Thesis

Title: Development of a multi-criteria, GIS-based, backcasting framework model (G-BFM) for progression towards zero waste futures, for holistic resource management policy and practice in Northamptonshire by 2050

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Development of a multi-criteria, GIS-based, backcasting framework model (G-BFM) for progression towards zero waste futures, for holistic resource management policy and practice in Northamptonshire by 2050

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Declaration:

This thesis is submitted in fulfilment of the requirements for the degree of Doctor of Philosophy.

I hereby declare that all materials contained within this thesis are original and have not been submitted in fulfilment of the requirements for any other degree (either in part or in full). Inclusion of the unpublished and/or published works of others is duly acknowledged in the text.

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Abstract:

The complex nature of waste management and planning requires a long-term strategic policy formation approach incorporating sustainable development principles. Consequently, the transition from a waste paradigm to valuing materials as resources is central for transitioning towards a 'zero waste' future. A need is identified, via infrastructure planning, to move beyond short-term forecasting and predictive methods previously used in waste research in order to overcome target-driven decision-making.

The application of a participatory backcasting methodology: visioning, baseline assessment, scenario development and feasibility testing; produced transformative scenarios which are visualised using GIS reflecting the choices, ideas and beliefs of participants. The structural governance (e.g. waste infrastructure planning and strategic waste policy) of an English county is used to evaluate the efficacy of waste management scenarios. A quantitative model was developed to test scenarios for three metrics (tonnages, economics and carbon). The final model utilises the synergy between backcasting and GIS to spatially and temporally analyse empirically quantified outputs.

This structured approach produced three transformative scenarios and one reference scenario. Waste prevention and changes to systemic waste generation produced long-term tonnage reductions across the transformative scenarios. Costs of future waste management witnessed the reference scenario outperforming one of the transformative scenarios; while the highest emissions savings were attributable to the scenario most closely reflecting the notion of 'deep sustainability'. In terms of waste infrastructure planning, a centralised pattern of large integrated facilities emphasising catchments rather than administrative boundary were most effective. All three transformative scenarios surpassed the 90% recycling and recovery level used as the zero waste benchmark.

The research concludes that backcasting can offer a range of potential futures capable of achieving an arbitrary definition of zero waste. Further, these futures can be visualised and analysed via GIS; enhancing stakeholder engagement. Overall, the GIS-based Backcasting Framework Model (G-BFM) produced has the potential to benefit a range of stakeholders and practitioners and is strategically scalable.

Keywords: waste paradigm; zero waste; backcasting; GIS; transformative scenarios; visualisation

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Glossary of terms and abbreviations:

.gdb	Geodatabase file	DECC	Dept. of Energy and Climate Change
.shp	Shape file	DEFRA	Dept. Environment Food & Rural Affairs
£pa	Pounds sterling per annum	DETR	Dept. for Environment Transport and the Regions
AD	Anaerobic Digestion	DFT	Dept. for Transport
ADAS	UK Consultancy	DGEnv	Directorate General Environment
ADBA	Anaerobic Digestion and Biogas Association	DH	District Heating
AEA	UK Consultancy	DIRFT	Daventry International Rail Freight Terminal
ALC	Agricultural Land Classification	DOENI	Dept. of Environment Northern Ireland
ANP	Analytical Network Process	DPD	Development Plan Document
AONB	Area of Outstanding Natural Beauty	DTZ	Consultancy firm based in UK
APSRG	Associate Parliamentary Sustainable Resources Group	EA	Environment Agency
ArcGIS 10	GIS software package by ESRI	EAC	Environmental Audit Commission
ATT	Advance Thermal Treatment	EC	Ecological Citizenship
AWM	Advantage West Midlands	ECB	Environmentally Conscious Behaviour
B1,B2,B8	Land use type	ED	Economic Destabilisation
BCW	Borough Council of Wellingborough	EEA	European Environment Agency
BF	Backcasting Framework	EEC	European Economic Community
BGS	British Geological Survey	EEF	Engineering Employers' Federation
BID	Business Improvement Districts	EfW	Energy from Waste
BIS	(Dept.) Business Innovation and Skills	EID	Eco-Industrial Development (theory of)
Bn	Billion	EIP	Eco-Industrial Park
BPMSG	AHP tool developer	ELV	End-of-life vehicles
BRE	Building Research Establishment	EM/ EVM	Eigenvector Method
BREW	Business Resource Efficiency &Waste	EMF	Ellen MacArthur Foundation
BW	Biodegradable waste	EMRA	East Midlands Regional Assembly
C&D	Construction and Demolition	EMS	Environmental Management System
C&I	Commercial and Industrial	ENC	East Northamptonshire Council
C2C	Cradle to Cradle	EOW	End-of-waste
CAT	Centre for Alternative Technology	EP0W	European Pathway to zero waste
CBA	Cost Benefit Analysis	ESA	Environmental Services Association
CBC	Corby Borough Council	ETC/ SCP	Former consultancy from the UK
CBI	Confederation of British Industry	EU	European Union
CD&E	Construction Demolition and Excavation	EuC	European Commission
CE	Circular Economy	EuSA	European Space Agency
CEH	Centre for Ecology and Hydrology	EvSA	Environmentally Sensitive Area
CIWM	Chartered Institution of Wastes Management	EWC	European Waste Catalogue
CO2	Carbon dioxide	FfTF	Forum for the Future
CO2e	Carbon Dioxide equivalent	FM	Framework Model
CR	Consistency Ratio	FOE	Friends of the Earth
CSR	Corporate Social Responsibility	FoM	Forecast Model
DCC	Derbyshire County Council	FoM	Forecast Model
DCLG	Department of Communities and Local Government	G-BFM	GIS-based Backcasting Framework Model
DDC	Daventry District Council	GCI	General Consistency Index

GEO-4	Scenarios used in UNEP reporting	LULU	Locally Unwanted Land Use
GIB	Green Investment Bank	MBT	Mechanical Biological Treatment
GIS	Geographic Information System	MCA	Multi-Criteria Analysis
GIS-AHP	GIS-Analytical Hierarchy Process	MCDA	Multi-Criteria Decision Analysis
GMA	General Morphological Analysis	MCE	Multi-Criteria Evaluation
GOS	Government Office for Science	Mind Genius	Mind mapping software package
Gov.uk	Government portal for data accessing	MIS	Management Information Systems
GST	General Systems Theory	MRF	Material Recycling Facility
GUC	Grand Union Canal	MSW	Municipal Solid Waste
ha	Hectare	Mt	Million tonnes
HCA	Homes and Communities Association	MtCO2	Million tonnes of carbon dioxide
HGV	Heavy Goods Vehicle	MWDF	Minerals and Waste Development Framework
HKGCC	Hong Kong Government Chamber of Commerce	MWLP	Minerals and Waste Local Plan
HMG	Her Majesty's Government	NACE	Nomenclature des Activités Économiques dans la Communauté Européenne
HMT	Her Majesty's Treasury	NBC	Northampton Borough Council
HoC	House of Commons	NCC	Northamptonshire County Council
HRA	Habitats Regulations Assessment	NGO	Non-Governmental Organisation
HWDI	Hazardous Waste Data Interrogator	NHS	National Health Service
HWRC	Household Waste Recycling Centre	NI	Northern Ireland
HzW	Hazardous Waste	NIA	Northern Ireland Assembly
IBA	Incinerator Bottom Ash	NIMBY	Not In My Back Yard
IE	Industrial Ecology	NISP	National Industrial Symbiosis Programme
IMD	Index of Multiple Deprivation	NJMWMS	Northamptonshire Joint Municipal Waste Management Strategy
INSPIRE	Directive (2007/2/EC)	NNR	National Nature Reserve
IPCC	Inter-Governmental Panel for Climate Change	NOMIS	Reporting portal for census data
IPPC	Integrated Pollution Prevention Control	NPPF	National Planning Policy Framework
IS	Industrial Symbiosis	NRW	Natural Resources Wales
IWM	Integrated Waste Management	NTS	Non-Technical Stakeholder
KBC	Kettering Borough Council	NWP	Northamptonshire Waste Partnership
kgCO2/t	Kilograms of carbon dioxide equivalent per tonne	ODPM	Office of the Deputy Prime Minister
Kt	Kilo-tonnes	OGL	Open Government License
LA	Local Authority(s)	OH	Oakdene Hollens, UK consultancy
LACW	(LA) Collected Waste	ONS	Office for National Statistics
LARAC	(LA) Recycling Advisory Committee	OS	Ordnance Survey
LATS	Landfill Allowance Trading Scheme	OSGB 1936	Coordinate system used for projection in ArcGIS 10
LCA	Life Cycle Analysis	OWA	Ordered Weighted Average
LDD	Local Development Document	PDL	Previously Developed Land
LDP	Local Development Plan	PFH	Problem Formation Hierarchy
LFD	Landfill Directive	Pop/ha	Population per hectare
LGA	Local Government Association	PPC	Pollution Prevention and Control
LLW	Low-Level Waste (Radioactive)	PPP	Public Private Partnership
LDD	Local Development Document	PPS10	Planning Policy Statement 10
LNR	Local Nature Reserve	PUA	Principal Urban Area
LSOA	Lower Super Output Area	QM	Quantitative Model

R&D	Research and Development	VAT	Value added tax
RAMSAR	RAMSAR Convention on Wetlands	VES	Veolia Environmental Services
RDA	Regional Development Agency	VLLW	Very Low Level Waste
REC	Resource Efficiency Club(s)	VM	Valorisation and Materials
RGMM	Row geometric mean method	WAG	Welsh Assembly Government
RICOH	RICOH UK office equipment supplier	WAP	Working Age Population
RM	Resource Management	WBCSD	World Business Council for Sustainable Development
RPS	Consultancy firm based in UK	WCA	Waste Collection Authority
RRP	Resource Recovery Park	WCED	World Commission Economic Development
RSS	Regional Spatial Strategy	WDA	Waste Disposal Authority
RTAB	Regional Technology Advisory Board	WDF	Waste Data Flow
SA	Sustainability Appraisal	WDI	Waste Data Interrogator
SD	Scenario Development	WEEE	Waste Electrical and Electronic Equipment
SDI	Sustainable Development Indicator(s)	WFD	Waste Framework Directive
SEA	Strategic Environmental Assessment	WIDP	Waste Infrastructure Development Programme
SEL	Strategic Economic Land	WMPE	Waste Management Plan for England
SERI	Swedish Environmental research Institute	WMS	Waste Management System
SI	Statutory Instrument	WPA	Waste Planning Authority
SITA	SITA Suez - waste management company	WPPE	Waste Prevention Plan for England
SLR	Consultancy firm based in UK	WRAP	Waste and Resource Action Programme
SNC	South Northamptonshire Council	WRATE	Life Cycle Analysis tool
SOC	Substance Oriented Classification	WRM	Waste and Resource Management
SPA	Special Protection Area	WRRAG	Waste and Resources Research Advisory Group
SPD	Supplementary Planning Documents	WTS	Waste Transfer Station
SPZ	Source Protection Zone	WwTW	Waste water treatment works
SSSI	Site of Special Scientific Interest	WYG	UK Consultancy
ST	Systems Thinking	ZW2L	Zero Waste to Landfill
STEEP	Social Technological Economic Environmental and Policy analysis	ZWI	Zero Waste Index
t/ha	tonnes per hectare	ZWIA	Zero Waste International Alliance
TEEP	Technically, Economically and Environmentally Practicable	ZWS	Zero Waste Scotland
TIFU	Technology and Infrastructure Finance Unit		
TNS	The Natural Step		
tpa	tonnes per annum		
TPB	Theory of Planned Behaviour		
TQM	Total Quality Management		
TS	Technical Stakeholder		
TSE	The Scottish Executive		
UA	Unitary Authority		
UNEP	United Nations Environment Programme		
UoN	University of Northampton		

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Chapter 1: Introduction

In this thesis, Chapter 1 sets out the context of the research in terms of envisaging waste management from a position of sustainability with the framing concept of zero waste acting as the change catalyst for transition. It will begin by introducing the main issues relating to waste in England so as to orientate the problem in terms of waste infrastructure provision in relation to the changed emphasis for waste planning at the local level before describing the study area for the research. The chapter then presents the rationale for the research before outlining the research aim and objectives. The final section of Chapter 1 gives a brief outline of the remaining chapters.

1.1 Context of the research

Waste management is a diverse and complex system which includes flows of materials at local; regional; national and international scales. In recent decades, a complex legislative and regulatory framework has developed around waste within England and the United Kingdom (see for example: 75/442/EEC; 99/31/EC; 2008/98/EC). In England, the last decade has witnessed a strategic policy change towards developing a ‘zero waste’ economy (DEFRA, 2007a; 2011a; 2013a). The Waste Strategy for England (DEFRA, 2007a) first introduced the concept of zero waste and this has remained the strategic position under the coalition government (from 2010). The Review of Waste Policy in England (DEFRA, 2011a) reiterated the zero waste ambition and also introduced new strategic policies on Anaerobic Digestion (DECC/DEFRA, 2011) to align waste policy with the broader debate around energy security. Most recently, the Waste Management Plan for England (WMPE) (DEFRA, 2013a) combined with the Waste Prevention Plan for England (WPPE) (DEFRA, 2013b) as well as equivalent documents from the devolved administrations

(Scotland, Wales and Northern Ireland[1]) and local waste management plans (produced at the Waste Planning Authority level in England) fulfils the requirement in Article 28[2] of the revised Waste Framework Directive (WFD). In parallel to the WMPE national planning policy on waste is set out in Planning Policy Statement 10 (PPS10) – Planning for Sustainable Waste Management (DCLG, 2013). PPS10 provides the planning framework enabling Local Authorities (LAs) in England to put forward strategies which identify sites and areas suitable for facilities (new or expanded) to meet the waste management needs of their areas (DCLG, 2013; DEFRA, 2013a). In this new planning context the provision of adequate and economically viable infrastructure, within the framework of the Waste Hierarchy, has increased the pressure on local level planners to find robust means of modelling future capacity with inadequate and out-of-date predictive modelling.

These strategic policy changes have placed significant pressure on practitioners within the public and private sectors as waste has operationally moved from being viewed as a public utility towards an increasingly valuable economic sector in its own right (Ohno, 1988; Seadon, 2006; APSRG, 2011). Developments around systems thinking have broadened the concept of waste to consideration of all inputs to and outputs from production and consumption processes including: raw materials; energy; water; labour and multiple other 'hidden' costs (Ohno, 1988). There are numerous reasons for such a broadening of the waste remit with the main drivers including:

- record highs for commodity prices over the last decade (McKinsey and co for EMF, 2011);
- ever more detailed reports and scientific understanding of the feedback loops and resultant impacts of waste generation on climate change (IPCC, 2007); and

[1] The devolved administrations also include Gibraltar but this is beyond the scope of the research which focuses on England in relation to the United Kingdom geographic area (DEFRA, 2013a).
[2] Article 28 of the revised Waste Framework Directive requires that Member States ensure that their competent authorities establish one or more waste management plans covering all of their territory.

- tangible security concerns relating to economic and social systems stability linked with growing awareness of finite resource depletion (Green Alliance, 2009; WBCSD, 2010).

Such concerns have led to greater consideration of the fundamental principles of sustainable development (e.g. the polluter pays and precautionary principles) in formal top-down policy formation at the levels of supranational governance; national and regional government; as well as for local authorities charged with delivery on the ground. Correspondingly, local communities; non-governmental organizations (NGOs); charitable organisations and environmental activist groups are putting considerable lobbying pressure on hierarchical governance structures to implement policies which reflect localised concerns (FOE, 2009; Transition Network, 2014).

In response to increasing calls for new approaches towards economic, social and environmental issues, the coalition government introduced a new policy agenda framed around 'localism' (HMG, 2010). This new policy lens has seen the regional tier of governance largely removed in matters concerning waste management (DCLG, 2012). Change has been accompanied by uncertainty and resistance, as policy review and implementation have been staged and somewhat light on detail in a number of cases (ESA, 2011). Further concerns have been expressed by practitioners and academics as to the efficacy of such a localism approach in delivering national obligations under European waste legislation (Salder, 2013). Principal among these concerns has been the potential to fall short of key targets for recycling, recovery and diversion of waste from landfill. At the time of writing, this position is being emphasised in relation to the slowdown in recycling and recovery rates for England (CIWM, 2013a; LARAC; 2014) (see Table 1.1).

Other concerns relate to a lack of policy ambition at ministerial level within the Department for Environment Food and Rural Affairs (DEFRA), particularly in relation to the stated objective of moving England towards becoming a zero waste economy (DEFRA, 2007a; 2011a; DEFRA, 2013a). For example; a pilot scheme, supported by accreditation, which aimed to move areas towards becoming 'zero waste places' focusing on LACW wastes (Phillips et al. 2011) has not been expanded in England in spite of meeting and surpassing the DEFRA objectives for the scheme (Warner et al. 2014). In contrast, the devolved Assembly Government in Wales and Parliament in Scotland have each set out ambitious plans for moving towards 'zero waste' (WAG, 2010; TSE, 2010). The focus of these policies has been on achieving high recycling rates combined with efforts to reduce unnecessary waste arisings. The policy in England, under the WMPE and WPPE, has taken an approach which can only be described as unambitious in terms of aiming to hit the minimum targets defined in the revised Waste Framework Directive (WFD) (e.g. 50% recycling rate for household waste by 2020).

Table 1.1: Impact of policy approaches on household waste recycling rates

Year	Measure	UK	England	NI	Scotland	Wales
2010	Arisings ('000 tonnes)	26,973	22,150	829	2,649	1,344
	Recycled ('000 tonnes)	10,879	9,112	315	861	591
	Recycling rate (%)	40.3	41.1	38.0	32.5	44.0
2011	Arisings ('000 tonnes)	26,810	22,187	810	2,484	1,329
	Recycled ('000 tonnes)	11,496	9,596	327	922	651
	Recycling rate (%)	42.9	43.3	40.4	37.1	49.0
2012	Arisings ('000 tonnes)	26,431	21,960	783	2,383	1,304
	Recycled ('000 tonnes)	11,607	9,684	326	912	685
	Recycling rate (%)	43.9	44.1	41.7	38.3	52.5

Source: (DEFRA, 2014)

Table 1.1 is used to show the slowdown in recycling in England compared with the devolved administrations. It can be seen that waste from household sources has marginally decreased in England between 2010 and 2012 (by 0.86%) compared with percentage decreases of 5.55% for NI; 10.04% for Scotland; and 2.98% in Wales for the same period.

This inability to fully develop a holistic approach towards waste in England, combined with the concerns raised previously, may be considered indicative of individuals 'bounded rationality' (Meadows, 2008, p.106). Such a position on waste, where policy decisions are made without adequate knowledge and data, entrench thinking and behaviour making these difficult to change. Evidence of a specific mind-set (or paradigm) within the waste sector can be seen with continued calls and reports espousing the dire need for large scale investment of around £20Bn in waste management infrastructure (ESA, 2011; Eunomia, 2012; CIWM, 2013). This is problematic for a number of reasons:

- Calls for such large scale investment have been made at a time of changing perceptions of investment risk as well as coinciding with the aftermath of one of the deepest economic recessions in UK history (APSRG, 2012);
- Much of the focus has been on large scale projects such as Energy from Waste (EfW) which suffers from a negative perception with the public;
- The emphasis on large infrastructure is fundamentally problematic in terms of the lack of demonstrable strategic thinking on the part of the sector towards the waste hierarchy and fails to adequately consider the waste prevention agenda.

Increasing emphasis in England is being placed on developing zero waste within a circular economy framework (Greyson, 2007; EMF, 2013). This requires capturing and recirculating materials to extend their useful life rather than losing these resources to energy generation (Braungart et al. 2007; Greyson, 2007). This subtle change in policy focus on waste, encompassing circularity within the economy, demonstrates the need for approaches capable of presenting multiple alternatives to decision-makers. These alternatives must be plausible but critically have the potential to offer visions of radical change which are based on sound assumptions on the role of waste materials (including solid waste; water; and embedded energy) as resources within the wider economy. In addition, such a scenario based modelling approach can analyse the future infrastructure needs for all facility types and waste streams at the local level with a view towards extending to regional and national scale assessments.

1.1.1 The role of the EU in UK waste policy formation

The European Union has been central in developing legislative frameworks on waste. In particular, the development and implementation of the Waste Framework Directive (WFD – 75/442/EEC) has led to numerous requirements being placed on Member States to control waste production within a paradigm of minimising environmental degradation and protection of human health. As part of this framework the approach has been to produce legislation aimed at specific components of the waste system with a view to mitigating potential harm from processes and procedures. The most significant of these for policy formation in England and the wider UK, has been European Council Directive 1999/31/EC (commonly and henceforth referred to as the 'Landfill Directive'), which introduced mandatory targets for the diversion of biodegradable waste (BW) from landfill. Other European Directives with wide ranging implications for waste are categorised in relation to products (Ecodesign Directive – 2009/129/EC); treatments (Waste Incineration Directive – 2000/76/EC; Industrial Emissions Directive – 2010/75/EC) and waste streams (covering such fractions as End-of-Life Vehicles; Batteries and Accumulators; Packaging & Packaging Waste).

A recent development at the level of the EU; has included the formation of roadmaps on resource efficiency (EC, 2011a); high recycling societies (ETC/SCP, 2011); low carbon economies (EC, 2011b) and scoping reports on materials security (GOS, 2013). These types of approaches are more focused on the design stages of the life-cycle of products and goods thus reflecting the shift in focus for Directives to cover supply-side characteristics of waste generation (e.g. through the Ecodesign Directive (2009/129/EC)). Indeed, this tier of policy development around waste has been the primary focus of the Horizon 2020 project

(Vasilakos, 2013); aimed at supporting research through EU funding; which has included the collaborative European Pathway to Zero Waste (EP0W) (WRAP, 2014a).

Box 1.1: Devolved administrations strategic approaches to waste

Both WAG and TSE set out long-term plans (to 2050) which outline overall policy direction on moving their economies towards a position of 'zero waste'.

The Welsh Assembly set out a vision for Wales becoming a high recycling society (75%) by 2025 before moving to a zero waste society by 2050 (WAG, 2010) outlining four key challenges to be addressed: sustainability, ecological footprint, climate change and security of resources.

Similarly, Scotland's vision sees a high recycling rate (70%) for all wastes by 2025 and sets out ambitious policies on: banning materials from landfill, capping the amount of materials which can be diverted to energy recovery (25% for MSW initially then all wastes), introduction of a carbon metric for waste and sector specific programmes to prevent and reduce waste generation.

At the time of writing the Northern Ireland Assembly (NIA) has introduced a new waste strategy – 'delivering resource efficiency' (DOENI, 2013). This waste strategy does not go as far as Wales and Scotland in defining a 'zero waste' vision but does frame the strategy around sustainability principles in terms of resource efficiency, particularly around LACW.

Differences in strategic policy implementation between England and the devolved administrations relate to LA structure. The LAs within Wales, Scotland and NI are all unitary authorities (single-tier) with responsibility for waste strategy development (including disposal and collection) whereas England has a mixture of UAs (covering between 60-70% of the population) and two-tier authorities; made up of a single Waste Disposal Authority – WDA (typically a county council) and multiple waste collection authorities - WCAs (typically district councils).

1.1.2 The policy context of waste – the impact of devolution

Since the process of devolution was introduced (1997-2010), waste management has become the responsibility of each devolved entity (England, Scotland, Wales and Northern

Ireland). However, policy formation has taken a number of different approaches between the devolved administrations when compared to England. Specifically, England has taken a policy position on waste, within the WMPE (DEFRA, 2013a) and WPPE (DEFRA, 2013b) where meeting European targets is the main aim rather than developing more ambitious and holistic approaches. This is in sharp contrast to positions taken by the Welsh Assembly Government (WAG) in their waste strategy 'Towards Zero Waste' (WAG, 2010) and The Scottish Executive (TSE, 2010) in their 'Zero Waste Plan' (see Box 1.1).

Taking the last point from Box 1.1 forwards; the introduction and implementation of strategic waste policy is oftentimes more protracted in the two-tier model due to competing local priorities and political dimensions (Gilford et al. 2013). This position is changing in England with the move towards a Unitary Authority (UA) model driven by considerations over budgetary constraints and the increasing use of public private partnerships (PPPs) for waste management contracts (Gilford et al. 2013).

1.1.2.1 Waste policy in England

In 2013 the Coalition Government introduced the WMPE (DEFRA, 2013a) which set out key goals on waste to 2020. The limited strategic scope is reflected in the moderate targets set for specific waste streams. A target of 50% recycling is set out for household waste by 2020 with a further target of 70% recovery for C&D wastes (which is already being exceeded). No specific target is set for C&I wastes or for reducing the overall toxicity of hazardous wastes. An approach which focuses on specific elements of C&I wastes is preferred via producer responsibility (SI/2007/871); with legislation and regulations on packaging, end-of-life vehicles and batteries as well as voluntary agreements between government and economic sectors (e.g. Love Food Hate Waste and the Courtauld Commitments (WRAP, 2007a); and Halving Waste to Landfill (WRAP, 2011).

Various policy approaches are also proposed with a view towards helping England move towards becoming a 'zero waste economy' including: setting out a Waste Prevention Plan (DEFRA, 2013b); and promoting the uptake of anaerobic digestion (AD) (DECC/DEFRA, 2011). Indeed, energy policy alignment with waste has been subject to considerable discussion over the last decade (Hughes, 2009). Scaling back of government involvement with waste is also evident from recent departmental communications (CIWM, 2014). The rationale for such 'disengagement' is linked to financial pressures placed on government but also reflects a continuing trend for waste policy in England since 2010. This policy trend shifts the focus of responsibility back to local authorities, business and individuals under the Localism agenda (DCLG, 2012; Coulson, 2012) as well as initiatives around increasing individual responsibility through the 'big society' (Scott, 2011). Evidence of this disengagement was also seen after the Resource Efficiency Delivery Landscape Review (DEFRA, 2009). This review focused on the Waste and Resources Action Programme (WRAP); National Industrial Symbiosis Programme (NISP); and Envirowise. The outcome of the review saw funding withdrawn from the latter two and reduced funding for WRAP. Further evidence can be seen with the scaling back of funding for the Environment Agency (EA) in England and the separation of the Welsh portion (becoming Natural Resources Wales - NRW).

1.1.2.2 Impact of historic waste policy on waste arisings

In spite of these diverging policy priorities across the various devolved administrations in the UK[3] significant progress has been made on reducing waste generation across economic sectors. The data in Table 1.2 identifies a number of key points. In terms of overall waste arisings across all economic sectors there has been a 27.5% (almost 98.5Mt) reduction between 2004 and 2010.

[3] Reporting to the EU is for the UK as a whole under the Eurostat data reporting scheme (see Eurostat, 2012).

Table 1.2: Reported waste arisings (thousand tonnes) in the UK under NACE categories between 2004 and 2010

Sector (thousand tonnes)	2004	2006	2008	2010
Agriculture, forestry and fishing	719	666	681	494
Mining and quarrying	93,883	86,779	85,963	23,092
Manufacturing	35,056	28,161	22,837	19,970
Electricity, gas, steam and air conditioning supply	6,915	6,873	4,885	6,239
Water supply; sewerage, waste / remediation	38,963	29,726	33,315	25,983
Construction	99,234	109,546	100,999	105,560
Services	39,120	41,088	39,584	31,648
Wholesale of waste and scrap	12,646	10,838	14,324	17,134
Households	31,007	32,466	31,539	28,949
Total	357,544	346,144	334,127	259,068

Source: (Eurostat, 2012)

The most significant reduction can be seen in mining and quarrying waste generation from 98.3Mt (2004) to 23.1Mt (2010), equivalent to a 76.5% reduction overall. Other notable sectors with reduced arisings include manufacturing (43.0%); water supply (33.3%); services (19.1%); and households (6.64%). The data also shows that construction and wholesale of waste/scrap are generating more waste in 2010 than 2004 (6.37 and 35.5% respectively).

1.1.3 The scale of waste arisings in England

England is by far the largest constituent part of the UK in terms of population (incorporating some 53m people or around 84% of the total population). As a consequence, policy formation around waste must deal with flows of significantly larger magnitude than those seen at the devolved (regional equivalence in England) scale. For comparison, Scotland (5.1m) is approximately equivalent in population to the South West or East Midlands regions of England, whereas Wales (3.1m) is on a par with the North East (2.9m) while Northern Ireland (1.8m) is around 60% of this figure making it the smallest population of all the regional entities in the UK. The issue of scaling will be examined in more detail when considering the modelling approach applied to the study area in Chapters 4 and 5. Scaling up is also considered in the impact analysis of scenarios developed within the GBFM quantitative model (see section 5.4).

1.1.3.1 Local Authority Collected Waste in England

Historically, waste generation has been linked most closely with economic growth (Sjöström, and Östblom, 2010). This has led to an increased policy focus, particularly within the EU 6th Environmental Action Programme (EC, 2013) and accompanying Thematic Strategy on Waste Prevention (COM (2005) 666), at the EU and national level on so-called 'decoupling' (Everett et al. 2010). Indeed, decoupling of waste generation from economic growth was a key aim of Waste Strategy for England (DEFRA, 2007a) and has remained a high priority in all subsequent reviews and plans (DEFRA, 2011a; 2013a).

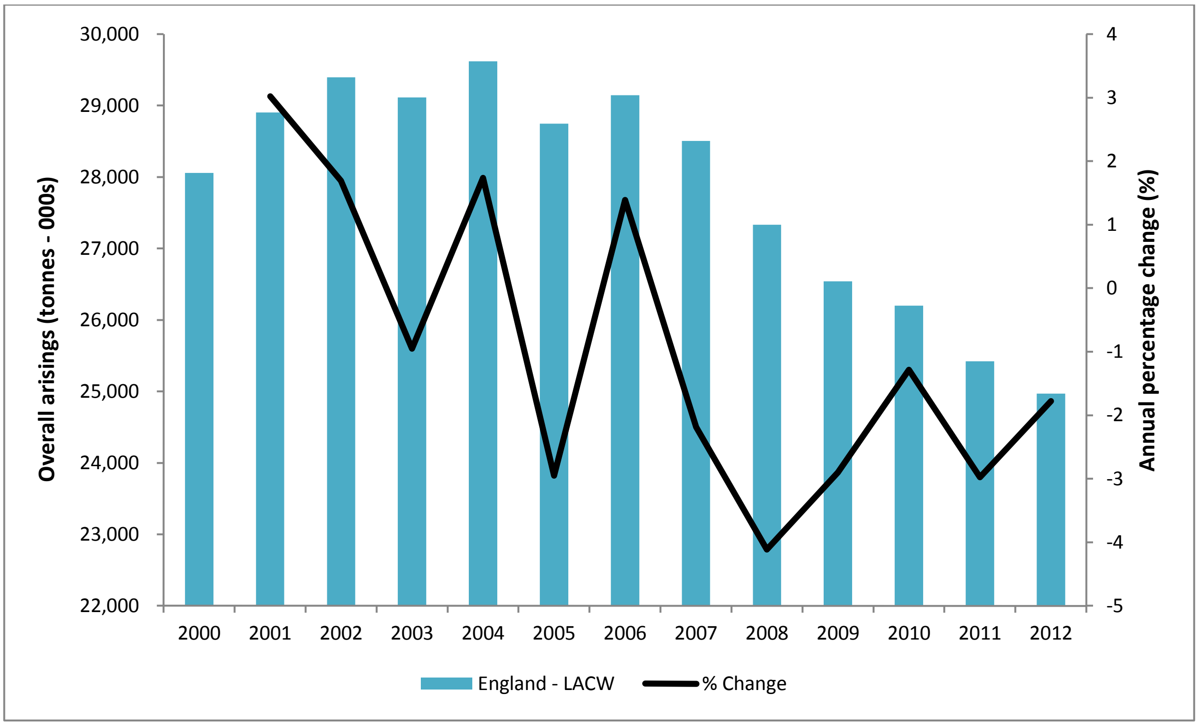

Figure 1.1: LACW arisings in England and annual percentage change between 2000 and 2012 (Source: DEFRA, 2013c).

In the context of England, LACW has been declining since 2006. It should be noted that LACW encompasses more than just households as defined in the NACE reporting (Table

1.2) with approximately 15% of the total coming from other non-household sources (DEFRA, 2013c). Figure 1.1 illustrates overall arisings of LACW during the period 2000 to 2012 and describes the annual percentage change in those arisings. This shows LACW arisings have followed three distinct phases during the 13 year period. These phases are characterised by increasing arisings between 2000 and 2002; significant fluctuations from 2002 to 2006; and consistently reducing arisings for the remaining period 2006 to 2012. The percentage change throughout the period follows a similar pattern moving from strongly positive percentage increases; to fluctuations between positive and negative change; and culminating in negative percentage change from 2006 onwards. Of note is the weakening of this percentage change since 2008 with reductions ranging between 1.29% (2010) and 2.98% (2011).

1.1.3.2 Commercial and Industrial waste in England

Commercial and industrial (C&I) waste arisings have historically been reported together. This reporting is somewhat sparse due to the lack of statutory reporting requirement as seen with municipal wastes. Indeed, national scale studies have only been carried out in 1998/99; 2002/03 and 2009 (EA, 2003; DEFRA, 2010). There have been a number of regional scale studies carried out which have challenged results from the last national scale study (Urban Mines, 2011; NCC, 2012). Given this lack of detailed data an approach has been taken by most planning authorities; relying on estimation based forecast modelling (FM) (DEFRA, 2013d). Indeed, much of the waste planning documentation scrutinised, utilises a model developed by ADAS consulting as part of their *'Study into commercial and industrial waste arisings'* (ADAS, 2009) for the East of England Regional Assembly. Table 1.3 shows the results of the last two national scale surveys into C&I waste arisings within England reporting the percentage change between them.

Table 1.3: Commercial and Industrial (C&I) waste arisings (kt) in England by reporting year and percentage (%) change

	Waste 2002/03 (kt)	Waste 2009 (kt)	Percentage change 2002/03 to 2009 (%)
Industrial Sector	37,587	24,173	35.7
Commercial Sector	30,320	23,844	21.4
England Total	67,907	48,018	29.3

Source: (after DEFRA, 2010 ‘Commercial and Industrial Waste Survey 2009’)

Analysis of the data in Table 1.3 shows considerable change between the periods. Specifically, the reduction of industrial waste generation is in keeping with a move away from a traditional manufacturing base towards a service based economy. The reduction in commercial waste during the same period is more complex and may reflect the similarities in waste composition between commercial and household waste and changes to the definition of municipal waste from the EU level. However, caution must be used given the lack of regular reporting and thus incompleteness of the data

1.1.3.3 Construction and Demolition waste in England

In England, the construction sector produces the largest single amount of waste arisings of all economic sectors. This figure is estimated to have declined in recent years but detailed provision of data at the sub-regional level is unavailable in the main. Estimation has been made at the national scale and is presented over the last reported period in Table 1.4.

Table 1.4: Estimated C&D waste arisings (kt) for England across the last three reported years (2008-10)

Management route (kt)	2008	2009	2010
C&D to waste transfer/treatment	7,053	6,885	7,203
C&D to landfill	23,785	18,192	19,839
C&D to exempt sites	10,978	9,708	8,150
C&D aggregate	52,730	42,184	42,184
Estimated Total	94,546	76,970	77,375

Source: (Gov.uk (2013) ‘CD&E waste generation estimate: England 2008-2010’)

A number of issues are raised by the data estimations in Table 1.4 First the very significant 18.6% reduction in arisings from 2008 to 2009 may reflect the substantial recession which affected the construction sector after the financial crisis of 2008. Second there is an observed increase of 0.53% in estimated overall arisings between 2009 and 2010 with a marked increase in landfill of C&D waste. However, the estimated increase in landfill does not bring it back to the 2008 level (3.9Mt lower in 2010). Third, C&D waste being sent for recovery via exempt sites and used as aggregates has declined by 2.8 and 10.6Mt respectively. This coincides with an overall increase (150kt) in materials being sent for recovery at treatment and transfer facilities.

1.1.3.4 Hazardous waste arisings in England

Data on hazardous waste is considered more accurate and is reported through the EA Hazardous Waste Interrogator database which holds information on arisings, movements and management method. Data for 2012 was accessed and is reported in Table 1.5.

Table 1.5 Hazardous waste arisings (tonnes) and management method for England in 2012

Origin	Recovery (tonnes)	Disposal (tonnes)	Treatment (tonnes)	Total waste arisings (tonnes)
East of England	99,283	147,083	103,450	349,816
East Midlands	121,609	179,843	69,796	371,248
North East	98,042	113,506	80,112	291,660
North West	217,771	160,673	119,531	497,975
South West	144,539	357,222	84,131	585,891
South East	172,770	189,372	178,670	540,811
London	82,042	78,899	193,744	354,685
West Midlands	179,309	165,538	139,697	484,545
Yorkshire & Humber	209,678	145,294	154,121	509,092
Not codeable	3,544	3,937	6,996	14,476
England	1,328,586	1,541,366	1,130,249	4,000,201

Source: (EA, 2012b; DEFRA, 2013a)

Total hazardous waste arising within the English regions in 2012 shown in Table 1.5 amounted to just over 4.0Mt. The South West region of England had the greatest level of arisings originating therein with almost 590kt followed by the South East region with 540kt. Of the 4.0Mt arising in England it can be ascertained that overall recovery and treatment accounted for 61.5% as the end fate for hazardous materials.

1.1.3.5 Controlled wastes in England

Table 1.6 provides a summary for controlled waste arisings in England and is followed by a summary of considerations to draw from the data.

Table 1.6: Summary of controlled waste arisings (kt) in England showing last reporting year available and type of data source used

Waste type	Sub-total (kt)	Reporting year	Validity
LACW	24,967	2012	Quarterly reporting
C&I	48,018	2009	Intermittent surveys
C&D	77,375	2010	Estimation methodology
Hazardous	4,000	2012	Annual reporting
Total	154,360		

Sources: (after DEFRA, 2013c; DEFRA, 2010; Gov.uk, 2013; EA, 2012b)

Table 1.6 indicates that when combined controlled waste arisings in England are likely to sum to 154.4Mt. As the reporting for C&I waste is based on national scale data this has the potential to be accurate and is used in all calculations by relevant government departments. However, the lack of any complete data series means evaluating the trend is somewhat meaningless. These shortcomings are addressed through alternative data sources when compiling the baseline estimation for the study region and for scaling up purposes (see section 4.3.1). A similar situation is seen with data for C&D but this data is based on the AEA developed estimation methodology (Gov.uk, 2013) and thus is likely to have a significant margin of error associated with it. The figure of 154.4Mt in Table 1.6 compares favourably with the estimated tonnage for England contained in the WMPE (DEFRA, 2013a) of 154.6Mt.

1.2 Study area

In light of changes to waste planning, with the removal of regional scale planning structures, the design of the research project focussed on the sub-regional scale, namely the county of Northamptonshire in the East Midlands of England (see Figure 1.2). This administrative level delineates an individual Waste Planning Authority (WPA) with responsibility for the strategic planning of waste management activities within its boundaries. The county has a two-tier system (see section 1.1.2) with the WDA undertaking the waste planning role as WPA responsible for local waste management strategy, encompassing minerals and waste planning within the Minerals and Waste Development Framework (MWDF)[4].

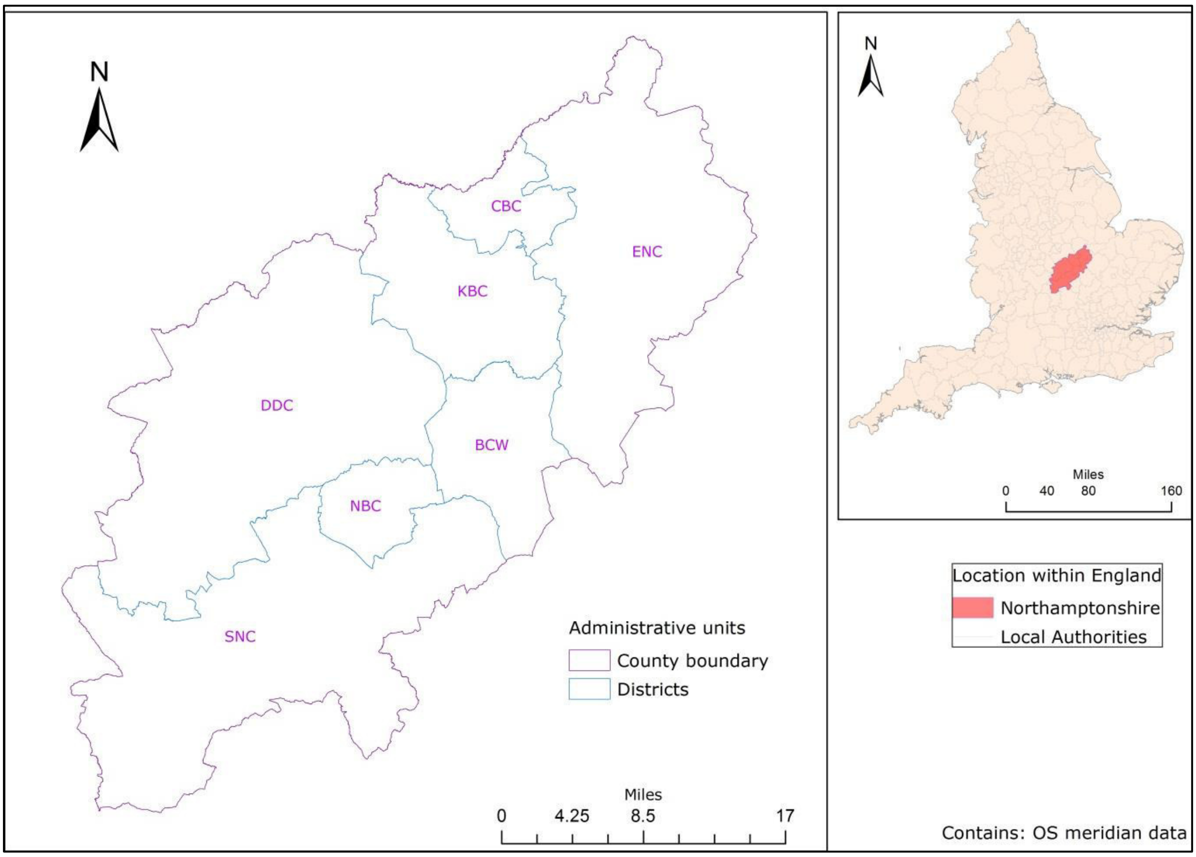

Figure 1.2: The centralised location of Northamptonshire within England and its seven boroughs and districts (Local Authorities).

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[4] This MWDF is to be replaced with a Minerals and Waste Local Plan (MWLP) to meet the requirements under the WMPE (DEFRA, 2013a) and NPPF (DCLG, 2012)

Further, as part of the National Planning Policy Framework (NPPF – DCLG, 2012), all WPAs exporting or importing waste have a Duty to Cooperate with all other WPAs impacted thereof. In practical terms this means offering ways of reducing the burden of exports and seeking alternatives wherever Technically, Economically or Environmentally Practicable (TEEP) (CIWM, 2012).

Northamptonshire is an affluent county with a broad economic base including specialised clusters of commerce and industry, including: finance and banking; automotive engineering; logistics, distribution and warehousing; and Information Technology companies. However, a number of areas of high deprivation (DCLG, 2011) are concentrated in the urban centres of Corby and Northampton.

1.2.1 Waste arisings within Northamptonshire

Total waste arisings within Northamptonshire in 2012 are estimated at 2.70Mt. Table 1.7 presents waste arisings by LA (with estimated figures based on per capita calculations).

Table 1.7: Estimated waste arisings (tonnes) based on per capita calculations by waste stream for Northamptonshire local authorities in 2012

LA	LACW	C&I	C&D	Hazardous	Sub-totals
CBC	30,074	84,529	116,444	8,343	239,390
DDC	38,219	107,419	147,977	10,602	304,217
ENC	42,599	119,731	164,938	11,817	339,085
KBC	45,893	128,991	177,693	12,731	365,309
NBC	104,119	292,645	403,137	28,884	828,785
SNC	41,825	117,557	161,942	11,603	332,926
WBC	36,997	103,987	143,250	10,263	294,498
Totals	339,727	954,859	1,315,382	94,243	2,704,212

Sources: (DEFRA, 2013c; 2009; 2010; Gov.uk, 2013; EA, 2012a; 2012b; NCC, 2013).

Table 1.7 shows estimated C&D waste to be around 50% of overall waste arisings followed by estimated C&I wastes of around 35%, LACW of around 12% and hazardous wastes accounting for around 3% in Northamptonshire. When calculations are made according to population of each LA, overall arisings are directly correlated. This is problematic at the micro-scale as individual areas have different concentrations of activities (industry type and sector) as well as the intensity of waste from these activities and from household sources which can differ markedly (being reflective of local initiatives on waste prevention, resource efficiency and type of collection system). However, for the purposes of macro-scale analysis these figures give an acceptable level of indication[5].

1.2.1.1 Waste arisings trends

The most complete data set available at the county scale in England is for LACW wastes. Indeed, this data set has complete results (quarterly) for all LAs in England between 2006/07 and 2013/14 (time of writing). For indicative purposes the trends in household waste arisings (which account for around 90% of all LACW) are presented in order to visualise the changes which have occurred over this 8 year period in Table 1.8.

Table 1.8: Total household waste collected (tonnes) by LA in Northamptonshire (2006/07 to 2013/14)

LA	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
CBC	22,126	22,541	23,393	23,202	23,966	23,100	23,836	25,104
DDC	35,952	35,291	34,315	33,872	33,801	32,565	28,767	33,899
ENC	31,463	30,753	29,527	29,126	29,447	26,831	24,800	25,582
KBC	38,858	39,035	37,392	35,908	36,493	35,777	36,400	37,613
NBC	80,488	79,127	78,214	75,081	75,419	77,753	81,635	76,894
SNC	38,463	38,314	37,952	36,840	36,780	36,296	36,829	37,687
WBC	30,395	29,910	28,925	28,258	28,903	28,150	29,246	28,812
NCC	347,122	344,888	336,846	327,906	324,729	316,634	315,693	322,041

Source: (Waste Data Flow, 2014).

Table 1.8 shows total household waste has decreased at the county scale by more than 25kt (7.23%). Performance at the LA level is mixed with 6 LAs seeing an overall decrease and

[5] See Chapter 4 for a more detailed macro-scale baseline assessment of waste arisings.

1 LA (CBC) showing an overall increase of almost 3kt (13.5%). ENC has seen the largest overall percentage decrease at 18.7% while SNC has seen the smallest decrease of 2.02%.

1.2.2 Population and demographics

The county has witnessed a significant influx of migrants from South Asia and Africa in the early 2000s with large numbers of Eastern European migrants subsequent to the freedom of movement extended to European Union accession states in the mid-2000s. The combination of economic growth, witnessed in the county, attracting internal migration from parts of the UK and the arrival of overseas migrants, the county has had a rapidly increasing population for more than a decade. The 2011 census showed the county as having a resident population of 691,952 (ONS, 2012) representing an increase of 61,500 since the 2001 census (Northamptonshire Observatory, 2012). Northampton is the largest urban centre in the county. In addition, there are a further three principal urban areas (PUAs) centred on Kettering; Wellingborough; and Corby. Key demographic information for the study area is presented in Table 1.9.

Table 1.9: Key demographic data for Northamptonshire

LA	LA Classification	Resident population	Area (ha)	Population density (pop/ha)	Average household size
CBC	Other Urban	61,255	8,028	7.63	2.42
DDC	Rural-80	77,843	66,259	1.18	2.40
ENC	Rural-50	86,765	50,979	1.70	2.38
KBC	Significant Rural	93,475	23,349	4.00	2.33
NBC	Other Urban	212,069	8,076	26.26	2.35
SNC	Rural-80	85,189	63,402	1.34	2.43
WBC	Significant Rural	75,356	16,304	4.62	2.33
NCC		691,952	236,397	6.68	2.38

Source: (ONS, 2012; DEFRA, 2012d)

The seven districts which comprise the county are defined in the DEFRA rural-urban classification scheme ranging from Rural-80 for Daventry and South Northamptonshire to Other Urban for Northampton and Corby.

1.2.2.1 Population trends

While the population of Northamptonshire for the baseline year (2012) is derived from the official census data, reporting of population change is also undertaken by LAs within the county. Table 1.10 shows the reported population of Northamptonshire has increased by just over 50,000 (or 7.72%) between 2006/07 and 2013/14 from 651k to 702k residents. In terms of LAs all have seen an overall increase, although the change is varied between LAs. The largest increase is seen for CBC, KBC and NBC (18.4, 10.5 and 10.3% respectively). While the smallest overall changes are seen in SNC, WBC and DDC (0.73, 2.93 and 3.23% respectively) which show populations peaking in 2009/10 before declining until 2012/13 (or in the case of WBC declining to 2011/12).

Table 1.10: Population change of LAs in Northamptonshire (2006/07 to 2013/14)

LA	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
CBC	53,500	54,800	54,900	55,200	55,200	55,800	61,968	63,358
DDC	75,900	78,200	78,425	79,100	79,050	79,000	78,145	78,350
ENC	81,500	84,000	84,350	85,400	85,300	85,300	87,016	87,516
KBC	86,000	87,900	88,300	89,500	89,650	90,600	94,060	95,068
NBC	195,000	200,100	200,775	202,800	204,725	212,100	213,017	215,109
SNC	86,000	88,800	89,175	90,300	89,850	88,800	85,638	86,629
WBC	73,900	75,500	75,600	75,900	75,850	75,700	75,725	76,065
NCC	651,800	669,100	671,400	678,300	679,675	687,300	695,644	702,094

Source: (Waste Data Flow, 2014).

1.2.3 Administrative structure – waste planning

The county council as WDA (with responsibility for final disposal of LACW) is also the Waste Planning Authority (WPA) responsible for developing and implementing strategy, infrastructure provision and policy measures to manage waste in line with national targets. As part of their legislative requirements the WPA must develop and keep up-to-date a Minerals and Waste Development Framework (MWDF). This MWDF is a portfolio of individual Local Development Documents (LDDs). There are two types of LDD, Development Plan Documents (DPDs) and Supplementary Planning Documents (SPDs) (NCC, 2012). In the most recent partial review (NCC, 2012) of the MWDF the WPA has maintained its recommended plan for the provision of waste management at a number of main and non-main sites throughout the county. However, this spatial plan dates back to earlier planning documentation (2008) and has not been revisited in terms of advances in spatial analysis techniques and thus requires further evaluation.

The MWDF must account for all other controlled waste streams as well as planning for minerals provision (ODPM, 2005). The scope of the study herein focuses on MSW (defined as Local Authority Collected Waste – LACW since 2010); C&I; C&D and Hazardous wastes. Agricultural wastes and radioactive wastes are not included within the scope of the study other than in the context of key strategic policy approaches, namely: The AD Strategy and Action Plan (DECC/DEFRA, 2011) as well as the National Infrastructure Plan (HMT, 2013) which addresses sites defined as having a national significance either in terms of scale or from a strategic perspective. This holistic planning context dictates a more systemic approach to future infrastructure provision which accounts for the uncertainty created by incomplete data. A scenario-based approach such as backcasting avoids the limitations associated with current predictive modelling methods (e.g. forecasting) and has considerable flexibility and an inherent ability to visualise future states for complex issues while accounting for uncertainty (Robinson, 1990; Quist, 2007; Quist et al. 2011) and represents a novel application in the context of this research.

1.3 Research aim and objectives

This section outlines the need for the research in terms of the research agenda around strategic waste planning, before presenting the main research aim and key objectives (1-6) proposed to achieve the research aim addressing the identified research gaps. This identified need is presented in the form of a rationale for choosing a hybrid approach to waste and resource management systems assessment.

1.3.1 Research agenda

The waste management system (including strategic planning of infrastructure) in England is facing multiple challenges which are adding to the complexity of finding suitable and environmentally sustainable solutions to the problem of shifting towards a 'zero waste economy' (DEFRA, 2007a; 2011a; 2013a). The Environment Agency recently commissioned a study to identify potential gaps in waste infrastructure provision for the Anglian Region with a view to 2031 (Head et al. 2013 unpublished). This research looked extensively at all treatment options on the table, including landfill as a continued waste management method for the future. A number of potential scenarios for the future of waste management, affecting a significant section of the English population (~8.9m or 16.8%), were developed. These scenarios are incorporated into this research as part of the non-linear quantitative model (QM) developed to test the impact of the backcasting scenarios. Within this study, recommendations were made to apply a broader scenario based approach with visualisation techniques; this approach is relevant for stakeholder engagement allowing the 'geography of waste' (Mihai, 2012) to be mapped and presented.

Policy approaches seeking to shift the emphasis up the waste hierarchy do not address the fundamental need to view waste from a systems perspective (Dace et al. 2014). Indeed, current policies which rely on predicting levels of waste generation, composition of waste streams and developing infrastructure to manage these materials can often be part of the underlying problem (Seadon, 2010). Predictive methodologies based on forecasting and trend analysis may not be adequate to deal with the uncertainty and complexity of future waste and resource management systems (Dreborg, 2004; Robinson et al. 2013).

Backcasting offers a novel means by which to perceive waste and has the capacity to view the problem from a systems perspective (Robinson, 2003; Quist et al. 2011). The process of developing visions and scenario pathways, grounded with detailed analysis of the current waste system, allows more radical transformative change to be evaluated. Further, embedding backcasting analysis within a GIS environment has the potential to enhance the process of stakeholder engagement, thus addressing issues around public perception and inclusion (Hicks, 2004) within the wider decision-making process on waste and resource management issues (De Beer, 2013).

1.3.2 Research aims

Using the County of Northamptonshire within the East Midlands of England as the case study area, the aims of the project are twofold:

1. *"Evaluate backasting as a holistic multi-criteria modelling approach for moving towards zero waste, by 2050."* and:
2. *"Spatially and temporally visualise the 'geography of waste' to enhance the decision-making process."*

The model is designed for use by waste planning practitioners and decision-makers including Government Departments and Agencies; and Local Authorities in England; as well as private and third sector decision makers for strategic foresight on waste and resource management issues.

1.3.3 Research objectives

The research aims outlined above were disaggregated to produce the following objectives (two distinct objectives per aim and a fifth synthesising objective) in order to offer measurable outputs from the research process. Aim 1 had the following two objectives:

1. Analyse the likely causes for variation of waste arisings through stakeholder participation and baseline analysis of the case study area.

2. Evaluate potential “future” scenarios for zero waste management through utilization of a backcasting approach.

Aim 2 had the following objectives:

3. Analyse the future infrastructure capacity needs at the sub-regional level for effective management of waste using Geographic Information Systems (GIS).
4. Visualise the spatial characteristics of the waste management system within a case study area.

The final objective is proposed to coherently blend the research aims

5. Synthesise the backcasting outputs with GIS to produce a scenario-based practitioner focused holistic model of zero waste futures.

1.4 Chapter Outlines

This thesis consists of nine chapters, the remainder of which is summarised briefly below:

Chapter 2 presents a review of the key literature, starting with definitions of waste and waste management. It discusses waste management in England as well as the formation of waste policy at the European, United Kingdom and England spatial scales. The chapter ends with a review of previous research on backcasting and GIS in relation to waste and resource management.

Chapter 3 presents the main research methodology applied and discusses the key methods used within the methodological framework developed. It begins with a description of the research design and the techniques used for data collection, sampling and field work undertaken. The chapter ends with a detailed discussion of the key data sources and main methods used in the analysis and serves as an introduction to the next chapter.

Chapter 4 presents statistical results of the baseline analysis which forms the first stage of the backcasting framework proposed and presents the first results of mapping system conditions within a GIS environment.

These results are followed in Chapter 5 by the main results from the remaining stages of the backcasting process, namely: visioning, scenario development and impact analysis.

Chapter 6 presents the main GIS results in terms of mapping the spatial distribution of waste arisings and infrastructure. This chapter presents results of the GIS-AHP process used to evaluate the planned distribution of waste facilities in terms of identified areas of search relating to criteria identified as opportunities and constraints.

Chapter 7 presents the last results from the research in terms of the final GIS based Backcasting Framework Model (GBFM) which presents the visions in terms of spatial distribution of: waste tonnages; economic costs and savings associated with each scenario; and potential impacts in the form of direct and avoided carbon emissions within the envisioned waste management systems under each scenario.

Chapter 8 presents a detailed discussion of the main results from chapters 4 through 7 in relation to the research aim and objectives (Chapter 1) and the identified research gaps (Chapter 2). The chapter also discusses the strengths and weaknesses of the proposed methodology and individual methods used (Chapter 3) as well as problems encountered in the research and solutions found.

Chapter 9 presents a short conclusion and makes recommendations in relation to these before outlining potential areas of future research.

Chapter 2: Literature review

The aim of chapter 2 is to identify gaps within the literature around moving towards a zero waste future in line with long-term aspirational concepts such as circular economy (Greyson, 2007) and sustainable resource management (where waste is viewed as resource rather than a problem) (Seadon, 2006) as well as applying the waste hierarchy across the life-cycle of materials and products (Su et al. 2013).

2.1 Introduction

Waste management and the generation of solid wastes has increasingly become part of the policy agenda internationally in recent decades (Hoornweg and Bhada-Tata, 2012; EEA, 2013). Since the 1970's issues around exponential growth in production and consumption with corresponding growth in waste generation, has been framed as a significant challenge to be overcome (Meadows et al. 1972; WCED, 1987). Such concerns have come about largely as a consequence of transitioning to a consumption based economic model since the 1950's (WCED, 1987). Recent decades have accelerated this pattern with many developing economies following a rapid industrialisation pathway which has vastly increased the numbers of consumers and increased demand for services, products and raw materials (Deloitte, 2011).

The environmental impacts of such rapid industrialisation are well documented and have formed some of the assumptions behind global climate change modelling based on scenario planning methods (Borjesson et al. 2006; IPCC, 2007). However, such modelling is often predicated on methods and techniques which utilise analysis and extrapolation of past trends within predictive forecast models. Given the degree of feedback within complex systems of all kinds the use of predictive methods which exclude certain parameters (or variables) are almost certain to be unreliable over the long-term. Gleick (2008) eloquently captures this inherent problem of prediction thus:

"…trends in nature are real, but they can vanish as quickly as they come."

Source: (Gleick, 2008, p.94).

There is an important point to draw from Gleick's statement, if trends in nature vanish quickly then trends in the socio-political realm are likely to be just as ephemeral. To this end, planning for uncertain conditions and basing long-term economic investments on such approaches is problematic. Emblemsvag and Bras (2000) suggested that making decisions based on current conditions is ill-founded without consideration of change. Rapid industrialisation and economic development has been predicated on the need for change and innovation but has failed to adequately address the environmental impacts of production and growth; particularly in relation to the generation of wastes (World Bank, 2011). This has resulted in the waste of resources and associated environmental problems we see today.

2.1.1 Definitions of waste

2.1.1.1 Defining waste from an operational perspective

The most recognisable waste from an operational perspective is solid waste, which is that fraction of material input which is left over and thus requires a further management route (Ohno, 1988). For example; materials passing through production processes can be exposed to contaminants in the form of additive materials such as chromium (and previously to cadmium) in leather tanning. Such exposure does not impact on the functional properties of the product but has specific ramifications at the end of its useful life, post consumption (e.g. when they are discarded). These products then pass into a waste stream which must consider the material composition of the product and the concentrations of additives used in the production process.

This example illustrates that waste can be produced at different stages along the 'life' of a product or service. A range of systems tools have been developed to 'map' the generation of wastes at different life cycle stages (Holmberg and Robert, 2000). Pires et al. (2011) suggest that system assessment tools such as Life-Cycle Assessment (LCA) should be considered within a 'technology hub' (Chang et al. 2009) (Figure 2.1) looking at waste from a systems perspective.

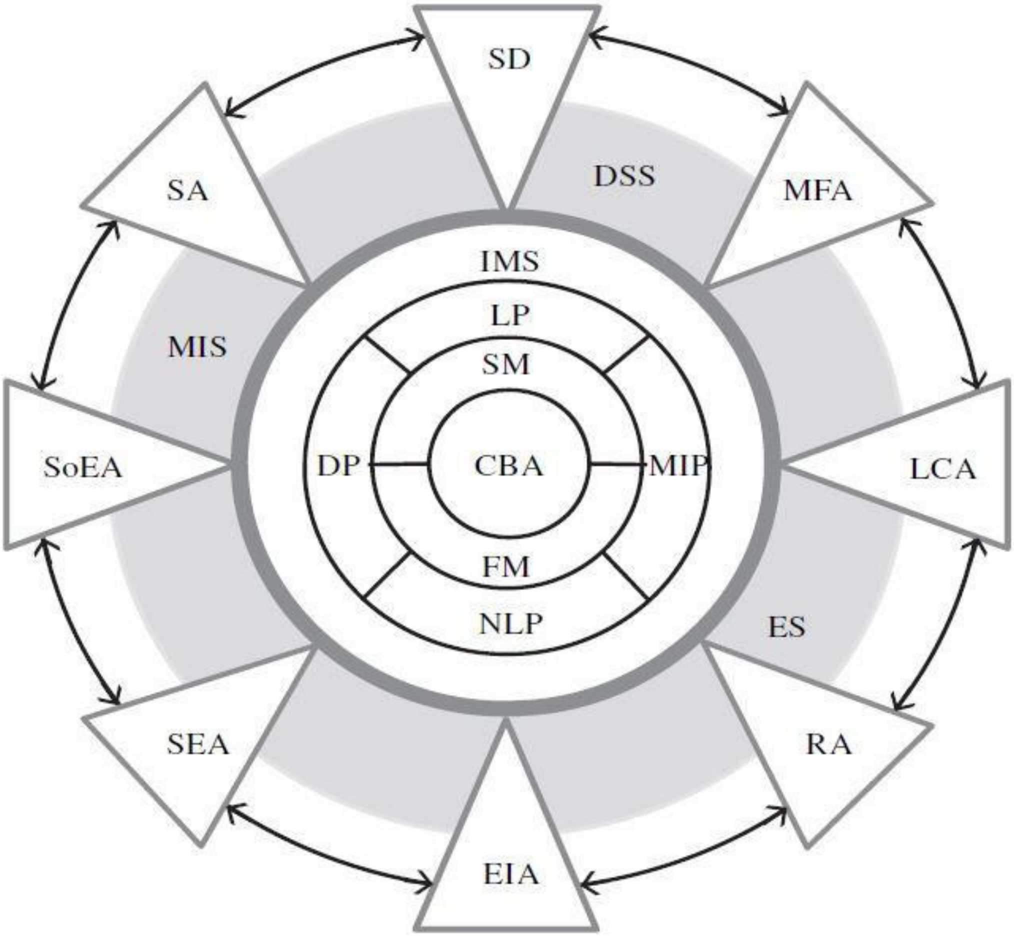


Figure 2.1: The technology hub for solid waste management (Source: Chang et al. 2009 in Pires et al. 2011).

Figure 2.1 holistically shows the range of systems engineering tools (e.g. forecast models (FoM) and cost-benefit analysis (CBA)) and the position of LCA (outer ring) as one approach among a range of system assessment tools applied to waste management research. However, it can be seen from the literature that LCA has in the main been applied to systems components (Badino and Baldo, 1996; EC, 2006; Hogg et al. 2007) or in a more limited role for specific materials (Finnvenden et al. 1995; Arena et al. 2003; Roy et al. 2009) and processes (Tukker, 2002; Perugini et al. 2005). Ekvall et al. (2007) emphasise the strength of LCA for waste management research (and Life Cycle Thinking more generally) in terms of expanding perspectives beyond the waste management system (WMS). Notably, they point out that a serious limitation of LCA relates to the inadequacy of the approach in identification and assessment of waste prevention strategies within waste management scenarios (Ekvall et al. 2007). As a means of overcoming some of the shortcomings they identify, Ekvall et al. (2007) suggest the use of futures studies techniques (including backcasting, forecast models and extrapolation of trends) to allow flexibility in the assessment and to account for waste prevention by means of developing different scenarios.

Broader systems thinking approaches (such as scenario development (SD in Figure 2.1)) are getting increasing attention from a waste perspective in England (DEFRA, 2012b). This ‘systems thinking’ (ST) approach has been a central consideration in research relating to Industrial Ecology (Isenmann, 2003; Korhonen, 2004) and Industrial Symbiosis (Chertow, 2007; Bain et al. 2010; Giurco et al. 2011). ST can also be considered central in research approaches looking at integrated waste management (Clift et al. 2000; Seadon, 2006; Consonni and Vigano, 2011). There has also been significant research using systems dynamics for waste systems analysis, with emphasis placed on dynamic modelling of urban-resource-environment (Guan et al. 2011); urban solid waste (Sufian and Bala, 2007); and modelling feedback loops in resource consumption (John, 1998).

2.1.1.2 The broader concept of waste

Solid waste is only one facet of total operational waste and has been extensively researched in terms of resource efficiency (Phillips et al. 2002; Oakdene Hollins, 2009; BIS, 2011), lean manufacturing (Ohno, 1988; Hicks, 2004) and increasingly so for circularity (McDonough and Braungart, 2002; Braungart et al. 2007; Greyson, 2007; Preston, 2012). For example; seven types of waste were identified by Ohno (1988) as part of the Toyota Production System for Lean Manufacturing.

The seven types of operational wastes described Table 2.1 can be summarised around critical business interests in terms of minimising costs; adding value; process and materials efficiency; and time savings. Similar work has been undertaken in the UK around waste minimisation clubs (Phillips et al. 1999; Pratt and Phillips, 2000; Clarkson et al. 2002) and later for resource efficiency clubs (Ackroyd et al. 2003; Mattson et al. 2010).

Table 2.1: Activity types and descriptions of Toyota System for Lean Manufacturing

Type of waste activity	Description
Overproduction	Making too many items or making items too early causes this situation. This produces excessive lead-times and storage times with increased inventory.
Waiting	Any time that materials or components are not having value added to them.
Transportation	The movement of materials within the factory adds cost but not value.
Inappropriate processing	The use of a large expensive machine instead of several small ones leads to pressure to run the machine as much as possible rather than only when needed. This can contribute to poor layout, extra transportation and poor communication
Unnecessary inventory	Inventory tends to increase lead-times, reduces flexibility and prevents the rapid identification of problems.
Unnecessary motions	Relates to ergonomics. If operators have to bend and stretch it may lead to quality and productivity problems.
Cost of defects	Includes internal failure (scrap, rework and delay) as well as external failure (re pairs, warranty cost and lost custom).

Source: (after Ohno, 1988 cited in Hicks, 2004).

This research focus has increasingly been supplemented and expanded in England by government efforts to raise awareness among businesses through delivery bodies (e.g. Business Resource Efficiency and Waste centre – BREW; National Industrial Symbiosis Programme – NISP; and Envirowise) largely funded from landfill tax returns post 1995.

2.1.1.3 Resource efficiency – broadening the policy definition of waste

As previously mentioned waste is far more than just the physical manifestation of materials being discarded or captured for recycling and recovery. Specific attention has been placed on energy and water as further significant opportunities for reducing costs (Scott et al. 2009). A number of reports have been produced in England on the potential scale of the opportunity for reducing costs and embedded CO_2 emissions across the three main areas of waste generation (Oakdene Hollins & Grant Thornton, 2007; Oakdene Hollins, 2009; BIS, 2011). The scale of these financial and CO_2 savings opportunities is shown in Table 2.2.

It can be seen from the data in Table 2.2 that the scale of opportunity for financial savings and emissions reductions which can be realised from resource efficiency in England is very significant (£55Bn and 90MtCO_2). The estimated financial savings from resource efficiency associated with waste alone is a combined £40Bn with the capacity to reduce emissions associated with the generation of waste by some 48MtCO_2.

Table 2.2: Summary of estimated resource efficiency opportunities based on 2009 data

Type of savings	Resource	Estimated Savings Opportunity £Bn	MtCO$_2$
No cost / low cost	Energy	4	13
	Waste	18	19
	Water	1	0
	Sub-total	23	29
Payback greater than 1 year	Energy	7	30
	Waste	22	29
	Water	4	1
	Sub-total	33	61
Grand Total		55	90

Source: (Oakdene Hollins, 2009 'Further business benefits of resource efficiency')

2.1.1.4 Defining waste from a legal perspective

The waste sector is heavily regulated, with substantial financial and regulatory incentives to reduce the quantity of waste arising and to reuse, recycle or recover value from waste materials (including energy recovery from residual fractions). Clarity is essential for both producers and consumers in understanding when materials shift into the waste remit. Figure 2.2 schematically illustrates the legal definition of waste from the EU.

It is important to note the subtle contradiction this definition poses. It is evident; if one views the schematic as a simplified model of the waste system; that two types of flow are occurring within the system.

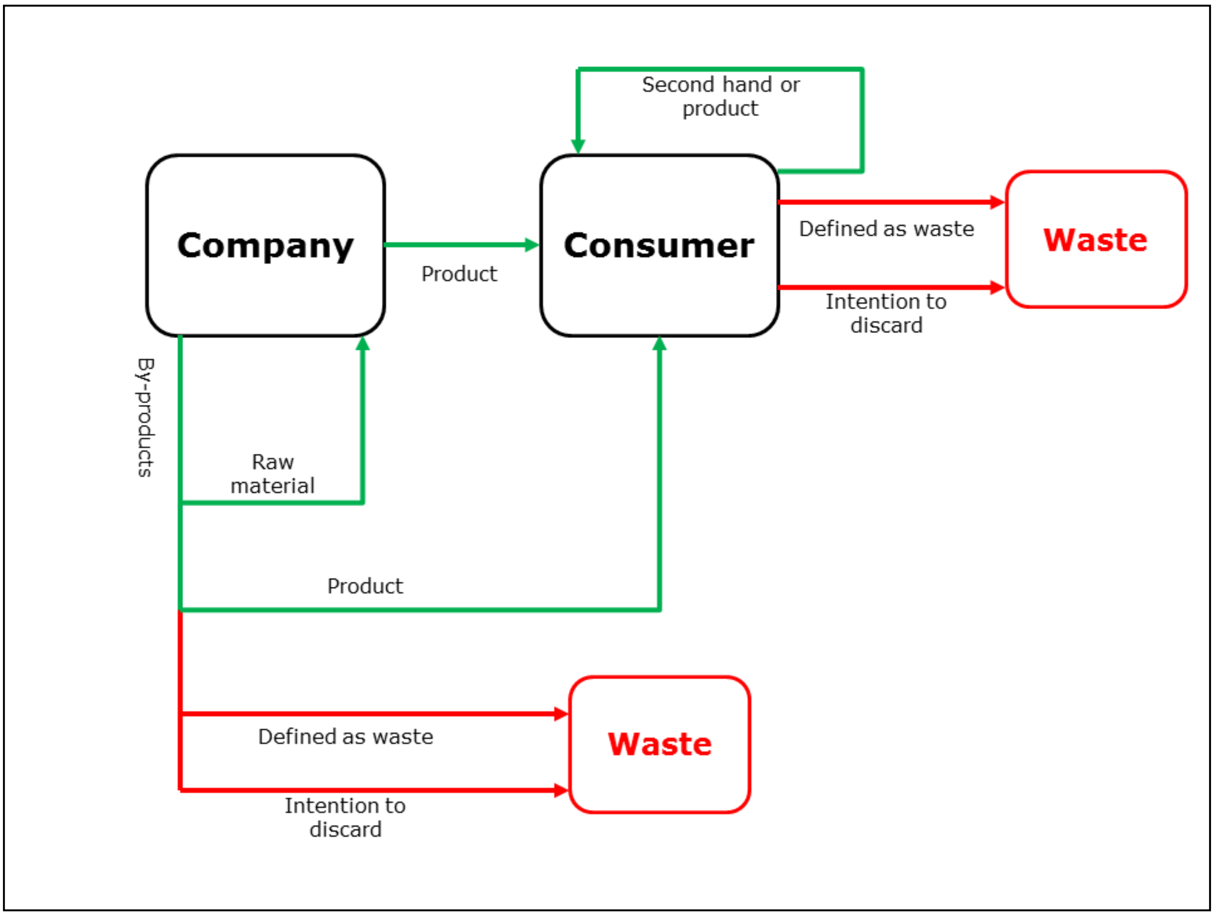


Figure 2.2: Illustration of the EU legal definition of waste (Source: after EC, 2012).

There is an obvious linear flow from production (company) and consumption (consumer) directly into the legally defined waste system (legally defined as waste or intended to discard as waste). However, cyclical flows are also evident within the system in the form of by-products which can be reused by the company or are suitable for use by a third party (as a consumer of such by products). In addition, goods consumed do not have to flow into the waste system and can be exchanged as second hand items.

Such system flows are evidence of both supply-side and demand-side developments which can: increase product life; maximise efficiency of materials use; and provide secondary markets which creates added value to otherwise worthless materials. It may be argued that far from being prescriptive the legal definition can legitimately form the basis for the development of new systems such as industrial symbiosis networks. What is often lacking is institutional and organisational capacity to perceive such legislative frameworks as anything other than prescriptive.

2.1.2 Impact of composition changes on waste management practices

Changing composition poses challenges to recovery of specific materials fractions and the effective management of the waste system (Dennison et al. 1996; Burnley, 2007a; Chang et al. 2008). This is particularly the case with waste from households in England, which represents around 9-10% of all wastes generated, but is perhaps the most challenging waste stream to capture materials from. Specific issues have been raised over household waste in relation to separation of materials at source (WYG, 2012); and after comingling (FOE, 2009) as well as levels of contaminants in material fractions destined for secondary usage as recyclate (Woodard et al. 2001; Timlett and Williams, 2008). Given this level of heterogeneity within the waste matrix, rigid waste management practices of diversion to a specific technological solution may be of limited value and potentially more expensive than 'soft systems' solutions such as prevention of waste or designing products with less toxicity (Curran and Williams, 2012; Freeman et al. 2013).

2.1.2.1 Diversion of waste from landfill and technological innovation

One of the key drivers for changes to waste management practices witnessed across the EU and within in England has been the introduction of key targets for the diversion of biodegradable waste from landfill. The so called 'Landfill Directive' (99/31/EC) set strict targets for diversion of biodegradable materials from landfill for milestone years (2010; 2013 and 2020 applicable to England because of the 4 year derivation allowed for those Member States whom sent more than 85% of waste to landfill disposal prior to 1995).

Box 2.1: Landfill Directive targets and key strategic targets in England

The Landfill Directive (99/31/EC) requires the amount of biodegradable municipal waste sent to landfill to be reduced:

- to 75% of 1995 levels by 2010
- to 50% of 1995 levels by 2013, and
- to 35% of 1995 levels by 2020

Waste Strategy for England (DEFRA, 2007a) set the following targets for diversion from landfill:

- Reduce the amount of household waste not re-used, recycled or composted from over 22.2 million tonnes in 2000 by 35% in 2015 with an aspiration to reduce it to 12.2 million tonnes in 2020 (a reduction of 45%).
- Increased recycling and composting of household waste to at least 45% by 2015 and 50% by 2020.
- Increased recovery of municipal waste to 67% by 2015 and 75% by 2020.

The Review of Waste in England (DEFRA, 2011a) amendments to the previous targets from 2007:

- Waste Framework Directive target to recover at least 70% of construction and demolition waste by 2020;
- A range of minimum producer responsibility targets covering packaging, WEEE, ELV and batteries.

The Waste Management Plan for England (DEFRA, 2013a) restates the previous targets.

Box 2.1 shows the structure of the key Landfill Directive targets as well as the response from successive governments in England since 2007. Significant emphasis within this target driven approach, was placed on the potential to incur significant fines

(£150/tonne/day) if these targets were not met. In response, the government in England have embedded responsibility for achieving diversion targets with Local Authorities and private contractors by means of setting the 'landfill tax' in accordance with an escalator mechanism (HMT, 2010).

A further mechanism was developed under the Emissions Trading Act (2003) which introduced a Landfill Allowance Trading Scheme (LATS) whereby LAs were able to trade allowances and thereby meet their obligations under the Landfill Directive (NCC, 2008; Audit Commission, 2014). The LATS scheme largely failed to establish a meaningful trading scheme between LAs and the private sector (EA, 2009) but may be attributed as contributing towards driving diversion from landfill as LAs sought to avoid fines by commissioning new types of residual waste treatment facilities (EA, 2009). The LATS scheme was ended by the coalition government in 2013 (Audit Commission, 2014) as the fiscal mechanism of the landfill tax was determined as being the most effective driver of diversion (BIS, 2012). As a response to the targets for diversion and subsequent management of residual waste fractions, much of the EU has taken a technology-led approach to managing material fractions of waste streams and residual waste (Ragazzi et al. 2011). This has produced innovative solutions aimed at recovering value through: automated sorting of multiple fractions within a single process (e.g. Material Recycling Facility screening technologies) or providing a solution to managing biogenic waste within a controlled environment (e.g. Anaerobic Digestion) with the added value of producing an energy source in the form of biogas (Bernsatd and la Cour Jansen, 2012).

Other innovations seek to reduce pollution and health risks. In particular, advanced thermal treatment (ATT) aims to neutralise the active biological content of waste streams (e.g. biogenic municipal waste and similarly constituted wastes from commercial and industrial sectors). Further by-products of such operations are excess heat which can be utilised for district heating schemes (Difs et al. 2010; Pattiya, 2011; Shabani et al. 2013) or the production of Syngas and/or hydrogen as fuel sources from Gasification processes (Cuoto, 2013). In addition, it is feasible for more technically challenging materials such as hazardous waste (e.g. asbestos) to be processed and altered at a chemical constituent level within Plasma Arc facilities to produce an inert by-product (Gomez et al. 2009).

2.1.2.2 Infrastructure provision for waste management

A significant factor for all such technologies is a requirement to build multiple facilities or integrated sites capable of handling large quantities of materials (primarily by means of road transportation). Therefore, a perceived need exists within the waste sector for the provision of land, investment and sympathetic planning in order to allow the sector to realise legislative targets on recycling and recovery (APSRG, 2011; ESA, 2013). Minehart and Neeman (2002) argued that responses to such varied and valid issues have been frequently muted by a lack of political will and outright public opposition. They go on to suggest NIMBYs (Not In My Back Yard) and LULUs (Locally Unwanted Land Uses) are directly related to a lack of consideration for local costs and benefits (Minehart and Neeman, 2002). On the other hand, Wright (1993) suggested there to be a relationship between site-relevant knowledge and NIMBYism. These factors are particularly germane when consideration is given to local planning issues around siting of waste management infrastructure (Bates et al. 2008). Seadon (2006) also highlighted planning factors when considering an integrated approach framed around sustainability principles, incorporating multiple types of facilities. Figure 2.3 shows the structure of the waste sector in England.

Given the systematic and hierarchical barriers to effective waste policy development stated previously; a need exists to address sustainability concerns around waste management systemically (Freeman et al. 2013). The longevity of problems; around transitioning waste management systems from landfill reliance to technological treatments of multiple material fractions; dictates approaches will be required which can account for dynamic complexity and long-term uncertainty while being capable of delivering sustainable outcomes. It is also the case that public engagement is an essential requirement for sustainable waste management planning (Bates et al. 2009).

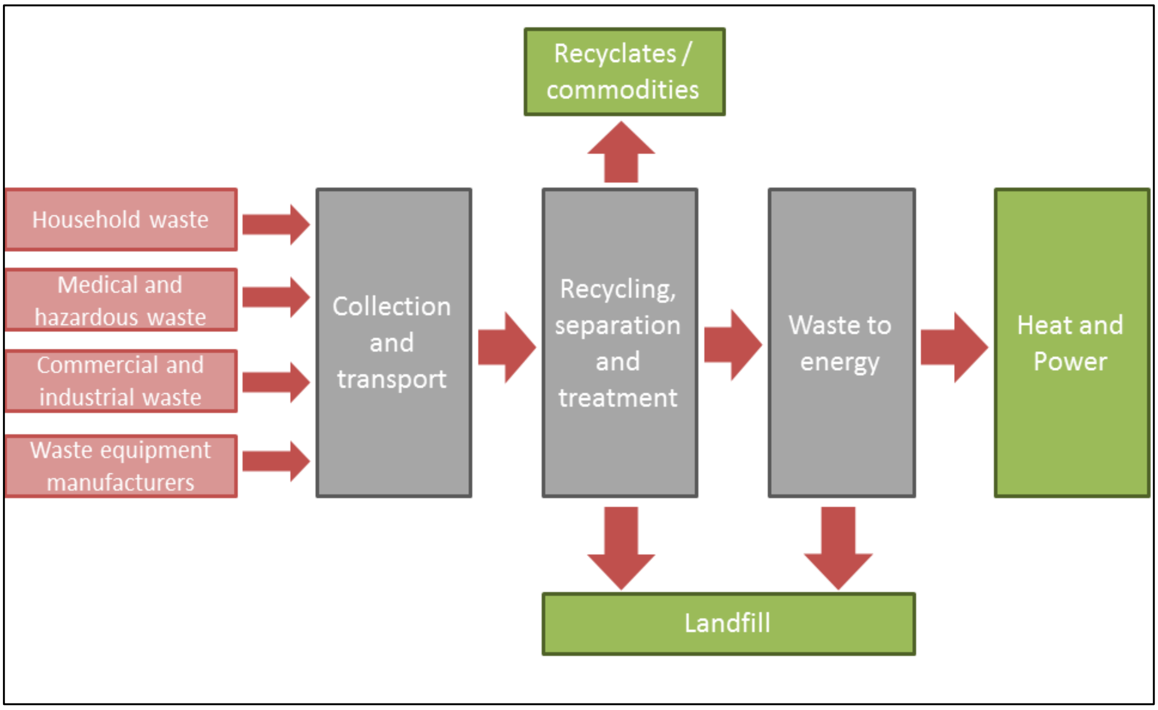


Figure 2.3: The waste sector in England and the wider UK (Source: Grant Thornton, 2011).

2.1.2.3 Barriers to waste infrastructure development

A number of key barriers to developing waste infrastructure have dominated the debate over the last 5 years in England. These barriers can be placed in three main categories: local, policy and industry. Figure 2.4 illustrates these categories and the individual elements within each as well as the interconnectedness of the elements and categories.

As Figure 2.4 shows a number of elements impact across all categories. Specifically, the planning system in England is often cited as a key barrier to developing waste infrastructure (Bates et al. 2008; DTZ/SLR, 2009; APSRG, 2010). However, the planning regime can only be considered as one contributing element.

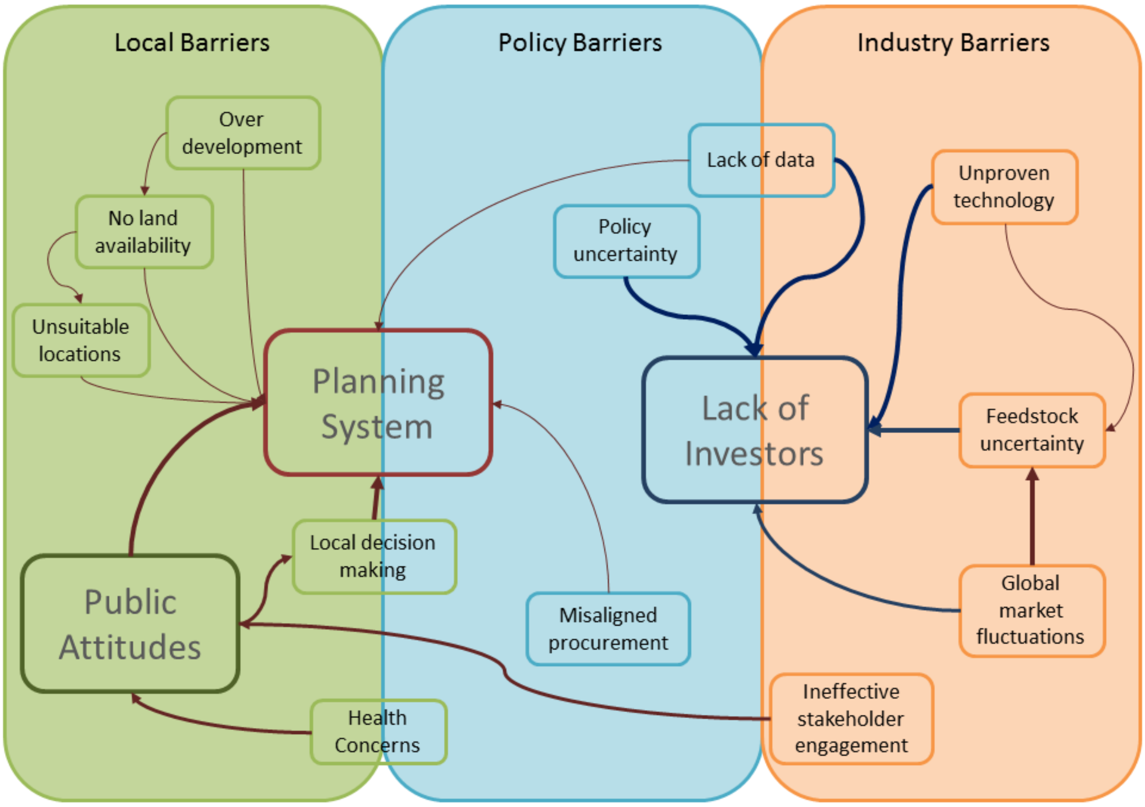


Figure 2.4: Barriers and complexity of waste infrastructure development in England (Source: AEA, 2012a)

2.1.2.3.1 Public attitudes and behaviour

Perhaps the most applicable element in decision making around waste infrastructure relates to public attitudes. As previously stated NIMBY attitudes and LULUs can be real problems (Wright, 1993; Minehart and Neeman, 2002) but these can be overcome if consideration is given to local circumstances, such as: housing types within locations; land availability; levels of development; and health concerns (Curran and Williams, 2012). Tonglet et al. (2004a; 2004b) suggested attitudes towards waste at the household level could be determined through consideration of the Theory of Planned Behaviour (TPB). They found that recycling attitudes were a key determinant for recycling behaviour (Tonglet et al. 2004a); which in turn required appropriate opportunities, facilities and knowledge to recycle as well as not being deterred by issues around physically recycling (e.g. time, space and inconvenience) (Tonglet et al. 2004b). A more in-depth examination of the literature undertaken by Timlett and Williams (2011) used the framing model of Infrastructure Service and Behaviour (ISB) to identify key variables which influenced recycling. Indeed, they found that focussing on recycling alone would be unlikely to exceed 50% and that 'upstream' interventions would be needed to move towards a zero waste future (Timlett and Williams, 2011).

In essence, there is a need for a transparent process of stakeholder engagement which includes taking account of local decision-making in cases of infrastructure siting (AEA, 2012a). Companies have increasingly sought to address this problem through communication (Read, 2011). This communication has taken the form of stakeholder engagement programmes and educational initiatives (VES, 2008) often at waste facilities or within schools. However, when considering provisioning of infrastructure cost is a major concern (see Figure 2.5).

2.1.2.3.2 Investment in infrastructure

Following the Comprehensive Spending Review (HMT, 2010) there has been a substantial reduction in public sector spending, leaving DEFRA with a 29% real terms reduction in its departmental budget for 2011-15. Further, government ceased funding for the Treasury Infrastructure Finance Unit (TIFU) as the lender of last resort (Coggins, 2011). As a result, the Government's National Infrastructure Plan suggested that 70% of investment must come from the private sector (HMT, 2010). This leads to the final point from Figure 2.4 in terms of the lack of investors. Investment is generally based on level of risk (BNP Paribas, 2009) which translates into uncertainty over level of returns. Government has gone some way to trying to address this uncertainty and has decreased fears over investment risk through the introduction of a Green Investment Bank (GIB) (EAC, 2011) and more recently with UK Green Investments (BIS, 2012). Notwithstanding the introduction of the

GIB and the £80m UKGI fund, there are further deep-rooted concerns amongst investors over a perceived lack of coherent policy towards waste.

2.1.3 Overcoming barriers

Since the introduction of Waste Strategy 2007 (DEFRA, 2007a) the overarching policy focus for waste has been framed around moving the economy towards a position of zero waste. At the time of writing, this position has not been realised in England, nor has it been formally adopted as a fully defined strategic policy, in contrast to Wales and Scotland. Indeed, the objective of attaining a zero waste economy remains an aspirational goal with many within the waste management sector openly questioning whether such a goal is achievable or desirable (CIWM, 2012).

Box 2.2: Exogenous factors impacting the WMS in England

- The economic downturn from 2008 restricting the availability of financing for new infrastructure capable of diverting waste from landfill and incineration;
- Drawback from the notion of the 'big society' and the localism agenda on achieving greater decision-making responsibility for waste matters;
- Population growth and internal migration towards areas of growth and development within England;
- Consumption patterns and environmental behaviour;
- Structure of the economy in terms of shifting towards decarbonising and greening the economy with a greater emphasis on eco-design of products and services; and
- Corporate eco-behaviour beyond corporate social responsibility (CSR) reporting towards embedding resource efficiency practices and processes.

Many of the factors previously mentioned (e.g. the legal definition of waste and end-of-waste criteria for materials to be recirculated; changing composition of residual waste streams; levels of technological innovation; infrastructure type, availability and scale;

planning considerations; public attitudes and behaviours; business attitudes towards reducing costs) have combined to provide significant internal obstacles (endogenous variables) towards realising this aspiration. A number of macro scale factors outside of but impacting on; so called exogenous variables (Robinson, 1990); the waste system have hindered the implementation of a specified zero waste strategy in England (Box 2.2). Although these exogenous variables are outlined here as obstacles to realising a zero waste vision, changes to any one of them has the potential to significantly reshape policy on waste and ultimately for achieving zero waste. For this reason, policy initiatives which focus on waste must also consider broader system variables (Freeman et al. 2013).

2.1.4 Complexity within the waste system

The generation of wastes has been postulated as an inevitable outcome of systematic production and consumption processes (DEFRA, 2007a; BIS, 2012). This position is premised on individuals; groups and organisations' inability to perceive large scale social, economic or environmental problems as a whole. Feedback loops and interrelationships between sub-systems can be overwhelming for decision-makers (Johnson-Laird, 2005; Chermack, 2011) and consequently in policy formation processes. Inaction and indecision within waste planning delays required action and leads to choices which do not reflect scientific evidence (Bates et al. 2008). Davoudi (2000) has further suggested that planning for waste management in England (as well as the wider UK) has been hindered significantly by the 'sectoral' nature of the system and end-of-pipe approach to participation. This viewpoint is endorsed by Seadon (2010) in his work on integrating waste management systems in New Zealand (see Box 2.3 and Table 2.3).

Seadon gives a number of examples which range from intervening too soon when a feedback period has not been established to focusing on detailed metric data at the expense of macro data on overall systems performance (Seadon, 2010).

Box 2.3: Seven shortcomings of traditional waste management

1. Effort is spent collecting and analysing immaterial data.
2. Interventions may be irreversible, rather than providing for mechanisms to deal with emerging correctable side effects.
3. Solutions are based around short-term goals rather than longer term sustainability thinking.
4. Time lags between intervention and effects are underestimated, thus misinterpreting the perceived lack of response as a need to invoke stronger interventions resulting in overcorrection that then needs to be fixed.
5. Disregard or undervaluing the side effects of intervention.
6. The focus on fixing individual problems rather than the viability of the Waste Management System (WMS).
7. Reliance on linear extrapolations of recent short-term events.

Source: (Seadon, 2010).

He also draws extensively on general systems theory (GST - von Bertalanffy, 1968) and systems thinking approaches (Capra, 1996; Vester, 2007) in positing waste management research between a reductionist and systems approach (as shown in Table 2.3).

Table 2.3: Comparison of reductionist and systems approaches

Reductionist	Systems
Analytical	Synthesis
Objects	Relationships
Parts	Holistic
Context independent	Context dependent
Practitioner independent	Practitioner dependent
Hierarchies	Networks
Structure	Process

Sources: after Tapp and Mamula-Stojnic (2001); Capra (1996) cited in Seadon (2010)

2.1.4.1 Changes to waste planning

One such variable which has long been considered as a major barrier to developing more sustainable systems of waste management is the planning system. Indeed, Ackers

(2012,p2) attributes great significance for increasing the complexity of waste planning in England to EU legislation requiring ever increasing diversion of municipal (now LACW) wastes from landfill. Ackers identified the Planning and Compulsory Purchase Act (2004; amended 2008) as the critical piece of waste planning regulation for England. More recently, an overhaul of the planning system in England under the National Planning Policy Framework (NPPF – DCLG, 2012) has witnessed planning being framed within the political lens of Localism (Davoudi, 2000; Clarke and Cochrane, 2013). This has largely been necessitated through the removal of the regional tier of governance in relation to strategic waste planning (HoC, 2011). The impact on waste planning has been mixed (Box 2.4) with Local Authorities and the waste sector claiming localism is not an appropriate mechanism to manage the strategic nature of waste planning (LGA, 2011; ESA, 2011).

Box 2.4: LGA position on the impact of localism on waste management planning

A report by the Local Government Association (LGA, 2012) states:

'…waste planning must account for multiple variables impacting on levels of waste generation'.

Source: (LGA, 2012).

According to the LGA such variables include: demographic pressures; changing seasonal composition of waste streams; non-standardised methods of collection and separation of recyclates; end market development for recyclable materials; and frequent regulatory change (LGA, 2012).

Nonetheless, the solutions being proposed by the waste sector as a whole are grounded within the paradigm of 'moving waste up the hierarchy' (DEFRA, 2011a; EEF, 2009; Ackers, 2012; CIWM, 2013).

Once again, this paradigm reflects Davoudi's argument about the planning regime systematically approaches waste from an 'end-of-pipe' direction (Davoudi, 2000), rather than planning systemically and thus considering prevention and reduction as the priority actions for sustainable waste management (Cole et al. 2014). Meadows (2008, p.92) suggests such a paradigm, or archetype, reflects certain perceptions and vested interests which themselves produce a state of ‘policy lock-in’.

For waste management planning, this ‘lock-in’ can be seen with an emphasis on recycling over waste prevention or through policy support for large scale development of AD (DECC/DEFRA, 2011) rather than initiatives to reduce food waste in households and the food processing industry. However, significant research has examined alternative waste management models where the traditional functions of waste management companies are taken on through existing organisational structures (Hickford and Cherret, 2007) or supported by the expansion of roles for the informal sector (Zaman and Lehman, 2013). Evidence of this can be seen through reverse logistics operations (Pourmohammadi et al. 2008) within many supply chains, where ‘waste’ materials are returned to central locations for sorting and separation prior to resale as a commodity or as a valuable ‘resource’ within industrial networks (Curran and Williams, 2012).

Such reverse logistics systems have been extensively explored in the literature on industrial symbiosis (IS) (Chertow, 2003; 2007) particularly in relation to by-product exchange (BPE) networks (Zhu et al. 2007). Hickford and Cherrett (2007) suggested that thinking of wastes and by-products as potentially valuable feedstock may allow for the design of a high degree of sustainability into them. The implications of such exchange networks are significant in terms of achieving stated government aims of developing markets for ‘waste materials’ (WRAP, 2010a).

2.1.4.2 Future waste management policies

Waste planners must consider the potential impact of certain policy choices within their local plans. In order to do this, they have historically examined predictive forecasting approaches such as that developed for the East of England (ADAS, 2009). Such tools bring together data on key variables thought to have the most significant impacts on future waste generation affecting households and economic sectors, often utilising economic forecasting tools (Oxford Econometrics, 2010; SERI, 2010). However, a number of key shortcomings are identified as problematic with such an approach: extrapolation of existing patterns become more uncertain the longer the time horizon (Robinson, 1990); not accounting for certain systems variables undermine the results (Dreborg, 1996; Borjesson et al. 2006); and the feedbacks within a system can amplify changes from a relatively small variation in a single variable (Capra, 1996; Gleick, 2008) thus rendering a predictive approach inappropriate. To address these problems, certain waste policies which have been implemented in some contexts may be considered in terms of their potential impact on: waste generation; infrastructure requirements (capital investment); and environmental emissions.

2.1.4.2.1 Waste generation as a recognisable evaluation metric

The Sustainable Development Indicators (SDIs) used by the UK government were revised in July 2013 bringing the total number of SDIs down from 68 (and 123 measures) to 12 (25 measures) headline and 23 (41 measures) supplementary indicators (DEFRA, 2013a). Within this revision waste became a supplementary indicator with two measures included to account for levels of waste generation in the economy:

1) Proportion of household waste recycled
2) Proportion of construction and demolition waste recovered

Such an approach is problematic for two main reasons. Firstly, household wastes account for around 10% of all controlled wastes in England (DEFRA, 2014a) and the factors which influence changes at the household level are considered more diverse than for other waste streams (see Resource Futures, 2009). Secondly, the data on C&D wastes is widely regarded as the most inaccurate and incomplete (RPS, 2009; EA, 2012a; NCC, 2012) which suggests the variances in estimations of recovered C&D materials, are likely to be unreliable at best. A more reasoned approach might include the level of waste generation from all controlled wastes as seen in requirements for the production of Minerals and Waste Development Framework (NCC, 2012). Such an approach would still utilise estimation methodologies for certain waste streams (e.g. C&D and some C&I wastes) but would employ a scenario based methodology thus normalising the potential for variance with this type of data. Indeed, a non-predictive scenario methodology would only apply quantifiable data as a means of determining the plausibility of a potential desirable future state (Robinson, 1990) rather than defining what that future state would entail.

2.1.4.2.2 Identifying an economic evaluation metric

Largely related to the use of forecast models (FoM's) within LAs for waste planning as well as utilising software packages designed to address the whole life-cycle of the WMS (e.g. WRATE), significant lobbying pressure has been placed on government as to the need for considerable capital investment within the WMS (e.g. waste treatment and recovery facilities, collection schemes and types thereof) (ESA, 2009; APSRG, 2011; Eunomia, 2012), some £20Bn of this on waste infrastructure alone by 2020. At the same time resistance to specific policies (e.g. landfill bans); which have been shown to rapidly increase diversion towards treatment and recovery (WRAP, 2010b; Green Alliance, 2010); has been justified on the grounds of having a waste planning system which cannot deliver the capacity required to meet statutory targets (Bates et al. 2009; Fitzgerald, 2011). This approach is problematic as it favours large-scale projects such as incineration which can have an attractive ROI if long-term LA contracts are included. Indeed, a series of reports by Eunomia Consulting has increasingly shown the potential for an over-capacity in terms of incineration (EfW) facilities to exist before the current plan period ends in 2031[6]. To put this in a systems context Figure 2.5 shows the waste hierarchy with economic costs.

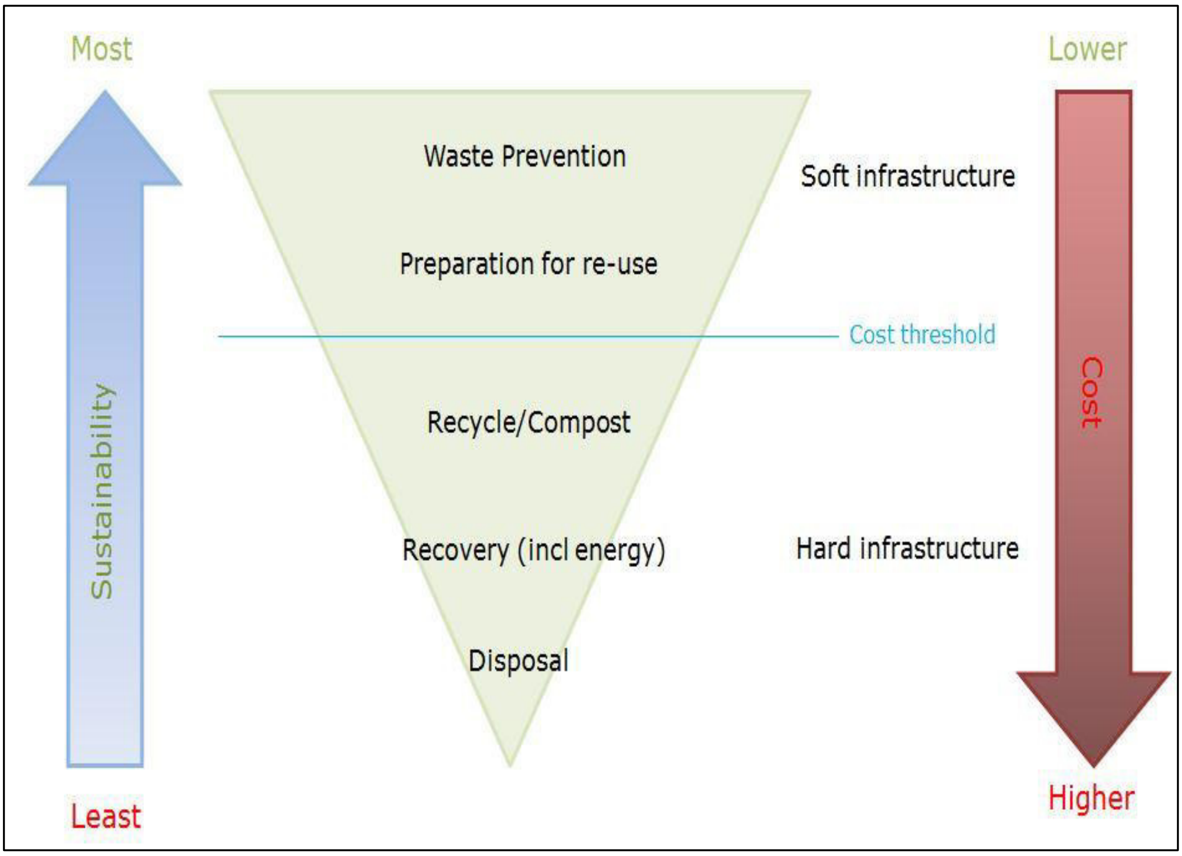


Figure 2.5: Economic impact of the waste hierarchy (Source: after DEFRA, 2011a).

Figure 2.5 shows the cost threshold for provision of infrastructure within a WMS centred on the waste hierarchy. This threshold separates elements requiring significant capital investment as 'hard infrastructure' (waste facilities or increased collection and separation capacity for kerbside collected materials) and initiatives and actions which require more systemic changes and interventions at low cost as 'soft infrastructure' (campaigns on preventing specific waste fractions – such as Love Food Hate Waste). The point, in terms of economic impacts, is that effort to view wastes as resources allows these materials to sit above the cost threshold and thus incurs a low cost / most sustainable outcome. In contrast;

[6] Waste Planning Authorities have a statutory requirement to show how a minimum of 10 years waste management capacity can be delivered within their administrative area under PPS10 (DCLG, 2013). Under the duty-to-cooperate brought in with the NPPF (DCLG, 2012) WPAs must have consideration for all areas which they interact with (import/export of wastes) which means Local Plans typically run from 2012 to 2026/31 and must also be kept up-to-date.

a traditional ‘waste paradigm’ approach is likely to sit below the cost threshold and thus incurs a high cost / low sustainability outcome. Given the calls for £20Bn investment (APSRG, 2011) in hard infrastructure, if the approach described in Figure 2.5 were applied this would suggest a considerable investment savings opportunity at a time when LAs budgets are stretched (Gilford et al. 2013).

2.1.4.2.3 Identifying a robust emissions evaluation metric

Reducing emissions associated with waste is another key policy aim in England (CAT, 2010; DEFRA, 2013a). Statistical releases in England on LACW are accompanied by calculation of the carbon emissions associated with the constituent material types and destination route (recycling, composting, recovery or residual disposal) (DEFRA, 2013). The calculations used are in line with those developed under the carbon metric for Scotland (TSE, 2010); the first of its kind to be utilised in a coherent strategy of quantifying the environmental impacts of waste management.

The basis for such calculations used with the ZWS and DEFRA carbon metric comes from a considerable amount of climate change research (IPCC, 2007; Gomes et al. 2008; Kennedy et al. 2010) as well as specific research into the GHG and climate change potential of waste management (Consonni et al. 2005; Fisher et al. 2006; Cleary, 2009; Muhle et al. 2010; Luckow et al. 2010). The comprehensive study by Muhle et al. (2010) made a comparison between the UK and Germany on carbon equivalent emissions which used compositional characterisation of MSW to assign emissions values to. In terms of the results for the UK these were derived from an earlier DEFRA report ‘Carbon Balances and Energy Impacts of the Management of UK Wastes’ (Fisher et al. 2006). This work was incorporated into the calculations for carbon metric reporting by DEFRA and ZWS; along with the updated greenhouse gas inventories for England and the Devolved Administrations (AEA, 2012b).

2.2 Zero Waste: an evolving conceptualisation of resources

Zero waste is not a new concept having first been mentioned by economist Kenneth Boulding in 1966 in relation to what Greyson (2007) describes as a circular economy goal-set: “a [CE] is a long-term aim compatible with economic growth, sustainability and zero waste”. In this context, zero waste is being used in the broadest sense – preventing waste of resources as well as associated actions and activities. Perhaps the most structured definition of the term comes from Zero Waste International Alliance (Box 2.5).

The term zero waste has also been formalised in terms of lean manufacturing approaches since the 1980s as an organisational response to concerns over environmental impacts of resource depletion (Ohno, 1988). However, the developmental goal of zero waste is frequently diluted with incremental change the default policy approach which Greyson argues produces a situation where: no waste becomes less waste in practice (Greyson, 2007).

Box 2.5: Zero Waste International Alliance definition of zero waste
‘‘Zero waste” means designing and managing products and processes systematically to avoid and eliminate the waste and materials, and to conserve and recover all resources from waste streams’
(Source: ZWIA, 2004)
In 2009 a revised definition was accepted by ZWIA which aimed to assist businesses and communities in defining their **own** zero waste goals (ZWIA, 2013). A figure of 90% diversion of waste from landfills and incinerators is considered to have met the new definition.

Zaman and Lehman (2013) support this stance arguing that terminology such as zero waste to landfill is often substituted for the preventive aspect of ‘zero waste’. In both cases a position of less bad is not good enough (Greyson, 2007; Zaman and Lehman, 2013).

2.2.1.1 Conceptual origins

Zero waste is a goal, an aspiration, or a mind-set which profoundly changes society's approach to resources, production processes and consumption practices (DEFRA, 2007a; TSE, 2010; Phillips et al. 2011). The notion of zero waste has been discussed in the academic literature for a number of years and has its philosophical origins in the management approaches of Lean Manufacturing (Ohno, 1988) and Total Quality Management (TQM) (Petek and Glavic, 1993; May and Flannery, 1995) used in many Japanese corporations since the late 1980s and 1990s. The focus of Lean Manufacturing and TQM; is to minimise wastes from all areas of production (Ohno, 1988). Similarly, the concepts of Industrial Ecology (IE) and Industrial Symbiosis (IS) recognise the need to reorganise production systems around by-product exchange (BPE) (Chertow, 2007; Mattila et al. 2012) and redesign of products and production processes (Isenmann, 2003) with the aim of minimising waste and reframing waste as a resource of value.

2.2.1.2 Zero waste in practice

Zero waste remains a firm aspiration for governments across the globe (DEFRA, 2011a). This has materialised in terms of specific policy formation at the national level in only a handful of locations (TSE, 2010; WAG, 2010; Young et al. 2010). However, it is uptake at regional and city level; organisations; interest groups and applied research which is seeing significant results in terms of innovative research towards making the transition to zero waste. As identified previously (section 2.2) 'zero waste' has developed from Lean Manufacturing and TQM (Seadon, 2006). This view is supported by Womack and Jones (2003) whom suggested the automotive industry embraced such concepts based on a refusal to accept the inevitability of waste. Indeed, Ohno (1988) put forwards and introduced; within the Toyota Production System; seven areas: overproduction, waiting time, transportation, inappropriate processing, unnecessary inventory, unnecessary motions and cost of defects; where intrinsic waste can be addressed.

A number of major cities around the world have introduced and implemented zero waste strategies and community based initiatives (e.g. Stockholm and Adelaide) (Zaman and Lehman, 2011; 2013). In addition, "zero waste commitments" have been introduced in a number of countries including: New Zealand; China; Taiwan; USA (California); Canada (Nova Scotia) Australia (South Australia) and South Africa (Greyson, 2007; Zaman and Lehman, 2014).

Empirical research has been undertaken at different scales; from area based approaches, to a whole city context as well as from a systems perspective. An early piece of zero waste research looked at a university campus and how grassroots concerns could be addressed through the implementation of an EMS approach (Mason et al. 2003). Other area based approaches have been undertaken relating to IWM in Chennai (Colon and Fawcett, 2006) which found that almost 95% of wastes from households were potentially recyclable. Similarly, Matete and Trois (2008) looked at an IWM system within an urban setting of South Africa using a zero waste model. Another project was implemented in two phases within England in 2008/09 and 2009/10 using the Zero Waste Places model (Phillips and Tudor, 2011; Warner et al. 2014).

At the city scale, Fujita and Hill (2007) explored the concept of a zero waste city which was followed by Zaman and Lehman (2011) using a comparative analysis of three large developed cities looking at consumption levels of these urban centres. Other research has tried to quantify changes to systems which are high producers of wastes. For example; Kinuthia and Nidzam (2011) examined the C&D waste stream using the eco-efficiency principle of doing more with less. In the UK, Curran and Williams (2012) have proposed the philosophical approach of zero waste and applied this as a whole system approach for industrial networks within an EU funded research programme. Research beyond these scales is lacking with one study found which explored the application of C2C design within a zero waste context, in order to maintain materials as a resource (Braungart et al. 2007). While these studies were undertaken as independent pieces of research, the findings and outputs identified a number of key synergies across multiple contexts (Box 2.6).

Box 2.6: Key considerations of zero waste research studies

- a focus on the reduced consumption of resources;
- eco-effectiveness of products and systems of production;
- the role of individuals consumptive behaviour;
- product design and early intervention at this stage to mitigate end-of-pipe problems;
- the maximisation of landfill diversion; and
- the optimum recovery of resources.

Alongside these synergies a number of studies identified conflicts between policy aspiration on zero waste and policy implementation. For example; the Zero Waste Places project in England was a government based initiative with broad support from communities, regional government, the public sector and government departments (Warner et al. 2014). Both pilot schemes (running 2008/09 and 2009/10) met key performance criteria and were judged successful overall (Phillips et al. 2011; Warner et al. 2014). However, the projects coincided with the severe economic downturn in England and found their funding sources evaporate as DEFRA has increasingly sought to withdraw from waste in favour of actions driven from the local level (Edie.net; 2013). Projects undertaken by Zaman and Lehman have been some of the most extensive on implementing zero waste laws (e.g. South Australia) and have gone on to develop a Zero Waste Index (ZWI – Zaman and Lehman, 2013) which if adopted has the potential to standardise the method of measuring the efficacy of different zero waste policies. At the time of writing (late 2014) there was no detailed evidence available of the ZWI being evaluated outside the original research project or being utilised to quantify the impacts of zero waste strategies.

2.2.2 The 'holistic' approach in waste management

The European Commission has introduced much of its waste legislation predicated on either a specific waste stream (e.g. ELV and batteries) or a specific area of operation (e.g. packaging) (Figure 2.6). This analytical viewpoint towards 'waste' reflects the dominant Cartesian paradigm of scientific investigation. This may explain responses to the problem of waste as a technological challenge (e.g. a symptom which requires a cure) rather than a socially constructed phenomena (Capra, 1996) requiring a broader view of the overlapping systems which produce the notion of a wicked problem (Meadows, 2008). In short, if the problem is socially constructed then it is feasible to suggest it can be deconstructed through changes to beliefs, values and norms which perpetuate the concept of waste.

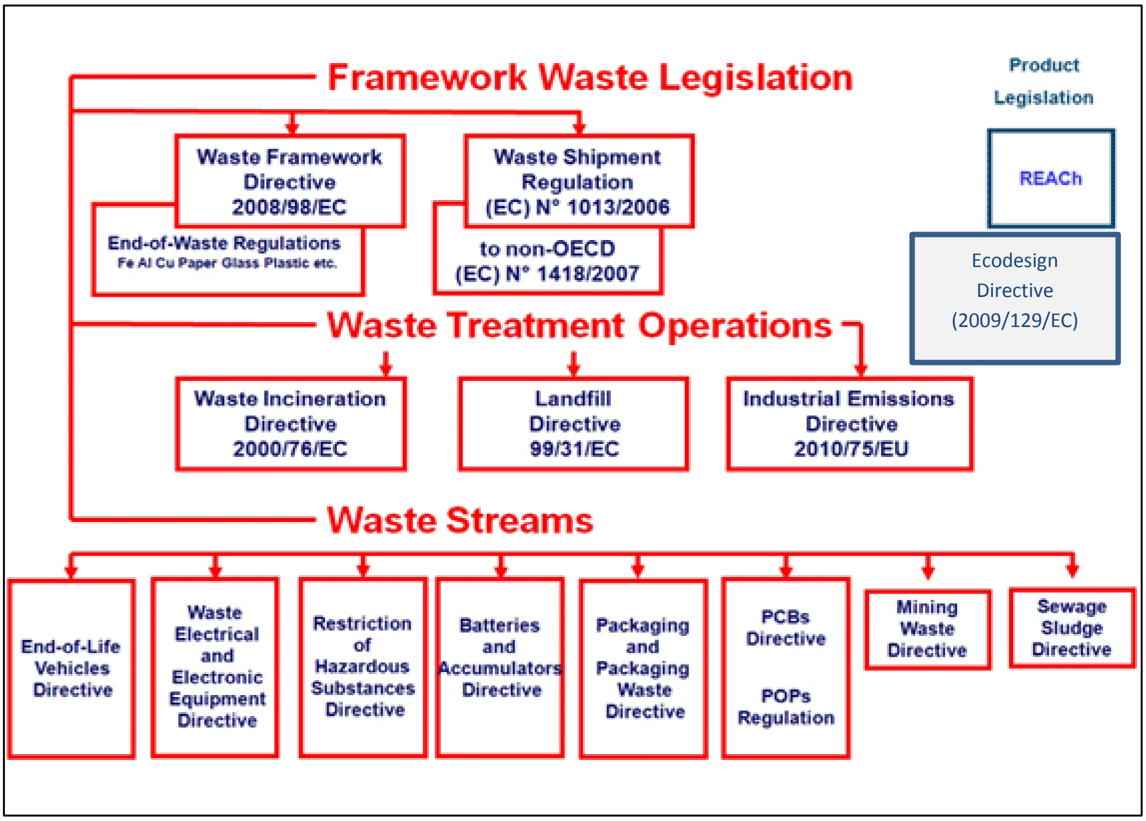


Figure 2.6: European Union waste related framework legislation (Source: after EC, 2013).

