.76	0
Other ferrous metal		0
Non-ferrous metal		
Unspecified non-ferrous metal	0.37	0
Aluminium drinks cans	0	1.865
Foil	0.38	0
Other non-ferrous metal		0.06
Fine material <10mm		
Unspecified fine material	1.55	0
Waste electrical and electronic equipment		
Unspecified WEEE	0.11	0
White goods	0.12	0
Large electronic goods (excluding CRT TVs and monitors)	0.01	0
CRT TVs and monitors	0.75	0
Other WEEE		0
Specific hazardous household		
Unspecified hazardous household waste items		0.055
Batteries	0.07	0.19
Clinical waste	0.13	0
Paint/varnish	0.08	0
Oil	0.02	0
Garden herbicides & pesticides	0.08	0