It may thus be suggested that a holistic approach to waste management must consider not only the visible system of infrastructure and material flows but also the policy frameworks and overlapping areas of synergy with debates around energy (CAT, 2010; HMG, 2010; 2011; Ernst and Young. 2011); transport policy (DFT, 2005); and materials security (CBI, 2011; Deloitte, 2011) with a view to protecting the economy from system shocks. Perhaps through addressing such systems conditions it may be possible to view waste as resources which are nested within 'systems of systems' (Kefalas, 2011). In other words, a holistic approach towards achieving a zero waste future addresses the three main characteristics of systems thinking: as a world view; interdisciplinary by nature; and phenomena in the real world have interactions and interrelationships (Kefalas, 2011). The notion of interactions (positive and negative) and the concept of feedback (Capra, 1996; Gleick, 2008) are useful when considering environmental impacts of waste systems.

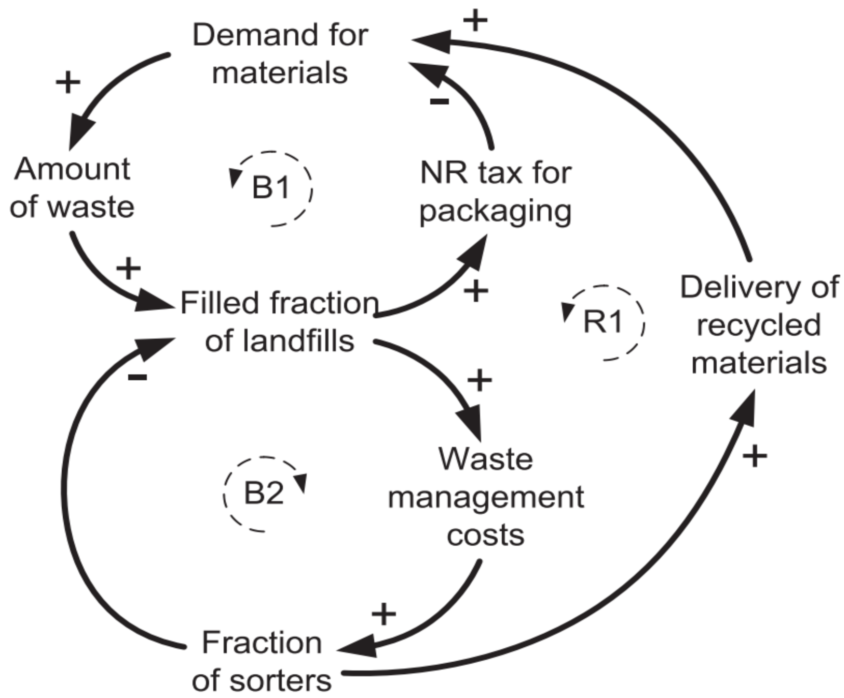


Figure 2.7: Causal loop diagram showing feedback loops in a waste management system (B1, B2 balancing loops and R1 reinforcing loop) (Source: Dace et al. 2014).

For example; sending discarded materials to landfill is an example of a reinforcing feedback loop (see Figure 2.7) where more extraction and thus depletion of natural resources is required to replace those 'lost' materials. In contrast, preventing the wastage of resources and their embedded factors is an example of a balancing feedback loop which seeks to move the system towards equilibrium.

2.2.2.1 Zero waste as a holistic waste management approach

There is a need to fully define the problem of waste and ultimately this may require a less rigid approach to the 'concept of waste'. Freeman et al. (2013) suggest both the 'definition of waste' and 'end-of-waste criteria' represent significant barriers towards bringing materials back into the resource value chain. This point is also highlighted by Curran and Williams (2012) in terms of zero waste for: resources, emissions, activities, product life and use of toxics when looking at zero waste in industrial networks (ZeroWIN).

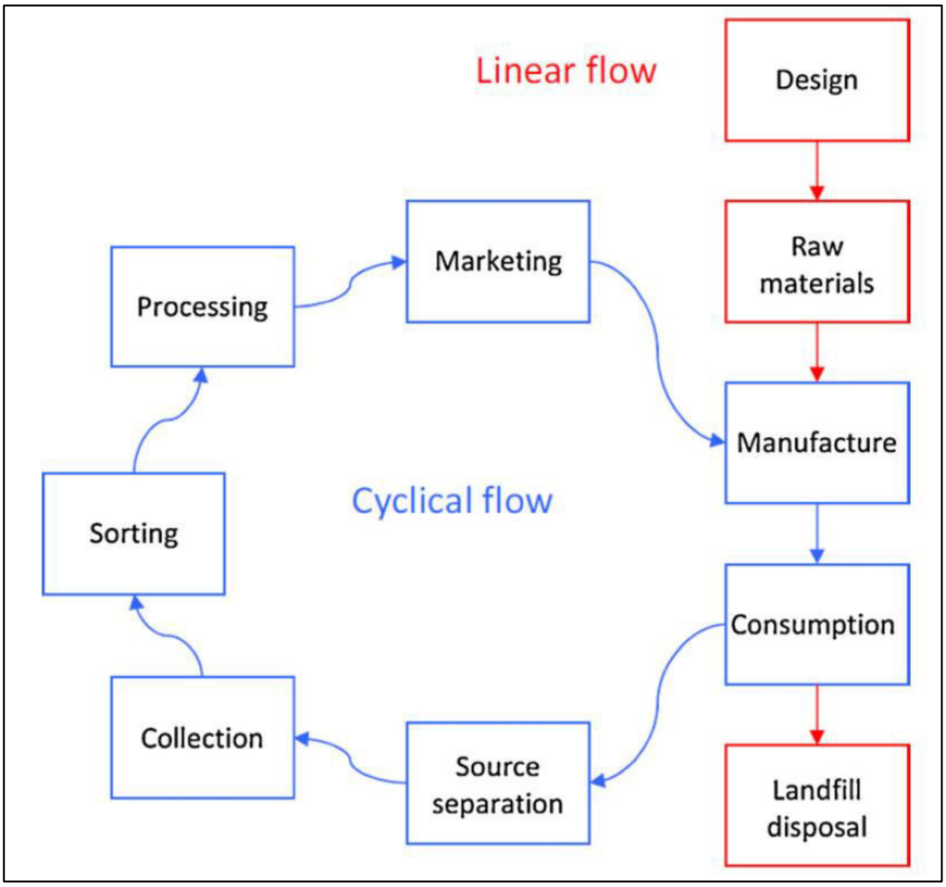


Figure 2.8: Linear and cyclical resource flows (Source: Curran and Williams, 2012).

Freeman et al. (2013) focus on changing the perception of materials as resource to prevent those becoming wastes; while Curran and Williams emphasise the business case for minimising wastes through applying a closed-loop philosophy thus increasing 'the productivity of raw materials' (Curran and Williams, 2012). They are focusing attention towards a more holistic view of waste management by examining the upper tiers of the waste hierarchy (e.g. prevention) as a means of closing loops and shifting away from a linear waste model.

In a similar way to Figure 2.2; which identified the potential for cyclical flows of materials within the regulatory framework; the two types of flow (linear and cyclical) shown in Figure 2.8 demonstrate a specific understanding of such flows within the confines of current thinking. As previously raised, Meadows (2008) would describe this as a bounded rationality closely aligned with the notion of lock-in. Figure 2.8 represents material flows within two waste systems, it is possible to envisage new arrows from raw materials 'reservoirs' and landfill 'reservoir' through landfill mining (van der Zee et al. 2004; van Pessel et al. 2013) as well as significantly increasing cyclical flows from landfill bans on specific material types (WRAP, 2010).

2.3 From linear waste models to a circular economy

It may be argued the model for waste management in England has been in transition from a linear (take-make-dispose) (Figure 2.9) model towards a more cyclical model (where increasing amounts of materials are recycled and to a lesser extent reused) since first Waste Strategy for England (DETR, 2000; Preston, 2012). Recognition of recycling limitations in moving towards sustainable waste management were raised soon after its introduction (Strategy Unit, 2002) and increasingly so by the mid-2000's (Green Alliance, 2006).

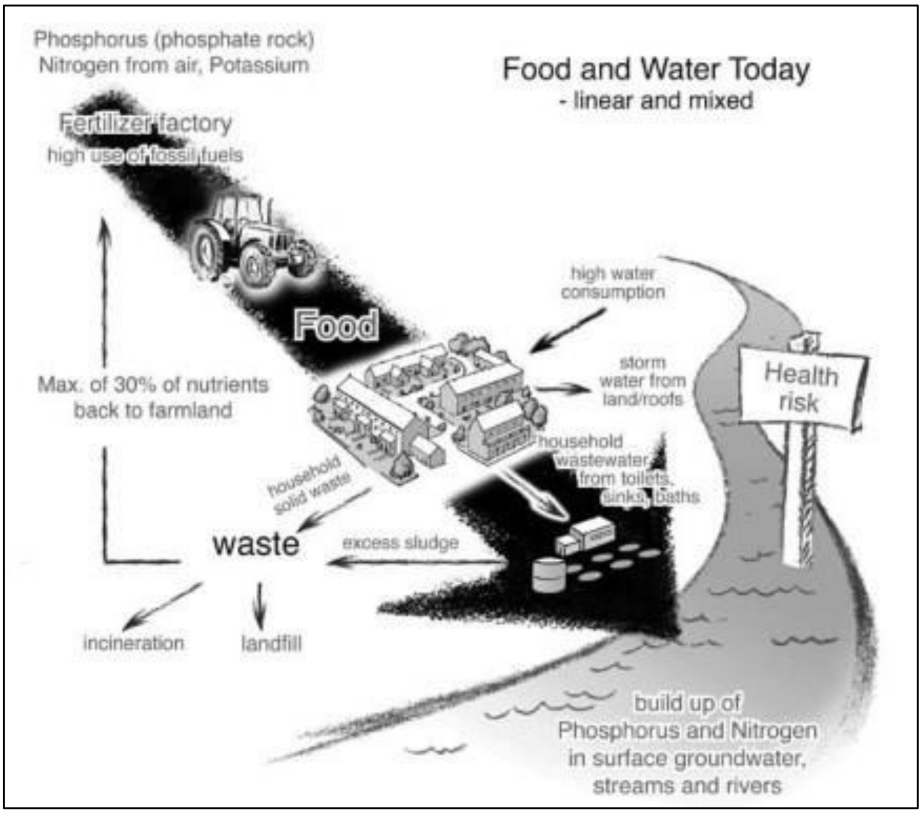


Figure 2.9: A linear economy (take-make-dispose) (Source: Webster and Johnson, 2010).

These concerns were embodied within the aspiration of moving towards a zero waste society (DEFRA, 2007a; Greyson, 2007) in the subsequent strategic plan and have remained on the policy horizon ever since (DEFRA, 2013a; 2013b).

2.3.1 Circular economy origins

The "circular economy" concept has its theoretical foundations in the works of Boulding (1966), Stahel (Stahel and Reday-Mulvey, 1981), Pearce and Turner (Pearce and Turner, 1990). These foundations come from the field of environmental economics with its concern with the long-term sustainability of human systems with nature. Pearce and Turner's (1990) seminal work 'Economics of Natural Resources and the Environment' stated that an open-ended (linear) economy had no built-in capacity to recycle and consequently the environment (natural ecosystems) were treated as waste reservoirs. In their work, the earth was viewed as a closed economic system where the economy and environment had a circular relationship; thus drawing on Boulding's (1966) earlier idea of a 'spaceship earth'. Stahel's vision of the circular economy began with thinking about the notion of 'cradle-to-cradle' (C2C) for wastes in society (Stahel and Reday-Mulvey, 1981).

This thinking transformed through recognition of the fundamental need for considering the economy as this would drive the elimination of wastes (Stahel, 2013). This would be achieved through a regenerative economy where some types of 'wastes' re-enter the biosphere and are recycled as nutrients while others are designed to continuously circulate in the human 'technosphere' (Making It, 2013; Garcia-Olivares and Sole, In Press). Braungart and McDonough (2002) significantly expanded the concept of C2C as a fundamental principle from which economic, social and environmental considerations may be accounted for. This is extended in terms of the fundamental focus on design in their work on upcycling (McDonough and Braungart, 2013); where products and services can be manufactured and structured around modular designs or through leasing packages.

Within the literature other authors link CE with specific theoretical approaches on reorganising systems. Geng et al. (2011) suggest that the CE concept originates from eco-industrial development (EID) theory; a position supported by Spiegelman (2001); an extension of industrial ecology thinking (see Isenmann, 2003; and Korhonen, 2004 for more detailed exploration of the IE concept) most often linked with the formal organisation of eco-industrial parks (EIPs) (Tudor et al. 2007; HKGCC, 2010) based on the broader principle of industrial symbiosis (IS) (see Chertow, 2003; 2007; Zhu et al. 2007; Bain et al. 2010; Giurco et al. 2011 for the development of IS in recent years incorporating theory and empirical research on EIPs). Indeed, the notion of re-circulating wastes as secondary materials through by-product exchange is well recognised within the waste literature (Kurup et al. 2005; Zhu et al. 2007; Chertow, 2008).

2.3.1.1 Implementing the Circular Economy

The notion of a CE is a relatively recent shift in economic thinking but has increasingly gained legal status in some developed countries (e.g. Germany and Japan) (Davis and Hall, 2006) and is becoming increasingly influential among businesses and government bodies in the UK (EMF, 2013).

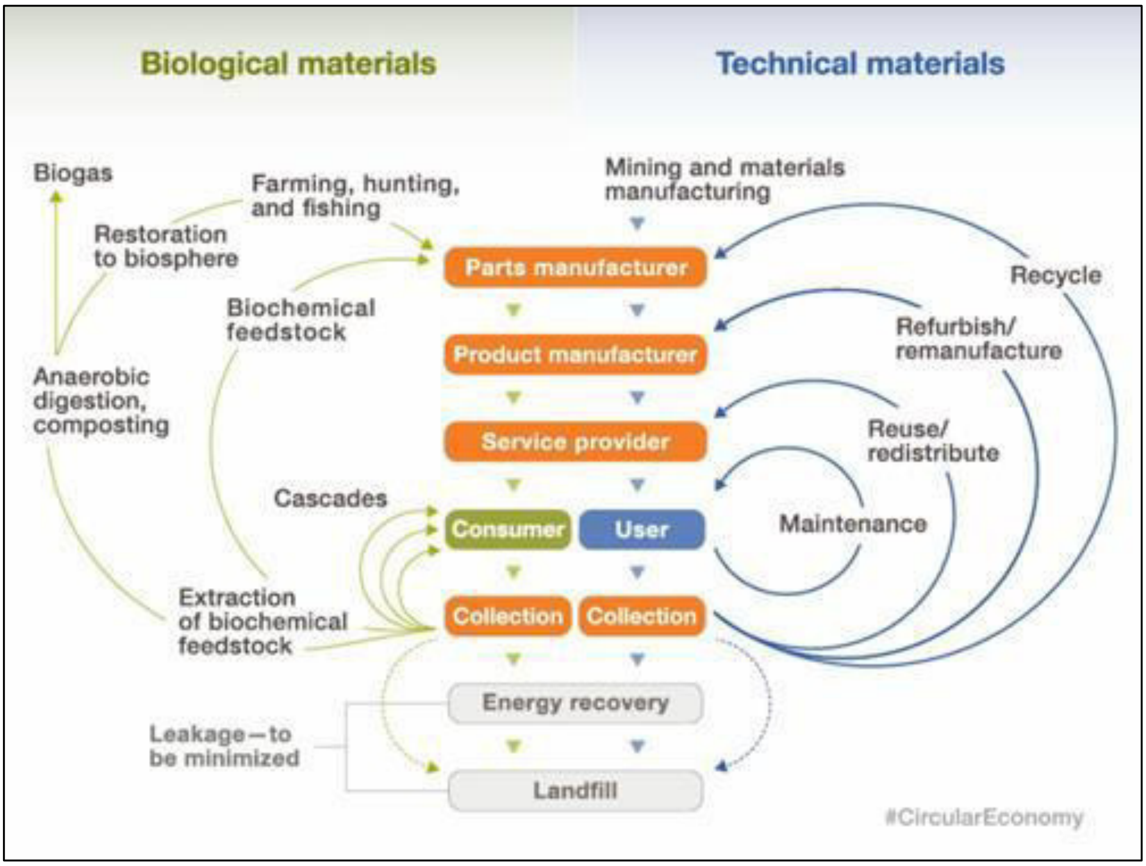


Figure 2.10: The circular economy framework (Source: McKinsey.com, 2014).

The concept is based on a number of key principles: redesigning industrial systems (Dewberry and Sherwin, 2002; EMF, 2012); C2C production (Stahel and Reday-Mulvey, 1981; Braungart and McDonough, 2002); a shift towards collaborative consumption (Botsman and Rogers, 2010); and measuring progress (see Box 2.7). The CE framework (Figure 2.10) suggests the inherent value of wastes can be realised as economic, technical or biological value through a continuous process of recirculating these 'resources' in the economy (McDonough and Braungart, 2013; McKinsey.com, 2014). This extends resource life and reduces the input of other finite resource such as water or energy (Preston, 2012).

Box 2.7: A note on Circular Economy principles

Redesigning industrial systems (the right side of Figure 2.10) has long been a consideration for policy-makers and academics seeking ways of increasing efficiency (Ohno, 1988; Oakdene Hollens, 2009) or minimising waste within production networks (Chertow, 2003; Curran and Williams, 2011). Fundamental concepts to achieve such a redesign include: industrial ecology; industrial symbiosis (Korhonen, 2004); and biomimicry (Benyus, 1997) (this concept speaks to realising value from the biological materials in Figure 2.10 as much as it does to technical innovation).

Cradle-to-cradle (C2C) is about the circulation and design (Dewberry and Sherwin, 2002) of biological and technical materials (represented as loops from one life-cycle stage to an earlier stage in the system in Figure 2.10). The aim is to avoid energy recovery and landfill as these represent losses to the system which must be replaced with new inputs. For consumers and users an increasing role is seen for leasing and rental models to change the notion of ownership through ideas such as collaborative consumption and the shared economy (Botsman and Rogers, 2010). This allows producers to retain resource ownership increasing quality and boosts bottom line, exploiting reverse logistics practices across supply chains (Zheng and Zhang, 2010).

To *measure progress towards CE* new approaches which can map resource flows within the economy would be useful. These are under-utilised currently at national scales because of the problems of acquiring resource-related data (Preston, 2012). The use of spatial models built around scenarios of the future may be a useful tool for measuring this progress; additionally allowing consideration of other conditions (valorisation and sustainability) as either transitional phases or as alternatives which can still deliver the overall goal (the elimination of waste from the economy – zero waste).

2.3.2 Circular economy in practice

A number of countries (Germany, Japan and China) have been developing legislation and implementing national laws requiring waste management to be reframed around the concept of CE (HKGCC, 2010). More recently, uptake of the CE banner has been driven by business and industry in response to materials and energy security concerns amid rapidly increasing commodity prices (EMF, 2011) and the imposition of caps on the export of certain key materials at the national scale (BIS, 2012). In the UK and internationally, this has manifested itself at the business level through the CE 100 (a group of companies under the auspices of the Ellen MacArthur Foundation committed to the CE principles). This is supported at government level through the CE Taskforce to enable sharing of best practice and delivering knowledge exchange between business and governments.

2.3.2.1 Policies implementing circular economy as law

In Europe, Germany has been the lead country on implementing CE principles within policy approaches and through legislation (Davis and Hall, 2006). Karavezyris (2010) points out that the paradigm shift from waste management to a circular economy is in line with the EU goal of a ‘recycling society’ and has been underway in Germany since the 1990’s. The first substantive CE law introduced globally was the ‘Closed Substance Cycle Waste Management Act’ (Karavezyris, 2002) becoming law in 1996 “Kreislaufwirtschafts- und Abfallgesetz” (Janz, 2012). This has recently been overhauled; to reflect European priorities (high recycling society and roadmap to resource efficiency); under the new Closed Cycle Management Act, 2012 (Kreislaufwirtschaftsgesetz – KrWG) which prioritises recycling over other recovery in German law (Janz, 2012).

Laws have also been enacted in Japan (Davis and Hall, 2006; HKGCC, 2010) which have systematically moved towards greater embodiment of CE principles; with China utilising lessons from both of these first movers and developing a range of comprehensive laws (Li and Yu, 2011; Preston, 2012) as well as undertaking continuous research on the efficacy of specific interventions aimed at achieving an overhaul of the entire economy on circular, closed loop principles (Liu et al. 2009;Yang et al. 2011; Preston, 2012). There is growing recognition at government level in England on the rationale for shifting from a throw-away society to growing a circular economy (EAC, 2014). The influential Environmental

Auditing Committee's recent report called for a raft of changes to incentivise the transition including:

- lower VAT on recycled products;
- longer warranty periods for consumer goods; and
- banning food waste being sent to landfill

Source: (EAC, 2014).

However, under the lens of austerity which has been shaping government thinking (in England particularly) around cost savings wherever possible; this has seen a significant reduction lead from Defra, preferring an industry lead on waste matters, including circular economy research and development (Rogerson, 2014).

2.3.2.2 Business focus on the circular economy model

Progress on introducing CE through legislative mechanisms may be limited (particularly in England) but there are many examples from different industrial sectors of implementing CE business models which have increased competitiveness and profitability for companies. In some cases the development has been incremental in nature (e.g. RICOH UK Ltd) following continuous improvement (*Kaizen*) principles (Ohno, 1988). This has seen a number of companies and organisations transition through zero waste to landfill and onwards towards the aspiration of zero waste across all operations (RICOH UK, 2009; EMF, 2014b). Other organisations have gone further and are innovating around 'products of service' (EMF, 2014c); where an exemplar project saw lighting delivered as a service (so many hours of light per year at a certain specification) where the customer wanted the performance and not the need to replace a system once it became obsolete (EMF, 2014c; EMF, 2014d).

A significant amount of impetus has been building around raising awareness of the CE (SITA UK, 2011), at the business level, through the work of the Ellen MacArthur Foundation (EMF, 2011; 2012) supported by the economic profiling undertaken by McKinsey & Co. This has translated into the formation of the 'Circular Economy 100'; a group of companies, innovators and regions taking a lead on CE implementation globally within organisations and across supply chains (EMF, 2014). A further delivery body for CE under-utilised at present are LEPs (Peck et al. 2013); particularly in locations such as the study area, which may provide the interface between governance structures (e.g. WPAs and government departments) and locally specific aspirations on sustainable waste management (FfTF, 2011).

2.3.3 Circular Economy: future resource management strategy in England

The scale of the economic opportunity posed by shifting to a CE business model in England is well documented (Oakdene Hollens, 2009; BIS, 2012) (see Table 2.2).

Box 2.8: Global leverage points

1. Reframe global problems as whole system strategy
2. Redirect education away from reductionist herd thinking
3. Make markets design-out waste from all products in the entire economy
4. Reverse the arms race with a simple national accounting innovation
5. Rescue ecosystems and ecosystem services worldwide
6. Match the stockpile of legacy problems with the stockpile of funds
7. Get money supply monetary without rising debt

Source: (Greyson, 2009).

Indeed, the CE framework (Figure 2.10) identifies multiple leverage points on both the technical and biological materials spheres. In his work on global security, Greyson (2009) has emphasised the need for activating these leverage points (or ‘switches’) to achieve radical system change (see Box 2.8).

The key to these leverage points relates to the disproportionate (non-linear) impact of interventions within complex systems. Meadows (1992) describes these leverage points as “…where a small shift in one thing can produce big changes in everything”. A notion explored extensively in chaos theory; commonly referred to as ‘the butterfly effect’ (Lorenz, 1972). In terms of England, the change to a circular economy will necessitate radical change from the current ‘waste paradigm’. Indeed, there will be a requirement to adopt far more ambitious goals, in line with Scotland and Wales, than those outlined in the WMPE and WPPE (DEFRA, 2013a; 2013b). This transition faces significant hurdles in terms of the recycling focus adopted (DEFRA, 2013a) as Timlett and Williams (2011) have indicated in terms of the need for further initiatives to realise a zero waste goal. The absence of emphasis on the upper tiers of the Waste Hierarchy are a lost opportunity and only serves to delay actions which will become increasingly relevant in the future (Blindspot, 2014). Further, the cost differential between building large scale infrastructure and promoting waste prevention and reuse initiatives (see Figure 2.5) increases the business case for a more radical approach to ‘waste’. An approach is thus required which is capable of visualising plausible futures where specific policies have been implemented and assessed in terms of potential impact.

2.3.3.1 Limitations of the Circular Economy

In a comprehensive study of the potential offered by transitioning towards a CE, Preston (2012) identified seven key barriers to implementation (Box 2.8). A compelling alternative to the circular economy relates to ideas and thinking around the ‘blue economy’ (Pauli, 2014). This is a visionary approach heavily inspired by the natural world which draws on ‘deep ecology’ and ‘biomimicry’ (Benyus, 1997) ideas; coupling these with environmental economics to offer an alternative business model with minimal environmental impacts; social inclusion and cohesion through localised job creation; and a sustainable economic future decoupled from growth models. This is a more radical model than CE and is strongly grounded in the 'sustainability' archetype (see Dreborg, 2004).

Box 2.8: Seven barriers to implementation

1. Lock-in to resource-intensive infrastructure and development models;
2. Political obstacles to putting an appropriate price on resource use;
3. High up-front costs;
4. Complex international supply chains;
5. Lack of consumer enthusiasm;
6. Challenges for company-to-company cooperation; and
7. The innovation challenge

Source: (Preston, 2012)

2.4 Futures studies and the development of backcasting

2.4.1 Introduction

The field of futures oriented research is concerned with looking at real world issues and envisaging their long term impact on society. Borjesson et al. (2006) proposed placing futures studies into three main types dependent on three types of question: *What will happen? What can happen?* and *How can a specific target be met?* As pointed out, there is no consensus on scenario typologies (Borjesson et al. 2006) but several of the typologies in Figure 2.11 reflect the view that futures studies examine: possible; probable; and preferable futures (van Vliet, 2012). Futures studies' have previously been positioned by a number of researchers either within 3 categories (Amara, 1981) or added others (Marien, 2002); with Masini (1993) identifying 'vision' as a specific approach.

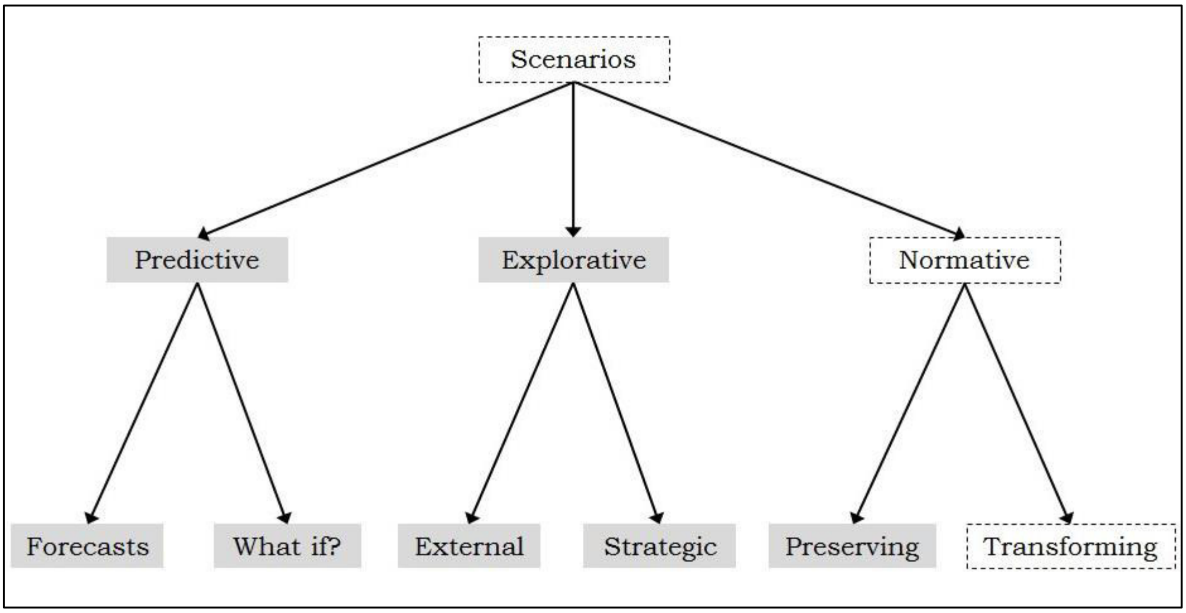


Figure 2.11: Scenario typologies with the normative scenario transforming approach identified (dashed boxes) (Source: Borjesson et al. 2006)

Of particular note in relation to backcasting, Dreborg (2004) identified visionary thinking as one of his three modes of thinking. He went on to suggest that backcasting represents a methodology which is a ‘pure’ form of the visionary mode of thinking (Borjesson et al 2006). This later work firmly acknowledges backcasting as a methodology in contrast to his seminal work on the ‘essence’ of backcasting (Dreborg, 1996) where he defines it as an approach rather than a specific method or methodology.

Notwithstanding the debate on typologies and methodologies; a range of other methods have been developed to provide potential solutions or desirable visions to address issues such as sustainability (Quist and Vergragt, 2011). A number of established and widely used quantitative and qualitative methods are employed in futures studies at governmental; organisational and societal levels (SERI, 2010a; DEFRA, 2011d; DECC, 2011a; Haslauer et al. 2012; DEFRA, 2013b). Figure 2.12 illustrates some of the main methods and complementary tools used. Quantitative methods used in futures studies, typically apply trend evaluation techniques and are premised around likelihood and predictability (see

Figure 2.11), particularly in terms of policy development (Schwartz, 2008). Such methods (e.g. forecasting) make prediction based on mathematical and statistical evaluations.

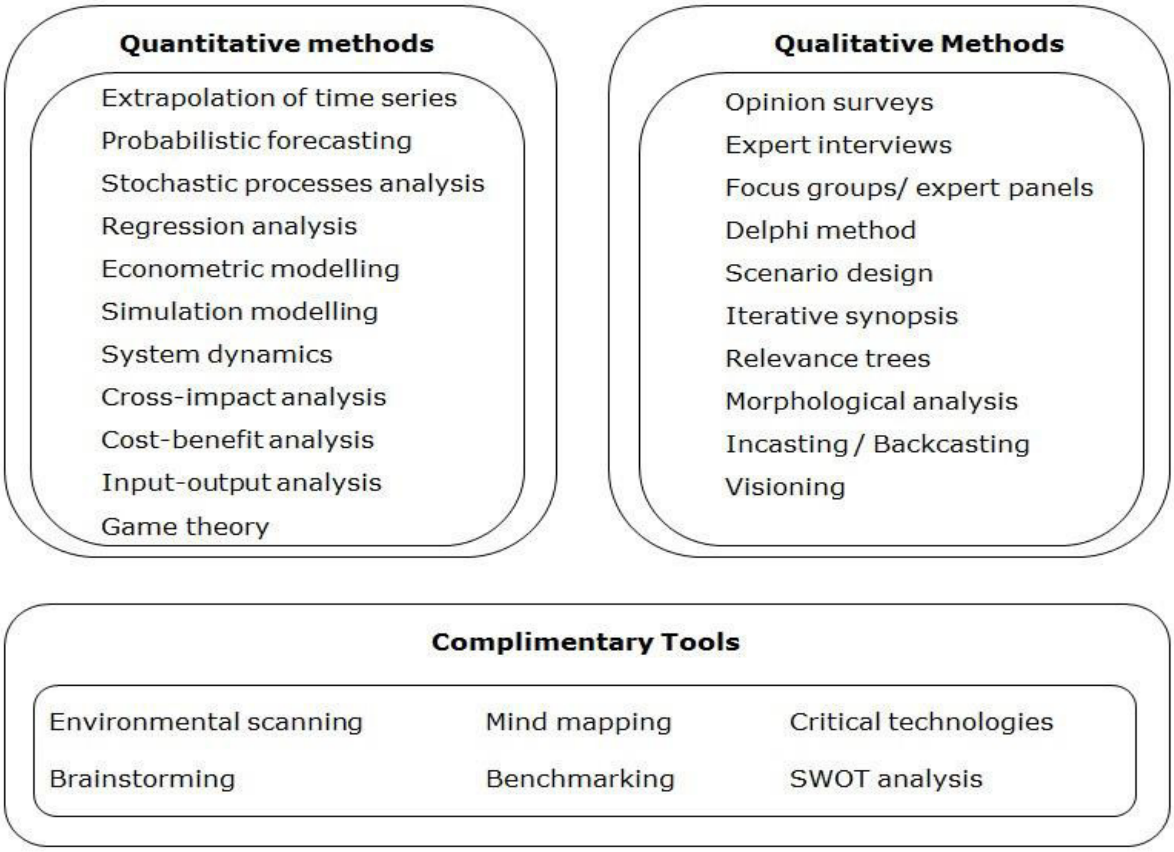


Figure 2.12: Classification of Futures Studies methods and complimentary tools (Source: after Guell, 2013).

Objectivity is a key strength of such approaches (Robinson, 2003) but requires historic and current numerical data to be effective. In contrast, qualitative methods (e.g. backcasting and visioning) are largely based on intuition and expert opinion. Qualitative methods have value through subjectivity and are often used when there is a lack of data. Their usefulness is further enhanced when the problem are long-term in nature (Guell, 2013).

2.4.2 What is backcasting?

The origins of backcasting date back to the 1970's when oil crises had a destabilising effect on many economies in the West. Royal Dutch Shell was the first to use a scenario based approach which was akin to later backcasting development (Schwartz, 1991;

Haslauer et al. 2012). At a national scale, concerns over the future of the electricity sector, partly in response to the oil crises, Lovins (1976) developed a method known as 'backwards looking analysis' which was further developed by Robinson (1982) and became referred to as backcasting. These early uses were technical in nature with small groups of researchers and experts undertaking the backcasting exercises (van Vliet, 2011; Haslauer et al. 2012). Dreborg (1996) systematically reviewed the emergent 'method' of backcasting and suggested it was not a method but an approach. But he differentiated backcasting as having a number of benefits over predictive methods including forecasting; directional studies; and short term studies.

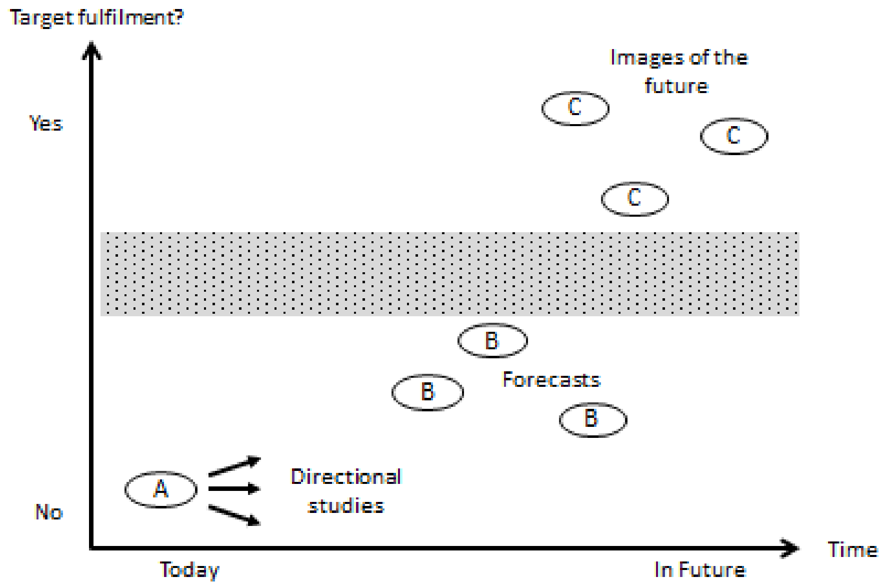


Figure 2.13: Application of backcasting to sustainability issues (Source: Dreborg, 1996).

Each approach is characterised by the level of uncertainty and the inability to achieve sustainability as the time horizon extends (Steen and Ackerman, 1994; Ackerman, 2011). To overcome the impact of uncertainty on short-term predictions the method of sensitivity analysis is often applied (Morrissey and Browne, 2004; DEFRA, 2013b) which offers different quantifiable 'scenarios' of likely future conditions based on current system trends.

Figure 2.13 illustrates Dreborg's interpretation of when backcasting should be applied to sustainability issues.

As can be seen in Figure 2.13, Dreborg (1996) sees a distinct barrier between predictive methods (A and B) and normative approaches such as backcasting (C) in reaching a position of target fulfilment. It is also clear that the timescale for studies based on images of the future extends much further along as these studies require a long-term perspective (Steen and Ackerman, 1994).Uncertainty within predictive models is acknowledged by means of utilising sensitivity analysis. To overcome the impact of uncertainty on predictions sensitivity analysis is often applied to offer different quantifiable 'scenarios' of likely future conditions based on current system trends (Morrissey and Browne, 2004; IPCC, 2007; DEFRA, 2013b). Such approaches are problematic over the long-term as predictions based on the current reality are significantly exposed to error when potential (or even desirable) political, economic, social and technological developments are explored (Eames and Egmose, 2011). To address this problem Hunt et al. (2012); drawing on earlier work by Dreborg (1996); postulate that:

'Future scenarios provide challenging, plausible and relevant stories about how the future could unfold'.

Source: (Hunt et al. 2012).

Disaggregating this statement shows four key components (**challenging**; **plausible**; **relevant**; and how the future **could** develop) of what it is such future scenario approaches offer differently from predictive methods.

To address each, scenario based approaches must challenge the current paradigm (e.g. resources rather than wastes) and offer visions of radical change (Robinson, 1990; Dreborg, 1996; Kok et al. 2011). But these radical visions must be both plausible (are somewhat realistic given the current position) and relevant (an important aspect of choosing time horizons of 25-50 years is the ability of people to perceive the impact of changes on theirs or their children's futures – Quist and Vergragt, 2006; van Vliet, 2011). Demonstrating how futures could develop is perhaps the defining characteristic of backcasting (Greyson, 2007; Giurco et al. 2011). This is especially so when one considers the divergence in approaches towards backcasting, as there are two commonalities. The first is the normative element with a concern for values, beliefs and ideas; while the second is 'working backwards from a desired future end-point (Robinson, 1990; 2003).

2.4.2.1 When to apply backcasting

The purpose of applying a backcasting methodology is primarily related to the long-term nature of the issues surrounding waste management and the complexity of those issues when considering waste from a systems perspective. The process is both explorative and interactive being described as a tool for 'social learning' (Robinson, 2003; Robinson et al. 2011). Backcasting is a process working backwards from future scenarios, 25-100 years ahead, to the present situation consisting of a rule based analysis and resulting in normative policies in order to achieve the desired goals, which are independent of present limitations and problems (Robert, 2005; Robinson, 2003). However, backcasting should not be used as a means of revealing policies in the future or for prediction of future situations, but instead should be used to assess the feasibility and potential impacts of different strategies as outlined in the final scenarios (Robinson, 2003; Robinson et al. 2011).

2.4.2.2 Backcasting and waste management

There are few empirical examples of backcasting being applied to issues around waste management. A study which looked at changing the structure of municipal waste management in Georgia (Antadze, 2004) found that producing a model of a desired future for municipal waste management revealed the underlying structure of the system and the amount of adaptation required to meet legislative requirements of the EU (e.g. those set out in the Waste Framework Directive). The framing parameters for the study were those stipulated in the waste hierarchy but were extended to include the minimisation of incineration and compliance with EU legislation (Antadze, 2004). A three step methodology was applied. The limited scope of the study (municipal waste only) reflected the main policy focus of the EU; namely the development landfill regulations in Member States in order to transpose the Landfill Directive (99/31/EC).

Another empirical study using backasting for waste management planning was undertaken as part of a broader study in Sweden (SERI, 2010a) on moving 'towards sustainable waste management'. This study produced four scenarios to 2030: global sustainability; global markets; regional markets; and European sustainability which were characterised by varying levels of global cooperation and political control/influence (Dreborg and Tyskeng, 2008). These framing scenarios were developed in a two stage process, with each of these projects forming the baseline assessment; pathways and impacts. The main finding relates to the considerably divergent futures which can be envisaged compared with a reference scenario based on forecasting approaches (Dreborg and Tyskeng, 2008). In addition, economic and political situations can have markedly different impacts on achieving a position of sustainable waste management. These empirical studies (Antadze, 2004; Dreborg and Tyskeng, 2008) are undertaken at the national scale, with no other studies found offering empirical evidence of applying backcasting to waste. However, other studies, applying backasting in the form of scenarios, do mention waste in terms of resource depletion (ETC/SCP, 2012); urban planning (Eames and Egmose, 2011; Haslauer et al. 2012); and within life-cycle inventories for climate change (Shepherd et al. 2011).

2.4.2.3 Social learning and mental models

Social learning in the context of backcasting studies, can be viewed as a qualitative outcome of the scenario development and visioning processes which has been linked with altering individual and organisational perceptions of the world (so-called mental models – see Box 2.9) (Levanen and Hukkinen, 2013).

Box 2.9: A note on mental models

A 'mental model' may be described as a cognitive mechanism for representing or constructing situations which may be real, imagined or hypothetical (Glick et al. 2011). Al-Diban and Ifenthaler (2011) develop this notion further by suggesting '…a person constructs a mental model in order to explain or simulate specific phenomena of objects or events if no sufficient schema are available'. They go on to propose that '…a domain expert's mental model is considered more elaborate and complex' when compared with that of a novice (Al-Diban and Ifenthaler, 2011).

Craik suggested that 'thought' was the critical means by which one experiences the external world (Craik, 1943). Crucially, he argued the fundamental property of thought, in this regard, was '…its power to predict events' (Johnson-Laird, 2005).

Craik went on to suggest this power depends on three steps, namely:

1. The translation of an external process into words, numbers, or other symbols, which can function as a model of the world
2. A process of reasoning from these symbols leading to others.
3. The retranslation back from the resulting symbols into external processes, or at least to a recognition that they correspond to external processes.

Source: (Craik, 1943 cited in Johnson-Laird, 2005).

Forrester captured the essence of Craik's theorising in terms of the function and role of mental models in the statement:

> *"...mental models are the lenses through which we see the world ...incorporating our preferences, experiences and beliefs about how the world works."*

Source: (Forrester, 1961 cited in Glick et al. 2011).

In terms of waste generation and natural resource depletion, it has been suggested that issues of governance (e.g. waste policy formation and implementation) are closely related to 'practices of policy deliberation and institutional lock-in' (Young, 2002; North, 2005 cited in Levanen and Hukkinen, 2013, p15). This notion of institutional lock-in reflects Meadows' views about bounded rationality (Meadows, 2008, p106) and vested interests producing 'policy lock-in' (Meadows, 2008, p92).

2.4.2.3.1 Reframing the waste hierarchy with social learning

This research uses the concept of zero waste to visualise scenarios towards attaining a more sustainable system of waste management in England by 2050. Robinson (2003) and Quist (2006) have emphasised the need to broaden the scope of backcasting to become a participatory process for multiple stakeholders in order to make the decision-making process more inclusive. In doing so, stakeholders are exposed to innovative ways of viewing, interacting with and participating in sustainability issues (Quist and Vergragt, 2006; Anderson et al. 2008; Mander et al. 2008; Wangel, 2012). From the perspective of viewing waste as resource (Braungart et al. 2007) the waste hierarchy is a powerful tool (see section 2.2). However, the upper tiers (waste prevention and reuse) are more difficult for stakeholders to visualise as this implies physical avoidance of materials entering the waste system and thus requires more abstract cognitive processes.

This is particularly pertinent when considering movement towards a zero waste economy (Greyson, 2007; Zaman and Lehmann, 2013); a circular economy (Su et al. 2013; DG Environment, 2014); or greater integration of material flows based on industrial ecology (Giurco et al. 2011; Kaufman, 2012). To achieve these goals, tools and methods are required which can visualise these tiers of the waste hierarchy (see Objective 4) and account for policy changes (see Objective 2) such as end-of-waste (EOW) which reclassify waste materials as by-products or products (Levanen and Hukkinen, 2013). However, current approaches which seek to incrementally change the waste management sector are unlikely to achieve a position of sustainability (Dreborg, 1996; Hickman and Bannister, 2007) as the apparatus of policy development is not systemically focused and may even be locked-in (Meadows, 2008) to responding to change in order to 'preserve' the current system (Borjesson et al. 2006). This 'waste paradigm' opposes the dynamic and proactive development of mechanisms and applications capable of transformational change based on systems thinking principles (Boulding, 1966; Lovelock, 1971; Robinson, 1982; 1990; Borjesson et al. 2006).

As previously mentioned, evidence of the systematic approach to policy development is seen with emphasis placed on moving up the waste hierarchy (ESA, 2011; CIWM, 2012); applying technological solutions to residual wastes (Eunomia, 2013); becoming high recycling societies (EC, 2011a); and to a certain extent altering processes to be more resource efficient (BIS, 2012). Notwithstanding, this evidentiary policy development within England, facilitating deep changes within the waste system have been identified in terms of: changing attitudes and behaviours (Williams and Kelly, 2003; Tonglet et al. 2004b; Barr, 2004; Timlett and Williams, 2011); innovations around design of products embodied within eco-design principles (WRAP, 2013a); accreditation for schemes designed to move communities to becoming 'zero waste places' (Phillips et al. 2011; Warner et al. 2014); and industry lead on circular economy development (Greyson, 2007; EMF, 2011).

2.5 Waste systems visualisation with GIS

2.5.1 GIS development and application to waste

Developments in geographic information science, particularly spatial databases, spatial analysis, global positioning technologies, remote sensing, earth observation technologies and geo-visualisation have progressed significantly both during and since the 1990's (Longley et al. 2005; Goodchild, 2009). Geographic information systems (GIS) have been used to produce data models since the 1950s (Goodchild, 2000). The techniques of data modelling within GIS were further applied in pioneering work on site suitability analysis by Ian McHarg (McHarg, 1969).

McHarg (1969) articulated the basic mapping ideas for site suitability analysis; which had a specific focus on identifying the best location for a specific function. To achieve this aim, McHarg proposed the preparation and use of thematic maps (layers) and superimposing them to create a composite structure which would facilitate comparison with a pre-existing set of interacting factors. This simple overlay analysis technique has subsequently been refined and used in diverse research fields such as land use planning (Dobson, 1979; Blaschke and Strobl, 2001); ecology (Clevenger et al. 2002); transport system development (Goodchild, 2000; Miller and Wu, 2000); and waste facility siting (Clark, 1970; Helms and Clark, 1971; Lin and Kao, 1998; Kontos et al. 2005).

Today multiple techniques are implemented through GIS from landscape and spatial planning of urban design (Sumathi et al. 2008) to ecological monitoring of habitat change (Jensen et al. 2012). In the field of waste management GIS is increasingly being applied. This is not surprising considering the spatial data being gathered around arisings and the need to plan transportation/logistics around route optimisation for fuel economy, emissions reductions and wider cost savings. GIS is now an important tool for simulating future changes on the Earth's surface through the implementation of digital representations (e.g. maps and conceptual models) of landscape-modifying processes.

2.5.2 Spatial planning for waste and resource management

Waste management systems are inherently spatial in character, enabling detailed geospatial analysis to determine optimum facility location based on specified criteria. Further, non-spatial criteria impacting choice of facility type (e.g. economic considerations) can be captured and analysed within a bespoke GIS environment (Goodchild et al. 2007).

GIS is increasingly being utilised in the field of WRM to understand the spatial distribution of waste arisings and management solutions aimed at achieving a more integrated approach. The literature shows that GIS has primarily been utilised in research on waste focusing on collection systems and route optimisation (Kanchanabhan et al. 2011); site selection (Kontos et al. 2005; Sumathi et al. 2008; Tavares et al. 2011; Chatzouridis & Komilis, 2012; Gorsevski et al. 2012); systems dynamics (Guan et al. 2011); stakeholder involvement (De Feo & De Gisi, 2010); environmental assessment and profiling of waste activities (Antunes et al. 2001; Jensen et al. 2012; Khoo et al. 2012); and distributed generation through AD (Ma et al. 2005). However, there is scant evidence in the literature of applying GIS techniques (e.g. spatial analysis and modelling) towards integration of planning for waste management facilities.

2.5.2.1 The AWM regional approach to waste infrastructure provision

In 2009, Advantage West Midlands (AWM) the former Regional Development Agency (RDA) for the West Midlands launched the UKs first low carbon economic strategy (DTZ/SLR, 2009a). As part of their corporate plan, AWM identified a need within England for an approach which could identify priority locations for investment in waste infrastructure (DTZ/SLR, 2009b). The tool was linked with traditional planning approaches around forecasting capacity gaps (SLR, 2006; RPS, 2009; Sacks Consulting, 2012; Head et al. 2013) for provisioning adequate facilities to meet landfill diversion targets for England. The preliminary work undertaken by SLR consulting for the West Midlands RTAB as well as follow-on work for AWM led to a Waste Infrastructure Development Programme (DTZ/SLR, 2009a). These pieces of work forecast a future waste infrastructure capacity gap of 3.7Mt by 2021 which it predicted would require around 260ha of land take to facilitate.

Although the RDAs have largely been removed from the waste planning hierarchy in England (DCLG, 2013) since the coalition government came to power, the approach developed was a novel GIS-based location-analysis tool. The GIS tool extended the use of spatial analysis for waste infrastructure developed by the consultancy firm SLR (SLR, 2006), which had undertaken a regional assessment; in association with the University of Northampton; of infrastructure provision for the East Midlands region of England (EMRA, 2006). This level of development reflected changes within the functionality of GIS software from developers such as ESRI but also newer open access tools (e.g. Quantum GIS). The tool consisted of four distinct spatial analysis stages: identify and agree location drivers; mapping of location drivers; identify areas of search; and identify available sites (SLR, 2006). A similar approach has been used in a number of location analysis projects using multi-criteria assessment and evaluation (MCA/MCE) techniques on landfill site selection (Kao and Lin, 1996; Curtis et al. 2000; Sumathi et al. 2008; Yildrim, 2012; Gorsevski et al. 2012); as well as in studies for siting AD plants (Ma et al. 2005); and waste incineration plants in small island states (Tavares et al. 2011).

Other approaches have used binary programming for siting of municipal waste transfer sites (Chatzouridis and Komilis, 2012) as well as detailed and in-depth stakeholder involvement in order to produce robust criteria weightings which reflected local concerns (De Feo and De Gisi; 2010). This last point on local concerns is a critical factor in determining the use of a GIS-based tool. The generation of a location specific database of multiple variables (criteria) is identified as an enduring legacy of such studies (Blaschke, 2006; Haslauer et al. 2012) allowing future enhancement as better data become available or more powerful analytical approaches are developed. Given the structure of the AWM tool, based on a multi-criteria evaluation of regionally specific variables, as well as the high-level previous use (e.g. regional planning and governance) it may be considered robust. However, the tool is designed for regional scale evaluation and as such may require alterations and adaptation's to make it applicable at the individual WPA level (e.g. county or unitary scale in England).

2.5.2.2 Waste infrastructure assessment at the WPA scale in England

Within England, LAs have the responsibility to produce spatial plans within their remit as Waste Planning Authorities (WPAs). These WPAs are usually county level administrative units but also include Unitary Authorities (UAs) which a dual responsibility for collection and disposal of wastes within their localities (NCC, 2012; DCLG, 2012).

Until 2014, this required the production of Minerals and Waste Development Framework (MWDF) (Figure 2.14) documents[7], which includes an assessment of waste management needs covering a period a minimum of 10 years into the future (DCLG, 2013). The MWDF documents also include a plan for waste development (facility locations) (NCC, 2013a) which are subject to a Sustainability Appraisal (SA) and Habitats Regulations Assessment (HRA) as part of the Core Strategy consultation and implementation process. These environmental appraisals are required under European Directives 2001/42/EC (SEA Directive) and 92/43/EEC (Habitats Directive) with the SA expanding the assessment to encompass economic and social impacts.

The MWDF (Figure 2.14) uses the revised European WFD (2008/98/EC) to define 'waste' and covers municipal wastes (LACW); commercial and industrial wastes (C&I); and construction and demolition wastes (C&D) but must also consider other waste types (e.g. hazardous and agricultural wastes) (NCC, 2013a).

[7] The MWDF is proposed to be replaced with a Minerals and Waste Local Plan (MWLP) which at the time of writing had just finished its consultation process and was being schedule for introduction in 2015. However, delays have held this back and so the MWDF is still the applicable document set.

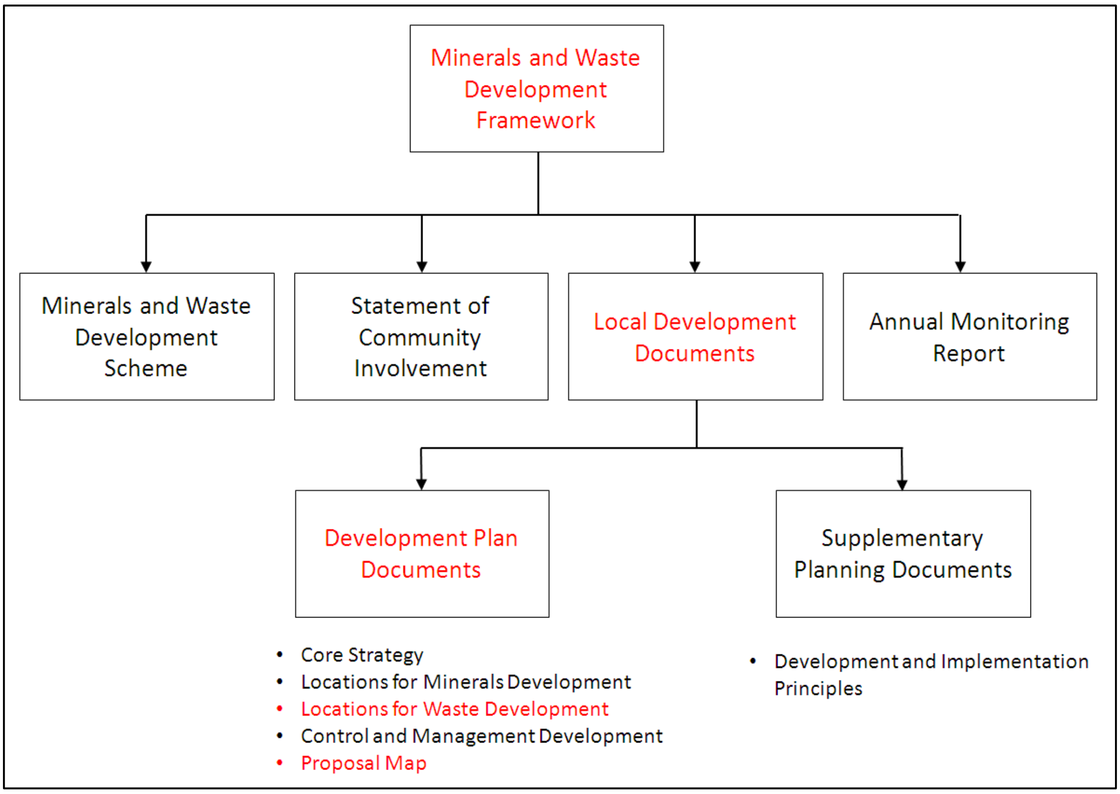


Figure 2.14: The Northamptonshire MWDF with relevant spatial documents highlighted (Source: NCC, 2013a).

The MWDF also stipulates criteria for waste management sites in terms of:

- Sites for integrated waste management facilities;
- Sites for waste management use in or adjacent to urban areas;
- Industrial area locations for waste management uses; and
- Sites for waste management use in rural areas.

Such planning requirements reflect the focus within England on environmental protection and transparency (community involvement). However, much of the documentation produced is based on considerations which at best can consider out-of-date. Indeed, planning for future capacity is based on a recognised LA forecasting approach (DEFRA, 2012). In terms of WPAs like Northamptonshire; the plan period runs from 2006-26 meaning that these forecasts are based on trends in waste which are not relevant given the scale of change witnessed between 2005/6 and 2012/13 (DEFRA, 2014).

As such a gap exists to bring up-to-date the development plan in terms of forecast arisings and potential capacity gap; suitability appraisal of locations for waste development (using the existing proposals maps to produce new spatial patterns meeting different future requirements); and providing practitioners with a database tool which is readily reproducible and robust for local waste planning requirements (see objective 3).

2.5.3 Utilising MCDA with GIS

The use of MCDA techniques allows multiple variables to be considered within a model of the system under consideration, which represents a means by which the non-linearity of said system can be visualised. GIS-MCDA is a complex process of analysis due to the intricacy of the variables being considered and their relative impact on the WMS under scrutiny. Chen et al. (2010) suggest GIS based MCDA approaches are primarily concerned with combining information from several criteria to form a simple index of evaluation. Malczewski (2006) suggested using MCDA techniques with GIS methods provided a framework for handling different views and conceptualisations of the elements within a complex decision problem. This allows them to be organised into a hierarchical structure thus permitting the relationships among the problem components to be studied (Malczewski, 2006). A further strength of using GIS with MCDA relates to the procedures within an MCDA avoid the users preferences and manipulation of data; this is overcome by combining preferences with the data according to 'specified' decision rules (Malczewski, 2004; Rahman et al. 2012). An example of this type of approach is seen with De Feo and De Gisi (2010) whom characterised their AHP criteria according to specified typologies: exclusionary, preferential or penalizing.

2.5.3.1 Saaty's AHP

The Analytical Hierarchy Process (AHP) developed by Thomas Saaty (Saaty, 1980) breaks down a decision-making problem into several levels producing a hierarchy which has unidirectional hierarchical relationships between levels (Aragones-Beltran et al. 2010). AHP uses the mathematical approach of pairwise comparison to allocate weights to the elements of each level (e.g. group criteria and individual criteria) measuring their relative importance on 1-9 scale (Saaty scale shown in Table 2.4).

Overall calculated weights are evaluated at the bottom level and verified for coherence of the judgments through a calculated consistency ratio (CR) which must be 0.10 or less to be acceptable (Aragones-Beltran et al. 2010; De Feo and de Gisi, 2010). The AHP tool is conceptually easy to use and the data capture stage is relatively simple to explain to stakeholders with limited knowledge of a specific decision problem (e.g. siting of waste facilities).

Tale 2.4: The Saaty Scale with definitions

Intensity of importance on an absolute scale	Definition
1	Equal Importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between the two adjacent judgements
Reciprocals	If activity *i* has one of the above numbers attached to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*
Rationales	Ratios arising from the scale

Source: (De Feo and de Gisi, 2010).

2.5.3.2 Alternatives to AHP

A more complex tool also developed by Saaty is the Analytical Network Process (ANP) (Saaty, 1999) and was designed to incorporate feedback and complex inter-relationships within and between clusters identified (from nodes of network clustering) (Aragones-Beltran et al. 2010). However, the predictive nature of the output within a decision-making model seemed at odds with the overall aim and rationale for employing GIS to represent future scenarios elicited from backcasting.

2.6 Research gaps identified

As a result of reviewing the literature a number of gaps in the research have been identified which can be addressed through the application of the research methodology. The first relates to the lack of holistic approaches taken to assessing waste at a systems scale. There are many examples in the literature which look at specific waste streams, producing models based on predictions of what will happen to the likes of LACW (DEFRA, 2011a) or C&I (ADAS, 2009) wastes. However, the predominant focus is on LACW, even within the planning literature (NCC, 2012, DCC, 2012) which has a requirement to consider all wastes within a specified administrative area (DCLG, 2011). Using estimations methodologies to base financial investment decisions on at a time of constrained budgets is problematic. So too is the use of predicted results based on extrapolated trends from past levels of wastes generated, which run the risk of providing over-capacity (Eunomia, 2014) and tying LAs into strategies focused at the lower tiers of the waste hierarchy through contractual limitations.

A gap also exists in terms of linking policy approaches across areas of synergy (e.g. waste. energy and climate change). The issue relates to a lack of systems thinking (DEFRA, 2012b) which would bring together research and produce a long-term strategy. This has been partially addressed within the ambitious zero wastes policies in Wales and Scotland (WAG, 2010; TSE, 2010) as well as medium-term studies in England (DEFRA, 2011b) but there is a failure to fully integrate these policy areas within such studies. Scenarios and scenario planning are tools widely utilised in climate research and energy policy development but this has not been embraced in determining the sustainability of the WMS within a future 'resource' paradigm (BIS, 2012).

Waste planning is another area where a lack of foresight derives from inadequate data at the local scale. Planners have been effective at producing schemes to deliver national objectives but these are undermined through the available data as well as the way that data is interpreted; with an understandable tendency to plan for the worst case scenario. For this reason, local waste plans (as part of MWDFs at the WPA scale) are questionable (Cochrane et al. 2013). Coupled with a need to identify potential sites for future waste facilities (DTZ/SLR, 2009a) and concerns around capacity being able to recirculate materials effectively within the current WMS; if CE business models are adopted; suggests the need to assess these plans as being fit-for-purpose (Hojer et al. 2011).

Chapter 3 Methodology and Methods

3.1 Introduction

In this thesis, a mixed methodology approach was utilised in order to achieve the desired aim and objectives (see Section 1.3) with a view towards framing sustainable waste management within the concept of a ‘zero waste’ economy. Such an approach has significant potential for improving long-term thinking on waste planning at Local Authority level. Backcasting is a strategic foresight method suitable for governmental and organisational decision-makers (GOS, 2010).

Application of a futures oriented methodology such as backcasting is in keeping with calls from government for a wider range of interdisciplinary research methods to be applied to waste management research in England (DEFRA, 2008). Specifically, the use of backcasting in this research may be seen as addressing thematic requirements of the WRRAG R&D Evidence Provision programme (DEFRA, 2008), namely:

- Theme 8 - decision tools and related evidence mechanisms
- Theme 2 – systems for waste collection, separation and resource
- Theme 1 (1.1) – understanding resource flows
- Theme 3 (3.3) – delivering waste management infrastructure

A backcasting framework is utilised as the principal qualitative research method (Robinson, 1990) in order to allow a broader strategic evaluation of a specified waste management system (Dreborg, 1996). This evaluation is then embedded within a Geographic Information System (GIS) framework in order to visualise the key findings and is analysed using the AHP method put forwards by Saaty (1977; 1980) and expanded on by De Gisi and De Feo (2010). These principal components are applied to a case study of a defined waste management system to test the robustness and validity of the methodological framework developed. GIS was utilised as a means of visualising results with a view to being an integral part of the model addressing the issue of stakeholder engagement (Zakaria, 2011; APSRG, 2010).

3.1.1 Research agenda for waste management

In this project, a number of key questions are raised relating to key policy objectives and their implementation, as well as the aspirational strategic goals on waste management and planning, as outlined in key Government documents (e.g. DEFRA, 2007a; 2009; 2011a; 2013a; 2013b; DECC/DEFRA, 2011; EA, 2011). The research agenda around moving towards sustainable waste management has been characterised by numerous policy changes over the last 10-15 years. The strategic policy objective has moved from disposal to resource management and recovery. These changes raise a number of questions:

1. What contribution can the concept of zero waste make to the wider sustainability agenda for England?
2. What new and existing approaches may be applied in order to generate innovations in managing wastes holistically and using wastes as a resource?
3. How can England meet its international obligations relating to waste over the short, medium and long-term?
4. What are the implications for/potential barriers to developing infrastructure at suitable sites under the new localised planning regime?

Addressing these questions was a fundamental driver when formulating the research aim and objectives (see Section 1.3).

3.1.2 GIS-based Backcasting Framework Model (G-BFM)

In this study, the overarching methodology was designed as a framework model (FM) following a logical and progressively detailed structure. The three key elements to the FM have been described previously but can be summarised as encompassing backcasting; GIS; and a quantitative model. The purpose of such a model is to deconstruct complex problems around waste management in order to develop a strategic vision of a desirable sustainable

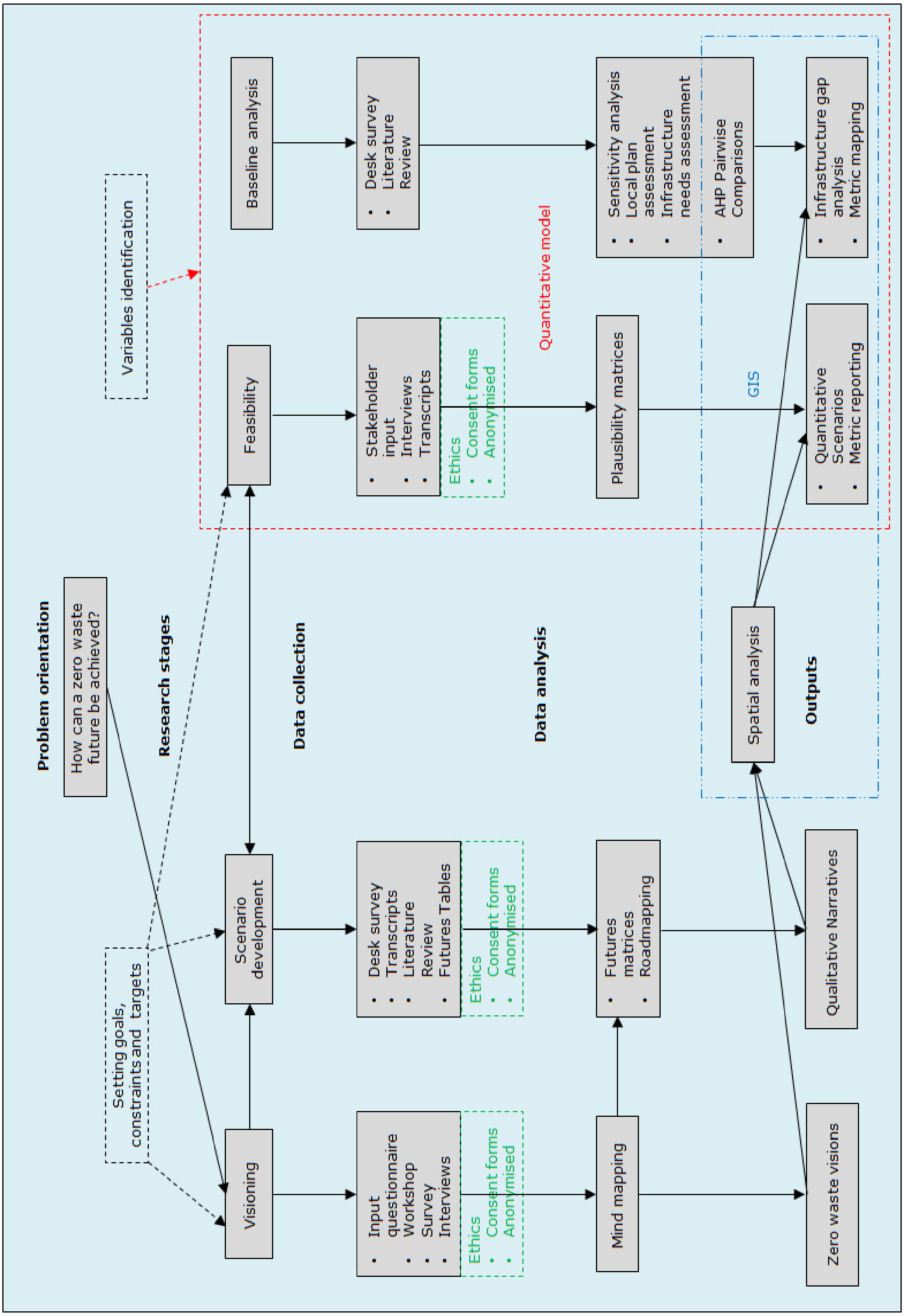


Figure 3.1: Empirical stages schematic of the GIS-based Backcasting Framework Model (G-BFM)

waste management future. The framework model uses a mixed methodology approach to generate data and capture inputs from stakeholders. This is in keeping with Robinson's original backcasting framework (Robinson, 1990) while being flexible enough to provide recognisable output for multiple stakeholders. Figure 3.1 describes the empirical stages within the GIS-based backcasting framework model (G-BFM) schematically.

3.2 Methods used

While there is no single defined methodology for backcasting a decision was taken to apply Robinson's original generic method (Robinson, 1990) and develop this in such a way as to meet the research aims and objectives. There are limitations with this approach as "second order" backcasting (Robinson. 2003; Quist, 2006) has shifted to a more participatory approach with large numbers of stakeholders and multiple large scale workshops being employed in the process (Hickman & Bannister, 2008). However, time and resource restrictions were drivers for adaptation while striving to maintain the integrity of the methodological approach. In order to present and analyse the output from the stages of the backcasting process an approach was formulated which used GIS to represent the quantitative output visually. Such an approach has been utilised in previous waste research on issues such as infrastructure provision (SLR, 2006); landfill siting (Sumathi, 2008) and testing scenarios for optimal MSW management (De Feo & De Gisi, 2010).The following sections (Sections 3.3 through 3.5) are used to detail the research methods used; limitations and adaptations; and potential areas for synergy.

3.3 Backcasting

Backcasting has been used in this research to provide a novel means of framing the complex issue of waste management to offer potentially radical visions of systems change. This process requires both qualitative research (in the form of visioning; and scenario development) as well as quantitative research methods (baseline analysis within a determined system boundary, including: waste arisings trends; compositional analysis; waste infrastructure capacity assessment; and impact analysis).

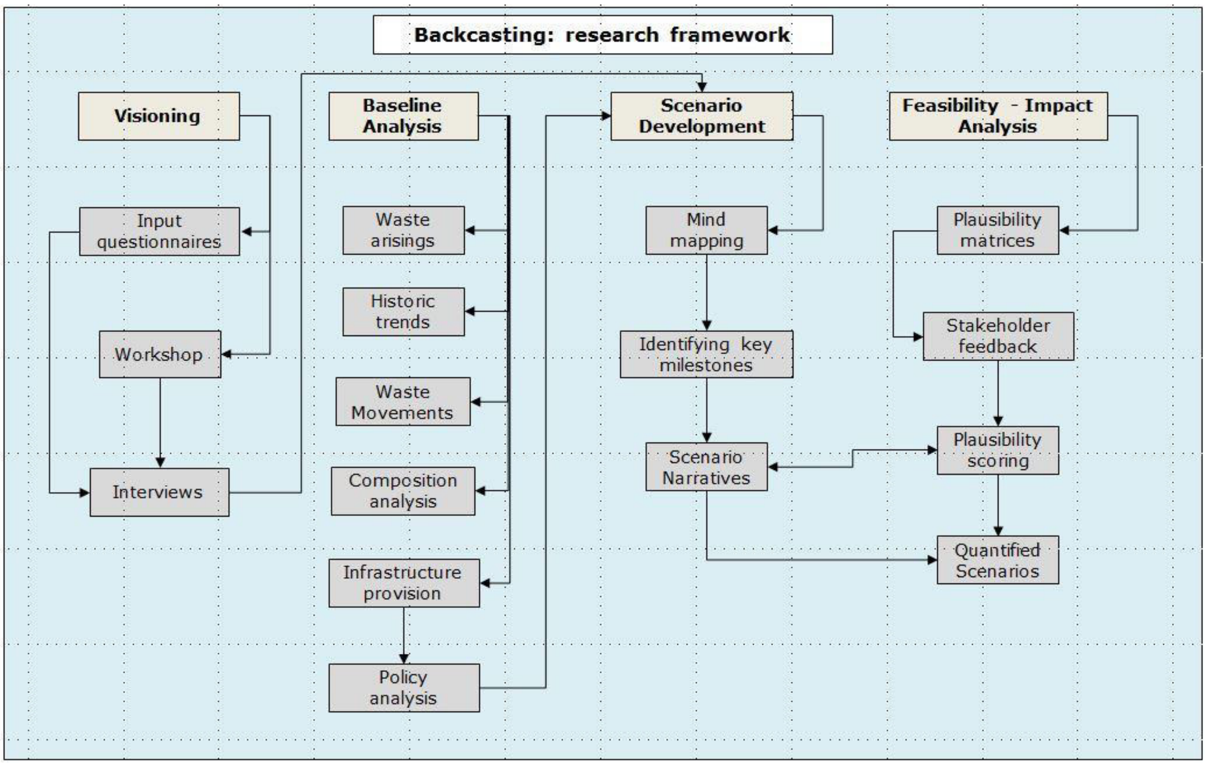


Figure 3.2: Workflow schematic of the backcasting research framework

Figure 3.2 illustrates the backcasting research framework schematically and shows the process moving from visioning and baseline analysis into the iterative stages of scenario development and feasibility testing in terms of impact analysis. The remainder of Section 3.3 will describe the individual stages in detail.

3.3.1 Designing the applied backcasting method

The literature differs on whether or not the visioning process should be the first step in the backcasting process. Robinson's original conceptualisation of the backcasting method (Robinson, 1990) followed a six step approach which is shown in Figure 3.3. It is possible and to some extent desirable, to integrate some of these generic steps to reframe the method into a simpler 4 step approach, as put forwards by The Natural Step (TNS)

(Holmberg, 1998). The purpose of doing so relates to the social learning element ascribed to undertaking backcasting and the potential benefits this can have for stakeholder engagement (Quist et al. 2011).

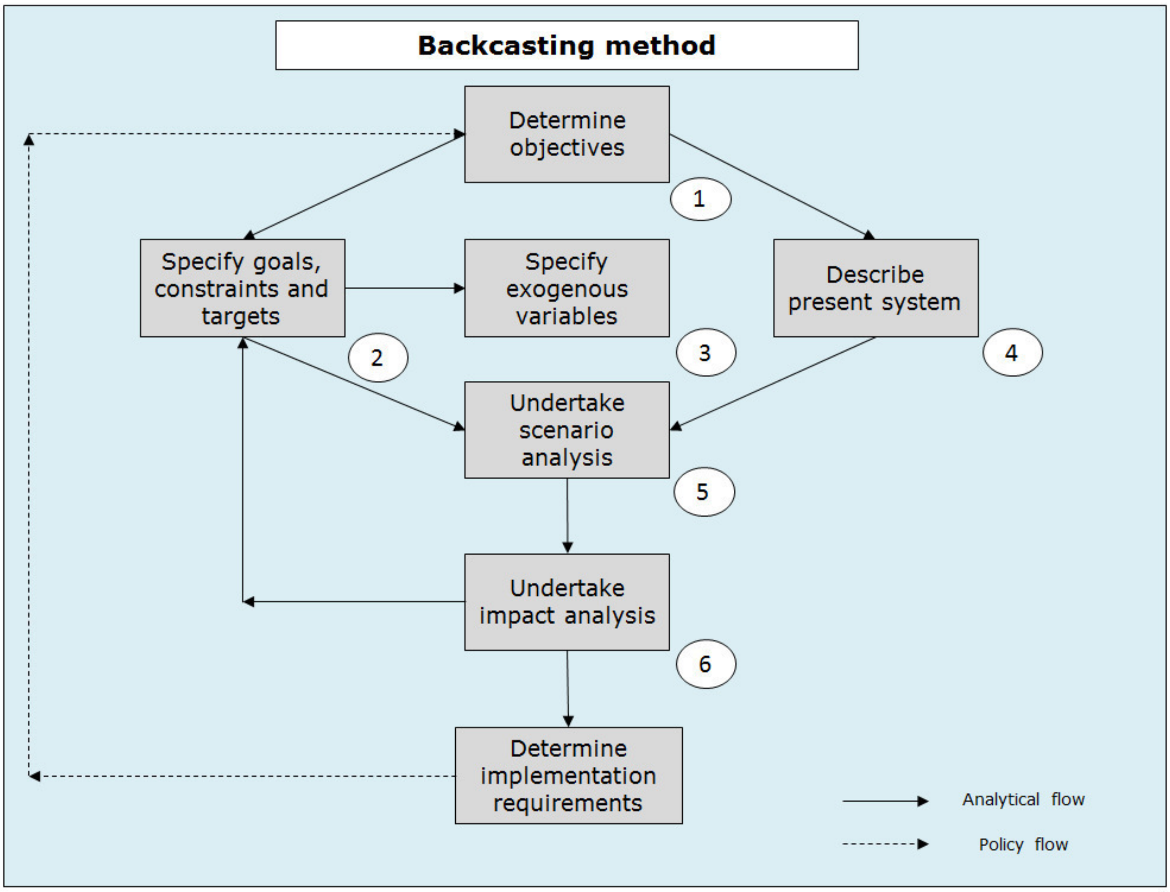


Figure 3.3: Outline of generic backcasting method (Robinson, 1990)

This research has taken the generic backcasting framework (Robinson, 1990) as a starting point for evaluation of the waste system. The proposed backcasting method combines steps 1 and 2 (determining objectives; and specifying goals, constraints and targets) into preliminary step covered in the formulation of the research aims and objectives (see Section 1.3). The research objectives are subsequently used to analyse and evaluate outputs (see Sections 4.5).

3.3.1.1 Objectives of the backcast – purpose and scope

The principal aim of the backcasting phase of the research was to determine whether the waste management sector in England could move towards a zero waste vision over the long-term. Scenarios were used to evaluate the desirability of such a zero waste vision(s) and what implications these have for wider economic, social and political systems.

The temporal scope of this research is out to 2050 with a baseline year of 2012. This gives a 38 year timeline which sits at the lower end of Robinson's recommended temporal scale of 20-100 years (Robinson, 1982). It can also be argued that 2050 goes far enough beyond the policy targets outlined in much of the recent European and national scale legislation (2020 is a pivotal year in much of the target driven literature) to offer potentially radical insight. The defined 38 year timeline may also be considered as generational with individuals being more able to comprehend impacts within their own or their children's lifetimes. Further, 2050 is a significant date in terms of climate change assessment (IPCC, 2007), providing a logical framing point.

The spatial scale of the study relates to England as a specific geographic and political entity with a county level administrative entity (Northamptonshire) used as a case study of a functioning waste management system. This level of administration is comparable to other European administrative levels with analogous data reporting allowing the potential for further evaluation. The waste and resource management sector, with inclusive policies and practices, provides the substantive scope of the study. Northamptonshire is chosen because of the existing two-tier waste system, where the county council is the Waste Disposal Authority (WDA) and the seven district and borough councils are Waste Collection Authorities (WCAs) responsible for the collection of municipal and some commercial wastes.

The number of scenarios put forwards is four (which includes a reference scenario of continuing current trends and practices). These scenarios are distinctly normative in nature drawing on qualitative data based on input of beliefs, ideas and opinions from stakeholders. The scenarios move on to more quantitative analysis drawn from the baseline assessment of the current system in order to determine the feasibility of policy choices and practical change required under each scenario.

3.3.1.2 Specifying the goals, constraints and targets

The specific goal of the backcasting was to determine if a zero waste vision was feasible in the context of transitioning towards a more sustainable system of resource management within England. In order to evaluate the feasibility of achieving a zero waste vision (or not) the four scenarios act to focus the evaluation of the proposed visions in terms of the criteria both internal to and external of the system boundary.

A range of quantifiable targets were set for system elements such as waste prevention; levels of reuse; recycling and recovery rates; and the role of landfill as a management option in 2050. In doing so, these targets provide a fixed level of assessment which can be presented visually to stakeholders by means of GIS mapping.

3.3.1.3 Specifying the main exogenous variables

As with most systems the waste management system is impacted either directly or indirectly by a range of variables. Waste arisings derive from all economic sectors as well as from the broader societal level. A number of these variables warrant consideration due to the degree of impact they can have on waste arisings, composition and infrastructure provision. The main points for consideration within Table 3.1 include: the impact of population growth which is addressed through census data; impact of prolonged periods of economic downturn on consumption patterns and subsequent waste arisings; the direction of economic development being pursued in policy initiatives such as housing and infrastructure development; and the degree to which resource efficient practices are embedded within corporate cultures. These latter points are addressed through policy analysis (Eriksson and Baky, 2010) and the potential for new policy directions associated with the outlined visions.

Table 3.1: Main exogenous variables and brief definition of main features considered

Variable	Definition of main features considered
Demographics	Population structure in terms of absolute numbers of persons; net migration; age structure or birth/death rates
Socio-Economic Situation	Levels of relative affluence or deprivation; numbers of households and persons per household; cultural norms; and housing type/density
Consumption patterns + environmental behaviour	Lifestyle choices and personal attitudes towards developing social norms such as recycling; reusing second hand items or reducing waste through changing shopping habits
Economic output	Whether or not the economy is growing or in recession can dramatically alter individuals and groups' behaviour
Economy structure	A continued shift towards a service based economy; energy and materials security focus; a new manufacturing base developed around the green economy
Corporate Eco-Behaviour	Broad initiatives to reduce waste sent to landfill; considerations of environmental impact from operating practices; shifting towards circular business models; and realising greater economic efficiency through better use of resources
Commodity Markets	Levels of volatility in markets; protectionist practices; upwards trending prices; strong downwards pressure on prices
Energy System	Increased alignment of policy surrounding waste as well as a need identified to recover energy from all possible sources can be an influence on policy choices around investing in technology capable of producing energy from waste

Source: (after DTZ/SLR, 2009a; DEFRA, 2011b, expert stakeholder input, 2011).

In terms of commodity prices and the potential for alignment of policy with energy, these are addressed through stakeholder opinion and examination of past trends in terms of the cyclical nature of economies.

3.3.2 The Visioning process: defining a zero waste future

The visioning approach developed was designed to produce an overall image of what a desirable zero waste future could look like. A number of key parameters had to be met in order to capture the essence of the backcasting methodology. These included: participation of stakeholders; adequate and appropriate timeframe; and establishing an ongoing dialogue to validate outcomes drawing on the hybrid-Delphi approach defined by Borjeson et al. (2006) which has a mixture of stakeholders (expert and lay persons). This approach addresses concerns around lack of stakeholder participation and the potential for researcher bias with first order backcasting (Quist, 2007; van Vliet, 2011).

3.3.2.1 Backcasting workshop

The workshop was designed around three sessions aimed at capturing ideas on: future states for waste; timeline – to identify critical points between the baseline and the end point; and scenario development (Anderson, 2000a) – including "what if?" questions and key social, technological, economic, environmental and political considerations. The workshop was designed to include a broad range of stakeholders but not to have too large a group as to exclude individuals from participating in discussions (Anderson, 2000b).

The workshop produced a range of output materials including: brainstorming maps; initial thematic analysis of ideas; transcripts and visualisations (by means of photographic recording); a synopsis report of the session disseminated for validation; and agreements for follow-up contact to give feedback on research stages.

3.3.2.2 Pre-workshop questionnaire

Prior to the workshop a questionnaire was developed, with the agreement of the supervisory team, to capture stakeholder's ideas on what a zero waste future could be. The questionnaire used open and structured questions to capture qualitative and some quantitative data. Key stakeholders were identified during the early stage of the research and approached for expressions of interest in attending or inputting to the visioning process. These stakeholders were asked to recommend others from their sector or field as a purposive snowball sampling approach (Goodman, 1961; Heckathorn, 1997) which sought expert opinion rather than a consideration of ethnography or demography. However, consideration was given to gender once potential participants were identified. A total of 115 forms were sent out to potential expert participants who were almost equally split between male and female; 59:56.

A key group of stakeholders identified for inclusion was the general public, a number of participants in previous waste and planning related consultations were recommended by Local Authorities, professional associations and research consultancies. In addition, contacts made through participation at open meetings attended were approached for expressions of interest and to recommend others. The limitations of snowball sampling (Hardon et al. 2004) (e.g. limiting variation in the population) were addressed by means of countering the potential for expert bias by sampling from lay persons (general public) as well as from interest groups whom have a tendency to scrutinise the waste sector and highly waste intensive industries. A total of 20 individuals expressed an interest in participating in the process along with a further 10 from local interest groups (including Transition Town Northampton; Peoples Supermarket; Freecycle; Permaculture Northampton; Friends of the Earth; The Green Party and Furniture Reuse Network). This participant group comprised 14:16 male to female and had an age range from 25-75, with 20 participants over the age of 50.

3.3.2.3 Capturing the waste sector view: CIWM survey data

At an early stage of the research, approaches were made to the Chartered Institution of Wastes Management (CIWM) around input to the visioning process as the main industry body for waste in the UK. CIWM were approached to see if they had data which could be used to capture the sector view. The annual survey was deemed most appropriate and a data set which asked for views on zero waste was provided for analysis.

The data set contained 222 responses from a total of 500 forms being sent out, giving a response rate of 44.4%. Responses from waste management professionals were thematically analysed and the output was incorporated with thematic analysis of the visioning process in order to capture sector views.

3.3.2.4 Continuing the dialogue: interviews, discussions and feedback

Although the data captured in the previous three stages of visioning was considerably detailed, it was necessary to continue a dialogue with stakeholders in order to clarify points and to reflect anything which was missed. Between June 2011 and February 2013 a total of 16 semi-structured interviews were undertaken. These interviews were mainly carried out by telephone or through Skype (n=11) with the remainder carried out face-to-face (n=5).

The aim of using semi-structured interviews was to clarify positions on specific points in terms of yes/no or giving a particular value or merely to expand on points made. One specific benefit of this approach was in capturing more detail on individual visions of zero waste futures. A further benefit was to establish a network of participants willing to give their views on the development of scenarios or assigning weightings to plausibility criteria and as part of the AHP process for location criteria.

3.3.2.5 Ethical considerations

All participants were asked to provide consent, either written or verbal. Forms were provided to participants detailing the research process and how the data provided would be used. It was also made clear that consent could be withdrawn at any point. Personal data other than names was not sought as this was not a focus of the analysis. Nevertheless, all data provided from individual participants was anonymised after input to database format with original forms destroyed to protect identification of individuals. Interviews and workshop sessions were recorded (audio) with transcriptions provided to participants for authentication and validation.

3.3.3 Describing the present system: baseline analysis

Analysis of the scenario pathways required contextualisation in terms of the physical processes (e.g. waste generation and movements), and activities (e.g. collection of waste and management method) within the waste management system under scrutiny. This physical context must address key flows into and within the system as well as those which persist and enter the natural environment after consumption (e.g. residual waste disposal to landfill). A detailed desk survey was undertaken to establish the current system for the management of controlled wastes within the case study area. A range of primary and secondary data sources were used to quantify the six key elements of the waste management system, namely: waste arisings; historic trends; waste movements; composition; infrastructure provision and legislative framework

This approach is represented schematically in Figure 3.4 and a discussion of the steps employed and the key data sources used in the baseline analysis is now presented.

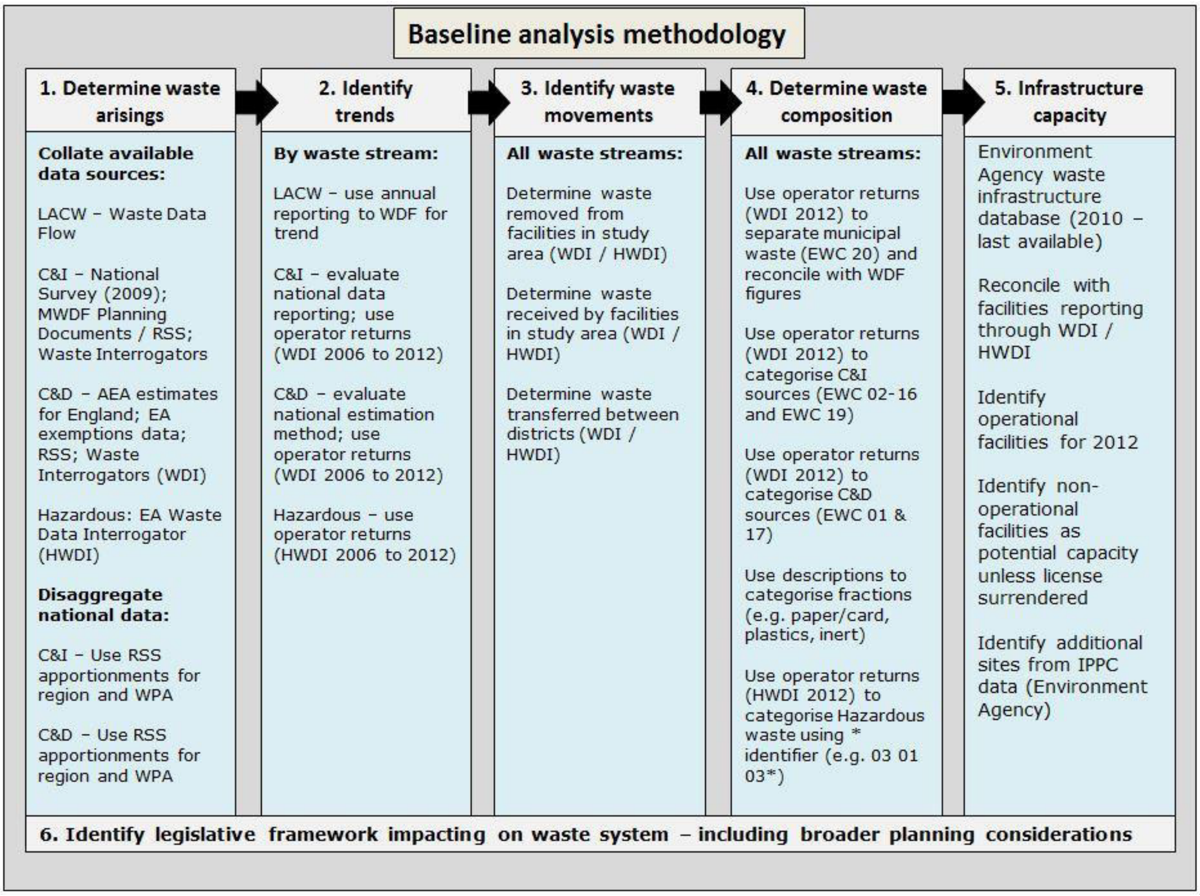


Figure 3.4: Schematic of the six step baseline analysis model and key data sources used in each step

Step 1 described in Figure 3.4 examines waste arisings data. Sources used include: Waste Data Flow for LACW; local planning documents for C&I and C&D; and waste returns data via the Environment Agency data interrogators (including hazardous waste).

Step 2 looks at historic trends within available data sets to determine patterns likely to impact on future policy formation (e.g. recycling rates decreasing or sustained reductions in per capita waste from households). These trends were used in a generalised manner in order to establish parameters for scenario testing in the next phase of the backcasting framework.

Step 3 examines the movement of waste into and out of the system boundary to determine if the area is a net importer or exporter of wastes. The data sources used for this step were the waste data interrogators obtained from the Environment Agency reporting operator waste returns notes (WRNs). This is utilised to determine if a gap exists in the provision of infrastructure capable of managing those materials arising within the system boundary. This assessment of need is an established assessment method for Waste Planning Authorities (WPAs) in England (NCC, 2012).

Step 4 analyses the available waste returns data to determine the fractional composition of materials moving through permitted facilities as changes to this has implications for the type and amount of capacity identified in step 5. Similar studies have been utilised at the regional planning scale (SLR, 2006; EMRA, 2009) to identify potential capacity gaps for infrastructure provision in line with previous guidance from government (ODPM, 2005 amended 2010).

Step 5 evaluates the amount of operational permitted capacity available currently as well as any pending capacity moving through the planning process to give an indication of potential future capacity. Key sources used in this step included the Environment Agency national database on waste infrastructure (EA, 2010), obtained under OGL license; and planning application documentation held by the WPA (Northamptonshire County Council - NCC) which is sub-divided by district or borough. At this point the various steps are integrated to determine any waste management capacity gap within the baseline year. The results are used within the quantitative model developed to test the scenarios in steps 3 and 4 of the backcasting framework.

Step 6 is the final stage of the process and outlines the key policy context impacting on the study area. The policy context is determined for international scale obligations; national scale strategies; and localised planning considerations (e.g. Local Development Plan documentation obtained from NCC). This policy analysis looks at the critical drivers and barriers currently in place as well as any legislation within the regulatory delivery pipeline.

3.3.3.1 Waste arisings: data availability and issues encountered

There are some significant limitations on data reporting for certain waste streams in England. Data reporting for LACW is a legal responsibility of Local Authorities in England and is submitted quarterly to the Waste Data Flow (WDF) system. This system was introduced in 2005/06 and now contains seven full years of detailed data on municipal waste (up to reporting year 2012/13). This source of data was utilised to form the baseline for LACW in the study area with a desk survey of local planning documentation also undertaken to determine and reconcile any significant gaps identified. Household and municipal waste is also reported under the EU data reporting requirements via Eurostat. This data is for the UK as a whole and is reported at 2 year intervals (2004; 06; 08 and 10). As 2010 was the last reporting point encountered in the data series (accessed July 2013) this data has been used as secondary data and to identify similarities and differences between the constituent national entities of the UK.

Unlike LACW there is no requirement to report C&I waste at a national scale on a regular basis. However, all permitted waste sites must report waste returns data to the Environment Agency (and similar bodies in Scotland; Wales and Northern Ireland). These waste returns data are captured and stored within the data interrogator system. Two interrogator databases are held on waste returns – the Waste Data Interrogator (WDI) and Hazardous Waste Data Interrogator (HWDI). Although these databases cannot be said to cover all waste within the waste system of Northamptonshire (as a significant percentage of low risk materials are dealt with by means of exemptions certificates), they do represent a detailed account of all waste streams managed at permitted facilities across England. These data sets were thus utilised to determine waste flows within the system of permitted facilities operating in the study area. Access was obtained to these datasets via user license agreement with the EA. This data was supported by means of desk survey covering local planning documentation and waste needs assessment.

To address any gaps in the flow of materials through the study area, waste exemptions data were also obtained from the EA for 2012. These data do not give overall tonnages and in many cases do not specify an amount of material which can be managed under said certificate. However, it is possible to categorise the regime and support any estimations based on secondary research identified in the planning literature for Northamptonshire. Such reporting is at best an estimate and will be treated as having the greatest amount of uncertainty in terms of reliability and accuracy. Further reporting on exemptions is provided for landfill tax returns (HMRC, 2013) at a national scale as well as within the latest modelling approach for CD&E arisings in England (Gov.UK, 2013). The various sources of primary and secondary data are thus collated to provide a range of values from which to test the scenarios developed by means of quantitative modelling.

3.3.3.2 Historic trends: extrapolating trends across data sets

The reporting system Waste Data Flow (WDF) is available for research purposes and was accessed to generate LACW data for the baseline year identified (2012) and preceding years in order to evaluate historic LACW trends. The WDF reporting system has been in place since 2005 and thus contains a significant time period for analysis of trends in municipal and household waste. Data reporting under WDF is by tonnage and thus requires further conversion to determine other metrics.

Reporting for commercial and industrial (C&I) waste has been intermittent throughout the last 15 years in England. The last national scale survey was undertaken in 2009/10. Other studies on C&I waste have been undertaken at the regional scale (ADAS, 2009; Urban Mines, 2011). These data sources were collated and analysed in order to assess the range of waste arisings from commercial and industrial sources within Northamptonshire. Waste returns data held by the EA were also accessed under license in order to address C&I waste data gaps.

Significant limitations were found with this process as the data sets were either incomplete, absent or not designed for disaggregation to the WPA level. To counter this problem, a modelling approach was developed which used a range of potential values for C&I waste within the system boundary. A quantitative model was thus developed and used, to produce quantifiable data for assessing the impact of scenarios. The model was run from 2050 to the baseline to produce non-linear (normative) backcasts aligned with the impacts of the exogenous and endogenous variables identified.

The availability of data on construction and demolition waste is the least detailed of all available. A modelling approach by AEA Technology (Gov.uk; 2013) has been based on estimated quantities at the national scale. To disaggregate the data, a similar modelling approach was developed for C&D waste as put forwards for C&I waste. Some variations had to be incorporated within the C&D model in order to account for wastes managed under exemptions and the potential level of recovery as aggregates.

3.3.3.3 Waste movements: examining the WPA and district levels

A number of considerations are necessary when determining movements of waste. First, the majority of municipal waste passes through transfer or bulking facilities prior to treatment or final disposal (EMRA, 2009). This must be considered to avoid double counting and thus overestimation of quantities. To address this issue, reported quantities of LACW were used to test accuracy of waste returns data. Any discrepancies (over the reported figures) were assigned to either C&I or C&D depending on the EWC description of the waste.

Second, C&I waste is likely to move the greatest distance as this is traditionally provisioned through national scale private sector contracts, where waste is sent to contractors own sites rather than the closest appropriate facility (ODPM, 2005). This assumption was tested in terms of the source WPA for the material types and reported in terms of percentage of materials from outside the WPA.

Finally, the use of exemptions within the wider permitting scheme potentially accounts for significant quantities of materials but is not required to report tonnages. This necessitates the need for an estimation approach to C&D figures.

3.3.3.4 Determining the composition of waste streams

Understanding and accounting for changes in the composition of waste from different waste streams is an essential part of developing reliable scenarios of future system conditions. Specific policy objectives such as banning waste from landfill or incineration routes can impact on implementation of technological innovations; calorific value of specific feedstock types; developing integrated facility sites; and collection services offered by local authorities (Burnley, 2007b; Tudor et al. 2007; Bates et al. 2008).

A more fundamental issue must also be considered when determining the composition of waste streams, that of waste prevention. The impact of waste prevention initiatives has far reaching implications in three main ways.

1. If waste prevention has a broad and constant impact this may diminish the requirement for new policy measures as composition too would likely remain constant.
2. Targeted and material specific prevention approaches would have implications for the traditional waste management sector and the design of supporting policies.
3. Low engagement levels with prevention initiatives or changes in behaviours would leave generation rates open to fluctuate according to existing policy initiatives and composition to alter accordingly.

Data availability and accuracy is again a difficulty in this area across all waste types as composition studies are expensive and time consuming. Such studies are also exposed to considerable variance associated with seasonality for specific waste fractions (i.e. green garden waste).

A supporting methodology is proposed which looks at waste returns data for district and county level. Such a methodology has certain strengths and weaknesses. Key strengths include:

- Returns data gives an indication of the composition of waste managed at facilities from all waste streams (as EWC reporting classifications); and
- Returns data provides granularity for C&I and C&D streams which has been absent in most recent reporting.

A significant weakness identified with waste returns data relates to missing fractions as not all waste streams come under the reporting regime (e.g. inert materials). To address this shortcoming localised composition research within the study area and former regional planning tier are utilised as secondary sources to validate results.

3.3.3.5 System structure: collection systems and facility types

Analysis of the waste management system needed to consider the broad range of elements which handle material flows within the legislative framework and informally. A desk survey was utilised to review the key components of the waste management system within England and Northamptonshire. The EA holds records of all permitted waste facilities within England. These records are stored in excel spreadsheet format and are available on request from the EA national authority under an OGL (Open Government License). These were accessed under license and used for this stage of the research in terms of the permitted capacity and the proven capacity based on waste returns tonnages for each site.

3.3.4 Scenario development and analysis

Scenario development is very time consuming as it is undertaken with consideration of the potential impact of each choice made. This stage requires high levels of participation from stakeholders with a need to obtain input at different stages of the process. To meet this requirement, results from the visioning process were combined with output from the baseline analysis in order to produce both qualitative and quantitative scenarios. These scenarios were used to form thematic narratives (section 5.4.2) in the form of futures tables as well as forming the basis for calculations within the quantitative model (section 5.4.3.2) for testing the feasibility of scenarios in terms of impacts on waste tonnages; economic impacts; and carbon equivalence impacts (section 5.5). Figure 3.5 is a schematic representation of the data collection stages and the outputs which required further analysis. The analytical phase was structured around the types of data collected from the various stages of the backcasting (represented as the left column in Figure 3.5).

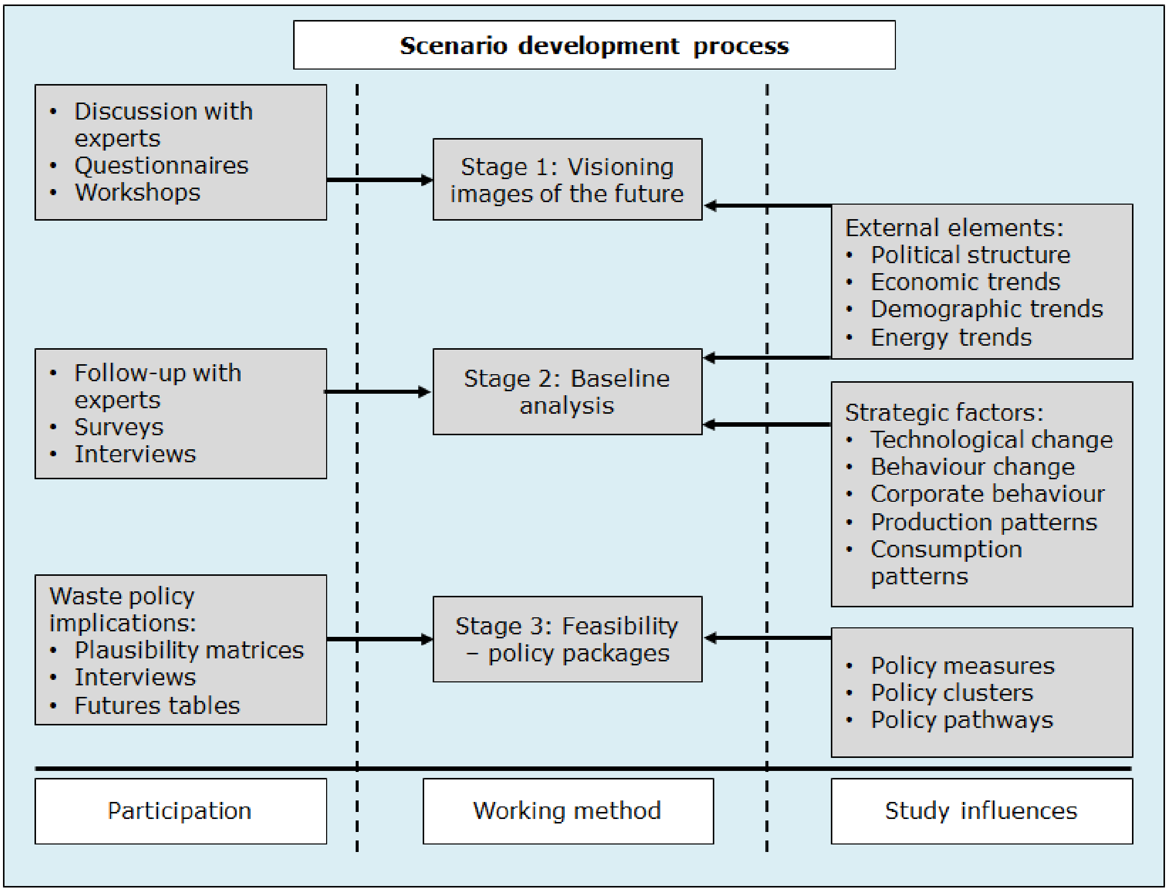


Figure 3.5: Schematic presentation of the scenario development process with participation processes, working method and influencing factors illustrated (Source: after Hickman and Bannister, 2007)

In terms of generating scenarios, questionnaires were structured to capture quantitative data such as levels of recycling and prevention/reuse which were used to formulate targets for specific visions. Capturing qualitative data was the main focus of questionnaires, as stakeholder views and opinions were sought which could be evaluated using thematic analysis based on Social Technological Economic Environmental and Political (STEEP) criteria. Mind mapping software (Mind Genius 4) was utilised for this data analysis as well as for the qualitative data captured within the workshop setting.

3.3.4.1 Ethical considerations addressed

The workshop and follow-up interviews were recorded and transcribed so as to capture ideas and visions from participants. They were then sent copies of transcriptions and asked to validate these in terms of accuracy and being a true reflection of their views and opinions on visions for the waste sector. Consent was sought from all participants at each stage of involvement, with it being made clear that they were free to withdraw this consent at any stage. All data was anonymised prior to distribution so as to avoid identification of individuals. The University of Northampton code of ethics was adhered to throughout (UoN, 2011).

3.3.4.2 Producing the visions and developing scenario pathways

The results of thematic analysis and categorisation according to STEEP criteria were combined with initial follow-up interviews and discussions (Bovea and Powell, 2006) in order to formulate futures tables showing the zero waste scenarios. The resulting visions were again distributed to stakeholders for authentication and further feedback, after which they were taken as the starting point for feasibility testing.

3.3.4.2.1 Plausibility matrix testing

Systems characteristics and variables were determined by means of a plausibility matrix. A plausibility matrix is one means of capturing qualitative and quantitative data from individual participants within a study. These are commonly used with General Morphological Analysis approaches (Ritchey, 2005; 2006) and have also been used to capture stakeholder views via Key Factor Analysis techniques (DEFRA, 2011b). Indeed, a foresight study carried out by Zpunkt for DEFRA on building future waste policy was used as a basis for the variables and policy options (projections) within the final matrix. Discussions with industry experts and the supervisory team in early-2012 were used to finalise these variables prior to sending out the matrices for stakeholder input.

The first stage in using plausibility matrix forms was to contact stakeholders (n=63) to give their preferences to 14 variables, each with 5 options, on a 1-5 ‘likert’ scale. A total of 22 stakeholders responded with sufficient detail to be used in the analytical phase with a further two of these proving incomplete in terms of sections omitted for evaluation. This meant 20 of the original 63 requests were returned fully completed giving a response rate of 31.7%.

Table 3.2: Individual response matrix showing indicative results for five variables (top row) with potential factors (options 1-5), first choices (in green); and preference scale (excel conditional formatting) shown.

Option	Demographics	Socio-Economic Situation	Consumption patterns + environmental behaviour	Economic output	Economy structure
1	Stable Population Growth	Growing affluence	Good attitudes, wasteful behaviour	Steady growth	Continued shift to services
2	Population boom	Income re-distribution	Strong increase in sustainable consumption	Rapid per capita growth	Resurgence of British manufacturing
3	Rapidly ageing population, stagnation	Inequality reigns	Steady buying power, conscious choices	Bust-boom cycle	Centre of excellence (quality based production)
4	Increasing population balances ageing, greater ethnic diversification	Poorer society	Low consumption and environmentally conscious behaviour	Double dip (recession)	Balancing (diversify - growth of green economy)
5	Decreasing population growth (EU migrants repatriate & skills quota approach)	Income squeeze	High consumption and low environmentally conscious behaviour	Triple dip (recession)	Product design and stewardship focus
Option	**Demographics**	**Socio-Economic Situation**	**Consumption patterns + environmental behaviour**	**Economic output**	**Economy structure**
1	3	5	1	5	5
2	1	4	3	2	1
3	2	3	5	4	3
4	5	1	4	1	4
5	4	2	2	3	2

The rationale for applying this analytical approach was to determine relative weightings of variables utilised in the quantitative model as well as the choices which would inform the qualitative scenario narratives. To this end, output was recorded in two ways. First, the forms were used to identify individual scenarios through choice of options within each variable grouping (see Table 3.2).

This method of recording visually captures the choice of scenario for individual respondents. The likert scale was utilised to score each choice with these scores then aggregated to produce overall weighted choices (as % scores) for each potential outcome. Once the matrices results had been produced, the second stage of the process was to again ask stakeholders to give their opinion on the outputs in terms of when the options were most likely to be applicable (or if these were to be taken as applicable for the duration of the scenario period). These responses were recorded as either a key milestone year or duration with numbers of respondents assigned to each category for all variables.

3.3.4.2.2 Quantifying the plausibility results

The quantitative data generated through the preference scale is derived from the preference scale shown in Table 3.3.

Table 3.3: Preference scale (based on Likert scale) and descriptor used in the plausibility matrices

Preference scale	Descriptor
5	Strong positive impact perceived
4	Positive impact perceived
3	Current trend dominates
2	Negative impact perceived
1	Strong negative impact perceived

Using this preference scale has some advantages in terms of stakeholder perception. It is often easier to perceive the best choice of categories in terms of a descending scale from 1

Table 3.4: Indicative results from plausibility matrices with data analysis stages shown

Demographics	Sum of scoring	Reversed scores	Priority weighting
Stable Population Growth	28	72	0.2057
Population boom	28	72	0.2057
Rapidly ageing population, stagnation	37	63	0.1800
Increasing population balances ageing	21	79	0.2257
Decreasing population growth (repatriation)	36	64	0.1829
Sub-totals	150	350	1.0000

to 5 with 5 being the least preferable choice. However, in terms of analysing the results this scale had to be reversed in order to give a priority weighting. Table 3.4 shows indicative results and the procedure for generating the priority weighting for individual criterion.

3.3.4.2.3 Methodological development

The approach in this research differs from the DEFRA study by utilising stakeholder responses as the determinant for each variable and choice. This is important when the approach is seeking to analyse potential policy pathways from 2050 to the present (as opposed to projecting from the present to 2020 or 2030 – DEFRA, 2011_b). Projections are extensions of current trends and policy directions whereas stakeholder choice can be based on desirability, values and beliefs which broaden the spectrum of options.

3.3.5 Impact analysis

The final stage of the backcasting method was to test the feasibility of the scenarios generated. In order to achieve this outcome a quantitative model was developed which could combine the baseline data with the quantified values for the relevant criteria within each narrative. This model was designed around producing results in terms of three metrics: overall waste arisings (tonnages); economic values (in terms of costs per tonne and savings per tonne); and carbon (as CO_2 equivalent).

Tonnage data is used specifically to determine whether or not national targets are being achieved or surpassed for each scenario. Economic values and carbon metrics are utilised in order to test the cost-effectiveness and potential environmental impact of scenarios associated with the waste sector.

3.4 Systems visualisation utilising GIS

A number of key tasks were identified in order to visualise the results of the backcasting method chosen. The software package ArcGIS 10 was utilised in order to visually project the system under scrutiny and the potential changes envisaged as a result of the scenarios outlined. ArcGIS 10 is a powerful analytical platform which allows data manipulation and analysis within a digital spatial environment. The goal was to embed the backcasting process within a GIS environment in order to meet Objective 4 and rigorously test the backcasting output. Figure 3.6 is schematic of the GIS modelling approach used showing the connections with the key stages of the backcasting process as well as the quantitative model outputs.

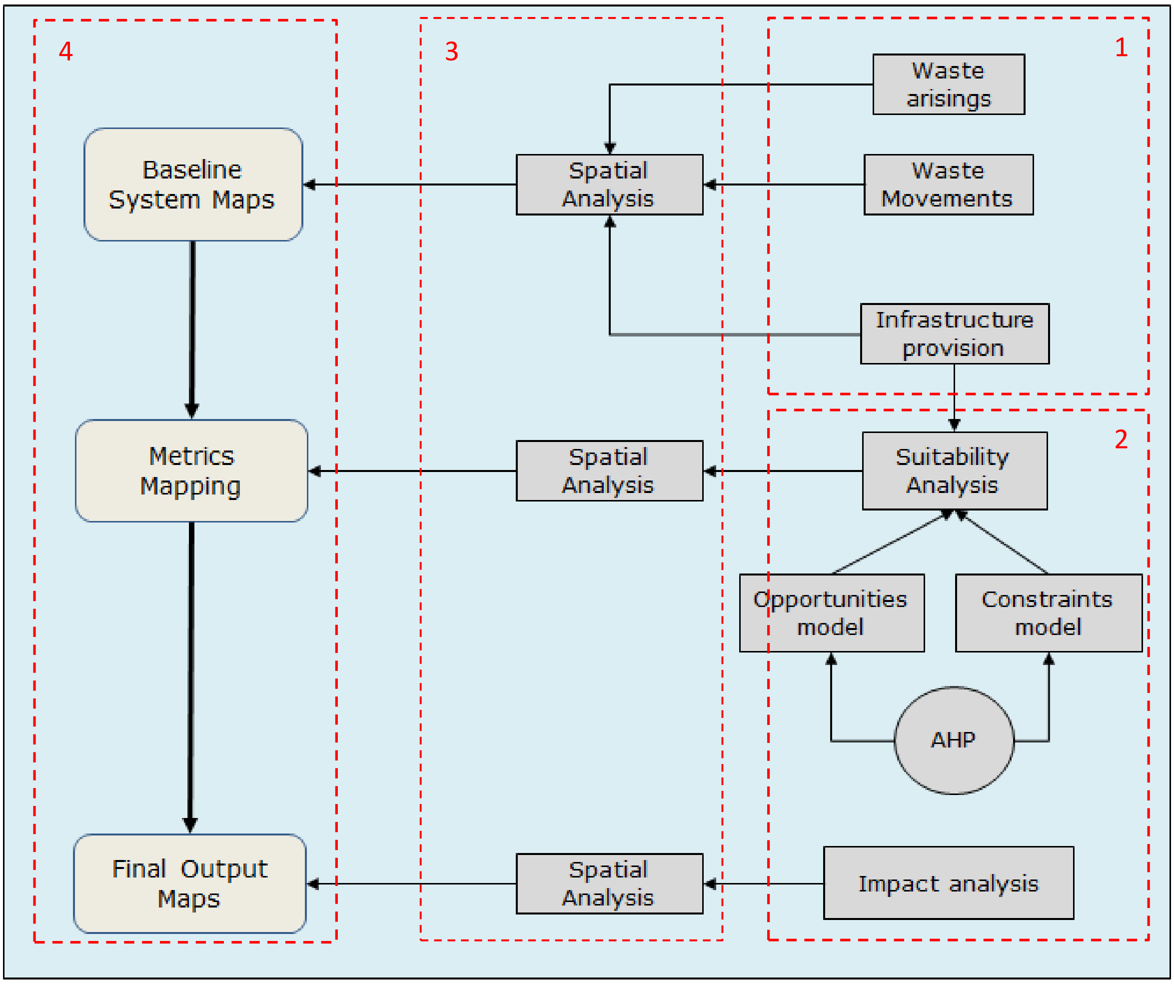


Figure 3.6: Workflow schematic of the GIS modelling approach used 1) data collection; 2) data analysis stages; 3) spatial analysis stages; 4) results maps.

3.4.1 Parameters for using GIS with backcasting

GIS modelling environments offer a range of powerful tools for the analysis of quantifiable data. To support the backcasting method applied in the research it was decided to concentrate on a number of key features in order to deliver meaningful outputs. Indeed, the quantifiable elements of the visioning process and the scenario development process can be represented and analysed by means of GIS tools and applications. The key parameters and methods used in developing the GIS model are outlined in Table 3.5.

Table 3.5: Methods and key parameters (spatial and temporal) used in the GIS modelling

Modelling Method	Spatial and Temporal parameters
MCDA (using AHP)	Proximity - minimum distances guidance; transport - modal
	Scale – investment required; planning process
	Feedstock availability – economic viability
	Suitability – needs assessment
Comparative analysis	Results versus policy objectives
Backcasting	Repeat above steps for desirable vision(s) and mid-points

3.4.2 Outline of the GIS modelling method

Systems modelling using GIS can be an effective tool for engagement with decision-makers and broader stakeholders (Guan et al. 2011). This was a central concern when designing the research methodology in terms of how to communicate results in a meaningful and robust manner to multiple stakeholder groups with differing levels of technical understanding. This section outlines the steps within the methodological process used and key considerations relating to type of data; accuracy; manipulation required and output reliability.

3.4.2.1 Data collection – thematic layer maps

Requirements under the INSPIRE Directive (2007/2/EC) established an infrastructure for spatial information in Europe. INSPIRE addresses 34 spatial themes relevant to environmental applications within three Annexes. Specific to this research, Annex III includes sub-category 11 – Area management / restriction / regulation zones & reporting units which outlines obligations on making data available on waste sites.

The EA as regulator responsible for waste management in England and a range of other organisations (e.g. Natural England; English Heritage; Defra; etc.) host and contribute to the Data Share portal (http://www.geostore.com/environment-agency/). This portal was accessed in order to retrieve required datasets (e.g. land use) (see Table 3.6). Where data was not available or data was not in geo-referenced format (e.g. waste arisings data) bespoke layers were created with ArcGIS 10 software and assigned geo-referencing attribute data (e.g. Eastings and Northings).

Table 3.6: Data collection requirements by criteria; INSPIRE Annex and organisation

Criteria / Layer	INSPIRE Annex	Organisation(s)
Waste sites (permitted facilities and exemption sites)	III	Environment Agency
Heritage sites (listed buildings; battlefields; monuments; parks and gardens)	I and III	English Heritage
Environmentally sensitive sites (RAMSAR, SSSI, AONB; SPA; etc.)	I & III	Natural England
Environmental data (flood risk; groundwater vulnerability; nitrate vulnerability; etc.)	I & III	Environment Agency; BGS
Assessment (land cover; elevation; geology; orthoimagery)	II	CEH; BGS; Natural England; EuSA

3.4.2.1.1 Data manipulation and formatting

Most data was available as shape (.shp) files or equivalent. In the absence of these file type's data was entered to Excel spreadsheet where geo-referencing data was added for conversion and import to geodatabase (.gdb) by means of the ArcCatalog tool. Forming the geodatabase (.gdb) requires entering, processing and analysis of data prior to combining and interpretation for producing outputs. The geodatabase (.gdb) format was chosen above individual shape (.shp) files because of issues around stability (Zeiler, 1999) with very large amounts of data storage and the production of analytical maps.

Determining the mapping methodology requires a detailed consideration of the level of analysis (disaggregation) required. As a consequence of the data available at Lower Super

Output Area (LSOA) and the constancy of association between LSOA and Census data, analysis at this scale seemed most appropriate. Northamptonshire contains 422 LSOAs (ONS, 2012) with a mean population of 1,640. These geographic units of analysis allow calculation of per capita figures for non-spatial data (e.g. tonnages, economic costs and carbon emissions) and can be scaled up or down depending on geographic location through relatively simple analytical procedures.

3.4.2.1.2 Data issues encountered

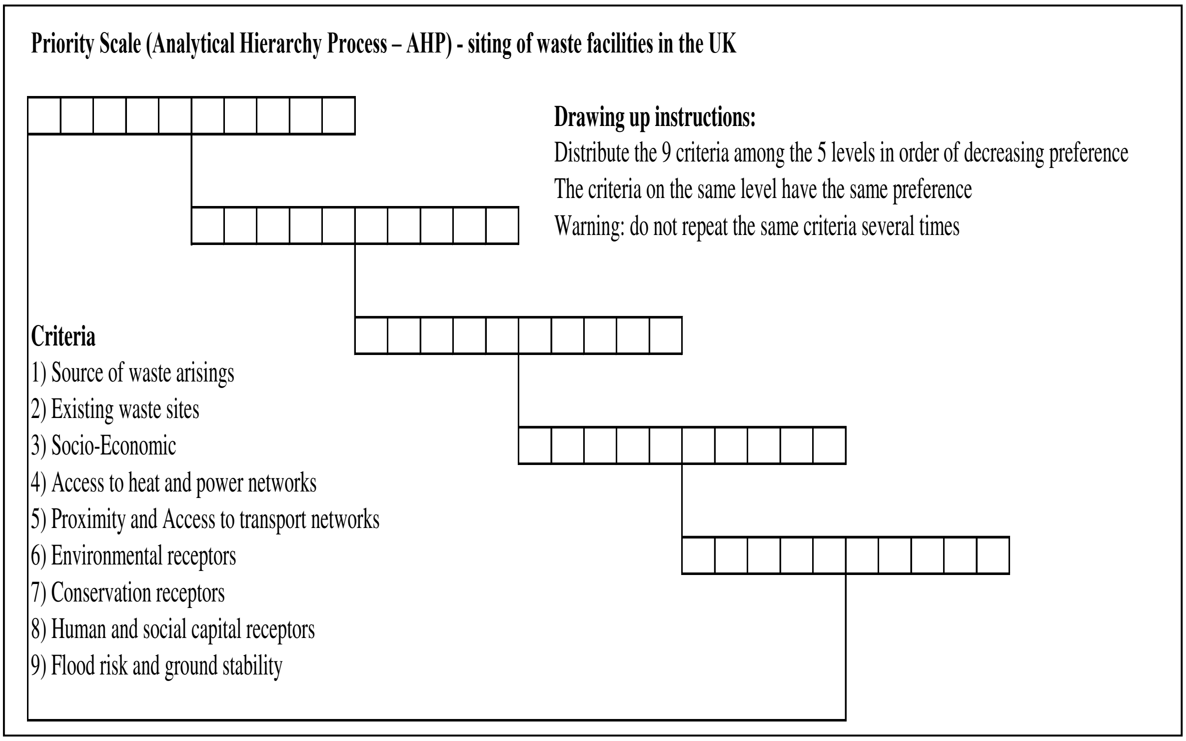
Not all datasets are available at LSOA level which requires further manipulation and formatting of the data. Previous studies have identified significant gaps in the data. Nevertheless; as mentioned; data gaps are increasingly being addressed and filled due to legislative requirements and commercial demands. In addition, geospatial tools available in ArcGIS allow the creation of specific bespoke map layers (point, polygon and polyline). Identified data gaps were addressed through the creation of bespoke layers (e.g. industrial parks, strategic employment land and previously developed land).

3.4.2.1.3 Data collection – priority scale forms for AHP

In order to develop and validate the weightings assigned to each criterion, priority scale forms were produced and sent to a number of technical stakeholders (n=30) and non-technical stakeholders (e.g. stakeholders from outside the waste and resource management field) (n=30). The response rate from these 60 stakeholders was high at 93% (56 out of 60). However, it is not necessary to have such a large group for analysis by means of AHP (e.g. pairwise comparison). As a result the first 40 respondents (20 from each group) were chosen as these were principally received within the originally specified time period (January 2012 to April 2012) with the remainder being received within a further one month window.

Table 3.7 shows the means of recording responses within the priority scale framework using the Saaty scale as proposed by De Feo and De Gisi (2010).

Table 3.7: Priority scale input forms for stakeholder responses



Source: (after De Gisi & De Feo, 2010)

3.4.2.2 Data analysis stage

The identification of most likely areas of search is the most involved aspect of the modelling methodology put forwards in this research. This consists of three main phases:

1. Developing a constraints model
2. Developing an opportunities model
3. Integration of constraints/opportunities models to produce a suitability model

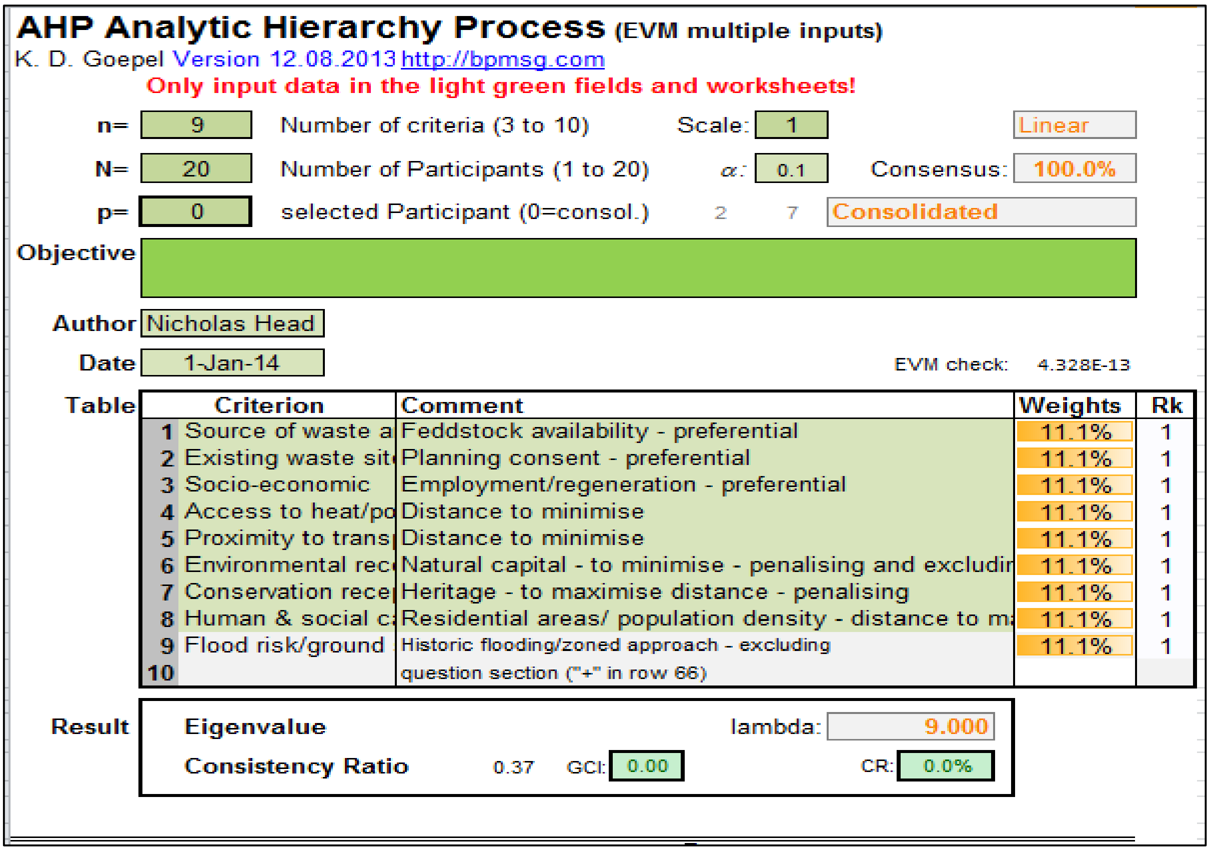
The model development process required the production of a set of weightings for each criteria grouping. The Analytical Hierarchy Process (AHP) was used to evaluate criteria based on input from stakeholders as to the degree of priority which should be assigned to each criteria group. Each sub-criterion was then assigned a weighting in a second round of comparisons according to preferences stipulated in AHP priority scale forms and through discussions with individual stakeholders.

3.4.2.2.1 Assigning weightings with AHP

The AHP was put forwards by Saaty as a general theory of measurement (Saaty, 1987). It is used to derive ratio scales from both discrete and continuous paired comparisons. In this case responses using the Saaty Scale (see Table 2.4) measuring the relative strength of preferences and feelings relating to waste infrastructure siting were entered into pair-wise matrices in order to produce a weighting value based on output Eigen values. Versions 2013-08-12 and 2013-12-24 of the AHP software package developed by BPMSG (Goepel, 2013) were used for data analysis as it meets the criteria set out in the Saaty AHP method and benefits from online support with a user friendly interface being based on spreadsheet formatting.

The AHP method is based on a pair-wise comparison of the importance of different criteria. The fundamental scale for pair-wise comparison defines and explains the values 1 to 9 with judgments comparing pairs of like elements in each level of a hierarchy against criteria in the next higher level.

This approach can be explained further in terms of the preference scale thus: a value 1 (equal importance) means that two criteria contribute equally to the objective. The next hierarchical level is represented by value 3 (moderate importance) meaning that experience and judgment slightly favour one criterion over another. A value of 5 (strong importance) would mean that experience and judgment strongly favour one criterion over another. The value 7 (very strong importance) means that a criterion is highly favoured over another. Finally, a value of 9 (extreme importance) would mean that the evidence favouring one criterion over another is of the highest possible order of affirmation. The values 2, 4, 6 and 8 have to be utilised for compromise between the above values and represent intermediate values (Saaty, 2001 cited in De Feo & De Gisi, 2010). Respondents in the study had the scale and values explained to them prior to completing the input forms. Specifically the use of intermediate values (i.e. 2, 4, 6 and 8) was discussed if there was any doubt in terms of assigning a marginal preference. However, none of the respondents expressed any such indication and as a result the intermediate values were not used. A comments box was incorporated with an indication given to respondents to use this for recommendations.


AHP Analytic Hierarchy Process (EVM multiple inputs)
K. D. Goepel Version 12.08.2013 http://bpmsg.com
Only input data in the light green fields and worksheets!

n= 9 Number of criteria (3 to 10) Scale: 1 Linear
N= 20 Number of Participants (1 to 20) α: 0.1 Consensus: 100.0%
p= 0 selected Participant (0=consol.) 2 7 Consolidated
Objective
Author Nicholas Head
Date 1-Jan-14 EVM check: 4.328E-13

Table	Criterion	Comment	Weights	Rk
1	Source of waste a	Feddstock availability - preferential	11.1%	1
2	Existing waste sit	Planning consent - preferential	11.1%	1
3	Socio-economic	Employment/regeneration - preferential	11.1%	1
4	Access to heat/po	Distance to minimise	11.1%	1
5	Proximity to trans	Distance to minimise	11.1%	1
6	Environmental rec	Natural capital - to minimise - penalising and excludir	11.1%	1
7	Conservation rece	Heritage - to maximise distance - penalising	11.1%	1
8	Human & social c	Residential areas/ population density - distance to m	11.1%	1
9	Flood risk/ground	Historic flooding/zoned approach - excluding	11.1%	1
10		question section ("+" in row 66)		

Result
Eigenvalue lambda: 9.000
Consistency Ratio 0.37 GCI: 0.00 CR: 0.0%

Figure 3.7: Example summary sheet from the AHP software used, showing results considerations around Eigenvalue and Consistency (Source: Goepel, 2013).

Analysis of the data was undertaken with the AHP software package developed by Goepel (2013). This open access software is in spreadsheet format requiring data input for each participant with a summary sheet for defining the variable set and reporting results for individual stakeholders or as an aggregated result of all stakeholders. The output gained from the AHP software is shown in Figure 3.7. The summary sheet allows weights and rank order to be determined at the macro scale (group criteria) micro scale (individual criterion). It is also possible to determine the consistency of the overall (consolidated) results as well as for each participant. The goal in terms of consistency is to achieve a value less than 10% otherwise criteria must be re-evaluated.

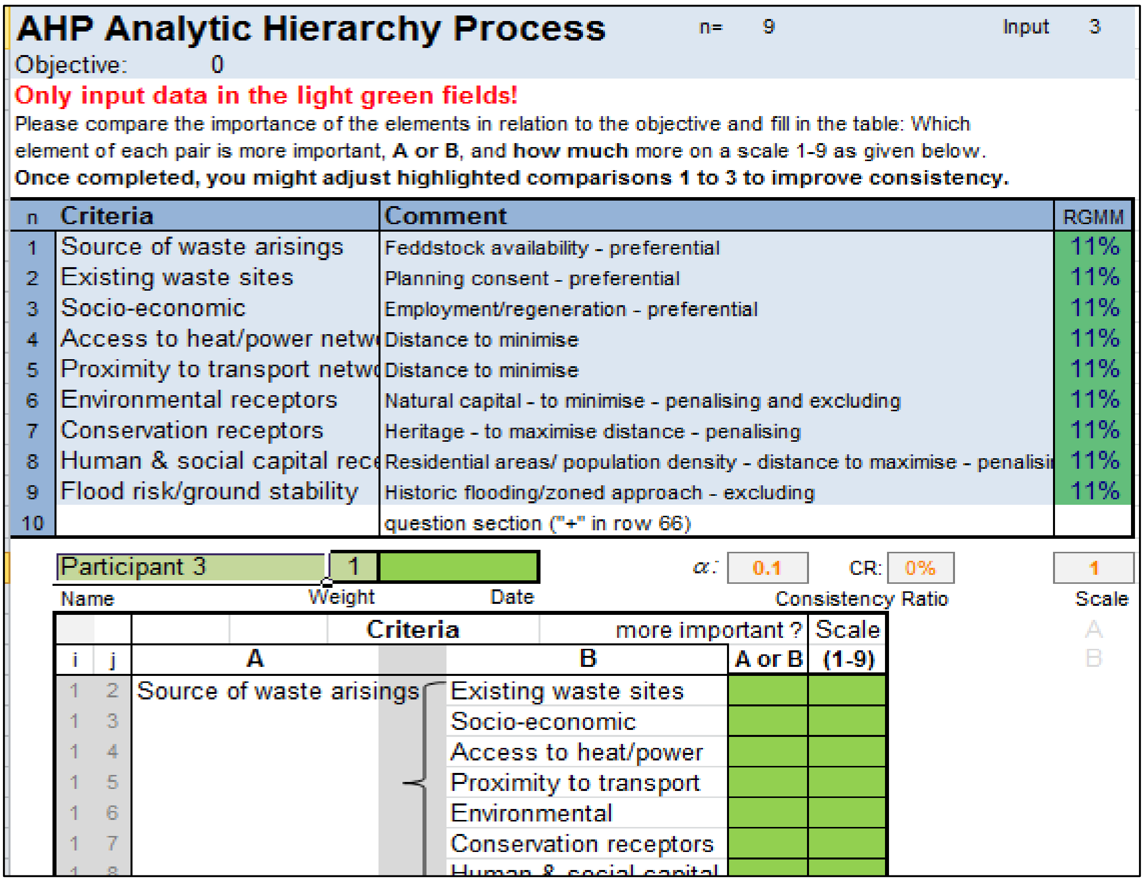


Figure 3.8: Structure of the AHP spreadsheet software for individual participants (Source: Goepel, 2013).

Figure 3.8 gives an example of the spreadsheet structure for entering data from the priority scale forms. Essentially, the column showing A and B represents where the score was in relation to any other score. For example; if a score of 1 was placed on the middle tier of the priority scale and a 2 was placed on the highest tier then a B would be entered in column ‘more important’ (Figure 3.8). This would be two tiers higher than the score 1 and so a value of 5 is entered in the ‘scale’ column. The converse is true if the 2 was a placed on tiers below the 1 and would therefore receive an A. The last consideration relates to values placed on the same tier, these are assigned an A and a scale value of 1 as they are deemed to be of the same level of importance as each other.

3.4.2.2.2 Ethical considerations

Ethical considerations with this stage of data collection were addressed with regards to the ethics policy of the University of Northampton (UoN, 2011). Consent was sought from all participants prior to sending priority scale forms, with participants being advised they were free to withdraw this consent at any time. Responses were anonymised by transferring the responses to numerical data sheets for input to the AHP spreadsheet. All records were kept in locked offices and once entered into secondary data sheets were destroyed. No personal details were used in the analysis as this was not a focus for the analysis.

3.4.2.3 Spatial analysis and results stages

Spatial analysis techniques were utilised at three separate stages of the research: mapping baseline system conditions and undertaking a suitability assessment for future waste facility siting; mapping the key metrics (from the visions through key milestone years); and in the final output maps (as part of the impact analysis).

3.4.2.3.1 Baseline mapping

The main waste system characteristics were mapped (e.g. tonnages, sources of waste and infrastructure type) in order establish a means of assessing each scenario. In addition, the main quantifiable exogenous variables were mapped (population density; areas of deprivation; areas of employment; and areas of future growth). These system characteristics were combined within the suitability assessment for waste infrastructure siting in order to test the appropriateness of sites chosen for future waste management facilities.

The findings of the suitability assessment produced opportunities and constraints maps as well as a final suitability map for potential locations to site waste facilities. This assessment was used to frame the scenario narratives for the spatial pattern of future waste facilities and the policy implications of such changes.

3.4.2.3.2 Key metrics mapping

A series of maps were produced showing the spatial distribution of key metric information (e.g. per capita tonnages by waste streams; per capita economic costs and savings; and per capita direct and avoided emissions of CO_2e associated with waste generation and management). These maps combined census and demographic data with non-spatial data to generate new attribute fields which could be projected within a GIS environment. The resulting information was analysed against baseline conditions to determine the relative level of impact between each scenario.

3.4.2.3.3 Final output mapping

The final output maps were produced in order to provide a means of comparing the overall impact of each scenario in terms of meeting the definition of zero waste. Each output map visualised the four scenarios before comparing these with the spatial pattern of waste facilities proposed within the LDP documentation (NCC, 2012).

3.5 Case Study approach

Rowley (2002) states that: 'A case study approach is utilised in order to explore in detail the efficacy of a specific method or approach proposed'. This is particularly the case for a model which has applications at both local and national scales. Using a case study approach in the context of modelling a waste management system has benefits in terms of data availability and the level of detail which can be achieved in terms of mapping collected data and results. While the main focus of the G-BFM (see Figure 3.1) is to qualitatively explore the scenarios for zero waste futures there is a need to determine 'how' the system can change to meet the desirable goal as well as 'why' certain choices are made during the process.

3.5.1 The use of Northamptonshire as a backcasting case study

These two questions are critical to the use of a well-defined administrative unit such as Northamptonshire. Mapping 'how' the system can change according to the characteristics of each scenario and subsequent pathway allows a detailed assessment of the data at a scale to which individuals, groups, businesses and decision-makers can relate. In addition, testing the model in terms of local conditions allows the possibility of delimiting a range of common parameters which would enhance the usability of the model by other WPAs; Local Authorities or stakeholders. Using a case study such as Northamptonshire may also allow answers to be found to 'why' certain choices can be made. For instance, through testing different criteria weightings it is possible to expand or restrict the potential areas of search which may be suitable as sites for the provisioning of waste infrastructure. Conversely, changing criteria such as the legal definition of waste or impact of waste prevention on a waste system may provide a visual indication of waste levels requiring treatment and potential level of investment for a sustainable future WMS.

Chapter 4 Results: Baseline analysis

Chapter 4 presents the results of the baseline analysis for the waste system within the study area of Northamptonshire for 2012. The results from this stage of the backcasting process form the basis for analysing the output from the visioning stage in terms of scenario pathways and the feasibility of such considerations of the future and begin to address objective 1. In order to analyse the scenario pathways it is necessary to determine the physical processes and activities which constitute the baseline system conditions within the study area. In addition, the policy considerations which guide current operations require outlining. A methodology was developed to analyse the strategic elements of waste systems, a schematic of the workflow is shown in Figure 4.1.

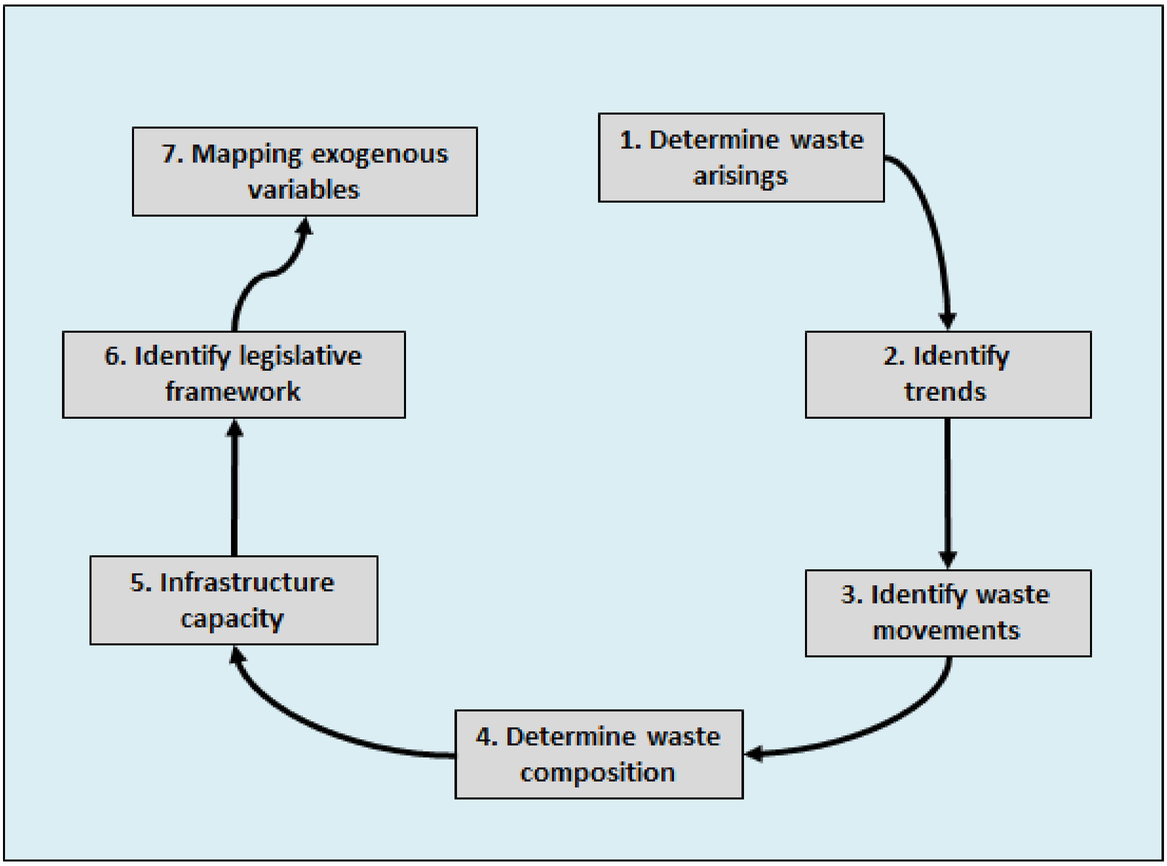


Figure 4.1: Schematic of the baseline analysis methodology

The section will explore the physical characteristics of the waste management system within the study area. The main emphasis will be analysis of controlled waste arisings;

other significant sources of waste; waste movements; management systems and regulatory requirements with a final assessment of policy targets and any potential capacity gap identified. This section analyses the operational context and briefly outlines the main exogenous variables impacting the waste system within the study area in 2012.

4.1 Waste arisings and historic trends

4.1.1 Local Authority Collected Waste (LACW)

Reported LACW arisings for Northamptonshire in 2012 totalled 339kt (DEFRA, 2013a) of which household waste accounted for 93.5% (see Figure 4.2). Total LACW in 2012/13 represents a reduction of 13.5% from the 2006/07 peak of 393kt while the percentage share of household waste has increased from 89.2%.

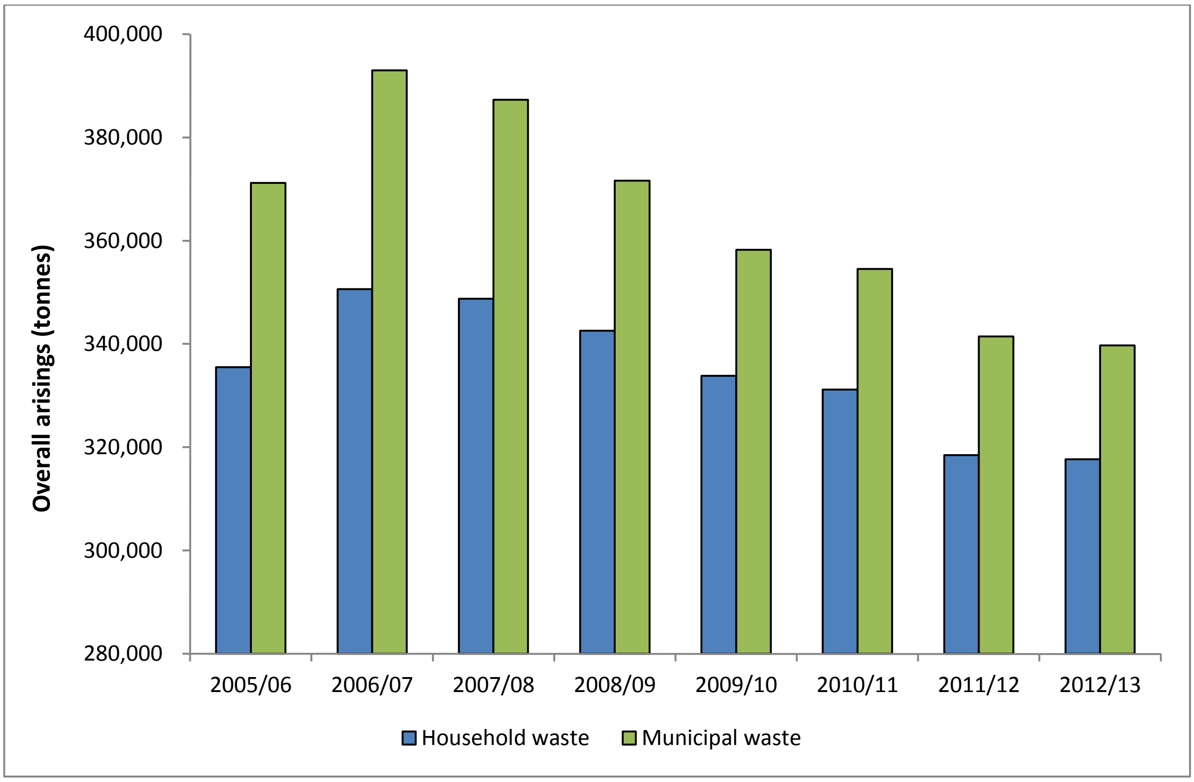


Figure 4.2: Changes in LACW (household and municipal waste) arisings in Northamptonshire between 2005/06 and 2012/13 (Source: DEFRA, 2013a).

It can be seen in Figure 4.2 that LACW arisngs (e.g. municipal and household waste) have been declining since 2006/07. The data also shows an erratic pattern between 2009/10 and 2012/13 with decreases fluctuating significantly. This change is illustrated in Figure 4.3.

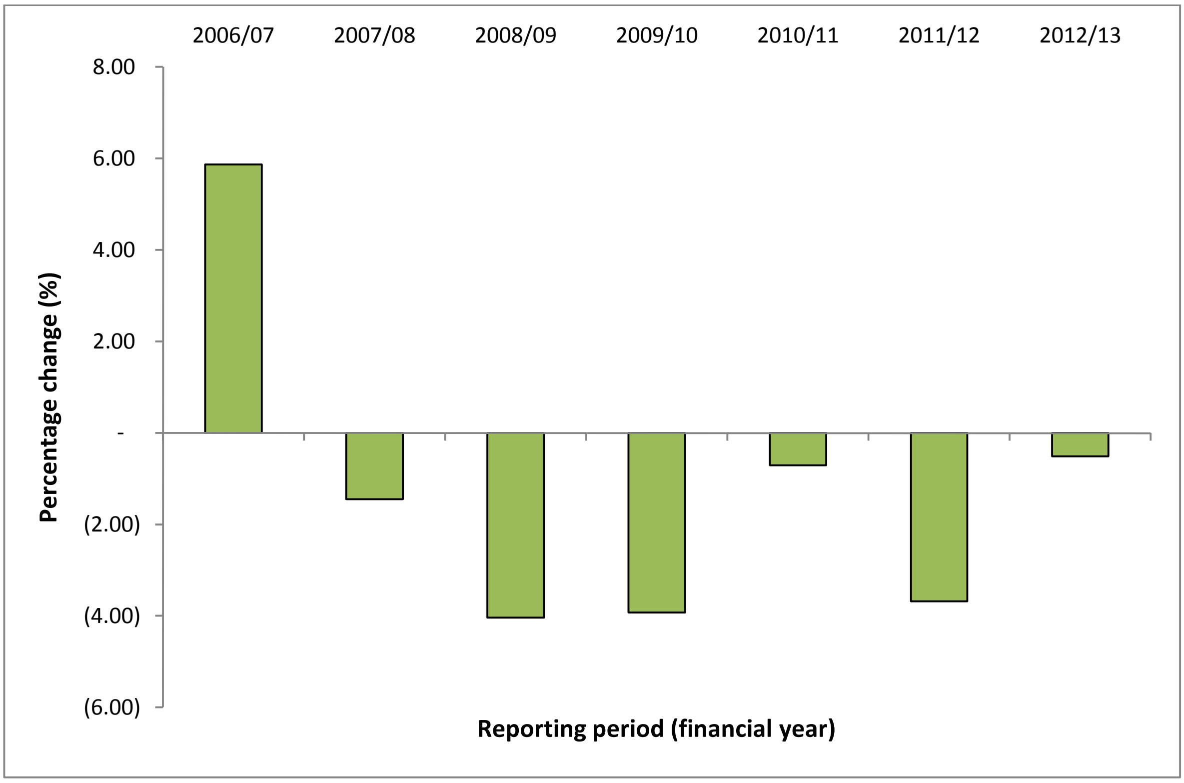


Figure 4.3: Annual percentage change in total municipal waste for Northamptonshire between 2006/07 and 2012/13 (Source: DEFRA, 2013a).

Although the pattern of reductions has been erratic throughout the period 2006/07 to 2012/13 it can be noted from Figure 4.3 that the pattern remains consistently within the negative percentage range and thus represents a sustained period, over 6 years, of reduction in LACW arisings since 2007/08. The mean value for year-on-year reductions across all 7 reported years is -1.21%, with a mean value of -2.39% over the 6 years reporting a reduction (2007/08 to 2012/13). The reducing trend has not been taken forwards in recent considerations within the WPAs (Northamptonshire County Council) local development plan (LDP) documentation. This omission of the recent trend is a weakness of forecasting approaches within England (DEFRA, 2013b) and is addressed through this research by means of scenario planning approaches based on a transforming backcasting approach (Borjesson et al. 2006).

4.1.2 Commercial and Industrial waste (C&I)

Waste returns data are reported under the waste interrogator database held nationally by the waste regulator, the Environment Agency (EA). This data source reports C&I waste by Substance Oriented Classification (SOC) and European Waste Catalogue (EWC) chapter classifications. In terms of granularity, the ECW classification allows more detailed analysis of the data and is utilised here. Calculations for C&I waste in Table 4.1 are based on summing 'Internal' movements (between study area facilities) of waste with 'Exported' wastes before deducting 'Imported' wastes to give an indicative figure for 'generated' C&I wastes.

Table 4.1: Waste returns data (tonnes) for C&I sources (EWC categories 2-16 and 19) in Northamptonshire between 2008 and 2012

Movement	2008	2009	2010	2011	2012
Internal	599,160	579,525	451,882	433,099	448,556
Exported	597,771	587,709	517,623	638,486	678,612
Imported	178,871	107,903	241,690	186,928	172,312
Generated C&I	1,018,060	1,059,331	727,814	884,657	954,856

Source: (EA, 2012a; EA, 2013a).

Table 4.1 shows historic C&I returns data for the EWC categories 2 to 16 and 19 as these capture the main areas of C&I generation as previously described. Waste returns data (Table 4.1) show an overall reduction in C&I waste generation between 2008 and 2012 of around 64kt (5.1%). However, the overall levels show a complicated situation as generated waste reduced significantly, by 28.5%, in 2010. After this low, returns data shows generated C&I waste has increased to just lower than 2008 levels. Movement of C&I waste within the WPA (internal) has declined by almost 151kt whereas exported C&I waste has increased by more than 181kt overall. Imports of C&I waste have fluctuated throughout the period 2008-12 with the 2012 level being around 3.5% below that of 2008.

Given the lack of data reporting at national scale for C&I waste and almost no detailed reporting at the sub-regional scale, the baseline can only be an estimate for C&I wastes. To test the waste returns data other reporting sources are utilised, namely: Jacobs (DEFRA, 2010) 'Survey of Commercial and Industrial waste' undertaken for DEFRA; and NCC reporting under the MWDF Partial Review (NCC, 2012).

Table 4.2: National survey of C&I waste arisings (tonnes) reported by sector for East Midlands and Northamptonshire for 2009

Business sector	East Midlands	Northamptonshire
Food, drink & tobacco	758,649	122,142
Textiles / wood / paper / publishing	503,633	81,085
Power & utilities	1,602,171	257,950
Chemicals / non-metallic minerals manufacture	493,479	79,450
Metal manufacturing	485,311	78,135
Machinery & equipment (other manufacture)	174,879	28,156
Retail & wholesale	699,724	112,656
Hotels & catering	190,363	30,648
Public administration & social work	251,110	40,429
Education	103,175	16,611
Transport & storage	202,210	32,556
Other services	843,497	135,803
Total	6,308,199	1,015,620
C&I share according to RSS (EMRA, 2006)	-	16.1%

Source: (after DEFRA, 2010; EMRA, 2006)

Table 4.2 shows the overall estimated tonnage for Northamptonshire, based on the Regional Spatial Strategy (RSS) apportionment method (EMRA, 2006), totalling 1.02Mt in 2009 (based on 2008/09 data). This total represents a 0.34% variance on 2008 returns data and a 4.13% variation on the waste returns data for 2009 shown in Table 4.1. Thus, C&I waste returns total for 2012 of 0.95Mt is taken forwards as the baseline figure for modelling as opposed to the quoted figure in the MWDF partial review (NCC, 2012) of

1.06Mt which is based on the ADAS model (ADAS, 2009) used by many Local Authorities in England to estimate and model C&I waste arisings.

The rationale for this choice of baseline relates to waste returns data for 2012 (Table 4.1) reflecting the impact of the economic downturn in England since late 2008. The ADAS model and Jacob's survey do not allow for such impacts on C&I waste as these were developed and compiled prior to the economic downturn.

4.1.3 Construction and Demolition waste

A number of factors require consideration in determining C&D arisings at the WPA scale. These include: waste returns data; exemptions data; planning documentation based on earlier regional apportionment; and disaggregating national scale studies. In order to disaggregate the national scale data to the study area level it was necessary to first ascribe a value to the East Midlands region, which was estimated at 10% of the total C&D waste for England within the RSS (EMRA, 2006). This figure was further reduced according to the apportionment allocated within the RSS for Northamptonshire, some 17% of the East Midlands total (EMRA, 2006).

Table 4.3: Estimated C&D tonnages (kt) and recovery rates (%) reported for England, East Midlands and Northamptonshire, 2010

Metric (kt)	Exempt sites	Aggregates estimate	Treatment	Landfill	Estimated Total
England	8,150	42,184	7,203	19,839	77,375
East Midlands (10% of England)	815	4,218	720	1,984	7,738
Northamptonshire (17% of EM)	139	717	122	337	1,315
Recovery/disposal rates (%)	10.53	54.52	9.31	25.64	74.36

Source: (after Gov.uk, 2013; EMRA, 2006).

The figure for estimated C&D arisings in Northamptonshire, 1.3Mt, shown in Table 4.3 is consistent with levels reported by the WPA, 1.31Mt (NCC, 2012). The data in Table 4.4 was generated by using Equation 4.1 for each reporting year:

Equation 4.1:

$$T = 2.86\left[\sum[A+B] - \sum[C+D]\right]$$

Where: $x = \frac{100}{100-(y+z)} = 2.86$ and: $T = 2.86x$

This similarity in the estimated data may be due to the WPA adopting the AEA estimation methodology (Gov.uk, 2013) in order to bring the review up to date (based on 2010 estimations as the construction sector has been subdued between 2008 and 2012). In order to further test this similarity the estimation data and waste returns data were synthesised to test any difference between the data for 2010 and the potential level in 2012. The synthesis of the estimation data (Gov.uk, 2013) is shown in Table 4.4.

Table 4.4: Waste returns data for EWC 01 and 17 (2008-2012) synthesised with estimation methodology giving estimated baseline (tonnes) for Northamptonshire

Reporting stage	2008	2009	2010	2011	2012
Internal (A)	646,076	480,672	553,930	572,427	576,853
Removed (B)	129,522	175,442	183,455	198,422	190,080
Imported (C)	188,628	171,057	185,040	201,488	271,314
Not coded (D)	115,485	56,389	94,761	99,218	28,012
At facilities (x)	471,484	428,668	457,584	470,144	467,607
Exempt estimate (y)	187,001	165,000	139,001	95,000	117,803
Aggregate estimate (z)	735,488	668,697	713,805	733,397	729,440
Estimated totals (T)	1,393,973	1,262,365	1,310,390	1,298,541	1,314,850

Sources: (after EA, 2008; 2009; 2010; 2011; 2012a; Gov.uk, 2013).

Given the significant lack of data for C&D waste at all scales, estimations are used in Table 4.4 so as to determine the accuracy of disaggregating national estimates with RSS apportionment figures (Table 4.3). As can be seen the estimated total for 2012 is almost equal to that gained using the disaggregation method (1.31Mt). However, the trend between 2008 and 2012 is somewhat erratic with a significant decline from 2008 to 2010 (9.44%) followed by an increase between 2009 and 2010 (3.80%). The estimated totals for

2010 to 2012 remain relatively constant despite significant changes in C&D wastes managed internally (23kt); being imported (86kt); and recorded as 'non-coded' (71kt). As a consequence of the consistency within the methods used, the figure of 1.31Mt will be taken forwards for modelling C&D wastes within Northamptonshire, but with a caveat around the inadequate nature of the available data.

4.1.4 Hazardous waste

Hazardous waste production is typically linked most closely with industrial business activities and displays similar generation drivers. According to waste returns data for 2012, facilities in Northamptonshire managed around 122kt of hazardous waste (with transfer).

Table 4.5: Summary of hazardous waste (tonnes) managed at facilities in Northamptonshire (2012)

EWC Code	Incineration with energy recovery	Incineration without energy recovery	Landfill	Recovery	Rejected	Treatment	Totals	Transfer (D)	Transfer (R)
02	-	2	-	-	-	-	2	1	0
03	-	-	-	-	-	-	-	1	-
04	-	-	-	-	-	-	-	1	-
05	-	-	-	24	-	1	26	-	-
06	-	-	-	1	-	1,340	1,341	55	7
07	-	10	-	21	-	5	35	77	608
08	-	1	-	209	-	45	255	165	426
09	-	-	-	68	-	8	76	20	12
10	-	148	-	35	-	128	311	10	-
11	-	-	17	88	-	664	769	150	153
12	2	233	1	5,630	-	22	5,888	4	1,923
13	5	0	-	7,214	10	1,085	8,314	300	2,756
14	6	-	-	54	-	10	70	51	181
15	-	3	-	44	1	74	123	378	695
16	0	226	92	8,688	8	397	9,411	3,120	5,109
17	-	3	2,422	-	-	986	3,411	185	151
18	6	1,335	-	5	-	171	1,518	342	2
19	-	274	57,320	2,467	-	1,687	61,748	1	109
20	-	-	-	946	-	0	947	120	1,514
Total	19	2,235	59,852	25,494	18	6,625	94,243	4,981	13,648

Source: (EA, 2012b).

Table 4.5 provides a summary of all hazardous wastes by management method and EWC Chapter code. Landfill handles the largest percentage flow of hazardous materials (61.9%) when considered as a final destination. Recovery is the management method with the next largest flow (28.9%) with smaller flows going to treatment operations and incineration. In Northamptonshire, some 73.3% of hazardous materials passing through transfer operations were further sent for recovery as opposed to disposal.

4.1.5 Other wastes

A number of other sources of waste arisings require mentioning as part of the wider dynamic system of waste management. These include agricultural waste; sludges from waste water treatment operations; and radioactive wastes (specifically low level waste – LLW). The study area has significant farming activity creating large amounts of slurries and compostable materials. In addition, there are around 100 sites which process waste water, including 6 large scale sites. In terms of radioactive wastes, the study area has a nationally significant facility which manages small quantities of very low and low level wastes (VLLW and LLW) (NCC, 2012).

4.2 Material flows within the study area

Significant quantities of materials pass between WPAs in England and the movement of waste is considerable at the district level where materials have to be shipped to facilities with the capacity to manage that material fraction (e.g. metallic wastes to Metal Recycling Sites). Certain WPAs are thus net importers or net exporters of waste.

4.2.1 Waste movements to Northamptonshire

At the time of writing, the waste data interrogator (WDI) and hazardous waste data interrogator (HWDI) were accessible for the reporting year of 2012. This provided a baseline year for data analysis; providing a snapshot of waste received by facilities in Northamptonshire.

Table 4.6 shows Northamptonshire received 0.77Mt of controlled waste imports (excluding hazardous wastes) to facilities in 2012. East Northamptonshire received the largest share (27.1%) followed by South Northamptonshire (20.3%) and Northampton (15.0%). The district of Northampton managed the largest percentage share of materials overall (24.5%), with the majority of these materials originating within the WPA. In spite of imports, South Northamptonshire facilities received the smallest share of all wastes (10.5%).

Table 4.6: Waste imports (tonnes) to Northamptonshire districts by overall quantity and origin, 2012

District	Total waste received at facilities (tonnes)	Received from WPA Districts (tonnes)	Imports to facilities (tonnes)
Corby	269,199	172,210	96,990
Daventry	323,900	244,649	79,251
East Northamptonshire	416,866	209,318	207,548
Kettering	260,115	225,521	34,593
Northampton	487,635	373,060	114,575
South Northamptonshire	249,844	94,709	155,136
Wellingborough	373,675	296,593	77,082
Northamptonshire	2,381,234	1,616,060	765,174

Source: (EA, 2012a)

Table 4.7: Hazardous waste imports (tonnes) to districts and by destination facility type, 2012

Deposit District	Landfill	Recovery	Transfer (D)	Transfer (R)	Treatment
Corby	-	-	-	273	-
Daventry	-	32	291	4,218	-
East Northamptonshire	27,443	4	20,139	45,059	32,351
Kettering	-	-	-	32.81	-
Northampton	-	330	151	10,249	-
South Northamptonshire	-	-	15	-	-
Wellingborough	-	7,797	-	42	-
Northamptonshire	27,443	8,163	20,596	59,874	32,351

Source (EA, 2012b).

Similar to other imported wastes, Table 4.7 shows East Northamptonshire facilities as the primary recipients of hazardous wastes in 2012 with small quantities received by facilities in the districts of Northampton, Wellingborough and Daventry. This outcome may be anticipated given the specialist nature of any operations and the location of the Augean multi-permitted hazardous waste facility at King's Cliffe in East Northamptonshire.

4.2.2 Waste movements from Northamptonshire

The returns data showed that a significant amount of waste moved outside the boundaries of Northamptonshire. The WPA is thus obliged under the NPPF (DCLG 2012) with a Duty-to-Cooperate with all other WPAs it sends waste to (and vice versa). The ability of the current permitting and reporting systems to deliver on these planning obligations forms part of this assessment and is explored further in section 4.3.4.

Table 4.8: Waste exports (tonnes) by district and end fate, 2012

Exporting district	Recovery	Incinerator	Landfill	Transfer	Unknown	Treatment	Totals
Corby	119,801	16,776	63	5,639	-	-	142,279
Daventry	70,249	90	7,703	3,577	10,293	3,686	95,599
East Northamptonshire	20,874	1,302	13,575	8,244	2,684	5,641	52,321
Kettering	12,934	1	1	342	-	3,063	16,341
Northampton	68,533	717	12,115	-	27,945	854	110,163
South Northamptonshire	21,127	-	2,540	841	4	-	24,512
Wellingborough	19,876	2,196	3,416	8,773	1,211	-	35,473
Northamptonshire	333,395	21,082	39,413	27,417	42,138	13,244	476,689

Source: (EA, 2012a)

Table 4.8 shows recovery to be the largest end fate category for waste exports from Northamptonshire (333kt). The LAs of Corby and Northampton export the largest quantities of materials overall with 142 and 110kt respectively in 2012. This may reflect the limited availability of land for large scale facilities in these more urban locations.

Facilities located in the districts of Kettering and South Northamptonshire exported the least in 2012.

Table 4.9 shows landfill to be the main destination for hazardous waste exports, with East Northamptonshire being the district accounting for the largest material flows to destinations outside the county. Recovery is the second largest end fate category accounting for nearly 28kt.

Table 4.9: Hazardous waste exports (tonnes) by district and end fate, 2012

Arising district	Incineration with energy recovery	Incineration without energy recovery	Landfill	Recovery	Treatment
Corby	0	411	160	1,318	304
Daventry	0	44	358	10,785	2,526
East Northamptonshire	0	22	57,932	2,644	873
Kettering	4	523	291	661	90
Northampton	7	1,035	430	10,439	1,258
South Northamptonshire	2	170	233	670	249
Wellingborough	5	29	448	1,390	1,326
Northamptonshire	19	2,235	59,852	27,907	6,625

Source (EA, 2012b).

4.2.3 Internal movements of waste

It was identified from the returns data that movements of waste between districts were commonplace at the time of the study. This is attributable to the different types of facility which operate in each of the districts and boroughs as well as the concentration of many facility types around urban centres, as these sites are likely to benefit from reduced transport costs and access to the largest possible source of materials for their operational needs. Table 4.10 shows that 0.62Mt (or 56.5%) of all waste removed from facilities were managed at other facility types within the WPA. This quantity of material is significant when consideration is given to the overall amount of waste generated in the county in 2012 (2.73Mt), indicating that 22.7% of all wastes require further management (e.g. after bulking at waste transfer stations). A substantial quantity of this material is likely to be from the LACW stream given the nature of the collection systems within Northamptonshire and more generally in England.

Table 4.10: Waste movements (tonnes) from WPA facilities and end fate, 2012

Fate	Waste removed from facilities and WPA	Waste removed but remained in WPA	Waste removed from facilities
Recovery	333,395	329,546	662,942
Incinerator	21,082	10,400	31,482
Landfill	39,413	177,559	216,971
Transfer	27,417	36,323	63,740
Treatment	13,244	28,653	41,898
Unknown	42,138	37,349	79,487
Totals	476,689	619,830	1,096,519

Source: (EA, 2012a).

4.3 Composition of waste arisings

Determining the composition of waste streams is an essential step in understanding the potential gap in capacity which may exist within the study area waste system. Figure 4.4 shows the results of the compositional analyses undertaken for Northamptonshire to provide a baseline figure for 2012. Supporting calculations and detailed breakdown of fractions are contained in Appendix 1.

Figure 4.4 shows the combined results for controlled wastes in Northamptonshire in terms of 14 indicator categories. A number of key features require explanation. Firstly, the categories concrete, inert and plasterboard are solely defined as originating from C&D sources. This is a distortion of the results as small amounts of these wastes arise within the LACW stream. Similarly, glass arises from the C&D stream but is defined as originating from LACW and C&I sources only. However, such issues arise as a result of reporting under waste returns as well as some studies assigning codes (either EWC or SOC) which are then collated according to these categories and not according to the source per se.

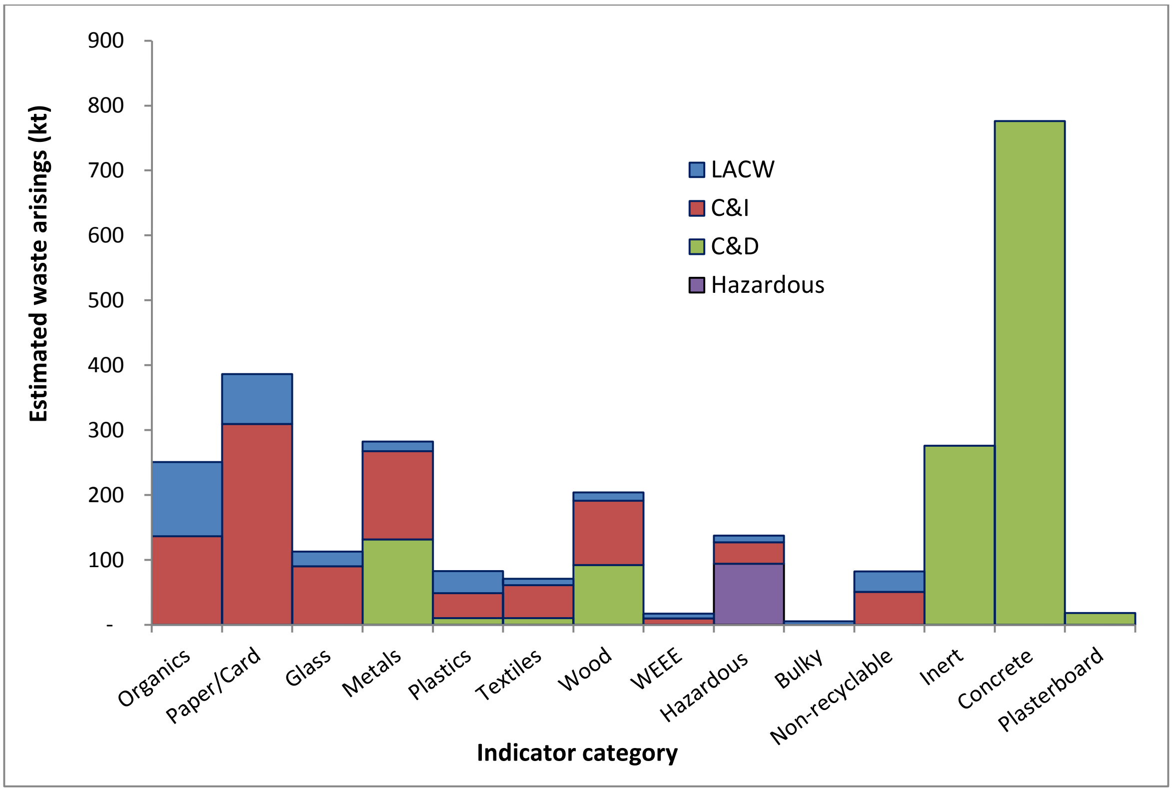


Figure 4.4: Estimated composition and tonnages (kt) of all controlled waste by indicator category for Northamptonshire (2012) (Sources: EA, 2012a; 2012b; Head et al. 2013).

Secondly, the five key materials (from an LACW perspective) of organics (251kt), paper/card (386kt), glass (113kt), metals (282kt) and plastics (83kt) are the most significant fractions after concrete. In addition, inert and wood categories contain significant tonnages from the C&D controlled waste stream within Northamptonshire (276kt and 92kt respectively). Finally, hazardous waste from all sources (136kt) is relatively high compared to what may be expected for the county and is likely to reflect the level of imported hazardous materials being treated in the county.

4.3.1 Analysis of controlled waste composition

In order to determine potential need in terms of infrastructure provision within the study area, it is necessary to analyse the composition of waste streams and compare these with targets and types of facility capable of managing each category of waste. Table 4.11 shows total baseline tonnages across all controlled wastes of 2.70Mt for Northamptonshire in 2012. These estimations are based on various sources from the waste planning literature and waste returns data where gaps have been identified. In terms of composition by indicator category, a number of indicators are very significant across controlled waste streams in Northamptonshire.

Table 4.11: Summary of tonnages by controlled waste stream and overall indicator category for Northamptonshire (2012)

(tonnes)	Controlled waste streams				
Indicator category	LACW	C&I	C&D	Hazardous	Sub-totals
Organics	114,318	136,639	-	-	250,957
Paper/Card	77,084	309,453	-	-	386,537
Glass	22,558	90,533	-	-	113,091
Metals	14,608	136,207	131,538	-	282,353
Plastics	33,939	38,603	10,523	-	83,065
Textiles	9,614	50,866	10,523	-	71,004
Wood	12,672	99,156	92,077	-	203,904
WEEE	7,440	9,789	-	-	17,229
Hazardous	10,328	32,889	-	94,243	137,460
Bulky	5,402	-	-	-	5,402
Non-recyclable	31,764	50,723	-	-	82,488
Inert	-	-	276,230	-	276,230
Concrete	-	-	776,076	-	776,076
Plasterboard	-	-	18,415	-	18,415
Baseline tonnages	339,727	954,859	1,315,382	94,243	2,704,212

Sources: (EA, 2012a; 2012b; after DEFRA, 2009; after DEFRA, 2010; BRE, 2009; WRAP, 2010; after Gov.uk, 2013).

Concrete is the largest category by tonnage being the only category in excess of 500kt. Paper and Card; Metals; Inert; and Organics are next most significant categories totalling between 250 and 500kt. Other significant categories include: hazardous; glass; plastics; textiles; and non-recyclables with much smaller quantities of plasterboard; waste electric and electronic equipment (WEEE) and bulky wastes.

4.3.2 Analysis of capacity versus targets

A range of sources have been utilised to determine recycling and recovery rates for each controlled waste stream by the first milestone year of 2020. Box 2.1 gave a detailed description of these targets (see Section 2.1.3).

Comparing waste streams in Table 4.11 shows a similar quantity of organic wastes arisings from LACW and C&I streams suggesting a potential need for between 160 and 250kt of organics recovery capacity (65% to 100% recovery rates) will be needed to meet 2020 targets. Paper/card; glass; plastics; and wood are typically managed via physical treatment routes (e.g. material recycling facilities - MRFs) which means recycling capacity will be needed of between 390 and 500kt (50% minimum recycling and between 67% and 75% recovery). In addition, textiles; WEEE and bulky wastes may be separable by such operations. However, textiles and bulky waste are currently separated either at kerbside or at civic amenity (CA) and transfer sites for reuse. WEEE is increasingly segregated from other metallic wastes (driven by value) and is thus likely to see a greater tonnage managed via specialist WEEE treatment facilities (see Section 4.4.2.1). Recycling and recovery rates for metallic wastes have historically been higher than other waste fractions.

Table 4.12: Baseline recycling, recovery and disposal rates (%) and quantities (tonnes) for controlled waste streams in Northamptonshire

	LACW	C&I	C&D	Hazardous	Sub-total
Recycling	155,554	547,317	839,609	17,435	1,559,914
Rate (%)	*45.79*	*57.32*	*63.83*	*18.50*	*57.68*
Recovery	19,738	65,694	138,510	23,892	247,834
Rate (%)	*5.81*	*6.88*	*10.53*	*25.35*	*9.16*
Disposal	164,435	341,847	337,264	52,916	896,448
Rate (%)	*48.40*	*35.80*	*25.64*	*56.15*	*33.15*
Totals	339,727	954,859	1,315,382	94,243	2,704,197

Sources: (DEFRA, 2013a; EA, 2012a; 2012b; after Gov.uk, 2013).

According to the composition across waste streams in Table 4.11 a capacity of between 140 and 210kt would be required to meet targets for metallic wastes recycling and recovery. A minimum capacity of between 530 and 720kt would be required to meet targets for inert; concrete and plasterboard (50% recycling as aggregates and 70% overall recovery). These estimates give a combined recycling requirement of 1.22Mt and an additional recovery capacity of 500kt.

Comparison between the estimated requirement and performance at the time of the study shows an overall surplus in recycling capacity by 2020 of 340kt. In contrast, a deficit of 250kt recovery capacity would be experienced if performance levels remained the same between the baseline and 2020. In reality, the surplus capacity within recycling is likely to be utilised for materials which would be destined for recovery routes (particularly for inert materials depending on local demand). Section 4.4 will evaluate the capacity in terms of individual facility types and material fractions.

4.4 Infrastructure provision within the study area

The number of operational waste management facilities within Northamptonshire in 2012 was 101. These facilities had an overall throughput of 2.38Mt and an overall permitted capacity of 6.67Mt. The operational types can be further reduced to specific management methods in the form of treatment type; transfer facilities; recovery operations and final disposal (landfill only for Northamptonshire). In addition to these large scale facilities all district councils (with the exception of Daventry) operate 360 individual bring sites which collected over 4,500 tonnes of up to 20 different material types for recycling. Appendix 2 gives a detailed analysis of infrastructure provision within the case study area.

Table 4.13: Summary of licensed infrastructure provision in Northamptonshire (2012)

Management method	Number of facility types	Number of facilities	Throughput (tonnes)	Permitted capacity (tonnes)
Treatment	15	48	595,421	1,900,000
Transfer	5	36	643,931	1,827,665
Recovery	4	5	117,759	n/a
Landfill	4	12	1,024,250	3,270,000
Totals	28	101	2,381,361	6,997,665

Source: (after EA, 2010; EA, 2012a; 2012b).

Overall waste management capacity for Northamptonshire in 2012 (Table 4.13) was permitted at 7.00Mt with an overall throughput to the 101 operational facilities totalling 2.38Mt. Transfer capacity is excluded in determining overall recycling, recovery and disposal rates for all controlled wastes. This consideration means a total of 1.74Mt were managed by these three methods. Based on throughput, the recycling rate for all wastes in 2012 was 34.3% with a further 6.78% of controlled waste (mainly inert) recovered separately. This gives a combined recycling and recovery rate of 41.1% with disposal via landfill accounting for the remaining 58.9% of controlled wastes.

4.5 Capacity gap analysis

This section briefly examines the potential capacity gap between available capacity, recycling & recovery rates and targets applicable to Northamptonshire. The section will look to 2020 and 2030 as these two milestones are mentioned within the stipulations of the Landfill Directive (99/31/EEC) and local planning documents (NCC, 2012) as well as forming two of the critical scenario milestones (see Section 5.4).

4.5.1 Meeting medium-term targets

Targets have been set by the WPA which addresses both national and EU obligations. These targets can therefore be used to analyse the ability of current recycling and recovery capacity to meet future obligations. Levels of waste arisings have been kept constant within Figure 4.5(a-d) for comparative purposes. In terms of recycling targets Figures 4.5a-c show that in 2012 the levels of recycling for LACW; C&I and C&D all exceed those for 2010 set out within the MWDF for Northamptonshire (NCC, 2012). Hazardous waste does not have a fixed target within the local plan but has been assigned a value (see Figure 4.5d) in line with C&I waste for modelling purposes[8]. In terms of recovery performance and targets for 2012, Figures 4.5c and 4.5d show only C&D[9] and hazardous waste exceed the 2010 targets.

[8] According to waste returns data hazardous waste primarily originates from industrial processes (EA, 2012b). Thus modelling this waste stream has been aligned with C&I waste in this research.

[9] C&D waste is shown as recycling only but this merely reflects the link between estimations methodologies previously used for aggregates and exempt sites

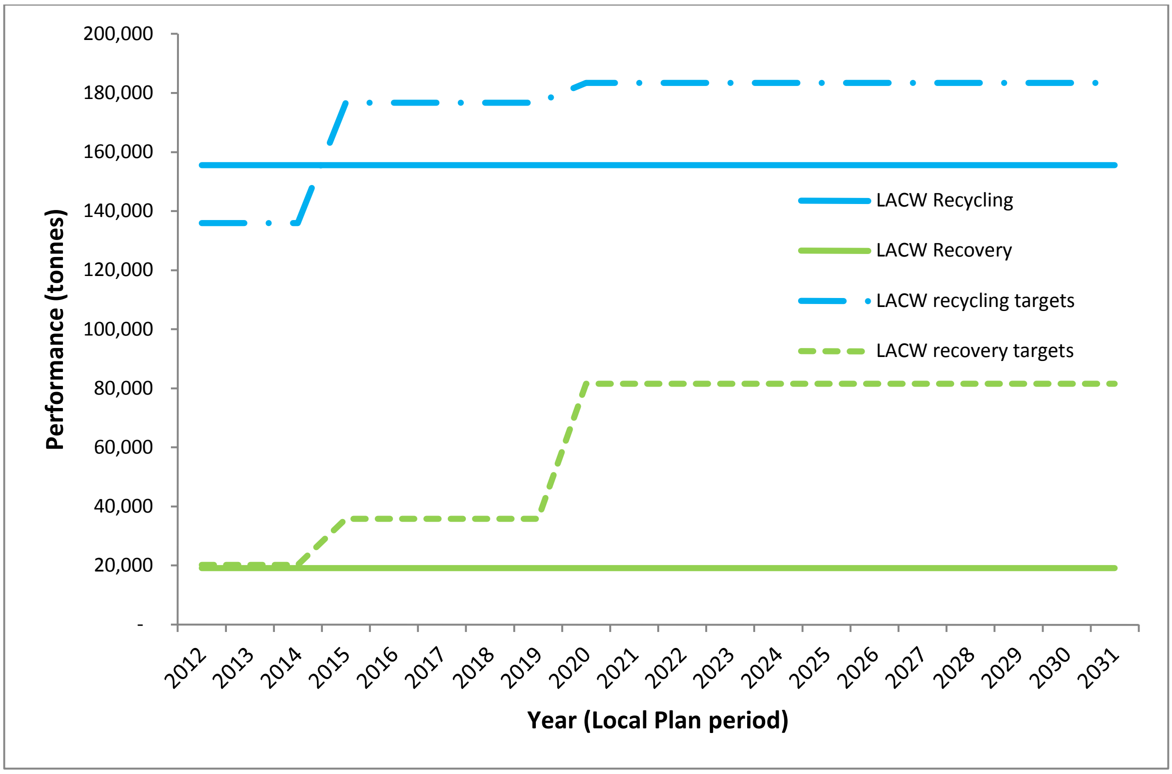


Figure 4.5a: Comparison of LACW recycling and recovery performance versus targets

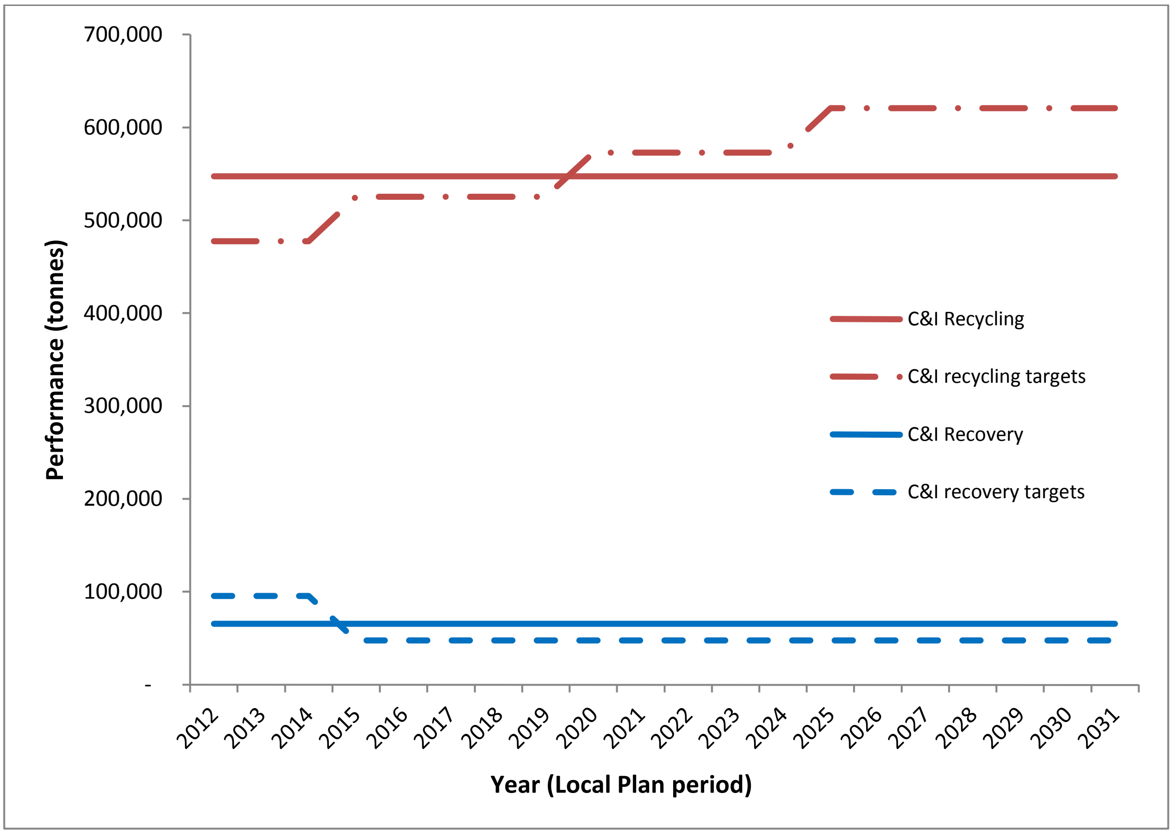


Figure 4.5b: Comparison of C&I recycling and recovery performance versus targets

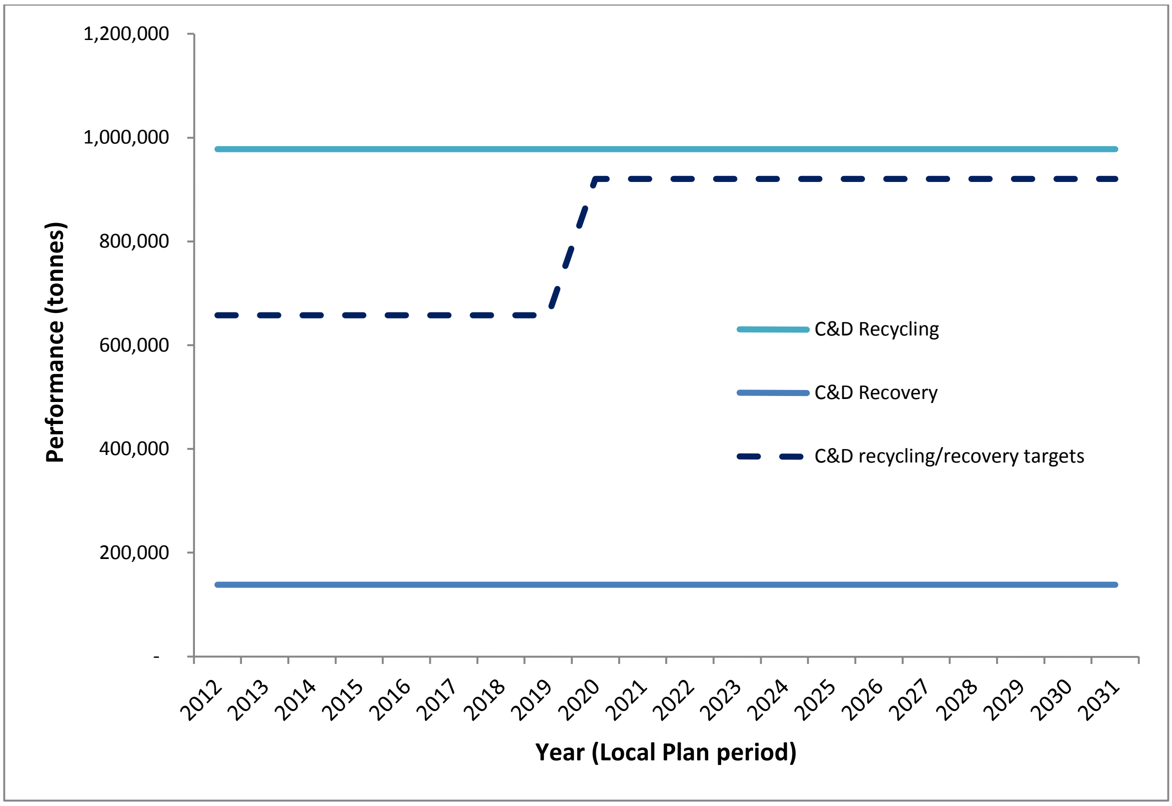


Figure 4.5c: Comparison of C&D recycling and recovery performance versus targets[10]

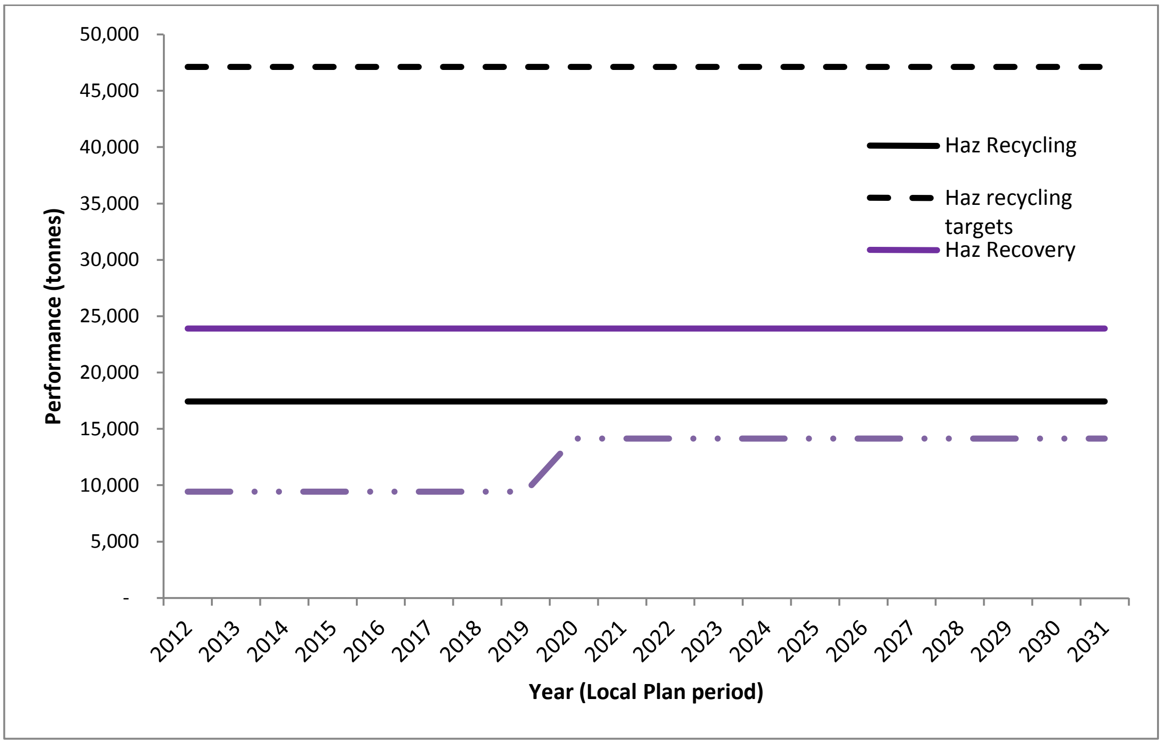


Figure 4.5d: Comparison of hazardous recycling and recovery performance versus targets

[10] C&D recycling and recovery performance is shown 'stacked' in order to make a visual comparison with the C&D recycling/recovery target

In terms of any potential capacity gap based on 2012 levels of waste generation and targets set out in the WPAs local plan, it can be seen from Figures 4.6a that LACW is the most likely to miss targets from 2015 onwards for both recycling and recovery. For C&I waste the outlook is similar for recycling which moves into deficit from 2020 (Figure 4.6b). In contrast C&I recovery levels are in deficit from 2012 to 2015 but then move into excess capacity from 2015 onwards. Lower proportional targets for recovery from 2015 onwards account for this anomaly.

No specific recycling targets stand within national legislation or at a local level for C&D wastes. A high target of 70% C&D waste recovery is set at both scales. Figure 4.6c shows combined levels of recovery and recycling will be sufficient to avoid any potential capacity gap throughout the plan period. However, given data limitations and the fluctuations in waste generation levels from the C&D sector associated with economic conditions suggests current capacity would not be sufficient if waste generation increased or if existing capacity ceased operations. No target is set for hazardous waste reduction; rather a commitment is made to reduce the toxicity of wastes originating from all sectors (DEFRA, 2013a). Figure 4.6d is provided for modelling purposes based on recycling and recovery levels for C&I waste. This indicates levels of recycling need to increase throughout the period. However, given the specialist nature of the management methods required and the health implications of hazardous materials specialist landfill and incineration are likely to remain the main method of managing hazardous wastes across the local plan period.

4.6 Legislative framework for waste in Northamptonshire

This section briefly outlines the key legislative framework applicable to Northamptonshire in terms of planning for sustainable waste management. It will outline the waste planning policy framework for the European; National and Local levels.

4.6.1 European planning context

The Waste Framework Directive (2008/98/EC) sets out the concepts of the waste hierarchy (see Section 2.2); proximity principle and self-sufficiency. It goes on to stipulate general targets to be achieved nationally for specific controlled waste streams. This is supported by the Landfill Directive (99/31/EEC) which sets targets for the reduction and diversion of biodegradable municipal waste from landfill.

Key targets applicable to Northamptonshire are: 50% recycling of municipal waste by 2020 (WFD); 70% recovery of C&D waste by 2020 (WFD) and to reduce biodegradable municipal waste to landfill by 65% (relative to 1995 levels) (LFD).

4.6.2 National planning context

The Waste Management Plan for England (WMPE) (DEFRA, 2013a) restates the government position on waste from the previous waste strategy (DEFRA, 2007a) and with regard to the Review of Waste Policy (DEFRA, 2011a). In terms of planning the WMPE refers to PPS 10 (DCLG, 2013) as current planning policy (DEFRA, 2013a). This PPS10 sets out the planning objective of showing a minimum of ten years equivalent waste management capacity for each WPA. Stated national targets are the recycling of 50% household waste by 2020 (WMPE); 70% recovery of C&D waste (WMPE).

4.6.2.1 Support mechanisms and financial instruments

To support waste infrastructure needs at the national and local levels the Waste Infrastructure Development Programme (WIDP) was introduced in 2006 (DEFRA, 2007a). This programme helps LAs plan for capacity provision and has also provided financial support (previously through PFI and subsequently through Waste Infrastructure Credits – WCIs). Landfill Tax has become the most significant driver of waste diversion and subsequent development of waste infrastructure in England (DEFRA, 2013a).

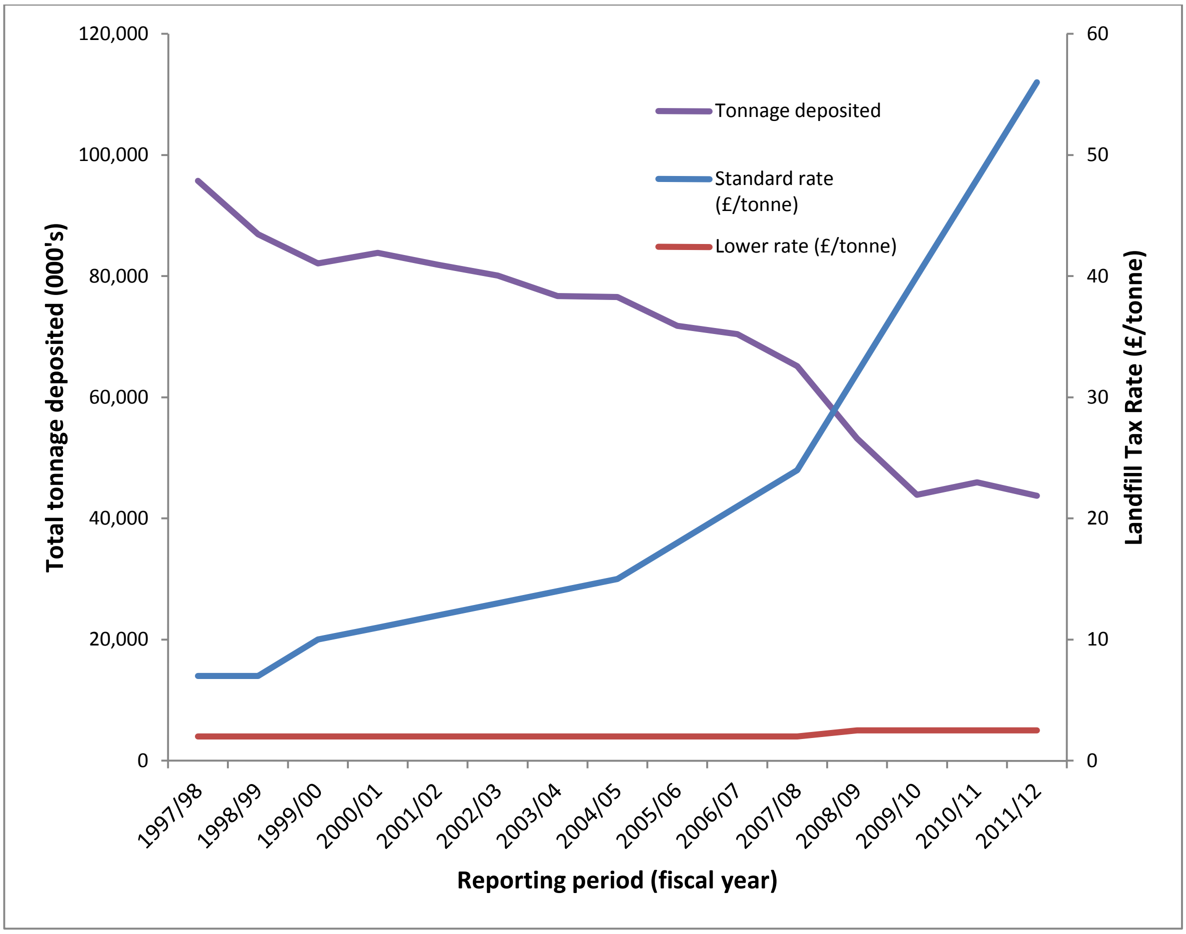


Figure 4.6: Landfill tax returns for England 1997/8 to 2011/12 showing tonnages and rates (Source: HMRC, 2013)

Figure 4.6 shows the consistent downwards trend in waste tonnages being sent to landfill since 1997/8. A total of 43.7Mt were sent to landfill in 2011/12 representing a 54.3% reduction. Of this total some 20.5Mt were deposited at the standard rate[11] with the remainder (23.3Mt) being split almost evenly between the lower rate charging and exempt materials (HMRC, 2013). This drive away from landfill requires alternative management routes for large quantities of materials.

4.6.3 Local planning context

A revised Minerals and Waste Development Framework (MWDF) sets the strategic spatial plan for waste-related development in Northamptonshire. At the time of writing, this

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[11] Standard rate landfill tax is applied to 'active' waste. This comprises heterogeneous wastes from municipal, commercial and some industrial sources

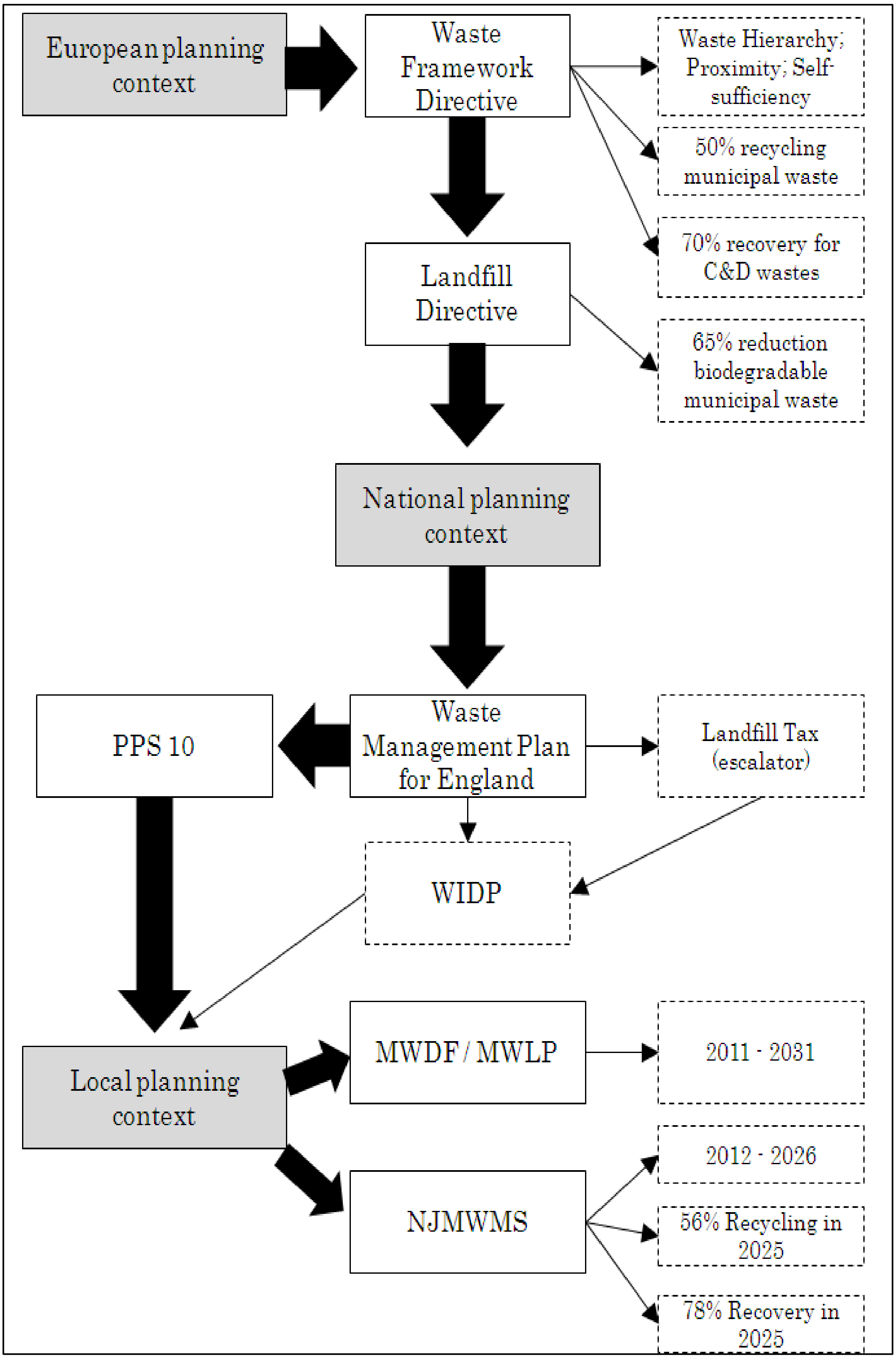

Figure 4.7: Policy hierarchy applicable to waste planning within a WPA in England

document was submitted for review incorporating all Development Plan Document's (DPDs) for the MWDF into a single Minerals and Waste Local Plan (MWLP). Once adopted, this MWLP will supersede the MWDF as part of the planning reform process associated with the NPPF (DCLG, 2012). Until the MWLP is adopted municipal waste in the county will be subject to the stipulations set out within the Northamptonshire Joint Municipal Waste Management Strategy (NJMWMS) (NWP, 2012).This strategic document sets out the vision for municipal waste management to 2025/26 and is thus likely to form a central part of the new MWLP. Figure 4.7 summarises the structure of the policy hierarchy applicable to WPAs.

4.7 Exogenous variables

This section presents results for the key system conditions (exogenous variables) for the baseline year of 2012. Results are based on the Lower Super Output Area[12] (LSOA) census unit for England as used in previous studies (DTZ/SLR, 2009b; ONS, 2012). Mapping the spatial distribution of waste allows analysis of change over time.

4.7.1 Key exogenous variables mapping

A number of key exogenous variables were identified; in consultation with stakeholders and through feedback from the supervisory team; as contributing to waste generation rates within the study area. These factors are presented in Figures 4.9 to 4.12 and cover population density; employment; strategic employment land (SEL); and deprivation.

4.7.1.1 Population density

Northamptonshire contains a total of 422 LSOAs (see Figure 4.8). Mean population per LSOA is 1,640 with a minimum of 995 and a maximum of 3,304. Northamptonshire covers an area of 236,409ha. The mean area of LSOAs is 560ha. The minimum area of an LSOA in Northamptonshire is 13ha, while the maximum LSOA area is 7,632ha. The percentage of LSOAs with an area over 1,000ha is 16.4% while the percentage of LSOAs

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[12] LSOAs are a robust unit of assessment as change between Census taking is limited (prior to the 2011 census the last changes were in 2004) whereas using 'wards' is more subjective given the frequent political boundary changes

with an area of less than 250ha is 74.4%. As LSOAs of this size are found in and around urban areas the urban population of Northamptonshire can be calculated at 498,020 or 72.0%.

4.7.1.2 Areas of employment and growth

There are two key factors which must be addressed in terms of employment, namely: the location of current employment and development; and areas of future growth. Figure 4.9 shows NBC is the most urbanised LA within the study area and contains the majority of business and industrial parks. The LAs of CBC, KBC and WBC contain mixtures of urban and rural land as well as most of the remaining significant business parks.

South Northamptonshire, Daventry and East Northamptonshire LAs are predominantly rural with mainly small scale urban centres and a small number of business park locations. Exemptions include Rushden and Daventry which are larger urban centres with a number of business parks located on their peripheries. In addition, Daventry LA has DIRFT located to the northern boundary which has a significant number of large scale enterprises.

4.7.1.3 Strategic Employment Land

A specific emphasis in terms of SEL is the provision of land parcels capable of supporting B1, B2 and B8[13] as well as 'mixed' land use categories. Analysis of proposed usage for SEL shown in Figure 4.10 indicates a total of 222 land parcels were identified in the 2009 survey (NCC, 2009). The total area of these parcels was 5,863ha with a maximum size of 340ha and a minimum size of 0.12ha. The mean value for such land parcels was thus 29.7ha. Table 4.14 shows the LAs of South Northants and Wellingborough had the largest areas of SEL identified in 2009 (1,477 and 1,413ha respectively). In contrast, Northampton had the smallest amount of available SEL (241ha). However, much of the SEL within

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[13] Codes are defined as: B1 – Office and Light Industry; B2 – General Industry; B8 – Storage and Distribution (see NCC, 2009)

South Northants is situated adjacent to Northampton (see Figure 4.11).

Table 4.14: Statistical summary of SEL by Local Authority for Northamptonshire in 2009

Local Authority	Total SEL (ha)	# of land parcels	Mean (ha)	Min (ha)	Max (ha)
Corby	461	24	19.21	0.75	125.00
Daventry	799	33	24.22	0.50	210.00
East Northants	505	29	17.41	0.20	223.00
Kettering	967	39	24.79	0.15	121.00
Northampton	241	37	6.51	0.12	32.37
South Northants	1,477	43	32.81	0.20	330.00
Wellingborough	1,413	17	83.13	0.64	340.00
Northamptonshire	5,863	222	29.73	0.12	340.00

Source: (after NCC, 2009).

4.7.1.4 Deprivation

Figure 4.11 shows the overall IMD score for LSOAs in Northamptonshire. Overall scores are an aggregation of a number of criterions, including: employment, income, crime, local environment, housing and health (DCLG, 2011). It can be seen in Figure 4.12 that levels of deprivation are higher in the urbanised LSOAs (e.g. Northampton and Corby) while rural locations (e.g. all of South Northamptonshire) tend to have low levels of overall deprivation. In relation to waste, it can be noted that areas of higher deprivation (scoring between 26.84 and 68.41) tend to have lower household recycling rates (Corby – 41.8% and Northampton – 38.3% in 2011/12) compared to more rural locales (Daventry – 48.2% and South Northamptonshire – 49.9%) (NWP, 2012).

Table 4.15: Northamptonshire LAs by highest and lowest 50% IMD rankings in 2010

Percentages (%)	CBC	DDC	ENC	KBC	NBC	SNC	WBC
LSOAs in lowest IMD 50%	81.08	15.56	29.17	35.85	55.04	4.17	51.06
LSOAs in highest IMD 50%	18.92	84.44	70.83	64.15	44.96	95.83	48.94

Source: (after DCLG, 2011[14]).

[14] IMD was calculated for 2010 based on 2004 LSOA classification and covered 407 LSOAs (see DCLG, 2011). In contrast the 2011 census had 422 LSOAs within Northamptonshire.

When considered against other LAs in England, CBC at 81.1% of LSOAs (Table 4.16) is comparable in deprivation to many urbanised LAs such as Merseyside or Greater Manchester (DCLG, 2011). In contrast, South Northamptonshire has 95.8% of its LSOAs in the highest 50% IMD rankings with 35.4% of LSOAs in the highest decile.

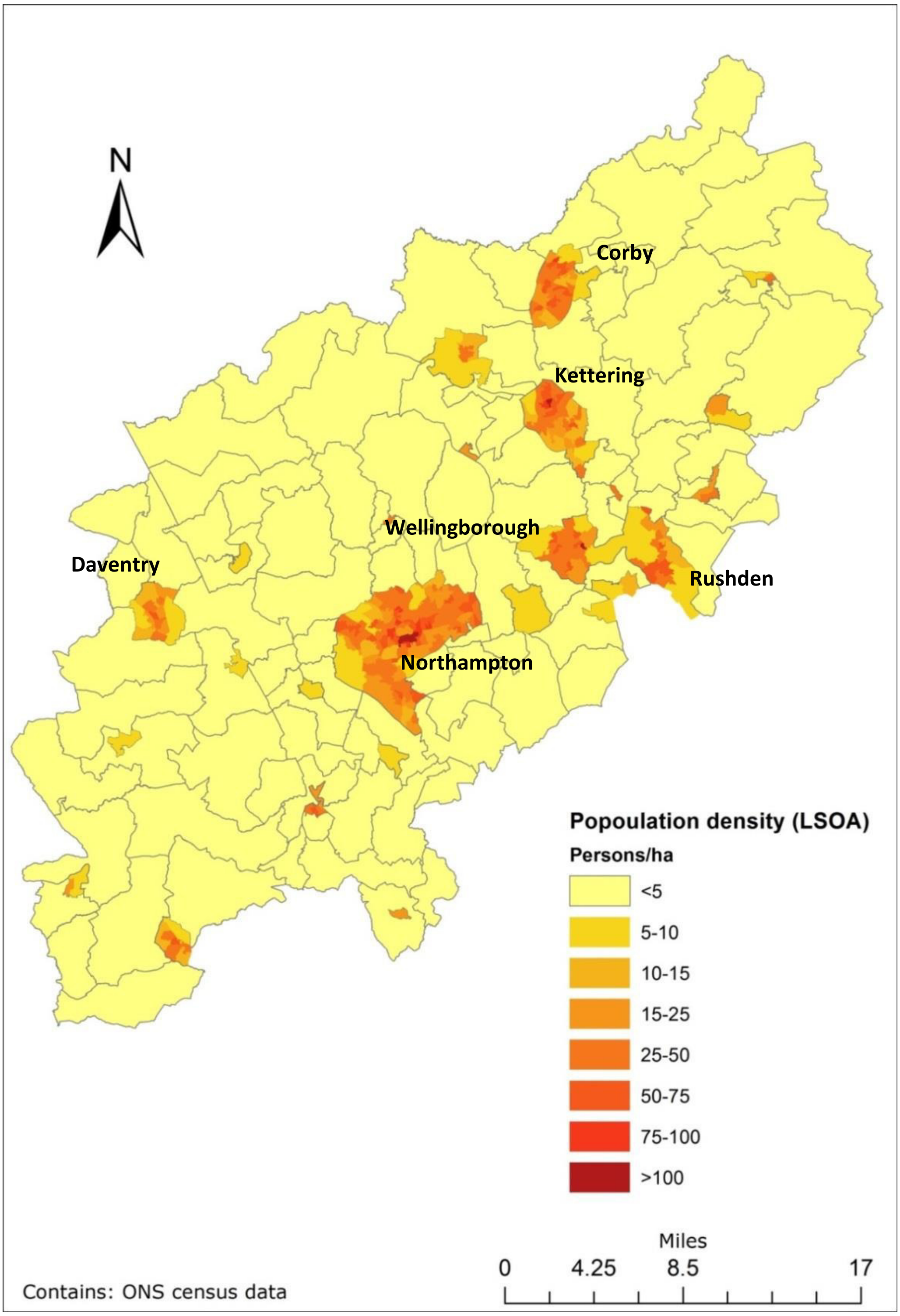


Figure 4.8: Baseline population density (persons/ha) by LSOA for Northamptonshire (2012)

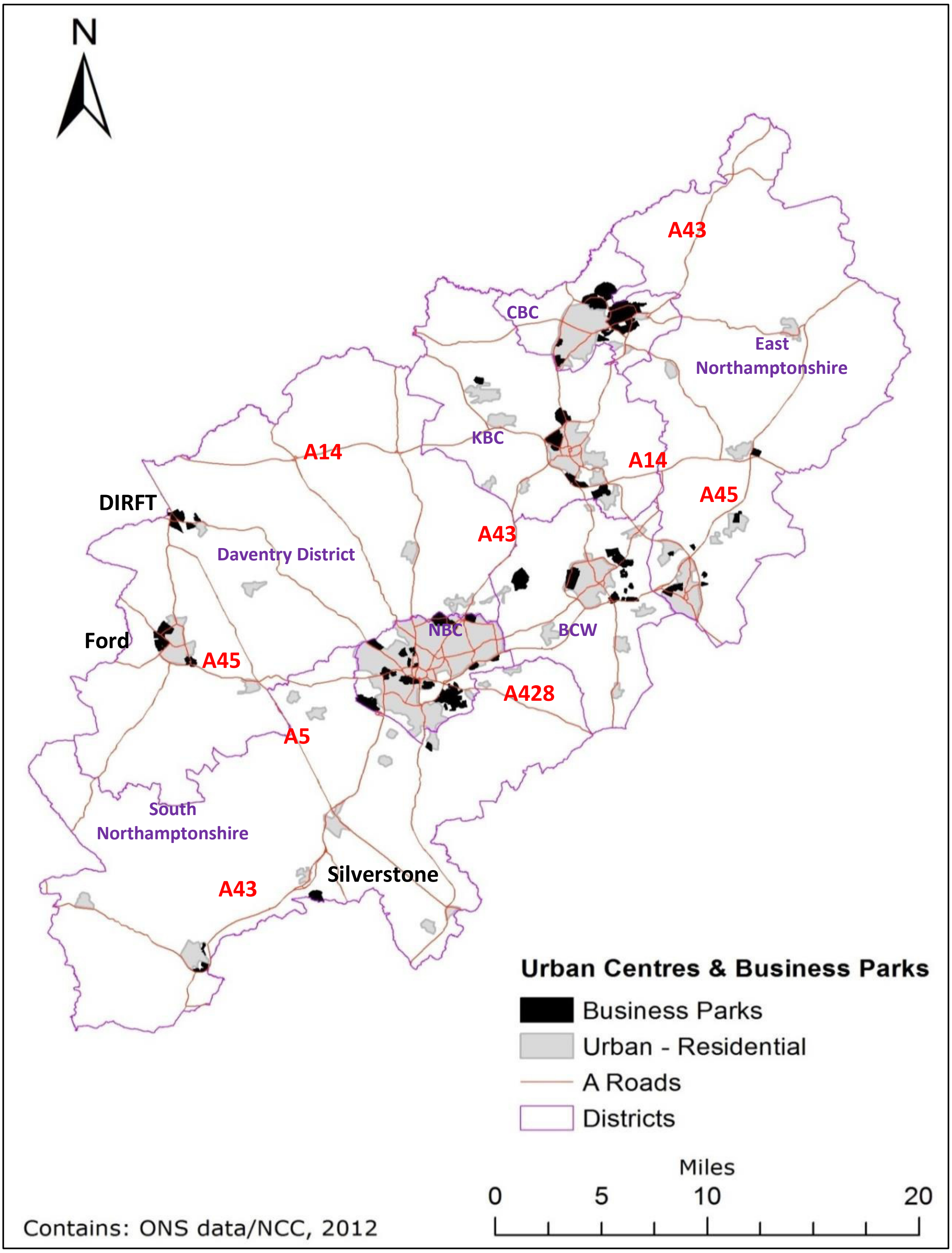


Figure 4.9: Locations of main urban centres and business park locations (principal employment areas) within Northamptonshire, with A Roads and Districts[15] shown.

[15] District abbreviations are: CBC - Corby Borough Council; KBC - Kettering Borough Council; BCW – Borough Council of Wellingborough; NBC – Northampton Borough Council

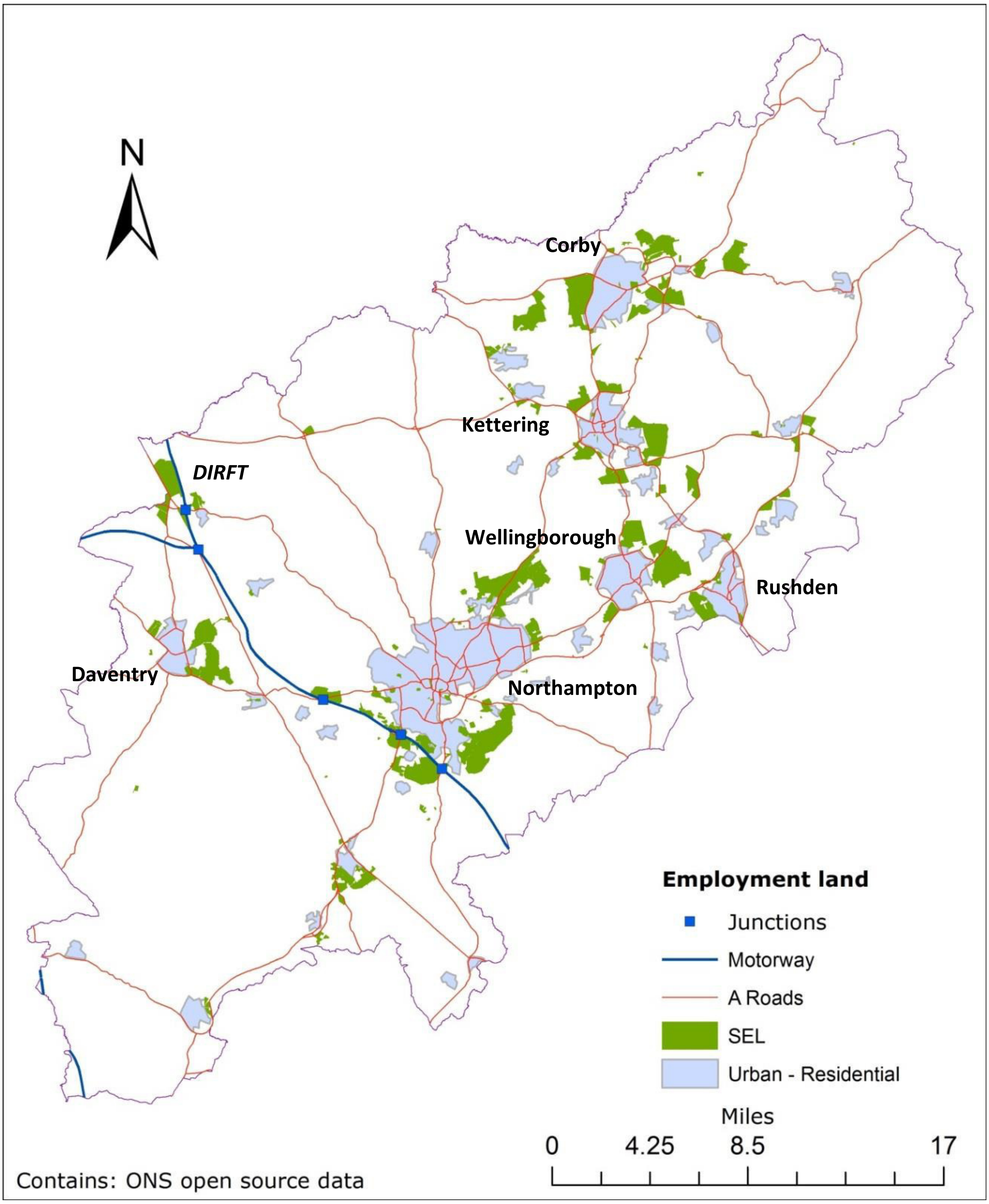


Figure 4.10: Distribution of Strategic Employment Land (SEL) in Northamptonshire (Source: NCC, 2009)

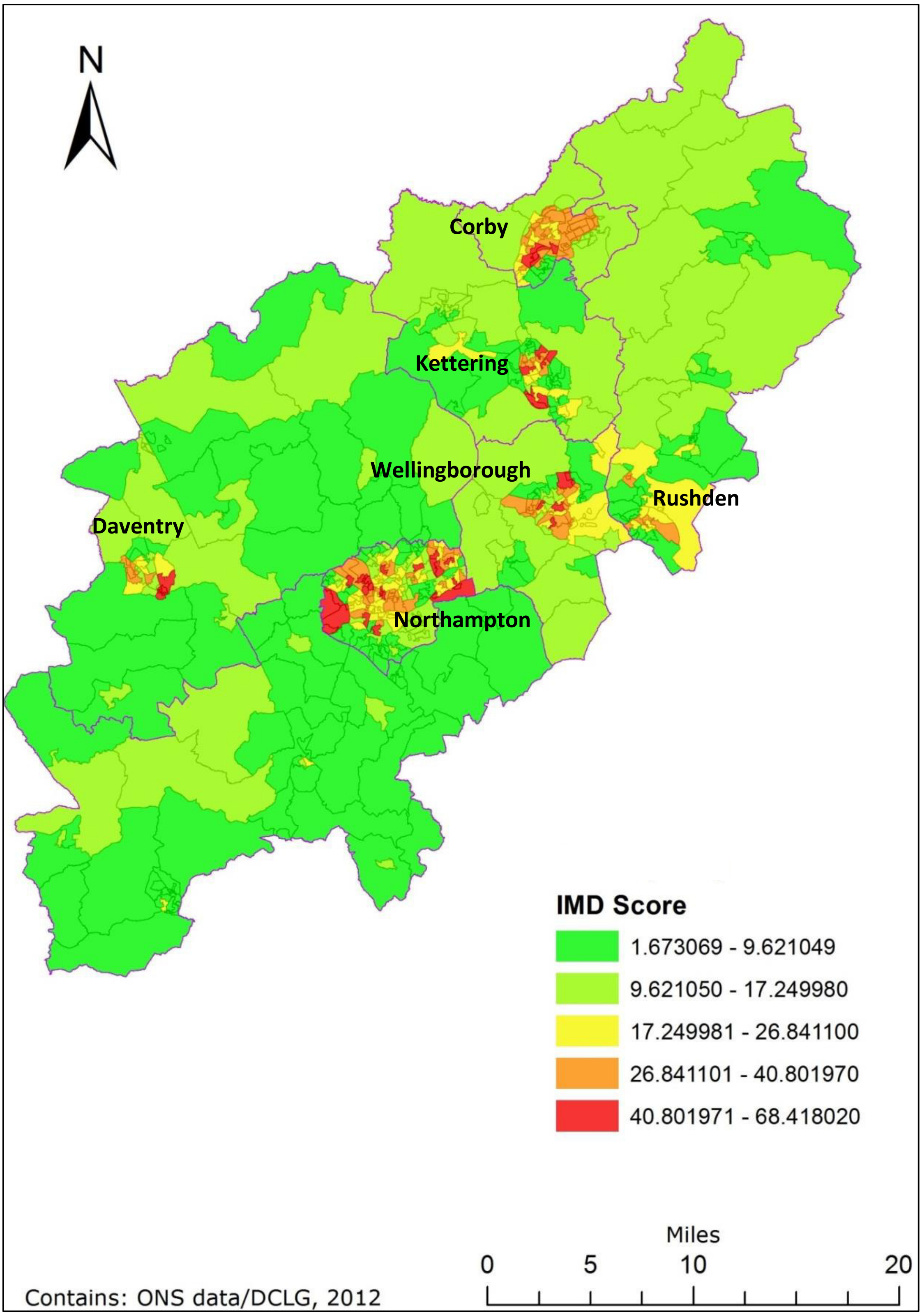


Figure 4.11: Index of Multiple Deprivation (IMD) Scores for Northamptonshire LSOAs in 2010 (Source: DCLG, 2011)

4.8 Summary

The baseline analysis (set at 2012 as the last year of available data from sources during the collection phase of the research – February 2011 to June 2012) is a critical step in both the backcasting methodology and in determining the conditions at the local scale for variations in waste generation rates thus addressing objective 1 of the research. The analysis must consider the internal aspects of the WMS (steps 1-5 in Figure 4.1) and the key factors external to the physical system (steps 6 & 7 in Figure 4.1). Waste arisings and any historic trends (depending on available data) are first determined at the individual waste stream level (LACW, C&I, C&D and hazardous wastes) to give a complete picture of controlled waste within the study area. Overall tonnages were estimated at 2.70Mt broken down as: 339kt for LACW (Figure 4.2); 954kt for C&I (Table 4.1); 1.32Mt for C&D (Table 4.3); and 94kt for hazardous wastes (Table 4.5).

Further important considerations are where these materials end up and the type of materials they contain. In terms of movements, these come under 3 types: imports, exports and internal in relation to the WPA. The study area WPA imported 797kt from outside its boundaries and exported 483kt making it a net importer of wastes in 2012 (314kt). The amount of materials move between WPA districts was considerable (619kt). Table 4.11 provides a detailed breakdown of each waste streams composition showing that key materials include: paper/card; metals, organics and wood as well as inert materials from the construction sector.

The capacities of facilities to handle wastes generated are next assessed against relevant legislative and local targets. This assessment showed throughput to facilities was 2.38Mt with a permitted capacity of 7.00Mt. Assessing the future capacity requirement against the targets and holding waste generation at a constant rate (baseline values) showed considerable shortfall in capacity capable of managing LACW, C&I and hazardous wastes

(Figure 4.5a-d) before any potential future increases in generation rates were taken into account.

The chapter concluded with an assessment of the relevant legislative framework (European, National and Local) for the case study area before showing key system variables as thematic layer maps within GIS (population density; areas of employment and growth; strategic employment land; and areas of deprivation).

To address objective 1 specifically; the baseline assessment shows that waste generation rates have changed over recent years; in a downwards manner. This has been partly driven by the movements of wastes into and out of the study area. The total amount of wastes received at facilities in the WPA does not correspond to the estimated levels of generation suggesting substantial quantities of materials are managed within the exemptions regime. Any substantive changes to the composition of waste streams will have implications for the potential gap in capacity likely to occur at current levels of waste generation.

Chapter 5 Results: Backcasting – from visions to pathways

This chapter presents the results of the backcasting methodology applied within this study, in order to achieve objective 2 and contribute towards objective 5 (see Section 1.3). Section 1 gives a brief introduction to the backcasting framework used and schematically presents the workflow in Figure 5.1. The chapter then presents qualitative results in section 2 in terms of visioning based on questionnaires; workshop outputs; follow-up interviews and dialogue; and stakeholder feedback. This is followed in section 3 by a detailed quantitative assessment of the system within the study area while addressing any gaps in the required data. The chapter then explores the process of scenario development (Section 4.4) before concluding with results from the impact analysis of each scenario (Section 4.5).

5.1 Introduction

A refined version of Robinson's generic backcasting framework (Robinson, 1990) was proposed to allow the output data to be compatible with the mapping requirements of the GIS environment. This framework allowed flexibility in modelling the 'visions' in terms of their impact on a quantifiable system, namely; the waste and resource management system within the case study area of Northamptonshire. The sequencing of the steps within the chosen backcasting framework is presented schematically in Figure 5.1.

Preliminary steps have previously been outlined (see section 3.2). These sought to define the scope of the research, temporal scale and variables for consideration. These parameters were largely determined by the overall research aim and more specifically by the requirements of objectives 1 and 2.

Figure 5.1 illustrates the central role of the visioning and baseline analysis stages in building towards the latter stages. It is worth noting that the scenario development stage is explicitly connected with determining the feasibility of scenarios through an iterative process of impact analysis of various policy choices within each scenario.

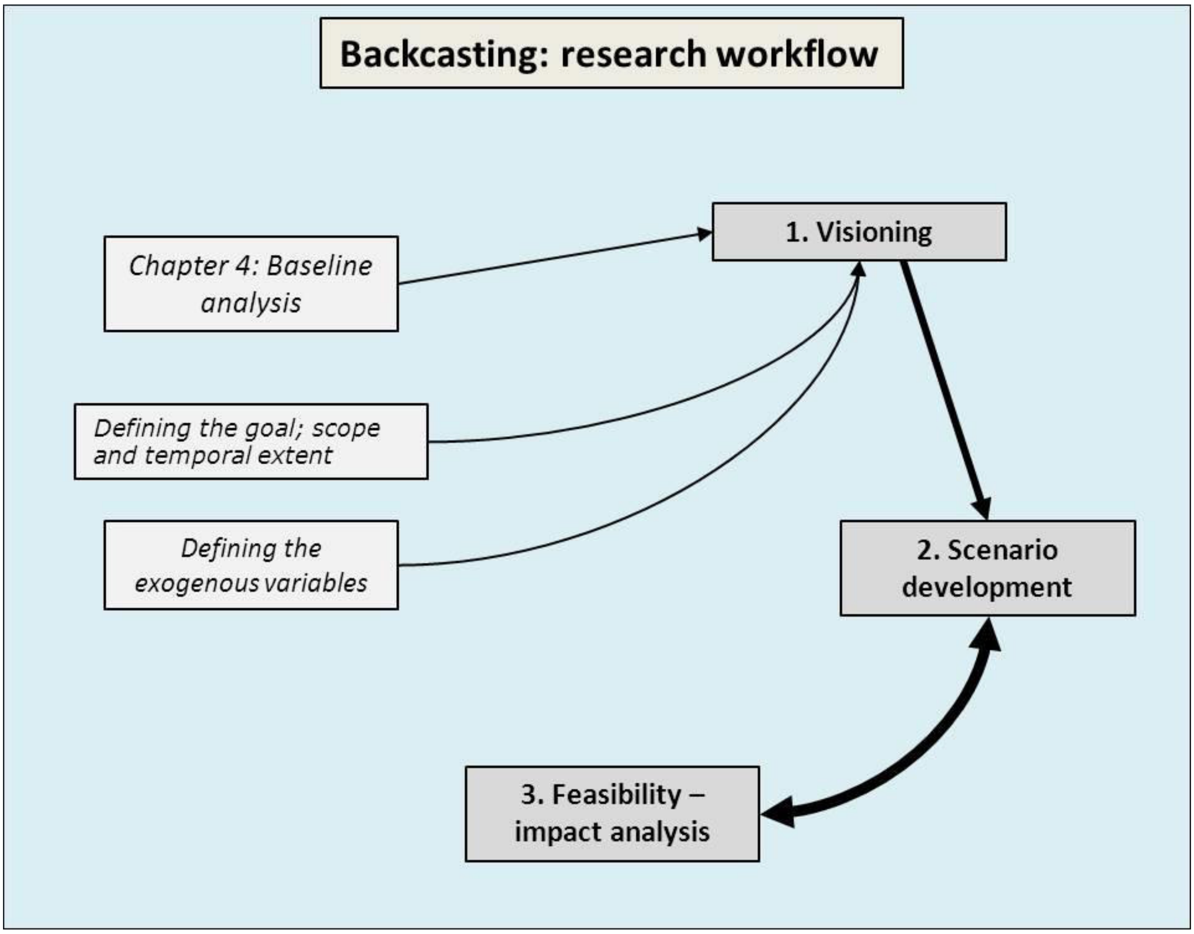


Figure 5.1: Workflow schematic of the backcasting framework utilised in the study

5.2 The Visioning Process

In order to produce visions (scenarios) of what a desirable zero waste future would be like a visioning workshop was designed to capture ideas and begin the process of forming pathways towards achieving a desirable future. Key stakeholders were identified by the researcher and agreed by the supervisory team reflecting both national and local considerations around waste management. A schematic of the key stakeholders identified is illustrated in Figure 5.2.

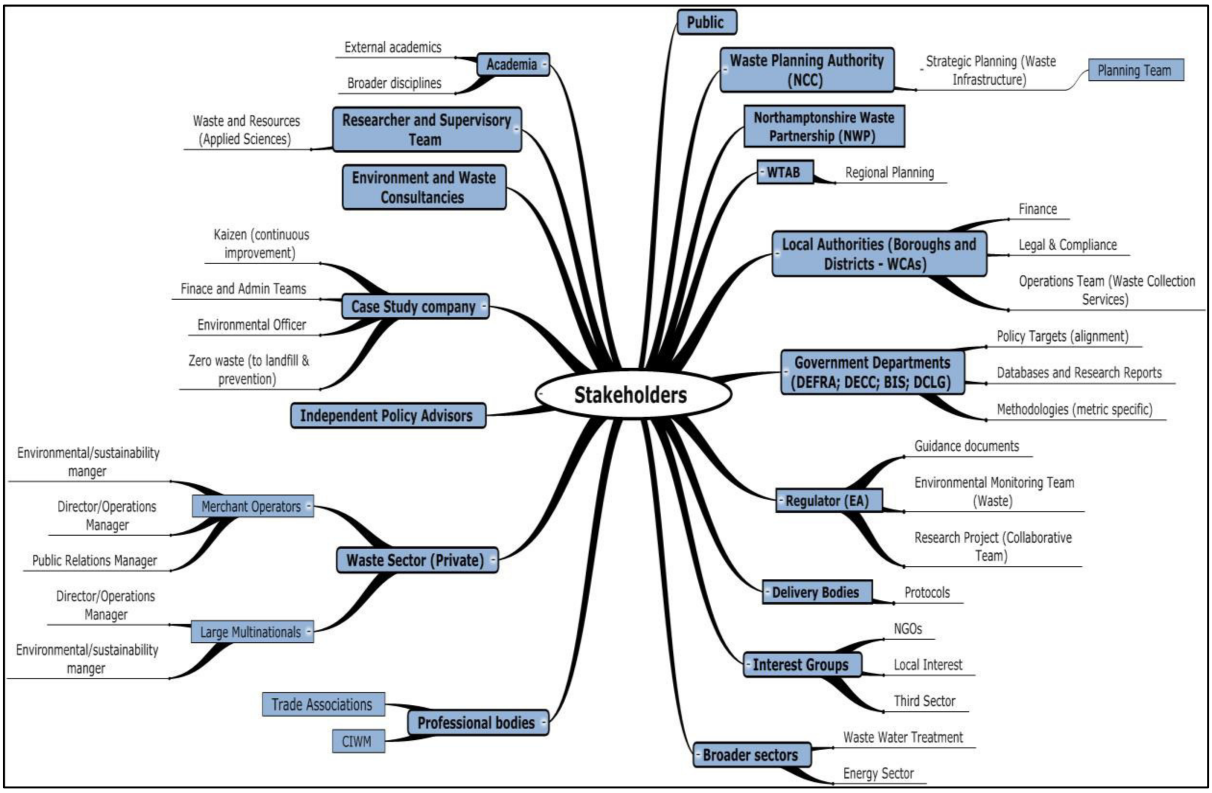


Figure 5.2: Key stakeholders within the waste sector at the national and local scales

In terms of stakeholders identified for direct contact Figure 5.2 shows these within the highlighted boxes. The branches which are not highlighted represent further considerations as to key roles of individuals (Anderson, 2000a). Individuals and organisations identified were then approached for expressions of interest and to complete questionnaires. The results of this approach are given in the following section.

5.2.1 The backcasting workshop

Workshops are widely used in organisations as training and learning tools but also require a significant amount of preparation time and preliminary contact work in order to maximise the effectiveness of the event itself. Prior to the event, questionnaires were designed and sent to experts; after being trialled and amended; expressing an interest in attending the event. The questionnaire was formatted with a range of open and structured questions in order to capture qualitative and quantitative data. Table 5.1 shows the response rate of potential attendees and their domains.

Table 5.1: Response rates to pre-visioning workshop questionnaire

Area of Expertise	No. of forms sent	No. of forms returned	Response rate (%)
Government departments	10	6	60.00
Waste management sector - private	20	8	40.00
Waste management sector - public	15	9	60.00
Local government	30	14	46.67
Local interest groups	10	3	30.00
General public	20	15	75.00
Academia	10	8	80.00
Totals	115	63	54.78

The overall response rate to the questionnaire was 54.78% with most groupings achieving over 50% as shown in Table 5.1. The aim of utilising a questionnaire was to capture ideas for supporting the workshop process as opposed to providing statistical data in the first instance. Post workshop analysis and subsequent thematic characterisation of ideas and visions was supported by the collected data. An example questionnaire is included in Appendix 3.

In order for the workshop to be manageable in terms of facilitation a number of key stakeholders identified were invited to attend. To maintain networks and allow later validation of the output individuals and organisations were asked if they would be willing to be approached for secondary research purposes. The final number of attendees on the day was fifteen; proving manageable in terms of structuring the sessions and allowing space for input from all involved. The workshop was designed around three sessions as illustrated in Figure 5.3.

These sessions used the structure shown in Figure 5.3 and concentrated on broad themes of future states (examining zero waste as a concept and goal orientation for 2050); timeline (examining critical points for policy development and implementation to facilitate zero waste as a vision); and finished with an initial thematic scenario development process (examining narratives of participants ideas, values and beliefs; technical, economic and social implications of ideas raised; and what ifs?).

Figure 5.3: Ideas generation process across the sessions within the visioning workshop context

5.2.2 Post workshop analysis

Post workshop analysis used successive phases of thematic analyses (applying a Social, Technological, Economic, Environmental and Policy analytical framework – STEEP) in order to classify and group responses. The final phase of analysis used a 'futures box' to produce coherent visions of zero waste futures based on the STEEP output.

5.2.2.1 First and second phase analyses

Post workshop, all recordings were transcribed and anonymised before sending out to attendees for feedback on accuracy and content. The mixed data captured in open forum and brainstorming was collated using mind mapping software (Mind Genius 4). This software package was also used to identify key themes relevant to the discussion and research aim.

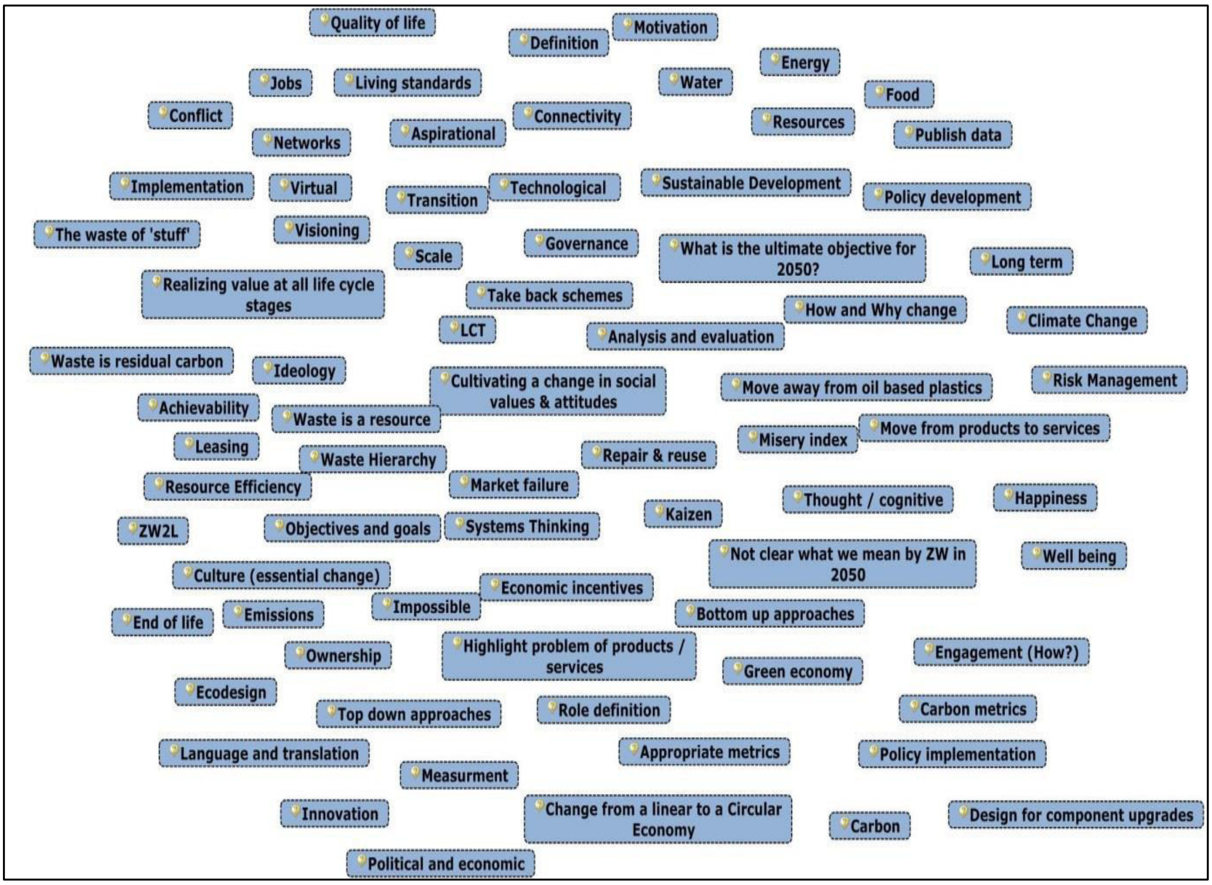


Figure 5.4: Second phase mind mapping of the 77 key factors and characteristics identified in the open forum and brainstorming sessions

First phase analysis of the workshop output identified some 168 factors, considerations and concerns regarding zero waste as a policy approach for the future of waste management in England. These 168 factors were further reduced through second phase analysis to identify areas of overlap, similarity in language, specificity and relevance. Figure 5.4 visualises the resulting 77 key factors and characteristics essential for understanding zero waste from a policy formation perspective. These factors range from issues around definition: "not clear what we mean by Zero Waste in 2050"; to practical systems changes such as: 'embedding Eco design principles' or the 'introduction of take back schemes' and 'leasing models'. Other key considerations identified included practicalities such as: 'introducing economic incentives', 'scaling of initiatives and technologies', or defining zero waste as "zero waste to landfill" (ZW2L).

5.2.2.2 Third phase analysis

Third phase analysis included grouping and categorizing these factors with particular consideration for social, technical, economic, environmental and political (STEEP) considerations. The results of this third phase incorporated inputs from session 3 around ‘potential pathways’ and questionnaires. The results for the open forum and brainstorming sessions; using the MindGenius software package; are visualised in Figure 5.5.

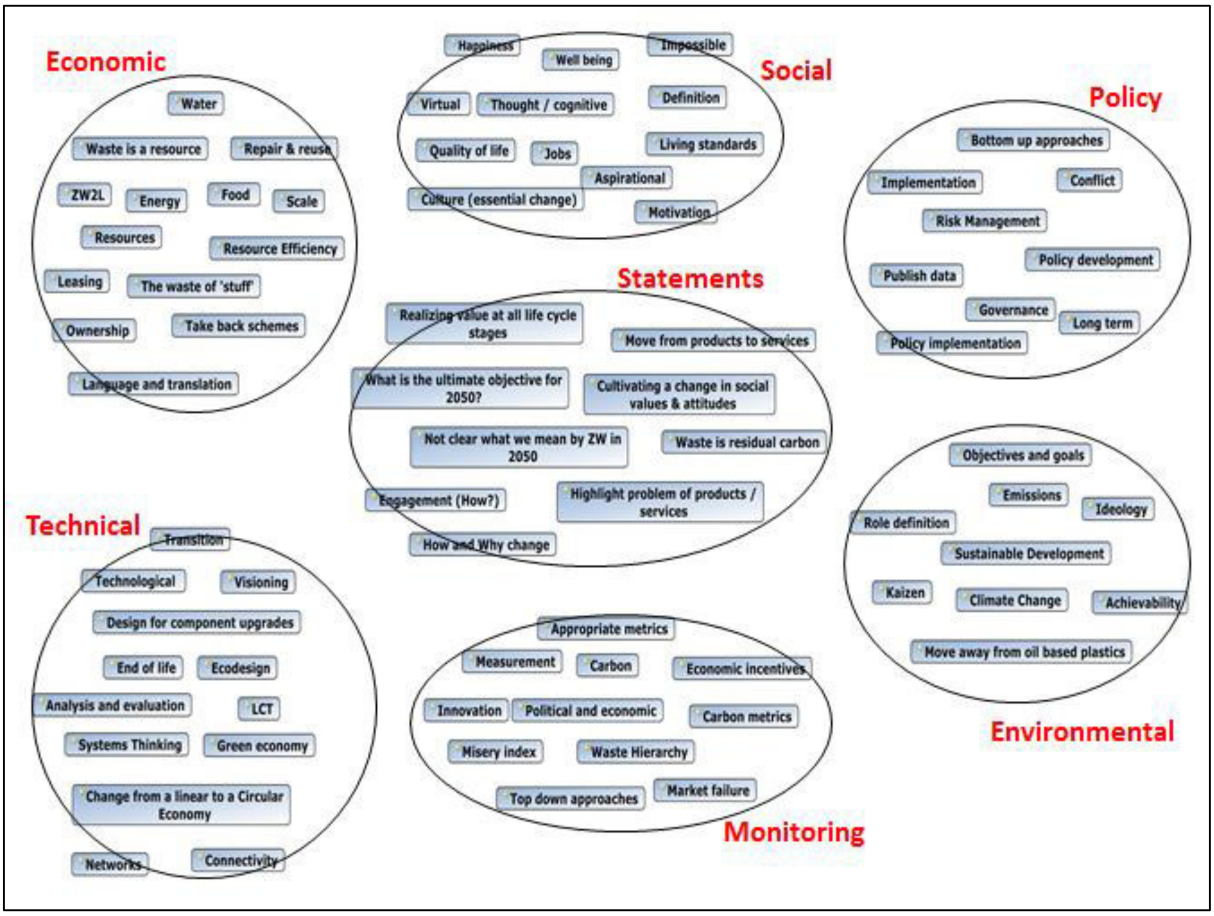


Figure 5.5: Categorisation of the 77 key factors identified from workshop sessions 1 and 2

STEEP analysis was used to broadly categorise the qualitative results. It is noteworthy at this point to state that certain factors and considerations are capable of being placed in multiple groupings but those chosen represent those groups, deemed by participants, to have the largest influence on the individual factors. For example; the use of objectives and goals can be applied across most of the STEEP categories but in the context of the discussions was being referred to most often in relation to environmental considerations.

As can be seen in Figure 5.5 further consideration was given to elements which did not easily fit within STEEP categories. This was due to two main factors. Firstly, monitoring was mentioned in relation to each category within the sessions. For example; appropriate metrics were mentioned as an environmental factor specifically in terms of 'carbon' as an appropriate means of reporting progress towards sustainability. At the same time it was felt that using a 'misery or happiness index' may be a more appropriate metric for measuring social perceptions of waste. Secondly, the researcher with agreement from the supervisory team specified a need to capture some of the statements made to capture the mind-set of certain individuals.

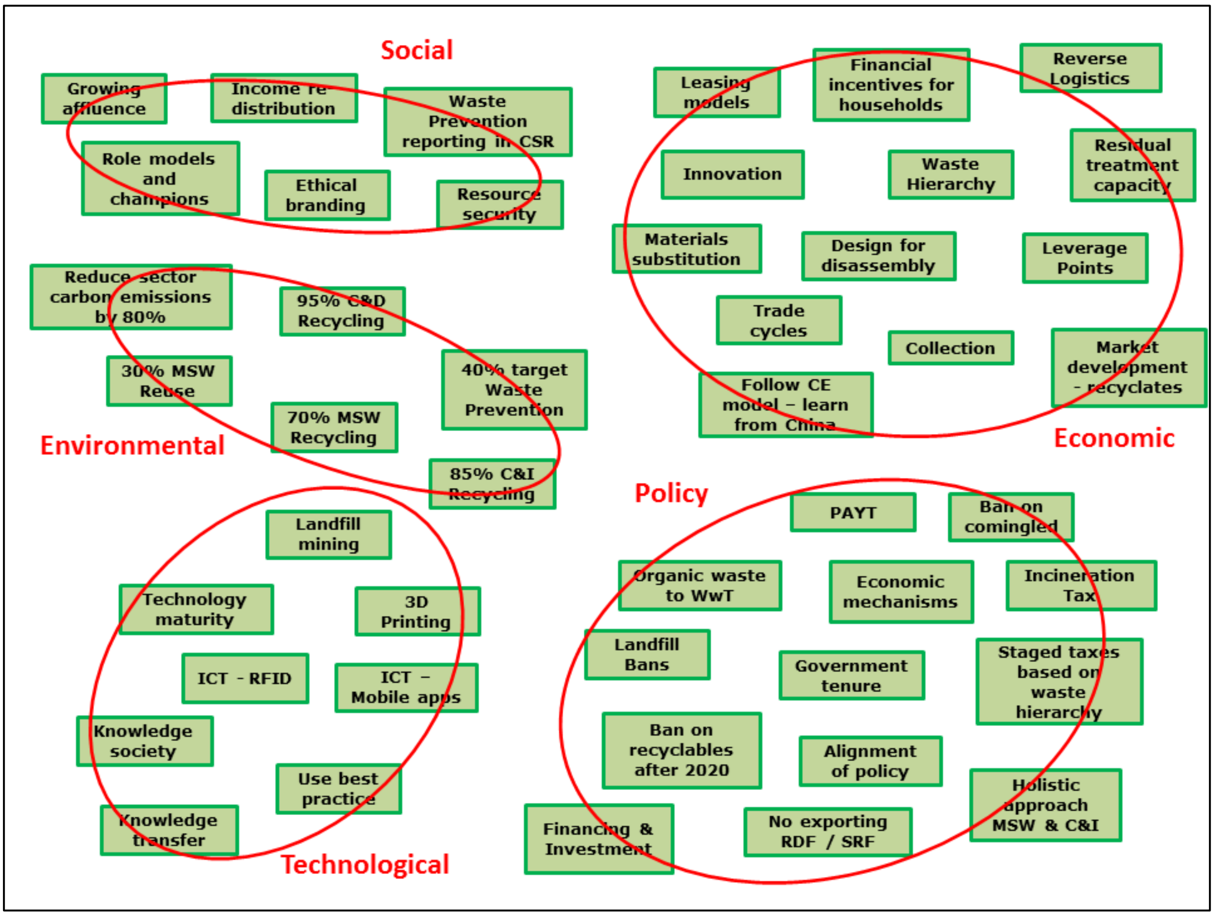


Figure 5.6: Thematic analysis using STEEP criteria for input questionnaire results and workshop session 3 'potential pathways'

This was followed up by scrutiny of comments later in the session and through discussions after the event to evaluate if any change had occurred in terms of language used.

As the questionnaires were more structured than the workshop sessions, responses received had a combination of qualitative and quantitative data. For example; a number of questions asked respondents to assign a potential value to levels of recycling or waste prevention for the waste sector in 2050. The responses, in terms of quantified targets, are grouped under environmental category, in Figure 5.6, to reflect the overarching goal of protecting the environment and human health. Notwithstanding this goal, these targets can be applied directly or indirectly to all the remaining categories.

Targets were also mentioned during the 'potential pathways' session of the workshop and are incorporated in terms of 'reducing sector carbon emissions by 80%'. However, the real value of this session was setting an initial framework of ideas that each pathway was likely to take as well as exploring the fundamental principles which would define a zero waste future based on sustainability.

5.2.2.3 Fourth phase analysis – futures table creation

The workshop closed with most individuals giving their own personal vision for the waste sector in 2050. These visions were varied with some having an economic focus around issues such as 'market development for recyclates' or introducing 'leasing models' to create a sense of materials ownership. Other visions focussed on technical or technological solutions to reduce waste at source, with '3D printing' or capturing all materials, through 'landfill mining'.

In essence, these visions allowed the creation of more structured scenarios. It was also clear that while zero waste was the goal, the pathways towards achieving this overarching goal could be markedly different. Table 5.2 shows the final iteration of the various visions combined with previous analytical phases in order to produce a futures table outlining the main change drivers and relevant trends within the four scenarios identified.

Table 5.2: Futures table showing the main drivers of change; economic, policy and social trends for the four scenarios based on thematic analysis and stakeholder feedback

	Circular Economy (CE)	Valorisation & Materials (VM)	Ecological Citizenship (EC)	Economic Destabilisation (ED)
Drivers				
Population	Stable	Decreasing	Increasing	Increasing
	Skills based migrants	Repatriation (voluntary)	Balances ageing	Rapidly ageing
Consumption patterns	Low consumption	Steady buying power	Sustainable consumption	High consumption
Environmental behaviour	Conscious choices	Conscious choices	Consumers aware and make deliberate choices	Low consciousness
Corporate eco-behaviour	Sustainability based on resource efficiency	Competitiveness hindered (behind CE curve)	Competitiveness enhanced (ahead of CE curve)	Diverse and uncoordinated
Landfill tax	Hammering of landfill	Gradual increases	Materials based	Decrease in landfill tax
	Incineration tax (escalator)		Incineration tax (escalator)	
Social justice (equity)	Income redistribution	Inequality	Growing affluence	Poorer society
Waste	Decreasing long-term trend	Decreasing trend after peaking (2020)	Significant reduction (waste prevention driven)	Increasing trend reflects economic trend
Economic trends				
Output/growth	Rapid growth	Double dip recession	Sustained growth	Volatility
		Bust-boom long-term		Bust-boom long-term
Structure	Product design	Diversified	Continued service focus	Manufacturing resurgence
	Product stewardship	Green economy	Redesign (products and services)	
Commodity markets	Increasing over long-term	Reversal of super-cycle	Closed markets	High prices
	More regional/local	Global markets	National and local focus	Strong volatility
Policy trends				
Energy	Increase in ATT	Market reform / small producers	Increase in AD for residuals	Slow shift to renewables
Waste to energy	Decoupled fuel production	Large scale	Small-scale	Large increase in AD
System support	Incentive schemes	Stable legislation	Zero Waste Strategy (from 2020)	More legislation

Table 5.2: (continued)

Policy trends				
	Secondary markets	Evolution of policies	Overarching goal	Standardisation
Waste Hierarchy	Adapted for closed loops	Materials based approach	Holistic and integrated	Focus on low end
	Holistic and integrated	Market driven		High cost of WM approach
Social trends				
Employment	Green jobs	Green jobs	Green skills through education	Low skilled / low paid
	Resource sector	Resource sector	New business models (diversification)	Waste management sector
Voluntary improvements	Respond to policies	Industry response to consumer demands	Industry lead on streams (C&I; C&D; hazardous)	No policy or industry lead
Recycling	Social norm	LACW focus	Coordinated focus	Uncoordinated approach
	High levels >70%	High levels >80%	High levels after prevention > 70%	Reducing after 2040 <50%
Prevention and reuse	Resource management approach	Focus on reuse not prevention	Strong focus on prevention first	Low emphasis and impact

Table 5.2 shows the main drivers and trends based on the previously identified exogenous and endogenous variables (see Table 3.6). Each scenario has markedly different characteristics within each cateogory (driver or trend) wich form the basis for the detailed development of sceanrio narratives (see Section 5.3). Crtically, the futures table (Table 5.2) incorporates some general quantitative elements (e.g. recycling rates) which can be used as guiding the development of the quantitative model (QM) in section 5.3.3.

The final step in the phase four analysis involves identifying the high level factors which shape the scenario development process. Figure 5.7 shows the high level factors (waste policy and values/behaviour) as a matrix showing the degree of coordination (vertical axis) for future waste policy on a scale between full policy integration and a state of uncoordinated policy development. In addition, the horizontal axis depicts values and behaviours across a range from being driven at the community scale to a corporate driven approach.

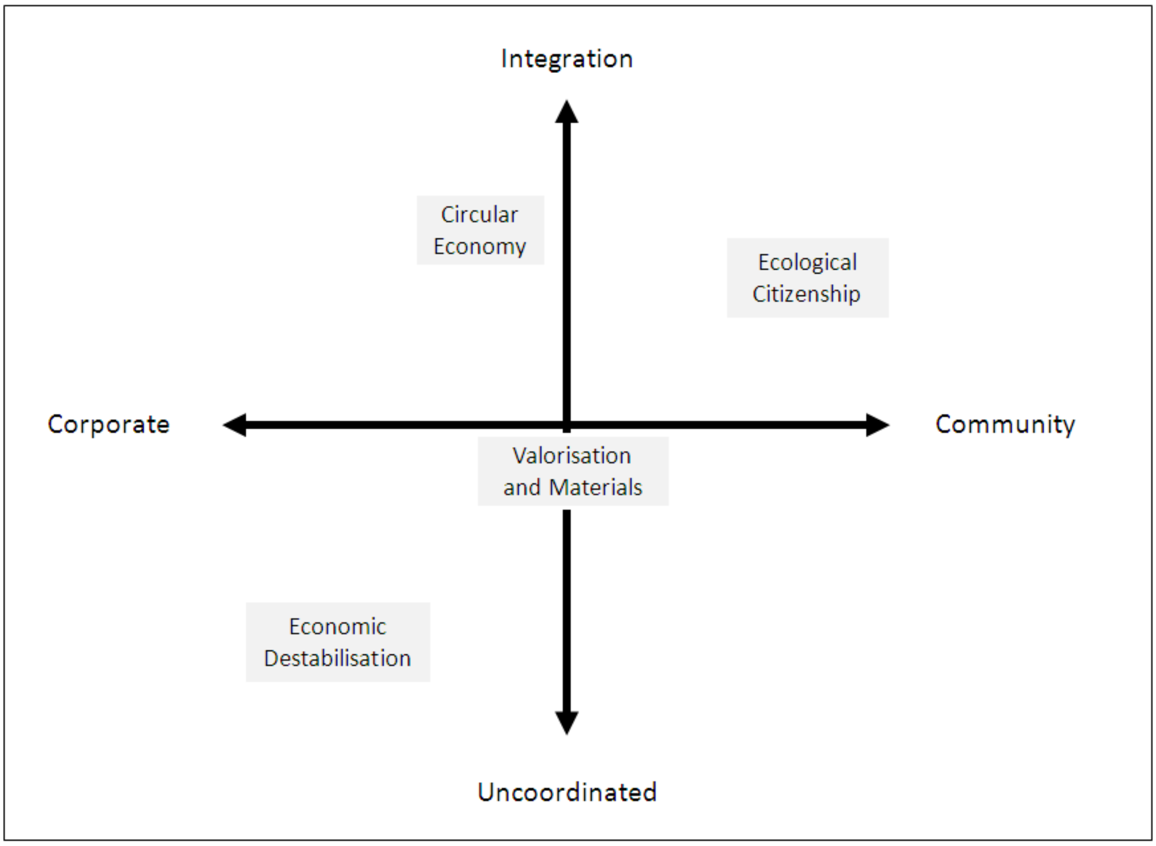


Figure 5.7: Four waste/resource futures scenarios placed within a policy/value matrix[16] (Source: after OST, 1999 cited in Berkhout, 2002, p42.).

Specifically, Figure 5.7 shows the position of the four scenarios. The ecological citizenship (EC) scenario is strongly focused on community scale values and behaviours with an emphasis on policy integration. In contrast, the circular economy (CE) scenario is more influenced by corporate considerations with a need for a strong integration of waste policies with other economic and social considerations. Valorisation and materials (VM) lies at the centre of the values behaviour axis as this scenario requires buy-in from both supply and demand-side entities. However, it sits slightly below the centre of the policy axis reflecting the continuing influence of waste thinking even with a transition towards a resource focused sector. Scenario economic destabilisation (ED) reflects the current situation most closely (uncoordinated and waste sector lead) and represents a reference case scenario with some accounting for continuance of negative trends.

[16] The horizontal axis represents values/behaviour; and the vertical axis represents waste policy

5.2.3 Triangulation: Stakeholder responses to the visioning process

In order to validate the results from the visioning process a survey questionnaire was designed around three specific questions and sent to stakeholders involved in the various stages (questionnaire; workshop and follow-up).

5.2.3.1 Rating the visioning process

The results are presented in Figures 5.8; 5.9; and 5.10. Survey questionnaires were sent out to 25 stakeholders with responses received from 11 individuals, a response rate of 44.0%.

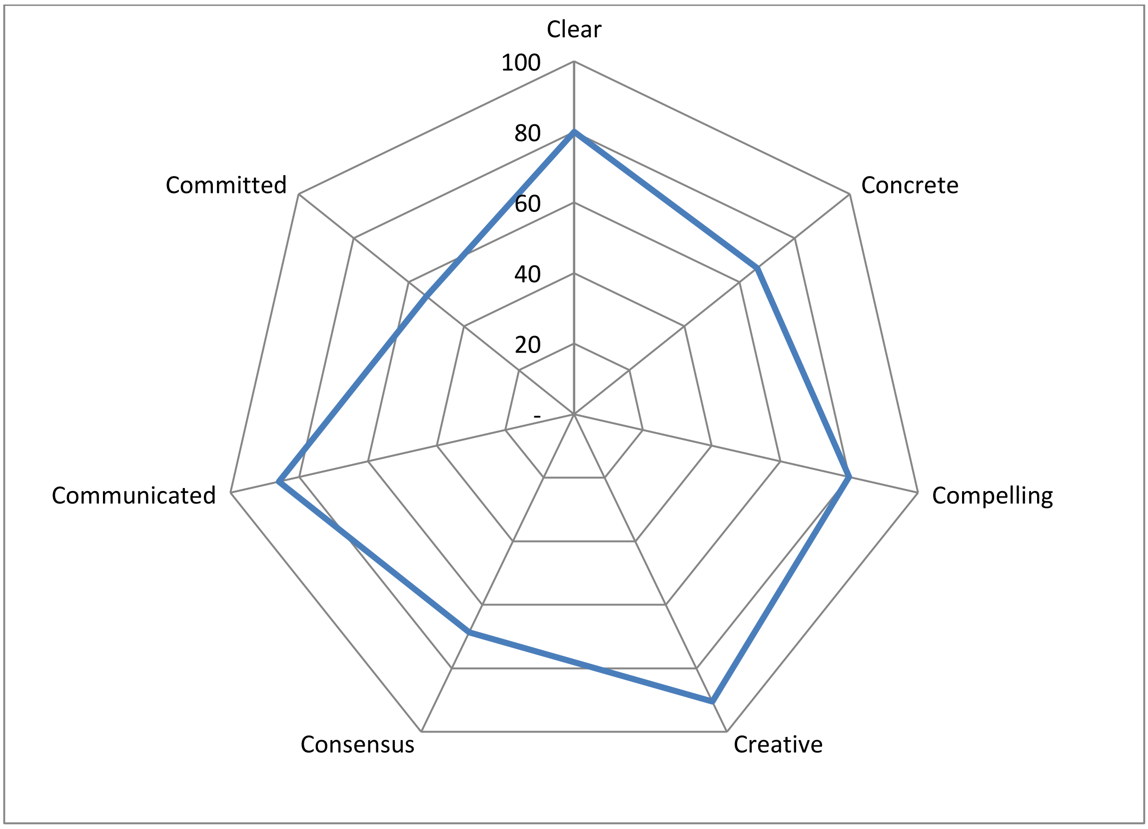


Figure 5.8 Summary of responses to survey question 1

Figure 5.8 shows responses to the question: *How would you rate the vision(s) produced from the backcasting process?* The overall response to the question was positive across all respondents (this is gauged as scoring above 50%). It is clear that one element of the process raised concerns in terms of being 'committed'. Respondents commented on the need to gain 'buy-in' within their organisations; from business; and from individuals. Key strengths identified from the analysis pertain to 'creative' and 'communicated' categories. This suggests the process has potential as a tool for enhancing creativity and communicating new ideas about specific complex issues (e.g. transitioning to a zero waste economy).

5.2.3.2 Organisational view of visioning

Figure 5.9 presents the results to the question: *How might key decision-makers within your organisation rate such visions?*

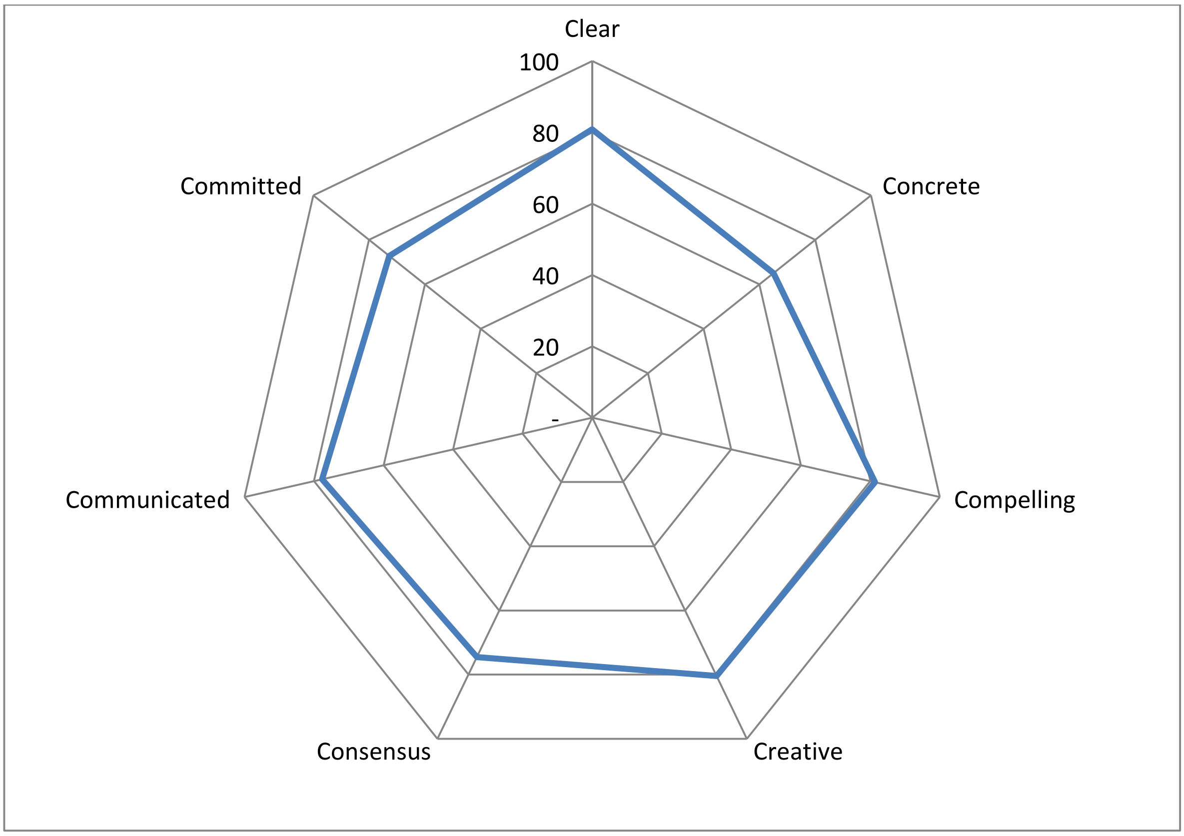


Figure 5.9: Summary of responses to survey question 2

Responses were generally similar to question 1 in that all had a positive response on all categories (>50%). A weaker score was identified in the 'concrete' category. This suggests a need for using language which positions the desirable future with tangible measures derived from the current understanding. Strengths were identified in terms of being 'clear' and 'compelling' as well as the 'creativity' of the process from an organisational perspective. All of these categories had aggregated scores >80% (80.9; 81.4 and 80.5% respectively).

5.2.3.3 Rating backcasting as a strategic foresight tool

Figure 5.10 presents the results to the question: *how would you rate the production of visions using a backcasting approach as a strategic foresight tool for decision-makers?*

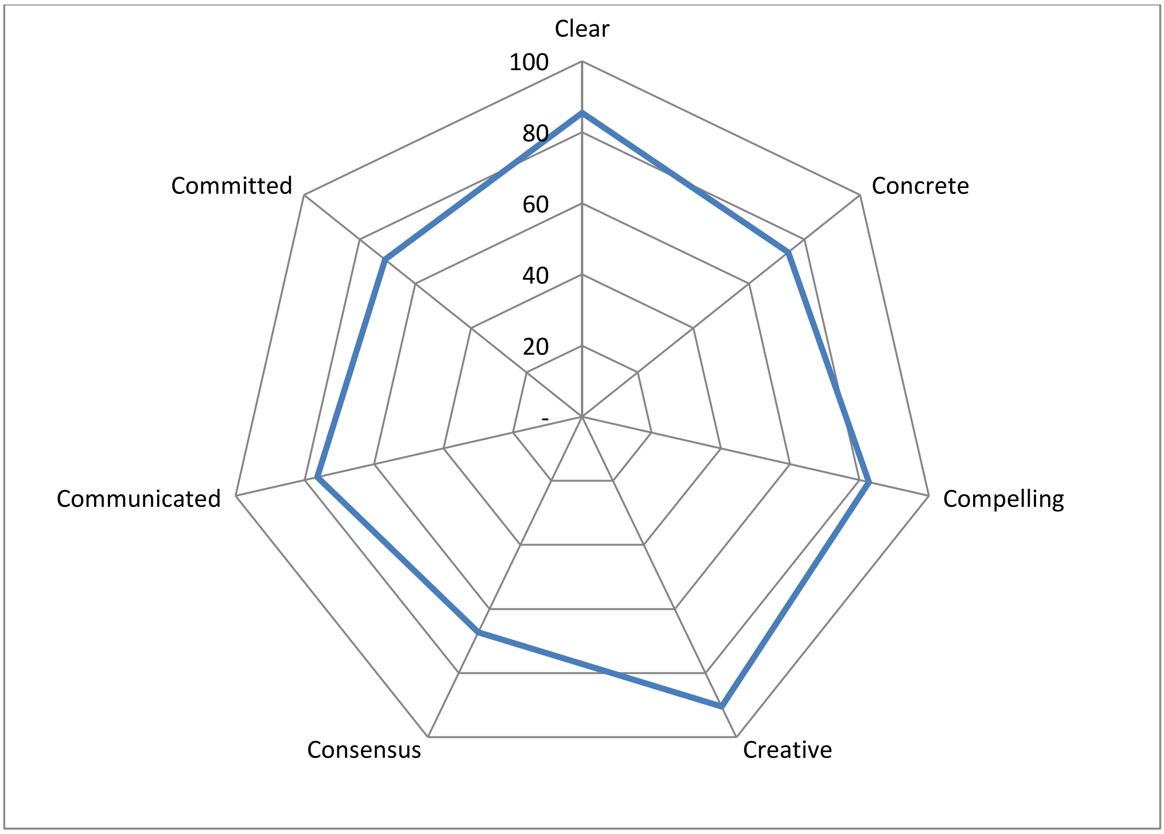


Figure 5.10: Summary of responses to survey question 3

Figure 5.10 shows aggregated responses were positive (scoring >50%). The lowest scoring category was ‘consensus’ (67.3%) which respondents suggested as an area where more detailed process objectives may have helped foster a greater feeling of building a consensus. The categories of ‘creative’ and ‘clear’ scored highest (90.5 and 85.5% respectively) with overall comments praising the clarity of the approach in terms of pre-workshop information and instructions on the day. Further, attendees at the workshop were very positive about the creative nature of the backcasting method for strategic foresight as well as the level of opportunity to input through follow up discussions and interviews.

5.2.4 The sector view on zero waste: 2012 survey data

Having been identified as a potential participant organisation CIWM expressed an interest in supporting the research. As part of this support CIWM supplied secondary data from the '2012 survey of waste professionals' (CIWM, 2012) on responses to the questions: "What is zero waste?" and "Is the sector capable of delivering such a concept as 'zero waste'?" The questionnaire was open to all subscribing and affiliated professionals from the UK with the dataset containing 222 responses. Open-ended responses were thematically coded as primary and secondary categories to allow comparison with analysis of visioning data. Analytical tables are contained in Appendix 4 with results presented here.

Respondents to the survey were asked in Question 1: *What is 'zero waste'?* Responses showed that zero waste to landfill (ZW2L – 30.6% of all respondents) was the main perception of the term 'zero waste' among respondents. There was a 2:1 ratio of respondents indicating zero waste was too ambiguous versus being an aspirational focus for policy. Other significant themes included 'valorisation', with an emphasis on value in terms of materials and energy; circularity and Circular Economy (CE); specifically referring to closed loop principles; and waste minimisation.

Secondary coding was undertaken to capture and assess more detailed responses of certain individuals. Of the 222 original respondents 60 did not give answers of enough detail to be placed in secondary categories. The results again showed ZW2L to be the most common response from waste professionals. A similar number of respondents felt 'zero waste' to be unattainable with a number qualifying their response with statements such as:

> *"…not zero waste but very close to it is possible."* and;

"…a challenging philosophy well worth pursuing."

Once again valorisation was identified as being significant for materials and energy security. In addition, systems approaches such as eco-design and circular economy were common responses which coincided with publication of the first McKinsey report (EMF, 2011) and media coverage around developing a Circular Economy.

Respondents to the survey were asked in Question 2: *Is the sector capable of delivering such a concept as 'zero waste'?* The majority of respondents to Question 2 felt the waste sector was not capable of delivering the concept of 'zero waste'. Results indicated that in 2012 waste professionals believed that for the sector zero waste was either 'unattainable' or was 'not currently achievable'. Specific reasons given included:

- *'there will always be a residual fraction';*
- *'lack of commitment'; or*
- *'the definition of waste is an obstacle'.*

The main point to take from the sector survey data related to the similarity in broad themes identified: valorisation and circular economy; as well as the perception of the sector as being incapable of delivering zero waste. These similarities and specific viewpoints were utilised in the final formation of the qualitative narratives (see section 5.3.2.1).

5.3 Scenario Development

The scenario development process is composed of distinct stages which seek to build up a coherent picture of necessary decisions and policy options which need to be implemented in order to achieve the specific vision. This section will detail the results of each of these distinctive stages and culminates with a brief summary of the key findings.

5.3.1 Generating the scenario narratives

This phase of the analytical process was perhaps the most critical in terms of achieving objective 2 as all subsequent analysis and testing derives from them. Recent developments in England have used plausibility matrices (in the form of morphological boxes) as part of a study using a normative forecasting approach (DEFRA, 2011_b). This study was used as a basis for developing the structured scenario formation process. Stakeholder inputs based on a priority 'likert' scale are utilised as a basis for further qualitative assessment. It was felt this approach best avoids stakeholder subjectivity and the potential for researcher bias.

5.3.1.1 Reporting the plausibility matrices

Stakeholders identified during the initial visioning stage of the backcasting process (see section 5.2) were asked to complete a plausibility matrix for their preferences on a range of key variables identified by the stakeholders, supervisory team and from key literature (UNEP, 2007; WBCSD, 2010; DEFRA, 2011b). Responses were captured within a simple matrix for 14 variables with 5 options for each (see section 3.3.4.1). These included 7 exogenous and 7 endogenous variables (see section 3.3.1.3). The matrices were numerically coded with preference scores and thus analysed by means of summing the scoring for each variable and choice made.

5.3.1.2 Capturing individual choices

Individual stakeholder responses were recorded in boxes below the options matrix (a sample copy is included as Appendix 5. These responses were then cross tabulated into a response matrix. All scores were recorded for each choice of option and summed in order to capture relative weightings. Table 5.3 shows the indicative results matrix from an individual stakeholder.

Table 5.3: Individual stakeholder response matrix with conditional formatting

Response matrix	Choice 1	Choice 2	Choice 3	Choice 4	Choice 5
Variable 1	3	5	4	1	2
Variable 2	1	2	3	5	4
Variable 3	5	3	1	2	4
Variable 4	1	4	2	5	3
Variable 5	1	5	3	2	4
Variable 6	5	4	3	2	1
Variable 7	2	5	4	3	1
Variable 8	5	2	1	4	3
Variable 9	5	2	3	1	4
Variable 10	4	1	3	2	5
Variable 11	3	2	5	1	4
Variable 12	4	2	3	1	5
Variable 13	3	1	5	2	4
Variable 14	5	1	3	4	2
Sum of scoring	47	39	43	35	46
Mean	3.357	2.786	3.071	2.500	3.286
Standard Deviation	1.598	1.528	1.207	1.454	1.326

5.3.1.3 Combining individual choices to produce weightings

The next stage of analysis was to combine all stakeholder responses to categorise choices and produce relative weightings (Table 5.4). Stakeholders were further defined as technical or non-technical in relation to their involvement with or knowledge of the waste sector. This was done to avoid bias within the weightings produced which may otherwise have favoured technical stakeholder views. Table 5.4 shows the scores for each choice within the 14 variables categories as well as stakeholder results separated as TS, NTS and a mean value. The mean value was used in the first instance in order to rank scoring according to preference, where obvious contradictions were found or a value was scored equally then consideration was given to the scores and rankings from the TS and NTS results depending on the type of variable under consideration, For example; under the waste system variable the mean of two values is 0.2099 in this case the TS score is looked at first as the

Table 5.4: Plausibility results (aggregated scores) for exogenous and endogenous variables by stakeholder groups

Exogenous Variables	Stakeholder results			Endogenous Variables	Stakeholder results		
Demographics	TS	NTS	Mean	Energy System	TS	NTS	Mean
Stable Population Growth	0.2057	0.2200	0.2129	Slow shift to renewables	0.1944	0.1700	0.1822
Population boom	0.2057	0.1743	0.1900	Increase in AD and associated EfW	0.2306	0.2210	0.2258
Rapidly ageing population, stagnation	0.1800	0.1743	0.1771	Large increase in ATT (centralised)	0.2056	0.2125	0.2090
Increasing population balances ageing	0.2257	0.2171	0.2214	Mergers between energy/waste companies	0.1889	0.1841	0.1865
Decreasing population (repatriation)	0.1829	0.2143	0.1986	Market reform for smaller producer entry	0.1806	0.2125	0.1965
Socio-Economic Situation	TS	NTS	Mean	Waste System	TS	NTS	Mean
Growing affluence	0.2371	0.2305	0.2338	Slow increase recycling/ recovery rates	0.2079	0.1695	0.1887
Income re-distribution	0.2114	0.2305	0.2210	Decreasing waste trend over long-term	0.2107	0.2090	0.2099
Inequality reigns	0.2029	0.1960	0.1994	Low impact of waste prevention policies	0.1713	0.1836	0.1775
Poorer society	0.1657	0.1614	0.1635	High impact of waste prevention policies	0.2107	0.2175	0.2141
Income squeeze	0.1829	0.1816	0.1822	Shift to materials based approach	0.1994	0.2203	0.2099
Consumption patterns + environmental behaviour	TS	NTS	Mean	EfW Capacities / Technologies	TS	NTS	Mean
Good attitudes, wasteful behaviour	0.1770	0.1847	0.1808	Small-scale EfW	0.2247	0.2039	0.2143
Increase in sustainable consumption	0.2275	0.2244	0.2260	Large scale EfW	0.2022	0.2039	0.2031
Steady buying power, conscious choices	0.2247	0.2045	0.2146	De-coupled fuel production/ consumption	0.2079	0.2011	0.2045
Low consumption and ECB*	0.2163	0.2330	0.2246	Large % increase centralised AD (biogas)	0.1910	0.1983	0.1947
High consumption and low ECB	0.1545	0.1534	0.1540	Large increase on-farm AD	0.1742	0.1927	0.1834
Economic output	TS	NTS	Mean	System Support + Intervention	TS	NTS	Mean
Steady growth	0.2436	0.2356	0.2396	Stable legislation	0.2056	0.2017	0.2036
Rapid per capita growth	0.2092	0.2241	0.2167	Push for deregulation	0.2139	0.1877	0.2008
Bust-boom cycle	0.1891	0.1724	0.1808	More legislation, more standardisation	0.1611	0.1625	0.1618
Double dip (recession)	0.1920	0.1868	0.1894	Zero Waste England (RM Strategy, 2020)	0.2000	0.2353	0.2176
Triple dip (recession)	0.1662	0.1810	0.1736	Secondary materials markets flourish	0.2194	0.2129	0.2162

Table 5.4: (continued)

Exogenous Variables	Stakeholder results			Endogenous Variables	Stakeholder results		
Economy structure	TS	NTS	Mean	Development of Landfill Tax (environmental taxes)	TS	NTS	Mean
Continued shift to services	0.2235	0.2094	0.2164	Gradual tax increases	0.2133	0.2000	0.2066
Resurgence of British manufacturing	0.1788	0.1818	0.1803	Hammering of landfill	0.2219	0.2197	0.2208
Centre of excellence (quality based)	0.1760	0.2094	0.1927	Landfill reduction and Incineration tax	0.1729	0.1915	0.1822
Balancing (growth of green economy)	0.2067	0.1928	0.1998	Sophisticated materials based approach	0.2305	0.2394	0.2350
Product design and stewardship focus	0.2151	0.2066	0.2108	Decrease in landfill tax	0.1614	0.1493	0.1553
Corporate Eco-Behaviour	TS	NTS	Mean	Voluntary Improvements	TS	NTS	Mean
Diverse approaches	0.1829	0.1576	0.1702	Stable support and participation	0.2006	0.2000	0.2003
Low level of concern and efficiency	0.1829	0.1576	0.1702	Increase in policy driven measures	0.2062	0.2114	0.2088
Sustainability / resource efficiency drive	0.2171	0.2292	0.2232	Decrease in policy measures / industry responses	0.1610	0.1629	0.1619
Competitiveness depends on CE (behind)	0.1743	0.2063	0.1903	No policy - strong industry response consumers	0.2119	0.1971	0.2045
Competitiveness depends on CE (leader)	0.2429	0.2493	0.2461	Industry lead on C&I and C&D	0.2203	0.2286	0.2245
Commodity Markets	TS	NTS	Mean	Recycle & Reuse Capacities / Technology	TS	NTS	Mean
Closed markets and protectionism	0.2206	0.2286	0.2246	MSW dominates development	0.2157	0.1834	0.1995
Open markets and stable supplies	0.1948	0.1857	0.1903	Coordinated expansion	0.2269	0.2206	0.2238
High prices and strong volatility	0.1891	0.1829	0.1860	High-Tech focus on C&I wastes	0.1821	0.2178	0.1999
Steadily increasing prices	0.1920	0.2143	0.2031	Low-Tech uncoordinated and diverse	0.1597	0.1519	0.1558
Reversal of super-cycle	0.2034	0.1886	0.1960	Holistic and integrated approach to RM**	0.2157	0.2264	0.2210

* ECB = environmentally conscious behaviour ** RM = resource management

endogenous nature of the variable would indicate a greater role for expert opinion.

5.3.1.4 Producing narratives from the plausibility results

In the last stage of the plausibility process, weights were combined to produce indicative scenarios based entirely on scores. These were then sent back to stakeholders for final feedback. Table 5.5 shows an indicative 'scored' scenario sent to stakeholders.

Table 5.5: Indicative scenario sent for stakeholder feedback

Variables	Options	Weight
Demographics	Increasing population balances ageing	0.2257
Socio-Economic Situation	Growing affluence	0.2371
Consumption patterns + environmental behaviour	Strong increase in sustainable consumption	0.2275
Economic output	Steady growth	0.2436
Economy structure	Continued shift to services	0.2235
Corporate Eco-Behaviour	Competitiveness depends on CE (leader)	0.2429
Commodity Markets	Closed markets and protectionism	0.2206
Energy System	Increase in AD and associated EfW	0.2306
Waste System	Decreasing trend in waste over long-term	0.2107
EfW Capacities / Technologies	Small-scale EfW	0.2247
System Support + Intervention	Zero Waste England (RM Strategy, 2020)	0.2000
Development of Landfill Tax	Sophisticated materials based approach	0.2305
Voluntary Improvements	Industry lead on C&I and C&D	0.2203
Recycle & Reuse Capacities / Technology	Coordinated expansion	0.2269

Feedback received was combined with previous thematic analysis and futures box results (see Section 5.2.2.3) to determine pathways based on variables identified from the plausibility matrices and entered into a morphological field. This process allowed refinement of choices and thus avoided any obvious contradictions and inconsistencies, such as lowering commodity prices driving the push for materials capture within the VM scenario. Undertaking this step allowed the inclusion of choices which were directly attributable to specific scenarios. Table 5.6 shows the final CE narrative for 2050 derived from the aggregated weights in Table 5.4 and final stakeholder feedback. All other scenario narratives captured within morphological fields are included in Appendix 6.

Table 5.6: CE Scenario narrative morphological field derived from plausibility scoring and stakeholder feedback

Option	Demographics	Socio-Economic Situation	Consumption patterns + EB	Economic output	Economy structure	Corporate Eco-Behaviour	Commodity Markets	Energy System	Waste System	EfW Capacities / Technologies	Sytsem Support + Intervention	Development of Landfill Tax	Voluntary Improvements	Recycle & Reuse Capacity
1	Stable Population Growth	Growing affluence	Good attitudes, wasteful behaviour	Steady growth	Continued shift to services	Uncoordinated approaches	Closed markets and protectionism	Slow shift to renewables	Slow increase in recycling and recovery rates	Small-scale EfW	Stable legislation	Gradual tax increases	Stable support and participation	MSW dominates development
2	Population boom	Income re-distribution	Strong increase in sustainable consumption	Rapid per capita growth	Resurgence of British manufacturing	Low level of concern and efficiency	Open markets and stable supplies	Increase in AD and associated EfW	Decreasing trend in waste arisings over long-term	Large scale EfW	Push for deregulation	Hammering of landfill	Increase in policy driven measures	Coordinated expansion
3	Rapidly ageing population, stagnation	Inequality reigns	Steady buying power, conscious choices	Bust-boom cycle	Centre of excellence (quality based production)	Sustainability / resource efficiency drive	High prices and strong volatility	Large increase in ATT (centralised)	Low impact of waste prevention policies	De-coupled fuel production and consumption	More legislation, more standardisation	Landfill reduction and Incineration tax	Decrease in policy measures / industry responses	High-Tech focus on C&I wastes
4	Increasing population balances ageing	Poorer society	Low consumption and high environmental consciousness	Double dip recession (cycle)	Balancing (growth of green economy)	Economic competitiveness depends on CE approach (behind curve)	Steadily increasing prices	Mergers between energy and waste companies	High impact of waste prevention policies	Large % increase in centralised AD (biogas production)	Zero Waste England (Resource Management Strategy, 2020)	Sophisticated materials based approach	No policy but strong industry response to consumer demands	Low-Tech uncoordinated and diverse
5	Decreasing population growth	Income squeeze continues	High consumption and low environmentally conscious behaviour	Triple dip recession (cycle)	Product design and stewardship focus	Economic competitiveness depends on CE approach (ahead of curve)	Reversal of super-cycle	Market reform for smaller producer entry	Shift to materials based approach	Large % increase in on-farm AD (decentralised)	Secondary materials markets flourish (replace virgin materials)	Decrease in landfill tax	Industry lead on C&I and C&D	Holistic and integrated approach to resource management

5.3.2 Outlining the scenario narratives

The purpose of producing detailed narratives for each of the scenarios is to make explicit the conditions prevalent within each vision. This is an essential step in differentiating between the scenarios for stakeholders and decision-makers alike. This section will first explore the qualitative narratives in tabular format before describing these in detail in terms of the key evaluative criteria (STEEP). It will then move on to quantifying the narratives and steps taken to validate these choices in forming the quantitative model.

5.3.2.1 Qualitative scenario narratives

The findings of the qualitative narrative formation process for the four scenarios are presented in Tables 5.7 to 5.10. These narratives have been assigned recognisable labels (Circular Economy - CE; Valorisation & Materials – VM; Ecological Citizenship – EC; and Economic Destabilisation – ED) but could equally have been assigned discrete numerators. The purpose is not to facilitate preconceptions based on the titles but to act as differential signposts for evaluation by stakeholders. The tables are accompanied by short descriptive outlines of the key themes and critical points across the timeline.

5.3.2.1.1 Scenario CE: A narrative on the Circular Economy

The narrative storyline for the CE scenario should be viewed in conjunction with Table 5.7. The vision of a zero waste future in 2050 within a Circular Economy (CE) scenario sees the waste sector reinvented as a resource management sector with ‘waste’ in all forms being targeted through an integrated policy approach. This scenario is significantly policy driven with government highly involved in trying to bring about its own version of a Circular Economy. This resource focused policy approach is an extension of previous policies based on achieving a ‘green economy’ (BIS/DECC/DEFRA, 2011) and sits within the broad government commitment to decarbonising the economy (Anderson et al. 2005; PWC, 2013). However, change is largely incremental and lacks any real ability to decouple economic growth from waste generation, although gains are made through resource efficiency.

Integrated approaches see modest reductions in waste generation rates particularly with the emphasis on product redesign throughout the economy. This integrated approach draws heavily on voluntary agreements with business and third sector organisations to divert materials from landfill to established secondary materials routes and markets. The case for resource efficiency throughout production processes has been well established with potential cost savings realised across all business classes and sizes. The period from 2012 to 2050 has seen an extended decreasing trend in solid waste generation particularly as the period up to 2030 saw an increased focus within the sector towards materials rather than waste.

There has been an increased alignment between the ‘waste’ and energy sectors throughout the period with a decoupling of fuel production and levels of production. This decoupling has largely been within the area of commercial and residential demand with a large amount of AD capacity coming on-stream. The scale of such facilities is ideally suited to locations close to business parks and new residential developments. These facilities have in certain instances been incorporated within larger energy production facilities employing Advanced Thermal Treatment (ATT) of residual waste. However, high investment costs combined with reducing levels of feedstock (residual fraction) has been problematic for contracts between Local Authorities and energy companies. These problems only become manifest later in the period as a sustained escalator on landfill tax has seen levels rise by around 25% each decade. A somewhat contradictory policy has been introduced in the form of an incineration tax which has added to operational problems for contracts and ATT facilities.

External pressures on absolute levels of waste have come from an increasing population,

Table 5.7: Key characteristics of the Circular Economy (CE) qualitative narrative

Key Factors	2050	2040	2030	2020	2012
Demographics	Stable Population Growth	Stable Population Growth	Increasing population	Increasing population	Increasing population
Socio-Economic Situation	Income re-distribution	Income re-distribution	Income re-distribution	Income re-distribution	Inequality reigns
Consumption patterns + environmental behaviour	Low consumption and environmentally conscious behaviour	Low consumption and environmentally conscious behaviour	Low consumption and environmentally conscious behaviour	Low consumption and environmentally conscious behaviour	Consumption patterns shift slowly towards 2020
Economic output	Rapid per capita growth	Rapid per capita growth	Rapid per capita growth	Rapid per capita growth	Bust-boom cycle to 2020
Economy structure	Product design and stewardship focus	Product design and stewardship focus	Product design and stewardship focus	Product design and stewardship focus	Service sector focus with some consideration of design
Corporate Eco-Behaviour	Sustainability / resource efficiency drive	Sustainability / resource efficiency drive	Sustainability / resource efficiency drive	Sustainability / resource efficiency drive	Sustainability / resource efficiency drive
Commodity Markets	Steadily increasing prices	Steadily increasing prices	Steadily increasing prices	Steadily increasing prices	Steadily increasing prices
Energy System	Large increase in ATT (centralised)	Large increase in ATT (centralised)	Large increase in ATT (centralised)	Large increase in ATT (centralised)	Large increase in ATT (centralised)
Waste System	Decreasing trend in waste arisings over long-term	Decreasing trend in waste arisings over long-term	Shift to materials based approach	Shift to materials based approach	Shift to materials based approach
EfW Capacities / Technologies	De-coupled fuel production and consumption	De-coupled fuel production and consumption	De-coupled fuel production and consumption	De-coupled fuel production and consumption	De-coupled fuel production and consumption
System Support + Intervention	Secondary materials markets develop	Secondary materials markets develop	Secondary materials markets develop	Secondary materials markets develop	Secondary materials markets develop
Development of Landfill Tax (environmental taxes)	Hammering of landfill/ incineration	Hammering of landfill/ incineration	Hammering of landfill/ incineration	Hammering of landfill	Hammering of landfill
Voluntary Improvements	Increase in policy driven measures	Increase in policy driven measures	Increase in policy driven measures	Increase in policy driven measures	Increase in policy driven measures
Recycle & Reuse Capacities / Technology	Holistic and integrated approach to resource management	Holistic and integrated approach to resource management	Holistic and integrated approach to resource management	Holistic and integrated approach to resource management	Shift towards holistic approach begins

particularly within Northamptonshire and other growth areas. In addition, there has been a sustained level of rapid per capita economic growth. Commodity markets have witnessed steadily increasing prices throughout the period which has put pressure on materials usage and issues around scarcity. This situation has boosted incentives to develop technologies capable of increasing reuse, recycling and recovery of valuable materials from ‘resource streams’. This concept has developed considerably and values have increased significantly for all fractions spurring technological development and the growth of secondary markets still further. Finally, the period has seen an increased focus on income redistribution in the wake of financial crises and increasing disenchantment with political parties. Policies have increasingly moved towards social justice which has brought environmental concerns further to the fore. This has manifested in lower levels of consumption after sustained education and awareness raising programmes on environmental issues including reducing waste.

5.3.2.1.2 Scenario VM: Value above all – Valorisation & Materials

This scenario is heavily focused on materials security and technological solutions towards capturing materials through recycling and recovery (shown in Table 5.8). It is largely driven by increased private sector influence and is thus comparable in some ways to the GEO-4 Security First scenario (UNEP, 2007). However, the position in England is exacerbated by a lack of clear policy direction on resource management issues. There is a continued focus on municipal waste throughout the period as market conditions are perceived to be the best solution for commercial and industrial waste streams (including those from the construction sector). The technological focus is on using large scale Advanced Thermal processes to convert waste-to-energy as this is seen as the most bankable option for investment.

The period sees no substantial change in legislation with continued emphasis on recovery as opposed to reducing the overall quantity of waste in order to safeguard feedstock's for large scale infrastructure and capital investment. The landfill tax is continued throughout the period in order to encourage diversion from landfill but the level is set at 1% above inflation. This approach is seen as the best way of maintaining the viability of large scale recovery while still meeting EU driven targets for overall recovery. There is no introduction of an incineration tax within this scenario. Ownership remains with large scale traditional operators acting within larger financing partnerships. This produces a 'stacking' effect of technologies at larger sites (similar to Amey Cespa's Integrated Waste Management Site at Waterbeach in Cambridge) which draw wastes in from large geographical areas. However, this arrangement is still characterised by Local Authority boundaries and contractual arrangements which hampers the overall operational efficiency and retains a policy focus on municipal waste. This scenario generates significant success in capturing larger percentages of materials for recycling with a large proportion of residual waste passing through EfW facilities to recover energy.

A number of significant external factors drive this technologically focused scenario. Principal among these are the steadily increasing prices of commodities and the resultant increase this leads to in recovered materials prices. In addition, concerns over energy security see a significant upscaling in diversion to EfW which includes large scale building of AD facilities with the resulting biogas being used for heat and power as well as for biomethane based transport fuels. This emphasis is marketed by corporations as progress towards a 'green economy' and evidence of their environmental credentials within CSR reporting. Policies in this area are also nested in the concept of a Circular Economy but the technological emphasis is the only aspect carried forwards in terms of recycling and recovery. Other factors with lesser impacts in this scenario include: the continuation of inequality which impacts on lifestyle choices for the majority; and an increasing population

Table 5.8: Key characteristics of the Valorisation & Materials (VM) qualitative narrative

Key Factors	**2050**	**2040**	**2030**	**2020**	**2012**
Demographics	Decreasing population growth (EU repatriation & skills quota approach)	Decreasing population growth (EU repatriation & skills quota approach)	Stabilising population	Population boom	Population boom
Socio-Economic Situation	Inequality reigns	Inequality reigns	Inequality reigns	Inequality reigns	Inequality reigns
Consumption patterns + environmental behaviour	Steady buying power, conscious choices	Steady buying power, conscious choices	Steady buying power, conscious choices	Steady buying power, conscious choices	Steady buying power, conscious choices
Economic output	Double dip (recession)	Bust-boom cycle	Double dip (recession)	Bust-boom cycle	Double dip (recession)
Economy structure	Balancing (diversify - growth of green economy)	Balancing (diversify - growth of green economy)	Balancing (diversify - growth of green economy)	Balancing (diversify - growth of green economy)	Manufacturing base begins to rebuild around greening infrastructure
Corporate Eco-Behaviour	Economic competitiveness depends on CE approach (behind curve)	Economic competitiveness depends on CE approach (behind curve)	Economic competitiveness depends on CE approach (behind curve)	Economic competitiveness depends on CE approach (behind curve)	Competitiveness concerns grow as emerging economies adopt CE
Commodity Markets	Reversal of super-cycle	Steadily increasing prices	Steadily increasing prices	Steadily increasing prices	Steadily increasing prices
Energy System	Market reform for smaller producer entry	Market reform for smaller producer entry	Market reform for smaller producer entry	Market reform for smaller producer entry	Public pressure to reform markets increases
Waste System	Decreasing long-term trend in waste arisings	Decreasing long-term trend in waste arisings	Shift to materials based approach	Shift to materials based approach	Shift to materials based approach
EfW Capacities / Technologies	Large scale EfW	Large scale EfW	Large scale EfW	Large scale EfW	Large scale EfW
System Support + Intervention	Stable legislation	Stable legislation	Stable legislation	Stable legislation	Stable legislation
Development of Landfill Tax (environmental taxes)	Gradual tax increases	Gradual tax increases	Gradual tax increases	Gradual tax increases	Gradual tax increases
Voluntary Improvements	No policy but strong industry response to consumer demands	No policy but strong industry response to consumer demands	No policy but strong industry response to consumer demands	No policy but strong industry response to consumer demands	No policy but strong industry response to consumer demands
Recycle & Reuse Capacities / Technology	LACW dominates development with technology focus on C&I	LACW dominates development with technology focus on C&I	LACW dominates development with technology focus on C&I	LACW dominates development with technology focus on C&I	LACW dominates development with technology focus on C&I

to 2030 before beginning to decline after 2040 with implications for per capita generation. These last two points are exacerbated by the continuation of traditional economic cycles (boom and bust) throughout the period which impacts on consumer choices over environmental considerations for products and services.

5.3.2.1.3 Scenario EC: sustainable consciousness - Ecological Citizenship

The EC scenario reflects the principles of sustainability from a deep ecological perspective with significant changes in behaviours from individuals, organisations and businesses. This scenario is consistent with the GEO-4 Sustainability First scenario (UNEP, 2007, p.410) as well as the more optimistic elements of 'Vision 2050' (WBCSD, 2010). The main characteristics and timeline for the EC scenario are described in Table 5.9 with a more detailed narrative of the key characteristics explored subsequently.

The population has increased throughout the period driven mainly by migration and increased birth rates within the population at large. This has gradually balanced the ageing effect witnessed prior to the baseline year. New skills from migrant workers, English people retraining around green business sectors and the availability of labour have allowed the expansion of reuse models as well as increased materials segregation in labour intensive recovery operations. Education and awareness of all resource issues and the benefits of more efficient business models has seen school and university leavers increasingly skilled around and aware of the need for ecological literacy (Capra, 1996, p.299) when doing business. This has embedded practices within corporate behaviour which has transformed many businesses into global leaders on applying Circular Economy principles. However, the EC scenario goes much further than the previous CE scenario with business models based on community ownership a key factor in influencing consumer choices and in redistributing wealth through share options for employees and investors. These models have allowed private sector funding for required reuse, recycling and recovery infrastructure. Notwithstanding this change, there is a significantly reduced need for such infrastructure as systems thinking approaches to waste have seen the waste hierarchy applied with regard to waste prevention as the first consideration. This principle is embedded within the Zero Waste Strategy for England introduced in 2020 representing a radical shift from the target driven approach of earlier years.

The outcome has been very significant percentage reductions in waste generation rates with increased use of redesign for products and services as well as substitution and innovation around materials utilised in manufacture of consumables. Leasing models have been widely utilised and developed throughout the period. This has drawn on early success from the automotive sector which quickly shifted towards a leasing model between 2015 and 2020 in order to maintain ownership of materials in light of concerns over resource scarcity and high commodity prices. Landfill bans have been introduced for all recyclable materials as well as a continued focus on high landfill tax for residual waste and the introduction of an incineration tax to discourage the diversion of valuable materials to EfW before it has been segregated for reuse or recycling.

The scenario also sees a more protectionist approach to materials and commodities at the national scale with increased protectionism from government. This negative outcome has implications for international trade but is countered by a strong movement towards localised networks with global reach. This process is transitional throughout the period and is largely established as a new model for globalisation reflecting networks of relationships and a shift away from materialism in favour of happiness and well-being by 2050.

5.3.2.1.4 Scenario ED: austerity prevails - Economic Destabilisation

The ED scenario largely fits with the description of a reference scenario as suggested in the literature (UNEP, 2007; Anderson et al. 2008; WBCSD, 2010; DEFRA, 2011$_b$). However, it departs from this role in certain aspects, largely concerning the impact of

Table 5.9: Key characteristics of the Ecological Citizenship (EC) qualitative narrative

Key Factors	**2050**	**2040**	**2030**	**2020**	**2012**
Demographics	Increasing pop balances ageing, greater diversity	Increasing pop balances ageing, greater diversity	Increasing pop balances ageing, greater diversity	Increasing pop balances ageing, greater diversity	Increasing pop balances ageing, greater diversity
Socio-Economic Situation	Growing affluence	Growing affluence	Growing affluence	Growing affluence	Income squeeze
Consumption patterns + environmental behaviour	Strong increase in sustainable consumption	Strong increase in sustainable consumption	Strong increase in sustainable consumption	Strong increase in sustainable consumption	High consumption and low environmentally conscious behaviour
Economic output	Steady growth	Steady growth	Steady growth	Steady growth	Double dip (recession)
Economy structure	Continued shift to services	Continued shift to services	Continued shift to services	Continued shift to services	Continued shift to services
Corporate Eco-Behaviour	Competitiveness depends on CE (ahead of curve)	Competitiveness depends on CE (ahead of curve)	Competitiveness depends on CE (ahead of curve)	Competitiveness depends on CE (ahead of curve)	Competitiveness depends on CE (ahead of curve)
Commodity Markets	Closed markets and protectionism	Closed markets and protectionism	Closed markets and protectionism	Closed markets and protectionism	High prices and strong volatility
Energy System	Increase in AD and associated EfW	Increase in AD and associated EfW	Increase in AD and associated EfW	Increase in AD and associated EfW	Increase in AD and associated EfW
Waste System	High impact of waste prevention policies	High impact of waste prevention policies	High impact of waste prevention policies	High impact of waste prevention policies	High impact of waste prevention policies
EfW Capacities / Technologies	Small-scale EfW	Small-scale EfW	Small-scale EfW	Small-scale EfW	Small-scale EfW
System Support + Intervention	Zero Waste England (Resource Strategy, 2020)	Zero Waste England (Resource Strategy, 2020)	Zero Waste England (Resource Strategy, 2020)	Zero Waste England (Resource Strategy, 2020)	Target driven to 2020 (continuation)
Development of Landfill Tax (environmental taxes)	Sophisticated materials based approach	Sophisticated materials based approach	Sophisticated materials based approach	Sophisticated materials based approach	Escalator continues to 2020
Voluntary Improvements	Industry lead on C&I and C&D	Industry lead on C&I and C&D	Industry lead on C&I and C&D	Industry lead on C&I and C&D	Industry lead on C&I and C&D
Recycle & Reuse Capacities / Technology	Coordinated expansion	Coordinated expansion	Coordinated expansion	Coordinated expansion	Coordinated expansion from 2015

specific destabilising events. These are limited in scope for the purposes of testing the impact of the scenario but have been broadened in terms of testing the sensitivity of this ‘continuation of current trends’ scenario against the previously described CE; VM; and EC scenarios.

The key characteristics of the ED scenario and timeline for changes are described in Table 5.10 with a detailed description of the key characteristics made subsequently. It is also noteworthy to mention that the results included in ED are the result of iterations with stakeholder input through plausibility testing (see section 5.3.3.1) rather than merely describing a ‘worst case scenario’. In essence, after scoring data was aggregated these results were given to stakeholders for feedback with a broad consensus being taken forwards rather than relying solely on scoring.

The economic downturn of the period immediately prior to the 2012 baseline has a marked and prolonged effect on society and all economic sectors. This squeezes investment opportunities for waste policy development resulting in a continuation of the approach ‘doing more with less’ (HMG, 2011). The squeeze carries over to incomes directly related to levels of economic growth which are either subdued or increase slowly during continuous periods of bust and boom. The population continues the trend of rapidly ageing particularly as former migrants begin to repatriate and skills based quotas have an impact after introduction prior to 2020. The EU continues to move between crises, particularly around the Euro, with resentment from southern states over imposed austerity measures. This leads to a strategy of blocking legislation passing through the parliament and impacts on new policy formation around waste and resource efficiency.

As a result, more stringent targets are delayed and countries seek to achieve their minimum requirements under existing legislation. This is heightened by some states not achieving

Table 5.10: Key characteristics of the Economic Destabilisation (ED) qualitative narrative

Key Factors	**2050**	**2040**	**2030**	**2020**	**2012**
Demographics	Rapidly ageing population, stagnation	Rapidly ageing population, stagnation	Rapidly ageing population, stagnation	Rapidly ageing population, stagnation	Rapidly ageing population, stagnation
Socio-Economic Situation	Poorer society	Poorer society	Inequality reigns	Inequality reigns	Income squeeze
Consumption patterns + environmental behaviour	High consumption and low environmentally conscious behaviour	High consumption and low environmentally conscious behaviour	High consumption and low environmentally conscious behaviour	High consumption and low environmentally conscious behaviour	High consumption and low environmentally conscious behaviour
Economic output	Triple dip (recession)	Bust-boom cycle	Bust-boom cycle	Bust-boom cycle	Triple dip (recession)
Economy structure	Resurgence of British manufacturing	Resurgence of British manufacturing	Resurgence of British manufacturing	Resurgence of British manufacturing	Shift to services slows
Corporate Eco-Behaviour	Diverse approaches, uncoordinated	Diverse approaches, uncoordinated	Low level of concern and efficiency	Low level of concern and efficiency	Low level of concern and efficiency
Commodity Markets	High prices and strong volatility	High prices and strong volatility	High prices and strong volatility	High prices and strong volatility	High prices and strong volatility
Energy System	Slow shift to renewables	Slow shift to renewables	Slow shift to renewables	Slow shift to renewables	Slow shift to renewables
Waste System	Low impact of waste prevention policies	Low impact of waste prevention policies	Low impact of waste prevention policies	Low impact of waste prevention policies	Low impact of waste prevention policies
EfW Capacities / Technologies	Large % increase in on-farm AD (decentralised biogas production)	Large % increase in on-farm AD (decentralised biogas production)	Large % increase in on-farm AD (decentralised biogas production)	Large % increase in on-farm AD (decentralised biogas production)	Large % increase in on-farm AD (decentralised biogas production)
System Support + Intervention	More legislation, more standardisation	More legislation, more standardisation	More legislation, more standardisation	More legislation, more standardisation	More legislation, more standardisation
Development of Landfill Tax (environmental taxes)	Decrease in landfill tax	Decrease in landfill tax	Decrease in landfill tax	Freeze in landfill tax	Escalator ends in 2015 with freeze thereafter
Voluntary Improvements	Decrease in policy measures / industry responses	Decrease in policy measures / industry responses	Decrease in policy measures / industry responses	Decrease in policy measures / industry responses	Decrease in policy measures / industry responses
Recycle & Reuse Capacities / Technology	Low-Tech, uncoordinated and diverse	Low-Tech, uncoordinated and diverse	Low-Tech, uncoordinated and diverse	Low-Tech, uncoordinated and diverse	Low-Tech, uncoordinated and diverse

targets (2020) which results in further crises over fines and the ability or refusal to pay these. Overall societies across Europe become poorer as newer global regions come to the fore often embedding circular economic models, thus producing further downwards pressure on growth in England and the wider EU.

The waste sector in general is characterised by a lack of coordination in approach with municipal waste remaining the focus for Local Authorities thus continuing existing inefficiencies in the system as a whole as wastes are treated as separate issues rather than holistically. The energy sector continues to slowly shift towards renewables and the uptake of AD at the farm scale is a driver for this. This in part is needs driven, on the part of rural communities, to diversify as they continue to lag behind urban centres in terms of income levels and employment opportunities. Conversely, manufacturing becomes resurgent on the back of renewables projects including AD which becomes home grown.

5.4 Evaluating the visions against the baseline: QM results

Having established the visions of what a zero waste future would be and the structural context of the system in terms of the baseline the next stage of the process is to establish the degree of change which would be required to achieve the desirable vision. A quantitative model (QM) was developed in spreadsheet format to undertake the assessment. This model incorporates targets and levels of waste prevention, reuse, recycling and recovery indicated in the visioning process. Given the difference in focus of each scenario these targets are likely to differentiate according to the focus of the specific scenario.

It is also important to demonstrate through the scenario pathways how visions can be achieved in terms of the degree of movement away from the baseline (e.g. through increases or decreases in waste generation; via economic costs and savings; or in terms of direct and avoided emissions of carbon). To this end, established targets in the literature are used to frame progress towards the vision in terms of generalised targets and absolute levels of reduction or recovery which may be required.

5.4.1 Impact on waste tonnages

5.4.1.1 Baseline tonnages

The baseline tonnages for the study area are shown in Table 5.11. These quantities formed the basis of the QM and were also used as the basis for conversion of the final outputs to economic valuations and levels of carbon emissions associated with the waste management system. Waste prevention and reuse are reported as nil in order to determine the impact of such policies against the starting quantities.

Table 5.11: QM baseline quantities (tonnes) for all waste streams in 2012

Baseline tonnages (2012)	LACW (t)	C&I (t)	C&D (t)	Hazardous (t)	All wastes (t)
Waste prevention	-	-	-	-	-
Reuse	-	-	-	-	-
Recycling	155,554	547,317	839,609	17,435	1,559,914
Recovery	19,738	65,694	138,510	23,892	247,834
Disposal	164,435	341,838	337,264	52,918	896,455
Totals	339,727	954,850	1,315,382	94,245	2,704,204

Table 5.10 shows that C&D waste is almost half (48.6%) of all wastes and accounts for 53.8% of all recycling and 55.9% of all recovery. C&I waste is the next largest proportion (35.3%) of all wastes accounting for 35.1% of all recycling and 26.5% of recovery. LACW is a smaller fraction of all wastes (12.6%) in the study area accounting for almost one tenth (9.97%) of recycling and slightly less (7.96%) of recovery. Hazardous waste is the smallest fraction of all wastes (3.49%) and accounts for just 1.12% of all recycling but surpasses LACW with 9.64% of all recovery. Overall quantities of all wastes were 2.70Mt in 2012 with 57.7% of this figure recycled, 9.16% sent for recovery with the remaining 33.2% sent for disposal via landfill or incineration without energy recovery.

5.4.1.2 Impact of system variables on waste arisings

The next stage in the QM is to produce factor values for each system variable (both exogenous and endogenous). A range of indicative values are shown in Table 5.12 for the per annum impact of all variables on each waste within each scenario. The full results are presented in Appendix 7.

Table 5.12: Factor values for per annum impact of system variables on waste generation

LACW	2012	2020	2030	2040	2050
CE	0.9975	1.0002	0.9984	0.9974	0.9963
VM	0.9974	0.9996	0.998	0.9977	0.9969
EC	0.9976	1.0003	0.9986	0.9984	0.9977
ED	0.9995	1.0013	1.0025	1.0038	1.0031
C&I	2012	2020	2030	2040	2050
CE	0.9983	1.0013	0.9989	0.9977	0.9966
VM	0.9982	1.0006	0.9984	0.9979	0.9971
EC	0.9984	1.0015	0.9991	0.9987	0.998
ED	1.0005	1.0026	1.004	1.0051	1.0041
C&D	2012	2020	2030	2040	2050
CE	0.9973	1.0002	0.9987	0.9974	0.9965
VM	0.9972	0.9985	0.9973	0.9968	0.9961
EC	0.9973	1.0003	0.999	0.9986	0.998
ED	0.9996	1.0013	1.0027	1.0038	1.003
Hazardous	2012	2020	2030	2040	2050
CE	0.9983	1.0013	0.9989	0.9977	0.9966
VM	0.9982	1.0006	0.9984	0.9979	0.9971
EC	0.9984	1.0015	0.9991	0.9987	0.998
ED	1.0005	1.0026	1.004	1.0051	1.0041
All wastes	2012	2020	2030	2040	2050
CE	0.998	1.001	0.999	0.998	0.997
VM	0.998	1.000	0.998	0.998	0.997
EC	0.998	1.001	0.999	0.999	0.998
ED	1.000	1.002	1.003	1.004	1.004

Note: values are shown to 4 significant figures to avoid automatic rounding

As can be seen in Table 5.12 the values across the significant milestones of the scenarios (CE, VM, EC and ED) are not linear. This non-linearity is further illustrated in Figure 5.11 in terms of the cumulative impact of system variables on overall waste arisings.

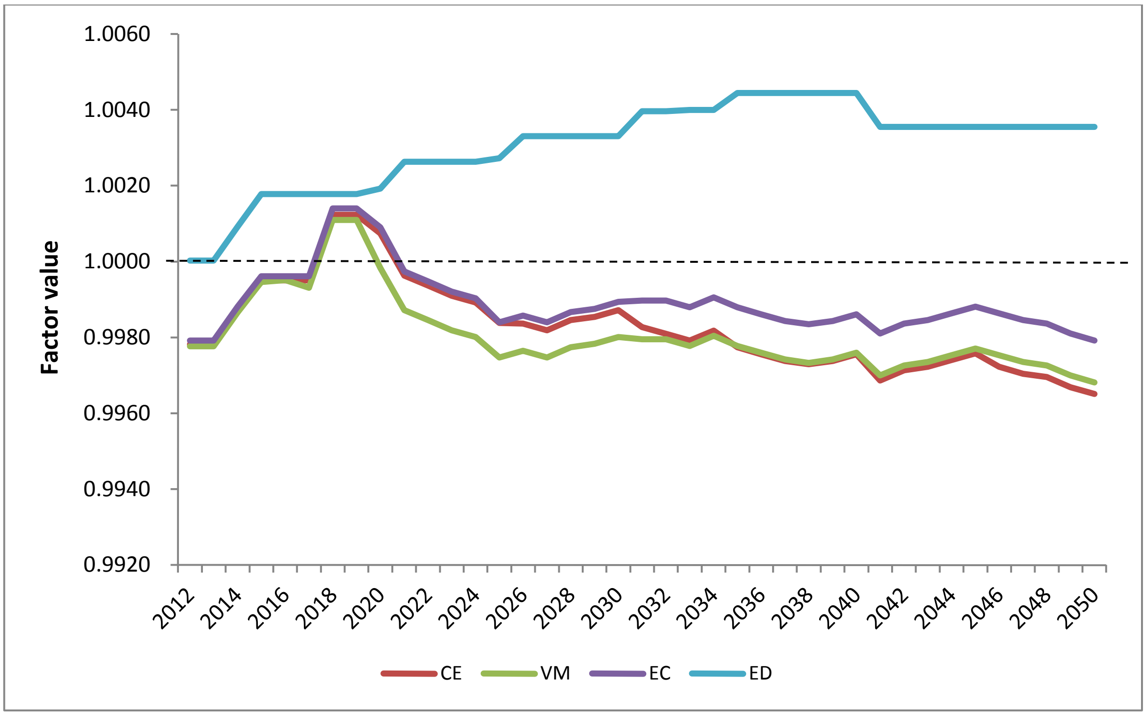


Figure 5.11: Per annum impact of system variables on overall waste arisings

Figure 5.11 shows that all scenarios witness an overall upwards pressure on waste arisings until 2019 associated with the cumulative impact of all 14 exogenous and endogenous variables. However, from 2020 there is a divergence between scenarios with ED maintaining an upwards pressure on arisings throughout the period of the backcast (being above the 1.000 factor from 2014 onwards) and all other scenarios experiencing a sustained downwards pressure on overall waste generation from 2020 (VM) and 2021 (CE and EC). The three reducing scenarios exhibit different profiles across the period (2021 to 2050) with VM having the largest and most sustained downwards pressure of 0.2-0.3% per annum (in the range 0.997 to 0.998 from 2024 to 2045). The period 2032 to 2045 shows a convergence between CE and VM before divergence at 2046 with CE reaching the largest annual value of 0.9965 (0.35% pa). A further convergence is seen between CE and EC during the period 2012 to 2025 whereupon EC parallels VM at a factor of between 0.0009 and 0.0011 higher than VM (0.9984 to 0.9979 compared with 0.9975 to 0.9968). Cumulative impacts for the backcast period were: CE (5.74% reduction); VM (7.29% reduction); EC (3.59% reduction); and ED (9.01% increase).

5.4.1.3 Impact of waste prevention and reuse on waste arisings

The impact of waste prevention initiatives (prevention and reuse according to the WFD definition – see section 2.3) are treated separately in terms of the calculations for impact on overall waste arisings. Figure 5.12 shows the impact of prevention initiatives across the backcast period for all scenarios.

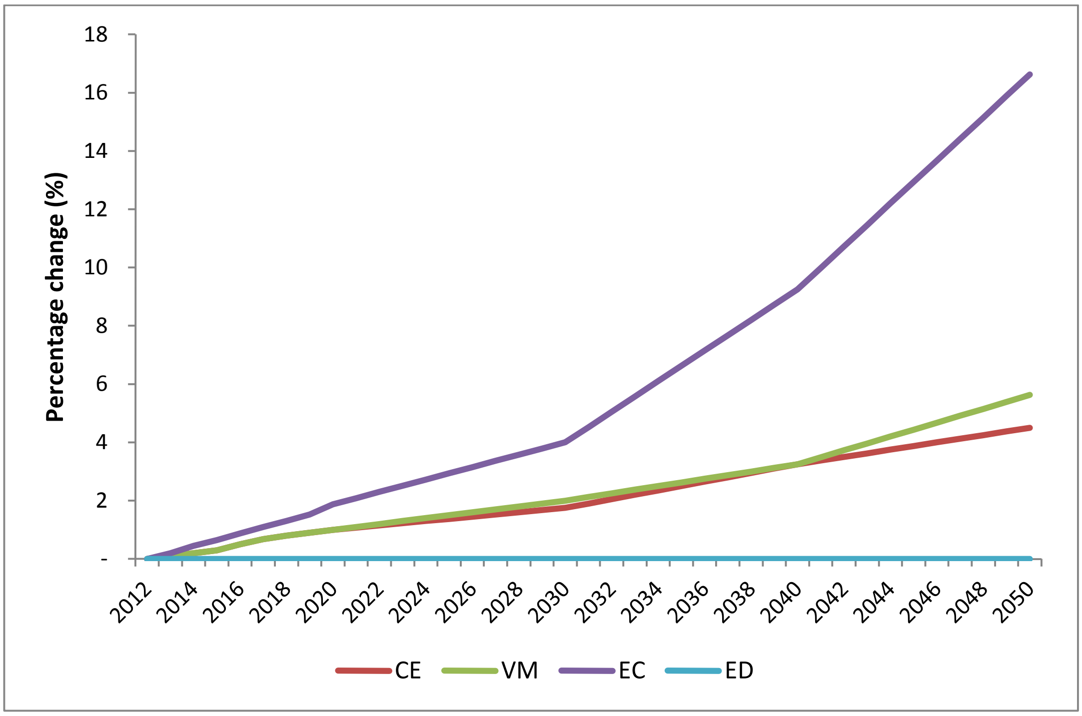


Figure 5.12: Cumulative impact of prevention initiatives on overall waste generation

Figure 5.12 shows prevention initiatives have the largest impact in scenario EC (16.63% against the baseline tonnage). This compares to a very similar impact for scenarios CE and VM until 2041 when there is a divergence until 2050 when prevention initiatives have a cumulative impact of 5.63% compared to 4.50% in scenario CE. Waste prevention initiatives do not have any impact across the period for scenario ED. In terms of the impact of reuse initiatives, Figure 5.13 visualises these as percentage change in overall waste generation against the baseline (2012 tonnages).

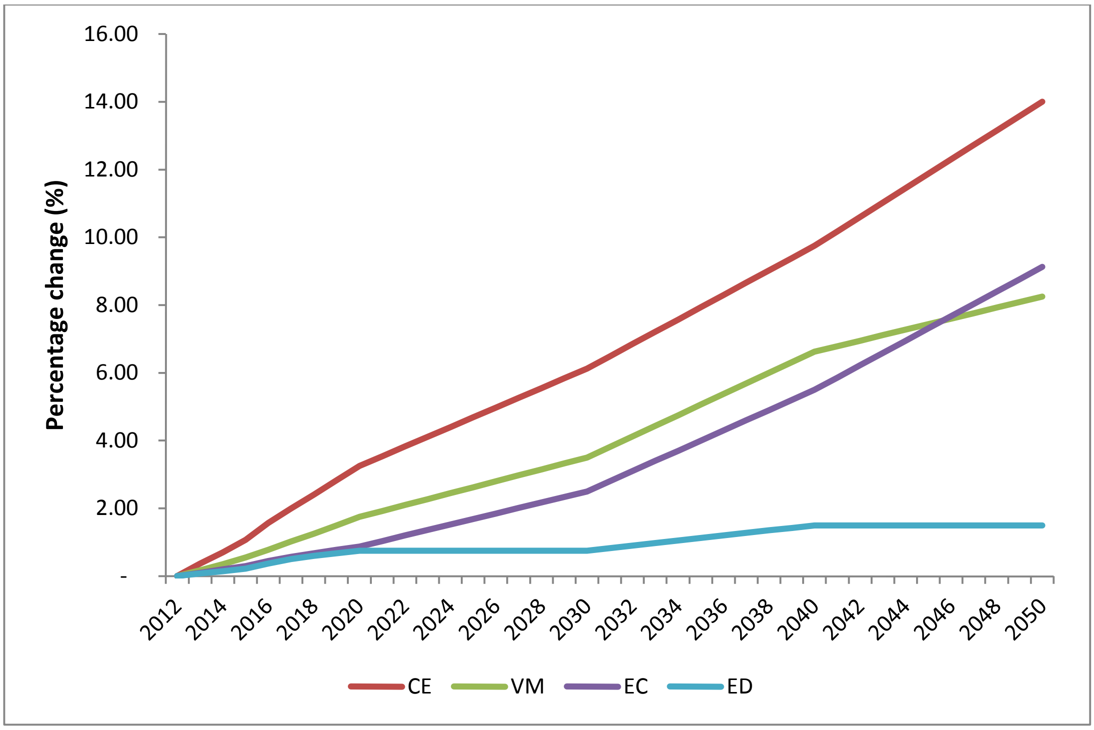


Figure 5.13: Cumulative impact of reuse initiatives on overall waste generation

Figure 5.13 shows that reuse initiatives have the greatest impact within scenario CE (14.00% by 2050 against the baseline). Scenario VM performs better than EC and ED throughout the period until 2045 when EC matches then surpasses VM. By 2050, scenario EC shows reuse initiatives as having a cumulative impact of 9.13% compared with 8.25% for scenario VM. Reuse has some impact within scenario ED and matches scenario EC until 2021, after which it remains between a range of 0.75 and 1.50% (to 2050).

These calculations are then combined to give an overall cumulative impact of all waste prevention initiatives on overall waste generation across the backcast period (2012 to 2050). Figure 5.14 shows the combined result for waste prevention.

The combined results show that scenario EC has the largest cumulative impact by 2050 on overall waste generation against the baseline (a 25.75% reduction). This compares with totals for CE (18.50% reduction); VM (13.88% reduction); and ED (1.50% reduction). It is also clear that scenario CE outperforms all other scenarios until 2034 when it is matched and subsequently passed by scenario EC.

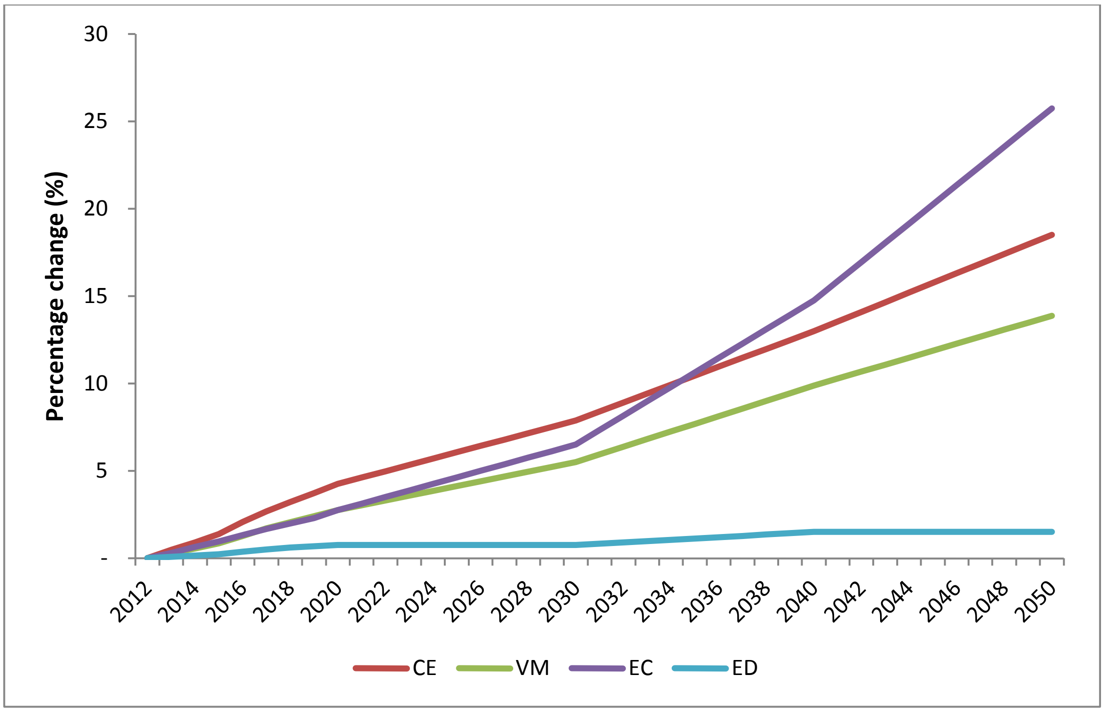


Figure 5.14: Cumulative impact of all waste prevention on overall waste generation

By 2050, overall waste prevention within scenarios EC, CE and VM are an order of magnitude greater than those within scenario ED.

5.4.1.4 Summary of impacts on waste tonnages

In order to make calculations for the economic and carbon equivalence impacts it is first necessary to apply the values for waste prevention and the values for systems variables to overall waste tonnages. In doing so, it is possible to produce the first results for impact of scenarios on waste tonnages allowing the performance to be measured against an industry and sector recognised metric.

When the results from the QM are compared it can be seen that CE has the largest overall decrease in waste arisings to just under 2.05Mt (Table 5.13) an overall reduction of 658kt from the baseline. Scenario EC has a similar level of overall reduction to just over 2.05Mt whereas VM has an overall reduction of 537kt to 2.16Mt in 2050. In contrast, ED is the only scenario with an overall increase of 270kt with a final level of 2.97Mt.

Table 5.13: Summary of recycling, recovery and disposal performance (tonnages and percentage change) by scenario in 2050

Scenario performance	Recycling (t)	Recovery (t)	Disposal (t)	Sub-total (t)
CE (tonnes)	1,600,276	272,648	173,105	2,046,030
CE (% change)	+2.59%	+10.01%	-80.69%	75.66%
VM (tonnes)	1,710,989	291,795	157,652	2,160,436
VM (% change)	+9.68%	+17.74%	-82.41%	79.89%
EC (tonnes)	1,753,747	165,134	135,251	2,054,132
EC (% change)	+12.43%	-33.37%	-84.91%	75.96%
ED (tonnes)	1,503,441	768,263	630,090	2,901,793
ED (% change)	-3.62%	+309.99%	-29.71%	107.31%

Note: Figures in red are minus values indicating an annual increase by the amount specified

Overall changes in controlled wastes (by tonnage) across the backcast period (2012 to 2050) are summarised for comparison in Figure 5.15.

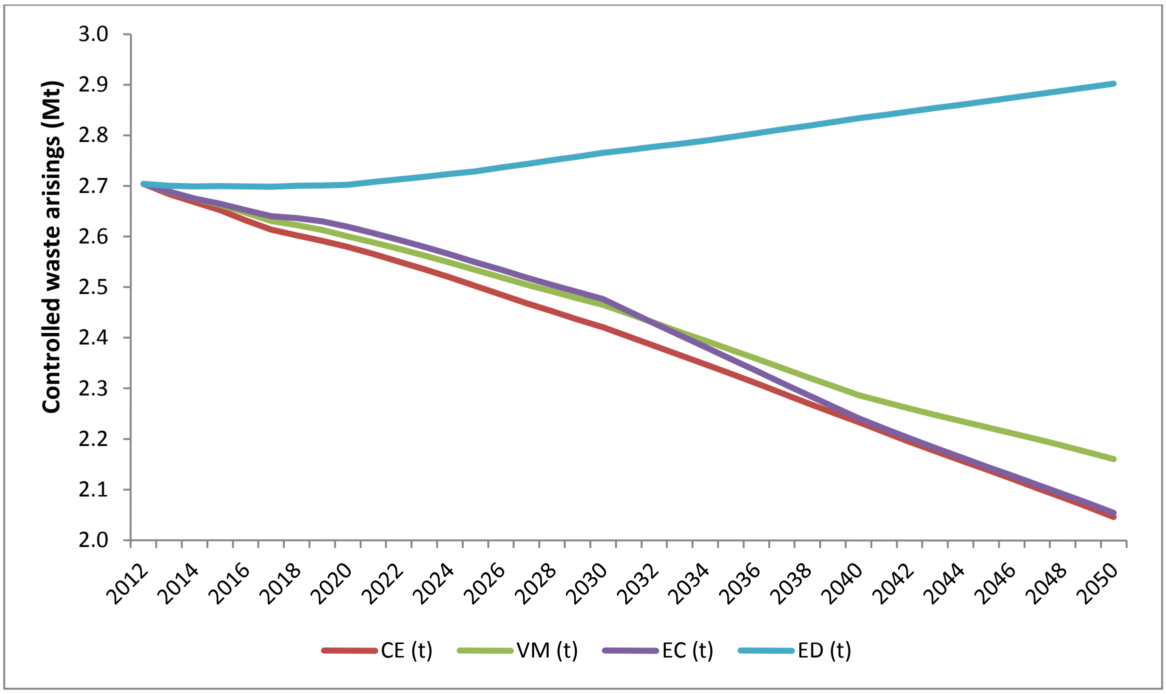


Figure 5.15: Impact of waste prevention and variables changes on total controlled wastes (Mt) in Northamptonshire for the four scenarios between 2012 and 2050.

Figure 5.15 illustrates the subtle differences between the three reducing scenarios (CE, VM and EC) with that of the reference scenario (ED) with reductions occurring throughout the period of the backcast (2012-2050). In terms of the continuing trends scenario (ED) arisings are relatively unchanged until 2020 when an upwards trend becomes established.

In terms of recycling performance; scenarios VM and ED maintain similar levels throughout the backcast period ranging from 1.61 to 1.50Mt for VM and from 1.56 to 1.53Mt for ED. Both CE and EC reduce the overall tonnages of wastes recycled by 291kt (CE) and 196kt (EC) respectively. Levels of recovery vary considerably across the four scenarios. Recovery levels for CE and VM fluctuate before returning to their baseline level in 2050 whereas scenario EC sees a reduction of 37.2%. In contrast, ED shows recovery increasing by more than 300% to 788kt. Disposal shows a reduction across all scenarios but is most pronounced within scenario EC going from 896kt to 71kt in 2050. Table 5.14 is a summary of system variables and waste prevention impacts.

Table 5.14: Summary of system variables and waste prevention impacts (t) across all scenarios in Northamptonshire (2012-2050)

Values	CE	VM	EC	ED
Systems variables	155,322	197,268	97,183	-323,694
Waste prevention	502,058	345,854	552,310	53,441

Table 5.14 shows that changes to system variables had the largest cumulative impact within scenario ED (an increase of 324kt) for the 38 year period. Scenario VM showed cumulative impacts for system variables producing the largest reduction in tonnages of 197kt. Waste prevention in scenario EC had the largest cumulative impact on all waste arisings (552kt) compared to the least impact within ED (53kt). Table 5.15 summarises overall impacts on total waste arisings.

Table 5.15: Statistical summary of impacts on total waste arisings (Mt) across all scenarios for key milestone years in Northamptonshire

Year	CE (Mt)	VM (Mt)	EC (Mt)	ED (Mt)
2012	2.70	2.70	2.70	2.70
2020	2.58	2.60	2.62	2.70
2030	2.42	2.46	2.48	2.77
2040	2.23	2.29	2.24	2.83
2050	2.05	2.16	2.05	2.97

Table 5.15 shows scenarios CE and EC as having the same level of overall arisings in 2050 (2.05Mt) compared with 2.16Mt for scenario VM. Scenario ED shows the highest level of waste arisings across all scenarios (2.90Mt).

5.4.2 Economic impacts of scenarios

There were three main factors considered for calculating the economic impact of each scenario, namely: gate fees; landfill tax; and new infrastructure provision (estimated). The following section addresses each in turn before summarising the overall economic impact. Estimated costs (direct cost to the LA) and savings (avoided costs through diversion and reduction) are based on cost per tonne (£/t) for gate fees and landfill tax. Infrastructure costings are based on average prices for specific facility types taken from planning documentation, government reports and academic literature where available.

5.4.2.1 Calculating gate fees for scenarios

Because of the different gate fees charged for materials destined for the same facility type (largely based on scale/capacity of such facilities) mean values were used to provide an indicative value per tonne of material handled.

Table 5.16: Summary of average gate fees (£/t) by management method 2008-2012

Management method	2008	2009	2010	2011	2012
Treatment	27.88	34.25	39.75	25.80	29.00
Treatment (hazardous)	n/a	n/a	n/a	n/a	78.00
Recovery	53.00	62.00	75.00	84.00	75.00
Landfill (non-hazardous)	21.00	22.00	22.00	20.00	21.00
Landfill (hazardous)	n/a	n/a	n/a	n/a	51.33

Source: (after WRAP, 2013c).

Table 5.16 shows gate fees are volatile for all management methods where historic data are available. Hazardous materials command a considerable premium being more than 2.5 times those of non-hazardous management methods. Recovery operations (e.g. incineration and MBT) are comparable to gate fees at hazardous facilities and have on average increased consistently throughout the period with the exception of 2012.

Table 5.17: Summary of LACW gate fees (£/t) for milestone years under CE scenario

Year	Recycling	Recovery	Disposal
2012	£ 29.00	£ 75.00	£ 21.00
2020	£ 30.48	£ 78.83	£ 22.07
2030	£ 33.67	£ 87.07	£ 24.38
2040	£ 37.19	£ 96.18	£ 26.93
2050	£ 41.08	£ 106.25	£ 29.75

Table 5.17 provides an indicative example of gate fees for LACW (£/t) across the milestone years of the four scenarios produced. The increases shown for all management methods under a CE scenario are based on incremental changes associated with inflationary pressures. However, such changes are not uniform across the scenarios. Figure 5.16 shows the profiles of LACW gate fees across the four scenarios.

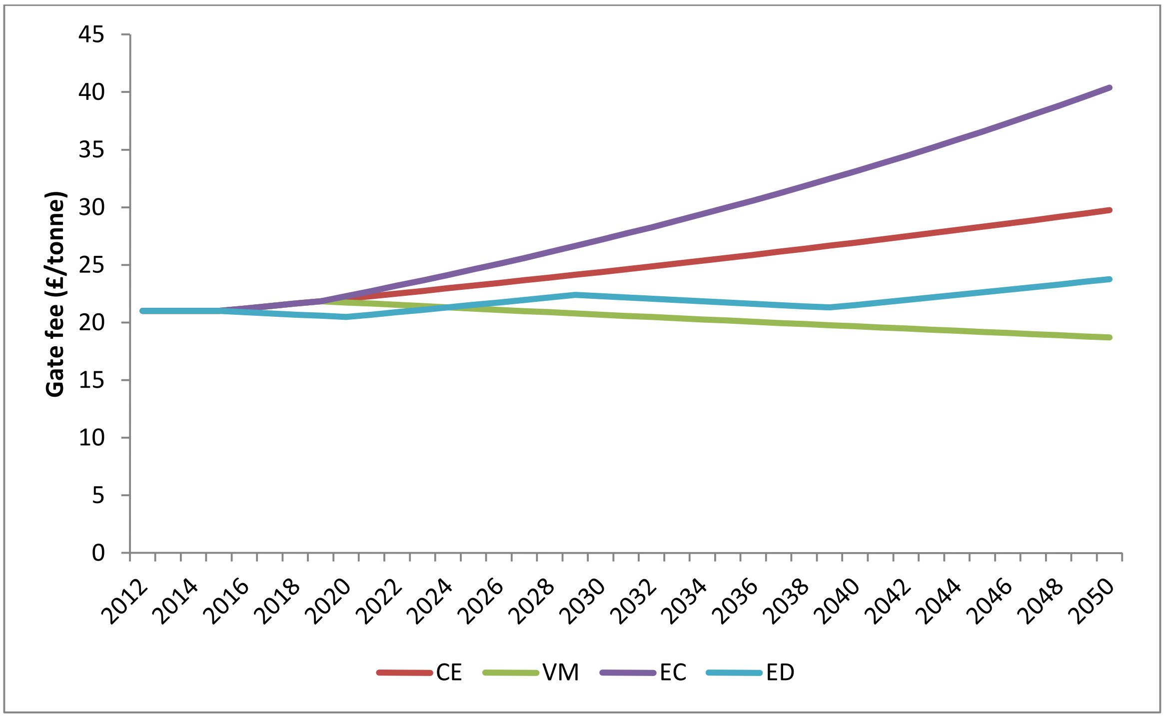


Figure 5.16: Changes in landfill gate fees for LACW across the four scenarios

It can be seen in Figure 5.16 that landfill gate fees increase significantly under scenario EC from £21/tonne in 2012 to more than £40/tonne in 2050. These increases reflect regulatory pressures focused on trying to minimise disposal of waste to landfill within a sustainability policy paradigm. Scenarios VM and ED reflect little regulatory influence and are more in line with market conditions. In particular, scenario VM shows an overall decrease from

£21/tonne in 2012 to £18.71/tonne in 2050. The final requirement in calculating the economic impact of gate fees is to combine gate fee values with waste tonnage data. The difference in gate fee costs across the backcast period is shown in Figure 5.17.

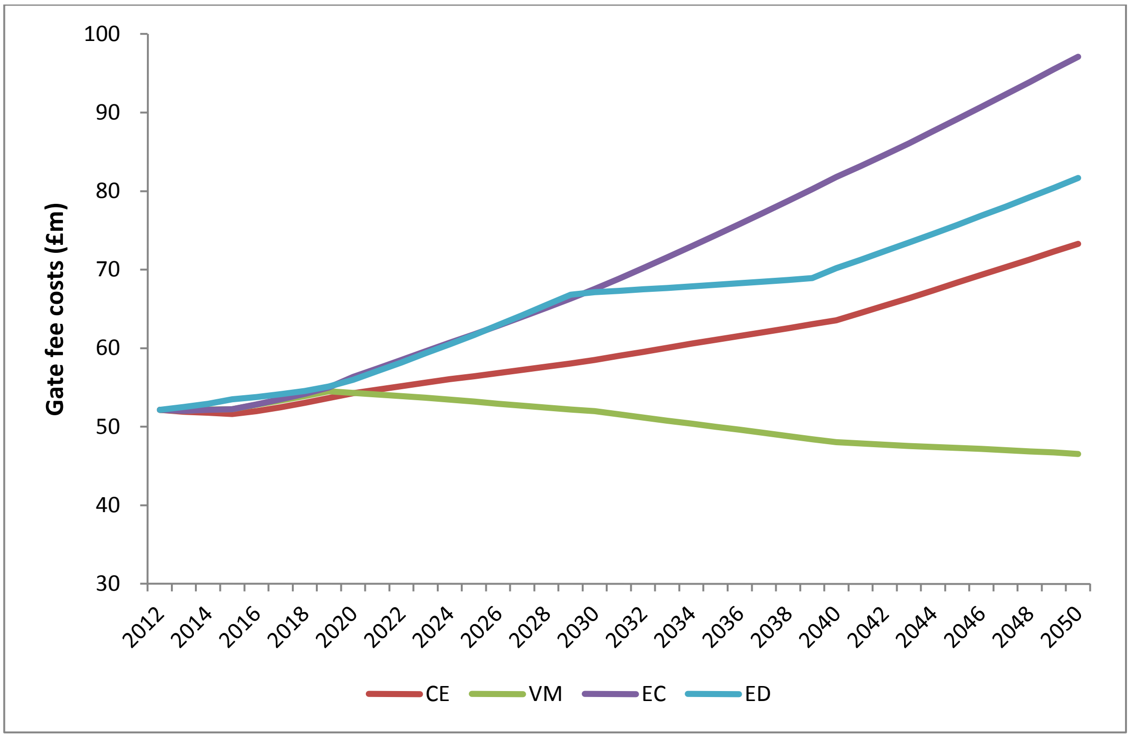


Figure 5.17: Gate fee costs (£m) for all scenarios (2012-2050)

As can be seen in Figure 5.17 gate fee costs across scenarios EC, CE and ED have very linear profiles (with the exception of the period 2029-39 for ED) increasing steadily throughout the period, shown in more detail for all waste types in Appendix 8. In contrast, after an initially small increase in costs between 2012 and 2019 (£2.15m) there is a sustained downwards trend from 2020 until 2050 (the overall reduction is £5.61m).

Figure 5.18 shows the profiles of the savings made for all four scenarios over the backcast period (2012-2050). It can be seen from Figure 5.18 shows savings in relation to gate fees are modest compared with overall costs. For example; the savings in 2050 across the four scenarios account for between 0.25% (ED) and 2.1% (CE). In general, savings for scenarios VM and ED peak between 2013 and 2020 before following an overall downwards trend between 2021 and 2050.

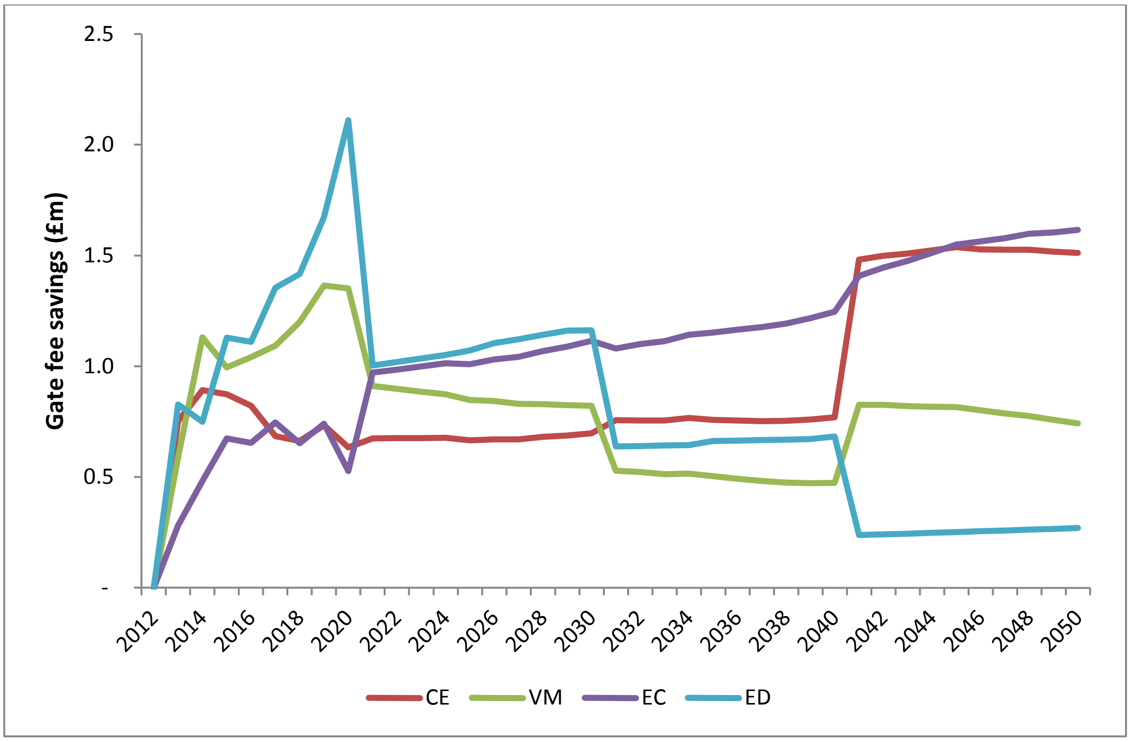


Figure 5.18: Gate fee savings (£m) across all scenarios (2012-2050)

Scenario CE has a relatively constant level of savings across the period 2013 to 2040 with a spiked increase from £0.77m to £1.48m which is roughly maintained until 2050. The only scenario with an overall upwards trend in savings from gate fees is EC. This trend is steadily upwards (increasing from £0.97m in 2021 to £1.62m in 2050) after a brief period of fluctuation from 2013-2020.

5.4.2.2 Calculating landfill tax impacts of scenarios

Historically landfill tax has followed a linear profile as it has been set by HMRC on behalf of HM Treasury (see Figure 4.6, p.150). Indeed, the waste sector and business have known what the level of landfill tax would be for at least 2 years into the future under budgetary announcements in relation to the landfill tax escalator (HMRC, 2013). As seen in Figure 4.6 landfill tax has been increasing on active waste since 1998/99 with a sustained increase of £8/t between 2007/08 and 2011/12 (with a further increase to £80/t introduced in April 2014). Consequently, a choice was made across all scenarios to maintain this trend until 2030.

Table 5.18: Summary of landfill tax rates (£/t) for controlled wastes streams across all scenarios and for key milestone years (2012, 2020, 2030, 2040 and 2050)

Waste streams	Year	Scenarios			
Active LACW and C&I wastes (standard rate)		CE	VM	EC	ED
	2012	64.00	64.00	64.00	64.00
	2020	104.00	120.00	128.00	80.00
	2030	140.00	120.00	160.00	60.00
	2040	140.00	120.00	160.00	60.00
	2050	140.00	120.00	160.00	60.00
Inactive C&I and C&D (low rate)		CE	VM	EC	ED
	2012	2.50	2.50	2.50	2.50
	2020	3.00	3.00	3.00	2.50
	2030	3.50	4.00	4.00	2.50
	2040	4.00	4.50	6.00	2.50
	2050	4.00	4.50	16.00	2.50
Hazardous wastes (estimated)		CE	VM	EC	ED
	2012	148.50	148.50	148.50	148.50
	2020	158.50	161.00	180.50	148.50
	2030	186.50	175.00	260.50	148.50
	2040	214.50	194.00	340.50	148.50
	2050	314.50	204.00	420.50	148.50

Table 5.18 shows that active waste (covering the LACW and around 70% of C&I wastes) has seen an increase in tax rates across scenarios CE, VM and EC. However, under scenario ED after the initial increase to £80/t which lasted until 2020 there was a reduction in the rate of landfill tax to £60/t by 2030 which is maintained until the end of the period (2030 to 2050). The rate of landfill tax for inert wastes (inactive C&I and C&D wastes) increases only marginally for CE and VM while remaining constant for ED. However, scenario EC sees a marked increase from £2.50/t to £16/t by the end of the backcast period. The baseline for tax on hazardous waste is estimated in the QM as 3 times the average gate fee (mean value of treatment, recovery and landfill multiplied by 3). The economic impacts of landfill tax rates on overall costs for the period are shown in Figure 5.19. Figure 5.19 shows the impact of differential rates of landfill tax for controlled waste streams on overall costs. The most significant point relates to the different points at which each scenario sees a reduction in overall costs associated with landfill tax rates.

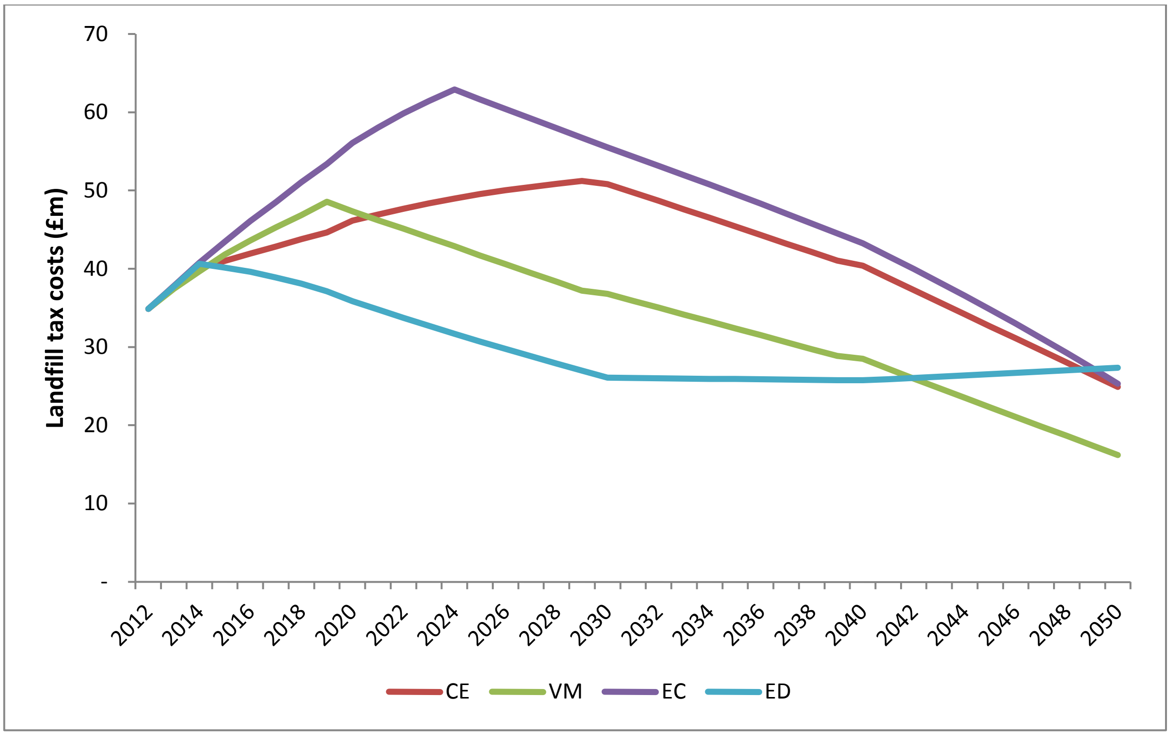


Figure 5.19: Landfill tax costs (£m) for all scenarios (2012-2050)

For example; Scenario ED sees a decrease beginning at 2014 which is sustained until 2030, whereas VM increases until 2019 before maintaining a downwards trajectory before reaching the lowest level of all scenarios in 2050 (£16.2m). The highest levels of costs associated with landfill tax are seen in scenario EC which peaks in 2024 at £62.9m.

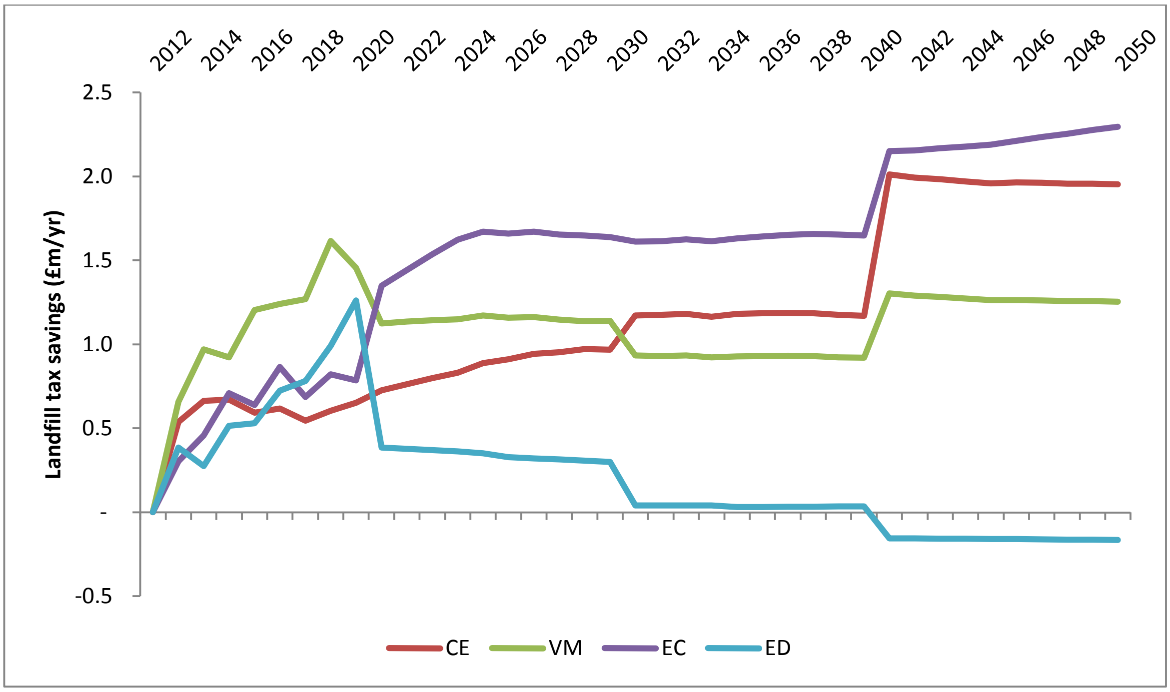


Figure 5.20: Landfill tax savings (£m) for all scenarios (2012-2050)

Scenario CE takes the longest period of time to begin reducing costs from landfill tax (2012-2029) after which it reduces to an equivalent level seen in scenario EC at 2050. Savings levels and profiles for the backcast period are shown in Figure 5.20. Similar to gate fees, landfill tax savings are modest when compared with overall costs. However, by 2050 these range between 0.75% (VM) and 0.95% (EC) with scenario ED witnessing an increase in landfill tax costs of £0.16m per year from 2041. The profile for each scenario shows EC and CE as generally increasing across the period. Scenario VM remains relatively constant within a range between £0.92m and £1.62m (2015 to 2050). Savings for scenario ED increase between 2012 and 2020 before declining markedly from 2021 to 2040 before becoming additional costs associated with landfill tax towards the end of the period.

A full summary of costs and savings associated with landfill tax for the period 2012-2050 for all scenarios is presented in Appendix 8. The baseline landfill tax costs for all scenarios are £34.9m. All scenarios see costs in 2050 considerably reduced (see Figure 5.20) with the lowest costs seen in scenario VM (£16.2m) and the highest costs for scenario ED (£27.3m). Savings across the period (cumulative) are significant across all scenarios ranging from £59.6m for EC to £7.65m for ED.

5.4.2.3 Estimating the costs of additional infrastructure requirements

The final element to calculate in order to determine the overall economic impact of each scenario relates to the potential level of additional infrastructure which would be required to deliver recycling, recovery and disposal rates associated with the scenarios. A range of literature sources were reviewed to give a range of values for infrastructure types based on scale and operation. Table 5.19 gives a summary of costs identified as well as showing operations by recycling and recovery (MBT and EfW) with landfill not accounted for as the existing capacity within the county would be adequate across all scenarios.

In order to calculate the estimated costs in Table 5.19 estimations were used from a government and waste sector report (APSRG, 2011) which estimated total required investment for a base case and high scenario profile (shown in Table 5.20).

Table 5.19: Indicative infrastructure costs (£m) for future waste management capacity

Operation	Scale (kt/year)	Estimated cost (£m)	Number of facilities required by scenario				Estimated investment cost (£m)
			CE	VM	EC	ED	
Integrated facility	< 150kt	13.51					-
	150-350kt	43.75		1			43.75
MRF	< 50kt	6.15	1				6.15
	50-100kt	12.30			1		12.30
	> 100kt	18.45					-
AD	<15kt	2.05	1				2.05
	15-50kt	6.15			1		6.15
	50-75kt	9.25					-
Composting	< 25kt	3.08	1				3.08
	25-75kt	9.25			1		9.25
	> 75kt	12.33					-
WEEE treatment	< 5kt	0.80	1				0.80
	5-25kt	3.08		1			3.08
	> 25kt	6.18			1		6.18
MBT	< 50kt	6.15	1				6.15
	50-150kt	18.45					-
	> 150kt	24.60				1	24.60
EfW	< 200kt	156.50		1			156.50
	200-350kt	251.54					-
	350-500kt	350.50				1	350.50

Sources: (after APSRG, 2011; WRAP, 2013d).

This data was used to produce a mean value for recycling and residual treatment capacities (t/year) as well as an estimated value for investment per facility (£m). These figures were then adjusted according to the scale of the operation involved by means of a simple division or multiplication process depending on whether or not the scale of operation was smaller or larger than the mean capacity. As a result of this methodology it was possible to determine the level of additional capacity required (see Tables 5.19 and 5.20) according to any increase or decrease in recycling and recovery across the backcast period (2012-2050). For example; ED has recovery increasing by around 540kt thus estimating additional infrastructure requirement as 1 MBT operation of >150kt capacity and 1 EfW facility with a capacity of between 350 and 500kt. Consequently, total additional investment for each scenario can be calculated as: £18.23m under scenario CE; £203.3m and £33.9m for VM and EC respectively; and £375.1m for scenario ED (2 facilities).

Table 5.20: Calculations for mean recycling and recovery capacity (t) and mean investment (£m) per facility

Calculations	Base	High
Recycling facilities	130	210
Residual facilities	20	40
Recycling capacity (Mt)	6.60	10.60
Residual capacity (Mt)	5.60	8.70
Recycling investment (£bn)	0.80	1.27
Residual investment (£bn)	4.03	6.26
Mean recycling capacity (kt)	50.76	50.58
Mean residual capacity (kt)	280.00	217.46
Mean recycling investment (£m)	6.15	6.05
Mean residual investment (£m)	201.50	156.50

Source: (after APSRG, 2011).

5.4.2.4 Summary of economic impacts

In order to gain a final figure for economic impact from each scenario it is necessary to consider all three factors together. Table 5.21 shows the overall costs and savings associated with gate fees, landfill tax and costs of additional infrastructure in 2050.

Table 5.21: Summary of economic impacts (£m) from gate fees, landfill taxes and additional infrastructure investment requirements

Economic impacts	CE	VM	EC	ED
Gate fees per annum (£m)	73.26	46.53	97.12	81.65
Cumulative savings (£m)	35.57	30.28	42.02	30.36
Landfill tax per annum (£m)	24.91	16.20	25.31	27.34
Cumulative savings (£m)	45.14	42.80	59.63	7.65
Infrastructure per annum (£m)	0.47	5.21	0.87	9.62
Total economic cost per annum (£m)	98.64	67.94	123.30	118.61
Total potential savings (£m)	80.71	73.08	101.65	38.01

Table 5.21 shows that costs associated with scenario VM are the least (£67.9m) overall followed by CE (£98.6m), ED (£118.6m) and EC (£123.3m) as the scenario with the

greatest level of economic cost. It is also clear that additional infrastructure to meet the policy objectives of VM and ED are the most significant influencing factors for economic impacts. In terms of potential savings, scenario EC has the greatest potential (£101.7m) while scenario ED has the least (£38.0m).

5.4.3 Impacts of scenarios on carbon emissions

In order to produce an overall figure for carbon emissions associated with each scenario consideration was given to direct emissions associated with landfill of residual wastes as well as indirect emissions (avoided emissions in the form of recycling and recovery operations versus landfill disposal). The data reporting tool for LACW carbon emissions was utilised as the starting point for producing values for constituent materials within each controlled waste stream. Table 5.22 provides a summary of these carbon factors by kilograms of carbon dioxide per tonne saving versus landfill (kgCO_2/t). The carbon factor of residual materials sent to landfill is 290kgCO_2/t under this carbon model (DEFRA, 2013e).

Table 5.22: Controlled waste streams (tonnes) by composition and showing carbon factors applied as kgCO_2/t saved versus landfill

Composition	Controlled waste streams (tonnes)				Carbon factor (kg CO_2/t saving versus landfill)
	LACW	C&I	C&D	Hazardous	
Organics	114,318	136,639	-	-	352
Paper/Card	77,084	309,453	-	-	847
Glass	22,558	90,533	-	-	352
Metals	14,608	136,207	131,538	-	5,014
Plastics	33,939	38,603	10,523	-	1,122
Textiles	9,614	50,866	10,523	-	4,133
Wood	12,672	99,156	92,077	-	1,276
WEEE	7,440	9,789	-	-	1,134
Hazardous	10,328	32,889	-	94,243	725
Bulky	5,402	-	-	-	921
Non-recyclable	31,764	50,723	-	-	717
Inert	-	-	276,230	-	10
Concrete	-	-	776,076	-	9
Plasterboard	-	-	18,415	-	139
Residual	-	-	-	-	-290
Totals	339,727	954,859	1,315,382	94,243	

Source: (after DEFRA, 2013e).

It is possible to identify from Table 5.22 that certain materials represent a priority for diversion from landfill, namely: metals, plastics, textiles, wood and WEEE. In addition, for every tonne diverted from landfill disposal there is an additional net gain of 290kgCO_2/t as these materials move out of the residual streams.

The values in Table 5.22 can also be used to calculate a hypothetical maximum value for avoided carbon if all wastes were sent to recycling and recovery (see Table 5.23). Conversely, it is possible to calculate a hypothetical maximum if all wastes were sent to landfill as residual wastes.

Table 5.23: Summary of carbon calculations for maximum values (tCO_2e) of avoided and residual carbon if 100% of all controlled wastes were recycled or sent for disposal

Calculations (annual)	LACW	C&I	C&D	Hazardous
Total tonnage (t)	339,727	954,859	1,315,382	94,243
Percentage share (%)	12.6	35.3	48.6	3.5
Maximum avoided carbon (tCO_2)	324,373	1,476,392	844,627	68,326
Maximum residual carbon (tCO_2)	98,521	276,909	381,461	27,330
Theoretical carbon savings (tCO_2)	422,984	1,753,300	1,226,088	95,657
Percentage share (%)	12.1	50.1	35.1	2.7

Sources: (after DEFRA, 2013e).

From these two variables a theoretical value can be determined for the maximum carbon savings (tCO_2e) which can be realised annually. The calculations of these maximum and minimum values as well as a value for theoretical annual carbon savings are summarised in Table 5.23. It can also be seen from Table 5.23 that the greatest potential carbon savings are to be found within the C&I waste stream which accounts for 35.3% of all tonnages but over half (50.1%) of all potential carbon savings.

5.4.3.1 Calculating direct emissions

Direct emissions from waste management operations within the calculations are those from landfilling of residual waste. The carbon model (DEFRA, 2013d) reports these as having a value of 290kgCO_2/t. A carbon model was produced within the QM (see Figure 8.2) which based calculations of CO_2 on overall waste tonnages sent for a specific management route (e.g. recycling, recovery or disposal) multiplied by the carbon factor in Table 5.22 with the result divided by 1,000 to give an overall tonnage equivalence for direct emissions of CO_2.

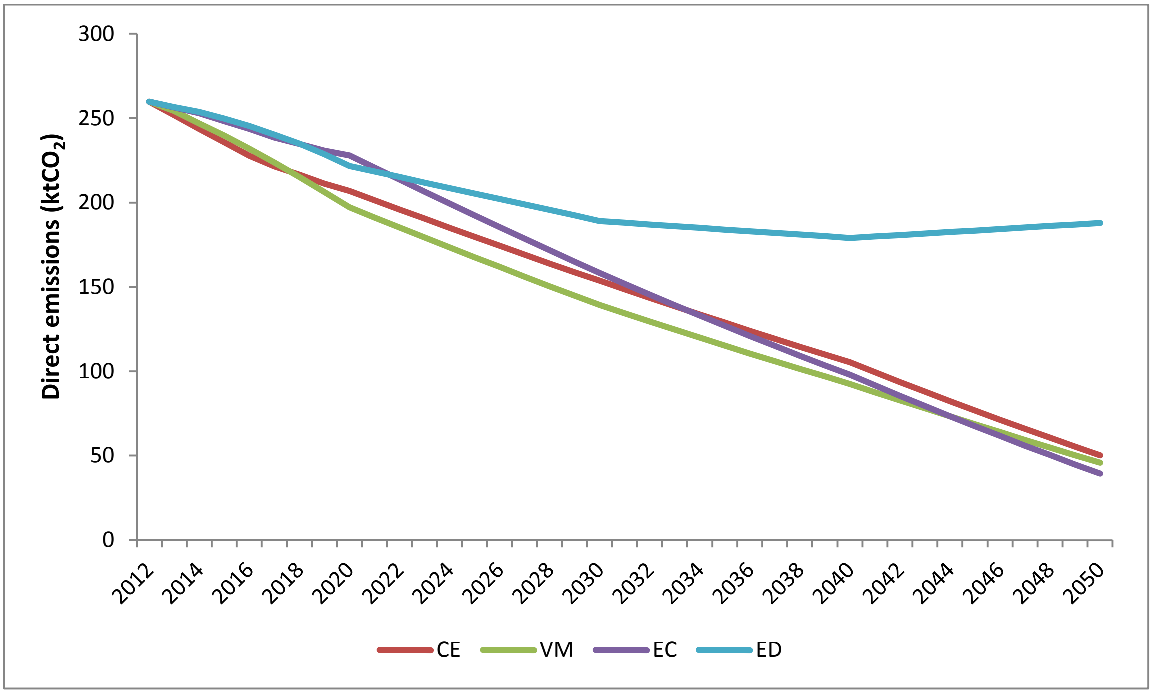


Figure 5.21: Direct emissions performance (ktCO_2e) of all scenarios (2012-2050)

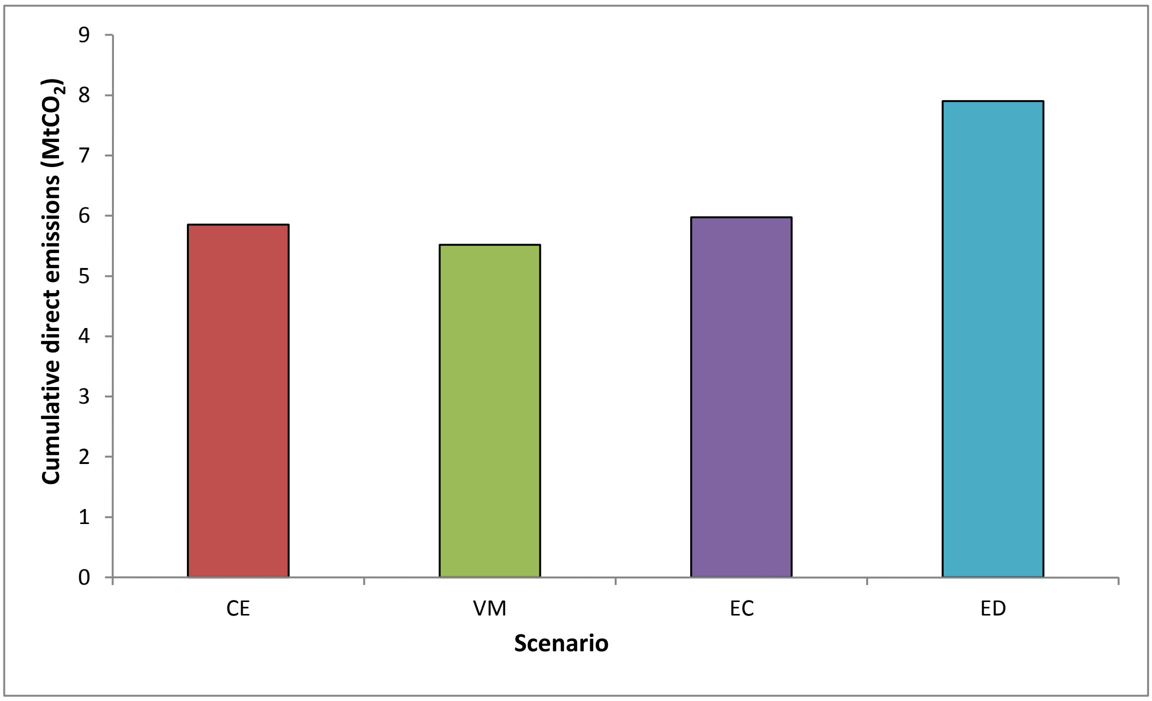


Figure 5.22: Cumulative direct emissions (MtCO_2e) across all scenarios by 2050

The performance of each scenario is captured in Figure 5.21 while the cumulative impact of scenarios is shown in Figure 5.22. As can be seen in Figure 5.21 direct emissions associated with all four scenarios reduce significantly until 2022 at which point scenario ED begins to level off before marginally increasing from 2040. In contrast, scenarios CE, VM and EC all continue to show a sustained downwards trend until 2050. There is only a marginal variation in direct emissions between these 3 scenarios in 2050. However, when cumulative emissions are considered it becomes clearer which scenario performs better across the period. Figure 5.22 shows scenario VM has the lowest cumulative direct emissions of 5.52MtCO_2e whereas scenario ED has the highest cumulative value at 7.90MtCO_2e. Scenarios CE and EC have similar levels at 5.85 and 5.98MtCO_2e respectively by 2050.

5.4.3.2 Calculating avoided emissions: savings versus landfill

The manufacture of products and goods creates greenhouse gas emissions; actions which seek to re-use or recycle these products and goods avoid some of the emissions associated with replacing them, and those generated from landfill. Savings versus landfill is thus calculated as a value for savings from recycling and a value for savings from recovery operations in line with the carbon model (DEFRA, 2013d).

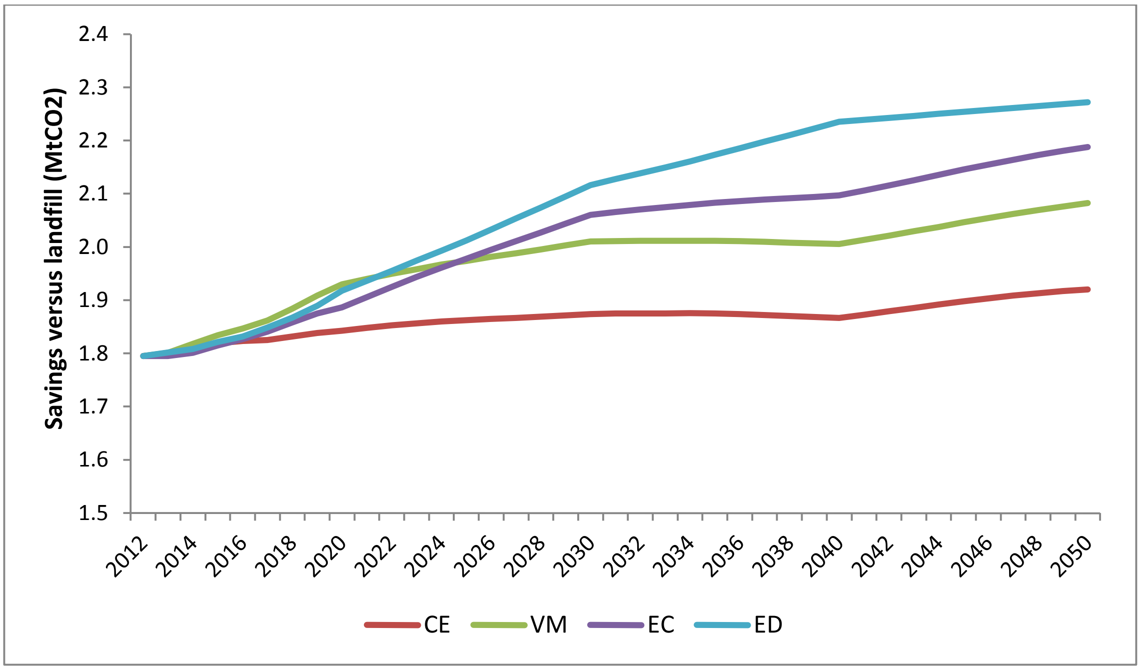


Figure 5.23: Emissions savings performance (ktCO_2e) of all scenarios (2012-2050)

Figure 5.23 shows the savings profiles for each scenario across the backcast period (2012-2050). Figure 5.23 indicates a reversal of the position for scenario ED in 2050 compared with direct emissions; which in terms of recycling and recovery savings is the best performing scenario. Scenario EC is the next best performing scenario in 2050 with savings of 2.19MtCO_2e. Overall performance is shown as cumulative totals in Figure 5.24.

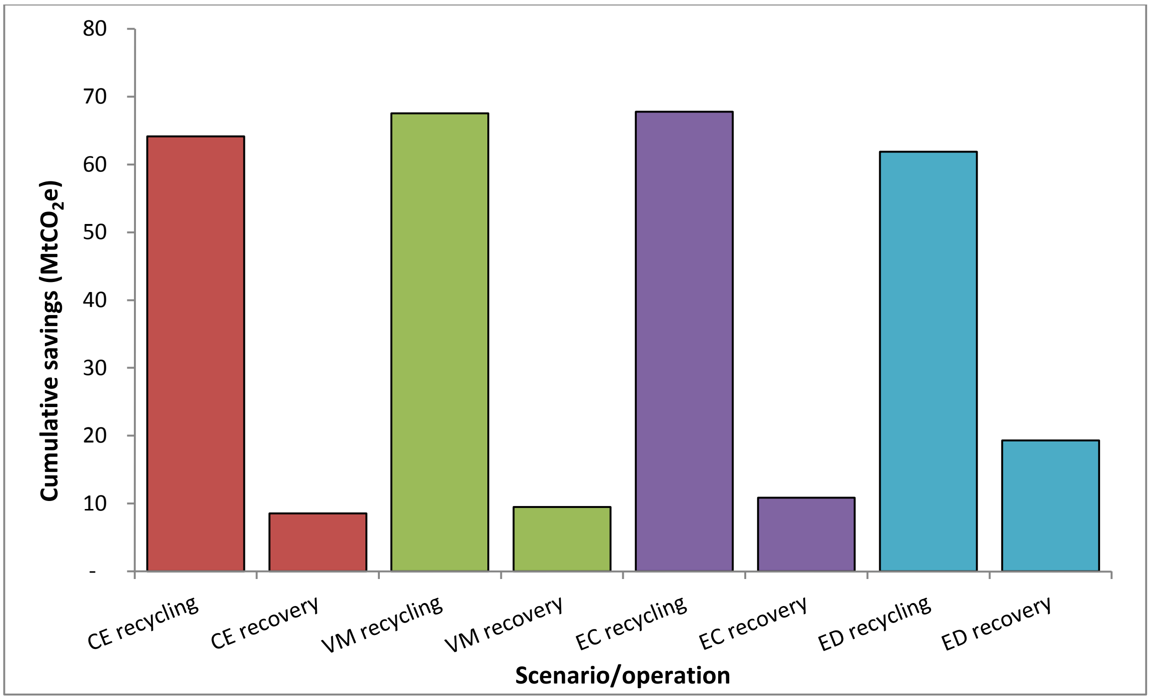


Figure 5.24: Cumulative savings (MtCO_2e) for recycling and recovery operations across all scenarios (2012-2050)

It can be seed form Figure 5.24 that scenario ED has become the best performing scenario because of the large increase in recovery operations (accounting for 19.3MtCO_2e between 2012 and 2050) which were described in Table 5.11. Scenario EC has the best performance for recycling (67.8MtCO_2e) with ED as the worst performing scenario for recycling (61.9 MtCO_2e).

5.4.3.3 Calculating changes from system variables and waste prevention

The final stage in determining carbon impacts for scenarios relates to changes as a result of systems variables as well as from waste prevention initiatives (e.g. prevention and reuse). These savings are calculated using the values for reuse within the English carbon model

(DEFRA, 2013e) which are extrapolated in percentage terms for any materials without a value. Values used in the calculations are shown in Appendix 9. The changes to waste prevention profiles are shown in Figure 5.25.

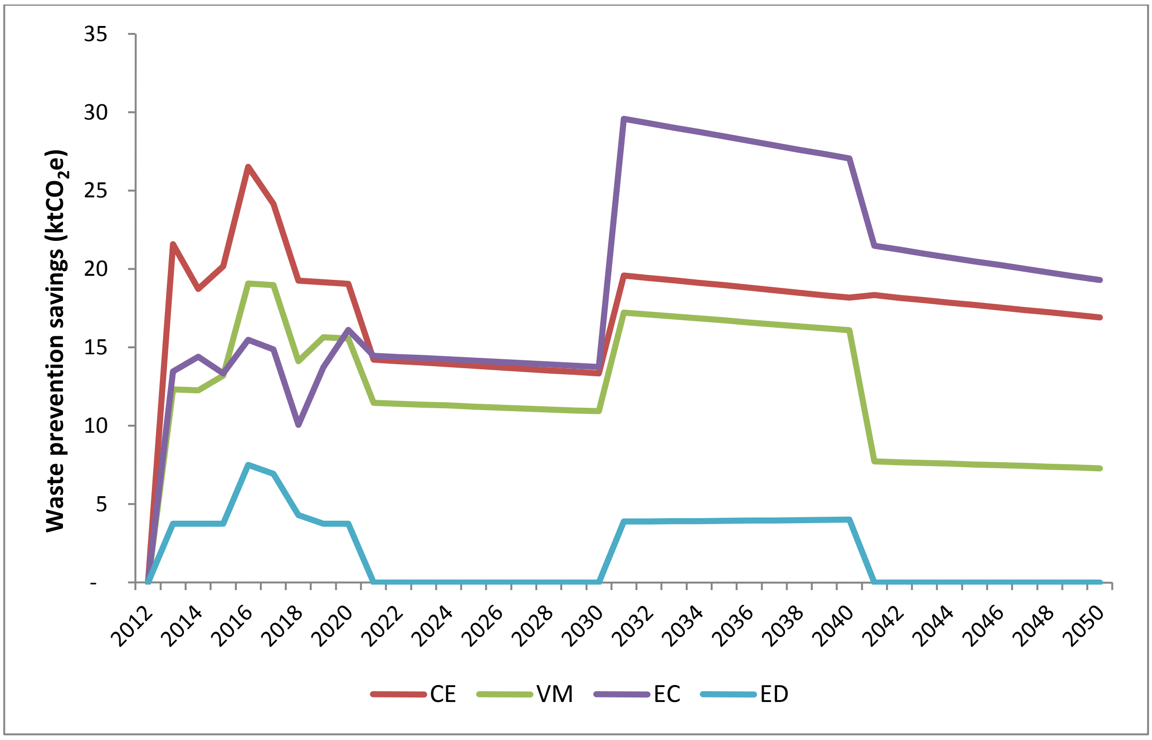


Figure 5.25: Carbon emissions savings (ktCO_2e) from waste prevention across all scenarios (2012-2050).

Figure 5.25 shows that by 2050 scenarios EC and CE are achieving annual savings of 19.3 and 16.9ktCO_2e from waste prevention initiatives. In contrast, scenario ED is characterised by low levels of annual savings throughout the period with no emissions savings being made from 2041 onwards. The second element to consider is the impact of changes to systems variables on carbon emissions. A number of key points are raised by Figure 5.26. After a period of flux between 2012 and 2020 there is a sustained upwards trend across scenarios CE, VM and EC until 2041. After this point scenario CE continues on an upwards trajectory while EC and VM show a sharp decline in emissions savings before resuming an upwards trajectory to 2050. Conversely, scenario ED sees a sustained downwards trajectory across the period (2012-2050). This downwards trend translates into an increase in emissions for scenario ED which by 2050 is at an annual rate of 15.5ktCO_2e.

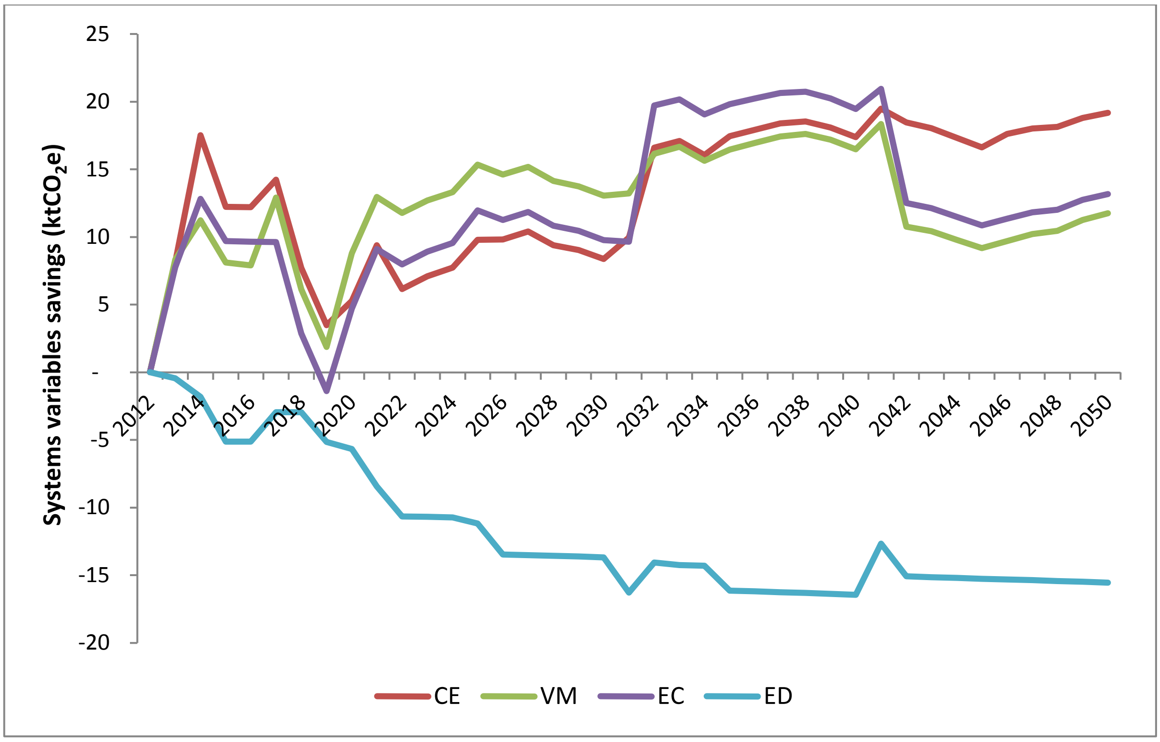


Figure 5.26: Carbon emissions savings ($ktCO_2e$) from system variables changes across all scenarios (2012-2050).

The overall impact of these two factors (e.g. waste prevention and systems variables changes) has a cumulative impact on carbon emissions which can be measured to differentiate performance by scenario.

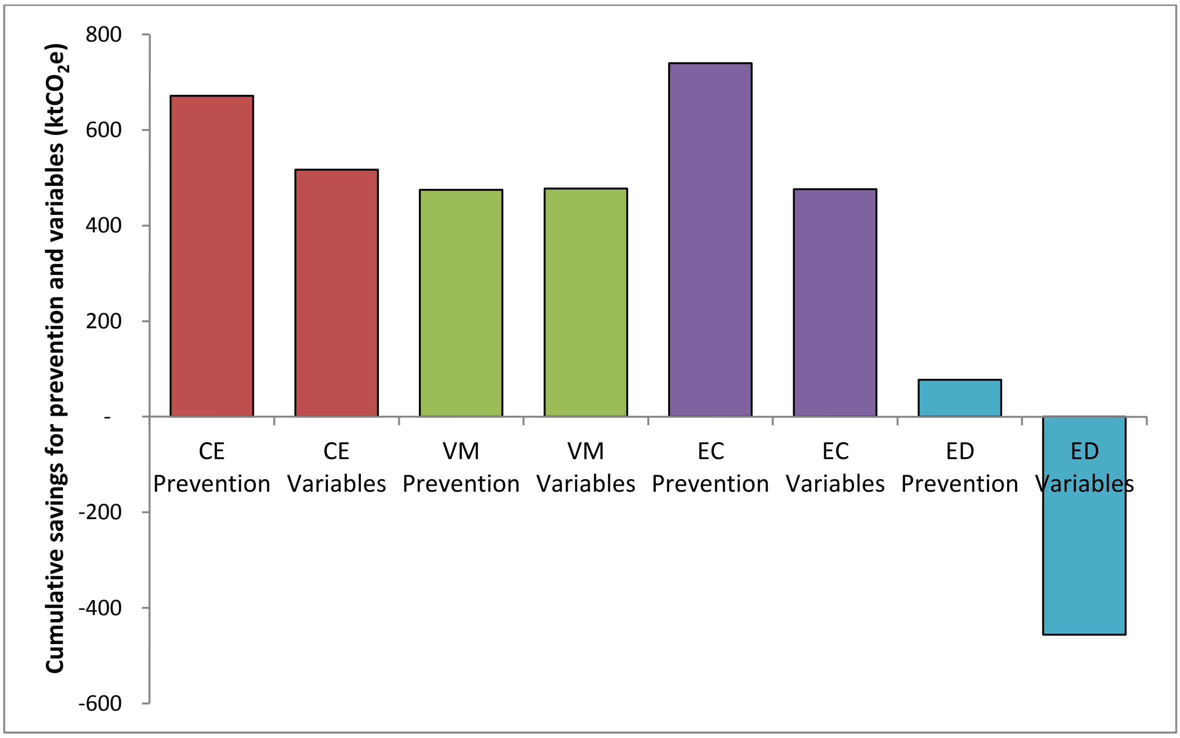


Figure 5.27: Cumulative savings ($ktCO_2e$) for prevention and variables across all scenarios (2012-2050).

While the totals in Figure 5.27 are a magnitude lower than those for recycling and recovery (Figure 5.24), the cumulative impact is significant in terms of overall emissions reduction performances. There is a significantly greater variance between prevention totals compared with that for systems variables. Scenario EC has the largest cumulative savings (740ktCO_2e) followed by CE (672ktCO_2e) and VM (475ktCO_2e) while scenario ED has the lowest savings associated with prevention (76.9ktCO_2e). In terms of systems variables scenario CE is performs marginally better than VM and EC. In stark contrast, the cumulative impact from systems variables changes in scenario ED is to increase emissions by 456ktCO_2e.

5.4.3.4 Summary of carbon emissions impacts

In determining the final level of carbon emissions impact from each scenario savings from recycling and recovery were added to those from prevention and systems variables before subtracting direct emissions values. This calculation is shown in Equation 5.1.

Equation 5.1:

$$Carbon\ impact = \left(S_{rcy} + A_{pv}\right) - Direct\ emissions$$

Where: S = savings; A = avoidance; rcy = recycling & recovery; and pv = prevention & variables. These calculations are summarised in Table 5.24.

Table 5.24: Summary of cumulative carbon emissions impacts (MtCO_2e) for all scenarios

Impact	CE	VM	EC	ED
Recycling and recovery	72,720,606	77,032,854	78,658,308	81,177,796
Prevention & variables	1,188,690	952,571	1,215,929	-379,048
Direct emissions	5,854,891	5,518,379	5,975,704	7,900,515
Carbon impact (savings)	68,054,405	72,467,047	73,898,534	72,898,233

Table 5.24 shows, when Equation 5.1 is applied to the results from the previously described steps, that scenario EC is the best performing scenario for overall carbon emissions impact

with a cumulative saving versus landfill of 73.9MtCO_2e. Scenario ED shows the second highest level of savings (72.9MtCO_2e) but has the largest cumulative amount of direct emissions (8.28MtCO_2e when the increase from prevention and variables is factored into the calculation). Scenario CE has the lowest level of carbon emissions savings for all scenarios. However, consideration must also be given to the level and scale of infrastructure development required under each scenario (see Table 5.19). Scenario CE has the lowest estimated need (<140kt across 5 facilities) compared with VM (575kt for 3 facilities including 1 small EfW plant), EC (>250kt across 4 facilities) and ED (>650kt for 2 facilities including 1 large EfW plant). Embodied carbon within these facilities is not calculated as part of the overall calculations as other variables would impact whether or not these facilities were commissioned. However, such embodied carbon is likely to be significant across the life cycle of facilities and may produce a different outcome in terms of overall carbon emissions performance as seen with economic calculations (see section 5.3.3.3.4). As an example; if a value of 300kgCO_2/t of additional capacity per annum were taken as a constant value and operational life was estimated as being 2020 to 2050 (30 years) this would produce additional direct emissions for each scenario shown in Table 5.25.

Table 5.25: Summary of potential direct emissions (MtCO_2e) associated with infrastructure development for all scenarios in Northamptonshire (2012-2050).

Calculation	CE	VM	EC	ED
Additional capacity (kt)	140	575	250	650
Annual emissions (ktCO2e)	42	173	75	195
Direct emissions (MtCO2e)	1.26	5.18	2.25	5.85
Total impact (MtCO2e)	66.79	67.29	71.65	67.05

Under the example described above Table 5.25 shows EC would remain as the best performing scenario with VM overtaking scenario ED and scenario CE remaining as the worst performing scenario. Indeed, scenario CE would not improve its performance (above the next performer) until a value of 318kgCO_2/t was reached and would not become the best performer until a value of 1775kgCO_2/t was reached (some 6 times higher than the initial example. Conversely, no change occurs in the ranked performance until a value of 200kgCO_2/t is introduced. By testing the performance in Table 5.24 in such a way it is possible to take forwards the performance rankings on carbon emissions savings as they are without accounting for infrastructure impacts.

5.4.4 Summary of all impacts on scenario performance

The results of the QM have been reported as three metrics: tonnages; economic costs; and carbon emissions savings. These outputs are brought together to quantify the performance of all scenarios across all three metrics in order to give an indication of the strengths and weaknesses of the scenarios in relation to one another. Table 5.26 provides a summary of all scenarios in terms of the three metrics.

Table 5.26: Summary of cumulative performances by tonnages (Mt); economic cost (£m); and emission savings (MtCO_2e) across all scenarios in Northamptonshire (2012-2050)

Metrics	CE	VM	EC	ED
Tonnages (Mt)	2.05	2.16	2.05	2.97
Economic cost (£m)	98.64	67.94	123.30	118.61
Emissions savings (MtCO_2e)	68.05	72.47	73.90	72.90
Performance matrix	CE	VM	EC	ED
Tonnages (Mt)	1	3	1	4
Economic cost (£m)	2	1	4	3
Emissions savings (MtCO_2e)	4	3	1	2
Scores	7	7	6	9

The results in Table 5.26 show scenario EC has the best overall rank score (6) and has the highest rank score in two categories (tonnages and emissions savings). Scenarios CE and VM have the same overall rank scores (7). However, scenario CE is the second overall ranked by virtue of having an individual highest score (1 joint with EC for tonnages) and a second placed ranking for economic costs. Scenario VM is ranked first for economic costs but third in performance across the remaining two metrics (tonnages and emissions savings).

In contrast, scenario ED is the worst performer in two categories (tonnages and economic cost) but is the second best performer on carbon emissions (before consideration is given to direct emissions from new infrastructure provisioning). These performance rankings are taken forwards as meeting objective 1 and fulfilling the requirements of objective 2 in terms of producing coherent future scenarios through applying backcasting (see section 1.3). The quantitative results of the impact analysis and scenario development stages also provide the outputs for mapping system conditions within the GIS model in order to provide a visualisation of the scenario impacts in line with objectives 3 and 4.

5.4 Chapter summary

The backcasting methodology is the primary focus of the research (aimed at addressing objective 1 through the use of multiple stakeholders and baseline analysis) specifically dealing with objective 2. It also constitutes the main analytical approach for the overall GBFM model developed to meet objective 5, with the outputs from the baseline analysis, scenario development and impact analysis stages all utilised and represented using GIS techniques to meet the requirements of objectives 3 and 4. The baseline analysis has already been addressed in Chapter 4.

The visioning process involved the generation of large amounts of original data (questionnaires; workshops; feedback and follow-up interviews). The timeframe for undertaking these activities was June 2011 to November 2012 (with overlaps for analysis). The workshop was probably the key piece of research which led to a continued dialogue with a number of industry and academic experts as well as a pool of additional stakeholders whom gave of their time tirelessly and provided a key source of encouragement throughout the process.

The data collection phase, although extended, gave way to data analysis which initially used qualitative methods (such as STEEP analysis; thematic analysis and mind mapping software packages) ultimately leading to the key development of futures tables and high level analysis matrices (see section 5.2.2.3). This marked the end of the first phase of the backcasting apart from triangulating the results with stakeholder feedback on the process (see section 5.2.3) and exploring secondary data from a national survey of waste professionals supplied by CIWM (see section 5.2.4). The feedback from stakeholders proved positive, emphasising the creativity, clarity and communicative nature of the visioning process to enhance strategic foresight at the organisational and individual levels. Survey data, showed the workshop and follow up data had gone much further than the survey in identifying where a zero waste future may be achieved. But there were similarities in terms of the aspirational nature of zero waste and concerns expressed by stakeholders and professionals alike over attainability and the ability of the sector to look beyond zero waste to landfill (ZW2L).

The scenario development phase continued to utilise qualitative outputs but also began to draw in quantitative outputs from the development of a QM utilising baseline data to test the policy packages being put forwards (e.g. for waste prevention). Stakeholder participation was once again sought to provide additional quantitative data in the form of plausibility scoring. These matrices (drawing on the morphological fields utilised in GMA) were useful tools for assigning a weighting value to qualitative visioning results in order to provide analytical data (see table 5.4) which could be used to speed up the scenario development process and allowed prospective scenarios (Table 5.5) to be sent to stakeholders for final feedback. This ultimately generated narrative profiles within a morphological field which in turn was used to frame the qualitative scenario narratives (Tables 5.6 to 5.9).

These scenario narratives and their policy packages could then be tested through the QM which compared results over the backcast period (2012-2050) with baseline metrics (tonnages, economics and carbon). The QM also allowed systems variables to be accounted for in a non-linear manner where each variable was assigned a relative impact on waste generation (+ or -) depending on feedback from stakeholders (Table 5.11). In addition, waste prevention and reuse were assigned values according to stakeholder input (from the beginning of the visioning process) which increased the non-linearity of the modelling and allowed values to be produced which were non-predictive.

The impact analysis ultimately found values for all three metrics which could be compared across the scenarios. In terms of tonnages; scenario CE marginally outperformed scenario EC (by 8,000 tonnes) with both receiving the same ranking for comparative purposes. For economic impacts scenario VM had considerably lower costs than any other scenario (£67.9m which was almost £31m less than the next best performer); with scenario EC having the highest potential savings of all scenarios. To close, carbon impacts (equating to savings) saw scenario EC as the best performer although it had the second highest direct emissions of all scenarios. When the individual results are placed in a performance matrix (Table 5.26) scenario EC is the best performing scenario. However, as described, all scenarios including the reference scenario had their advantages and disadvantages. Coupled with the goal of offering feasible alternate visions of the future then it can be stated the process achieved this and met the requirements of objective 2.

Chapter 6 Results: Waste system spatial analysis

This chapter will present the results of the GIS stage of the research with a view to achieving objective 3 'future infrastructure capacity needs at the sub-regional level' and objective 4 'embedding the backcasting output within a GIS environment'. The chapter will detail results from spatial analysis stages of the study utilising the methodological approach identified in section 3.5 (shown as a workflow in Figure 6.1).

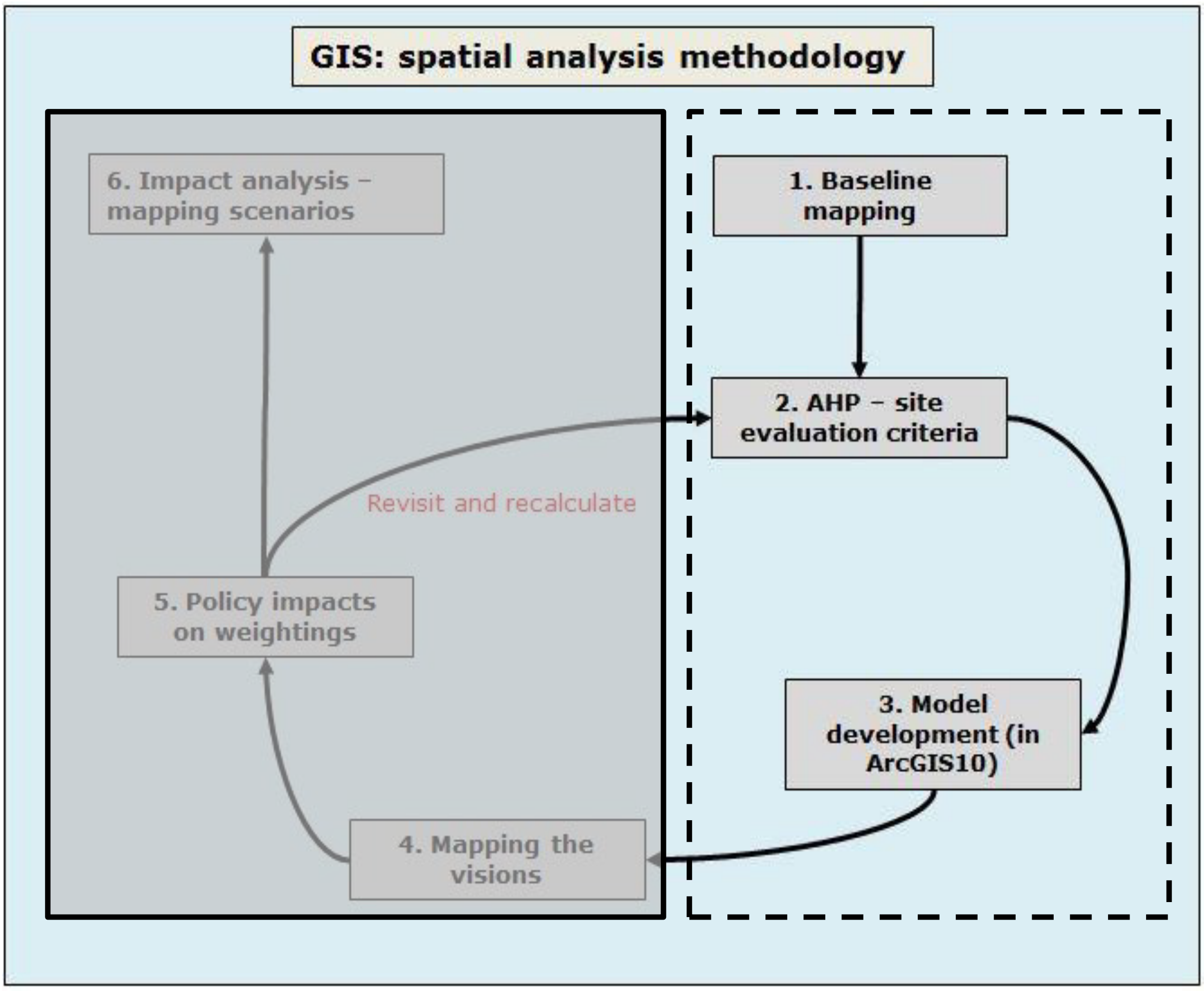


Figure 6.1: Spatial analysis methodology using GIS/AHP process (Results for 1, 2 and 3)[17]

This approach builds on earlier research on siting waste infrastructure (DTZ/SLR, 2009a) as a specific systems assessment tool and addresses the research agenda on waste infrastructure provision (EA, 2011a) within the context of producing a backcasting model for zero waste futures in England. Specifically, section 1 will map the baseline waste system conditions

[17] Stages 4,5 and 6 are covered in Chapter 7

(see Sections 3.2 and 4.3). Section 2 uses Saaty's Analytical Hierarchy Process (AHP) (Saaty, 1980) to evaluate siting criteria to produce a problem formation hierarchy for suitability of waste infrastructure siting at the local scale (e.g. individual WPA level). Section 3 details results from the model development process and is validated against the spatial plan from the MWDF (NCC, 2012) shown as section 4. Chapter 7 will address the remaining stages of the GIS methodology (Figure 6.1) and synthesise these results with the backcasting results (Chapter 4 baseline analysis and Chapter 5 backcasting).

6.1 Mapping waste system conditions

6.1.1 Waste arisings within Northamptonshire for 2012

Chapter 4 reported the results of the baseline waste management system conditions as well as mapping the main exogenous variables; this section expands on this in terms of mapping the spatial distribution of waste arisings and infrastructure.

6.1.1.1 Spatial distribution of total waste arisings

Results for controlled waste arisings are mapped according to per capita calculations where total tonnages data (see Table 4.11, Ch.4) was divided by overall population and subsequently multiplied by individual LSOA population (e.g. all residents category). This approach allowed a value to be produced as tonnes per annum (tpa) for each LSOA. The calculation is expressed in Equation 6.1 as:

Equation 6.1:

$$LSOA\ Waste\ (t) = \left(\frac{total\ tonnages}{overall\ population}\right) \times LSOA\ population$$

The baseline results for total controlled waste arisings (tpa) by LSOA in 2012 are shown in Figures 6.2a through 6.2d.

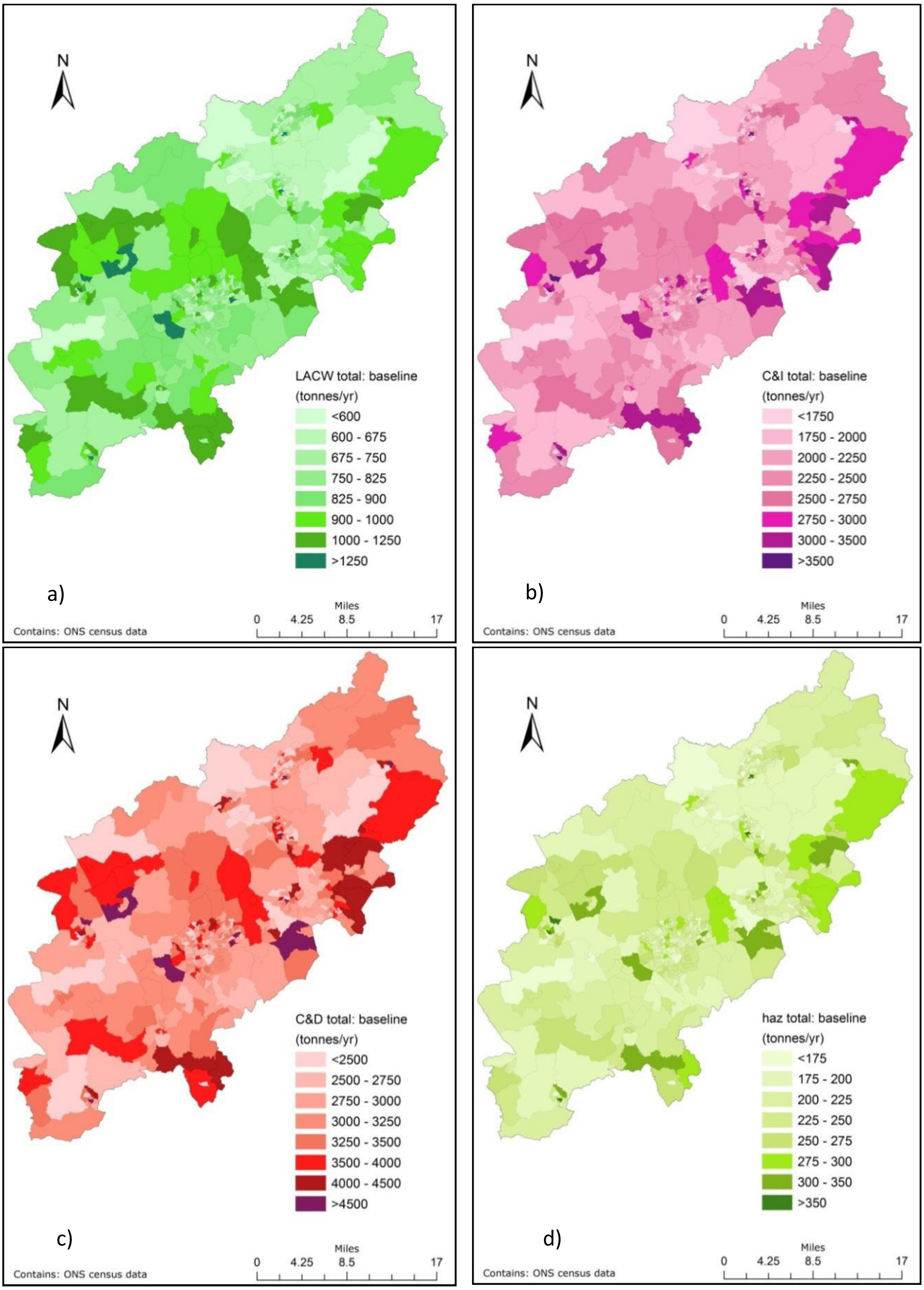


Figure 6.2a-d: Total waste (tpa) baselines by waste stream within Northamptonshire by LSOA in 2012.

The spatial distributions of all controlled wastes are shown in Figure 6.2a-d when Equation 6.1 is applied to baseline tonnages within the case study area. Values across the 422 LSOAs are classified into 8 categories (for all controlled wastes). In terms of LACW, Figure 6.2a shows 90.5% of LSOAs had a range between 600 to 1,250tpa. A further 32 LSOAs (7.58%) had annual LACW tonnages below 600tpa with the 8 remaining LSOAs (1.90%) having LACW tonnages above 1,250tpa. The mean value for annual LACW tonnages was 806tpa.

The spatial distribution of C&I waste is shown in Figure 6.2b. C&I classification ranged between 1,750 and 3,500tpa. A total of 91.2% of LSOAs had values within this range. A further 31 LSOAs (7.35%) had C&I tonnages below 1,750tpa with only 6 LSOAs (1.42%) having C&I tonnages above 3,500tpa. The mean value for C&I tonnages was 2,263tpa.

Figure 6.2c shows the spatial distribution of C&D waste. The classification of C&D wastes ranges between 2,500 to 4,500tpa with 85.6% of LSOAs having values within this range. A total of 49 LSOAs (11.6%) had C&D waste tonnages below 2,500tpa. In total 12 LSOAs (2.84%) had C&D tonnages above 4,500tpa. The mean value for C&D tonnages was 3,117tpa.

Finally, spatial distributions of hazardous waste are shown in Figure 6.2d. Hazardous waste (HzW) is classified in the range 175 to 350tpa with 90.1% of LSOAs having values within this range. A total of 37 LSOAs (8.77%) had HzW tonnages below 175tpa while 5 LSOAs (1.18%) had HzW tonnages above 350tpa. The mean value for HzW tonnages was 223tpa.

6.1.2 Spatial distribution of existing waste infrastructure

In order to meet the requirement for net self-sufficiency in waste infrastructure provision (NCC, 2012) it must first be determined where the existing facilities are located in relation to the potential catchment of materials. Figure 6.3 shows the location and permitted capacity of operational waste infrastructure within Northamptonshire in 2012.

Figure 6.3 shows the concentration of operational waste facilities around the main urban centres. Total permitted capacity shown is almost 7.00Mtpa (EA, 2012a; 2012b). In terms of the scale of operations these range from <5ktpa to 800ktpa. Analysis of the 101 operational

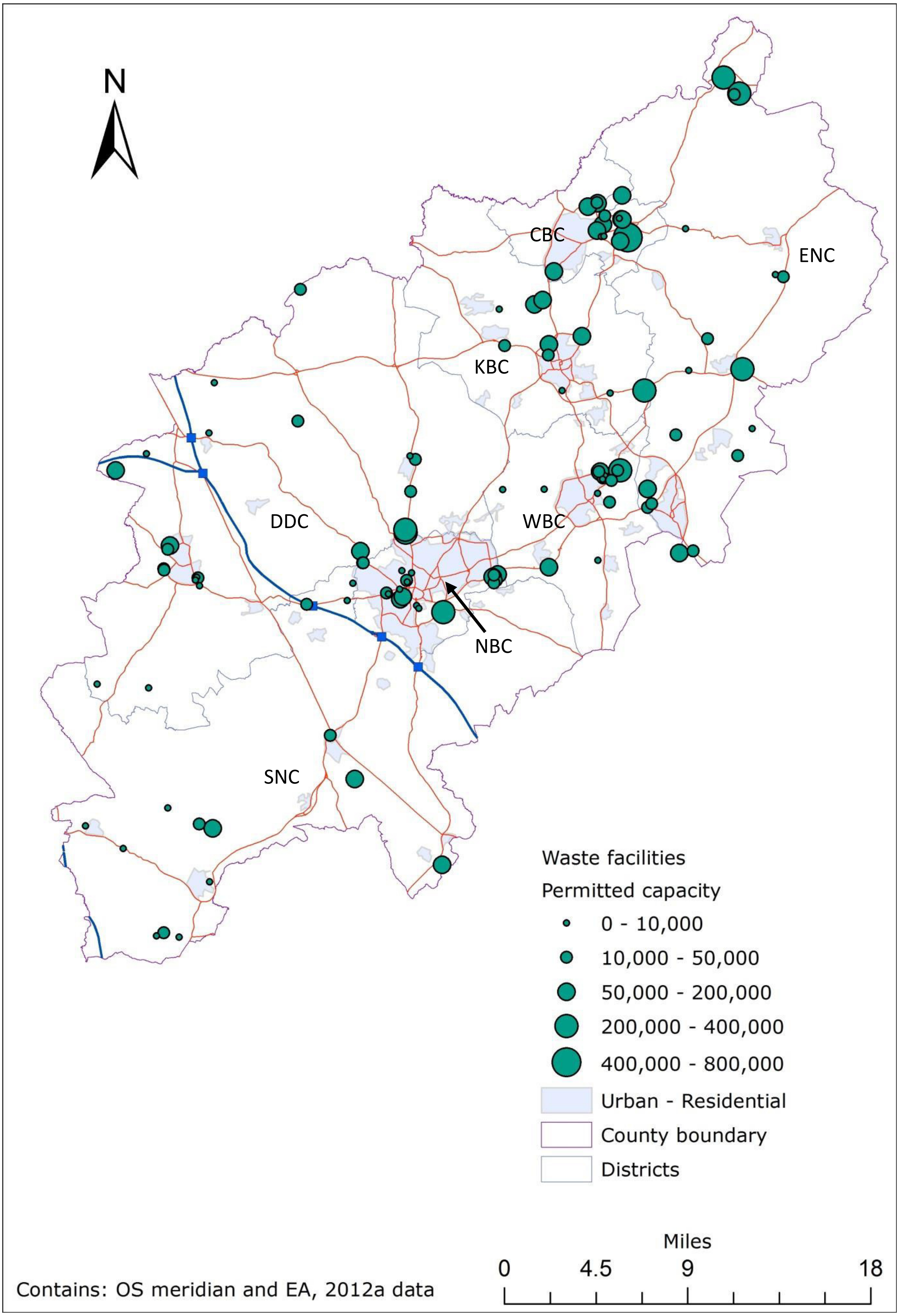


Figure 6.3: Location and permitted capacity of operational waste facilities for Northamptonshire in 2012 (Source: after EA, 2010; 2012a; 2012b).

facilities shows: 20 facilities with a permitted capacity of <5ktpa; 39 facilities with permitted capacities between 5 and 50ktpa; 27 facilities with permitted capacities between 50 and 200ktpa; 5 facilities with permitted capacities between 200 and 400ktpa; and 4 facilities (all landfill sites) with permitted capacities between 400 and 800ktpa.

It can also be seen that operational facilities, at the time of writing, were mainly situated in close proximity to the main road networks traversing the county (Motorways and A roads). Main results for proximity to communication and utility networks are presented in section 6.4.2. A total of 34 facilities are located more than 2.25 miles (3.6km) from an urban centre (residential); meaning that the remaining 67 facilities (66.3%) are located in positions in relatively close proximity to urban residential and commercial premises (section 6.4.3 analyses results for constraining factors on waste facility locating).

6.1.3.1 Operational capacity by district

Knowing where facilities are does not address the spatial question of what types of facility are in what location? Or indeed, are the facilities in a location the correct type of facility to manage the types of wastes produced in that location?

The distribution of permitted facilities and operational capacities across the 7 WCAs[18] is summarised in Table 6.1. In terms of received waste, the 7 WCAs managed a total of 2.38Mt in 2012, ranging from 250kt (SNC) to 488kt (NBC). Prima facie this total figure seems inadequate to manage the estimated baseline total of 2.70Mt of controlled waste generated within the county (see Table 4.11).

Given the amount of materials passing through the exemptions regime (up to 514kt – see Table 4.16) and the estimated levels of exempt materials (117kt) and aggregates recycling (729kt) within C&D estimations (see Table 4.4); it is possible to estimate the amount of

[18] The 7 WCAs are: shown as CBC, DDC, ENC, KBC, NBC, SNC and WBC in Figure 6.8 (Corby, Kettering, Northampton & Wellingborough Borough Councils; and Daventry, East Northamptonshire & South Northamptonshire District Councils).

Table 6.1: Operational and permitted capacities (tonnes/tpa) for all facility types by WCA for Northamptonshire (2012)

WCA	Received waste (tonnes)	Permitted capacity (tpa)	Removed waste (tonnes)	# of facilities
CBC	269,199	1,580,000	186,650	12
DDC	323,900	1,040,000	168,712	20
ENC	416,866	1,260,000	112,645	15
KBC	260,115	935,000	135,678	9
NBC	487,635	1,152,665	372,514	19
SNC	249,844	350,000	41,200	14
WBC	373,675	680,000	79,119	12
Totals	2,381,234	6,997,965	1,096,519	101

Source: (EA, 2012a).

material requiring active management within the range of 1.34 – 1.85Mt. This indicates a net surplus in operational capacity of approximately 850kt or that current capacity is broadly capable of managing levels of estimated waste arisings and a significant amount of imported materials. However, overall capacity must be disaggregated to determine if capacity is adequate by general material types (e.g. organic wastes).

6.1.3.2 Operational capacity by facility type

Any waste management system (WMS) within a typical WPA in England will have a range of facility types capable of managing multiple material types in terms of treatment operations. In addition such systems will have transfer facilities and final disposal sites (landfill or incineration) sufficient to meet the needs of the local area.

6.1.3.2.1 Operational capacity for organic waste treatment

A summary of operational and permitted organic waste treatment capacity for each WCA in 2012 is shown in Table 6.2. Total operational organics waste treatment capacity of >250kt exists across 12 facilities and within 6 of Northamptonshire's WCAs. CBC had no operational or permitted capacity at the time of writing (2013/14). NBC was the WCA with the highest received tonnage in 2012 (104kt) followed by ENC (92kt) which had the most permitted facilities (n=3).

Table 6.2: Operational and permitted organic waste treatment capacity by WCA in Northamptonshire (2012)

WCA	Received waste (tonnes)	Permitted capacity (tpa)	# of facilities
CBC	-	-	-
DDC	23,004	55,000	2
ENC	92,058	150,000	3
KBC	11,808	30,000	2
NBC	103,590	125,000	2
SNC	19,874	75,000	2
WBC	117	25,000	1
Totals	250,450	460,000	12

Source: (EA, 2012a).

6.1.3.2.2 Operational capacity for other waste treatment

Table 6.3 summarises operational and permitted capacities for all other waste treatment facilities by WCA in 2012. A total operational capacity of 345kt across 43 facilities existed in 2012. DDC was the WCA with the largest operational capacity (123kt) and number of facilities (n=14).

Table 6.3: Operational capacity of all other waste treatment facilities by WCA in Northamptonshire (2012)

WCA	Received waste (tonnes)	Permitted capacity (tpa)	# of facilities
CBC	75,628	355,000	8
DDC	123,254	580,000	14
ENC	46,105	80,000	5
KBC	7	5,000	1
NBC	90,508	360,000	8
SNC	2,380	15,000	3
WBC	6,963	45,000	4
Totals	344,844	1,440,000	43

Source: (EA, 2012a; 2012b).

Total treatment capacity (e.g. organic and general treatment) is thus 1.90Mtpa with a total received tonnage in 2012 of 595kt. This material flow is managed at 55 specialist facilities across 12 different facility types.

6.1.3.2.3 Operational capacity for waste transfer facilities

A summary of operational and permitted waste transfer facilities for each WCA in 2012 is shown in Table 6.4. Operational capacity totalled 644kt in 2012 and ranged from 11kt (DDC) to 236kt (NBC) with a total of 36 operational waste transfer facilities with a combined permitted capacity of 1.83Mtpa.

Table 6.4: Operational capacities (tonnes/tpa) of waste transfer facilities by WCA in Northamptonshire (2012)

WCA	Received waste (tonnes)	Permitted capacity (tpa)	Removed waste (tonnes)	# of facilities
CBC	125,705	425,000	125,971	5
DDC	10,905	85,000	11,485	4
ENC	22,061	80,000	22,868	4
KBC	126,930	250,000	132,342	3
NBC	236,033	667,665	229,484	8
SNC	51,018	110,000	38,446	6
WBC	71,279	210,000	68,471	6
Totals	643,931	1,827,665	629,069	36

Source: (EA, 2012a; 2012b).

6.1.3.2.3 Operational capacity for landfill facilities

A summary of operational and permitted landfill capacity for each WCA in 2012 is shown in Table 6.5. The 12 operational facilities had a combined capacity of 1.02Mt in 2012.

Table 6.5: Operational capacity (tonnes/tpa) of landfill facilities by WCA in Northamptonshire (2012)

WCA	Received waste (tonnes)	Permitted capacity (tpa)	# of facilities
CBC	67,866	800,000	1
DDC	166,737	320,000	2
ENC	234,202	950,000	3
KBC	116,272	650,000	3
NBC	-	-	-
SNC	145,152	150,000	2
WBC	294,020	400,000	1
Totals	1,024,250	3,270,000	12

Source: (EA, 2012a; 2012b).

The operational capacity of WBC was the largest at 294kt at one facility (Sidegate Lane) while the largest permitted capacity of 950kt existed at facilities (n=3) within ENC. No operational or permitted landfill sites are located within NBC given the urbanised nature of the WCA.

6.1.3.3 Summary of waste infrastructure spatial distribution

This section has shown the scale of the waste management system within Northamptonshire as a typical two-tier system in England. The 101 permitted facilities shown in Figures 6.3 (as well as the detailed breakdown in Appendix 2) and summarised in Tables 6.1 to 6.5 reports permitted capacity at almost 7.00Mt. Received waste (operational capacity) at all facility types is significant at 2.38Mt with a further 1.10Mt removed from permitted facilities for further processing or final disposal.

Table 6.6: Summary of capacities by facility type in Northamptonshire (2012)

Facility types	Received waste (tonnes)	Permitted capacity (tpa)	Removed waste (tonnes)	# of facilities
Organic treatment	250,450	460,000	107,924	12
Treatment	344,844	1,440,000	350,132	43
Transfer	643,931	1,827,665	629,069	36
Landfill	1,024,250	3,270,000	9,394	12
Recovery	117,759	-	-	5
Totals[19]	2,381,234	6,997,665	1,096,519	108

Source: (after EA, 2012a; 2012b).

However, Table 6.6 indicates a continued reliance on landfill within Northamptonshire in 2012, managing some 1.02Mt by this means. In order to meet targets and local objectives on waste (NCC, 2012), there is a need for greater use of treatment in order to increase recycling and recovery rates and meet the goal of net self-sufficiency (NCC, 2012). Such an expansion on operational and permitted capacity requires a more complete assessment of waste facility siting and is addressed in section 6.2 by means of applying Saaty's AHP process.

[19] Total number of facilities is higher than the operational figure here as it includes 7 facilities which were in closure stage of their permit and were removing waste only (4 MRS; 2 ELV and 1 Vehicle depollution – see EA, 2012a).

6.2: Utilising AHP to frame the problem of waste facility siting

The Analytical Hierarchy Process (AHP) is utilised to define the relative weightings of specific criteria on the site selection process. AHP is a widely used method in the academic literature for site identification and evaluation of various waste facility types (Sumathi et al. 2008; Bastin and Longden, 2009). A stepwise approach was developed which was readily repeatable in order to reflect the iterations within the scenario development phase of the backcasting process. The approach used the three critical steps identified in the literature, namely: problem modelling; weights evaluation; and weights aggregation. Sensitivity analysis was further considered in terms of the specific scenarios developed and modelled with their ensuing impacts on the criteria weights (addressed in Chapter 7).

6.2.1 The problem of siting waste facilities: Identifying relevant criteria

The problem of siting waste facilities is widely acknowledged (Minehart and Neeman, 2002; Bates et al. 2008; CIWM, 2013). When undertaking a modelling approach which looks at the wider systemic conditions, rather than single problem considerations, it is necessary to construct a model capable of addressing multiple situations. Moreover, if the single issue problem is considered as contributing to the wider systemic problem then approaches capable of isolating that set of criteria and incorporating them based on wider considerations are required.

This research has developed a model based on industry and academically accepted site screening methodologies (SLR, 2006; Bates et al. 2008; Sumathi et al, 2008; DTZ/SLR, 2009a; De Feo and De Gisi, 2010) which identify key criteria with input from stakeholders. The resulting output identifies a long list of opportunities and constraining criteria. Table 6.7 shows a total of 5 opportunities groups and 4 constraining groups were identified for evaluation along with 19 individual opportunities criterion (3, 4, 3, 4 and 5 respectively for the 5 opportunities groups) and 22 individual constraining criterion (10, 6, 3 and 3 respectively for the 4 constraints groups).

Table 6.7: List of opportunities and constraints groups with individual criterion identified

Opportunities groups	Opportunities Criterion	Constraints groups	Constraints Criterion
Source of waste	Waste Arisings - C&I	Environmental	Groundwater - SPZ
	Waste Arisings - LACW	Receptors	Rivers
	Waste Arisings - C&D		Lakes
			Local Nature Reserve
Existing waste site	Forecast capacity gap		National Nature Reserve
	Waste PPC sites		RAMSAR sites
	Landfills Active/Closed		Site of Special Scientific Interest
	Permitted sites		Special Protection Areas
			Environmentally Sensitive Areas
Socio-Economic	Regeneration Zones		Ancient Woodland
	Employment	Conservation	Agricultural Land – Grade 1
	Deprivation	Receptors	Agricultural Land – Grade 2
Heat /power networks	Viability of decentralised energy		Historic Parks and Gardens
	Gas Networks		Listed Buildings
	Electricity Networks		Registered Battlefields
	Households off gas grid		Scheduled Ancient Monuments
Transport networks	Rail / Stations / Sidings	Human & Social Capital	Urban - residential areas
	Motorway Access	Receptors	Urban - workplaces
	Access to A Roads		Population density
	Access to B Roads	Flood Risk	Historic flood extent
	Navigable waterways	&	Flood zones
		Ground Stability	Mining & quarry activities

Sources: (after DTZ/SLR, 2009b; De Feo and De Gisi, 2010).

6.2.1.1 Assigning typologies to opportunities criteria

De Feo and De Gisi (2010) in their study of composting plant siting; suggest grouping criterion according to 3 specific parameters; excluding, preferential and penalising. The grouping of criterion and describes considerations for each criterion according to these typologies in terms of opportunities. Table 6.8 shows 19 criterions within the 5 opportunities groupings. A total of 11 were considered as preferential criteria for consideration within the model while the remaining 8 were to be considered as penalizing criteria. No excluding criteria were identified for opportunities.

Table 6.8: Opportunities: grouping of criterion, descriptions and typologies considered

Opportunities	Criterion	Description	Typology
Source of waste arisings	Waste Arisings C&I	Proximity to commercial and industrial operations are to be considered preferential, distance to minimise (m)	Preferential
	Waste Arisings MSW (LACW)	Proximity to residential areas are to be considered preferential, distance to minimise beyond recognised buffer (m)	Preferential
	Waste Arisings C&D	Proximity to construction and redevelopment sites are to be considered preferential, distance to minimise (m)	Preferential
Existing waste site	Forecasted capacity gap	Areas identified as potential shortfall in capacity should be considered as priority, overcapacity considered for other operations and colocation	Penalizing
	Waste PPC sites (Incineration)	Represents a recognised demand and potential market for residual fractions to recover energy, distance to be minimised (m)	Preferential
	Landfills Active/Closed	Potential for redevelopment as waste sites with waste management planning classification	Preferential
	Existing licensed/permitted WM sites	Existing planning classification - potential to expand operations within boundary of site or using adjacent land	Preferential
Socio-Economic	Regeneration Zones	Certain operation types to be considered (MRF; transfer) to provide employment and potential for host community status with incentives	Preferential
	Unemployment	Certain operation types to be considered (MRF; transfer) to provide employment and potential for host community status with incentives	Penalizing
	Deprivation	Certain operation types to be considered (MRF; transfer) to provide employment and potential for host community status with incentives	Penalizing
Heat and power networks	Viability of decentralised energy	Areas of new build housing and business parks/estates are considered preferential	Preferential
	Gas Networks	Cost implications of connecting to grid AD, distance to be minimised (m)	Penalizing
	Electricity Networks	Cost implications of connecting to grid for EfW (AD), distance to be minimised (m)	Penalizing
	Proportion of hhlds off gas grid	Viability of AD with EfW technology for provision of energy	Preferential
Transport networks	Rail / Stations / Sidings	Economic considerations, distance to be minimised (m)	Preferential
	Motorway Access	Economic considerations, distance to be minimised to motorway junctions (m)	Penalizing
	Access to A Roads	Economic considerations, distance to be minimised (m)	Penalizing
	Access to B Roads	Economic considerations, distance to be minimised (m)	Penalizing
	Navigable waterways /large rivers	Potential of wharves and dock facilities on canals as well as marinas on navigable rivers, distance to be minimised (m)	Preferential

Source: (after De Feo and De Gisi, 2010).

6.2.1.2 Assigning typologies to constraints criteria

A stated aim of policy on waste management is to protect the environment and human health from pollution and harm. For these reasons a significant amount of guidance exists relating to distances for siting infrastructure to sensitive receptors (Nathanail and Bardos, 2005; EA, 2013). Table 6.9 shows the grouping of constraints criterion which is informed by such guidance and typologies identified in the academic literature (De Feo and De Gisi, 2010).

Table 6.9: Constraints: grouping of criterion, descriptions and typologies considered

Constraints	Criterion	Description	Typology
Environmental Receptors	Groundwater - Source Protection Zones	Areas of licensed water abstraction not considered for development	Exclusionary
	Rivers	Potential impact on aquatic environment of operations, beyond recognised buffer extent (m)	Exclusionary
	Lakes	Potential impact on aquatic environment of operations, beyond recognised buffer extent (m)	Exclusionary
	Local Nature Reserve (LNR)	Potential impact of operations degrading flora and fauna, distance to maximise (m)	Penalizing
	National Nature Reserve (NNR)	Potential impact of operations degrading flora and fauna, distance to maximise (m)	Penalizing
	RAMSAR (Convention on Wetlands)	Potential impact of operations degrading flora and fauna, distance to maximise (m)	Penalizing
	Site of Special Scientific Interest (SSSI)	Potential impact of operations degrading flora and fauna, distance to maximise (m)	Penalizing
	Special Protection Areas (SPA)	Potential impact of operations degrading flora and fauna, distance to maximise (m)	Penalizing
	Environmentally Sensitive Areas	Potential impact of operations degrading flora and fauna, distance to maximise (m)	Penalizing
	Ancient Woodland	Potential impact of operations degrading flora and fauna, distance to maximise (m)	Penalizing
Conservation Receptors	Agricultural Land – Grade 1	High value arable land not considered for development	Exclusionary
	Agricultural Land – Grade 2	High value arable land not considered for development	Exclusionary
	Historic Parks and Gardens	Potential impact of operations degrading amenity, distance to maximise (m)	Penalizing
	Listed Buildings	Potential impact of operations degrading amenity, distance to maximise (m)	Penalizing
	Registered Battlefields	Potential impact of operations degrading amenity, distance to maximise (m)	Penalizing
	Scheduled Ancient Monuments	Potential impact of operations degrading amenity, distance to maximise (m)	Penalizing

Table 6.9: (continued)

Constraints	Criterion	Description	Typology
Human & Social Capital	Urban - residential areas	Distance to be maximised in line with guidance, buffering (m)	Penalizing
	Urban - workplaces	Distance to be maximised in line with guidance, buffering (m)	Penalizing
	Population density	Distance to be maximised in line with guidance, buffering (m)	Penalizing
Flood Risk & Mining	Historic flood extent	Areas within historic flood extent to be considered as limiting, distance to be maximised (m)	Penalizing
	Flood zones	Areas classified as Flood Zones 3 and 2 not to be considered for development	Exclusionary
	Mining & quarry activities	Areas of mining activity to be considered as excluding, quarry sites considered preferential	Exclusionary / Preferential

Source: (after De Feo and De Gisi, 2010).

Table 6.9 shows that of the 22 criterion within the 4 constraints groupings, a total of 6 were considered as exclusionary; with the remaining 16 considered as penalizing. The reasons for the penalizing considerations in relation to constraining criteria typically reflected localised considerations. For example; areas of mining activities can be varied and do not always include tunnelling operations. Quarry activities, particularly for limestone and ironstone extraction in Northamptonshire, have historically provided opportunities for waste management operations in the form of landfill (e.g. for waste materials or as restoration of disturbed land). Such considerations were applied to all constraint criterion identified and thus produced more penalizing categories. It can also be seen that exclusionary criteria are either focused on the protection of resources suitable for human consumption (such as potable water sources or agricultural crops) or are for factors designed to protect human health and wellbeing (e.g. flood zones) or areas of habitation and economic activity (e.g. areas of mining activity).

6.2.1.3 Developing a problem formation hierarchy

A problem formation hierarchy (PFH) was used to frame the goal (overall objective); group criteria; and individual criterion. The overall objective was to develop a suitability model for potential sites within the case study area and evaluate these against preferred locations within the relevant planning framework (NCC, 2012). Figure 6.4 is a schematic of the opportunities PFH.

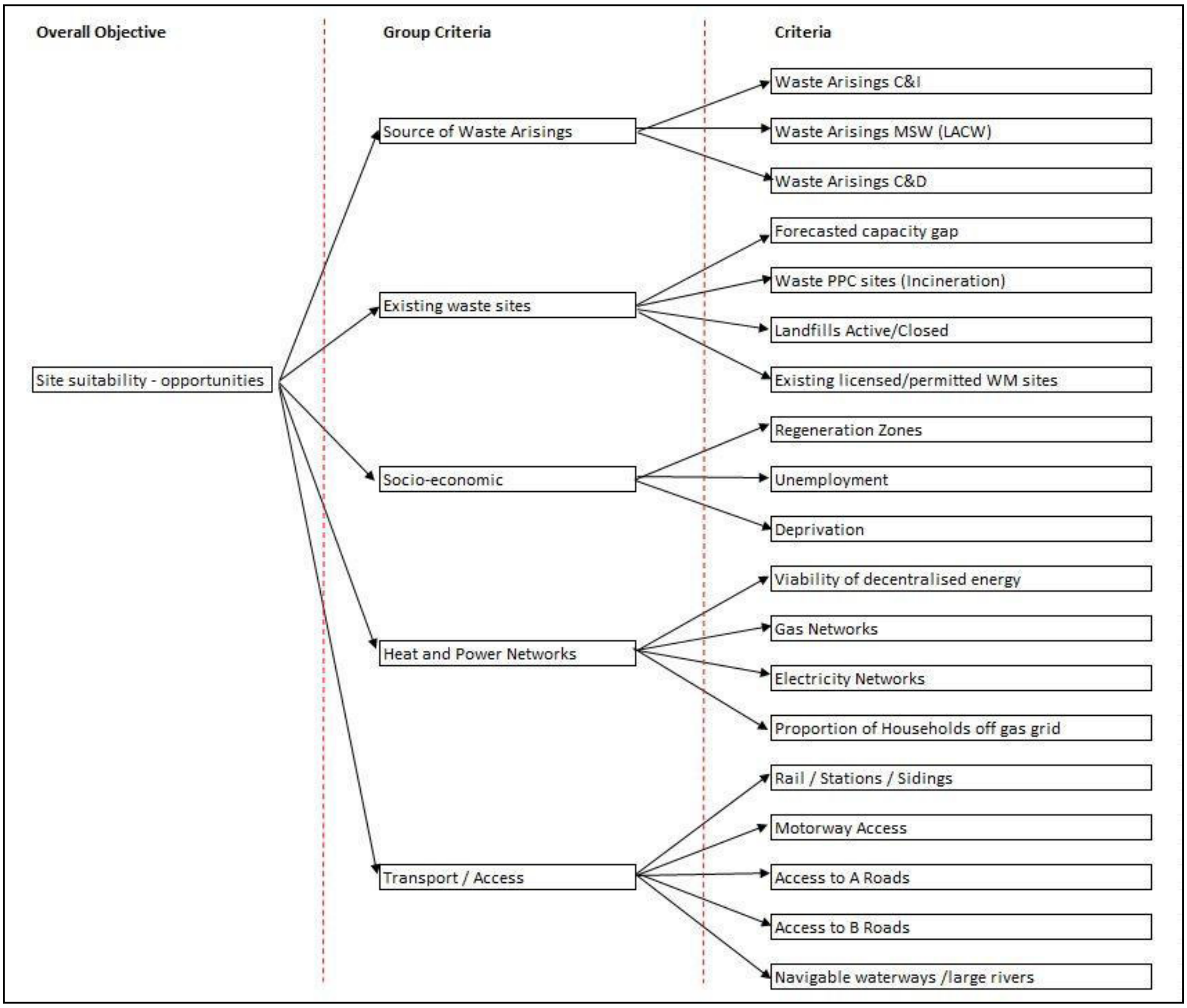


Figure 6.4: Problem formation hierarchy (PFH) for site suitability looking at opportunities

Figure 6.4, shows the overall goal is stated as 'site suitability' based on opportunities criteria. A total of 5 criteria groupings are then identified before being broken down into a further 19 individual criterion to be used in the analytical process. These individual criterions were chosen as being representative of local conditions and able to be applied at both macro and micro levels.

Figure 6.5 is a schematic of the constraints PFH. Again, the individual criterions were chosen for their applicability in assessing siting options at the macro and micro scales. The constraints PFH, shown in Figure 6.5, first states the goal of 'site suitability' accounting for constraining criteria. A total of 4 criteria groupings are then identified before being broken down into 22 individual criterions identified. These criterions were further evaluated in terms of their impact on site selection as being penalizing (i.e. providing a minimum or maximum distance for infrastructure siting) or specifically exclusionary.

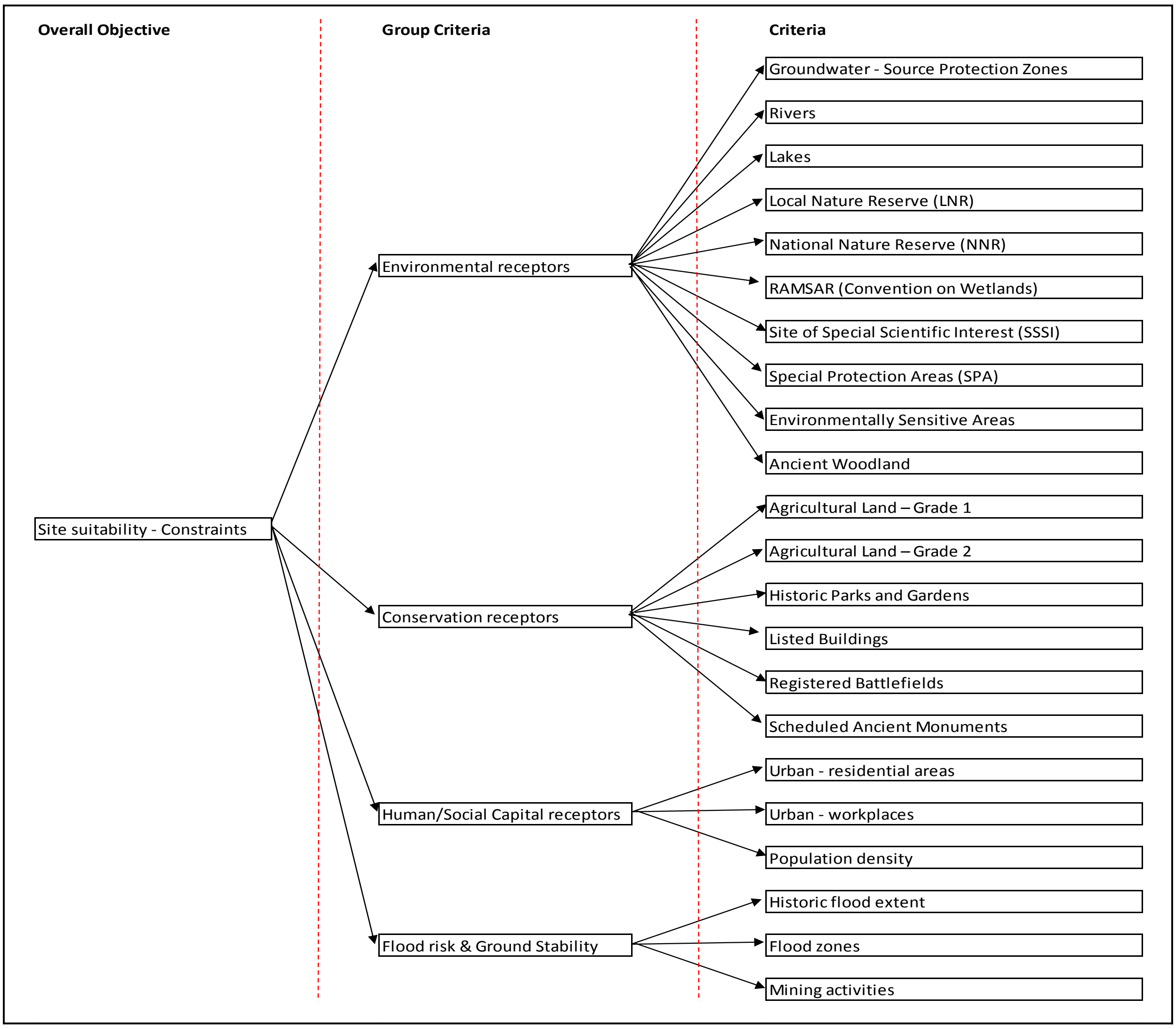


Figure 6.5: Problem formation hierarchy for site suitability looking at constraints

6.2.2 Weights evaluation

The next stage in the AHP process is to assign weightings to the criteria groupings and their constituent criterion. Stakeholders were asked to give preferences on the group criteria in the first instance in order to assign relative weightings to each group. Responses were collected via priority scale forms. An example of a completed form is shown in Figure 6.6.

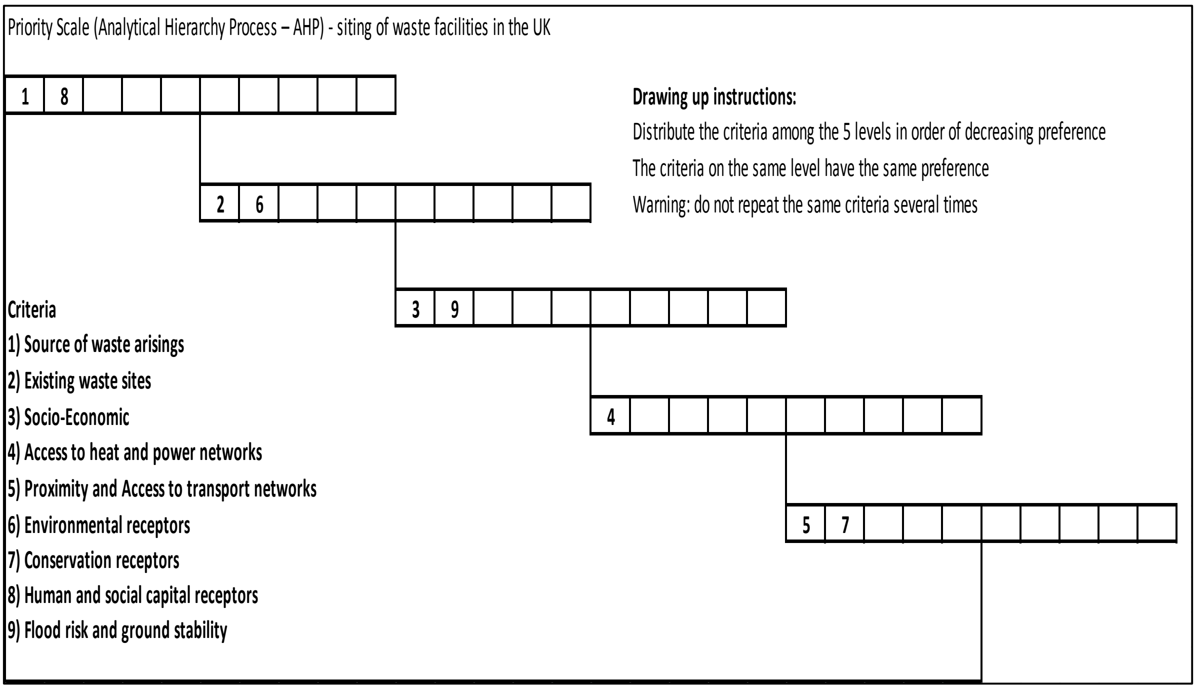


Figure 6.6: Example of completed priority scale input matrix for AHP analysis of group criteria (Source: after De Feo and De Gisi, 2010).

As can be seen in Figure 6.6 the AHP is applied to the criteria groupings identified following the structure of the PFH (section 6.3.1). Previous research at a regional scale has used the weightings for these macro factors with input from steering groups to determine weights for individual criterion (DTZ/SLR, 2009b). The potential for bias is evident from this process of evaluation and is avoided in this study through the use of stakeholder input at the micro scale (e.g. for individual criterion using AHP).

6.2.2.1 Calculating the group criteria weightings

To calculate the weights for each criterion it is first necessary to determine the weights from the stakeholder input process looking at the wider group criteria. The AHP software package developed by Goepel (2013) was used to enter results data from priority scale forms (Figure 6.6). Technical stakeholder (TS) and non-technical stakeholder (NTS) responses were entered separately to produce weightings which could be compared to give an overall weighted average. Figure 6.7 shows the pairwise comparison consolidated results for the 20 technical stakeholder responses.

Result					
Eigenvalue				lambda:	9.035
Consistency Ratio	0.37	GCI:	0.01	CR:	0.0030

Matrix

		1 Source of waste arisings	2 Existing waste sites	3 Socio-economic	4 Access to heat/power networks	5 Proximity to transport networks	6 Environmental receptors	7 Conservation receptors	8 Human & social capital receptors	9 Flood risk/ground stability	10 0	normalized principal Eigenvector
Source of waste	1	-	4/7	1 2/7	3 1/5	2 1/2	2/5	1 1/3	3/4	1	-	10.65%
Existing waste sites	2	1 7/9	-	2	4 1/3	3 4/7	2/3	2 1/9	1 1/6	1 4/9	-	16.64%
Socio-economic	3	7/9	1/2	-	2 4/9	1 7/8	3/8	1 1/5	5/7	5/6	-	8.85%
Access to heat/power	4	1/3	1/4	2/5	-	1	1/6	3/5	1/3	1/3	-	4.02%
Proximity to transport	5	2/5	2/7	1/2	1	-	1/4	5/9	3/7	3/8	-	4.65%
Environmental receptors	6	2 3/7	1 3/7	2 5/7	5 3/4	4 1/6	-	3 4/7	2	2 4/9	-	24.15%
Conservation receptors	7	3/4	1/2	5/6	1 2/3	1 4/5	2/7	-	5/8	4/7	-	7.38%
Human & social	8	1 3/8	6/7	1 2/5	2 7/9	2 2/7	1/2	1 4/7	-	1 1/7	-	12.42%
Flood risk/ground	9	1	2/3	1 1/5	2 4/5	2 5/8	2/5	1 7/9	7/8	-	-	11.25%
0	10	-	-	-	-	-	-	-	-	-	-	0.00%

Figure 6.7: Screenshot of consolidated results of technical stakeholder (TS) responses (Source: Goepel, 2013)

Consolidated results are produced in the summary sheet of the BPMSG software package providing an aggregated score (weight) in terms of the 'normalized principal Eigenvector'. These scores are taken forwards as the overall group weighting criteria and used to calculate the weights of individual criterion for micro-scale site evaluation.

Importantly, when considering the application of AHP, acknowledgement must be made as to the level of consistency within the results. The consistency ratio section shown in Figure 6.7 highlights the recommended range as GCI (Geometric Consistency Index) in this case 0.01 and CR (Consistency Ratio) in this case 0.0030. The figure 0.37 relates to the number of criteria chosen being a maximum value of 0.37 for (n=>4). This figure provides a measure of the level of inconsistency within the Eigenvector Method (EM or EVM) using a row geometric mean method (RGMM) prioritization procedure as is the case with the BPMSG spreadsheet package (Goepel, 2013). Finally the Eigenvalue is represented as lambda (9.035 in Figure 6.7) which is used to solve the EM problem with the power method algorithm (having a maximum of 12 iterations in this software).

Figure 6.8 shows the pairwise comparison consolidated results for the 20 non-technical stakeholder response. The results for consistency measures are GCI 0.009 and CR 0.0023 each being significantly below the Saaty threshold of 0.1 (Saaty, 1980).

Result	Eigenvalue			lambda:	9.027
	Consistency Ratio	0.37	GCI: 0.009	CR:	0.0023

Matrix		Source of waste arisings	Existing waste sites	Socio-Economic	Access to heat/power networks	Proximity to transport networks	Environmental receptors	Conservation receptors	Human/social capital receptors	Flood risk/ground stability	0	normalized principal Eigenvector
		1	2	3	4	5	6	7	8	9	10	
Source of waste arisings	1	-	1 1/5	2/3	1	1	7/9	3 1/2	1 1/2	2	-	12.20%
Existing waste sites	2	5/6	-	3/5	1	6/7	7/9	2 7/8	1	1 5/7	-	10.60%
Socio-Economic	3	1 4/7	1 5/7	-	1 7/9	1 5/7	1 1/3	5	2 1/4	3	-	19.36%
Access to heat/power networks	4	1	1	4/7	-	1 1/5	6/7	3 5/9	1 3/7	2 1/3	-	12.62%
Proximity to transport networks	5	1	1 1/6	4/7	5/6	-	5/6	3 5/8	1 1/3	2	-	11.89%
Environmental receptors	6	1 2/7	1 2/7	3/4	1 1/6	1 1/5	-	4	2	2 1/2	-	14.97%
Conservation receptors	7	2/7	1/3	1/5	2/7	2/7	1/4	-	1/3	5/7	-	3.55%
Human/social capital	8	2/3	1	4/9	5/7	3/4	1/2	3 1/5	-	1 5/8	-	9.06%
Flood risk/ground stability	9	1/2	4/7	1/3	3/7	1/2	2/5	1 2/5	3/5	-	-	5.76%
0	10	-	-	-	-	-	-	-	-	-	-	0.00%

Figure 6.8: Screenshot of consolidated results of non-technical stakeholder (NTS) responses (Source: Goepel, 2013)

6.2.2.1.1 Analysing the stakeholder responses

Tables 6.10 and 6.11 contain the results of the group criteria weighting calculations for both groups of respondents (TS and NTS respectively). These results are extracted from the BPMSG software package (Goepel, 2013) for further analysis of priorities given by participants. It can be seen that technical stakeholders (TS) gave priority to ‘socio-economic factors’ (16.48%) above all other opportunities groups. The next priority was in terms of ‘source of waste arisings’ (13.40%). Perhaps most interestingly the other opportunities criteria groups: ‘existing waste sites’ (11.97%); ‘access to heat and power networks’

Table 6.10: Results of the group criteria weighting calculations for technical stakeholders (TS - n=20)

	Criteria	Source of waste arisings	Existing waste sites	Socio-Economic	Access to heat/power networks	Proximity to transport networks	Environmental receptors	Conservation receptors	Human/ social capital receptors	Flood risk/ground stability	Sub Total	CR
Technical stakeholders	T1	0.0430	0.2147	0.2147	0.0914	0.0914	0.0914	0.0146	0.0240	0.2147	1.00	0.0291
	T2	0.1024	0.0149	0.1024	0.0423	0.1024	0.2454	0.0423	0.1024	0.2454	1.00	0.0212
	T3	0.0935	0.2077	0.2198	0.0990	0.0935	0.2077	0.0214	0.0246	0.0326	1.00	0.0185
	T4	0.1203	0.0175	0.2573	0.2573	0.1203	0.1203	0.0316	0.0578	0.0175	1.00	0.0459
	T5	0.0538	0.1049	0.2243	0.2243	0.1049	0.0168	0.0300	0.2243	0.0168	1.00	0.0309
	T6	0.0194	0.2079	0.2079	0.0805	0.2079	0.0805	0.0805	0.0805	0.0348	1.00	0.0285
	T7	0.1242	0.2607	0.1242	0.0349	0.2607	0.1242	0.0181	0.0349	0.0181	1.00	0.0118
	T8	0.0449	0.0248	0.1008	0.2219	0.2219	0.2219	0.0157	0.0475	0.1008	1.00	0.0300
	T9	0.2716	0.1382	0.1382	0.0709	0.2716	0.0363	0.0185	0.0185	0.0363	1.00	0.0223
	T10	0.0881	0.0381	0.2131	0.2131	0.0381	0.0881	0.0199	0.0881	0.2131	1.00	0.0367
	T11	0.0496	0.1146	0.2547	0.2547	0.1146	0.1146	0.0238	0.0496	0.0238	1.00	0.0149
	T12	0.2215	0.1006	0.1006	0.0474	0.0474	0.2215	0.0148	0.2215	0.0248	1.00	0.0216
	T13	0.2145	0.0904	0.0418	0.0218	0.2145	0.0904	0.0904	0.2145	0.0218	1.00	0.0243
	T14	0.1382	0.2716	0.0709	0.0363	0.0185	0.2716	0.0185	0.1382	0.0363	1.00	0.0174
	T15	0.2243	0.0168	0.2243	0.2243	0.1049	0.1049	0.0168	0.0538	0.0300	1.00	0.0367
	T16	0.2147	0.0914	0.2147	0.0430	0.0914	0.2147	0.0146	0.0914	0.0240	1.00	0.0285
	T17	0.0199	0.2131	0.2131	0.0881	0.0381	0.2131	0.0881	0.0881	0.0381	1.00	0.0212
	T18	0.2147	0.0914	0.0914	0.0430	0.0240	0.2147	0.0146	0.0914	0.2147	1.00	0.0149
	T19	0.1024	0.0149	0.2454	0.1024	0.0423	0.2454	0.1024	0.1024	0.0423	1.00	0.0212
	T20	0.3183	0.1604	0.0356	0.1604	0.0756	0.0356	0.0179	0.1604	0.0356	1.00	0.1850
	Total	2.6795	2.3946	3.2953	2.3572	2.2839	2.9592	0.6946	1.9138	1.4218	20.00	
	%	13.40	11.97	16.48	11.79	11.42	14.80	3.47	9.57	7.11	100.00	
	Stn Dev	0.08890	0.08583	0.07444	0.08365	0.07896	0.08050	0.02957	0.06507	0.07961		
	Consolidated CR											0.0023

Note: TS in this study are drawn from waste industry experts, academic disciplines related to waste and individuals involved in funded waste research

Table 6.11: Results of the group criteria weighting calculations for non-technical stakeholders (NTS - n=20)

Criteria		Source of waste arisings	Existing waste sites	Socio-Economic	Access to heat/ power networks	Proximity to transport networks	Environmental receptors	Conservation receptors	Human/ social capital receptors	Flood risk/ ground stability	Sub Total	CR
Non-Technical stakeholders	NT1	0.0567	0.1285	0.0158	0.0567	0.0272	0.2650	0.0567	0.2650	0.1285	1.00	0.0284
	NT2	0.0706	0.1569	0.0191	0.0706	0.0191	0.3144	0.1569	0.1569	0.0355	1.00	0.0321
	NT3	0.1513	0.3120	0.1513	0.0626	0.0626	0.1513	0.0295	0.0169	0.0626	1.00	0.0256
	NT4	0.0329	0.0642	0.1337	0.0179	0.0179	0.2678	0.0642	0.1337	0.2678	1.00	0.0357
	NT5	0.0253	0.1049	0.0463	0.0153	0.1049	0.2466	0.1049	0.1049	0.2466	1.00	0.0218
	NT6	0.0363	0.0185	0.2716	0.0363	0.0185	0.2716	0.1382	0.0709	0.1382	1.00	0.0367
	NT7	0.1322	0.2675	0.0623	0.0623	0.0299	0.2675	0.1322	0.0163	0.0299	1.00	0.0319
	NT8	0.2685	0.1340	0.0608	0.0330	0.0179	0.1340	0.0190	0.2685	0.0644	1.00	0.0336
	NT9	0.0623	0.1322	0.2675	0.0623	0.0299	0.2675	0.0163	0.1322	0.0299	1.00	0.0319
	NT10	0.1157	0.1157	0.0262	0.0510	0.2546	0.1157	0.0155	0.0510	0.2546	1.00	0.0262
	NT11	0.0623	0.2675	0.0299	0.0163	0.1322	0.0623	0.2675	0.1322	0.0299	1.00	0.0319
	NT12	0.0795	0.0382	0.0382	0.0191	0.0191	0.2856	0.0795	0.2856	0.1551	1.00	0.0395
	NT13	0.0683	0.3129	0.1637	0.1547	0.0322	0.0645	0.0178	0.1547	0.0313	1.00	0.0363
	NT14	0.0460	0.2213	0.0996	0.0225	0.0225	0.2213	0.0996	0.2213	0.0460	1.00	0.0196
	NT15	0.1322	0.2675	0.0623	0.0299	0.0163	0.2675	0.0299	0.1322	0.0623	1.00	0.0319
	NT16	0.1337	0.2678	0.2678	0.0642	0.0179	0.1337	0.0329	0.0179	0.0642	1.00	0.0357
	NT17	0.1189	0.2358	0.0312	0.0312	0.0638	0.2358	0.0312	0.0161	0.2358	1.00	0.0264
	NT18	0.1049	0.2466	0.1049	0.0153	0.0253	0.1049	0.2466	0.0463	0.1049	1.00	0.0218
	NT19	0.1157	0.0510	0.2546	0.0155	0.0262	0.1157	0.0510	0.2546	0.1157	1.00	0.0262
	NT20	0.1006	0.2215	0.0474	0.0248	0.2215	0.1006	0.0148	0.2215	0.0474	1.00	0.0243
	Total	1.9139	3.5645	2.1542	0.8614	1.1595	3.8931	1.6042	2.6986	2.1507	20.0	
	%	9.57	17.82	10.77	4.31	5.80	19.47	8.02	13.49	10.75	100.0	
	Stn Dev	0.05562	0.09466	0.09142	0.03283	0.06915	0.08365	0.07515	0.09273	0.08308		
Consolidated CR												0.0030

Note: NTS in this study are composed of members of the general public and interest groups who have stated they have no active involvement or working knowledge of waste management companies or organisations

(11.79%); and ‘access to transport networks’ (11.42%) scored similarly. This position differs considerably for NTS (Table 6.11), assigning ‘existing waste sites’ (17.8%) by far the greatest priority. In this case ‘socio-economic factors’ (10.8%) and ‘source of waste arisings’ (9.57%) are preferred over the worst performing groups of ‘access to heat and power networks’ (5.80%) and ‘proximity to transport networks’ (4.31%).

In terms of constraining criteria, TS prioritised ‘environmental receptors’ (14.8%) above ‘human & social capital’ (9.57%) and ‘flood risk’ (7.11%) with the least priority given to ‘conservation receptors’ (3.47%). For constraining criteria, NTS produced the same priority profile but assigned greater relative values to each: ‘environmental receptors’ (19.5%); ‘human & social capital’ (13.5%); ‘flood risk’ (10.8%); and ‘conservation receptors’ (8.02%). The last point to draw from Tables 6.10 and 6.11 relates to the priority assigned to opportunities in relation to constraints between the two participant groups. TS prioritised opportunities criteria (65.1%) over constraints criteria (35.0%). In contrast NTS only slightly prioritised constraints (51.7%) over opportunities (48.3%). The consolidated consistency ratios (CR) were 0.0023 for opportunities and 0.0030 for constraints criteria.

6.2.2.2 Calculating the individual criterion weightings

Pairwise comparison matrices were also generated for criterion within each grouping[20]. The second round of weighting using priority scale forms took the same format as that of the group criteria weighting (section 3.4.2).

6.2.2.2.1 Opportunities criterion weighting

Results of priority scale forms were entered into an individual AHP spreadsheet for each criteria grouping. Technical stakeholder (TS) and non-technical stakeholder (NTS) responses were entered together at this stage as the OWA method had already been applied to group criteria. A random sample of 5 responses for each criteria group was used to

[20] Pairwise comparison matrices are shown in Appendix 10

address any potential bias. The results of opportunities criterion weighting is given in Tables 6.12.

Table 6.12: Results of the random sample responses for opportunities criterion weighting

Source of waste	R1	R2	R3	R4	R5	Mean	Weight
C&I waste	0.2790	0.4545	0.3333	0.6000	0.6370	0.4608	5.29
LACW waste	0.6491	0.4545	0.3333	0.2000	0.2583	0.3791	4.35
C&D waste	0.0719	0.0909	0.3333	0.2000	0.1047	0.1602	1.84
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	11.49
CR	0.0677	0.0000	0.0000	0.0000	0.0402	0.0216	
Existing waste sites	R1	R2	R3	R4	R5	Mean	Weight
Waste PPC sites (incineration)	0.0675	0.0675	0.0550	0.0963	0.0513	0.0675	1.01
Landfills active/closed	0.3908	0.1509	0.1178	0.2495	0.2118	0.2242	3.34
Permitted existing WM sites	0.3908	0.3908	0.5638	0.5579	0.2118	0.4230	6.30
Forecast capacity gap	0.1509	0.3908	0.2634	0.0963	0.5252	0.2853	4.25
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	14.90
CR	0.0115	0.0115	0.0435	0.0212	0.0277	0.0231	
Socio-economic factors	R1	R2	R3	R4	R5	Mean	Weight
Regeneration zones	0.6491	0.1488	0.7306	0.4737	0.1884	0.4381	5.97
Employment	0.2790	0.7854	0.1884	0.4737	0.7306	0.4914	6.70
Deprivation	0.0719	0.0658	0.0810	0.0526	0.0810	0.0705	0.96
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	13.63
CR	0.0677	0.0838	0.0677	0.0000	0.0677	0.0574	
Access to heat/power networks	R1	R2	R3	R4	R5	Mean	Weight
Viability of decentralised energy	0.1250	0.2634	0.1509	0.5205	0.1178	0.2355	1.90
Gas networks	0.3750	0.5638	0.3908	0.2010	0.2634	0.3588	2.89
Electricity networks	0.3750	0.1178	0.0675	0.0776	0.0550	0.1386	1.12
Households off gas grid	0.1250	0.0550	0.3908	0.2010	0.5638	0.2671	2.15
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	8.05
CR	0.0000	0.0435	0.0115	0.0169	0.0435	0.0231	
Access to transport networks	R1	R2	R3	R4	R5	Mean	Weight
Rail stations and sidings	0.0857	0.1588	0.2461	0.5011	0.3638	0.2711	2.33
Motorway access	0.2033	0.0753	0.0453	0.1038	0.0383	0.0932	0.80
Access to A roads	0.4656	0.3638	0.1038	0.1038	0.3638	0.2801	2.41
Access to B roads	0.2033	0.3638	0.1038	0.0453	0.1588	0.1750	1.51
Navigable waterways/ large rivers	0.0421	0.0383	0.5011	0.2461	0.0753	0.1806	1.55
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	8.61
CR	0.0282	0.0232	0.0318	0.0318	0.0232	0.0276	

To determine individual criterion weighting, the mean was calculated and multiplied by the group criteria OWA value. Consistency was tested using the software calculations and is reported as CR in Table 6.12. All responses achieved a CR of below the 0.1 threshold.

6.2.2.2.2 Constraints criterion weighting

The results of constraints criterion weighting is given in Table 6.13 and are once again based on a random sample of responses.

Table 6.13: Results of the random sample responses for constraints criterion weighting

Environmental receptors	R1	R2	R3	R4	R5	Mean	Weight
SPZ - GW	0.2939	0.2505	0.2125	0.2407	0.2421	0.2480	3.67
Lakes	0.1469	0.0519	0.1001	0.0436	0.1151	0.0915	1.35
Rivers	0.1469	0.1230	0.2125	0.1095	0.2421	0.1668	2.47
LNR	0.0619	0.0227	0.0224	0.0436	0.0524	0.0406	0.60
NNR	0.0619	0.0519	0.0475	0.0436	0.0257	0.0461	0.68
RAMSAR sites	0.0266	0.0519	0.0224	0.0436	0.0524	0.0394	0.58
SSSI	0.0619	0.2505	0.2125	0.1041	0.1151	0.1488	2.20
SPA	0.0266	0.0519	0.0475	0.0212	0.0144	0.0323	0.48
ESA	0.0266	0.0227	0.1001	0.1095	0.0257	0.0569	0.84
Ancient Woodland	0.1469	0.1230	0.0224	0.2407	0.1151	0.1296	1.92
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	14.80
CR	0.0220	0.0215	0.0216	0.0172	0.0283	0.0221	
Conservation receptors	R1	R2	R3	R4	R5	Mean	Weight
Agricultural land - Grade 1	0.4576	0.3206	0.1131	0.3185	0.0943	0.2608	0.90
Agricultural land - Grade 2	0.2392	0.1338	0.1131	0.1291	0.0943	0.1419	0.49
Historic parks and gardens	0.1070	0.1338	0.3075	0.1291	0.2564	0.1868	0.65
Listed buildings	0.1070	0.3206	0.3075	0.3185	0.2564	0.2620	0.91
Registered battlefields	0.0447	0.0599	0.1131	0.0524	0.2564	0.1053	0.37
Scheduled ancient monuments	0.0447	0.0313	0.0458	0.0524	0.0422	0.0433	0.15
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3.47
CR	0.0325	0.0203	0.0080	0.0123	0.0062	0.0159	
Human & social capital receptors	R1	R2	R3	R4	R5	Mean	Weight
Urban - residential	0.2583	0.2000	0.2583	0.4286	0.4286	0.3147	3.01
Urban - workplace	0.1047	0.2000	0.1047	0.1429	0.1429	0.1390	1.33
Population density	0.6370	0.6000	0.6370	0.4286	0.4286	0.5462	5.23
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	9.57
CR	0.0400	0.0000	0.0402	0.0000	0.0000	0.0160	
Flood risk & ground stability	R1	R2	R3	R4	R5	Mean	Weight
Historic flood event	0.2583	0.2583	0.2583	0.2583	0.6370	0.3340	2.37
Flood zones	0.6370	0.6370	0.6370	0.6370	0.2583	0.5612	3.99
Mining activity	0.1047	0.1047	0.1047	0.1047	0.1047	0.1047	0.74
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	7.11
CR	0.0402	0.0402	0.0402	0.0402	0.0402	0.0402	

Consistency was tested using the software calculations and is reported as CR in Table 6.13. All responses achieved a CR of below the 0.1 threshold.

6.2.3 Weights aggregation

The final stage of the AHP process is to aggregate the weights derived from the pairwise comparisons. The first step in this process is to produce the ordered weighted average (OWA) for group criteria shown in Table 6.14.

Table 6.14: Final group weightings derived from stakeholder participation

Criteria grouping	TS (n=20)	NTS (n=20)	Mean
Source of waste arisings	13.40	9.57	11.48
Existing waste sites	11.97	17.82	14.90
Socio-Economic	16.48	10.77	13.62
Access to heat/power networks	11.79	4.31	8.05
Proximity to transport networks	11.42	5.80	8.61
Opportunities Weighted %	65.05	48.27	56.66
Environmental receptors	14.80	19.47	17.13
Conservation receptors	3.47	8.02	5.75
Human/social capital receptors	9.57	13.49	11.53
Flood risk/ground stability	7.11	10.75	8.93
Constraints Weighted %	34.95	51.73	43.34

The final OWA is taken from the mean weighting score in Table 6.14. By using these values it is possible to even out the potential bias from each participant group which produces some interesting results. One significant change has occurred in the OWA results compared with the previous TS results, in that ‘socio-economic factors’ (13.6%) are now the second opportunities priority compared to ‘existing waste sites’ (14.9%) which had scored much lower for TS (12.0%). No other group criteria have changed position in the OWA ranking and this noted change appears to be a result of averaging two groups as opposed to the ‘rank reversal phenomena’ previously identified as an underlying problem with applying AHP (Aguaron and Moreno-Jimenez, 2003; Tung et al. 2012). The final point to note from the OWA results in Table 6.14 relate to the overall weighting of opportunities versus constraints. The OWA results (56.7% versus 43.3%) reflect most closely the values assigned by TS. This appears to be an acceptable outcome thus avoiding excessively favouring one group over another.

6.2.3.1 Aggregated weights for opportunities criterion

The final step is to calculate the weightings for each individual criterion (the last column in Tables 6.10 and 6.11). This aggregated weight is achieved by multiplying the mean value of responses by the OWA group criteria value. The results are summarised in Tables 6.15 and 6.16 with subsequent analysis of the results.

Table 6.15: Summary of opportunities criterion weights for GIS modelling

Group weight	Criterion and weight				
Source of waste arisings 11.49	C&I waste arisings 5.29	LACW waste arisings 4.35	C&D waste arisings 1.84		
Existing waste sites 14.90	Waste PPC sites (incineration) 1.01	Landfills active/closed 3.34	Permitted WM sites 6.30	Forecast capacity gap 4.25	
Socio-Economic 13.63	Regeneration zones 5.97	Employment 6.70	Deprivation 0.96		
Access to heat/power networks 8.05	Viability of decentralised energy 1.90	Gas networks 2.89	Electricity networks 1.12	Households off gas grid 2.15	
Proximity to transport networks 8.61	Rail stations and sidings 2.33	Motorway access 0.80	Access to A roads 2.41	Access to B roads 1.51	Navigable waterways/ large rivers 1.55

The results in Table 6.15 show opportunities criterion weights. In terms of waste arisings, C&I waste (5.29%) achieved the highest priority ahead of LACW (4.35%). For existing sites; permitted waste management sites (6.30%) were assigned the highest priority. PPC sites (1.01%) achieved the lowest priority as many participants had strong views on incineration. Socio-economic factors weightings were relatively evenly spread between regeneration zones (5.97%) and employment (6.70%). Weightings were relatively evenly spread across criterion for both access to heat and power networks and proximity to transport networks.

6.2.3.2 Aggregated weights for constraints criterion

As with opportunities criterion, weights were assigned through calculating the mean value and multiplying this by the OWA group criteria value.

Table 6.16: Summary of constraints criterion weights for GIS modelling

Group	Environmental receptors		Conservation receptors	Human and Social capital	Flood risk
Weight	14.80		3.47	9.57	7.11
Criterion and weights	SPZ - GW 3.67	RAMSAR 0.58	Agricultural land - grade 1 0.90	Urban - residential 3.01	Historic flood event 2.37
	Lakes 1.35	SSSI 2.20	Agricultural land - grade 2 0.49	Urban - workplace 1.33	Flood zones 3.99
	Rivers 2.47	SPA 0.48	Historic parks and gardens 0.65	Population density 5.23	Mining activity 0.74
	LNR 0.60	ESA 0.84	Listed buildings 0.91		
	NNR 0.68	Ancient woodland 1.92	Registered battlefields 0.37		
			Ancient monuments 0.15		

Table 6.16 shows some surprisingly mixed results. For environmental receptors; water related criterion, SSSI and ancient woodland are prioritised over all other criterion. There is an even distribution of weights across conservation criterion with the exception of ancient monuments (0.15%) being least prioritised. In terms of human and social capital weights reflect most guidance and academic literature by assigning the highest constraint values to population density (5.23%) and urban residential (3.01%). The final grouping of flood risk assigned significant weighting to flood zones (3.99%) and historic flood event (2.37%) with a low value for mining activity (0.74%).

6.3. GIS model development

The development of the GIS model builds on the previous stages of spatial analysis and problem formation using AHP and has a number of key requirements:

- Developing site selection criteria – constraints and opportunities (section 6.2)
- Thematic maps – producing layer maps of criteria
- GIS analysis of layer maps
- Constraints and opportunities models – using aggregated weights (section 6.2.3)
- Site suitability model – using aggregated weights (section 6.2.3)

This section will present the results for each of these stages of model development.

6.3.1 Site selection criteria

Section 6.2 has outlined the key stages of developing criteria groupings for opportunities and constraints. All that remains for this step is to define the criteria in terms of their impact on suitability for each facility type. Table 6.17 sets out the key site selection criteria for each facility type currently in operation within the case study area but also includes consideration of large scale energy-from-waste (EfW) facilities which may come on-stream during the backcast period.

Analysis of the site selection criteria for each facility type in Table 6.17 shows typical land take for waste facilities is estimated as being between 0.5 and 5ha. Resource Recovery Parks (RRPs)[21] by their nature are likely to be of considerable scale with up to 60ha indicated in the literature (DCC, 2011). In terms of land use, most facility types can be found in proximity to business and industrial areas. Certain activities (e.g. windrow composting and AD) are found mainly in rural locations or close to specific types of industrial activity. Operations which entail producing energy (e.g. incineration) are also

[21] RRPs are generally associated with logistics and distribution activities in the UK. Such sites have been utilised internationally and designated as Eco-Industrial Parks (EIPs) (see Tudor et al. 2007 or Chertow, 2008 for detailed discussion of EIPs and underlying Industrial Symbiosis principles).

Table 6.17: Site selection criteria by facility type

Facility type	Land take (ha)	Land use	Access	Vehicle type	Common features	Sensitive receptors
HWRC	0.8 or >	business or industrial but proximate to residential	from primary roads space for queuing	Cars and some HGV (low volume)	often sited with WTS	250m from housing
MRF	1 to 2	industrial but B2/B8 also	primary roads no HGV restriction	HGV (medium volume)	needs storage space	100m or less
WTS	0.5 or >	industrial degraded or close to existing WM sites	primary roads	HGV (high volume) with smaller vans, etc.	often sited with HWRC	250m to housing, recreation and commercial
Aggregates recycling	1.5	industrial and employment areas	primary roads no HGV restriction	HGV (medium volume)	needs storage space	250m unless noise can be reduced
Windrow composting	1	Rural developments but some industrial types	primary roads no HGV restriction	HGV (medium volume)	often sited with large WwTW	250m
In-Vessel Composting	1 to 1.5	industrial locations	primary roads no HGV restriction	HGV (medium volume)	typically within building but storage required for final compost output	250m
AD	1 to 1.5	suburban and rural developments	primary roads no HGV restriction	HGV (medium volume)	often sited with MBT or at WwTW	250m
MBT	1.5 to 5	industrial locations	primary roads no HGV restriction	HGV (high volume)	mixed municipal waste mainly treated but can take other biogenic	250m from properties
Resource Recovery Park	up to 60	Industrial, business or degraded land	primary roads no HGV restrictions, potential of water and rail	multi-modal (rail, water) but with road connection	have been created in parts of England draws on EIP and IS principles	sensitive to industrial park operations (250m)
Incineration	3 to 5	industrial locations with DH potential	primary roads no HGV restriction but consider rail transfer	HGV (very high volume)	Requires IBA removal or further treatment (aggregates, etc.)	250m from properties
Pyrolysis & Gasification	1 to 4	business or industrial proximate to residential for DH potential	primary roads no HGV restriction but consider rail transfer	HGV (medium volume)	can include recycling of materials (storage)	250m (less for smaller if part of DH)
Autoclave	1 to 4	business or industrial proximate to residential for DH potential	primary roads no HGV restriction but consider rail transfer	HGV (medium volume)	sanitises waste materials (healthcare mainly)	250m

Sources: (ODPM, 2004; DCC, 2011; NCC, 2011) suitable for siting in proximity to residential areas due to the potential for District Heating (DH) provisioning. Site access for most facility types is generally achieved through primary roads (though HWRCs are likely to make use of local roads in many urban and rural locations). All waste sites require no restriction on heavy goods vehicles (HGV) as all operations involve movement on and off site of bulked materials. Larger existing and proposed sites (e.g. gasification and RRPs) also have the potential to utilise other modal forms of transport (i.e. rail and water) depending on proximity and existing infrastructure. All sites are typically served by HGVs with volume of traffic largely determined by the size of individual operations and sites. Certain operations: WTS, MBT and incineration; are likely to have very high volumes of HGV movements, particularly in urban settings.

A number of common features between waste facilities can be identified from Table 6.17. Colocation of facility types is common within England and the wider UK. Transfer operations (e.g. WTS and HWRC) are commonly found on sites, although the WTS operation would typically be for WCA/WDA or contractor usage as opposed to having public access. Composting operations are often located with operations dealing with organic fractions of waste streams (e.g. MBT or WwTW) as these can be sequential in character (e.g. the use of AD for the separated organic fraction from MBT). Storage space is another key consideration in terms of handling materials moving on and off site or for secondary operations such as windrow composting. In terms of proximity to sensitive receptors Table 6.17 shows the recommendation for most facilities is to be sited at least 250m from residential properties. However, certain operations (MRF) are often located within urban locations and can be sited 100m or less from residential and commercial properties.

6.3.2 Thematic map development and GIS analysis

A total of 41 separate criterions were identified as requiring data collection and thematic map layer creation (19 opportunities and 22 constraints). In total 34 layers were developed from existing data sets supplied by various organisations and research institutes (as identified in Table 3.5, Ch.3). A further 5 layers were developed as bespoke maps through utilisation of non-spatial data. Bespoke layers included: source of waste (all controlled waste streams and waste densities); navigable waterways; population density; existing facilities; and urban (residential and workplaces). A thematic map was not produced for mining activity as no deep mining activity exists within the county. Also, quarrying activities are covered within the MWDF as employment and development opportunities (NCC, 2012) and are captured within the plan covering SEL (NCC, 2009 - see section 6.2.1.3).

6.3.3 Delimiting areas of search through constraints mapping

A key feature of defining the suitability of locations for waste infrastructure is consideration of wider impact through emissions to air, water and land. To account for this geographic buffering is applied. Table 6.18 sets out the key buffering distances applied to each constraints criterion.

Table 6.18: Buffering distances used in the suitability analysis for constraining criteria

Restriction	Minimum buffer distance (m)	Maximum buffer distance (m)	Analysis buffer distance (m)
Rivers	10	200	200
Lakes	250	500	500
SPZ - groundwater	50	250	250
Flood risk zones/historic extent	50	200	200
National Nature Reserves	50	200	200
Local Nature Reserves	50	200	200
ESA	200	200	200
RAMSAR	200	500	500
SSSI	200	500	500
Ancient Woodland	50	200	200
Monuments	250	250	250
Battlefields	250	250	250
Listed buildings / grounds and parks	250	250	250
SPA	200	500	500
Urban – Residential/workplaces	250	250	250

Sources: (EA, 2012c; after Bastin and Longden, 2009; after Kara and Doratli, 2012).

As Table 6.18 shows there is significant variation in minimum and maximum distances within guidance and key literature. The maximum buffering distance from EA guidance in England was used to create buffers for constraining criteria as these values are closest to those identified for waste facilities in Table 6.17 (sensitive receptors).

6.3.3.1 Thematic maps GIS analysis - constraints

6.3.3.1.1 Land use map

The land use map (Figure 6.9) displays the main land use types (11 categories under BH grouping) depicting both human and natural landscapes within Northamptonshire. This map is one of the fundamental maps for GIS analysis and underpins analysis of agricultural land classification (Grade 1 and 2). However, individual data layers (.shp file format) are available in the UK for land use classes such as rivers, lakes and ancient woodland. These data sets are used accordingly with conversion to raster format made at a 25m resolution (one pixel) for comparable analysis.

The distribution of land use types shown in Figure 6.9 shows settlements, main areas of surface water, woodland, agricultural land classes (e.g. arable & horticulture; improved grassland and neutral grassland) and low productivity land (e.g. bare rock, rough grassland and acid grassland).

The majority of the county (82.0%) is covered with agriculture & horticulture as well as improved grassland (136kha and 59kha respectively). Woodland and forest make up 6.28% of land use while built-up areas account for 7.07% of land use. These built up areas are sub-divided into 3 classes: suburban (5.69%); urban (1.13%); and urban industrial (0.25%). Freshwater (rivers and lakes) accounts for 0.84% of land cover while the remainder (10.1%) is a mixture of other grassland types and bare rock.

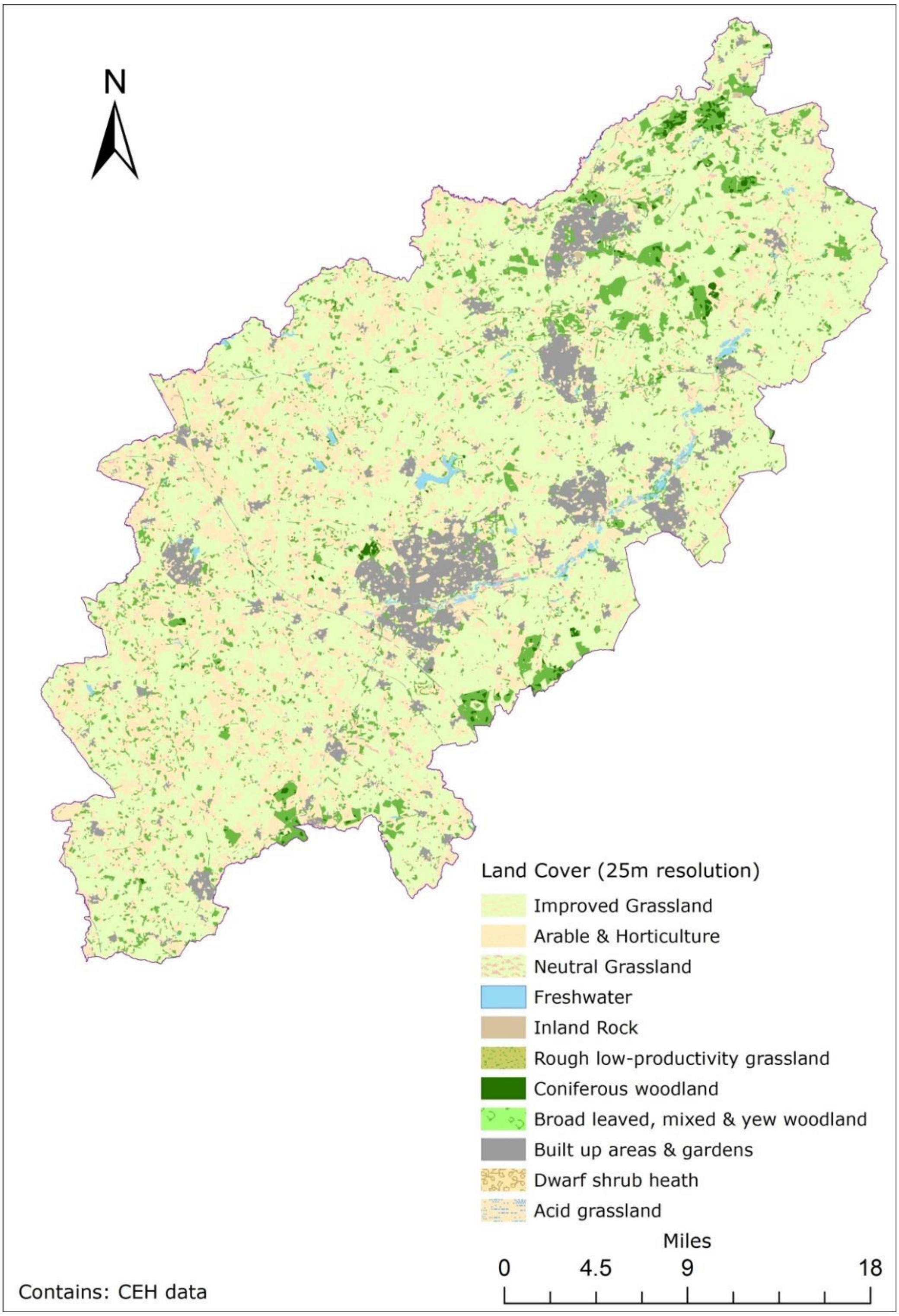


Figure 6.9: Land cover map of Northamptonshire (25m resolution) (Source: CEH, 2010).

6.3.3.1.2 Surface water map

The surface water map (Figure 6.10) shows the main rivers, lakes and canals within Northamptonshire. Also, included are the locations of Source Protection Zones (SPZs) which are taken from geological data supplied by the British Geological Survey (BGS).

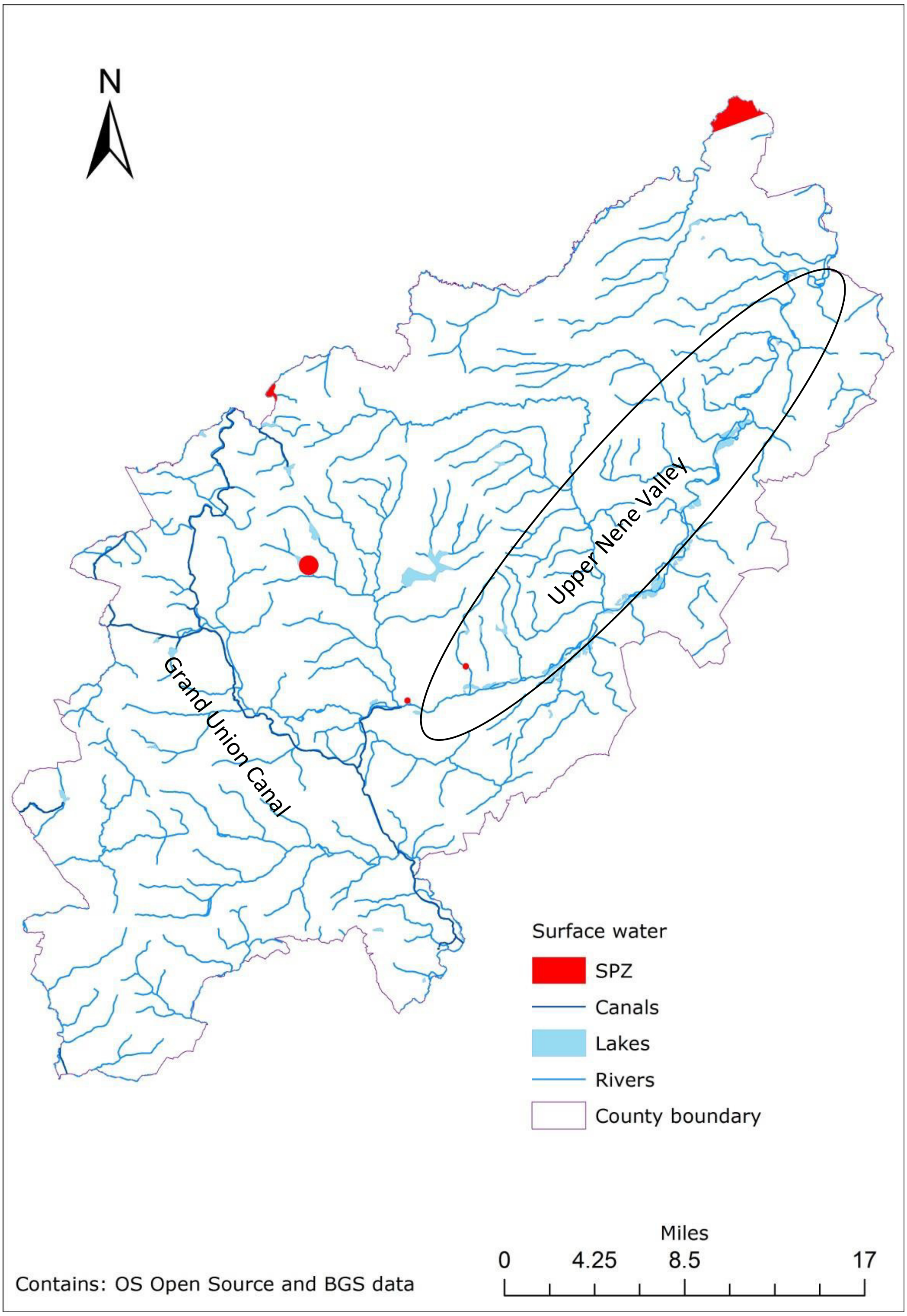


Figure 6.10: Surface water map (including Source Protection Zones – SPZs).

The majority of Northamptonshire is drained by the River Nene which flows to the North Sea via Cambridgeshire. The upper Nene valley is marked and shows the position of a number of lakes (e.g. Stanwick Lakes) which are former gravel extraction sites; flooded and restored as nature reserves and leisure sites. The rivers within the south west of the county primarily flow into the Thames river basin area; with a number of small rivers passing southwards into Buckinghamshire and Oxfordshire. The Grand Union Canal (GUC) runs almost north to south across the western part of the county. In terms of lakes, besides the former gravel pits there are a number of reservoirs to the north west of the county, including the significant water body of Pitsford Reservoir.

6.3.3.1.3 Environmental receptors map

The environmental receptors map (Figure 6.11) is a refinement of the previous land use map (Figure 6.9) based on data sets made available by Natural England and the Centre for Hydrology and Ecology (CEH). Northamptonshire contains a range of sites which are scientifically and civically important covering a total area of 13,346ha. There are: 7 country parks covering 585ha; 1 ESA site (Upper Thames tributaries) covering 1,238ha; 17 Local Nature Reserves covering 319ha; 2 National Nature Reserves (Collyweston Great Wood and Buckingham Thick Copse) covering 195ha; 1 RAMSAR convention site (Upper Nene Valley Gravel Pits) covering 1,358ha; 1 Special Protection Area (Upper Nene Valley Gravel Pits) covering 1,358ha; 58 SSSI sites covering 3,802ha; and 7,207ha of designated ancient woodland.

It is of note that Upper Nene Valley Gravel Pits are designated under multiple schemes (RAMSAR convention on Wetlands; Special Protection Area; and SSSI). All areas identified are designated as penalizing (Table 6.9) which requires a minimum buffer (see Table 6.21) after which waste facilities are allowed to be sited.

6.3.3.1.4 Conservation receptors map

The conservation receptors map (Figure 6.12) shows data on registered battlefields; scheduled ancient monuments; historic parks and gardens; and listed buildings in Northamptonshire. All conservation receptors other than agricultural land (Grades 1 & 2) are classified as penalizing and are thus subject to site by site assessment. There are two registered battlefields in Northamptonshire (Naseby and Delapre) which are nationally

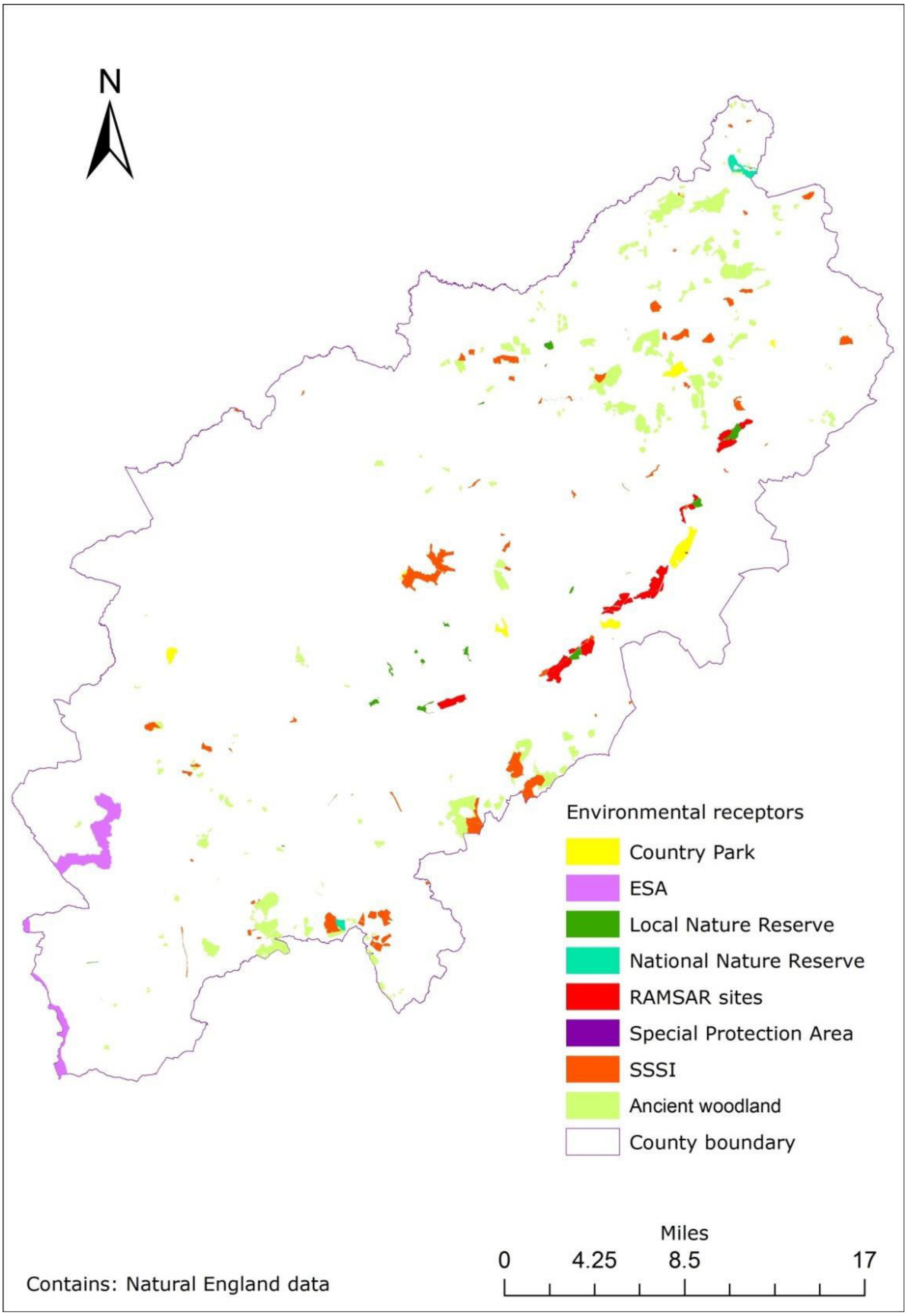


Figure 6.11: Environmental receptors map (including ESA and SSSI[22]).

[22] ESA = Environmentally Sensitive Area; SSSI = Sites of Special Scientific Interest

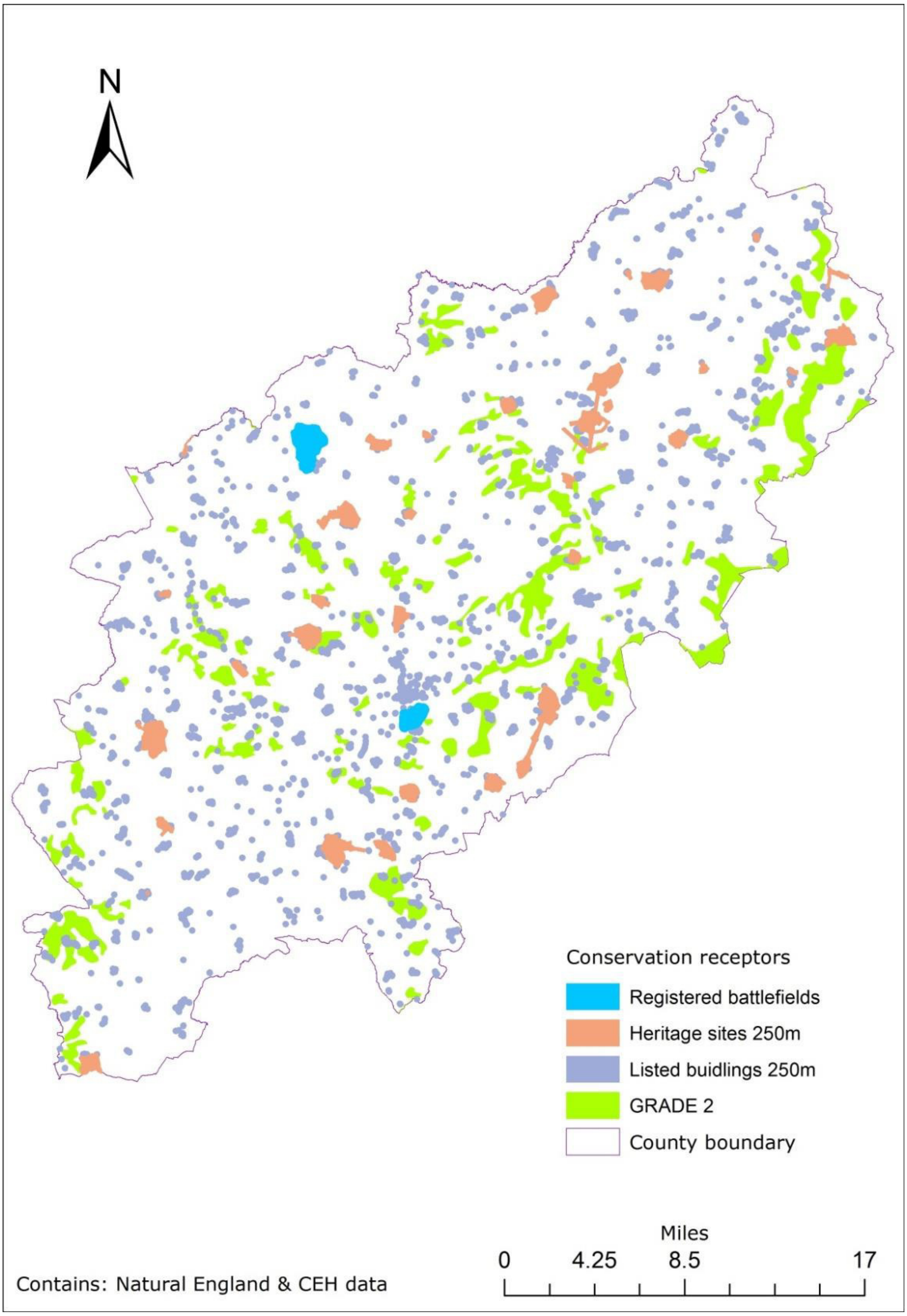


Figure 6.12: Conservation receptors map (250m buffers are included for heritage sites – scheduled ancient monuments and historic parks & gardens; and listed buildings).

significant heritage sites. Heritage sites within Northamptonshire total 38 (with 5 scheduled ancient monuments and 33 historic parks and gardens). Listed buildings are found throughout the county and do not exclude siting waste infrastructure. However, consideration is required as to the aesthetics of historic versus modern architectural styles.

Northamptonshire does not contain any agricultural land classified as Grade 1 but does contain substantial Grade 2 agricultural lands (ha). Much of this land use type is found within the river valleys of the Nene and Welland. Grade 3 agricultural lands has not been classified as a constraint within this analysis as there is no distinction made in the land cover map for Grade 3a and 3b (ALC, 2010). As such, Grade 3 would have excluded almost all land areas within the county. Grade 4 agricultural lands are not considered constraining for development in general (forming much of the 'greenfield' allocation within the SEL assessment) and are thus not considered as constraining criteria.

6.3.3.1.5 Flood risk map

The flood risk map (Figure 6.13) shows flood zones in terms of their risk definition (low, moderate and significant) as opposed to the EA classification as this would have put all zones within exclusionary typologies. Instead, only significant is considered exclusionary, while moderate and low are considered penalizing. Historic flood extent is also shown and is considered as penalizing given the infrequency of serious flood events recorded for the River Nene.

As Figure 6.13 shows the majority of the rivers in Northamptonshire are in the significant risk category with smaller areas along the river courses with low and moderate levels of flood risk. These areas correspond with areas where rivers pass through urban centres such as Northampton, Wellingborough (River Nene), Kettering (River Welland) and Towcester. Areas such as Northampton and Wellingborough have had significant amounts of flood defences installed following the Easter flood event of 1998. Similarly, Kettering and Towcester have seen flood defences increased in order to protect new housing and commercial developments situated on flood plains. The historic flood event shown to the north east of the county (River Nene) corresponds with the broadest and most navigable stretch of the Nene within the county and thus represents the greatest extent for flood risk.

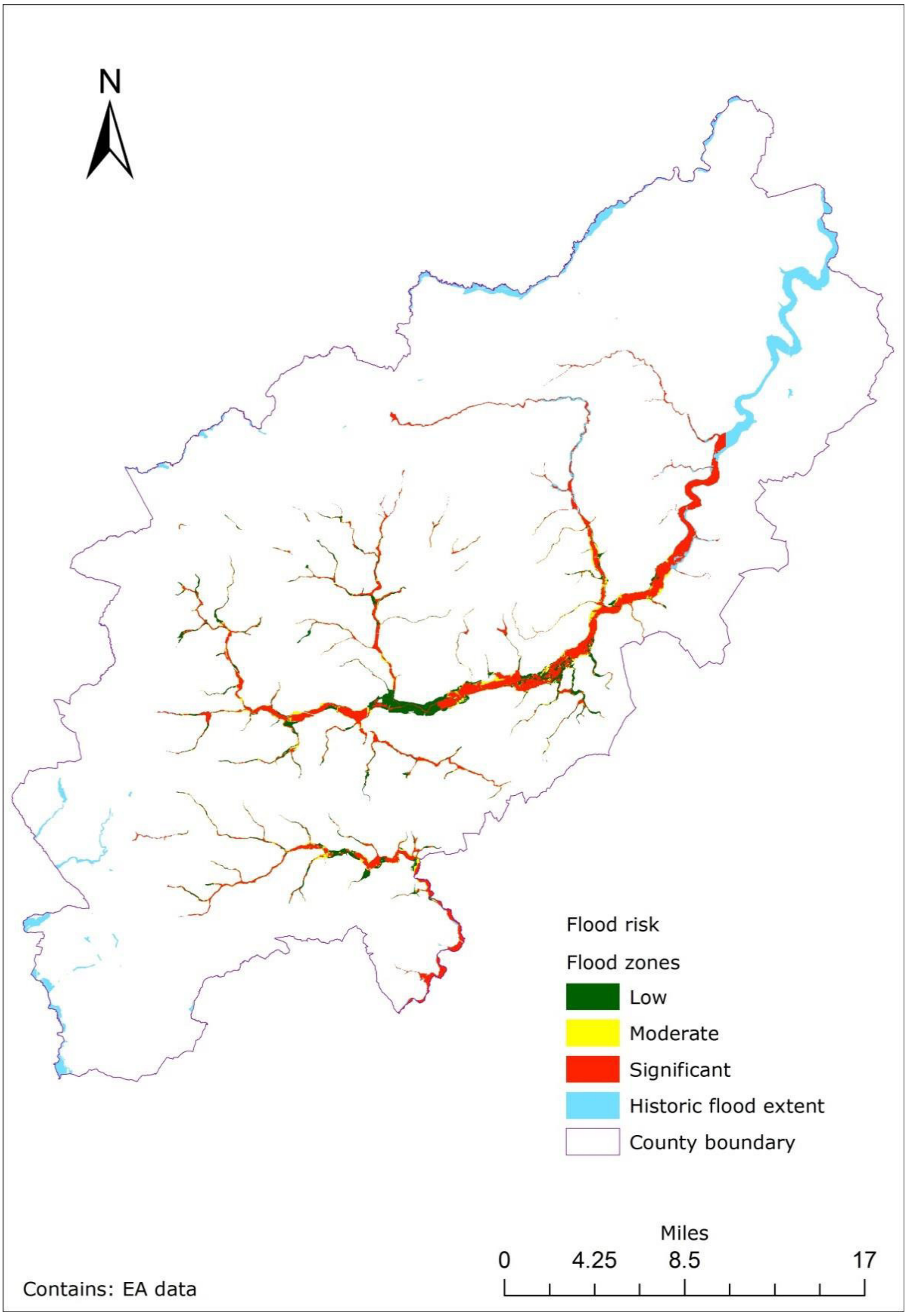


Figure 6.13: Flood risk map

6.3.3.2 The constraints model

The constraints model uses restriction values to produce a buffered output of areas unsuitable (excluded and penalizing) for siting waste facilities. The suitability model is shown in Equation 6.2; where suitability (S) of a site is the sum of the weighted (w_i) criteria (C_j) multiplied by the product of the restrictions (r_j).

Equation 6.2:

$$S = \sum_{i=1}^{n} w_i \, C_j \prod_{j=1}^{m} r_j$$

The constraints model is shown in Equation 6.3.

Equation 6.3:

$$\prod_{j=1}^{m} r_j$$

Where the restrictions modelled are the individual criterion of the four constraints groups: ($r_{environmental} * r_{conservation} * r_{human\ capital} * r_{flood\ risk}$). For example; the environmental group criterions are:

($r_{spz} * r_{rivers} * r_{lakes} * r_{lnr} * r_{nnr} * r_{ramsar} * r_{sssi} * r_{spa} * r_{esa} * r_{ancient\ woodland}$)

6.3.3.2.1 Individual constraints mapping

Figure 6.14a through 6.14d show an example constraint from each group criteria. Appendix 11a contains all output maps for each constraint criterion with weights and buffering applied. The constraining criteria are scored with a ‘boolean’ system; shown as ‘0’ on the maps meaning they are either excluded from further or analysis (e.g. for surface water layers) or must be considered as penalizing (e.g. conservation receptors). If a layer is characterised as penalizing this will be reconciled when the final suitability assessment is undertaken. Any areas of the maps scoring a ‘1’ are considered as options for siting of facilities. As can be seen from Figure 6.14 areas of constraint can be very limited (Figure 6.14b) or extensive (Figure 6.14a).

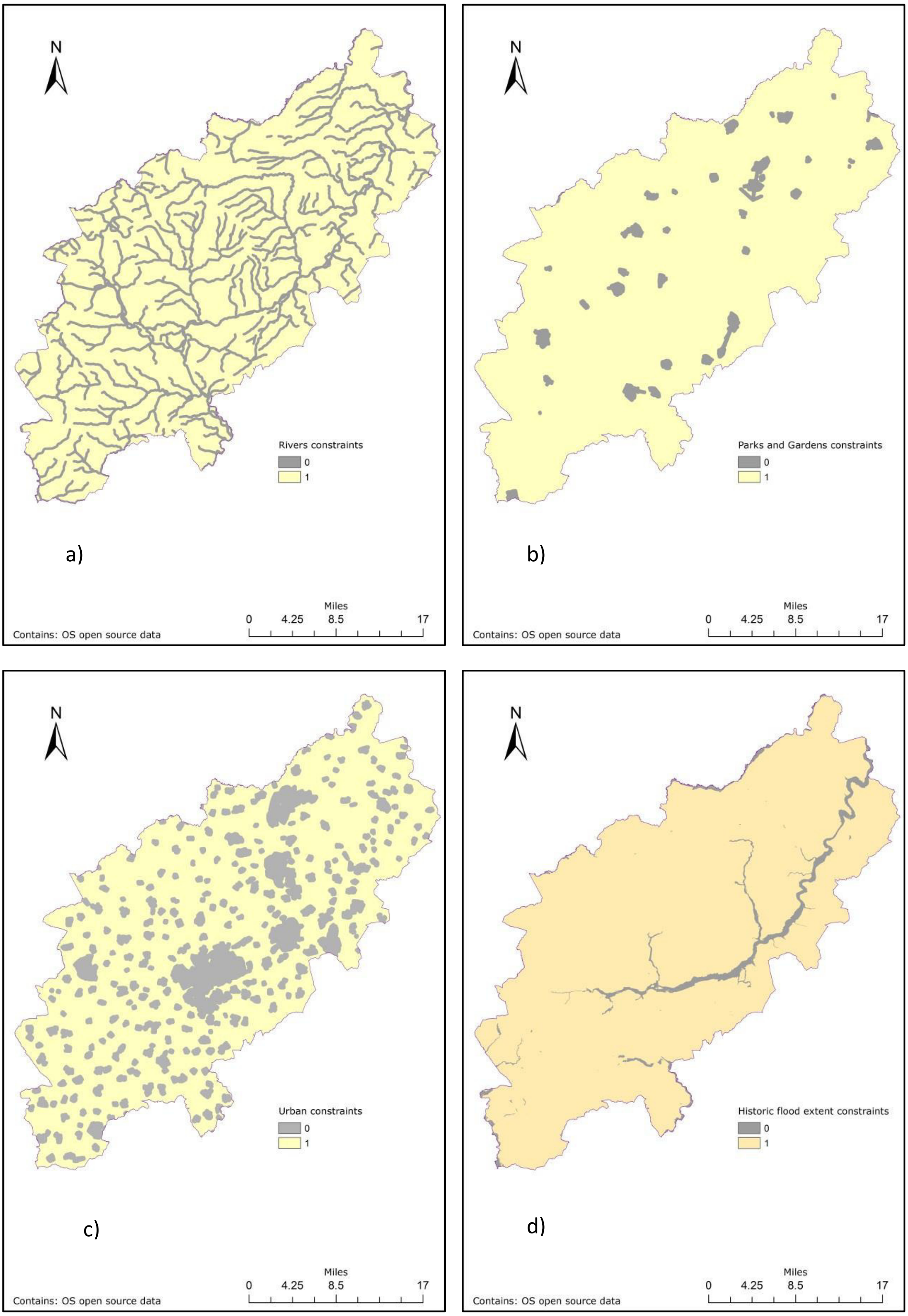


Figure 6.14a-d: Indicative constraints maps (Rivers; Parks & Gdns; Urban; and historic flood event).

6.3.3.2.2 Combined constraints mapping

Figure 6.15 shows the final constraints output map for Northamptonshire based on the constraints (restrictions) model expressed in Equation 6.4. In total 55.1% of land is classified as constrained within Northamptonshire (i.e. within the 4 constraints groups).

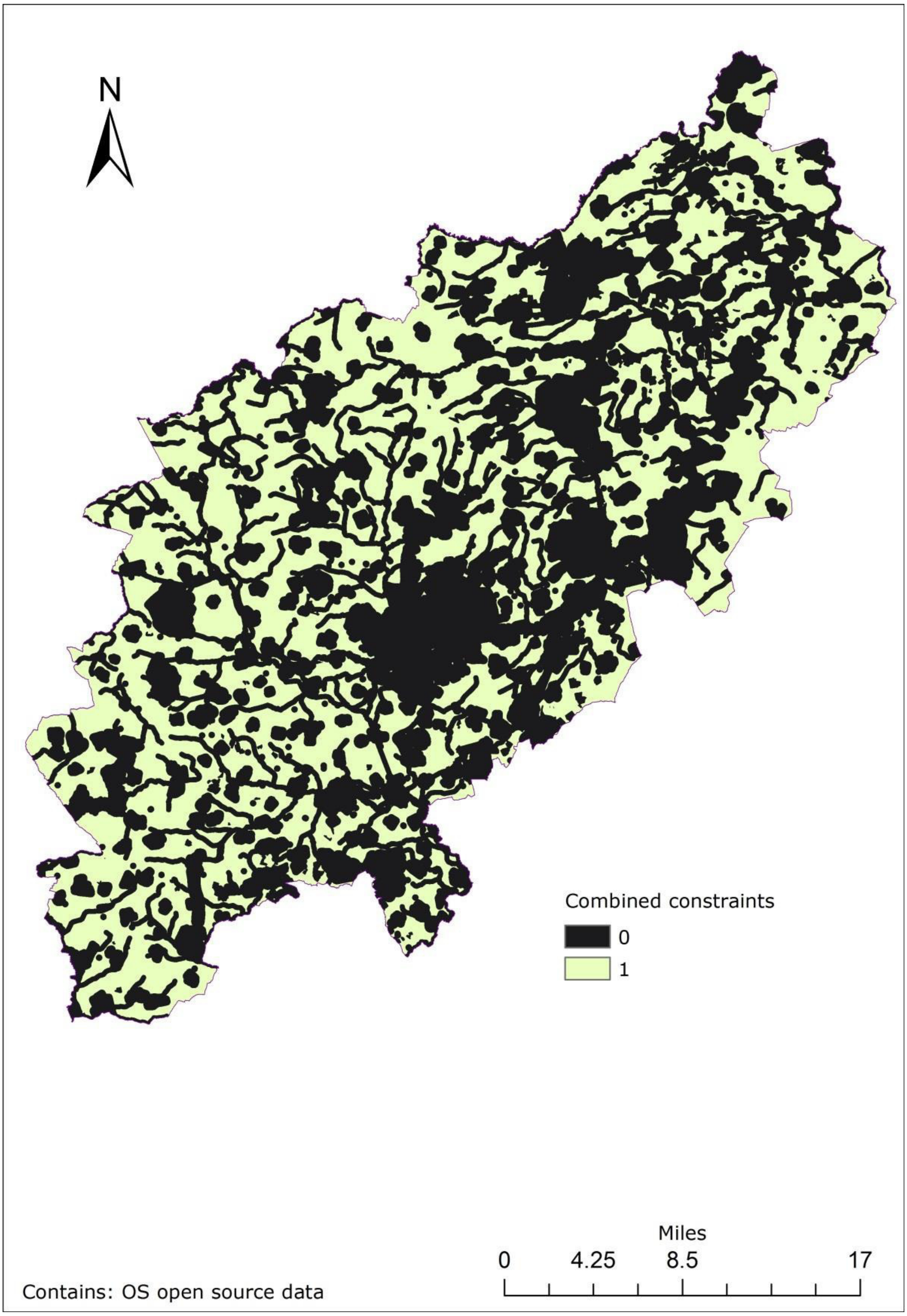


Figure 6.15: Combined constraints map.

6.3.4 Identifying areas of search from opportunities modelling

Thematic layers were developed which incorporated opportunities criterions were entered into the model builder tool in Esri's ArcGIS10 for further evaluation and to produce a visual output. The final weights applied through weighted overlay analysis (WOA) to the opportunities criterions are shown in Table 6.19.

Table 6.19: Opportunities criteria buffering distances (m) and weightings (%) used for analysis and final thematic layer map creation

Criteria	Analysis buffer distance (m)	Weights applied (%)	Final weights (%)
Sources of waste (urban residential)	250	7.96	8.00
Sources of waste (workplace)	250	10.21	10.00
Sources of waste (SEL)	100	3.84	4.00
Landfills (active)	250	4.54	5.00
Landfills (historic)	250	4.54	4.00
Operational facilities (& PPC sites)	250	16.68	17.00
Regeneration (PDL)	100	9.96	10.00
Employment	250	11.56	12.00
Deprivation (IMD)	250	1.91	2.00
Gas networks (& off grid)	250	10.85	11.00
Electricity networks (& off grid)	250	3.96	4.00
Proximity to rail	250	3.66	4.00
Proximity to junctions	250	1.11	1.00
Proximity to A roads	250	5.97	6.00
Proximity to navigable waterways	250	1.78	2.00

Sources: (EA, 2012c; after Bastin and Longden, 2009; after Kara and Doratli, 2012).

Table 6.19 shows minimum distances of between 100 and 250m for the final buffering of opportunities criteria analysis. Weights applied are taken from the aggregated weights in Table 6.15 with a number of criteria combined to produce an overall weight (e.g. PPC sites weighting was split between active landfills and operational facilities as these data sets contained PC listings). The original weights in Table 6.15 were grossed up in order to make the weights out of 100 in order to produce weights which could be used with the ArcGIS weighted overlay spatial analyst application. Final weights are rounded to nearest whole number as the software does not accept decimals.

6.3.4.1 Identifying opportunities through thematic mapping

6.3.4.1.1 Sources of waste

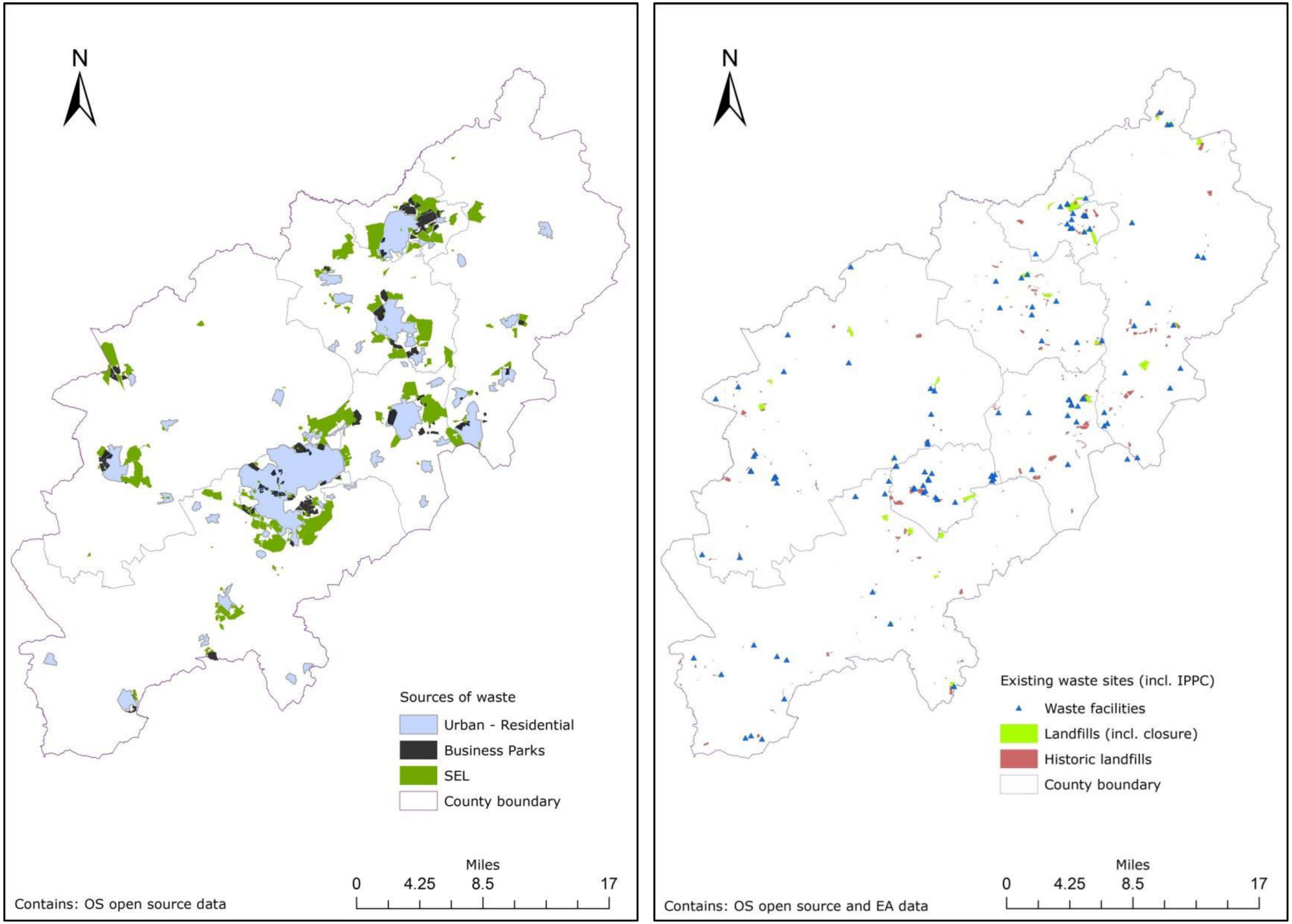
The sources of waste map (Figure 6.16) shows the spatial distribution of the main areas of controlled waste generation within Northamptonshire, including: urban areas (residential - LACW but also commercial and construction wastes); business parks (workplaces - C&I waste generation with similar composition to LACW from many commercial premises); and SEL (would be phased C&D wastes initially followed by C&I and LACW depending on the development type). Facilities should be sited as close to these areas as possible.

6.3.4.1.2 Existing waste sites

The existing waste sites map (Figure 6.17) includes operational waste facilities (see Figure 6.3) including 2 IPPC licensed sites; active landfills (with area calculated) including 9 IPPC licensed landfill sites; and historic landfill sites (with area calculated). Figure 6.17 shows the 101 operational waste facilities discussed previously (see section 6.1.2). Landfill sites with active permitting status; cover 853ha across 46 locations. A total of 15 of these landfill sites are in closure status with a further 2 licenses surrendered. Historic landfill sites cover a total of 1,673ha covering 371 locations; some 207 of these sites are greater than 1.5ha in area. Most of these sites are capped and closed but represent a significant land bank with waste permitting history for planning purposes.

6.3.4.1.3 Socio-economic factors

A total of three thematic maps were produced for socio-economic factors including deprivation (IMD); employment; and regeneration areas (as PDL). IMD and employment are exogenous factors (i.e. outside of the waste system but impacting on it); whereas areas of regeneration as PDL have often been identified within local planning policy as sites suitable for industrial and waste management usage. IMD scores (Figure 6.18a) have been discussed previously (see section 4.7).



Figures 6.16 and 6.17: Sources of waste and existing waste sites maps

Employment levels at LSOA level are shown in Figure 6.18b as absolute values (e.g. the actual numbers of people employed) (ONS, 2014). To expand, NOMIS reports labour market profiles data for LAs in England (ONS, 2014). This data is summarised for Northamptonshire in Table 6.20.

Table 6.20: Labour market profile for Northamptonshire LAs in 2012

Local Authority	WAP	EcA	EcA (%)	Em	Em (%)	UEm	UEm[23] (%)
Corby	35,706	29,600	82.9	26,922	75.4	3,049	10.3
Daventry	51,742	40,100	77.5	38,444	74.3	2,165	5.4
East Northants	55,844	47,300	84.7	42,832	76.7	3,075	6.5
Kettering	60,950	52,600	86.3	48,516	79.6	3,682	7.0
Northampton	146,402	118,000	80.6	107,898	73.7	9,676	8.2
South Northants	59,558	53,900	90.5	52,947	88.9	1,563	2.9
Wellingborough	48,553	36,900	76.0	33,501	69.0	3,395	9.2
Northamptonshire	458,755	378,400	82.64	351,062	76.80	26,605	7.07

Source: (ONS, 2014).

As can be seen in Table 6.20 economically activity among working age population is high within Northamptonshire (82.6%). Numbers of people employed (as employees or self-employed) is measured by ONS as percentage of working age population (76.8%) whereas the percentage unemployed is modelled as a percentage of economically active residents (7.07%). The LA of Northampton contains 31.9% of all WAP and 31.2% of all economically active residents in the county.

Figures 6.18c-d shows areas of previously developed land (PDL) and their spatial distribution across Northamptonshire. There are a total of 42 sites identified covering 307ha (HCA, 2009). Corby has the most significant amount of PDL in the county having been the site of significant industrial activity with the Corus steel works operating until the 1990s. Much of this land requires remediation works and would thus be suitable for collocating multi-permitted waste facilities thus reducing costs (Bates et al. 2008).

[23] WAP: working age population; EcA: economically active; Em: employed; UEm: unemployed

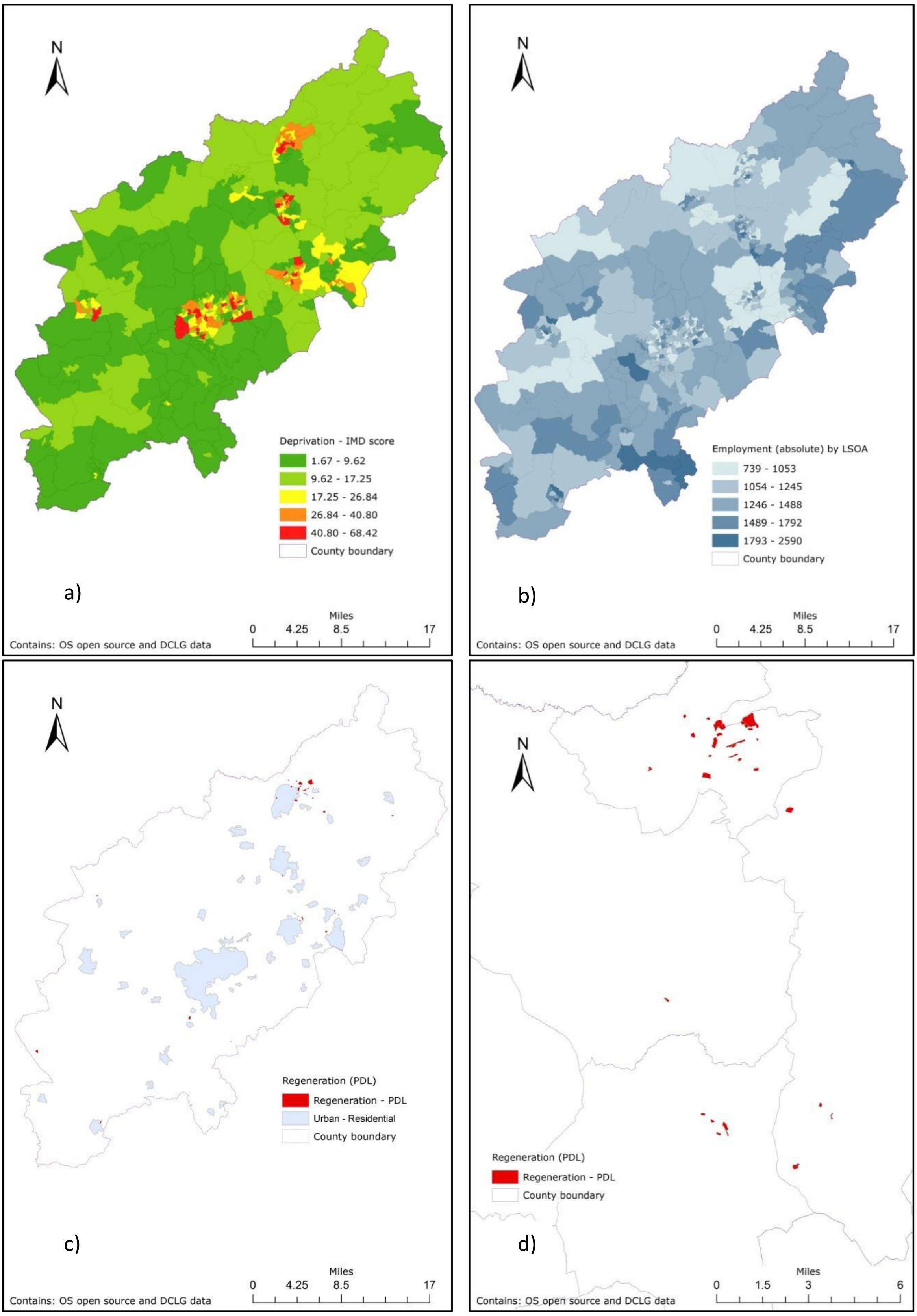


Figure 6.18a-d: Socio-economic factors maps a) IMD score b) employment map c) areas of regeneration – county level d) previously developed land (PDL) sites – LA level.

6.3.4.1.4 Proximity to transport networks

The spatial pattern of facilities (Figure 6.17c) shows most waste sites have been located in close proximity to major roads (A roads). Figure 6.19a shows the road networks map for the study area. There is an extensive network of major roads (Motorway and A roads) connecting the main urban centres as well as providing regional connection to other urban centres and areas of commerce in England and beyond. Motorway junctions and bypass roads have increasingly seen the location of business parks and large housing developments.

Figure 6.19b shows the other primary modal transport networks within the case study area. Northamptonshire is served by rail with the West Coast Mainline, which spurs at Rugby picking up stations at Long Buckby and Northampton before re-joining just south of Northampton. The Midland railway connects the eastern towns of Corby, Kettering and Wellingborough. Navigable waterways include the Grand Union Canal; Upper Nene; and River Welland, with numerous wharves along the GUC and marinas on the Upper Nene.

6.3.4.1.5 Proximity to heat and power networks

The heat and power networks maps (Figure 6.20a-b) include consideration of where the primary and secondary gas grid locations; primary electricity grid locations; households off gas grid; and households off electricity grid.

Areas with high numbers of households off grid connections coupled with proximity to main grid networks are considered most suitable for waste facilities capable of delivering heat/power (e.g. AD or EfW sites). Figures 6.20a and 6.20b show the locations of the main (primary and secondary) lines and networks for gas and electric utilities within the study area. The main gas lines follow a north-south axis in close proximity to the primary electric grid. However, the main electric grid has more lines connecting the main grid with large urban centres.

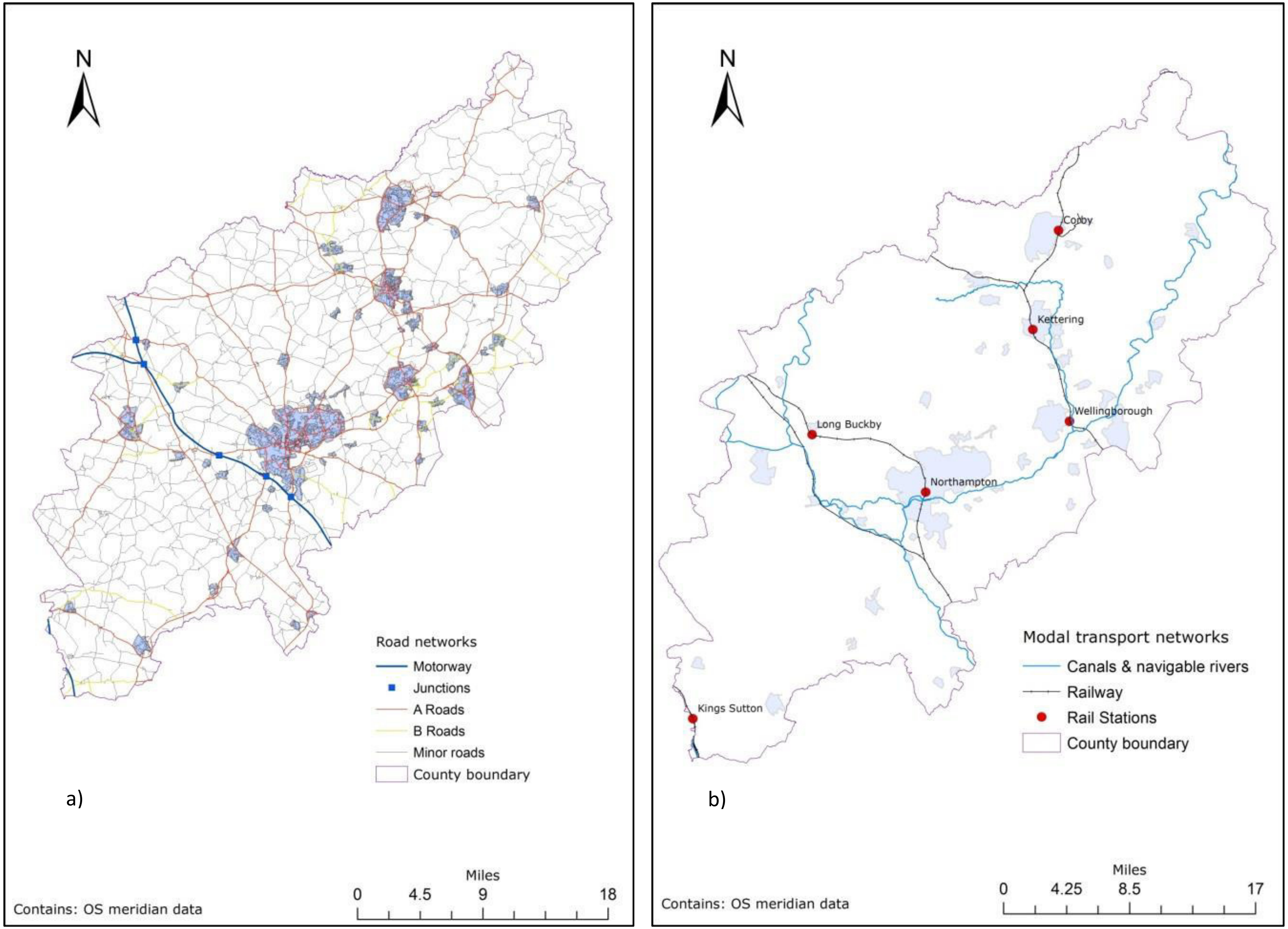


Figure 6.19a-b: Road networks and modal networks maps

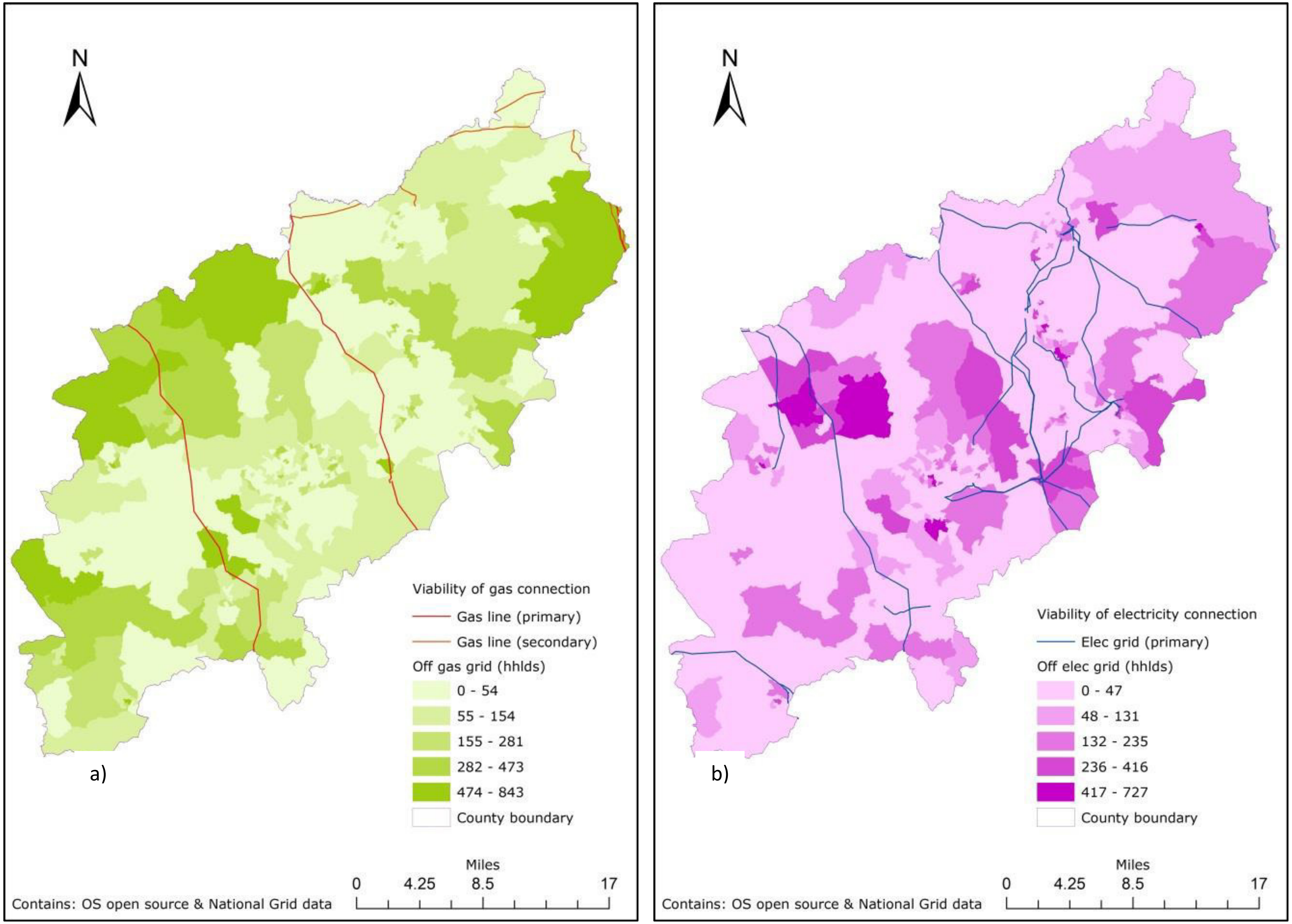


Figure 6.20a-b: Viability of decentralised energy maps (gas lines; electricity grids; households off gas and electric grids shown by LSOA).

In terms of numbers of households off gas and electric grids Figure 6.20a shows LSOAs with the highest numbers are mainly located at the periphery of the study area as well as being proximate to primary gas lines. The picture is similar for electrical connectivity, although a number of LSOAs within the central portion of the study area (in areas between the main urban centres) have higher numbers off-grid. These areas of low connectivity are found proximate to main electricity lines potentially reducing any future connection costs.

LSOAs with high numbers of household's off-grid and with gas and electric grids passing through them will score highest as areas of opportunity.

6.3.4.2 The opportunities model

The opportunities model uses criteria weights values derived from the AHP process (see Section 6.2) to produce areas of opportunity (preferential and penalizing criteria) according to a weighted scale for siting facilities. The opportunities model is shown in Equation 6.4.

Equation 6.4:

$$\sum_{i=1}^{n} w_i \, C_j$$

Where the weights modelled are for individual criterion from the five opportunities groups: ($W_{\text{sources of waste}} * W_{\text{existing sites}} * W_{\text{socio-economic}} * W_{\text{transport}} * W_{\text{heat\&power}}$).

6.3.4.2.1 Individual opportunities mapping

Figure 6.21a through 6.21d show an example opportunities map from the group criteria. Appendix 11b contains all output maps for each opportunity criterion with weights and buffering applied.

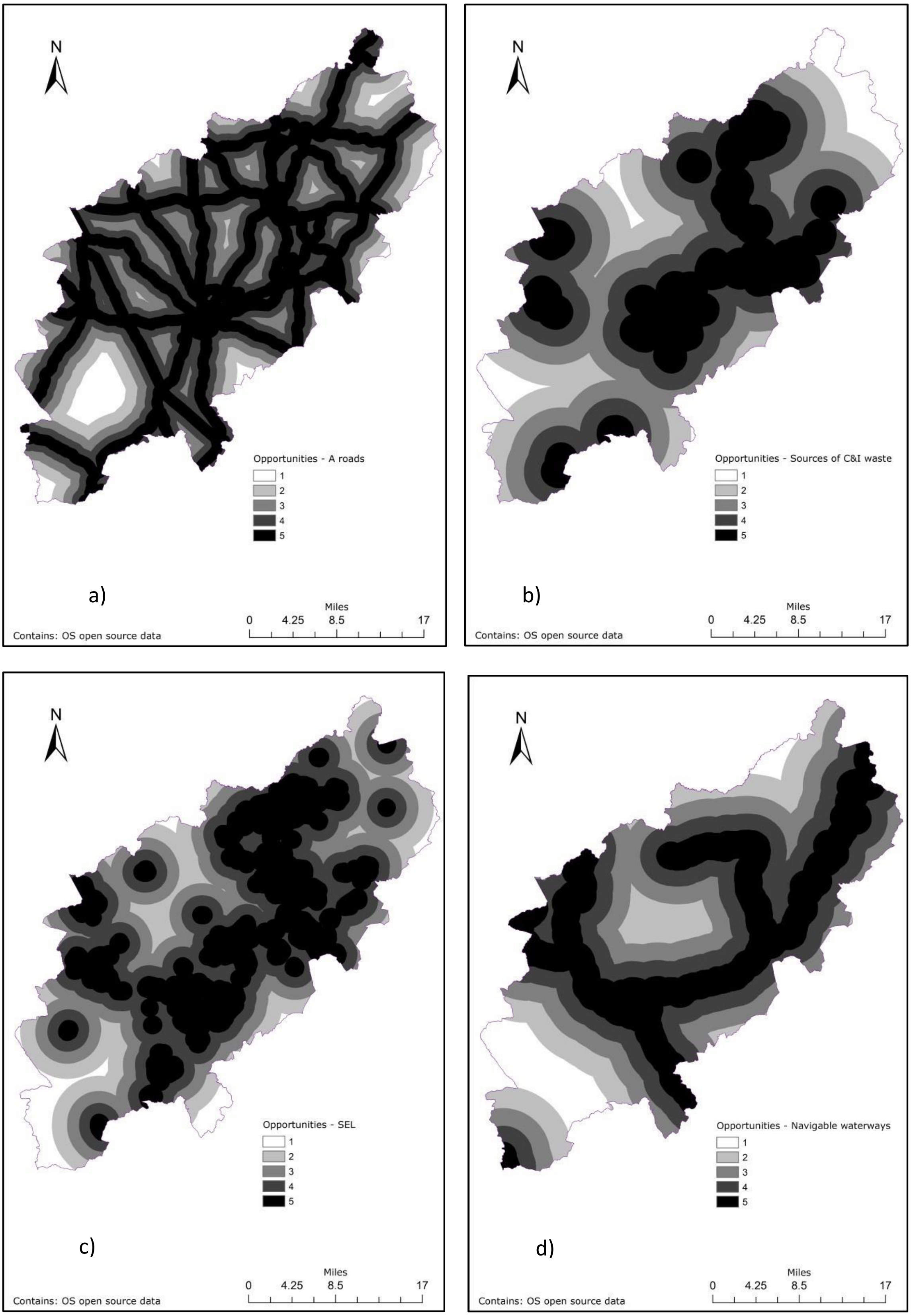


Figure 6.21a-d: Indicative opportunities maps: a) A roads; b) main sources of C&I waste: c) SEL; and d) navigable waterways.

6.3.4.2.2 Combined opportunities mapping

Figure 6.22 shows the final opportunities output map for Northamptonshire based on the opportunities model expressed in Equation 6.5. In total 12,773ha (5.40%) of land is classified as highest suitability within Northamptonshire (i.e. within the 5 opportunities groups). A significant amount of land is classified as moderate suitability, mainly around the extent of the Northamptonshire Arc (Northamptonshire Observatory, 2010).

6.3.5 Identifying areas of suitability

Figure 6.23 shows the areas of suitability after Equation 3 is applied to both opportunities and constraints criteria. A total land area of 3,338ha was identified as being most suitable for waste facility siting in Northamptonshire using the suitability model developed.

Of this land bank, some 2,842 ha were contained in 14 land parcels in sizes greater than 65ha making them potentially suitable for all facility types identified in Table 6.17. A further 415ha across 19 land parcels were identified ranging in size from 10 – 65ha. The remaining 81ha were identified across a further 23 land parcels ranging in size from 1 to 10ha. Available land was concentrated in four main locations: around Corby (particularly to the north-east of the main residential area and are centred on the former Corus steelworks sites traversed by the A43 trunk road); Kettering (particularly to the west of the main residential area and town centre and extending from the smaller towns of Rothwell and Burton Latimer along the A14 corridor which by passes Kettering to the west and south), Wellingborough-Rushden (wrapping around the town of Wellingborough and extending towards the former shoe manufacturing centres of Irthlingborough, Finedon and Rushden traversed by the Midlands Railway; River Nene; and A45/A6 trunk roads) and DIRFT (prime development sites adjacent to the existing logistics hub as well as the M1/M6 confluence and junctions; the A5 trunk road; Grand Union Canal and West Coast Mainline with a dedicated spur line for freight trains).

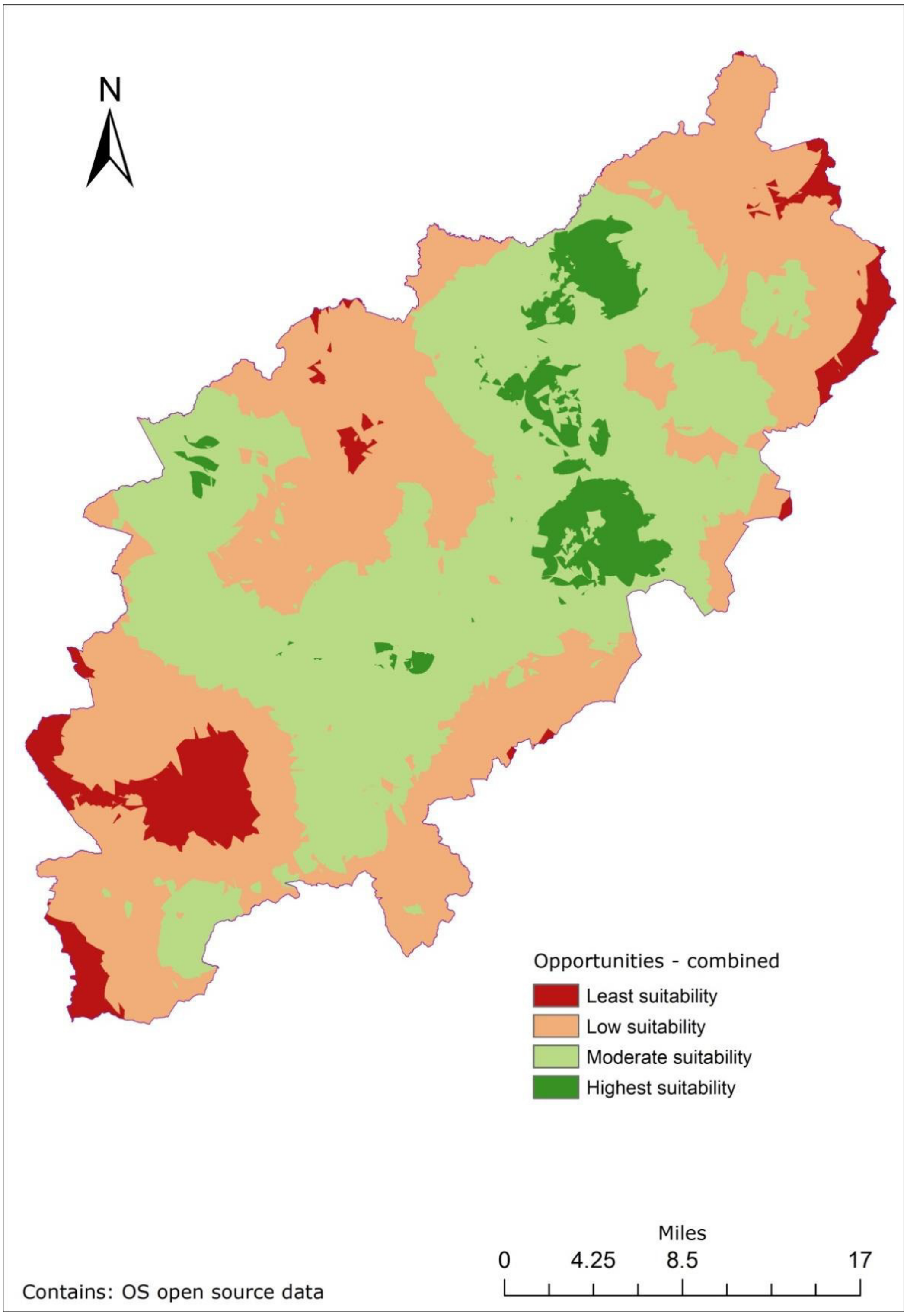


Figure 6.22: Combined opportunities map showing areas of suitability.

One further area of high suitability is situated close to the Brackmills industrial estate on the southern fringe of Northampton as well as other locations to the south-west of the town in close proximity to the M1 junctions (15, 15a and 16).

The next step in the process is to differentiate the areas of highest suitability in terms of land parcels of appropriate scale. Figure 6.23 shows areas of high suitability subdivided into land parcels of 1-10ha; 10-65ha and >65ha with main residential areas excluded.

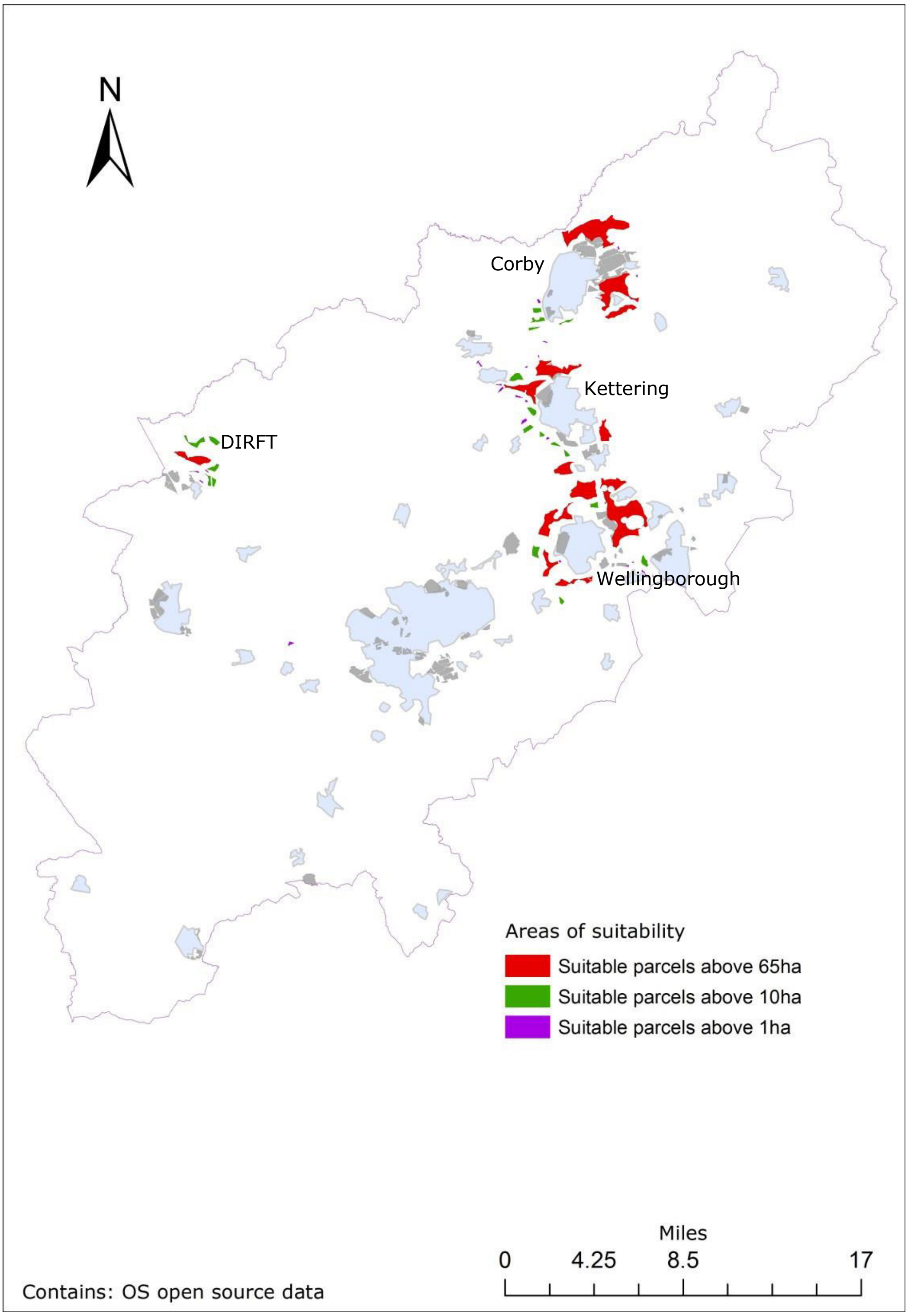


Figure 6.23: Areas of highest suitability (land parcels of >1 ha; >10 ha; and >65 ha).

The process of excluding residential areas results in the removal of Northampton from the areas of highest suitability and further confines appropriate scale land parcels to locations in close proximity to existing industrial and business parks on the fringes of Corby, Kettering, Wellingborough and DIRFT (Figure 6.23).

6.4 Suitability analysis of MWDF main sites

The final stage in the GIS analysis is to evaluate the suitability of the proposed main sites within the MWDF (NCC, 2012) in terms of being within areas of highest suitability. This step is undertaken to determine the potential of these sites to expand operations in order to achieve higher recycling and recovery rates. Any expansion of such sites should meet the criteria outlined within the GIS modelling approach described in sections 6.2 and 6.3. In addition, areas for potential new sites should encompass the site selection criteria (Table 6.17) which can be broken down into 3 spatial scales (land parcels between: 1 and 10ha; 10 – 65ha; and greater than 65ha in proximity to modal networks).

6.4.1 Main sites in areas of highest suitability

There are 39 sites specified within the MWDF as main sites (and 59 non-main) for waste management to 2031 (NCC, 2012), Table 6.21 and 6.22 show sites of highest suitability. As Tables 6.21 and 6.22 show there are 12 sites (6 main and 6 non-main) which have scores of 5 (high suitability) through the site appraisal process. Of these sites, 5 are landfill sites (4 main and 1 non-main sites).

A further 5 sites are aimed at treatment activities (treatment, composting and recycling) with the remaining 2 sites being transfer operations. A total of 9 sites out of 12 are located within CBC. This means that only 12 out of the total 98 sites within the MWDF (as main and non-main sites) achieved high suitability under the spatial appraisal methodology proposed. This suggests a limited scope for development of such infrastructure in light of the potential environmental impact from such expansion of activities in areas susceptible to environmental degradation via pollution, noise, odour, loss of amenity or visual intrusion.

Table 6.21: MWDF main sites by district (with facility type and secondary operations) in areas of highest suitability with penalizing considerations shown

District	Facility type	Secondary operations	Suitability value	Penalizing considerations	Mitigation
CBC	Landfill	Recycling (Inert), Transfer Station	5		
CBC	Landfill	Civic Amenity, Landfill Gas Energy Scheme	5		
WBC	Landfill	Landfill Gas Energy Scheme, Composting	5		
KBC	Landfill (Inert)	Recycling (Inert)	5		
CBC	Recycling (Inert)	Composting	5	Urban residential	On existing IE location
CBC	Transfer Station	Recycling	5	Urban residential	On existing IE location

Sources: (after EA, 2010; NCC, 2012).

Table 6.22: MWDF non-main sites (with facility type and secondary operations) in areas of highest suitability with penalizing considerations shown

District	Facility type	Suitability values	Penalizing considerations	Mitigation
CBC	Composting	5		
CBC	Landfill Gas	5		
WBC	Recycling	5	Urban residential	On existing IE location
CBC	Recycling	5	Urban residential	On existing IE location
CBC	Treatment	5	Urban residential	On existing IE location
CBC	Waste Transfer	5	Urban residential	On existing IE location

Sources: (after EA, 2010; NCC, 2012).

Figure 6.24 shows the location of main and non-main sites with a score of 5 (high suitability) in relation to land parcels identified as areas of highest suitability. The 12 sites identified are clustered around Corby, Kettering and Wellingborough with no sites from the MWDF being classified as high suitability within any other parts of the study area. As this pattern of site distribution serves only around half the population and main areas of waste generation it must be assessed as being unsuitable as a viable system of sites capable of capturing the highest proportion of materials within the scope of the MWDF (NCC, 2012; 2014).

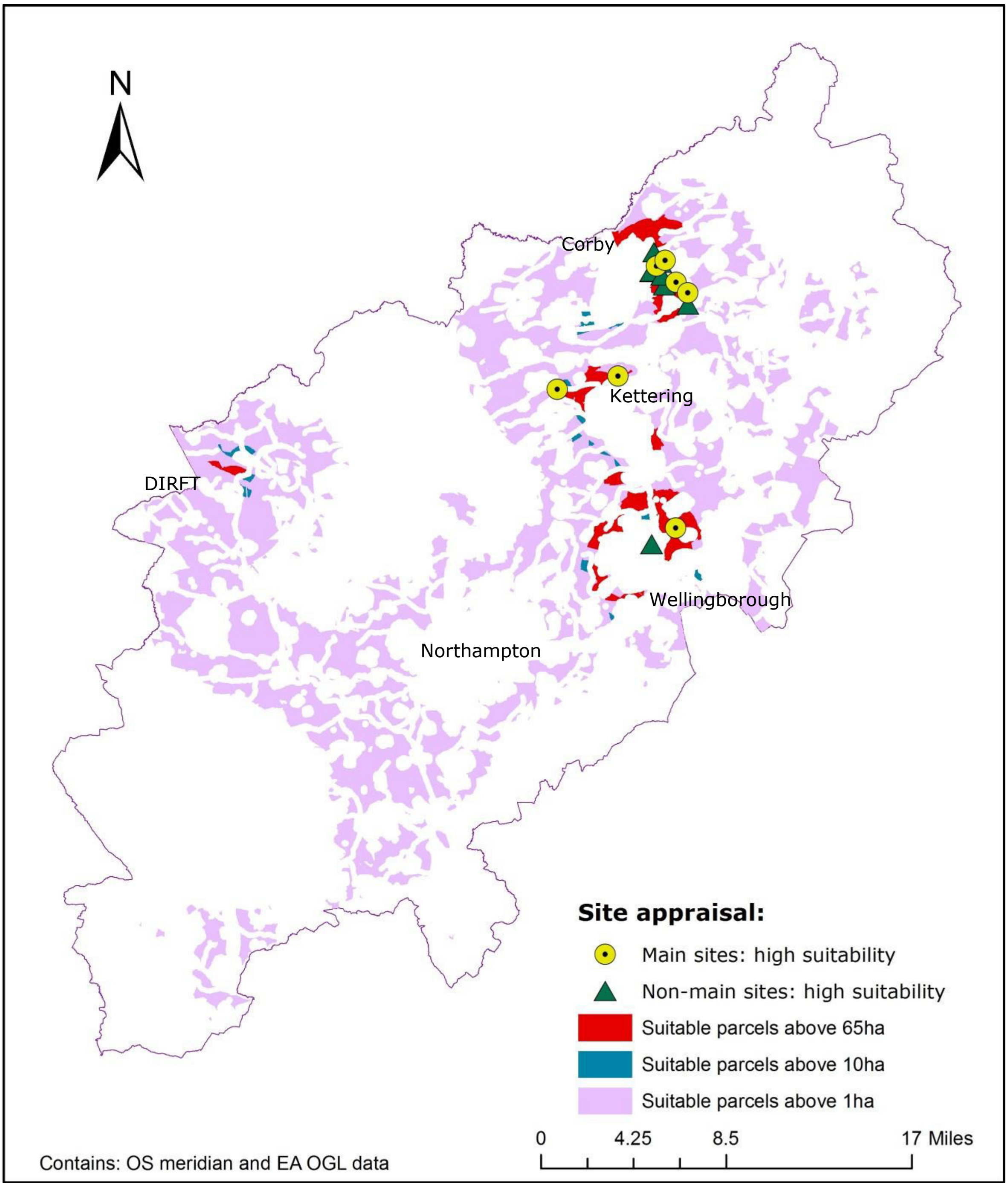


Figure 6.24: Assessment of land parcels with highest suitability against MWDF main sites.

6.4.2 Main sites in areas of moderate suitability

With so many sites failing to meet the assessment criteria, the remaining 33 main sites were assessed against areas of moderate suitability. A total of 16 sites were found to be in areas of moderate suitability (6 landfill sites [2 in closure status as well as 1 closed MRS site] and 10 waste transfer/CA sites). This means that the remaining 17 MWDF main sites are in areas of low or least suitability for waste facility siting according to the modelling criteria (see Sections 6.4.3.2 and 6.4.4.2). Given the low number of facilities (n=22) identified in the site appraisal process as main sites for waste activities to 2031, a second tier of sites (n=59) are put forwards in the local plan (as non-main sites). The results for moderate suitability are presented in Table 6.23 and 6.24.

Table 6.23: MWDF main sites by district (with facility type and secondary operations) in areas of moderate suitability with penalizing considerations shown

District	Facility type	Secondary operations	Suitability values	Penalizing considerations
DDC	Civic Amenity		4	Urban residential
KBC	Civic Amenity		4	Urban residential
NBC	Civic Amenity		4	Urban residential
SNC	Civic Amenity		4	Historic flood
DDC	Civic Amenity		4	Urban residential
NBC	Integrated Waste Handling Facility Recycling	Transfer Station Green Energy Centre	4	
ENC	Landfill	Landfill Gas Energy Scheme	4	SSSI
DDC	Landfill	Landfill Gas Energy Scheme	4	
KBC	Landfill	Landfill Gas Energy Scheme	4	
DDC	Landfill (Inert)	Recycling (Inert)	4	
DDC	Landfill (Inert)	Recycling (Inert)	4	
ENC	Landfill (Inert)/ Soil Storage	Recycling (Inert)	4	Urban residential
ENC	Recycling Centre		4	Urban residential, listed bldng
NBC	Transfer Station	Recycling/Composting	4	Urban residential
DDC	Transfer Station	Materials Recycling Facility (MRF)	4	Urban residential
WBC	Transfer Station (Inert)	Recycling (Inert)	4	Urban residential
ENC	Landfill / soil storage	Recycling inert	3	SSSI

Sources: (after EA, 2010; NCC, 2012).

Table 6.23 shows that 16 main sites were scored as moderate suitability (with a further facility for hazardous waste treatment scored as low suitability). A total of 6 facilities were landfill operations with a further 9 described as CA/transfer operations. One remaining site was described as a ‘recycling centre’. It is also shown that 6 sites are in DDC; 4 in ENC; and the remaining 6 sites are spread across NBC, KBC, WBC and SNC. Table 6.23 also shows that 12 sites had penalizing considerations including: proximity to urban residential, listed buildings and SSSI designated sites.

Table 6.24: MWDF non-main sites by district (with facility type and material type) in areas of moderate suitability with penalizing considerations shown

District	Facility type	Material type	Suitability values	Penalizing considerations
DDC	Composting	Non-Inert	4	
ENC	Composting		4	
DDC	Landfill	Inert	4	
ENC	Recycling	Non-Inert	4	
ENC	Recycling	Non-Inert	4	
DDC	Recycling	Non-Inert	4	
NBC	Recycling (MRF)	Non-Inert	4	
WBC	Treatment	Non-Inert	4	
NBC	Waste Transfer	Non-Inert	4	
SNC	Waste Transfer	Non-Inert	4	
CBC	Waste Transfer	Non-Inert	4	Urban residential
ENC	Waste Transfer	Non-Inert	4	
NBC	Waste Transfer	Non-Inert	4	Urban and historic flood
KBC	Waste Transfer	Non-Inert	4	
WBC	Waste Transfer	Non-Inert	4	
DDC	Waste Transfer	Non-Inert	4	Listed bldngs

Sources: (after EA, 2010; NCC, 2012).

Table 6.24 shows a further 16 non-main sites as having a moderate suitability score of 4. A total of 8 of these are waste transfer operations, one is a landfill site and the remaining 7 are treatment operations (treatment, recycling and composting). Similar to main sites DDC and ENC each have 4 sites located in their areas with NBC having a further 3 sites and the remaining 5 are spread across the other four Northamptonshire LAs. It can also be see that 3 sites have penalizing considerations in terms of proximity to urban residential and listed buildings. While one site (waste transfer) has two penalizing factors (proximity to urban residential and historic flood extent). Figure 6.25 shows the spatial distribution of all facilities (n=44) with high and moderate scores (from Tables 6.20 through 6.24).

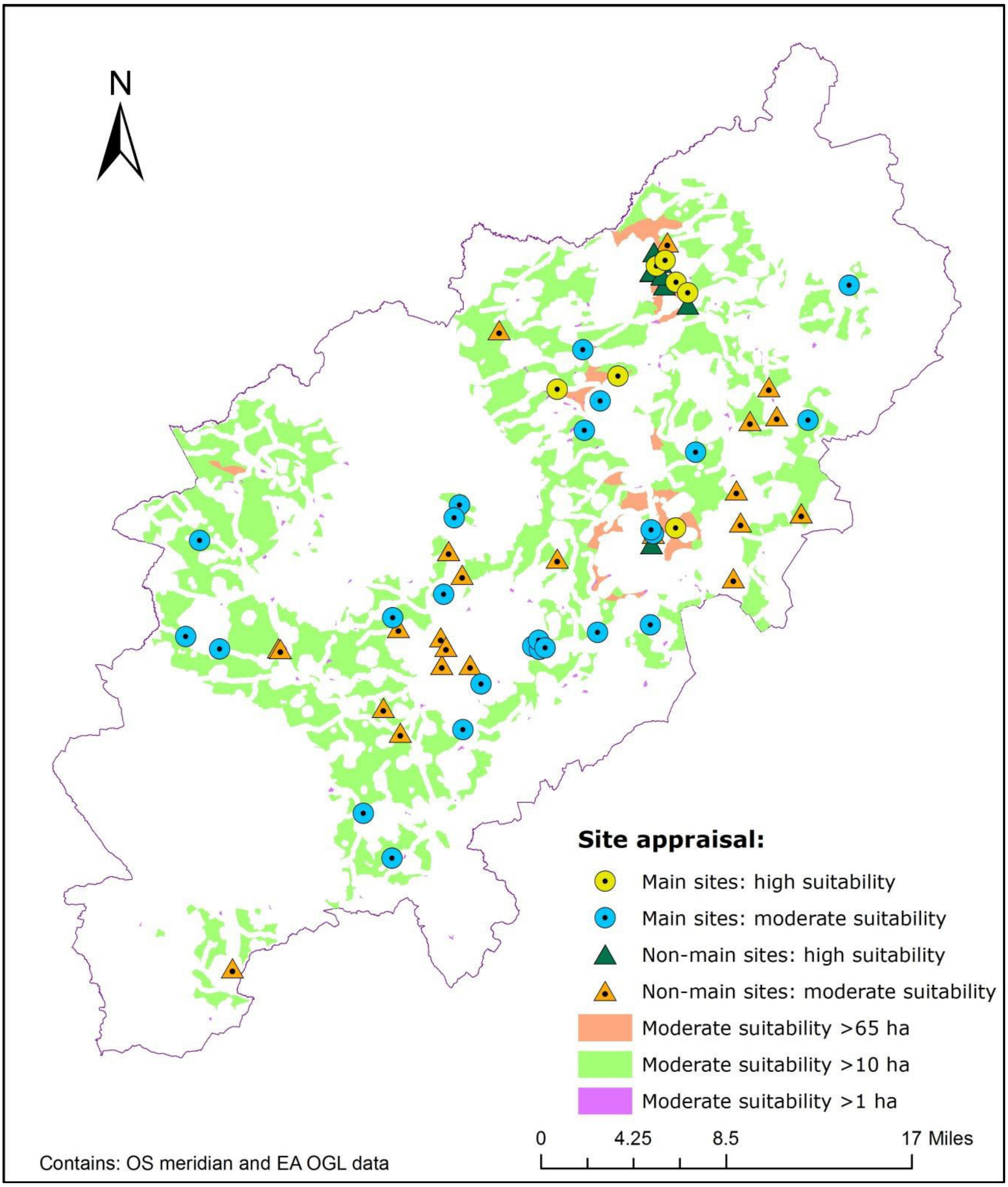


Figure 6.25: Assessment of land parcels with moderate suitability against MWDF main sites and non-main sites.

6.4.3 Spatial patterns of facilities

A total of three spatial patterns are set out for testing; these are:

- Centralised – 4 large integrated sites;
- Central core with outliers – 15 sites in close proximity to large and small urban centres (moderate/high suitability);
- Dispersed – main sites (n=22) and non-main sites (n=22).

Previous research (Bates et al. 2008) has identified different spatial patterns of facilities as being the most appropriate for managing non-municipal wastes in England. However, this approach viewed wastes as requiring separate management methods associated with a number of key barriers to achieving greater recycling and recovery of materials fractions. Such an approach was also developed with a view to coordinating efforts at the regional scale through Regional Development Agencies (RDAs) which are no longer applicable. In addition, planning reform under the NPPF (DCLG, 2012) also places a requirement on WPAs and individual LAs to cooperate when managing wastes moving across their jurisdictions (e.g. between waste facility types). To address these changes, the approach of this research seeks to determine if an optimal spatial pattern is achievable in order to account for changes to planning while still fulfilling requirements which will meet national obligations on waste targets and help transitioning England towards a zero waste economy. Figures 6.26, 6.27 and 6.28 show the spatial patterns of facilities under the three scenarios described. The spatial patterns are assessed against levels of waste generation (and accompanying recycling, recovery and disposal) associated with each scenario in 2050.

6.4.3.1 Centralised pattern of waste facilities

Figure 6.26 shows a viable pattern of facilities having two main integrated sites within areas of highest suitability (one in proximity to Corby and the other in close proximity to Wellingborough) with a further large integrated site in close proximity to Northampton. There would be a requirement for a further site (materials recycling) which could be located at a site of high suitability near DIRFT to access logistics and modal networks.

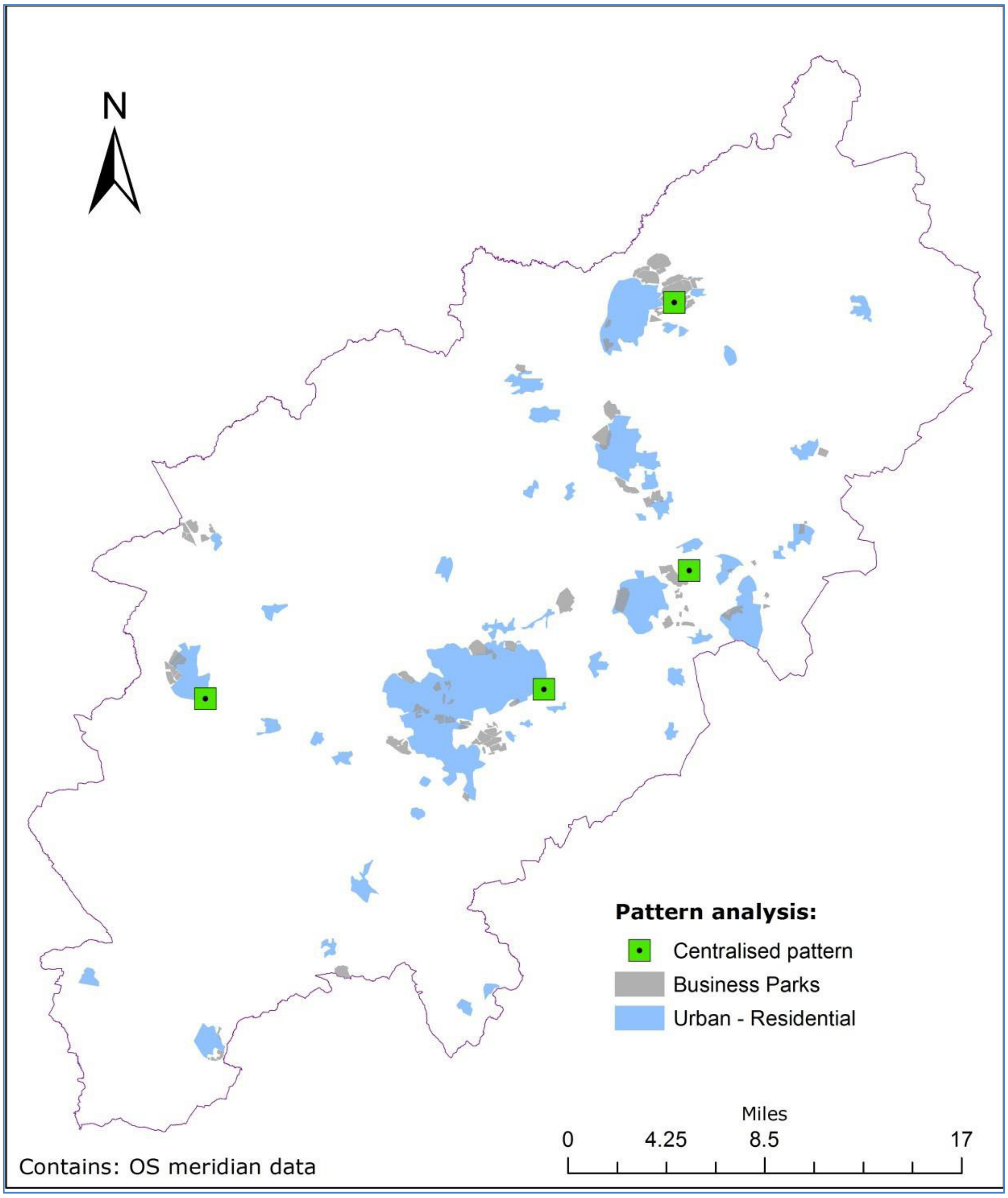


Figure 6.26: Centralised pattern of waste facilities (4 large integrated sites around 500ktpa capacity each).

This would essentially be a centralised spatial pattern of large integrated facilities with 4 main sites (existing waste operations and industrial site locations). This pattern assumes the presence of similar scale and type facilities in surrounding WPAs (e.g. one facility in close proximity to each of the urban centres of Milton Keynes, Bedford, Peterborough, Banbury, Rugby and Market Harborough). Such facilities would be more geographically proximate to rural areas of East Northamptonshire; South Northamptonshire and Daventry

District. This centralised spatial pattern would thus be able to service over 90% of the WPA population and cover around 95% of main waste generation locations. The centralised pattern would thus require the locating of a single site in an area of moderate suitability. In terms of the scenario profiles for future waste generation this spatial pattern would be most effective for scenarios CE and EC which show the largest overall reductions in waste generation (see Tables 5.16-5.19, section 5.4.1.4). Scenario CE also has the lowest increase in recycling (2.59%) and recovery (10.01%) which suggests 4 large integrated sites of 500kt capacity (65kt for LACW; 170kt for C&I wastes; 230kt for C&D wastes; and 15kt for hazardous wastes) would be required based on targets specified in the MWDF (NCC, 2012) (see Table 4.14). Scenario EC would also fit well with this spatial pattern of facilities as recycling has increased by 12.4% in 2050 while requirement for recovery capacity has declined by 33.4% (see Table 5.18).

Scenario VM has a requirement for a 9.68% increase in recycling and a 17.74% increase in recovery by 2050 (see Table 5.17). Such an increase could be accommodated within a centralised pattern but the overall scenario aim of recycling and recovering as much materials as practicable suggests a greater role for minimising distances by which those materials move. Thus a pattern of facilities focused on minimising distances may be more appropriate for scenario VM. Scenario ED shows a significant increase in wastes generated and has recovery operations (mainly via ATT's such as large scale EfW) increasing significantly (by 337%). This is also the scenario closest to being a reference scenario which fits best with an unchanging (albeit reduced number) pattern of facilities.

6.4.3.2 Central core with outlier's pattern of waste facilities

Figure 6.27 shows a spatial pattern which has a central core of large facilities (approximately 6 faciliites of ~250kt/annum) with a number of smaller outlier facilities (9 facilities of ~50-60kt/annum capacity).

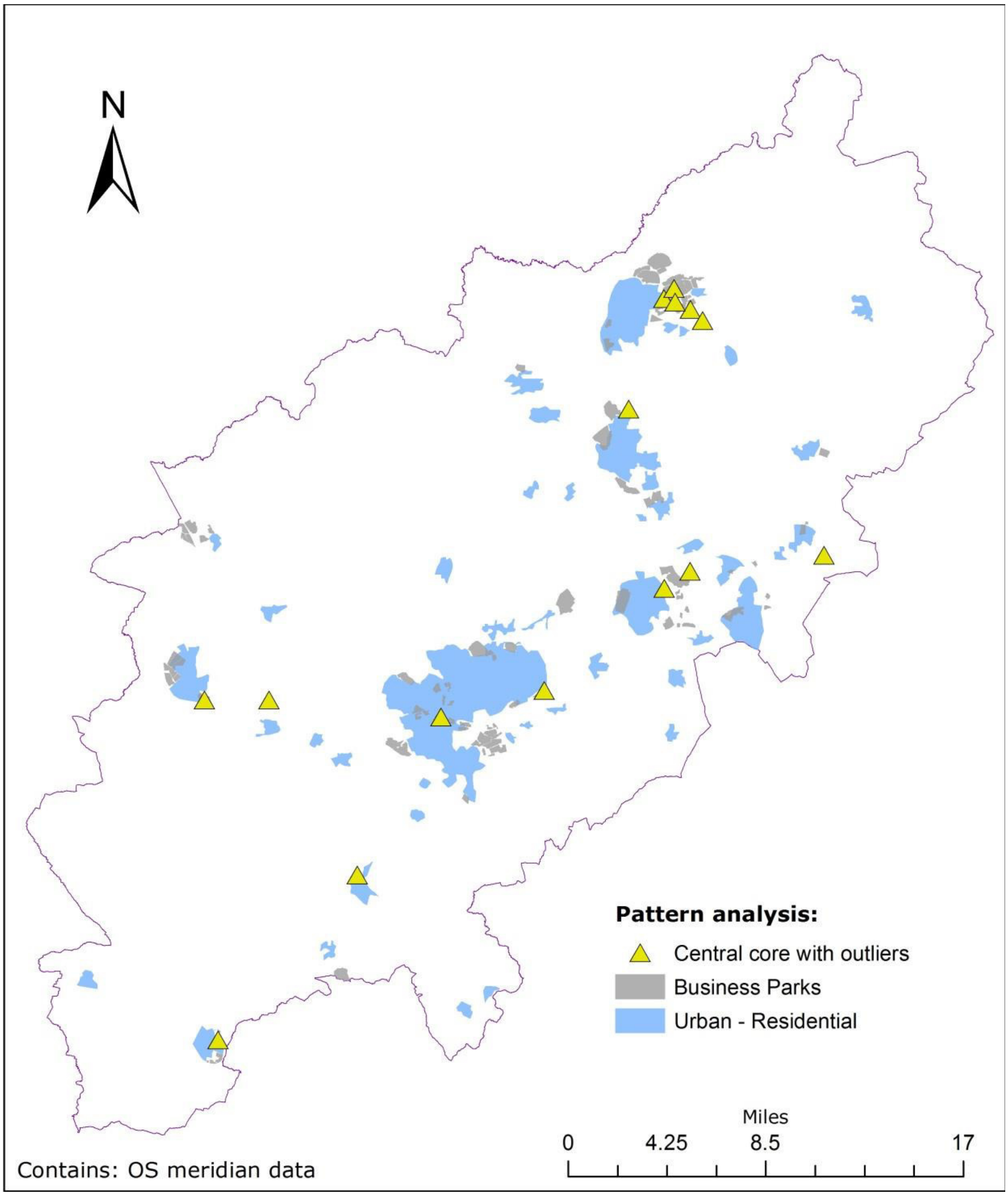


Figure 6.27: Central core with outlier's pattern of waste facilities (15 large sites ranging between 50kt/annum and 250kt/annum capacity).

This spatial pattern has the larger facilities located around the major urban centres (e.g. Northampton, Corby and Kettering) as the areas with the largest quantities of wastes generated. The distribution of the other facilities is to act as materials processing and transfer sites to integrated operations at the core sites. This approach represents and incremental change designed to keep pace with the increasing diversion of wastes from landfill (as seen under all scenarios).

The ‘central core with outlier’s’ spatial pattern is best matched with scenario VM which achieves a recycling and recovery rate in 2050 of 92.7% (79.2% recycling and 13.5% recovery) and converts to 2.00Mt of materials, the highest level for the three reducing scenarios. Considerations as to the distances moved and types of technologies required to manage such large amounts of materials drive the use of more dispersed sites which can significantly reduce the number of times materials require shipment and maximise the operational capacity of large sites which can accept bulked materials at a more controlled rate dependent on seasonal variations.

6.4.3.3 Dispersed pattern of waste facilities

This spatial pattern represents a continuation of current plan requirements with the omission of sites which did not achieve high or moderate suitability scores (e.g. 5 or 4 respectively).

The dispersed pattern in Figure 6.28 is focused on managing waste at the county level, a continuation of the approach put forwards in the MWDF (NCC, 2012). The difference lies in the number of facilities which reduces from 98 to 44 and thus requires operations to be changed at some sites (through secondary permitting) as well as the operational capacity of many sites to be increased in the range of 20-60%. Sites would be of differing scale with larger facilities existing close to the main urban centres (5 sites of 100ktpa capacity and 15 sites of 50-75ktpa capacity). Smaller facilities would be numerous (n=24), typically between 5 and 50ktpa capacity and located close to sources of materials with former and operational landfill sites having secondary permits for waste activities (e.g. composting and recycling as well as landfill energy scheme permits for methane extraction). Scenario ED is proposed to have this pattern of facilities as the closest to current conditions prevailing. In terms of recycling and recovery facilities these would have to manage 2.27Mt by 2050.

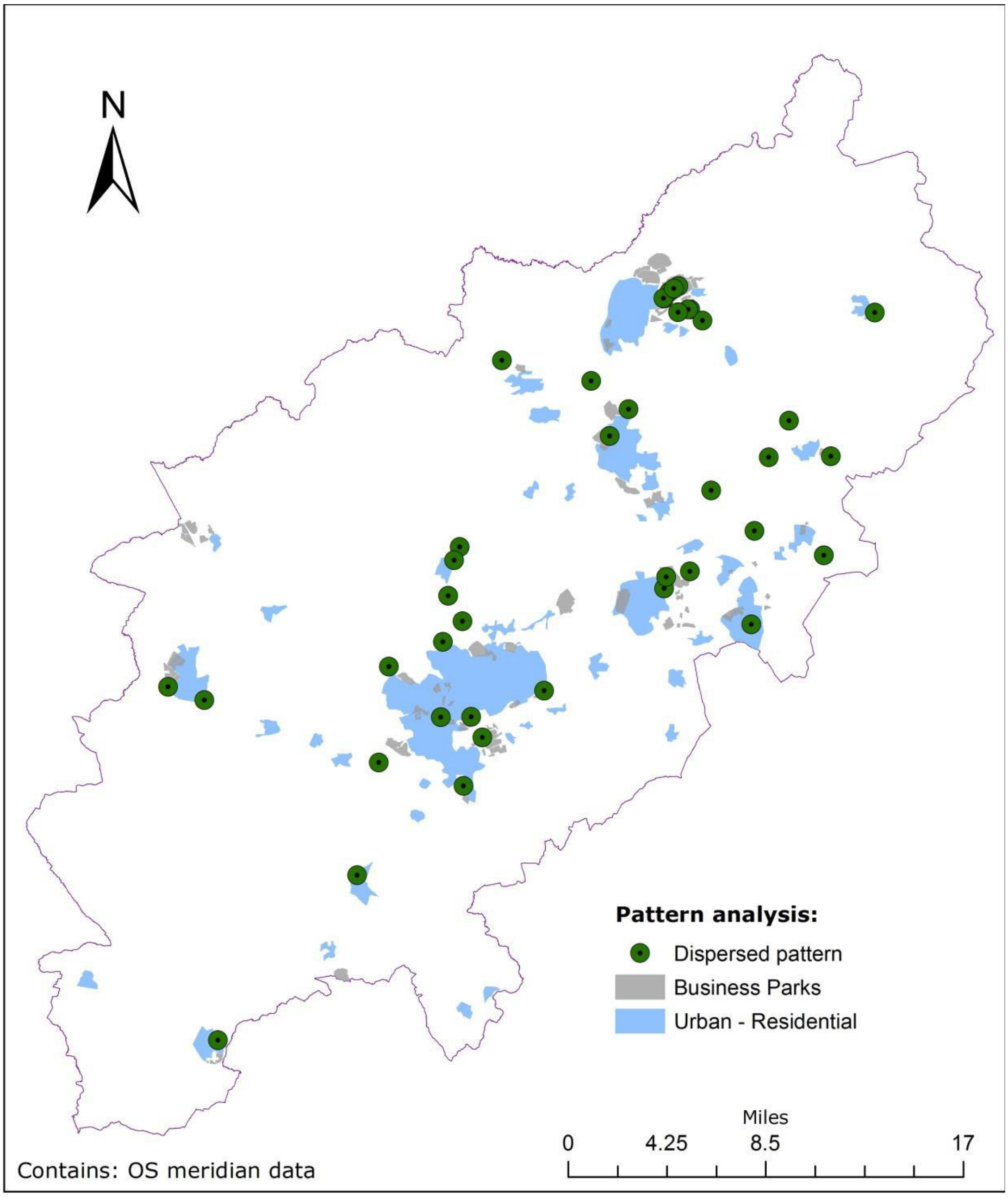


Figure 6.28: Dispersed pattern of waste facilities (44 existing sites ranging between 5-100ktpa similar capacity).

6.5 Chapter summary

This chapter produced the preliminary spatial analysis results with GIS-AHP procedures in order to address objectives 3 and 4. This approach drew upon regional infrastructure assessment tool (DTZ/SLR, 2009a) in order to visualise the spatial distribution of waste facilities in the study region, assess these in terms of suitability and propose other spatial patterns which could meet the requirements of radically different visions of the WMS by 2050.

The first stage was to map out the baseline conditions of the WMS (focusing on arisings and infrastructure types). This stage reported waste as separate streams (which were later presented as ‘all waste’ in section 7.1.1.1) and calculated values of each at the LSOA level before spatially projecting these findings (Figure 6.2a-d). The focus then shifted to infrastructure and the capacity of the existing system to manage both current and future levels of waste generation. This visualised operational capacity in terms of permitted (Figure 6.3) before disaggregating this overall capacity by facility types and found the case study area as constituting 108 active facilities with a permitted capacity of 7.00Mtpa but with a proven capacity of 2.38Mtpa.

The next consideration was in terms of the proposed waste facilities plan as part of the MWDF (NCC, 2012) and whether the 98 facilities proposed as being suitable for use to 2031 were in the right locations to optimally manage the wastes being produced or those expected under each scenario (see section 5.4.1.4). The plan indicated that assessment of suitability has been carried out previously (NCC, 2012) but the original format of the document hadn’t changed since it was first published in 2006, suggesting the assessments were at best out-of-date. The AHP process was used (Saaty, 1980) with stakeholder participation to be in keeping with the stakeholder approach applied within the backcasting methodology. Participants used the AHP to assign weightings (Figure 6.6) to opportunities and constraining criteria identified from the literature and assessed as locally relevant (Table 6.7). These criteria were also determined to be of three typologies: exclusionary, penalizing or preferential (see Tables 6.8 and 6.9). AHP results were analysed using Goepel’s spreadsheet tool (Goepel, 2013) for both opportunities and constraints groups as well as for individual criteria to calculate the weightings used in the GIS suitability analyses. Group and individual criteria assessments for TS and NTS were finalised and evaluated in terms of consistency before finally being aggregated (Tables 6.15 and 6.16) showing existing waste sites as the highest weighted opportunity criteria and environmental receptors as the highest weighted constraining criteria.

Determining the distances required for facility types to be separated from specific receptors established the analytical buffers for each criteria (see Tables 6.17 and 6.18). The individual criteria were then mapped as thematic layers for constraints (n=17) and opportunities (n=16). These thematic layers and their associated weights were utilised in the constraints and opportunities models to produce the individual (see sections 6.3.3.2.1 and 6.3.4.2.1 and Appendix 11) and final combined constraints and opportunities maps (see Figure 6.15 and Figure 6.22).

The final stage is to apply the areas of suitability analysis (Figure 6.23) to the MWDF local plan. The extraction tool (spatial analyst toolbox) was used in ArcGIS 10.1 to extract and then apply values from the suitability and constraints models (Appendix 12) to MWDF main and non-main sites. Only 12 sites of the total 98 were found to be in areas of high suitability (Figure 6.24) with a further 32 sites in areas of moderate suitability (Figure 6.25). This meant the MWDF plan was found not to be fit-for-purpose and a range of spatial patterns were proposed utilising sites of high and moderate suitability only and reflecting the scenario narrative conditions and policy packages as well as the performance results for each scenario.

End of Volume 1

Volume 2

Development of a multi-criteria, GIS-based, backcasting framework model (G-BFM) for progression towards zero waste futures, for holistic resource management policy and practice in Northamptonshire by 2050

Submitted for the Degree of Doctor of Philosophy
At The University of Northampton

2015

Nicholas Head

Declaration:

This thesis is submitted in fulfilment of the requirements for the degree of Doctor of Philosophy.

I hereby declare that all materials contained within this thesis are original and have not been submitted in fulfilment of the requirements for any other degree (either in part or in full). Inclusion of the unpublished and/or published works of others is duly acknowledged in the text.

All works have been undertaken by the author in accordance with guidance from the University of Northampton; at which seat of learning the research was undertaken. I agree to the deposit of this thesis in the University of Northampton electronic repository subject to Copyright and University of Northampton Library conditions of use and acknowledgement.

Signed:

Date:

Abstract:

The complex nature of waste management and planning requires a long-term strategic policy formation approach incorporating sustainable development principles. Consequently, the transition from a waste paradigm to valuing materials as resources is central for transitioning towards a ‘zero waste’ future. A need is identified, via infrastructure planning, to move beyond short-term forecasting and predictive methods previously used in waste research in order to overcome target-driven decision-making.

The application of a participatory backcasting methodology: visioning, baseline assessment, scenario development and feasibility testing; produced transformative scenarios which are visualised using GIS reflecting the choices, ideas and beliefs of participants. The structural governance (e.g. waste infrastructure planning and strategic waste policy) of an English county is used to evaluate the efficacy of waste management scenarios. A quantitative model was developed to test scenarios for three metrics (tonnages, economics and carbon). The final model utilises the synergy between backcasting and GIS to spatially and temporally analyse empirically quantified outputs.

This structured approach produced three transformative scenarios and one reference scenario. Waste prevention and changes to systemic waste generation produced long-term tonnage reductions across the transformative scenarios. Costs of future waste management witnessed the reference scenario outperforming one of the transformative scenarios; while the highest emissions savings were attributable to the scenario most closely reflecting the notion of ‘deep sustainability’. In terms of waste infrastructure planning, a centralised pattern of large integrated facilities emphasising catchments rather than administrative boundary were most effective. All three transformative scenarios surpassed the 90% recycling and recovery level used as the zero waste benchmark.

The research concludes that backcasting can offer a range of potential futures capable of achieving an arbitrary definition of zero waste. Further, these futures can be visualised and analysed via GIS; enhancing stakeholder engagement. Overall, the GIS-based Backcasting Framework Model (G-BFM) produced has the potential to benefit a range of stakeholders and practitioners and is strategically scalable.

Keywords: waste paradigm; zero waste; backcasting; GIS; transformative scenarios; visualisation

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I would like to extend my sincere gratitude to the large number of participants within the different stages of my research; without whose input the Thesis could not have been undertaken. Numerous people involved in the detailed research have provided me with invaluable insight into the generosity we humans possess; thank you for giving your time freely.

To close, a special word of thanks to someone whom opened my eyes to the importance of other things besides my research, dearly missed and keep a Fosters chilled for me.

Glossary of terms and abbreviations:

Acronym	Descriptor	Acronym	Descriptor
.gdb	Geodatabase file	DECC	Dept. of Energy and Climate Change
.shp	Shape file	DEFRA	Dept. Environment Food & Rural Affairs
£pa	Pounds sterling per annum	DETR	Dept. for Environment Transport and the Regions
AD	Anaerobic Digestion	DFT	Dept. for Transport
ADAS	UK Consultancy	DGEnv	Directorate General Environment
ADBA	Anaerobic Digestion and Biogas Association	DH	District Heating
AEA	UK Consultancy	DIRFT	Daventry International Rail Freight Terminal
ALC	Agricultural Land Classification	DOENI	Dept. of Environment Northern Ireland
ANP	Analytical Network Process	DPD	Development Plan Document
AONB	Area of Outstanding Natural Beauty	DTZ	Consultancy firm based in UK
APSRG	Associate Parliamentary Sustainable Resources Group	EA	Environment Agency
ArcGIS 10	GIS software package by ESRI	EAC	Environmental Audit Commission
ATT	Advance Thermal Treatment	EC	Ecological Citizenship
AWM	Advantage West Midlands	ECB	Environmentally Conscious Behaviour
B1,B2,B8	Land use type	ED	Economic Destabilisation
BCW	Borough Council of Wellingborough	EEA	European Environment Agency
BF	Backcasting Framework	EEC	European Economic Community
BGS	British Geological Survey	EEF	Engineering Employers' Federation
BID	Business Improvement Districts	EfW	Energy from Waste
BIS	(Dept.) Business Innovation and Skills	EID	Eco-Industrial Development (theory of)
Bn	Billion	EIP	Eco-Industrial Park
BPMSG	AHP tool developer	ELV	End-of-life vehicles
BRE	Building Research Establishment	EM/ EVM	Eigenvector Method
BREW	Business Resource Efficiency &Waste	EMF	Ellen MacArthur Foundation
BW	Biodegradable waste	EMRA	East Midlands Regional Assembly
C&D	Construction and Demolition	EMS	Environmental Management System
C&I	Commercial and Industrial	ENC	East Northamptonshire Council
C2C	Cradle to Cradle	EOW	End-of-waste
CAT	Centre for Alternative Technology	EP0W	European Pathway to zero waste
CBA	Cost Benefit Analysis	ESA	Environmental Services Association
CBC	Corby Borough Council	ETC/ SCP	Former consultancy from the UK
CBI	Confederation of British Industry	EU	European Union
CD&E	Construction Demolition and Excavation	EuC	European Commission
CE	Circular Economy	EuSA	European Space Agency
CEH	Centre for Ecology and Hydrology	EvSA	Environmentally Sensitive Area
CIWM	Chartered Institution of Wastes Management	EWC	European Waste Catalogue
CO2	Carbon dioxide	FfTF	Forum for the Future
CO2e	Carbon Dioxide equivalent	FM	Framework Model
CR	Consistency Ratio	FOE	Friends of the Earth
CSR	Corporate Social Responsibility	FoM	Forecast Model
DCC	Derbyshire County Council	FoM	Forecast Model
DCLG	Department of Communities and Local Government	G-BFM	GIS-based Backcasting Framework Model
DDC	Daventry District Council	GCI	General Consistency Index

GEO-4	Scenarios used in UNEP reporting	LNR	Local Nature Reserve
GIB	Green Investment Bank	LSOA	Lower Super Output Area
GIS	Geographic Information System	LULU	Locally Unwanted Land Use
GIS-AHP	GIS-Analytical Hierarchy Process	MBT	Mechanical Biological Treatment
GMA	General Morphological Analysis	MCA	Multi-Criteria Analysis
GOS	Government Office for Science	MCDA	Multi-Criteria Decision Analysis
Gov.uk	Government portal for data accessing	MCE	Multi-Criteria Evaluation
GST	General Systems Theory	Mind Genius	Mind mapping software package
GUC	Grand Union Canal	MIS	Management Information Systems
ha	Hectare	MRF	Material Recycling Facility
HCA	Homes and Communities Association	MSW	Municipal Solid Waste
HGV	Heavy Goods Vehicle	Mt	Million tonnes
HKGCC	Hong Kong Government Chamber of Commerce	MtCO2	Million tonnes of carbon dioxide
HMG	Her Majesty's Government	MWDF	Minerals and Waste Development Framework
HMT	Her Majesty's Treasury	MWLP	Minerals and Waste Local Plan
HoC	House of Commons	NACE	Nomenclature des Activités Économiques dans la Communauté Européenne
HRA	Habitats Regulations Assessment	NBC	Northampton Borough Council
HWDI	Hazardous Waste Data Interrogator	NCC	Northamptonshire County Council
HWRC	Household Waste Recycling Centre	NGO	Non-Governmental Organisation
HzW	Hazardous Waste	NHS	National Health Service
IBA	Incinerator Bottom Ash	NI	Northern Ireland
IE	Industrial Ecology	NIA	Northern Ireland Assembly
IMD	Index of Multiple Deprivation	NIMBY	Not In My Back Yard
INSPIRE	Directive (2007/2/EC)	NISP	National Industrial Symbiosis Programme
IPCC	Inter-Governmental Panel for Climate Change	NJMWMS	Northamptonshire Joint Municipal Waste Management Strategy
IPPC	Integrated Pollution Prevention Control	NNR	National Nature Reserve
IS	Industrial Symbiosis	NOMIS	Reporting portal for census data
IWM	Integrated Waste Management	NPPF	National Planning Policy Framework
KBC	Kettering Borough Council	NRW	Natural Resources Wales
kgCO2/t	Kilograms of carbon dioxide equivalent per tonne	NTS	Non-Technical Stakeholder
Kt	Kilo-tonnes	NWP	Northamptonshire Waste Partnership
LA	Local Authority(s)	ODPM	Office of the Deputy Prime Minister
LACW	(LA) Collected Waste	OGL	Open Government License
LARAC	(LA) Recycling Advisory Committee	OH	Oakdene Hollens, UK consultancy
LATS	Landfill Allowance Trading Scheme	ONS	Office for National Statistics
LCA	Life Cycle Analysis	OS	Ordnance Survey
LDD	Local Development Document	OSGB 1936	Coordinate system used for projection in ArcGIS 10
LDP	Local Development Plan	OWA	Ordered Weighted Average
LFD	Landfill Directive	PDL	Previously Developed Land
LGA	Local Government Association	PFH	Problem Formation Hierarchy
LLW	Low-Level Waste (Radioactive)	Pop/ha	Population per hectare
LDD	Local Development Document	PPC	Pollution Prevention and Control

PPP	Public Private Partnership	UA	Unitary Authority
PPS10	Planning Policy Statement 10	UNEP	United Nations Environment Programme
PUA	Principal Urban Area	UoN	University of Northampton
QM	Quantitative Model	VAT	Value added tax
R&D	Research and Development	VES	Veolia Environmental Services
RAMSAR	RAMSAR Convention on Wetlands	VLLW	Very Low Level Waste
RDA	Regional Development Agency	VM	Valorisation and Materials
REC	Resource Efficiency Club(s)	WAG	Welsh Assembly Government
RGMM	Row geometric mean method	WAP	Working Age Population
RICOH	RICOH UK office equipment supplier	WBCSD	World Business Council for Sustainable Development
RM	Resource Management	WCA	Waste Collection Authority
RPS	Consultancy firm based in UK	WCED	World Commission Economic Development
RRP	Resource Recovery Park	WDA	Waste Disposal Authority
RSS	Regional Spatial Strategy	WDF	Waste Data Flow
RTAB	Regional Technology Advisory Board	WDI	Waste Data Interrogator
SA	Sustainability Appraisal	WEEE	Waste Electrical and Electronic Equipment
SD	Scenario Development	WFD	Waste Framework Directive
SDI	Sustainable Development Indicator(s)	WIDP	Waste Infrastructure Development Programme
SEA	Strategic Environmental Assessment	WMPE	Waste Management Plan for England
SEL	Strategic Economic Land	WMS	Waste Management System
SERI	Swedish Environmental research Institute	WPA	Waste Planning Authority
SI	Statutory Instrument	WPPE	Waste Prevention Plan for England
SITA	SITA Suez - waste management company	WRAP	Waste and Resource Action Programme
SLR	Consultancy firm based in UK	WRATE	Life Cycle Analysis tool
SNC	South Northamptonshire Council	WRM	Waste and Resource Management
SOC	Substance Oriented Classification	WRRAG	Waste and Resources Research Advisory Group
SPA	Special Protection Area	WTS	Waste Transfer Station
SPD	Supplementary Planning Documents	WwTW	Waste water treatment works
SPZ-GW	Source Protection Zone – Groundwater	WYG	UK Consultancy
SSSI	Site of Special Scientific Interest	ZW2L	Zero Waste to Landfill
ST	Systems Thinking	ZWI	Zero Waste Index
STEEP	Social Technological Economic Environmental and Policy analysis	ZWIA	Zero Waste International Alliance
t/ha	tonnes per hectare	ZWS	Zero Waste Scotland
TEEP	Technically, Economically and Environmentally Practicable		
TIFU	Technology and Infrastructure Finance Unit		
TNS	The Natural Step		
tpa	tonnes per annum		
TPB	Theory of Planned Behaviour		
TQM	Total Quality Management		
TS	Technical Stakeholder		
TSE	The Scottish Executive		

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Chapter 7 Synthesis results

Chapter 7 brings together results from the backcasting methodology (specifically in terms of the visioning; scenario development and impact analysis stages) and the GIS spatial analysis method (Chapter 6) in order to visualise the backcasting outputs for stakeholder engagement in line with Objectives 4 and 5. Stages 1, 2 and 3 of Figure 7.1 were covered in Chapter 6, this chapter uses stages 4, 5 and 6 to synthesise all of the results.

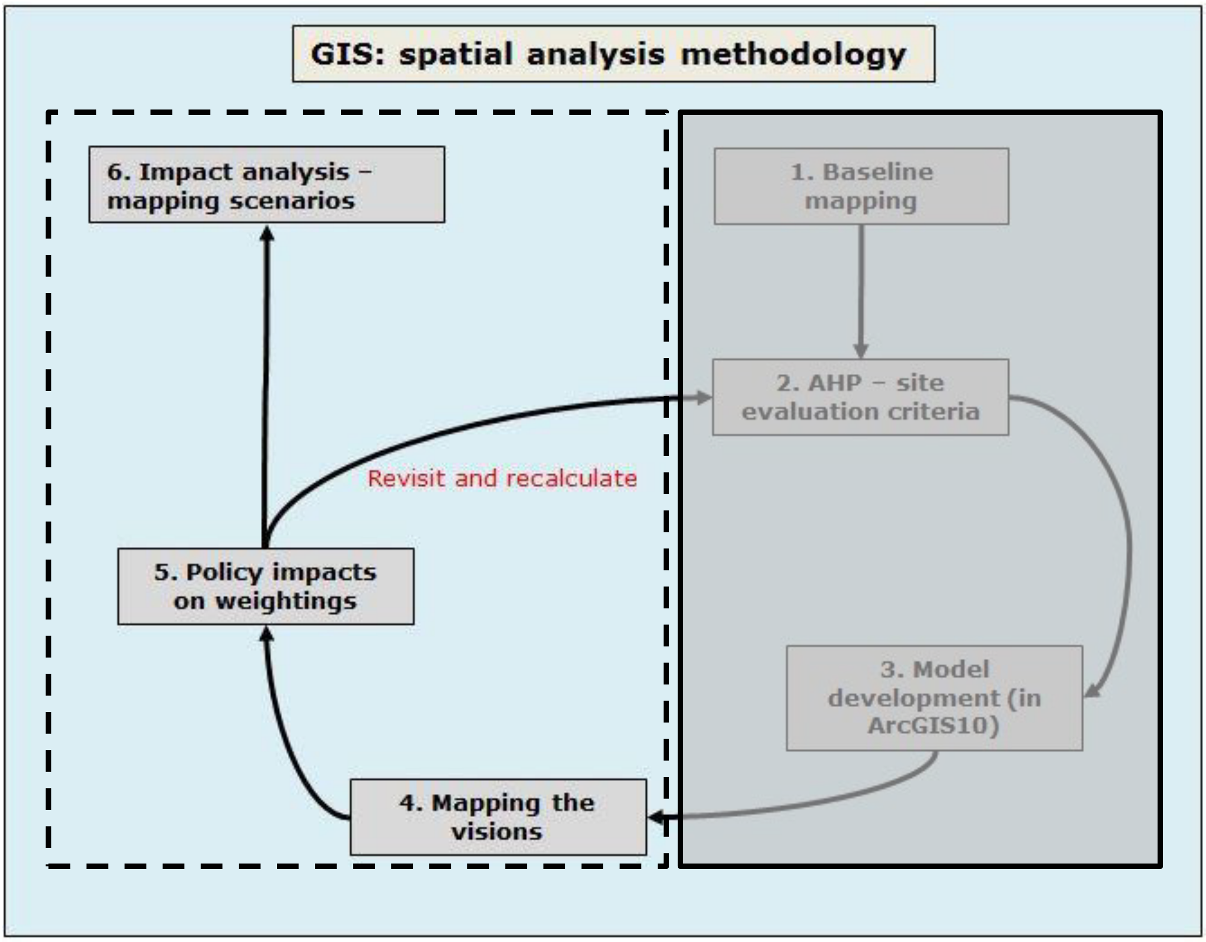


Figure 7.1: Methodology for synthesising backcasting with GIS (Results for Stages 4, 5 and 6).

7.1 Mapping the visions

In this section the future visions (Circular Economy – CE; Valorisation and Materials – VM; Economic Citizenship – EC; and Economic Destabilisation - ED) are presented spatially as GIS maps of controlled wastes and associated impacts under each scenario. These results are further disaggregated as tonnages, economic and carbon factors. A selection of tables are also presented in order to depict the key milestone years (2020, 2030 and 2040) with the full set of maps for milestone years presented in Appendix 12.

7.1.1 Visualising the futures scenarios

7.1.1.1 Spatial distribution of waste tonnages - baseline

Total controlled waste is calculated for each LSOA by means of simple division of annual baseline tonnages (2012) by the population of each LSOA to give an overall tonnage for each waste type. These totals are summed to produce a value for all waste as tonnes per annum (tpa). The equation applied is presented as equation 7.1.

Equation 7.1:

$$\text{All waste by LSOA (tpa)} = \sum \left[\frac{\text{annual baseline tonnages}}{\text{resident population}}\right]$$

Results are presented spatially in terms of 'all wastes' (controlled wastes) per annum (tpa) and as waste densities (t/ha) where all waste (t) within each LSOA is divided by the area, measured as hectares (ha), presented here as Equation 7.2.

Equation 7.2:

$$\text{Waste density by LSOA (t/ha)} = \sum \left[\frac{\text{all waste by LSOA (tpa)}}{\text{area (ha)}}\right]$$

Figure 7.2a shows the spatial distribution of all wastes across Northamptonshire LSOAs in 2012 when equation 7.1 is used to calculate overall tonnages for the county against the resident population of each individual LSOA. In doing so, wastes produced across all economic sectors are tracked back to a per capita calculation in line with national scale data collection methodologies for England. This method of calculating LSOA tonnages is utilised in order to give an indication of where arisings were at the start of the backcast period and thus provide a metric by which the future end-point can be assessed as well as the key milestone years identified. Figure 7.2a shows a stochastic pattern of distribution which may reflect the changing demographics of the county more so than any real

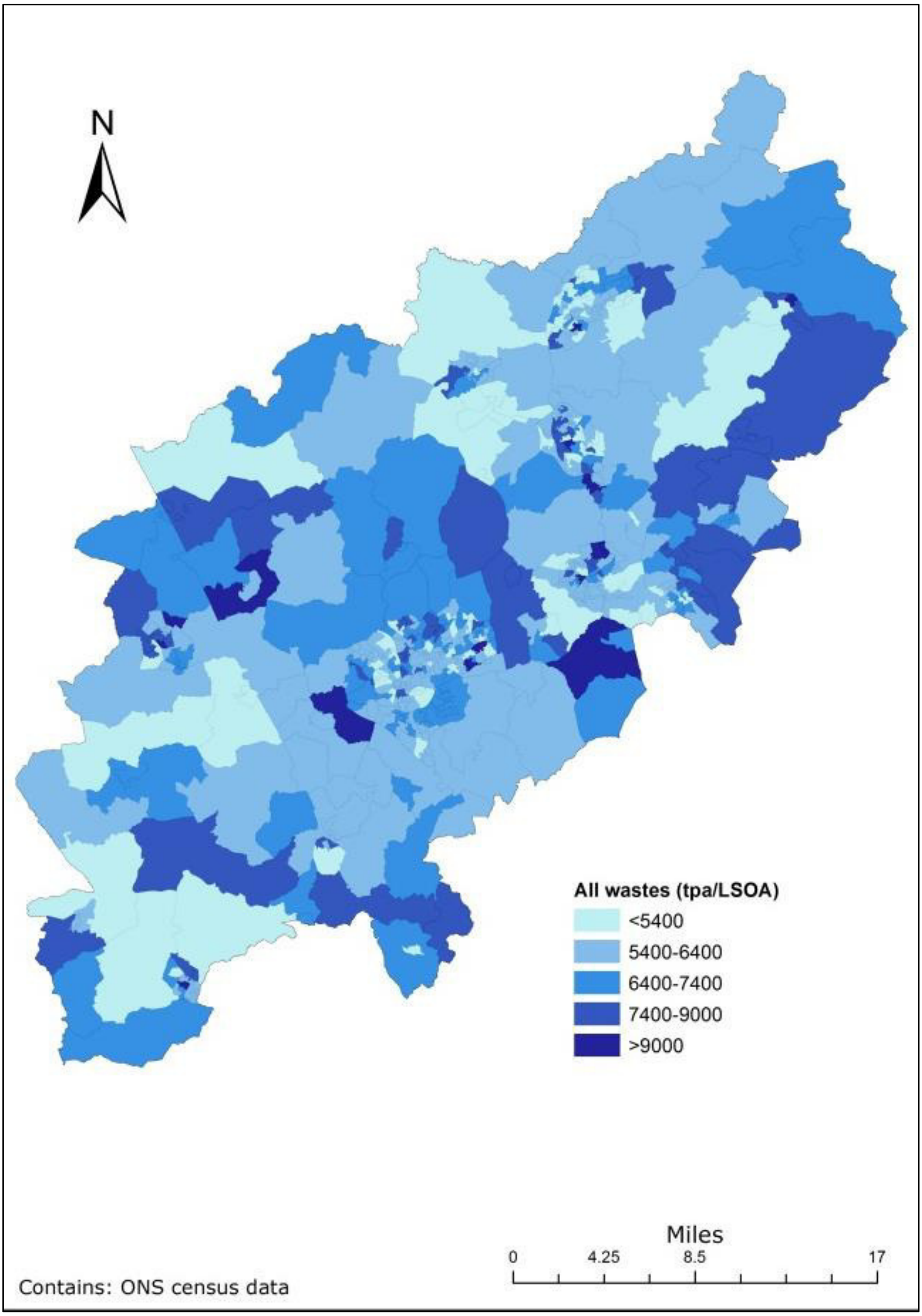


Figure 7.2a: All wastes (tpa/LSOA) baseline assessment for Northamptonshire (2012)

differences in waste generation rates between LSOAs. For instance an LSOA with an increasing population would show a higher overall tonnage than an equivalent LSOA with a stable population. This happens within census data for areas of population growth as was seen with the creation of 15 new Northamptonshire LSOAs between 2001 and 2011 (ONS, 2012). Figure 7.2b is a statistical summary of the spatial distribution of all wastes for the baseline (2012) in Northamptonshire using the geo-statistical analysis tool in ArcGIS 10.1.

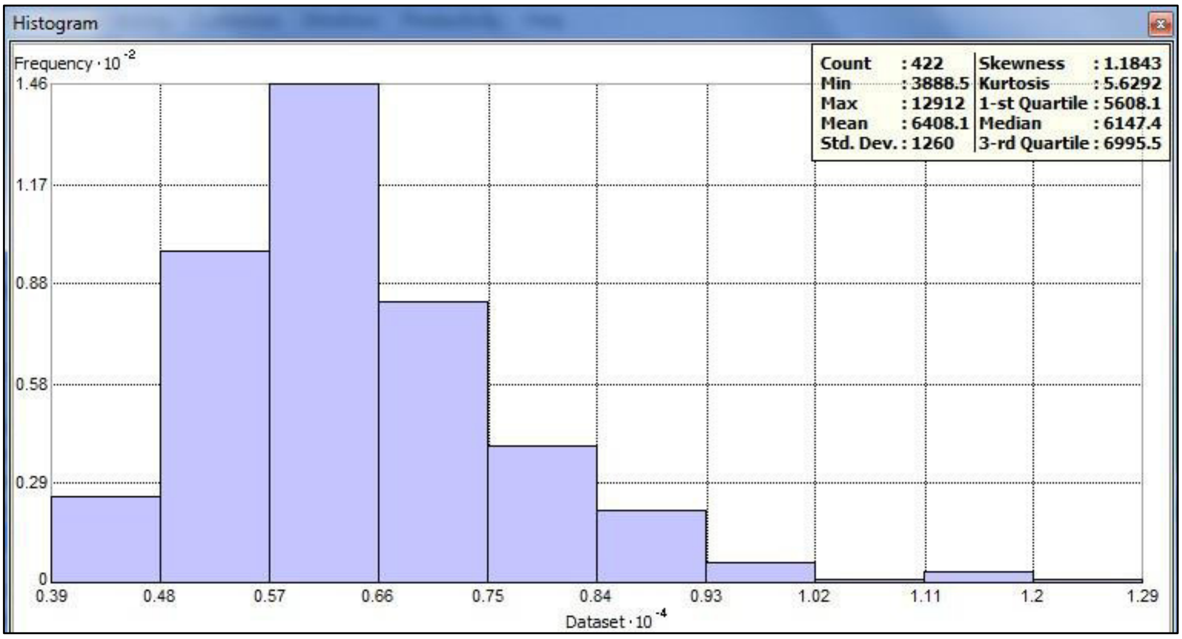


Figure 7.2b: Statistical summary of all wastes baseline assessment for Northamptonshire (2012)

The statistical summary in Figure 7.2b shows the total number of LSOAs (n=422) separated as 10 columns with the y-axis representing frequency of LSOAs within each column. It can be seen that the minimum value for an LSOA was 3,889tpa with a maximum value of 12,912tpa. The mean value was 6,408tpa with 146 LSOAs situated in the column (5700-6600tpa) containing both the mean and median values. Further, 25% of all LSOAs (n=105/6) had a value below or equal to 5,608tpa with 75% of all LSOAs (n=316) having a value below or equal to 6,995tpa. At the upper end, 105 LSOAs had all wastes values of between 6,995 and 12,912tpa which cover the last 7 columns of Figure 7.2b indicating a small number of LSOAs with the highest values.

The overall tonnage of all wastes by resident is calculated using Equation 7.3.

Equation 7.3:

$$\text{Overall tonnage all wastes by resident} = \sum \left[\frac{\text{Mean (tpa)} \times \text{LSOA count}}{\text{resident population}} \right]$$

or

$$\text{Overall tonnage all wastes by resident} = \sum \left[\frac{6408 \times 422}{691{,}592} \right]$$

Thus:

Overall tonnage all wastes by resident = 3.91tpa

7.1.1.2 Spatial distribution of waste densities

In order to assess the efficacy of the spatial plan the distribution of overall tonnages is only the starting point. It is necessary to take overall tonnage figures and divide by area to give 'density' (as tonnes per hectare – t/ha) of all wastes within the county (see equation 7.2).

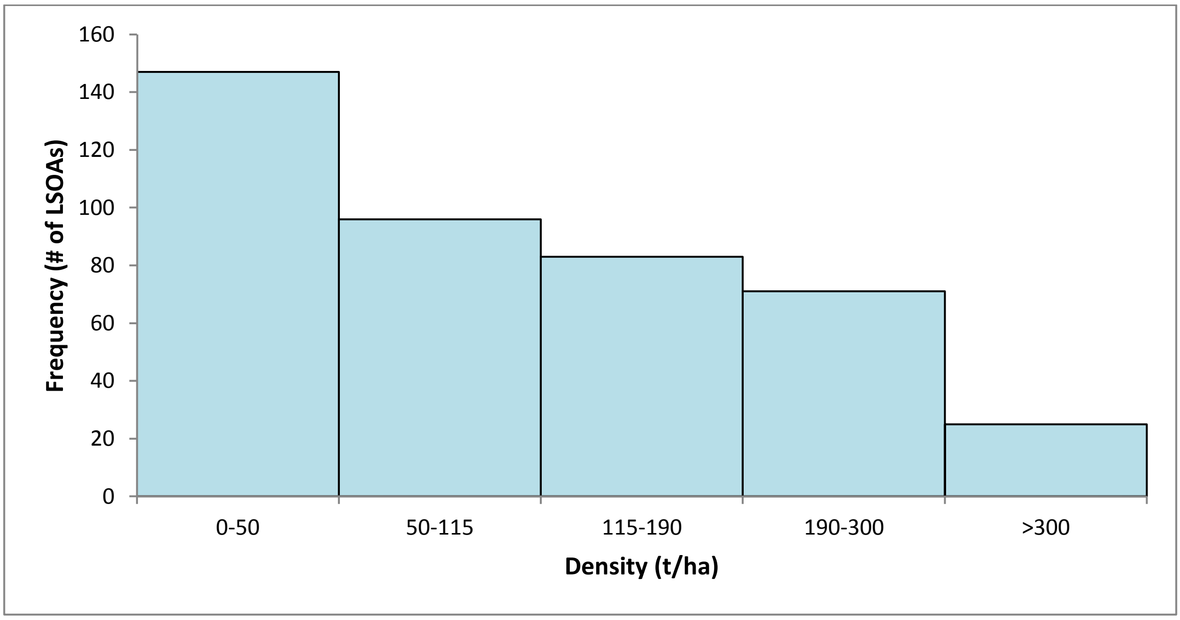


Figure 7.3: Frequency distribution of waste density by LSOA for 'all waste' baseline

Figure 7.3 shows the frequency distribution of waste density by LSOA for the baseline year. In total, 25 LSOAs (5.9%) had a waste density above 300tpa, with 42.4% of LSOAs

(179) having density values greater than 115t/ha. Figure 7.4a shows the output map from these calculations (as tonnes per hectare – t/ha) utilising the GIS environment for the baseline year (2012) within Northamptonshire.

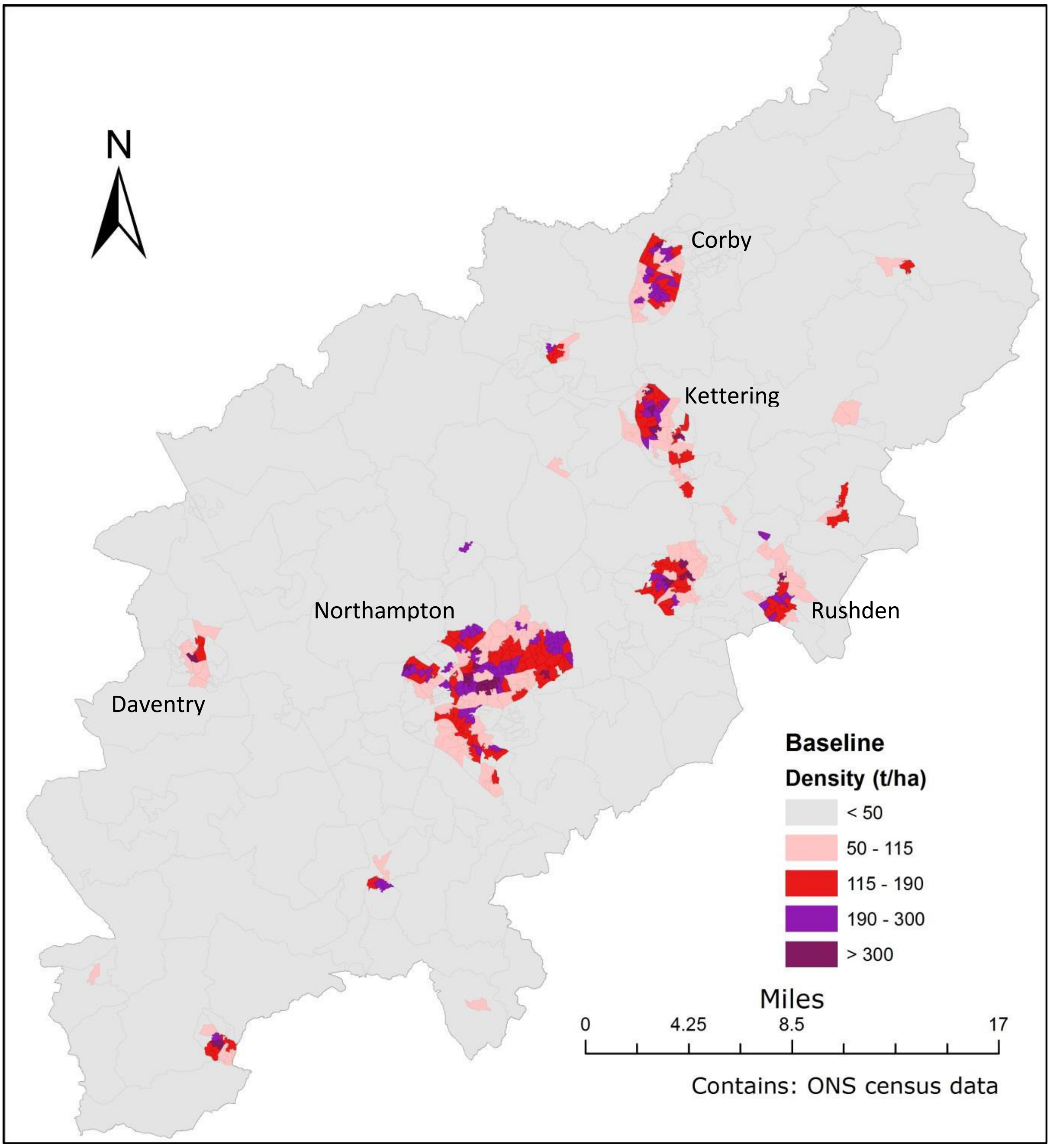


Figure 7.4a: All controlled wastes density (t/ha) baseline assessment for Northamptonshire in 2012

The spatial distribution of all wastes densities is highly concentrated on urban centres as areas of significant population within small geographic areas. The highest concentrations

(190-300 and >300t/ha) are seen within the central areas of the main urban centres. Conversely, rural areas of Northamptonshire have typical density values of less than 50t/ha (147 LSOAs). Figure 7.4b provides a statistical summary of all wastes densities for the baseline year in Northamptonshire.

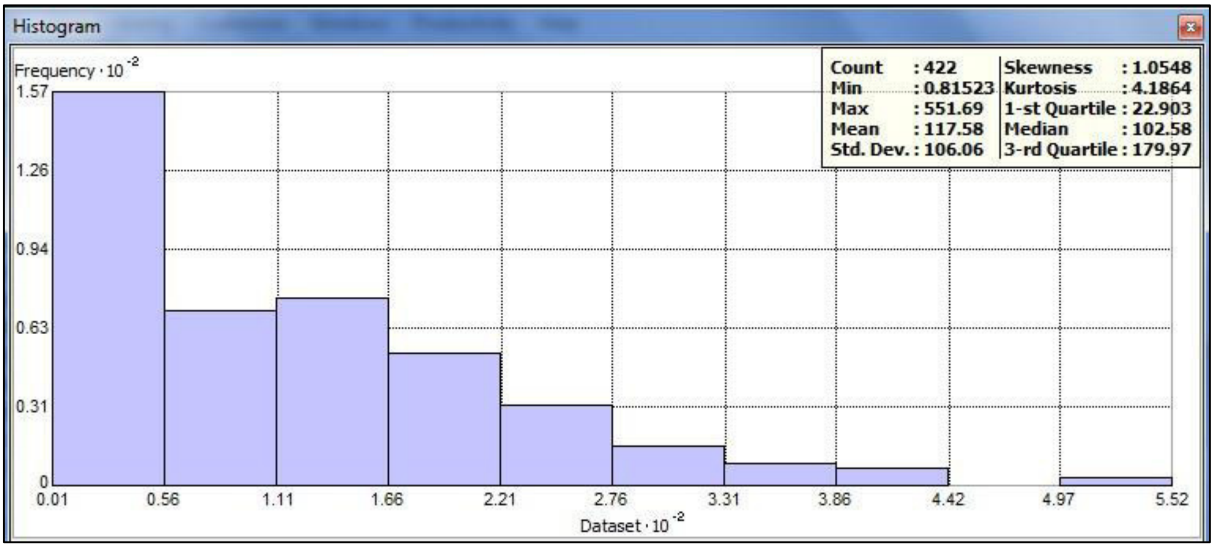


Figure 7.4b: All controlled wastes density statistical summary for Northamptonshire (2012)

The statistical summary (Figure 7.4b) shows 157 LSOAs with a density below or equal to 56t/ha. Of this figure 105 LSOAs (25% or the 1st Quartile) had a density below or equal to 22.9t/ha leaving 52 LSOAs in a range between 22.9 and 56.0t/ha. The mean value for all LSOAs (n=422) was 118t/ha with a minimum value of 0.82t/ha and a maximum of 552t/ha. In total a further 105 LSOAs had densities between 180 and 55t/ha.

7.1.1.3 Population changes

Changes to the population are a significant factor across all scenarios representing a consistent figure to test the impacts on waste tonnages, economics and carbon. Table 7.1 shows population increases across all four scenarios with scenario VM having the largest value (752k) in 2050, having peaked in 2040 with a value of 760k. By 2050, scenarios CE and EC have population levels close to those within scenario VM (748k and 747k respectively). In contrast, scenario ED has a population of 705k in 2050 (1.92% overall increase).

Table 7.1: Summary of population change under all scenarios in Northamptonshire

Scenario	Baseline	2020	2030	2040	2050
CE	691,952	705,913	723,760	740,949	748,392
VM	691,952	720,119	753,934	759,985	752,420
EC	691,952	703,101	717,290	731,766	746,534
ED	691,952	694,725	698,206	701,705	705,221

Sources: (after ONS, 2012; WDF, 2014a).

Scenario VM is characterised by rapid growth between 2012 and 2030 before slowing and then declining between 2040 and 2050 (-1.00%) with an overall change of 8.74%. Scenario CE has a similar profile to VM but at a reduced rate and does not decline. Overall change in population for scenario CE is 8.16%. In contrast scenarios EC and ED have stable population growth profiles throughout but scenario EC is four times greater than ED with overall change in populations being 7.89 and 1.92% respectively.

7.1.2 Future waste tonnages

In order to determine the relative impacts of the policy packages outlined in the qualitative scenarios (see section 5.3) on controlled wastes tonnages (all wastes), the resulting outputs are compared. The tonnage results from the QM for all wastes are shown in Table 7.2.

Table 7.2: Summary of all wastes (tonnes) under all scenarios and for milestone years in Northamptonshire

Year	CE	VM	EC	ED
2012	2,704,209	2,704,209	2,704,209	2,704,209
2020	2,579,723	2,600,235	2,619,395	2,702,281
2030	2,420,734	2,464,766	2,476,237	2,765,413
2040	2,233,714	2,286,881	2,241,123	2,833,484
2050	2,046,030	2,160,436	2,054,132	2,901,793

Table 7.2 shows scenario CE outperforming scenario EC, VM and ED (respectively) in 2050. Overall tonnages for each scenario in 2050 are presented spatially in Figure 7.5a-d.

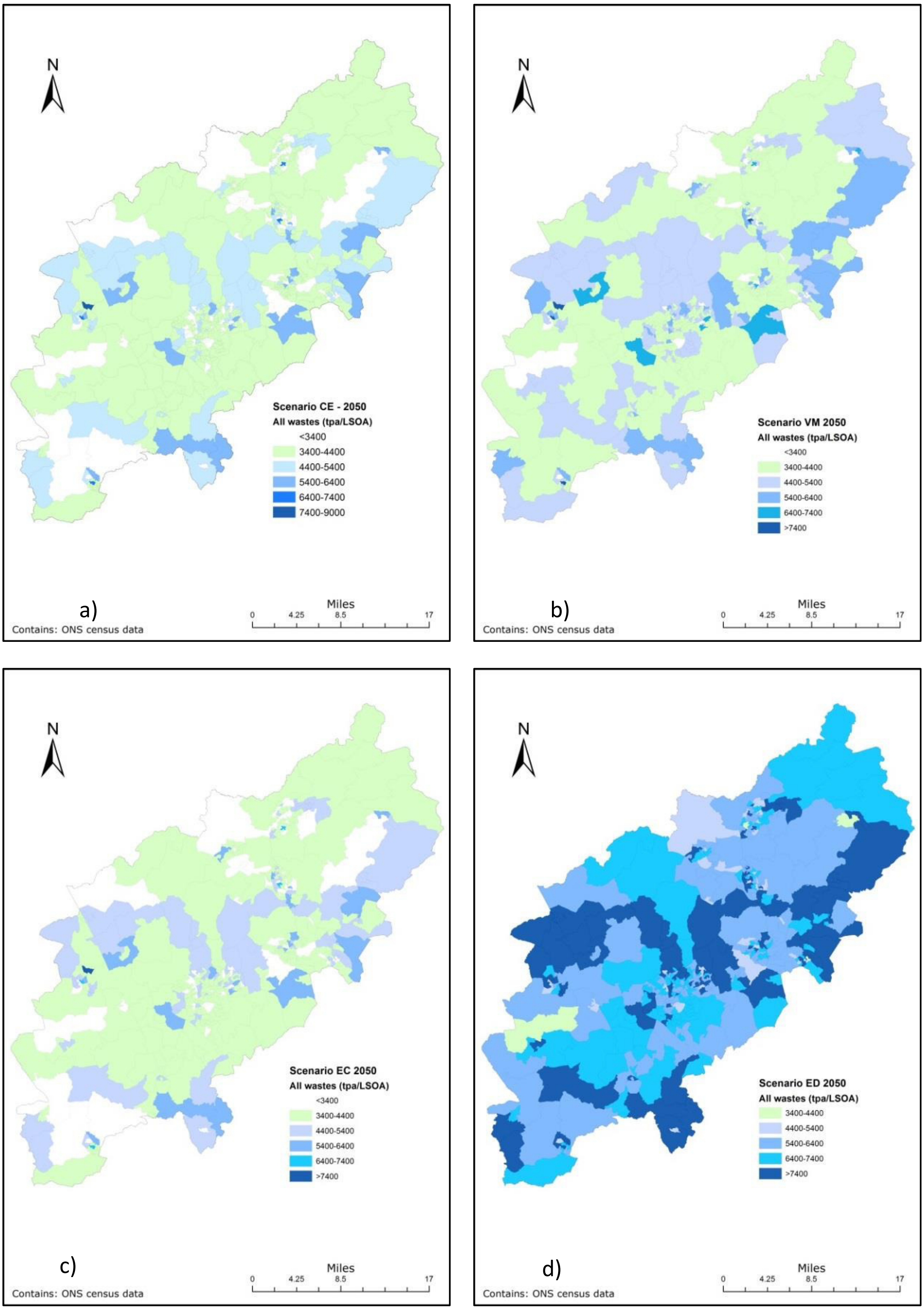


Figure 7.5a-d: Comparison of total waste generated (tpa) in 2050 across the four scenarios (a=CE; b=VM; c=EC; and d=ED).

Figure 7.5a-d spatially contrasts totals for waste generation (tpa/LSOA) under each of the four scenarios for 2050. It is clear that scenario CE and EC (Figure 7.5a and 7.5c) have the lowest levels of total waste generation (as tpa) followed by scenario VM (Figure 7.5b). In terms of performance, scenario ED (Figure 7.5d) shows an overall increase on the baseline (Figure 7.2a) and consequently represents the worst performing scenario for all waste tonnages. Statistical analyses of 'all waste' results are shown in Table 7.3.

Table 7.3: Statistical summary of 'all wastes' (tpa/LSOA) under all scenarios for Northamptonshire in 2050

Statistics	CE	VM	EC	ED
Min value	2,942	3,107	2,954	4,173
Max value	9,770	10,316	9,808	13,856
Mean	4,848	5,120	4,868	6,876
3rd Quartile	5,296	5,592	5,317	7,511
Median	4,654	4,914	4,673	6,601
1st Quartile	4,243	4,480	4,260	6,018

The statistical summary (Table 7.3) shows scenario CE slightly outperforms EC in all categories. In particular the mean value is lower at 4,848tpa/LSOA compared with 4,868tpa/LSOA. Table 7.4 also indicates that 75% of all LSOAs under scenario CE are generating below 5,296tpa. Statistically, scenario ED is the worst performing with the highest values recorded across the 6 descriptive categories with the mean value (6,876tpa) being 41.8% higher than the lowest mean value under scenario CE in 2050. Changes to the mean are a useful indiactor as to the preformance of each scenario across the period of the backcast. Table 7.4 shows the changes to all wastes mean values for all scenarios.

Table 7.4: Mean values (tpa/LSOA) for all wastes under all scenarios in Northamptonshire

Year	CE	VM	EC	ED
2012	6,408	6,408	6,408	6,408
2020	6,113	6,162	6,207	6,404
2030	5,736	5,841	5,868	6,553
2040	5,293	5,419	5,311	6,714
2050	4,848	5,120	4,868	6,876

Table 7.4 shows that scenario CE has the lowest mean value throughout the period of the backcast (2012-2050) which contrasts with scenario ED which has the highest mean value across the same period. Scenario VM outperforms scenario EC between 2012 and 2030 before scenario EC outperforms VM and maintains its position just behind CE until 2050. Equation 7.3 is once again applied to the outputs in order to calculate per capita values with Table 7.5 showing the results.

Table 7.5: Average per capita values (tpa) for all wastes under all scenarios in Northamptonshire

Year	CE	VM	EC	ED
2012	3.91	3.91	3.91	3.91
2020	3.65	3.61	3.73	3.89
2030	3.34	3.27	3.45	3.96
2040	3.01	3.01	3.06	4.04
2050	2.73	2.87	2.75	4.11

It can be seen that in 2050 scenario CE is once again the best performer in terms of per capita values (all wastes) with an average of 2.73tpa. This is closely followed by scenarios EC and VM (2.75 and 2.87tpa respectively) with scenario ED having the highest per capita value in 2050 (4.11tpa). However, scenario VM is the best performer between 2012 and 2040 before being overtaken by scenarios CE and EC. In terms of overall change, scenario CE shows a 30.2% reduction on the baseline followed by a 29.7% reduction for EC and a 26.6% reduction for VM. Scenario ED shows a small increase in overall per capita tonnages of 5.1% between 2012 and 2050. The performance of each scenario across the key milestones is briefly covered in section 7.3 with all comparison maps provided in Appendix 12.

7.2 Spatial distribution of economic impacts

Economic impacts are measured as waste management costs (£pa) and savings from avoidance (£pa). The summary calculations are shown in Table 7.6 with detailed analysis provided subsequently as a series of GIS generated overlay maps.

Table 7.6: Summary of the economic impacts of waste management (£pa) by LSOA for all scenarios in Northamptonshire

Year	Scenario	Mean Costs (£pa/LSOA)	Mean Savings (£pa/LSOA)	Mean per capita costs (£pa)	Mean per capita savings (£pa)
2012	Baseline CE	207,295	-	126.42	-
	Baseline VM	218,542	-	133.28	-
	Baseline EC	208,246	-	127.00	-
	Baseline ED	228,979	-	139.65	-
2020	CE	239,016	25,932	142.89	15.50
	VM	248,187	42,050	145.44	24.64
	EC	269,568	23,856	161.79	14.32
	ED	244,222	38,136	148.35	23.17
2030	CE	253,764	61,183	147.96	35.67
	VM	208,505	84,621	116.71	47.36
	EC	288,961	84,524	170.00	49.73
	ED	246,386	72,191	148.92	43.63
2040	CE	235,743	103,477	134.27	58.93
	VM	179,833	115,338	99.86	64.04
	EC	287,825	146,713	165.98	84.61
	ED	251,552	88,377	151.28	53.15
2050	CE	220,477	180,389	124.32	101.72
	VM	151,066	162,458	84.73	91.12
	EC	276,288	227,768	156.18	128.75
	ED	281,335	90,158	168.35	53.95

Table 7.6 shows that all scenarios start with a different baseline for economic costs as these totals reflect the different levels of waste infrastructure thought to be required for each scenario (see section 5.4.2.3). In addition, the mean LSOA and per capita values (£pa) show considerable variation as these are generated according to the different levels of gate fees and landfill charged under each scenario (see sections 5.4.2.1 and 5.4.2.2). In terms of mean costs by LSOA, all scenarios experience an increase between 2012 and 2020 with scenario ED having the least increase (6.7%). This increase continues between 2020 and

2030 apart from scenario VM which reduces by 16.0% to £208kpa (some £10kpa below its baseline value). All scenarios except ED see a reduction between 2030 and 2040 with LSOA costs for scenario VM reducing by 13.8%. Up until 2050 this trend is continued with VM reducing LSOA costs by 16.0% on 2040 levels. In addition, across the backcast period scenario VM is the only scenario to have seen an overall reduction in LSOA costs (30.9%). In contrast, scenario EC has the largest percentage increase (32.7%) on the baseline with scenario ED having the highest mean costs (£281k/LSOA pa). Mean costs per capita follow a similar pattern to LSOA costs with scenario VM having the lowest costs per capita in 2050 at £84.73pa (an overall reduction of 36.4% on the baseline). Savings by LSOA and per capita are closely correlated (as seen with mean costs) with the most significant savings seen by 2050 under scenario EC (£228kpa/LSOA and £128.75pa per capita) thus avoiding scenario EC becoming the most costly scenario because of policy packages designed to drive waste away from landfill and incineration via environmental taxes (e.g. the extant landfill tax and potential introduction of an incineration tax).

7.2.1 Economic impact mapping by scenario

7.2.1.1 Scenario CE

It is important to examine the economic impact of policy packages on each scenario against the baseline calculations (see section 5.4.2). This evaluation defers density assessment in favour of LSOA and per capita calculations. A summary of economic impacts is given in Figure 7.6a for scenario CE followed by a visual assessment between the baseline and 2050 (Figure 7.6b-c).

Figure 7.6a clearly shows the level of correlation between per capita and LSOA mean values for costs and savings. In addition, the cost profiles show a marked increase between 2012 and 2030 before declining to the 2050 end point. LSOA costs in 2050 remain above the baseline whereas per capita costs in 2050 are below the baseline value. Savings profiles show an exponential pattern of increase across the backcast period. Figures 7.6b-c shows the spatial distribution of costs at the LSOA scale for the baseline and for 2050.

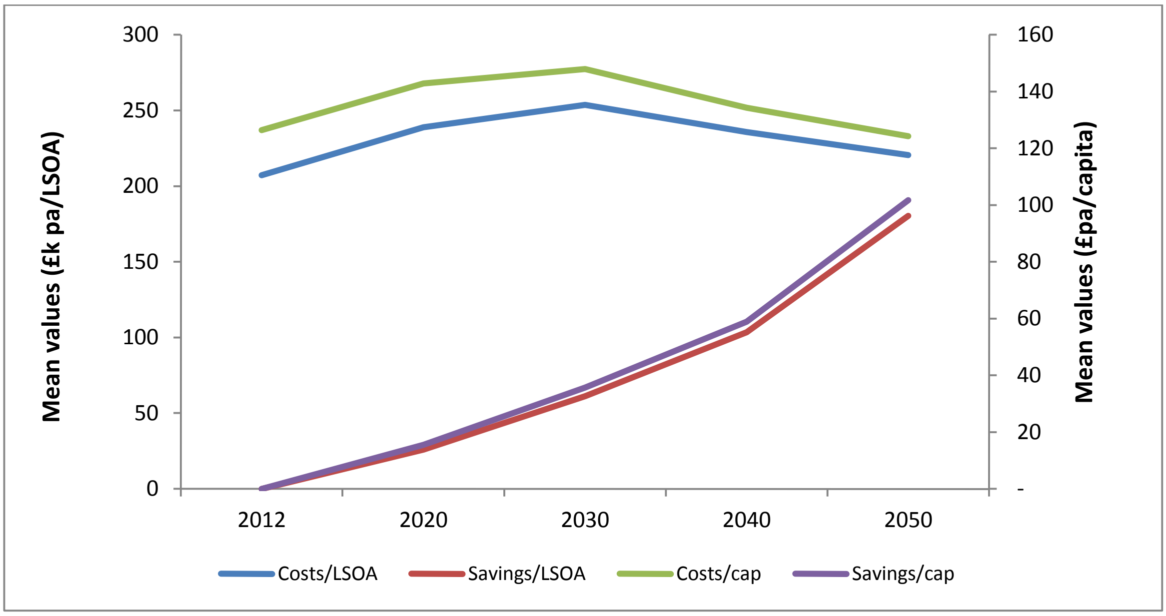


Figure 7.6a: Summary of economic impacts (£pa) by LSOA and per capita for scenario CE

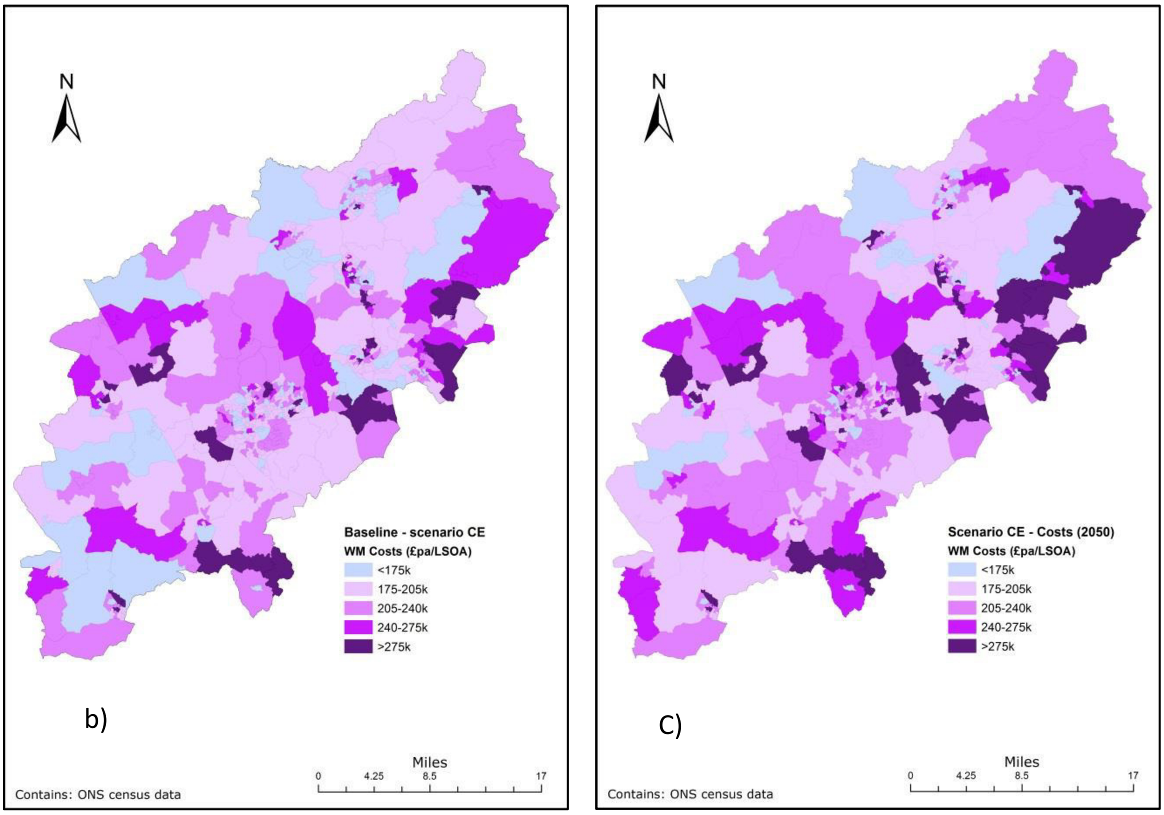


Figure 7.6b: Baseline costs (£kpa) by LSOA versus Figure 7.6c: scenario CE costs (£kpa) in 2050 for Northamptonshire

The spatial pattern of economic costs in both Figure 7.6b and 7.6c is stochastic. However, it is clear that a number of LSOAs have increased in value and moved into a new category (for example; the darker colours seen to the East of the county in Figure 7.6c). Figures 7.6d-e show the statistical changes between baseline and 2050 for LSOA costs under scenario CE.

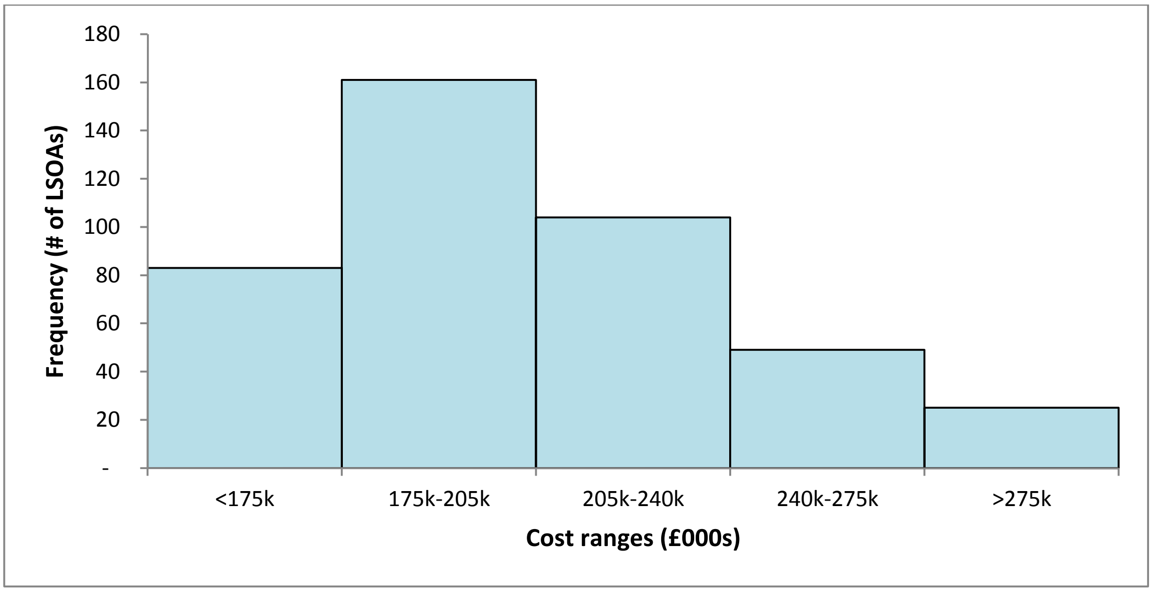


Figure 7.6d: Frequency distribution of LSOA baseline costs (£000s) under scenario CE

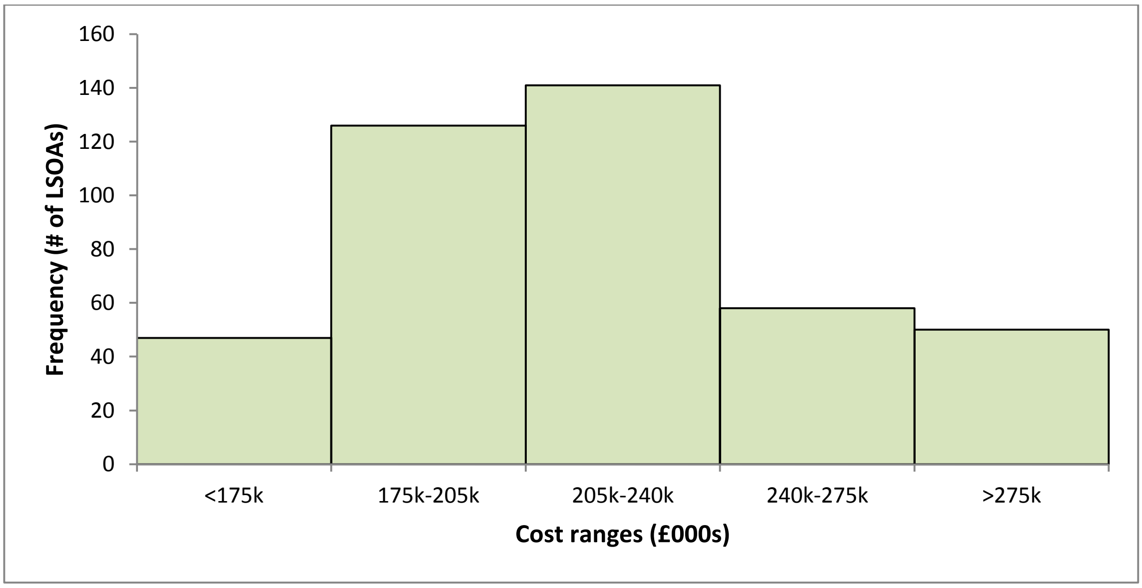


Figure 7.6e: Frequency distribution of LSOA costs (£000s) in 2050 for scenario CE

Comparing Figure 7.6d with 7.6e it can be seen that the number of LSOAs within the higher categories has increased markedly with a corresponding reduction in numbers within the lower value categories. For example; category >275k has increased from 25 to 50 LSOAs whereas category <175k has changed from 83 to 47 LSOAs.

7.2.1.2 Scenario VM

The evaluation of scenario VM is undertaken across Figures 7.7a-e with results described after each individual Figure. Figure 7.7a shows the economic impact of scenario VM over the period of the backast.

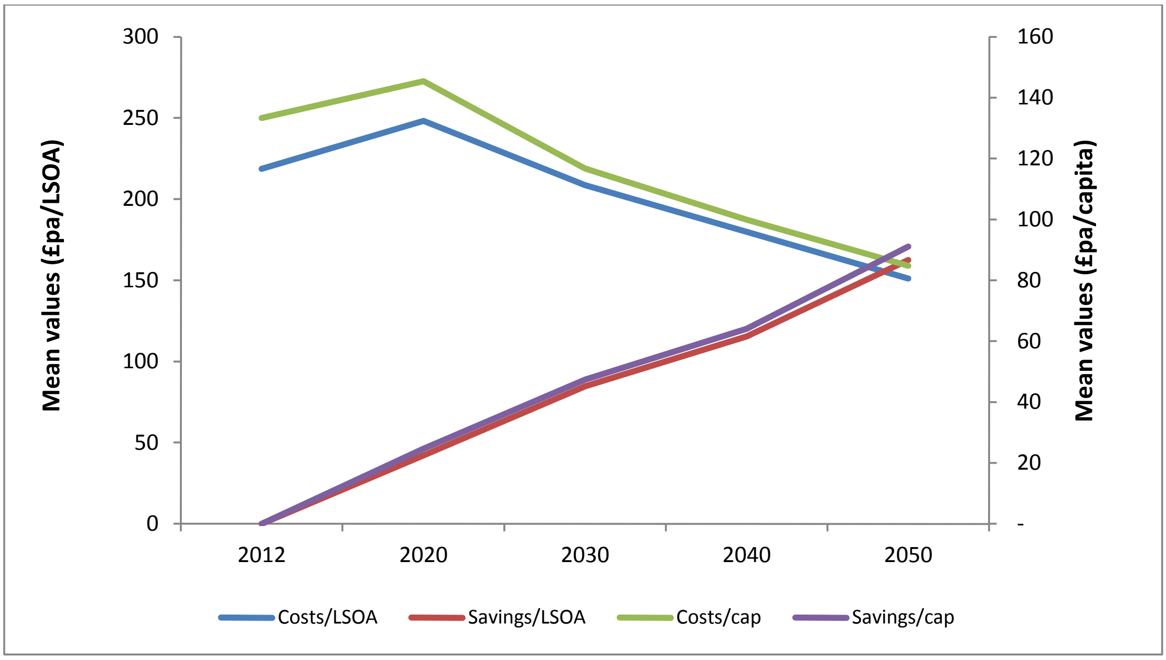


Figure 7.7a: Summary of economic impacts (£pa) by LSOA & per capita for scenario VM

Once again the strong correlation between LSOA and per capita values is seen in Figure 7.7a, although there is a greater variance between costs in the early period of the backcast as well as the beginning of a divergence between savings towards the end of the period. The cost profiles show an increase between 2012 and 2020 with a sustained linear decline after 2020 to the end of the period when both values are considerably below the baseline values. The savings profiles are closely matched until 2040 and exhibit an overall linear increase across the period. Figures 7.7b-c shows the spatial distribution of costs at the LSOA scale for the baseline and for 2050.

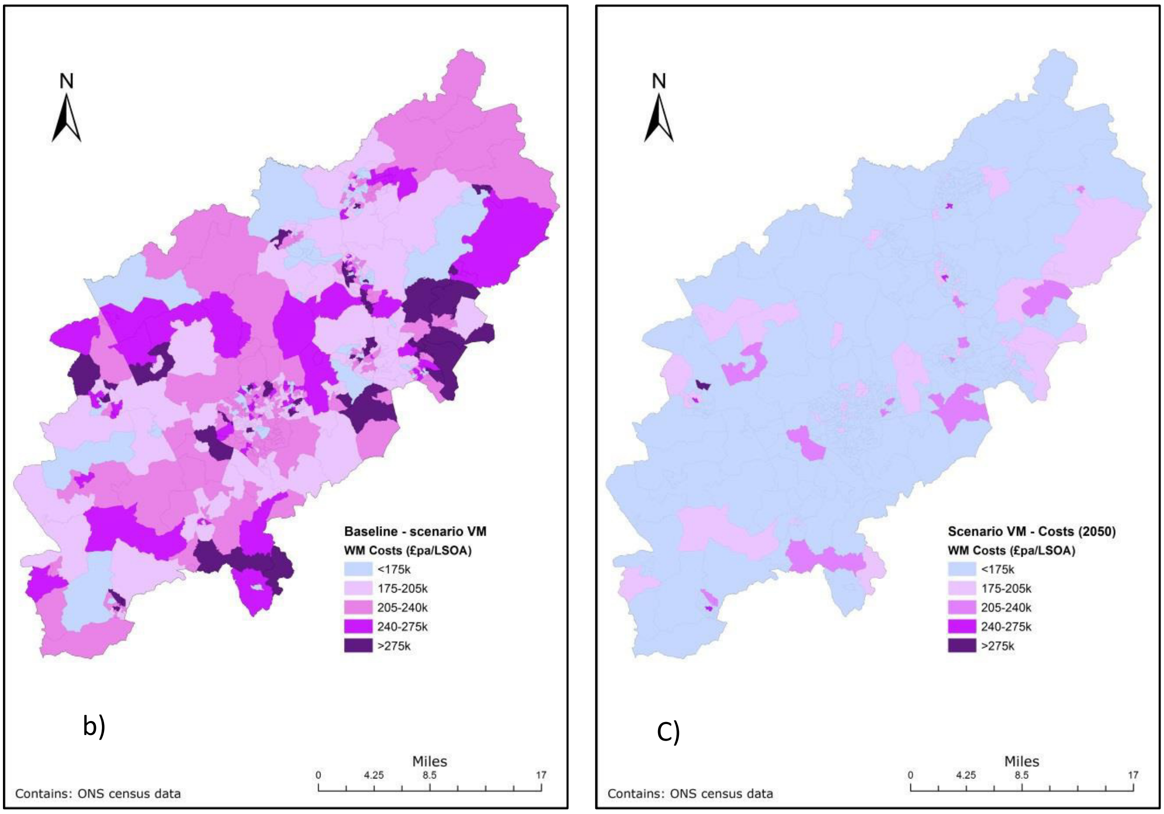


Figure 7.7b: Baseline costs (£kpa) by LSOA versus Figure 7.7c: scenario VM costs (£kpa) in 2050 for Northamptonshire

The most significant reductions in costs associated with the future WMS are witnessed under scenario VM (Figure 7.7c). The spatial pattern has gone from stochastic to almost uniform pattern as the majority of LSOAs have moved between categories with the bulk of LSOAs now classed as <175k.

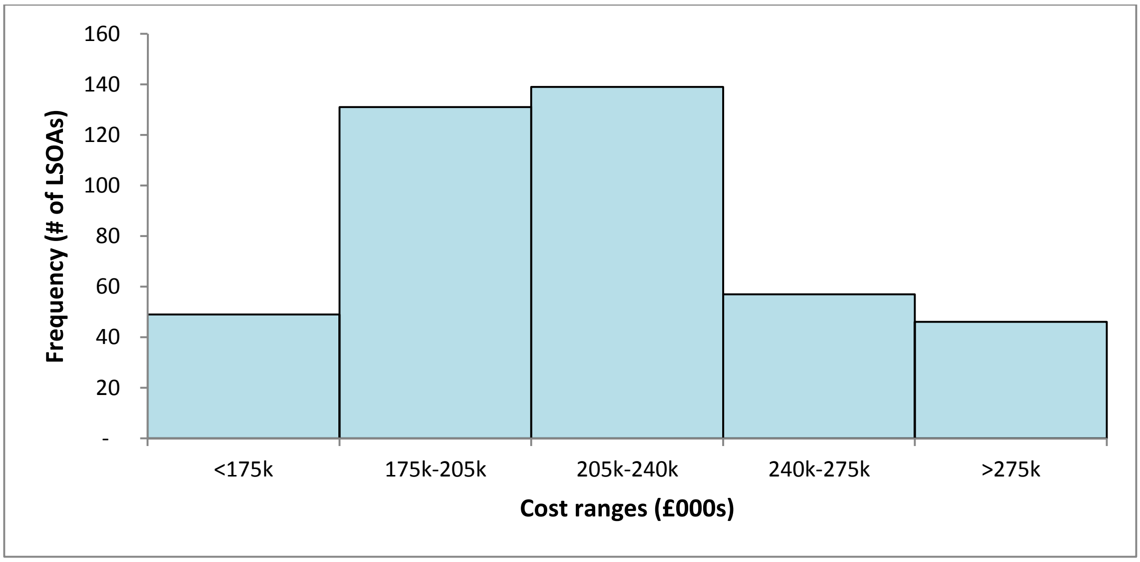


Figure 7.7d: Frequency distribution of LSOA baseline costs (£000s) under scenario VM

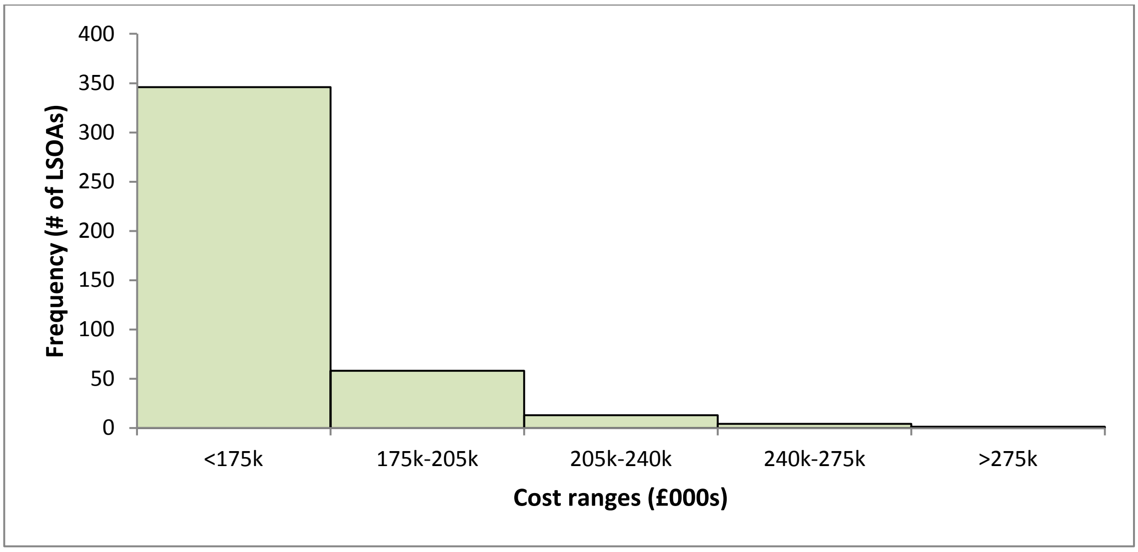


Figure 7.7e: Frequency distribution of LSOA costs (£000s) in 2050 for scenario VM

The shift in LSOAs to the category <175k is most clearly demonstrated in Figures 7.7d-e. This category has increased in LSOA count from 49 to 346 between baseline and 2050. In total, 95.7% of all LSOAs under scenario VM in 2050 have costs below £205k pa.

7.2.1.3 Scenario EC

The evaluation of scenario EC is undertaken across Figures 7.8a-e with results described after each individual Figure. Figure 7.8a shows the economic impact of scenario EC over the period of the backcast.

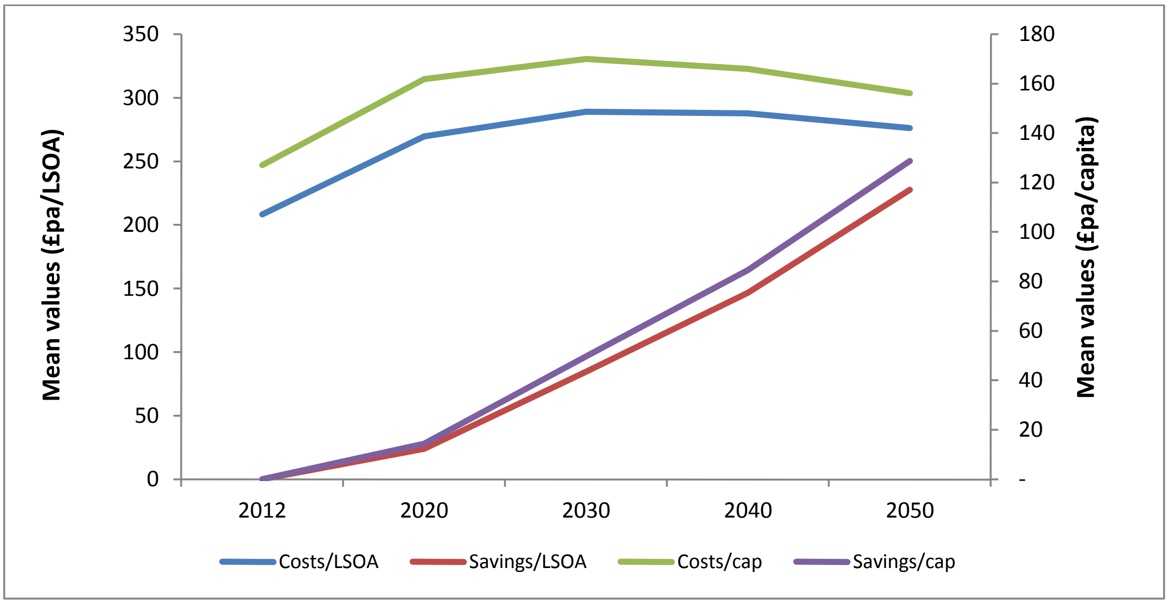


Figure 7.8a: Summary of economic impacts (£pa) by LSOA & per capita for scenario EC

Figure 7.8a shows the correlation between costs and savings at the LSOA and per capita levels. In terms of costs, scenario EC shows an upwards trend from 2012 to 2030. Costs per capita after 2030 slowly decline to 2050 but remain 23.0% higher than the baseline value (£156.18 in 2050/capita against £127.00/capita in 2012). At the LSOA level, costs marginally reduce from 2030 to 2050 (by £12.7k/LSOA) but remain significantly higher than the baseline (around £68k/LSOA). The profiles for savings at the LSOA and per capita levels display a significant linear increase throughout the period with a small divergence between per capita and LSOA from 2020 through to 2050. Figures 7.8b-c shows the spatial distribution of costs at the LSOA scale for the baseline and for 2050.

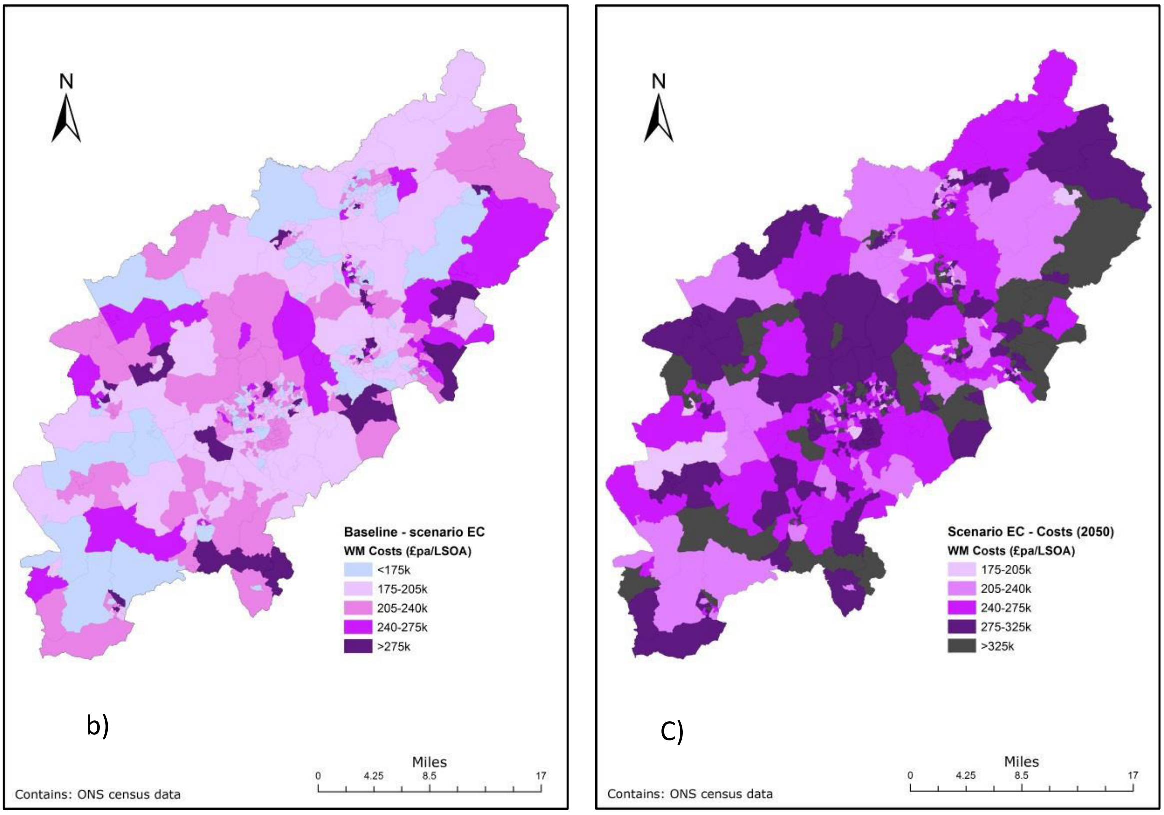


Figure 7.8b: Baseline costs (£kpa) by LSOA versus Figure 7.8c: scenario EC costs (£kpa) in 2050 for Northamptonshire

Figures 7.8b-c shows a large increase in costs between the baseline year (2012 - Figure 7.8b) and the future end point (2050 – Figure 7.8c) under scenario EC. Costs have increased to such an extent by 2050 that a new category is applied (>325k), with 72

LSOAs moving into this category. The spatial pattern remains stochastic albeit with a greater emphasis on the upper categories.

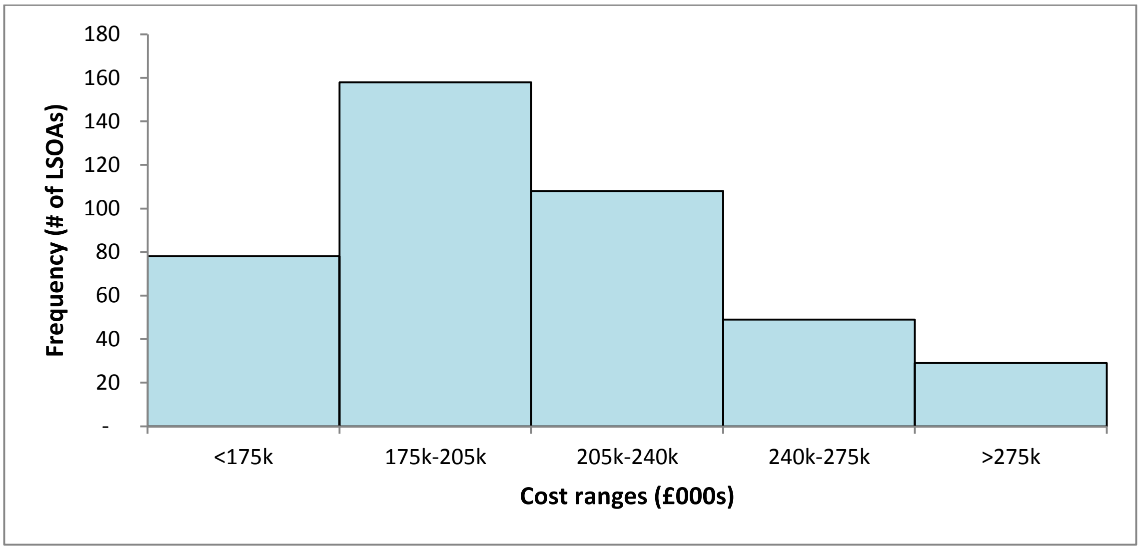


Figure 7.8d: Frequency distribution of LSOA baseline costs (£000s) under scenario EC

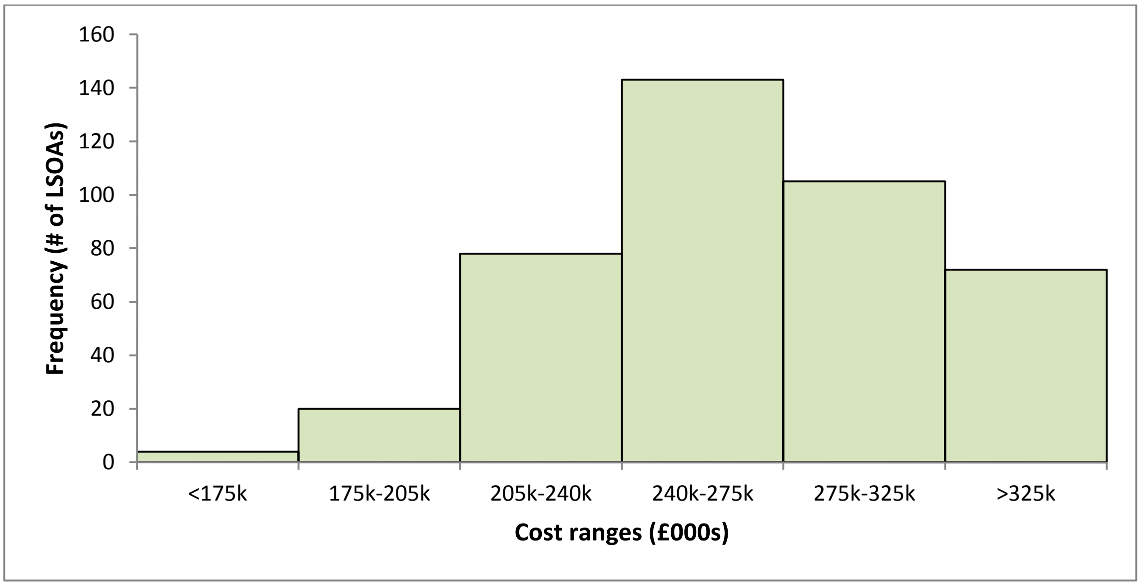


Figure 7.8e: Frequency distribution of LSOA costs (£000s) in 2050 for scenario EC

Comparing the baseline distribution (Figure 7.8d) with the distribution in 2050 (Figure 7.8e) shows a marked increase in costs/LSOA. Some 344 LSOAs were classified in the lowest 3 categories in 2012 whereas only 102 are in these categories by 2050. Coversely, 78 LSOAs were in the highest categories (240k-275k and >275k) in 2012 which by 2050 had become 320 LSOAs in the highest 3 categories.

7.2.1.4 Scenario ED

The evaluation of scenario ED is undertaken across Figures 7.9a-e with results described after each individual Figure. Figure 7.9a shows the economic impact of scenario ED.

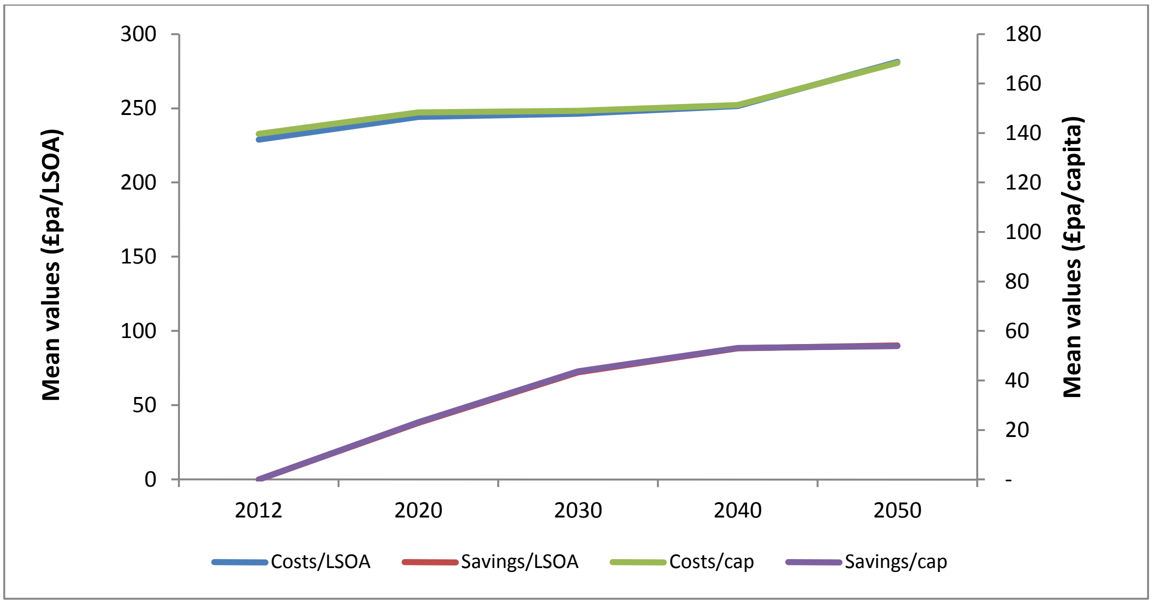


Figure 7.9a: Summary of economic impacts (£pa) by LSOA & per capita for scenario EC

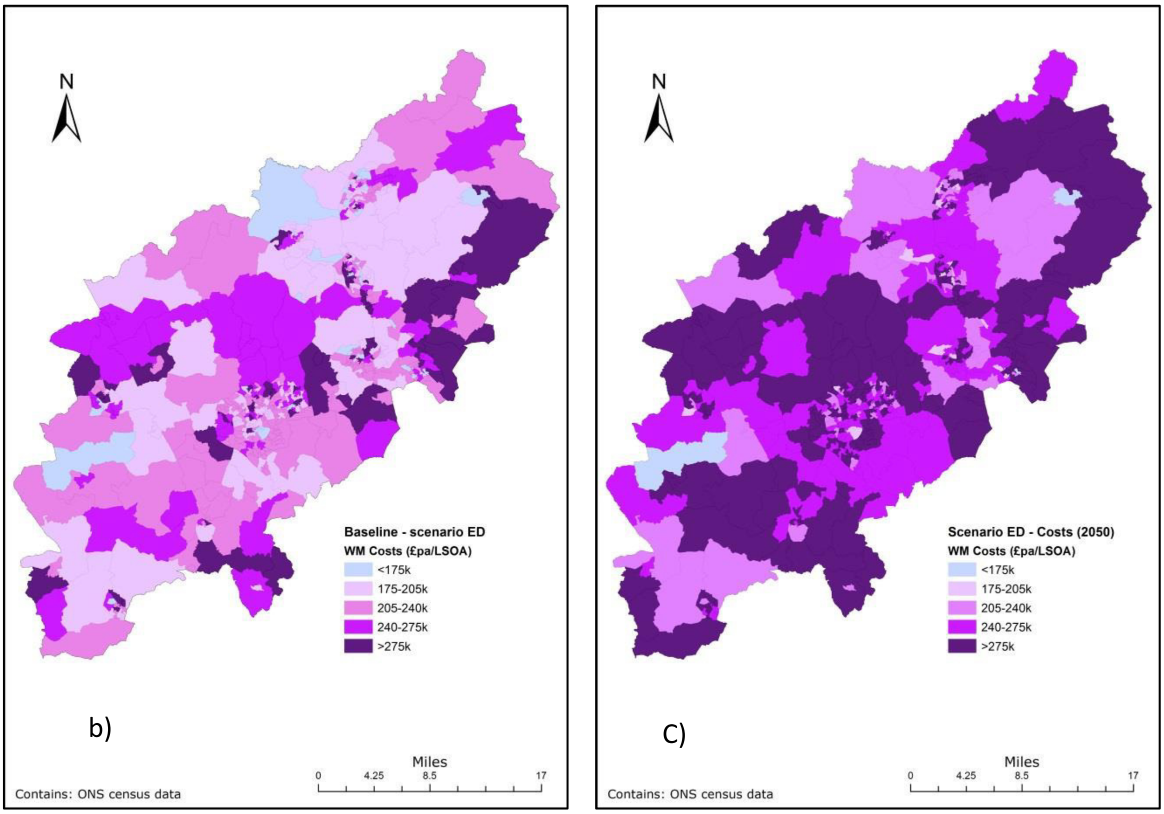


Figure 7.9b: Baseline costs (£kpa) by LSOA versus Figure 7.9c: scenario ED costs (£kpa) in 2050 for Northamptonshire.

Figure 7.9a shows the strongest correlation between profiles for LSOA and per capita costs as well as for LSOA and per capita savings. In terms of costs, these increase slowly across the period to 2040 before increasingly more significantly between 2040 and 2050. Levels by 2050 are higher than those from the baseline, which were the highest starting points of all four scenarios. Comparing the spatial pattern between baseline (Figure 7.9b) and end point (Figure 7.9c) shows a considerable increase in costs per LSOA (as a significant darkening of the colours) with the pattern becoming less stochastic.

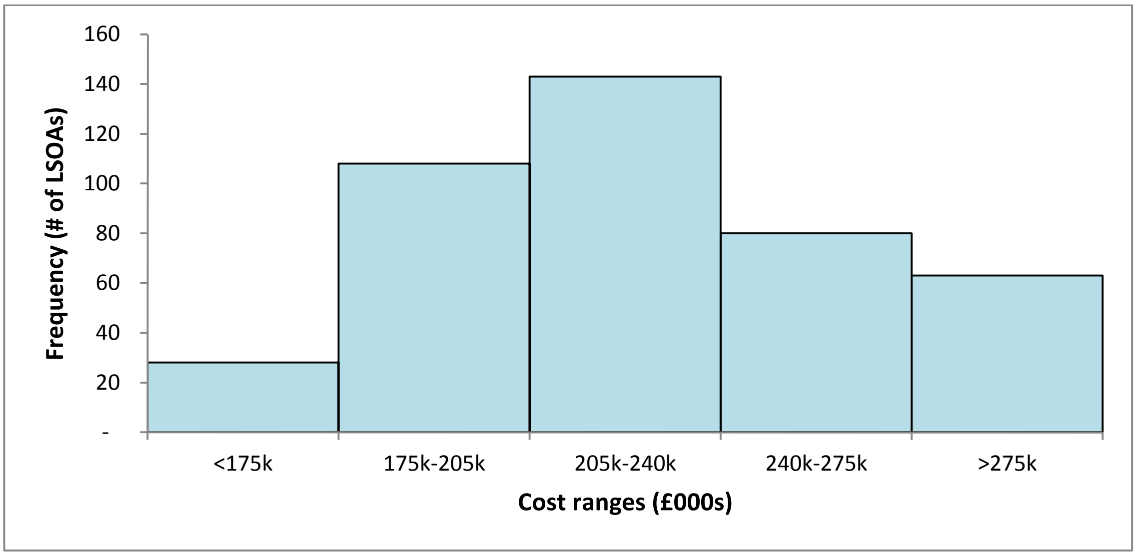


Figure 7.9d: Frequency distribution of LSOA baseline costs (£000s) under scenario ED

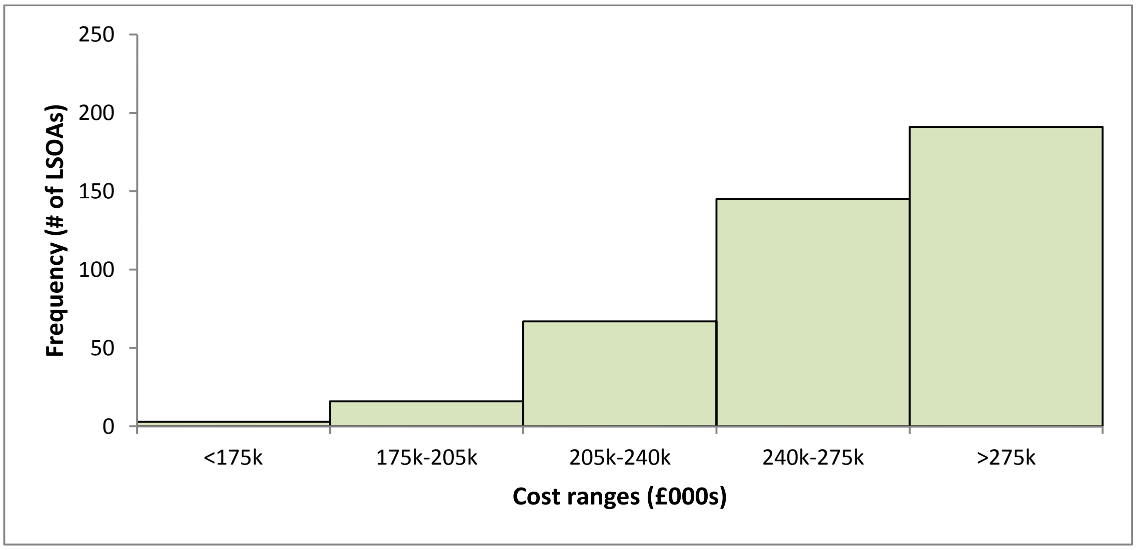


Figure 7.9e: Frequency distribution of LSOA costs (£000s) in 2050 for scenario ED

A comparison of the frequency distribution for LSOAs between the baseline (Figure 7.9d) and 2050 (Figure 7.9e) shows a considerable increase in costs under scenario ED. By 2050, some 336 LSOAs have moved into the highest two categories (240k-275k and >275k) compared with 143 in 2012. In contrast, only 86 LSOAs remain within the lower 3 categories in 2050 compared with 279 in 2012.

7.2.2 Comparison of savings across scenarios

A comparison of the savings across all scenarios is shown in Table 7.7 with overall savings (£m); mean savings per LSOA (£/LSOA); and mean per capita savings (£/capita).

Table 7.7: Comparison of savings across all scenarios for milestone years and future end point in Northamptonshire

Year	Scenario	Overall savings (£m)	Mean LSOA savings (£/LSOA)	Mean per capita savings (£/capita)
2020	CE	10.94	25,932	15.50
	VM	17.75	42,050	24.64
	EC	10.07	23,856	14.32
	ED	16.09	38,136	23.17
2030	CE	25.82	61,183	35.67
	VM	35.71	84,621	47.36
	EC	35.67	84,524	49.73
	ED	30.46	72,191	43.63
2040	CE	43.67	103,477	58.93
	VM	48.67	115,338	64.04
	EC	61.91	146,713	84.61
	ED	37.29	88,377	53.15
2050	CE	76.12	180,389	101.72
	VM	68.56	162,458	91.12
	EC	96.12	227,768	128.75
	ED	38.05	90,158	53.95

With regards to savings, both LSOA and per capita savings have increased across the backcast period (Table 7.7). Savings at the LSOA level peak at £90kpa in 2050. By the end of the period per capita saving reach £53.85pa. The level of potential savings for each scenario are directly related to: amount of wastes directly avoided (through prevention initiatives and reuse); indirectly (changes to systems variables); and through diversion from landfill (e.g. recycling and recovery operations). Table 7.7 also shows considerable variation in performance across scenarios during the backcast period. In 2050, savings are greatest under scenario EC followed by scenario CE, VM and ED. However, these position change in each of the milestone years. For 2020, savings are most significant under scenario VM followed by ED, CE, and EC. By 2030, VM has the highest overall and mean LSOA savings with EC having the highest mean per capita savings and is second for overall and man LSOA savings. Scenarios ED and CE are third and fourth for all savings performance respectively in 2030. In 2040, the situation has once again changed, with EC being the highest performer across savings categories followed by VM, CE and ED.

In order to compare overall savings, these are presented in Figure 7.10a-d (e.g. a=CE; b=VM; c=EC; and d=ED) for the end point of the backcast period (2050) with overlay maps for milestone years shown in Appendix 12. Figure 7.10a-d show savings performance at the LSOA level with 7 categories provided to illustrate the differences in performance; these categories are: 50-70k; 70-100k; 100-125k; 125-150k; 150-200k; 200-250k; and >250k. Given the variation in savings and the 7 categories direct comparison is more difficult than for cost savings. However, using the colour scheme (darker colours represent higher savings) shows that scenario EC (Figure 7.10c) has the most significant savings at eh LSOA level. This compares starkly with scenario ED (Figure 7.10d) which has the least savings at the LSOA level. The contrast between scenarios CE (Figure 7.10a) and scenario VM (Figure 7.10b) is less stark. It is possible to determine that scenario CE outperforms VM through the more uniform dark colouring (showing 150-200k savings/LSOA) as well as the presence of the highest category (>250k) and the absence of the 70-100k category seen in Figure 7.10b.

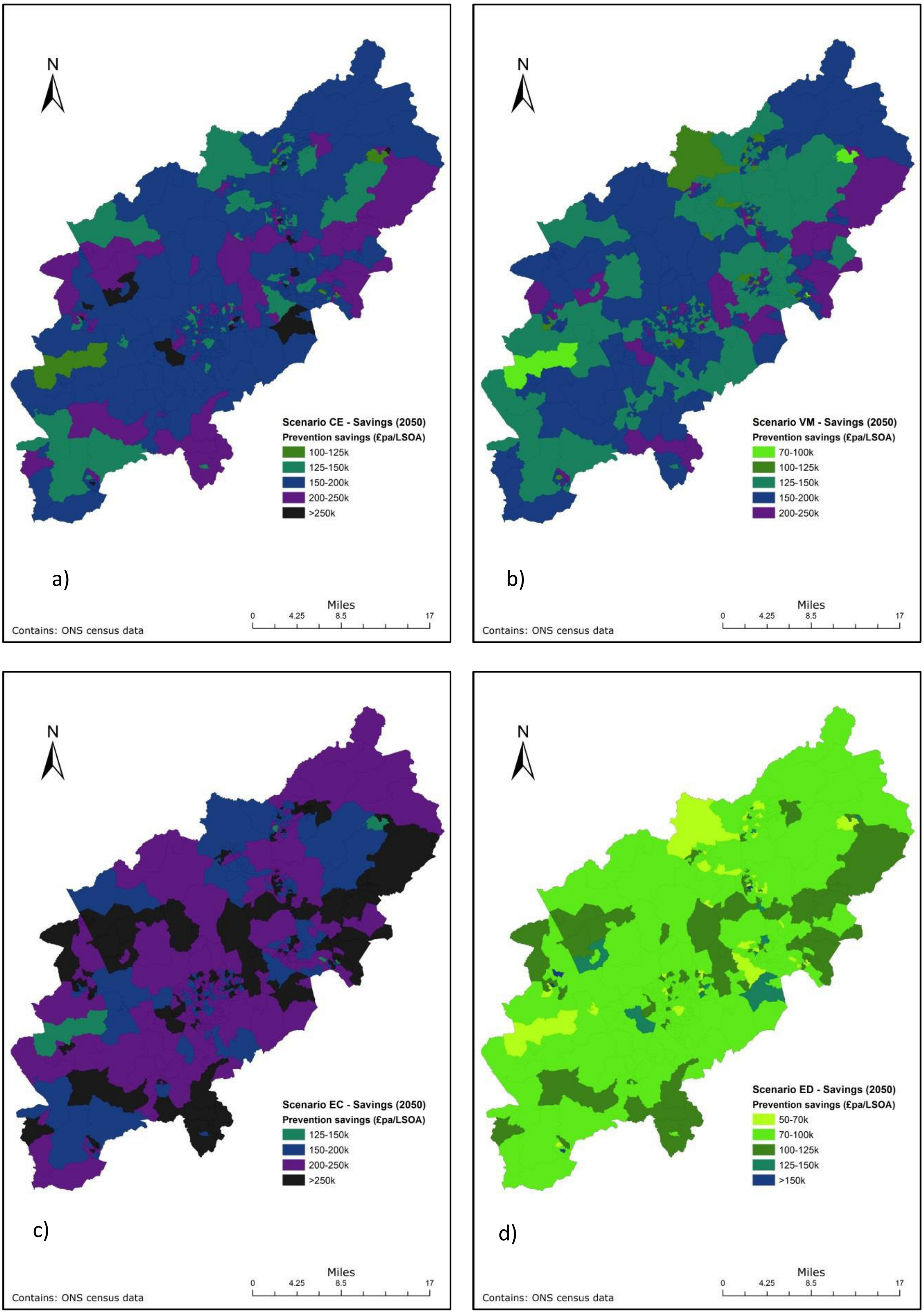


Figure 7.10a-d: Savings (£k) by LSOA for all scenarios (a – CE; b – VM; c – EC; and d - ED) in Northamptonshire (2050).

The difference between LSOA performances across scenarios can also be visualised by means of frequency distributions, shown in Figure 7.11.

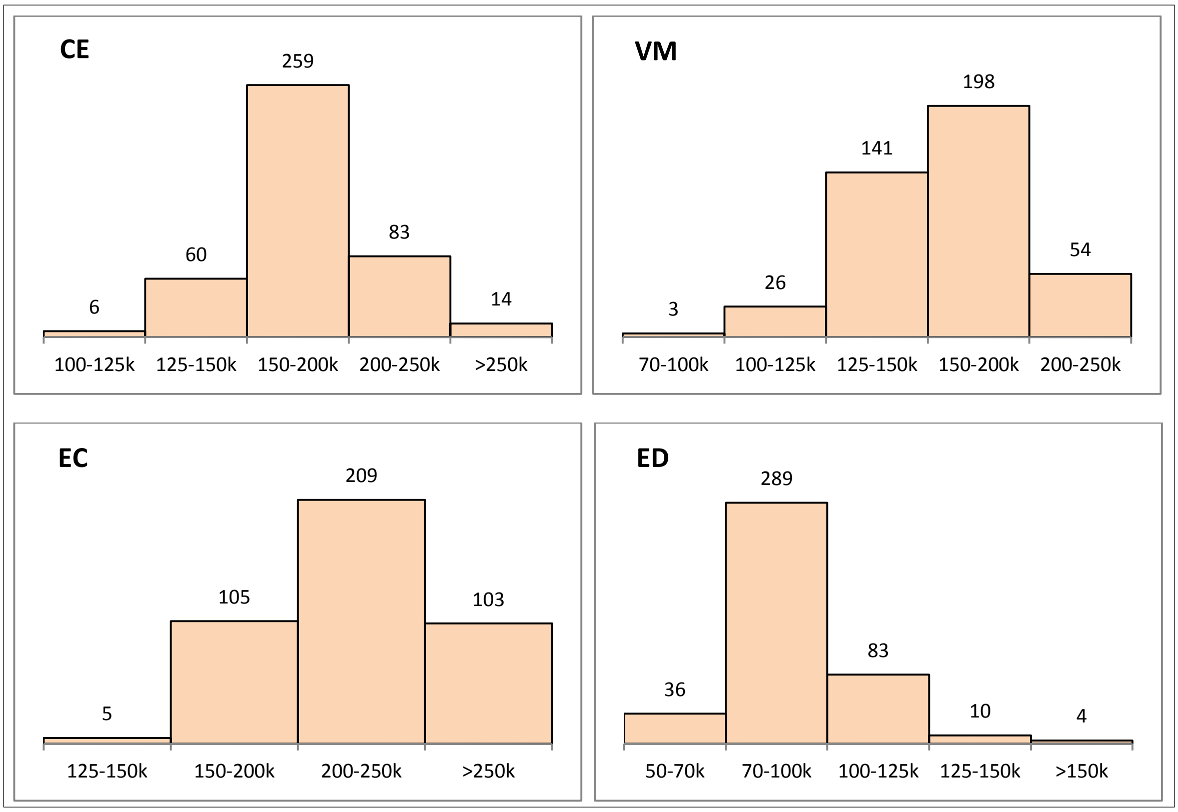


Figure 7.11: Frequency distribution of savings (£000s) by LSOA under all scenarios for Northamptonshire in 2050.

Figure 7.11 shows the relative performance of each scenario for LSOA savings by means of the distribution of LSOA numbers across the 7 savings categories. Using the category 150-200k as the assessment point scenario EC has 417 LSOAs within or above this level. This compares with 356 for CE; 252 for VM; and only 4 LSOAs in scenario ED.

7.3 Spatial distribution of carbon impacts

The third metric chosen for impact assessment of policy packages within each scenario was carbon (as tCO_2e). Table 7.8 provides a summary of carbon emissions (from waste management operations); prevented emissions (avoided); and emissions densities (as tCO_2e/ha).

Table 7.8: Summary of carbon emissions; prevented emissions (tCO_2e); and emissions density (tCO_2/ha) for the backcast period across all scenarios in Northamptonshire

Year	Scenario	Emissions (avoided - direct) (tCO_2e)	Prevented emissions (tCO_2e)	Emissions density (tCO_2/ha)
2012	Baseline	1,534,827	-	66.7
2020	CE	1,635,899	249,460	71.1
	VM	1,732,462	186,254	75.3
	EC	1,658,370	166,651	72.1
	ED	1,696,063	26,712	73.8
2030	CE	1,720,305	474,457	74.8
	VM	1,871,114	435,045	81.4
	EC	1,902,133	409,452	82.7
	ED	1,927,201	-92,852	83.8
2040	CE	1,761,436	830,797	76.6
	VM	1,913,158	765,424	83.2
	EC	1,998,661	882,511	86.9
	ED	2,056,211	-210,045	89.4
2050	CE	1,869,865	1,188,690	81.3
	VM	2,036,514	952,396	88.6
	EC	2,148,692	1,215,354	93.4
	ED	2,084,260	-360,569	90.6

Table 7.8 shows emissions from waste operations as 1.53MtCO_2e in 2012 with all four scenarios showing an overall increase of avoided emissions (e.g. direct emissions from waste facility operations and avoided emissions as savings versus landfill disposal). Overall emissions performance by 2050 shows that scenario CE has the lowest value (1.87MtCO_2e) followed by scenarios VM (2.04MtCO_2e); ED (2.08MtCO_2e); and EC (2.15MtCO_2e). In terms of prevented emissions; associated with direct avoidance (from prevention and reuse); and indirect avoidance/accruing (from system variables changes); scenarios EC, CE and VM see large prevention values. In contrast, scenario ED has accrued additional emissions through little impact from prevention and reuse initiatives but in the main due to the impact of systems variables changes (see section 5.3.2). The final measure of performance; emissions density (as tCO_2e/ha); has implications for assessing the type and locations of infrastructure within each scenario (see section 7.2). Table 7.8

shows baseline emissions density as 66.7tCO_2/ha, by 2050 all scenarios show an increase over the baseline with scenario CE showing the lowest level of increase (21.9%) from 66.7 to 81.3tCO_2/ha. Scenario EC has the highest increase over the period to 93.4tCO_2/ha.

7.3.1 Carbon impact mapping by scenario

In order to determine the spatial distribution of carbon emissions it is first necessary to calculate the mean emissions based on overall emissions levels (Table 7.8). A summary by LSOA and per capita values is shown in Table 7.9.

Table 7.9: Summary of LSOA and per capita emissions and prevention calculations (tCO_2e) for all scenarios across the backast period (2012-2050) in Northamptonshire

Year	Scenario	Mean emissions (tCO_2e/LSOA)	Mean prevention (tCO_2e/LSOA)	Per capita emissions (tCO_2e)	Per capita prevention (tCO_2e)
2012	Baseline	3,637	-	2.22	-
2020	CE	3,877	591	2.32	0.35
	VM	4,105	441	2.41	0.26
	EC	3,930	395	2.36	0.24
	ED	4,019	63	2.44	0.04
2030	CE	4,077	1,124	2.38	0.66
	VM	4,434	1,031	2.48	0.58
	EC	4,507	970	2.65	0.57
	ED	4,567	-220	2.76	-0.13
2040	CE	4,174	1,969	2.38	1.12
	VM	4,534	1,814	2.52	1.01
	EC	4,736	2,091	2.73	1.21
	ED	4,873	-498	2.93	-0.30
2050	CE	4,431	2,817	2.50	1.59
	VM	4,826	2,257	2.71	1.27
	EC	5,092	2,880	2.88	1.63
	ED	4,939	-854	2.96	-0.51

Table 7.9 shows mean emissions have increased above the baseline value (3,637tCO_2e) within a range from 794tCO_2e (CE) to 1,455tCO_2e (EC). Per capita emissions have increased in percentage terms by between 12.6% (2.50tCO_2e/capita for CE) and 33.3% (2.96tCO_2e/capita for ED).

7.3.1.1 Scenario CE

Carbon emissions impacts for scenario CE are assessed through Figures 7.12a-e. The emissions and prevention impacts under scenario CE are shown in Figure 7.12a.

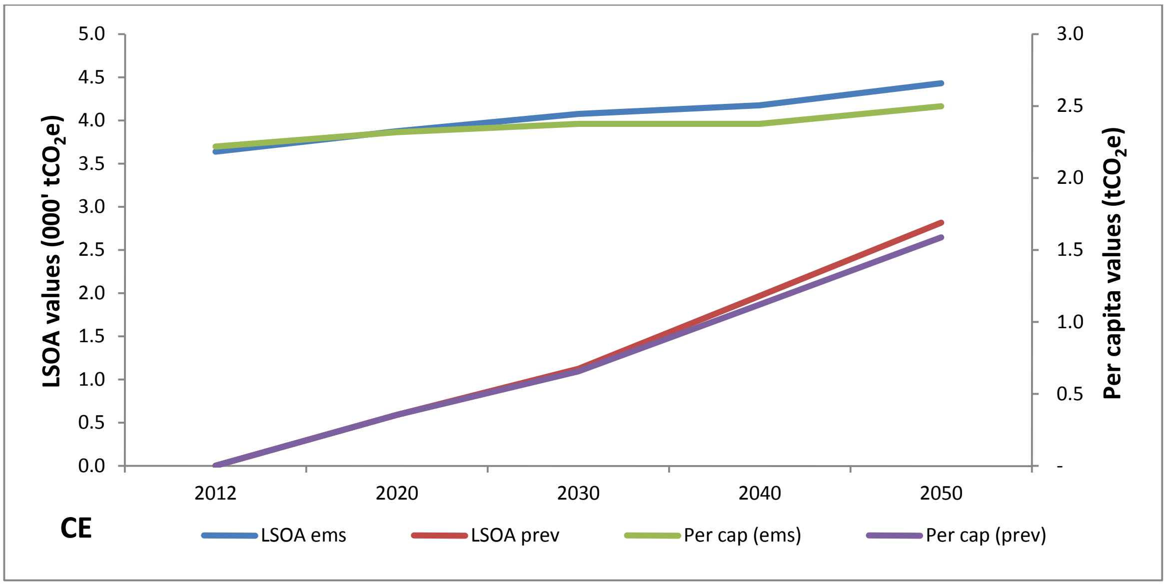


Figure 7.12a: Summary of carbon emissions and prevention impacts (tCO_2e) by LSOA & per capita for scenario CE.

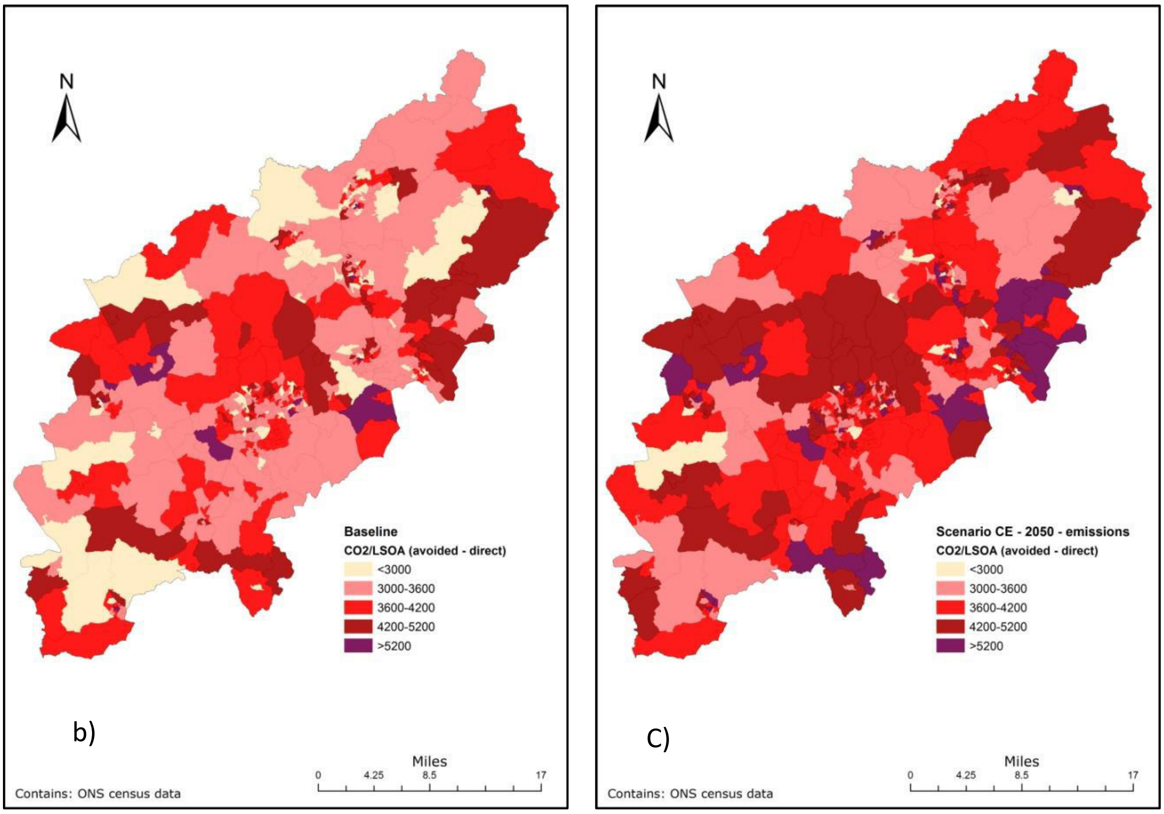


Figure 7.12b: Baseline emissions (tCO_2e) by LSOA versus Figure 7.12c: scenario CE emissions (tCO_2e) by LSOA in 2050 for Northamptonshire.

The profiles of LSOA and per capita carbon emissions under scenario CE in Figure 7.12a show a small increase across the backcast period (2012-2050). In contrast, the profiles for LSOA and per capita prevention show linear increases of greater magnitude with a more pronounced increase from 2030 as well as a small divergence between LSOA and per capita profiles. In terms of emissions scenario CE has the lowest levels of all scenarios and the second highest levels of prevention (see Table 7.8). Figures 7.12b-c shows the difference in spatial distribution of carbon emissions under scenario CE between the baseline and 2050. The spatial pattern of baseline carbon emissions (Figure 7.12b) is somewhat random and remains stochastic in 2050 for scenario CE (Figure 7.12c). Increase in emissions values for LSOAs are generalised and occur in both rural and urban LSOAs.

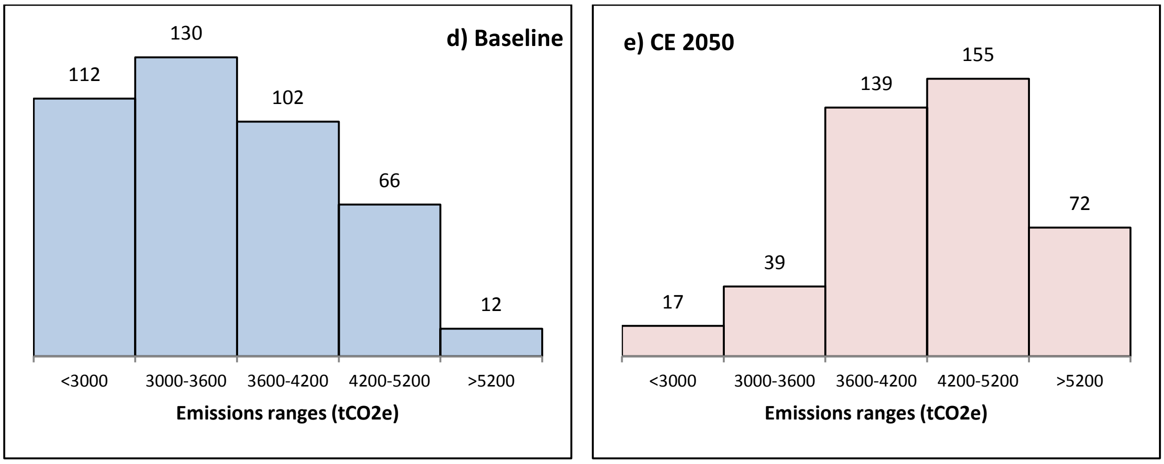


Figure 7.12d: Baseline distribution of emissions (tCO_2e) by LSOA versus Figure 7.12e: Distribution of emissions (tCO_2e) under scenario CE for Northamptonshire in 2050.

In terms of the frequency distribution of emissions between LSOAs the change between the baseline and 2050 is shown in Figures 7.12d & 7.12e. Under scenario CE by 2050 there has been a major shift from the lower categories towards the highest. For example; 242 LSOAs had emissions levels in the categories <3000 & 3000-3600 whereas in 2050 only 56 LSOAs were in these categories. Conversely, 78 LSOAs were in the two highest categories in the baseline year compared with 227 LSOAs in 2050.

7.3.1.2 Scenario VM

Carbon emissions impacts for scenario VM are assessed through Figures 7.13a-e. The emissions and prevention impacts under scenario VM are shown in Figure 7.13a.

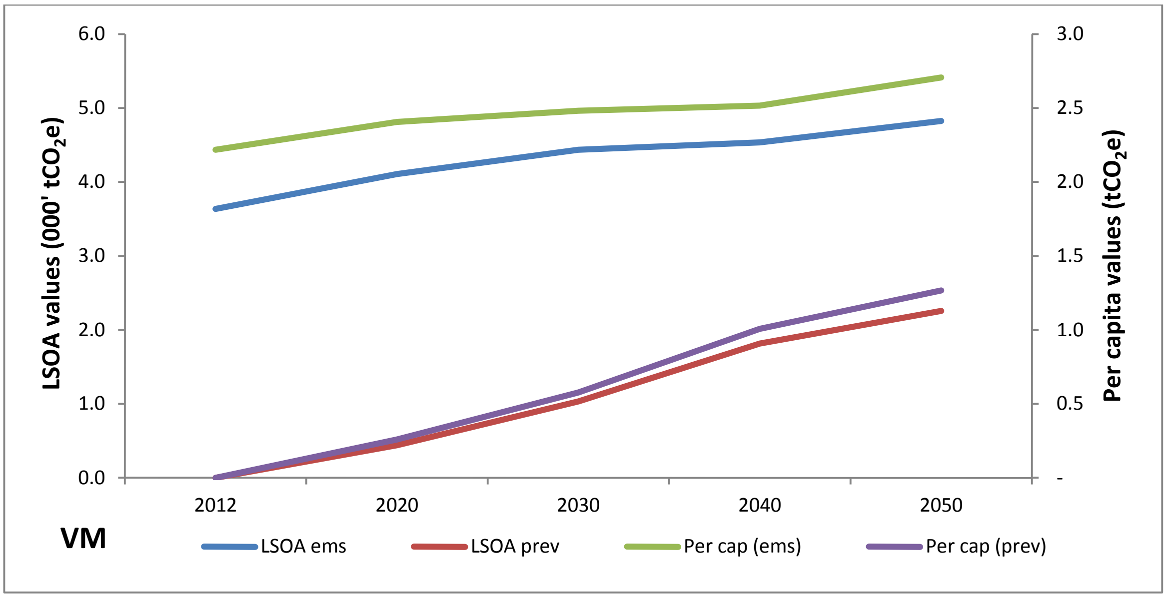


Figure 7.13a: Summary of carbon emissions and prevention impacts (tCO_2e) by LSOA & per capita for scenario VM.

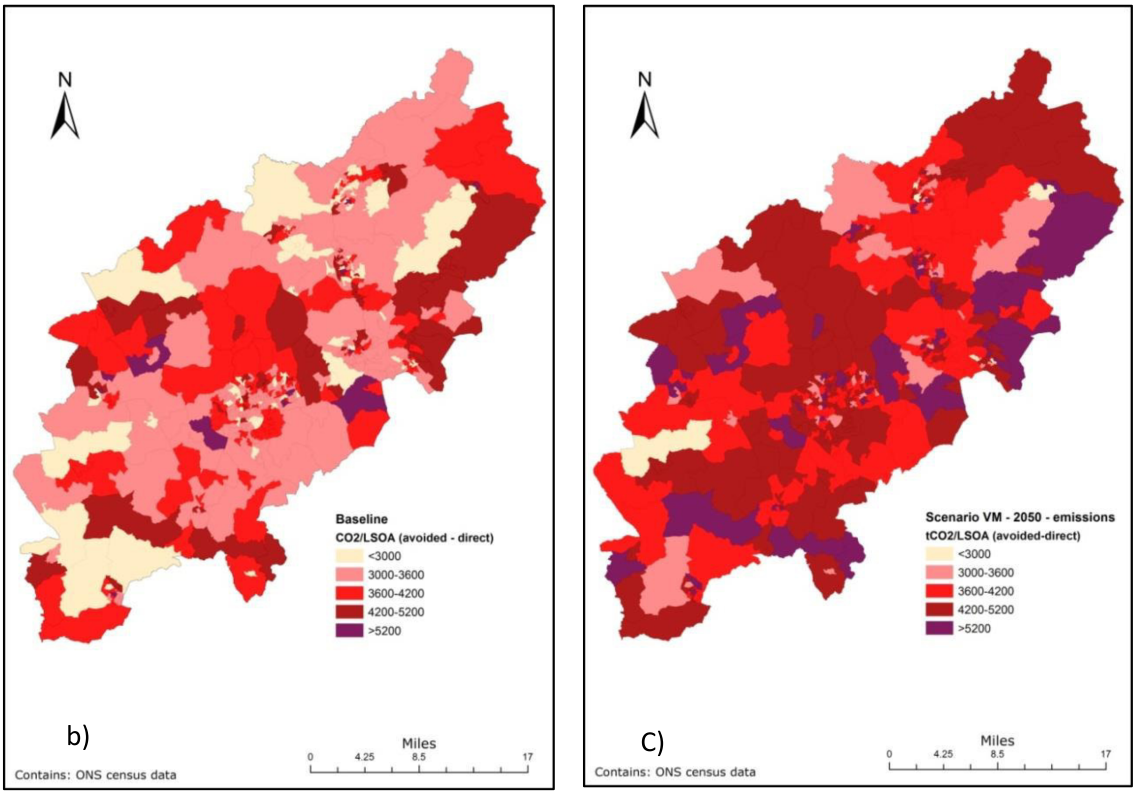


Figure 7.13b: Baseline emissions (tCO_2e) by LSOA versus Figure 7.12c: scenario VM emissions (tCO_2e) by LSOA in 2050 for Northamptonshire

The profiles for LSOA and per capita emissions show steeper increase than seen with scenario CE. Profiles for prevention show shallow increases when compared with scenario CE. Both sets of profiles show relatively strong positive correlations with some divergence towards the end of the period for prevention. Figures 7.13b-c shows the difference in spatial distribution of carbon emissions under scenario VM between the baseline and 2050. The spatial pattern in 2050 for scenario VM is stochastic (Figure 7.13c) but shows signs of uniformity compared with the baseline (Figure 7.13b) and with scenario CE as greater numbers of LSOAs have increased their emissions levels than seen under scenario CE in 2050.

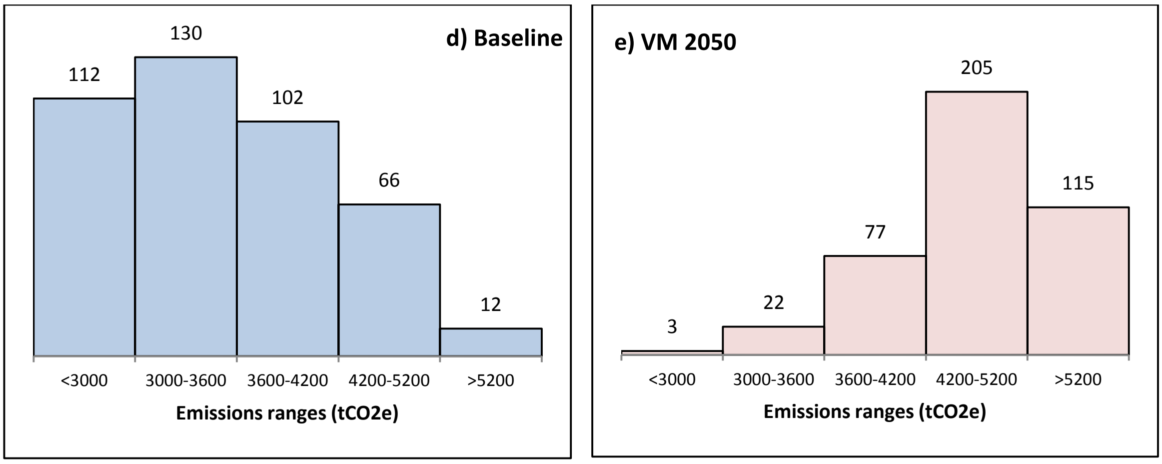


Figure 7.13d: Baseline distribution of emissions (tCO_2e) by LSOA versus Figure 7.13e: Distribution of emissions (tCO_2e) under scenario VM for Northamptonshire in 2050.

The frequency distribution of LSOAs under the five emissions ranges once again shows a marked change over the baseline (Figure 7.13d) when scenario VM is considered. Under scenario VM in 2050 (Figure 7.13e) only 25 LSOAs remain in the bottom two ranges compared with 242 at the baseline. In addition, the shift to the highest ranges is more significant with 320 LSOAs in the top two ranges compared with the 78 LSOAs under baseline conditions.

7.3.1.3 Scenario EC

Carbon emissions impacts for scenario EC are assessed through Figures 7.14a-e. The emissions and prevention impacts are shown in Figure 7.14a.

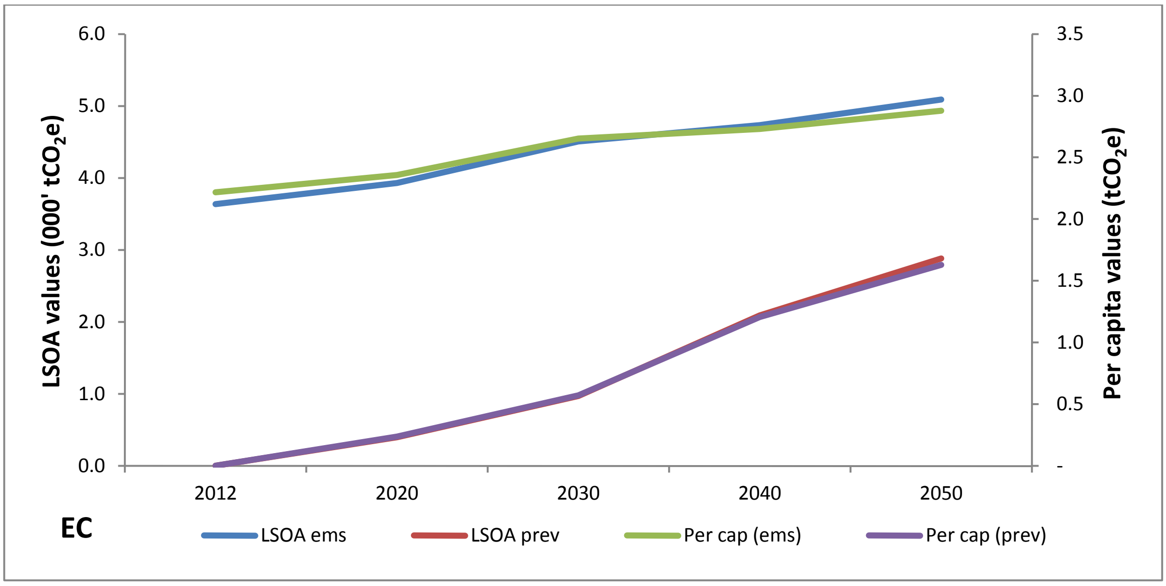
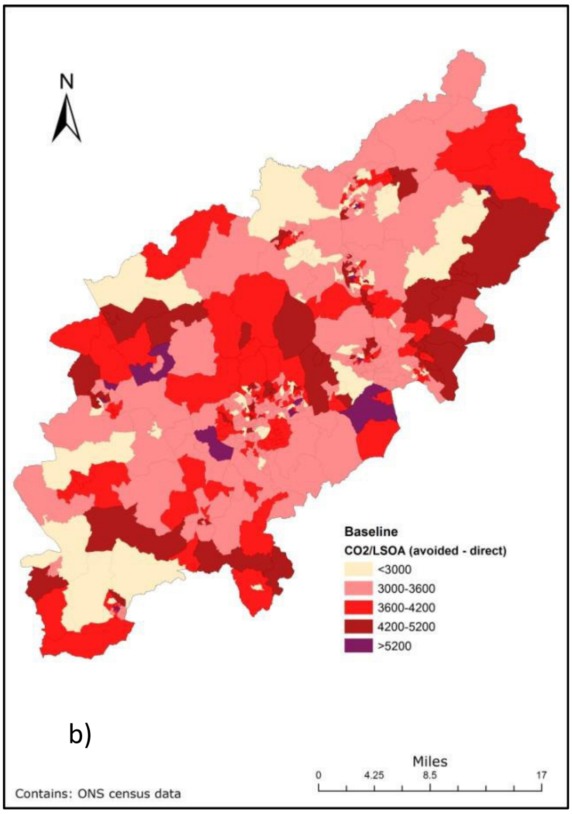


Figure 7.14a: Summary of carbon emissions and prevention impacts (tCO_2e) by LSOA & per capita for scenario EC.



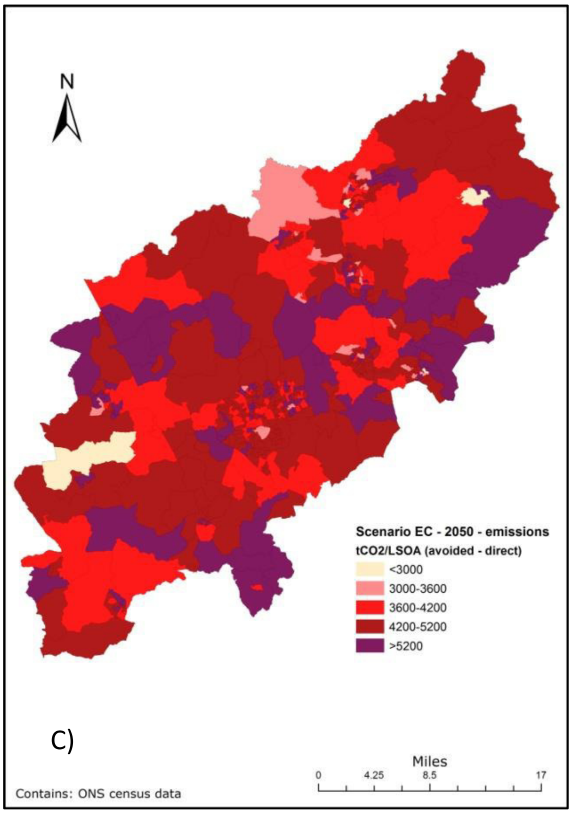
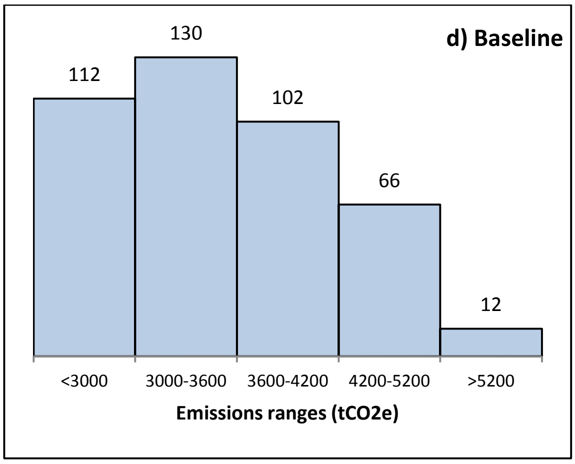


Figure 7.14b: Baseline emissions (tCO_2e) by LSOA versus Figure 7.12c: scenario EC emissions (tCO_2e) by LSOA in 2050 for Northamptonshire.

The profiles for LSOA and per capita emissions (Figure 7.14a) show a similar rate of increase seen with scenario VM but the level of positive correlation is stronger under scenario EC. Profiles for prevention are very closely matched with those of scenario VM but reach higher absolute values by 2050 (5,092tCO_2e LSOA emissions and 2.88tCO_2e per capita emissions). Figures 7.14b-c shows the difference in spatial distribution of carbon emissions under scenario EC between the baseline and 2050. Scenario EC has the highest overall and mean emissions per LSOA of all scenarios. The spatial pattern for scenario EC in 2050 (Figure 7.14c) is more uniform than that of scenario VM with large swathes of the study area showing the darkest colours (highest values). Indeed, when compared with the baseline (Figure 7.14b) the constituent LSOAs seem almost fully transformed.



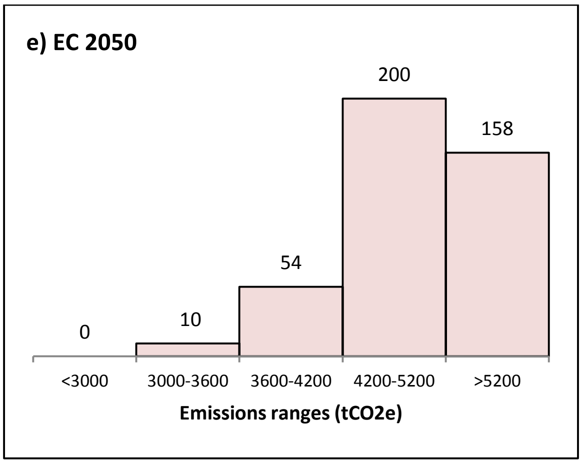


Figure 7.14d: Baseline distribution of emissions (tCO_2e) by LSOA versus Figure 7.14e: Distribution of emissions (tCO_2e) under scenario EC for Northamptonshire in 2050.

The frequency distribution of LSOAs under the five emissions ranges shows the greatest change of any scenario over the baseline (Figure 7.14d) when scenario EC is considered. By 2050, scenario EC (Figure 7.14e) has 10 LSOAs within the two lowest emission ranges compared with 242 in the baseline assessment. In contrast, the two upper ranges contain 358 LSOAs (84.8% of the total number – n=422) compared with 78 (18.5%) under the baseline.

7.3.1.4 Scenario ED

Carbon emissions impacts for scenario ED are assessed through Figures 7.15a-e. The emissions and prevention impacts are shown in Figure 7.15a.

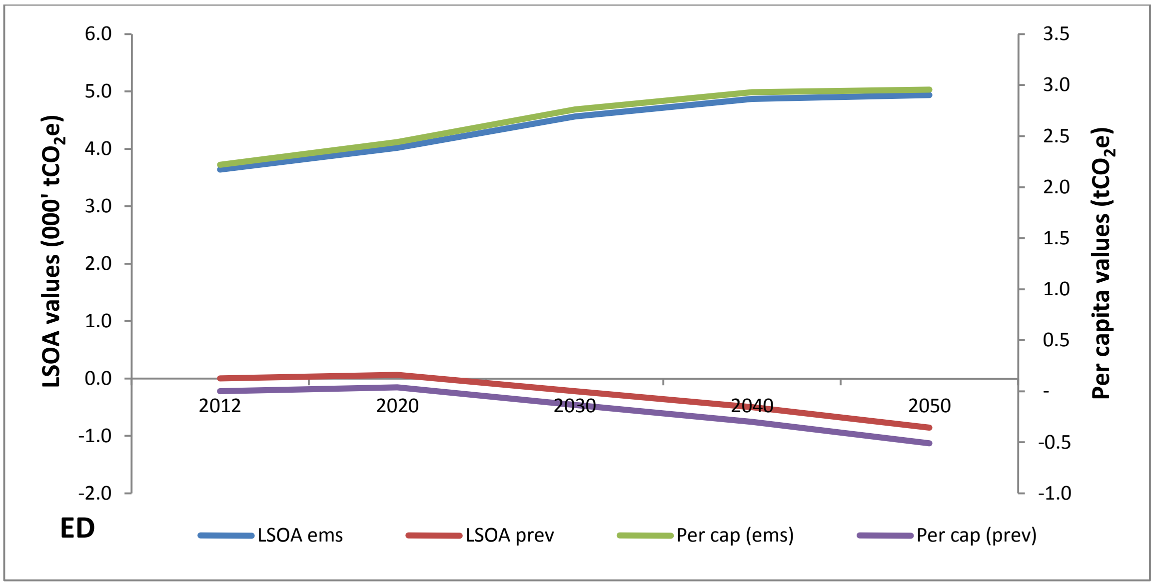


Figure 7.15a: Summary of carbon emissions and prevention impacts (tCO_2e) by LSOA & per capita for scenario ED.

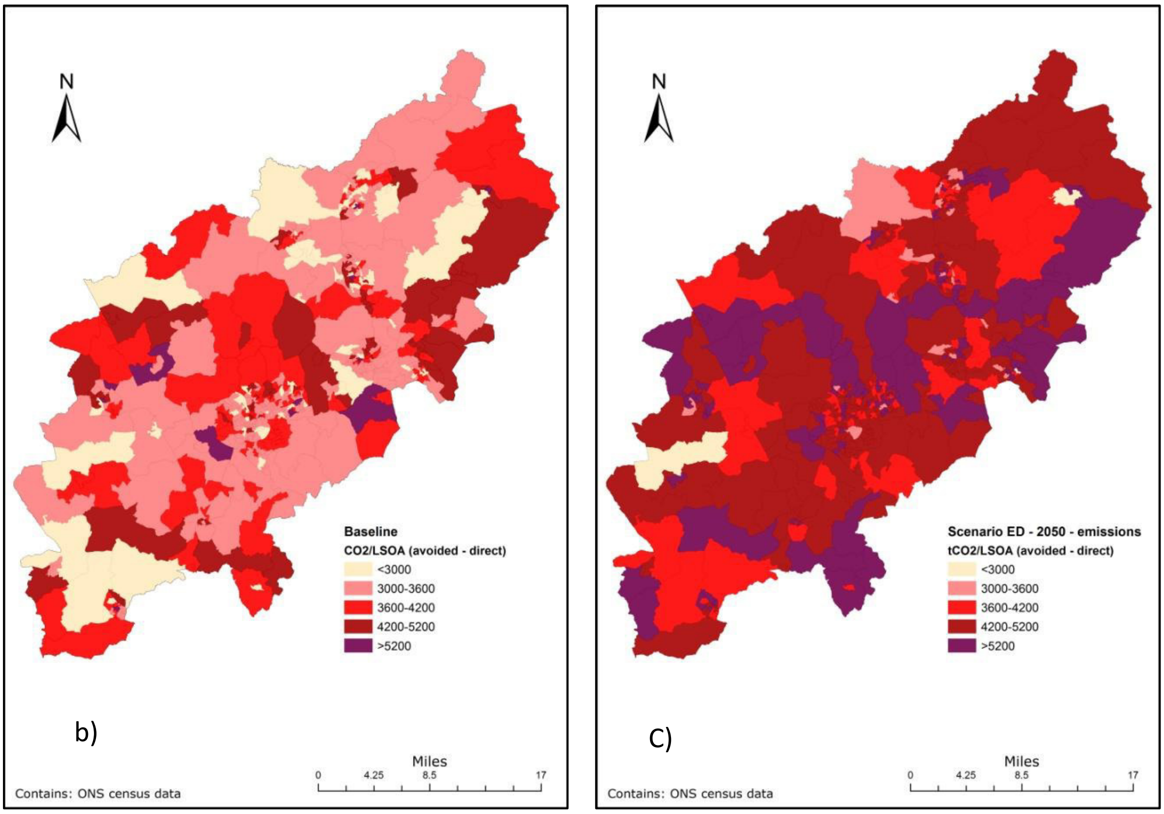


Figure 7.15b: Baseline emissions (tCO_2e) by LSOA versus Figure 7.12c: scenario EC emissions (tCO_2e) by LSOA in 2050 for Northamptonshire.

The profiles for LSOA and per capita emissions (Figure 7.15a) are closely matched with scenario EC, although there is a period of plateauing between 204 and 2050 rather than an increase in emissions values under EC. Prevention profiles actually show a negative value and thus represent an additional increase in emissions associated with changes to systems variables (e.g. population and reductions in landfill tax). Scenario ED shows an additional increase of 361ktCO_2e.

Figures 7.15b-c shows the difference in spatial distribution of carbon emissions under scenario ED between the baseline and 2050. The spatial pattern under scenario ED (Figure 7.15c) is closely matched with that of EC and is far more uniform than the stochastic pattern of the baseline year (Figure 7.15b).

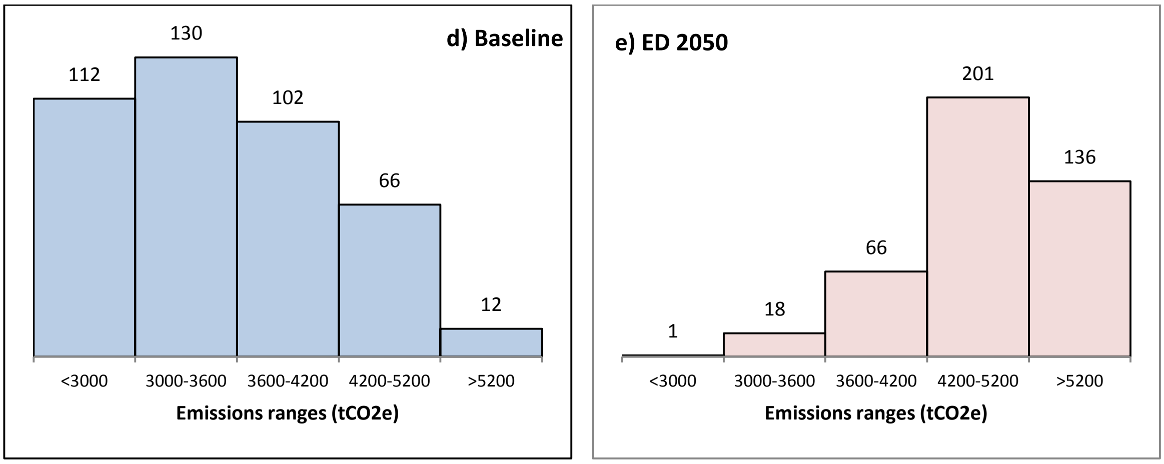


Figure 7.15d: Baseline distribution of emissions (tCO_2e) by LSOA versus Figure 7.15e: Distribution of emissions (tCO_2e) under scenario ED for Northamptonshire in 2050.

The frequency distribution of LSOAs under the five emissions ranges shows a significant change over the baseline (Figure 7.15d) when scenario EC is considered. In total, under scenario ED (Figure 7.15e) 19 LSOAs are seen in the two lowest emissions ranges compared with a baseline count of 242. The two upper emissions ranges contain 337 LSOAs in 2050 compared with a baseline count of 78.

7.3.2 Assessing carbon densities

Carbon emissions densities are mapped in order to increase the robsutness of the site evaluation function of the G-BFM model. Figure 7.16 shows the spatial distribution of emissions densities (tCO_2e/ha) under the baseline conditions in Northamptonshire.

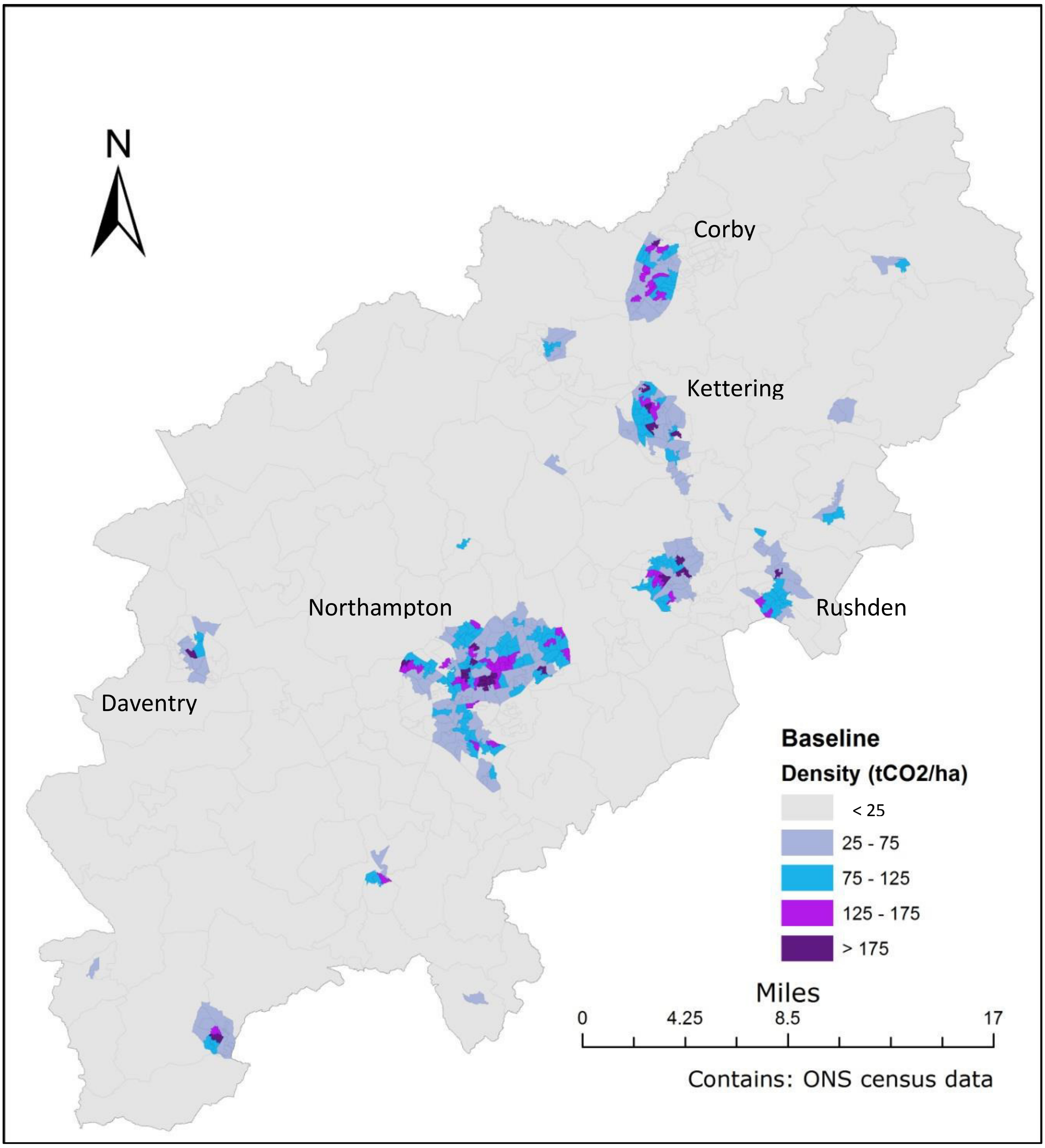


Figure 7.16: All emissions densities (tCO_2e/ha) baseline assessment for Northamptonshire in 2012

The highest carbon density values are once again found around the main urban centres (see Figure 7.4a on tonnage densities). The majority of the county (by land area) has a density value of <25tCO_2e/ha. The highest values (>175) are found within the central urban cores of the major population centres (e.g. Northampton and Kettering). Indeed, the highest baseline density value is 313.12tCO_2e/ha. Table 7.10 shows a statistical summary of density calculations for the baseline year and the end-point (2050) under all scenarios for Northamptonshire.

Table 7.10: Statistical summary of density calculations (tCO_2e/ha) for the baseline year (2012) and all scenarios for Northamptonshire in 2050

Year	Scenario	Min value	Max value	Mean	3rd Quartile	Median	1st Quartile
2012	Baseline	0.46	313.12	66.74	102.54	58.27	13.00
2050	CE	0.56	381.47	81.30	124.92	70.99	15.84
2050	VM	0.61	415.47	88.55	136.06	77.32	17.25
2050	EC	0.65	438.36	93.43	143.55	81.57	18.20
2050	ED	0.63	425.21	90.63	139.25	79.13	17.65

Determining the performance of scenarios around waste densities is paradoxical. On the one hand, a lower density value overall may indicate a better overall performance as this is related to a lower overall level of emissions. On the other hand, LSOAs with a higher density value may represent a real opportunity for waste planners as these areas can be targeted with more resource to achieve a greater level of impact from interventions. At this stage the first option is considered with the second revisited in terms of planning for modifications within the physical system. Table 7.10 shows all density values in 2050 have increased above the baseline values. In 2050, scenario CE has the best performance in all categories, of particular note is the significantly lower value of the mean compared with other scenarios.

At the LSOA level, the distribution of densities within the five ‘emissions density’ ranges (<25; 25-75; 75-125; 125-175; and >175) gives a further indication as to the performance of scenarios for the purposes of comparison. Figure 7.17a shows the baseline frequency distribution of LSOA count within these five ranges.

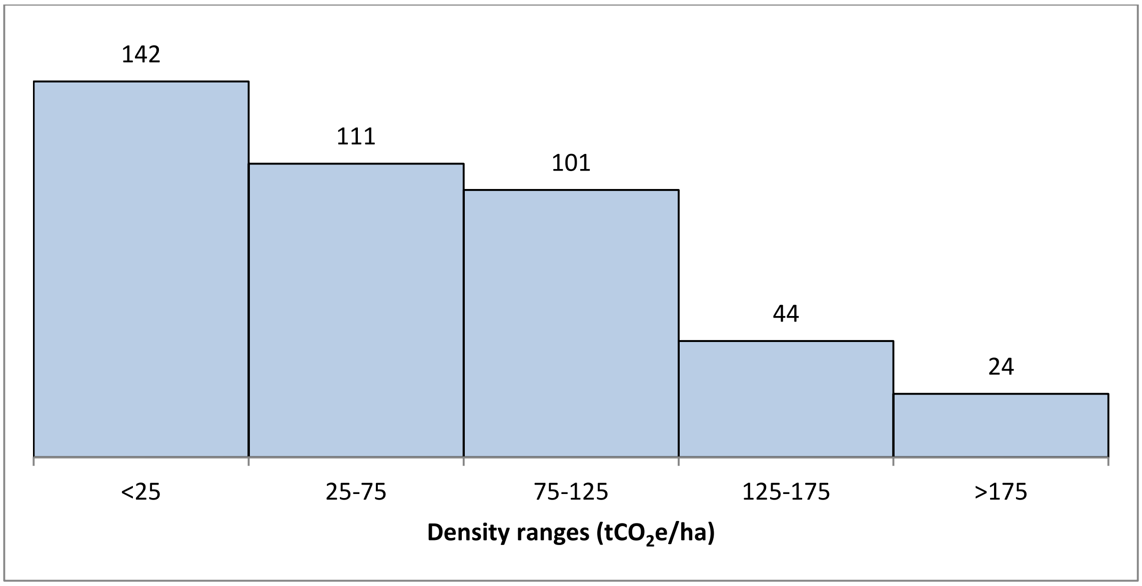


Figure 7.17a: Baseline frequency distribution emission densities (tCO_2e/ha) for Northamptonshire

Of note, in terms of the distribution (Figure 7.17a), is the concentration of LSOAs within the two lowest ranges (253) as well as within the mid-range (101). Relatively few (15.6%) of LSOAs are within the two upper density ranges. Figure 7.17b shows the frequency distribution of LSOA counts under all scenarios (CE, VM, EC and ED) in 2050 for comparison.

It can be seen in Figure 7.17b that scenario CE has the least movement of LSOAs between value ranges. In particular, by 2050, scenario CE has increased its count to 43 within the highest range compared with scenarios VM (54); ED (64) and EC (68). There are similar values reported for each scenario within the three mid-ranges with a maximum variance of 13 (range 75-125) and a minimum variance of 5 (range 125-175). There is only a small change within the lowest value range, which is expected as these LSOAs are likely to have the largest land areas (ha). Scenario CE reduced the count by 10 LSOAs in this range compared with 16 each for VM and ED, with scenario EC reducing the number of LSOAs in this rage by 17.

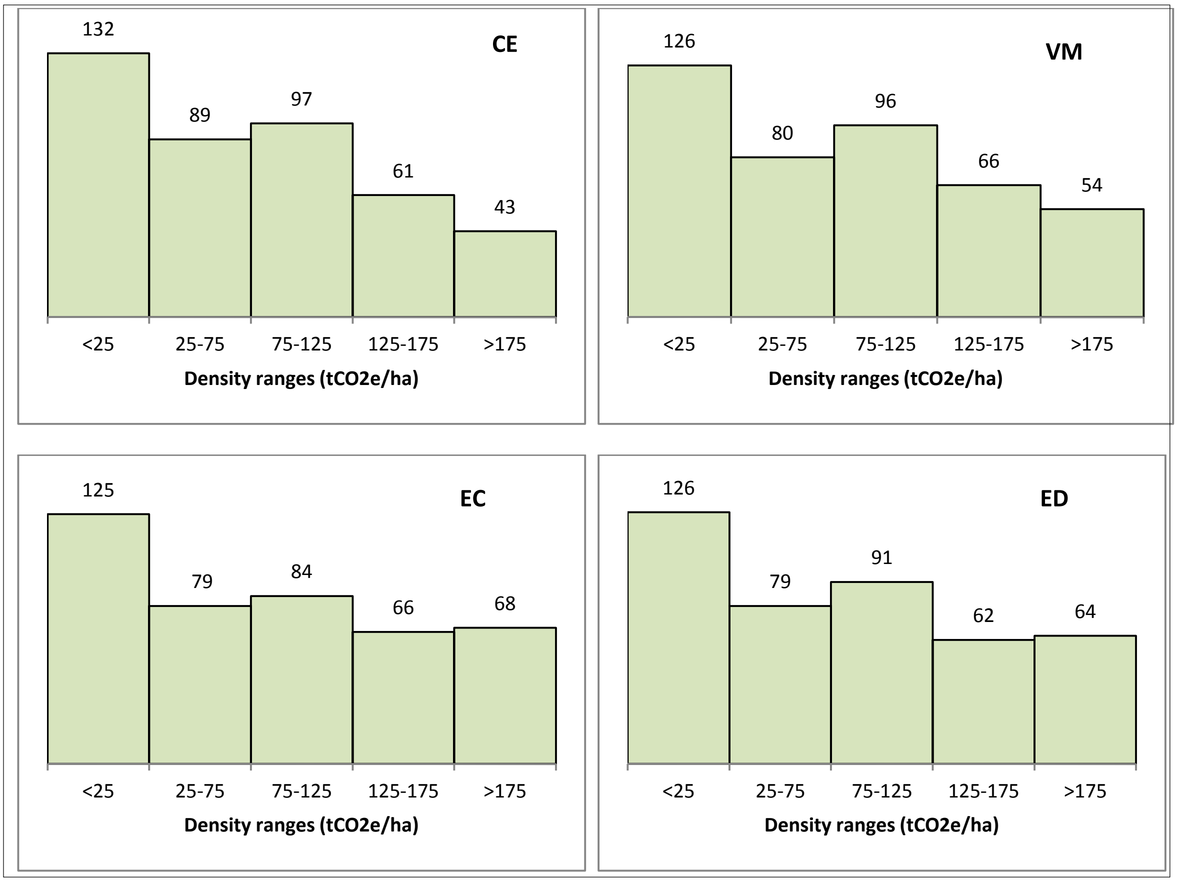


Figure 7.17b: Frequency distributions of LSOA count by emissions density under all scenarios for Northamptonshire in 2050.

7.4 Evaluating optimal sites with density calculations

The three spatial patterns identified in Chapter 6 (see section 6.4.3): 'centralised'; 'central core and outliers' and 'dispersed', are utilised at this stage to assess whether the patterns are able to cope with tonnages identified in the impact analysis as well as the ability of such a spatial pattern to impact on carbon emissions densities.

7.4.1 Assessing scenarios with spatial patterns

The assignment of a scenario to a particular spatial pattern is undertaken based on the focus of the scenario in terms of overall sustainability; technological development and application; levels of waste generation; expected increases in recycling and recovery required; and levels of disposal (requirement for landfill sites). In terms of scenarios CE and EC, these have previously been positioned as being best suited to a ‘centralised’ spatial pattern (see section 6.4.3) given levels of waste reduction and lower increases in recycling and recovery capacity. Of the two scenarios, CE is perhaps most suited to the centralised pattern as this represents a radical systems change in terms of the level of agreement between WPAs and the restructuring of the waste system away from WPA boundaries to a site specific focus on capacity to manage a range of material resources from a defined geographic location (e.g. buffer zones). In contrast, scenario EC may have been placed with the ‘central core’ pattern as this has a local focus in keeping with waste moving towards a community based resource approach. However, the strategic element of the narrative (Resource Strategy by 2020) elicits a strategic pattern of facilities.

Scenario VM is a materials capture/technologically focused scenario and is best suited to the ‘central core with outlier’s’ pattern of facilities (see section 6.4.3.3). Scenario VM is an incrementally changing scenario which begins with addressing targets but then becomes oriented around maximising recycling and recovery. The spatial pattern of 15 facilities requires changes to the permits of a number of sites with operations requiring secondary permits for recycling or recovery processes (or both within a single larger site). Unlike the ‘centralised’ pattern the use of more facilities reduces the distances materials are moved thus keeping in-line with planning policy centred on the WPA. Scenario ED is the reference scenario and thus reflects policy in the MWDF. Although, the number of sites is reduced from 98 to 44, thus requiring some changes to permitting and the use of secondary permits to expand operations where possible (particularly for recovery operations)..

7.4.1.1 Centralised pattern and waste density

Figure 7.18a shows the spatial distribution of the four integrated facilities with buffer zones identified to assess the catchment requirements of each facility in order to manage the highest proportion of the wastes generated. The baseline density is used for the assessment as this represents the highest density of wastes under all scenarios (with the exception of scenario ED) across the backcast period.

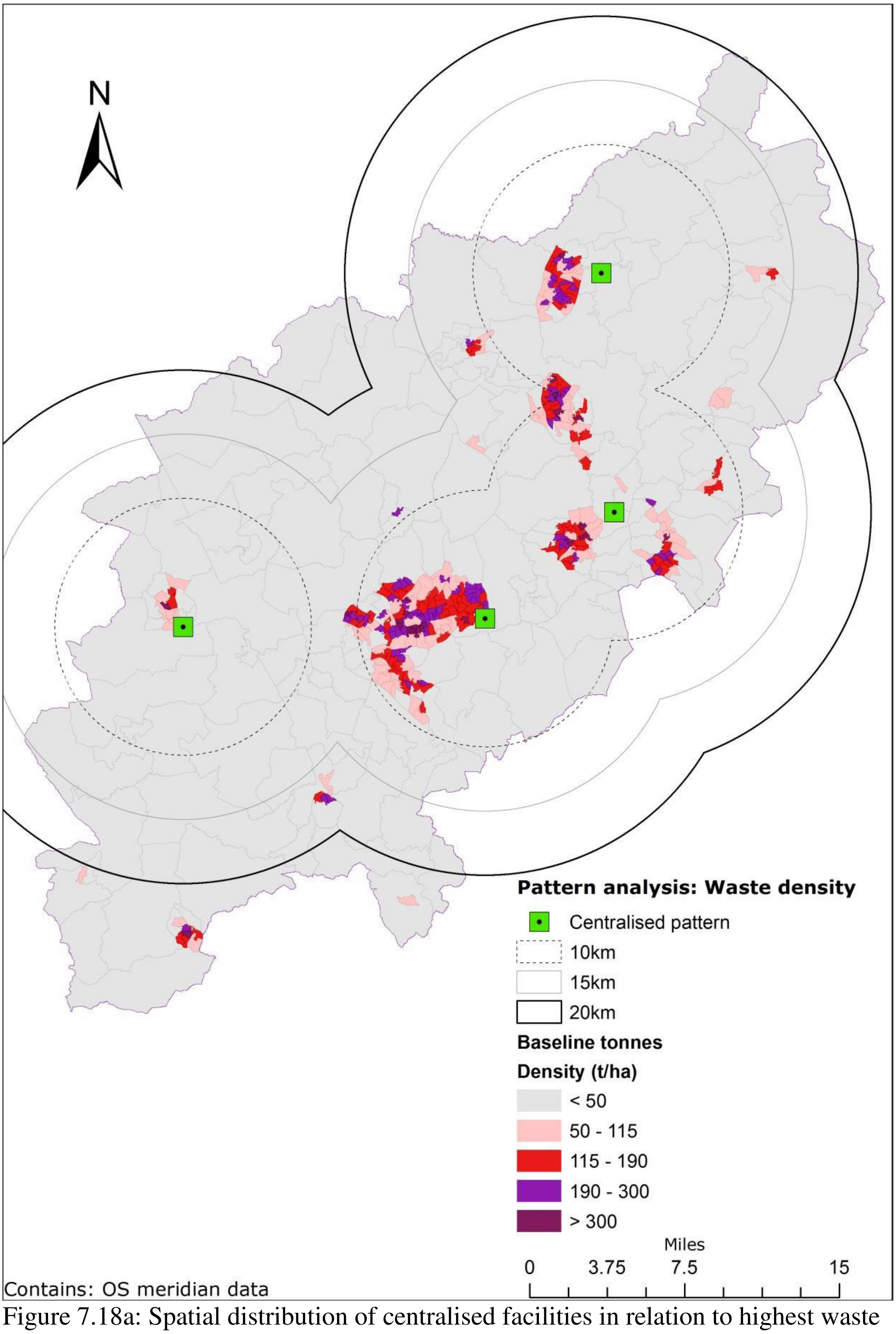


Figure 7.18a: Spatial distribution of centralised facilities in relation to highest waste densities (t/ha) in Northamptonshire during backcast period (2012-2050).

When consideration is given to the buffers (10, 15 and 20km rings) around the four facilities (Figure 7.18a) it can be seen that the first buffer (10km) encompasses the majority of the urban centres and high density LSOAs contained therein. A further buffer out to 15km shows most of the urban core of the county is covered by operations to this distance. Large rural areas to the East; South and North West are not covered at this scale including the town of Brackley (to the far south of the study area in Figure 7.18a). However, the assumption is made that neighbouring WPAs (e.g. Milton Keynes UA; Peterborough UA; and Warwickshire – including the urban centre of Rugby) will have similar agreements in place as part of the wider policy changes envisaged under scenarios CE and EC (particularly under a Resource Strategy, 2020 for scenario EC (see Table 5.12) or a greater focus on holistic and integrated resource management approach for scenario CE (see Table 5.10)). For example; administrative boundaries are removed in favour of location and ability to collect material resources. Indeed, the third buffer (20km) is included to illustrate where areas of cooperation may be envisaged between neighbouring WPAs (i.e. South East towards Bedford and Milton Keynes).

This pattern of facilities also has a number of significant cost implications for waste operations. Firstly, collection schemes become more standardised and targeted at specific material types allowing optimal loading and minimal journeys. Secondly, bring schemes are significantly rolled out for outlying areas with incentive schemes (similar to those seen in Germany and Sweden – Rousso and Shah, 1994; Hage, 2007) reducing per capita costs through lower resource collection charges and revenues streams from returned packaging and other resources. Finally, additional costs of expanding four locations to become integrated sites (including the five additional facilities under CE and four under EC (see Table 5.23) is more cost-effective than building new integrated sites. These costs would also be minimised via achievement of economies-of-scale and modularisation (Anon, 2011).

7.4.1.2 Centralised pattern and carbon density

Figure 7.18b shows the centralised facilities spatial pattern against baseline 'carbon denisties' with buffers applied for (10, 15 and 20km).

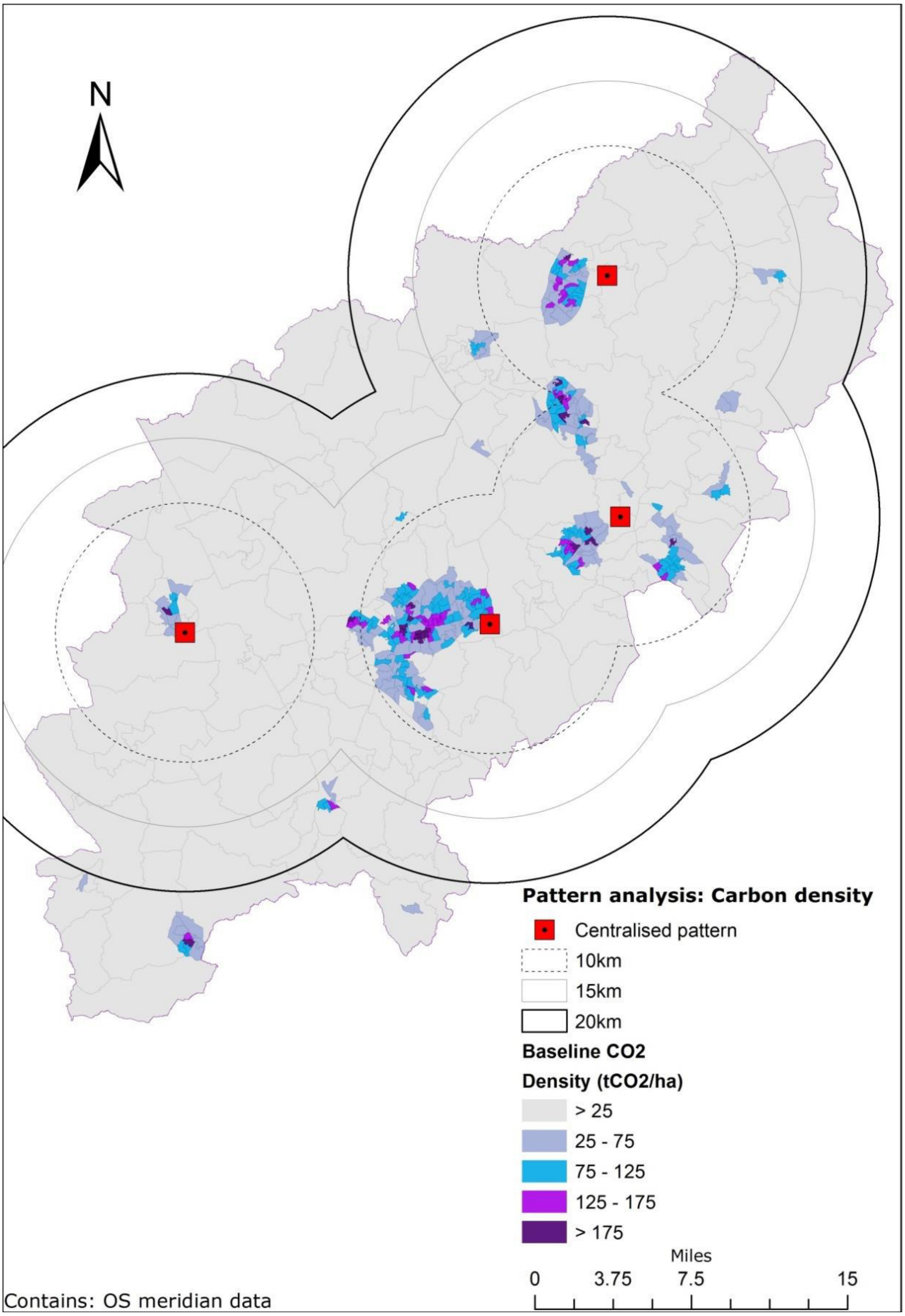


Figure 7.18b: Spatial distribution of centralised facilities in relation to carbon densities (tCO_2/ha) in Northamptonshire during backcast period (2012-2050).

The baseline carbon density values (313.3tCO_2e/ha maximum and 0.46tCO_2e/ha minimum; and 66.74tCO_2e/ha mean value) increase for both scenario CE and scenario EC (381.47, 0.56 and 81.30 for scenario CE and 438.36, 0.65 and 93.43 for scenario EC) (see Table 7.10). However, a more efficient and cost effective system has the potential to reduce levels of emissions through:

- Reduced numbers of vehicle movements;
- Increasing resource processing efficiencies (less embedded emissions);
- Greater consumer awareness of waste production leading to reduction (including emissions); and
- Increased energy efficiency through on-site biogas recovery (reducing emissions).

Given these points and the increasing population a baseline assessment is considered a more appropriate point to assess the potential of integrating waste facilities onto a small number of sites. In terms of the differences in carbon densities at the LSOA level previously discussed; these suggest that any savings would be more significant for scenario EC as this scenario has the higher ‘density’ values hence there would be proportionally larger savings (carbon emissions) than under scenario CE.

This assessment focuses on the spatial dimension of waste tonnages, monetary and carbon savings, so is used to determine the appropriateness of the spatial pattern rather than potential savings (which have been addressed in section 5.4).

7.4.1.3 Central core and outliers pattern and waste density

Scenario VM is identified as having this spatial pattern of facilities across the backcast period. Under this spatial pattern a total of 15 sites are identified, with urban centres as the main focus for larger sites with a number of smaller sites located in proximity to the smaller urban centres on the periphery of the study area. A 5km buffer is used under this spatial pattern to indicate the localised nature of the operations and subsequent catchment requirements for waste tonnages.

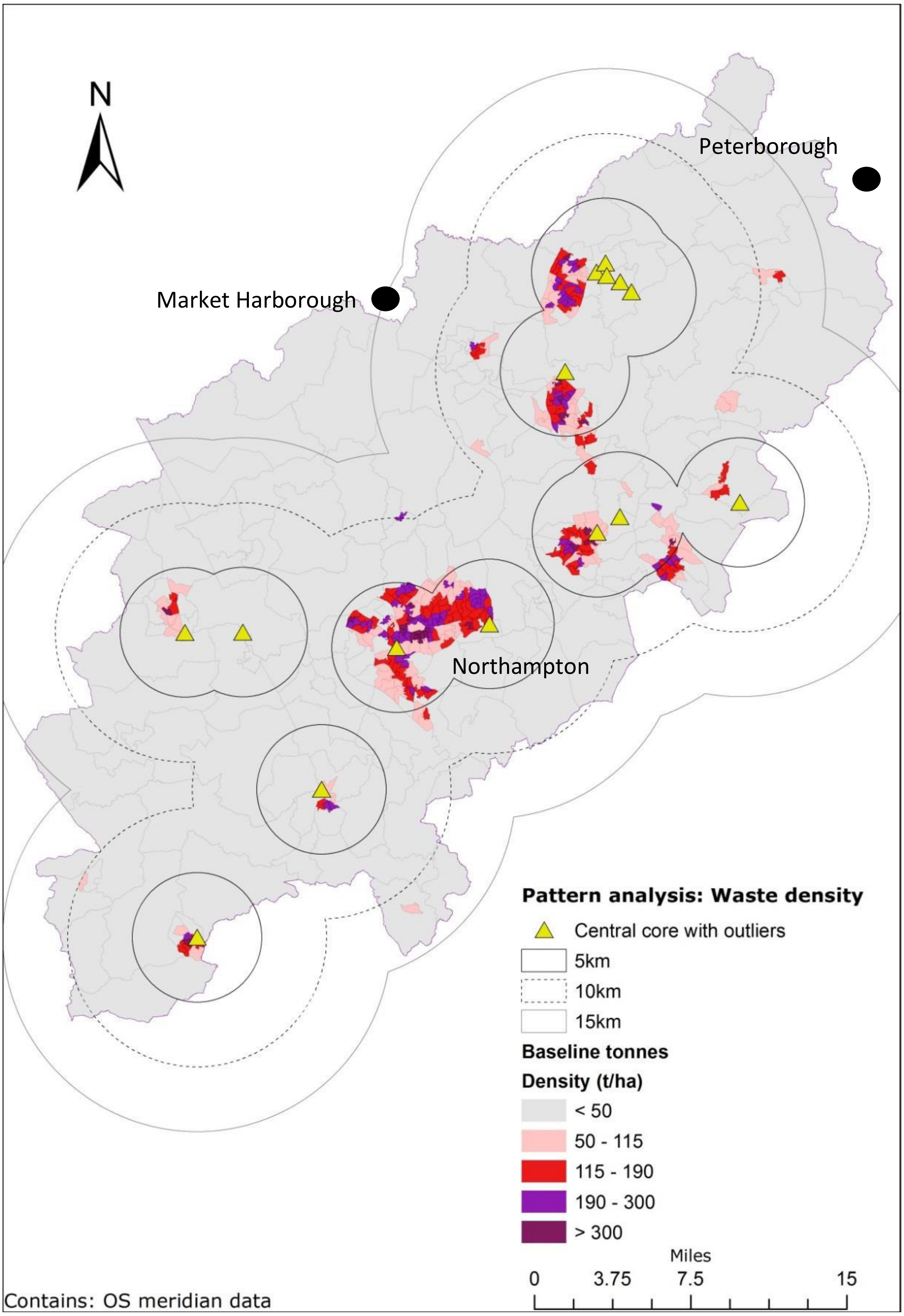


Figure 7.19a: Spatial distribution of central core with outliers facilities in relation to waste densities (t/ha) in Northamptonshire during backcast period (2012-2050).

Figure 7.19a shows the 5km buffer effectively covers the majority of the LSOAs with highest waste density levels as well as the majority of sites identified as generating most wastes (e.g. business parks, residential areas and central business areas (see Figures 4.9 and 4.10)). Moving out to the 10km buffer this spatial pattern covers almost all of the highest waste density LSOAs and covers areas of future waste generation in terms of Strategic Employment Land around the main urban centres (see Figure 4.11). The 15km buffer encompasses over 95% of the study area with the remaining land parcels situated in proximity to urban centres beyond the administrative boundary (e.g. Market Harborough is adjacent to areas outside the 15km to the NW of the county).

The focus of the scenario is maximum capture of materials through diversion from landfill towards a range of technological facilities capable of extracting multiple 'waste' fractions. An additional EfW facility is envisaged as well as an integrated facility (Table 5.23), both capable of locating to the east of Northampton (e.g. at the Great Billing former sewage treatment works with existing AD capacity). This location would minimise journey distances through its central location and proximity to modal transport networks (see Figures 6.19a-b). This would reduce transportation costs for materials collected at outlying facilities and maximise economies-of-scale for processing recyclate for value creation (e.g. monetary or energy). Indeed, scenario VM is identified as having the lowest overall economic costs (Table 5.25) of all scenarios even with the additional investment requirement.

7.4.1.4 Central core and outliers pattern and carbon density

The main assessment criteria in terms of carbon densities are to minimise the potential for creating further emissions and to achieve the maximum amount of emissions avoidance as possible. Scenario VM has the lowest level of direct emissions (Table 5.30) of all scenarios as well as a high level of overall emissions savings versus landfill (through maximising recycling). The level of direct emissions associated with scenario VM suggests such a spatial pattern minimises additional emissions from operations and as such represents the optimum scenario for reducing direct emissions.

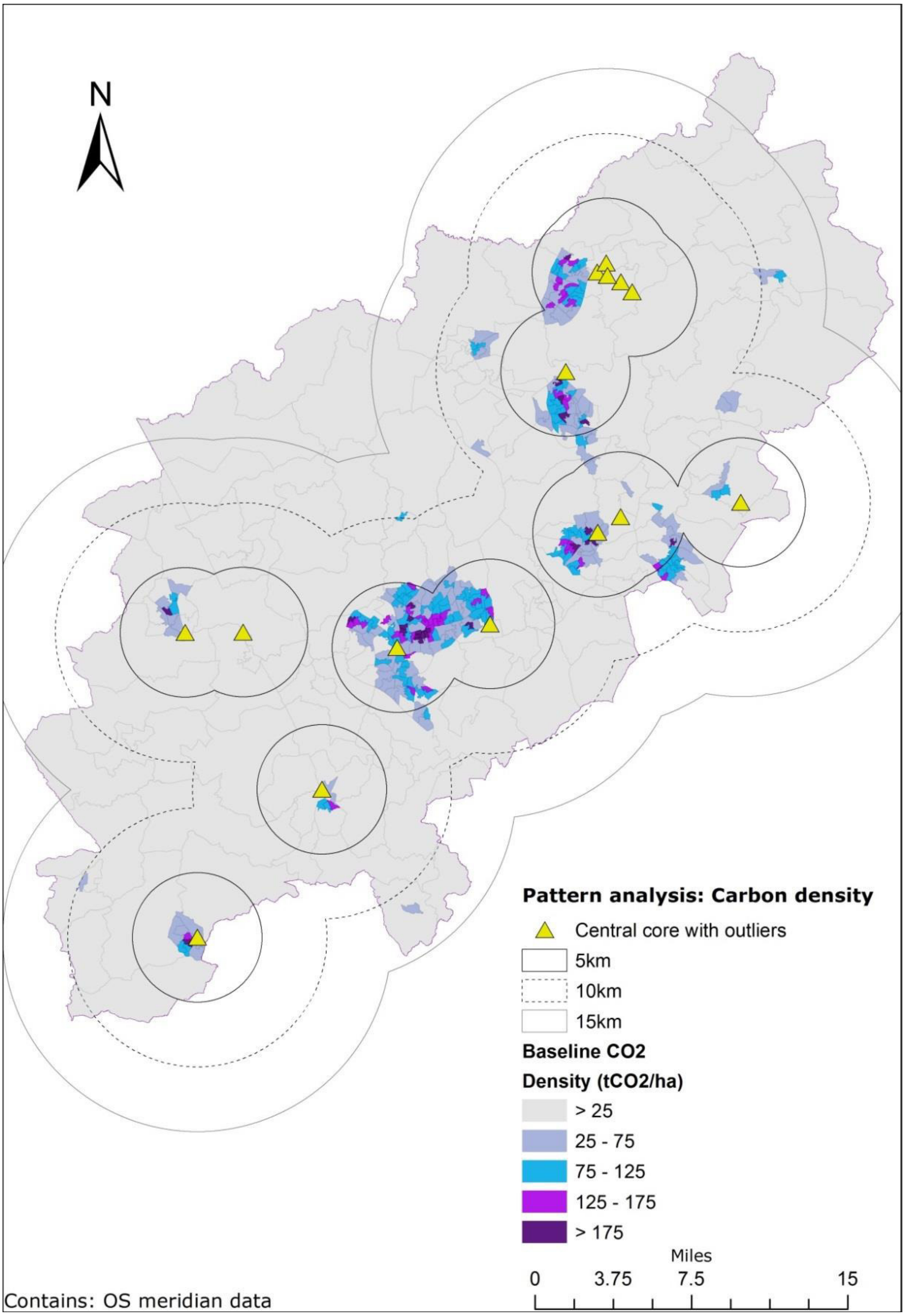


Figure 7.19b: Spatial distribution of 'central core with outliers' facilities relative to carbon densities (tCO_2/ha) in Northamptonshire during backcast period (2012-2050).

The buffering scales (5, 10 and 15km) produce the same coverage as that witnessed for waste densities, which suggests neighbouring WPAs take the same approach to facility locating with a view to minimising direct emissions. In spite of the incremental approach of adapting sites to achieve maximum diversion and minimum additional direct emissions the scenario achieves the ZWIA definition of zero waste but only through the inclusion of a significant use of EfW (which under certain definitions does not constitute a zero waste approach (Zaman and Lehman, 2013; 2014)).

7.4.1.5 Dispersed pattern and waste density

The dispersed pattern of facilities represents the reference case scenario and thus fits with scenario ED within this research. The key difference between proposed pattern and that found within the MWDF local plan (NCC, 2012) is the removal of all sites scoring below moderate levels of suitability (see section 6.4.3.3). This spatial pattern does not have any collaboration across boundaries and thus must cover the entire study area in terms of catchment zones (buffers).

The dispersed pattern has a total of 44 sites, with nine locations being multiple permit sites (this reduces the number of physical locations shown in Figures 7.20a-b to 35). Figure 7.20a shows the distribution in relation to waste densities and illustrates the catchment area of each facility in terms of three buffers (5, 10, and 15km). It can be seen that 5km buffering (with individual buffers dissolved using the geo-processing toolbox to provide a series of contiguous zones) that two large zones in the central and eastern study regions serve the bulk of the LSOAs with highest waste densities. Two smaller zones to the west and south are centred on higher density LSOAs away from the main areas of population, economic activity and waste generation.

Buffering at 10km produces a continuous zone which services the majority of the study area but still has a number of LSOAs left unserved. These areas are minimised under the

15km buffer zone with the majority of the study area served at this distance from dispersed facilities. The entire study area can only be served with the addition of a 20km buffer (see Figure 7.18a) but this would impact on costs and emissions from the inefficient collection

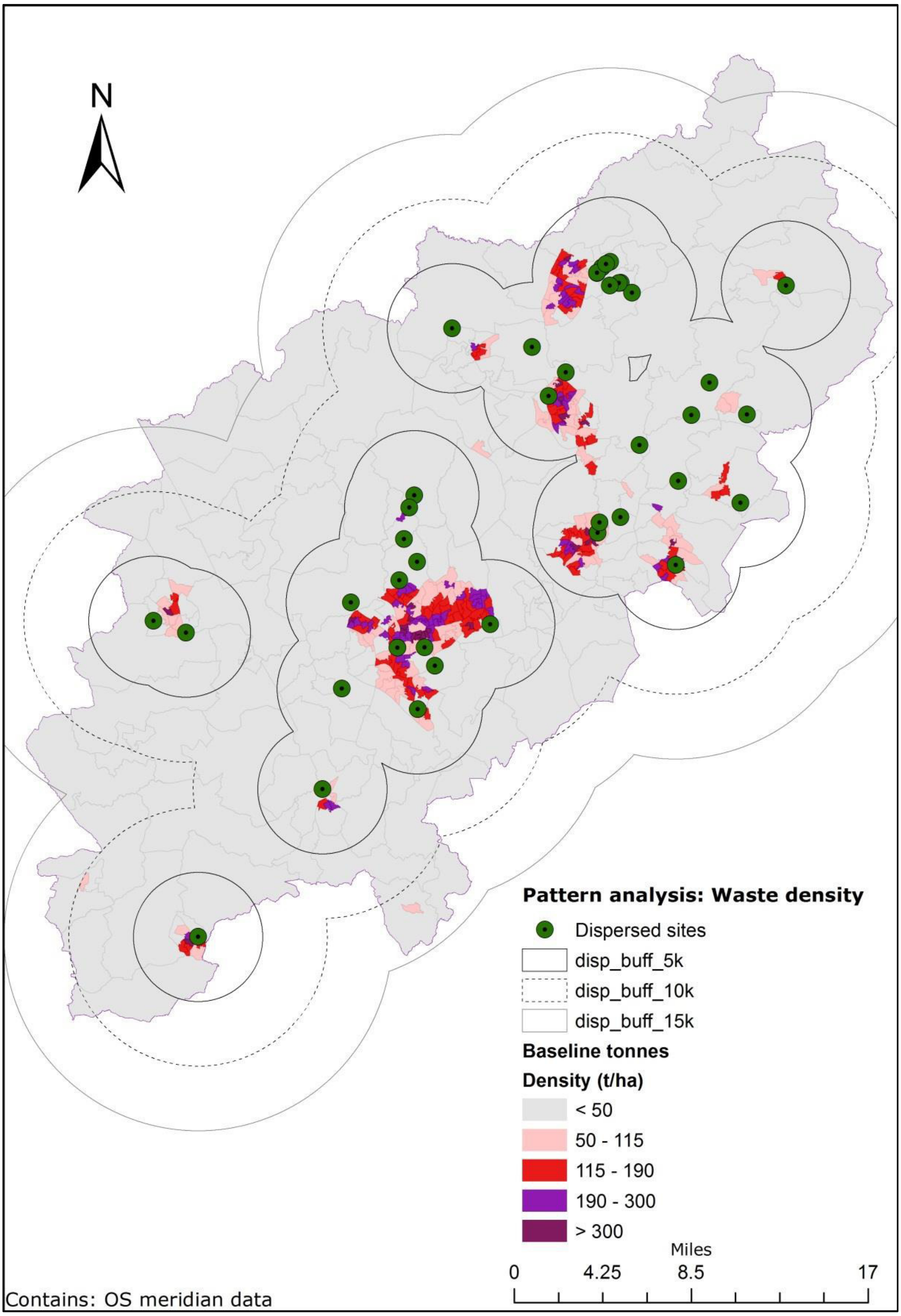


Figure 7.20a: Spatial distribution of dispersed facilities in relation to waste densities (t/ha) in Northamptonshire during backcast period (2012-2050).

of materials at these distances from the destination facilities. The inefficiency within the proposed WMS (e.g. multiple movements of materials between different facility types attracting additional gate fee charges) produces the lowest level of potential savings (£38.0m) for any scenario (see Table 5.25). In terms of costs this spatial pattern requires the addition of a large-scale MBT facility and a large-scale EfW facility (see Table 5.23) reflecting existing policy approaches around AD coupled with the waste sector focus on EfW capacity within the planning system (at the time of writing in late 2014).

Scenario ED is the only scenario not to achieve the zero waste definition (ZWIA, 2009) and is the only scenario to see recycling rates decline. However, there is a major shift towards recovery (with 26.5% of all materials going towards this management method in the study area by 2050) as the emphasis within the sector is on moving waste up the 'waste hierarchy' with little to no consideration given to waste prevention.

7.4.1.6 Dispersed pattern and carbon density

Figure 7.20b shows the dispersed pattern of 44 sites has at least one facility type in close proximity to the main concentrations (tCO2/ha/LSOA) of carbon densities by LSOA in Northamptonshire. There is a significant cluster (n=12) in the central area around Northampton as well as a looser clustering (n=21) around the three urban centres of Corby, Kettering and Wellingborough/Rushden.

Coverage of the buffer zones has the same profile as for waste densities. The outcome in terms of emissions is to produce the highest level of direct emissions (see Table 5.30). Conversely, the emphasis on diversion to recovery has the effect of producing the largest cumulative 'savings versus landfill' of any scenario (81.2mtCO_2e). This dichotomy between direct (including an increase in emissions because of system variables changes) and avoided emissions produces the second highest performance of any scenario in terms of overall carbon impact (i.e. savings). The inefficiency of the collection system is directly related to an approach which does not seek to collaborate with neighbouring WPAs. The inefficiency is, however, masked by the levels of avoided emissions by virtue of maximising recovery operations.

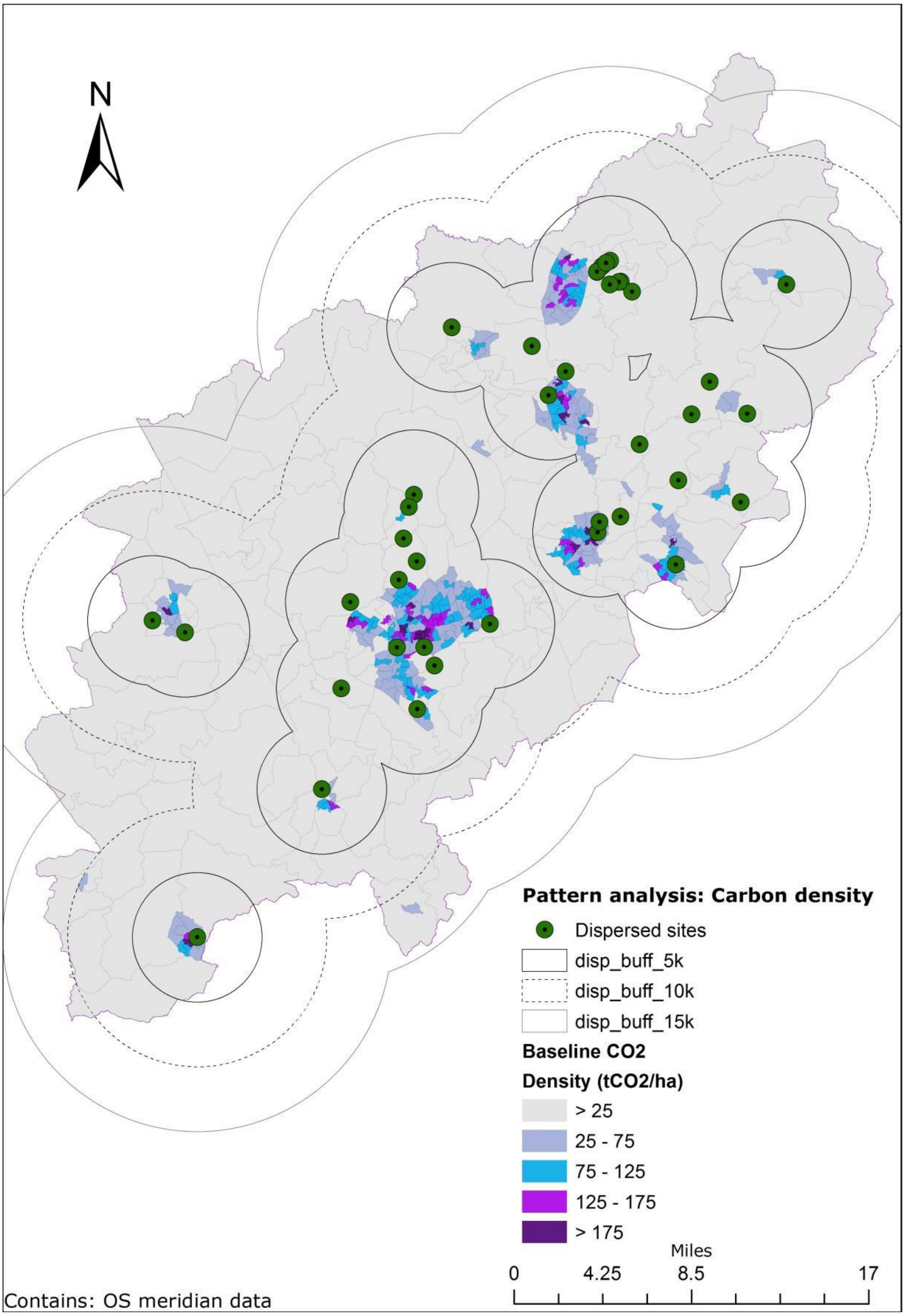


Figure 7.20b: Spatial distribution of dispersed facilities in relation to carbon densities (tCO_2/ha) in Northamptonshire during backcast period (2012-2050).

7.5 Chapter summary

This chapter has brought together results from the backcasting methodology and combined them with GIS to address objectives 4 and 5. The output results from the previous backcasting stages and baseline GIS calculations were explored to synthesise the results and fully embed the backcasting outputs within a GIS environment. Through the use of equations 7.1 to 7.3 baseline tonnage values ('all wastes' represents all controlled wastes) are calculated as 'all wastes' tonnes per LSOA (t/LSOA); 'all wastes' density per hectare (t/ha); and 'all waste' per capita (t/cap). These values were geo-referenced to LSOA data (ONS, 2013) and represented as a series of baseline maps (see Tables 7.2a and 7.3a) and calculations (see section 7.1.1.3). This baseline was then compared with future waste calculations from the QM (see section 5.4.1.4) and was spatially represented as discrete mapping layers (Figure 7.2) before being analysed in terms of value changes for LSOAs and per capita to visualise the performance. The findings ranked scenario CE as the best performing scenario in terms of waste tonnages at LSOA and per capita levels (reduction and achieving > 90% recycling and recovery of remaining materials).

The next stage was to determine the economic impacts and performance of scenarios based on QM results (Table 7.6). The economic impacts of overall costs were mapped for each scenario with geo-statistical analysis undertaken to quantify the visual outputs (see for example Figure 7.6a-e). This process was also undertaken on QM results for overall savings which were visually and statistically compared (see Figures 7.10 and 7.11). Scenario VM was the best performing scenario in terms of costs (overall, LSOA and per capita) with scenario EC having the best performance on potential savings.

The same process was applied to carbon impacts based on emissions and prevention at the LSOA and per capita levels (see Table 7.9). Emissions were mapped in order to visualise change from the baseline with geo-statistical analysis used to quantify these visualisations.

In terms of carbon impact (overall savings calculated with equation 5.1); scenario EC had the best overall performance (Table 5.30). Carbon densities were also calculated and expressed statistically (Table 7.10) (performance maps are located in Appendix 12 as the visual changes are very subtle). Results were evaluated in terms of the arithmetic mean; this measure of performance showed scenario CE as having the lowest mean in 2050 and the least change from the baseline value.

The final part of the chapter looked at synergies between the spatial assessment results for optimal infrastructure siting from Chapter 6 with the spatial patterns of infrastructure provision elicited from the narratives and policy packages of each scenario (see Tables 5.6 to 5.9). This assessment was then compared with the density calculations for tonnages and carbon as well as considering the economic implications of the spatial pattern assigned to each scenario. Section 7.4.1 assigned a centralised spatial pattern of 4 large integrated facilities to scenarios CE and EC. A pattern referred to as 'central core with outliers' was evaluated for scenario VM before the reference 'dispersed pattern' was evaluated for scenario ED which was a continuation of the MWDF spatial plan which was adapted to have facilities which achieved high or moderate suitability within the spatial assessment tool.

Chapter 8: Discussion

The purpose of this chapter is to discuss the research results in terms of the research aims and objectives previously outlined (section 1.3) and how far they go to addressing the research gap identified from the key literature. It will also bring together a discussion of problems encountered in developing the methodological framework (see Figure 5.1 for the overall backcasting framework and Figure 4.1 for the baseline analysis methodology) and discuss how these were overcome as well as the implications such adaptations have for further refinement and research.

8.1 Introduction

In order to develop any model of zero waste it must be recognised that no single accepted definition exists as to what 'zero waste' is or what the concept fully encompasses (TSE, 2010; DEFRA, 2011a). Such a starting point has the potential to be viewed as undermining the foundations of the model. However, the purpose of including stakeholders within the backcasting process is to normatively determine **their** visions and interpretations of a zero waste future. Hence in this research zero waste is taken conceptually rather than as a literal interpretation.

8.1.1 Contribution of the research

The major importance of a method is encapsulated in its usefulness, particularly within the field of application but also for its ability to be applied across disciplines. This research has sought to expand the field of waste management research through the application of an integrated GIS-based backcasting model (GBFM) by means of:

- Application of pluralistic backcasting (e.g. multiple scenarios) to other sectors and to integrated policies that cut across the different sectors (e.g. the synergy between waste and energy policy through infrastructure planning and provisioning)

- Relating backcasting studies to transformative studies encompassing political, economic, social and technological considerations (via the differing emphases within the policy packages developed in the zero waste and reference narratives)
- Methodology development across all aspects of the method (in particular through synthesis with GIS to enhance the quantitative analyses of zero waste scenarios)
- Improving the linkage between futures images development and feasibility analysis in backcasting studies (through the use of futures tables in combination with plausibility matrices based on morphological fields from GMA).

By focusing on these aspects of methodological development a novel contribution has been made to the fields of waste management, futures studies (backcasting) and land-use planning (GIS-AHP).

8.1.2 Critical evaluation of the research methodology

One of the drivers for applying backcasting was to move beyond isolated department formed policy agendas to the development of issue-based policy making (e.g. zero waste or waste to resources), which requires enlisting actors across and beyond government institutions and which Doyle (2013) states is “reminiscent of collaborative governance ideas”. However, developing an inclusive participatory backcasting study of scale is time consuming and requires significant commitment of time and resource (Hickman and Bannister, 2007). This is a real weakness of so-called “second order backcasting” (Quist, 2007) as it moves such studies from desktop deliverability (albeit with the challenges of undertaking Delphi or Hybrid-Delphi approaches within the research timescale) to long-term studies, typically 3-5 years in duration, requiring teams of researchers and large numbers of participants (Robinson et al. 2011).

This major limitation is addressed through scaling back the numbers of events requiring participant attendance but increasing the level of participant interaction (e.g. through interviews, surveys and questionnaires) over a shorter timescale (around 15-18 months with iterative analysis and dissemination included). In addition, the selection of a key spatially and temporally explicit problem; such as waste infrastructure planning; allowed the strengths of MCDA methods (GIS and AHP) to be used in order to produce robust quantifiable results for inclusion within the scenario narratives.

8.1.2.1 Qualitative methods: limitations and developments

There are a number of key qualitative elements employed within a backcasting study of this type: visioning (which can be undertaken as an individual method termed a 'backcast' (van Vliet, 2011)) and scenario development (which looks at developing 'pathways' which are formed around policy packages which emphasise the differing goals of the visions). The participant workshop delivered a rich pool of ideas and visions from which to draw but could benefit from a more structured approach with more prior discussion to build from. This has been raised in a number of previous studies (Antadze, 2004; van Vliet, 2011), however, little direction is given as a final definitive form of backcasting remains elusive. To overcome these limitations, follow-up interviews, questionnaires and one-to-one discussions went some way to addressing these issues. Similarly, during the scenario development phase there is a risk of participants losing a sense of ownership (Doyle, 2013), which must be addressed in order to maintain a sense of shared vision based on the desirability of the future visions. However, a key outcome was the change in participants own views based on the formation of scenario packages and the new ideas these combinations of policies yield.

8.1.2.2 Quantitative methods: limitations and developments

Although backcasting is essentially a qualitative methodology as depicted in the scenario narratives; the addition of detailed quantifiable data to the desirable future visions can add a greater sense of clarity to such visions without being prescriptive. Communication of the process is vital for influencing policy and this dialogue must be rooted in recognisable information such as that derived from the baseline analysis. However, data limitations typical within waste management can create levels of uncertainty which must be addressed through assumptions made within the scenario modelling process. This weakness undermines traditional predictive methods (e.g. forecasting) when time horizons are extended (Robinson, 1982) and threatens to undermine the validity of outputs within the backasting scenarios. To overcome this, participant input is crucial in order to move beyond the scenarios being viewed as a form of sensitivity analysis (Morrissey and Browne, 2004).

To facilitate this process of validation, the field of GMA was explored for a potential solution, as it had most recently been utilised within a normative forecasting study in England (DEFRA, 2011e). The morphological field used to display the characteristics of variables was used as a means of producing weightings for such variables based on their degree of impact (positive or negative) on levels of waste generation. Essentially, this approach builds on the earlier DEFRA (2011e) study, providing a means of quantifying variables impacts reflecting participants' mental models.

A further limitation of backcasting studies has been to find ways of visualising the outputs, beyond individual depictions of future conditions (Robinson et al. 2011). More recently, this has led to mapping with GIS forming a central core of the methodological approach (Haslauer et al. 2012). The use of GIS-based backcasting for land-use planning demonstrates the spatial and temporal nature of visions in a way previously absent. However, GIS has extensively been utilised with MCDA methods such as AHP to produce spatial snapshots of specific sets of system conditions under certain scenarios (Sumathi et al. 2008; De Feo and De Gisi, 2010). These studies are developed further in the context of waste infrastructure planning alongside an established infrastructure siting tool (DTZ/SLR, 2009a) to produce spatially accurate and temporally relevant attribute layered maps which reflect the variables weightings from the morphological fields and further described within the scenario narratives.

The following sections of Chapter 8 provide a more detailed discussion of the results from the various stages of the GIS-based backcasting (GBFM) methodology developed (see Figure 3.1, p.94)

8.2 Backcasting

The backcasting framework applied in this research revisits and expands on Robinson's (1990) original generic framework. The methodological framework uses four main steps with preliminary research undertaken around scope, extent, timeline, objective and variables to be included. Backcasting is approached from a systems perspective as a specific tool for assessing the efficacy of the current waste management system within a case study area of England. It goes further than providing an assessment; as one may suggest that backcasting; through the use of scenarios and visions of the future; is offering radically different pathways towards sustainable waste management which may not be perceived without taking such an approach. Pires et al (2011) suggested a range of systems assessment and systems engineering tools which could be of benefit to stakeholders and key decision-makers including 'scenario development' (SD) & 'management information systems' (MIS) (system assessment tools) and 'forecasting models' (FoM) (system engineering tools).

This research identifies backcasting as linking assessment and engineering tools through the incorporation of the backcasting framework with a spatial planning approach utilising GIS and AHP (these will be discussed in section 8.2.2). Indeed, a stated objective of backcasting is to offer feasible visions of the future (Robinson, 1990; Dreborg, 1996; Shaw et al. 2011) with such feasibility being tested by means of a quantitative model (QM) which explores the potential impact of each vision and pathway towards achieving such. Figure 8.1 provides an illustration of where a backcasting framework (BF) may potentially sit within the technology hub proposed by Chang et al (2009).

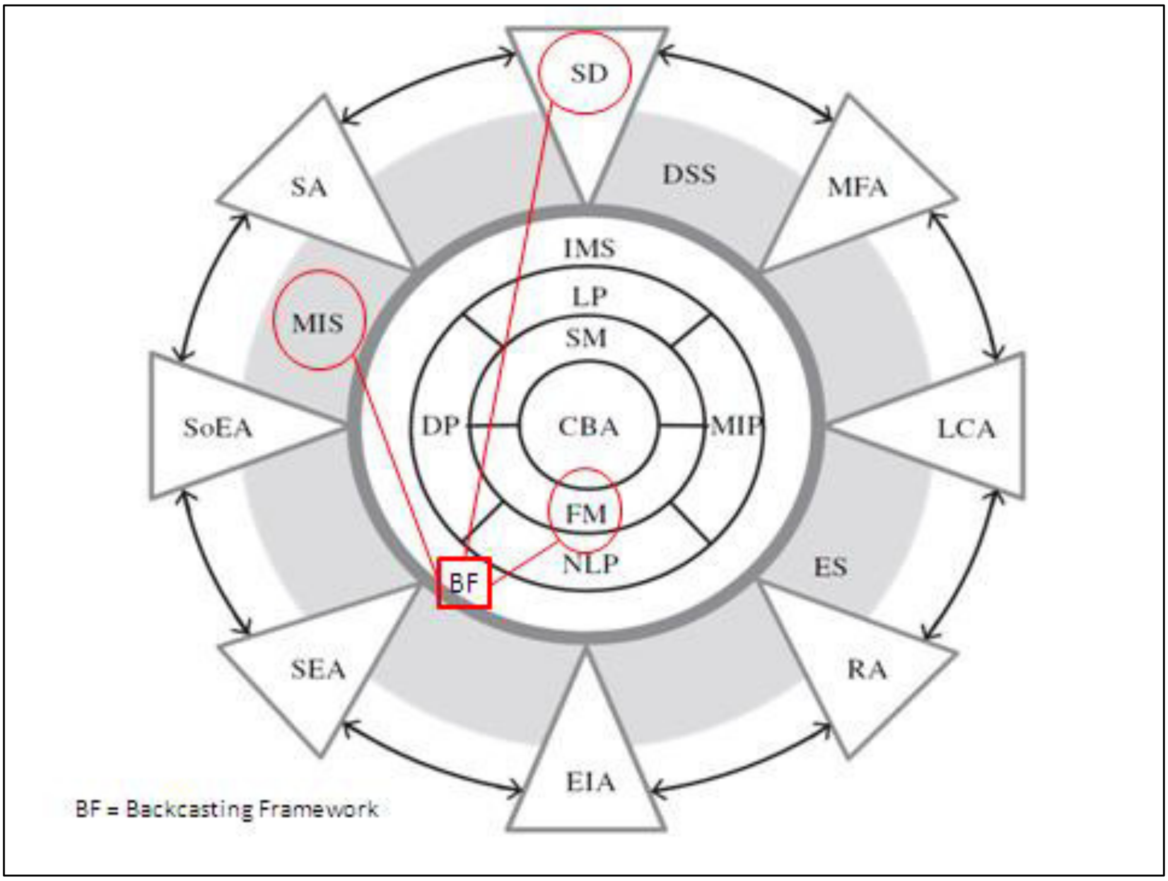


Figure 8.1: The technology hub for solid waste management and the potential thought space (highlighted) for backcasting (Source: Chang et al. 2009 cited in Pires et al. 2011)

For clarity, Figure 8.1 shows that BF sits at the periphery of system engineering tools (within the grey ring) and is surrounded by the range of system assessment tools currently applied in solid waste research (triangles around the inner ring).

8.2.1 Defining the scope, objectives and variables

The first stage in the backcasting process requires the identification of key systems variables for the waste management system (endogenous) and across social, economic and political systems (exogenous) which impact on the generation and management of wastes.

A total of 14 variables were identified (see Figure 5.11, section 5.3) as encompassing the critical factors with the greatest potential impact on transitioning towards a zero waste economy; with materials viewed as resources for new and existing economic processes and practices.

Previous research within England has identified many of these exogenous variables: demographics, socio-economic considerations, commodity markets, economic output and economy structure (DEFRA, 2011b; EMF, 2011); while a detailed literature search identified key areas of waste policy: waste system trends; reuse & recycling capacities; recovery & EfW capacity; technological development & implementation; landfill and environmental taxes; system support and voluntary agreements (WRAP, 2013a; Cole et al. 2014) as well as alignment with other sectoral policies such as those on energy security (e.g. through biogas production from AD within the AD Strategy and Action Plan) (DECC/DEFRA, 2011).

Those factors identified were used as areas of discussion and lines of questioning within the pre- and post-workshop questionnaires (used from June 2011 to August 2012); preliminary interviews (June to September 2011); workshop session (26th September 2011) and follow-up interviews (November 2011 to February 2013).

8.2.2 Baseline analysis

Chapters 4 presents the results from the baseline analysis stage of the backcasting framework applied within the research. The baseline analysis is a critical step within the backcasting framework (Robinson, 1990; Hickman and Bannister, 2007) as it is used to bring together the qualitative results of the visioning stage and key policy areas identified in the scenario development stage within a quantitative model (QM) which is used to test the feasibility of both visions and scenario pathways based on specified policy packages. In addition, baseline data is utilised to determine any existing and potential future capacity gap in part to address objective 3.

8.2.2.1 Waste arisings

Results reported in Table 4.11 give an overview controlled waste arisings within the case study area of 2.70Mt in 2012. These arisings disaggregate as 337kt for LACW (Figure 4.2); 984kt of wastes from C&I sources (Table 4.1); 1.32Mt originating from C&D sources (Table 4.4); and 94kt of hazardous wastes (Table 4.5) separately reported but derived from household, commerce and industry sources (see Figure 4.2 and Tables 4.1, 4.2 and 4.4). These results proved comparable to levels reported within local minerals and waste planning documentation (NCC, 2013). This was an interesting outcome for a number of reasons.

Firstly; LACW was expected to be broadly in line because of the continuity between sources (both are derived from Waste Data Flow reporting). Secondly; hazardous waste data is publicly available under the HWDI and is a legal requirement for WPAs to report on within planning documents. For this reason, there was alignment between the main data source utilised in the research and those for WPA reporting. Finally; C&I and C&D data used in the research was primarily derived from waste returns data reported under the WDI (EA, 2012a); exemptions reporting (EA, 2013a) and an estimation methodology derived from landfill tax returns (Gov.uk, 2013).

Given the similarity in levels reported (C&I wastes in Table 4.1 were 3,000t above those reported by the WPA for 2008 (a 0.34% variance) in Table 4.2; while C&D waste in Table 4.4 were 5,000t below WPA reporting levels for 2010 in Table 4.3 (a variance of 0.38%) it is reasonable to assume the methodologies for determining the overall arisings are comparable and thus represented a reliable base to take forwards for impact analysis modelling.

8.2.2.2 Waste movements

Waste movements are defined as encompassing 3 materials flow processes in the research: imports, exports and internal movements (see section 4.2). The data used for determining these movements reports hazardous wastes separately from other waste types. These figures are reported separately for all categories before being combined to produce an overall value for material flows from each controlled waste stream.

In total, Tables 4.6 and 4.7 showed waste imports to facilities in Northamptonshire were 914kt with 16.2% of this total (148kt) reported as hazardous waste and the remaining 95.9% from all other controlled waste streams. This high percentage of hazardous materials is reported as being caused through the location of a nationally significant hazardous waste treatment facility within the case study area. This level of import for hazardous waste would thus be expected to be much lower for planning areas without such facilities and implies the LA of East Northamptonshire acts as a host community thereby taking responsibility for a greater proportion of this waste type than might be expected other controlled wastes.

In terms of waste exports, Tables 4.8 and 4.9 indicate the case study area sends a total of 574kt of wastes for treatment to WPAs and other destinations. This total disaggregates as 97kt (16.9%) of hazardous waste and 477kt (83.1%) of other controlled wastes are exported. Recovery operations are the most significant destination route, accounting for 380kt of all material flows in 2012. A comparison between imports and exports shows the case study to be a net importer of wastes (340kt) primarily from adjacent WPAs.

When consideration is given to the internal movement of wastes, Table 4.10 shows that 56.5% of all waste removed (620kt) from facilities are managed at other facility types within the WPA. This demonstrates the varied nature of waste operations at the district level with factors such as level of urbanisation, population density and geographic area (see section 4.7) all acting as barriers or drivers to the locating of facilities at this scale. An example can be seen with landfill operations as these are restricted to 8 sites throughout the county. This has the effect of requiring 178kt of materials to be moved between districts which are likely to increase the overall economic (costs) and environmental (carbon) impacts of waste management in the case study area.

8.2.2.3 Composition of wastes streams

In order to determine where improvements may be achieved within the existing waste system it is necessary to understand the types of materials being managed at waste facilities (e.g. materials imported and moved internally). Previous composition studies were scrutinised (NCC, 2007; DEFRA, 2009; BRE, 2009; DEFRA, 2010; WRAP, 2010; Head et al. 2013 unpublished) as well as waste returns data (EA, 2012a; 2012b) to identify key materials types which can be used as indicator categories for specific types of treatment operation. A total of 14 indicator categories were identified (see Figure 4.5) which could account for the main waste streams identified by the 20 EWC chapters (e.g. Chapter 17 for construction wastes).

Further analysis of the data in Table 4.11 showed LACW and C&I waste to have the most categories (11 and 10 respectively). C&D waste had a total of 7 categories with two (inert and concrete) accounting for 80.0% of all wastes. Hazardous waste comes under a single indicator category but in reality originates within all waste streams (as shown in Table 4.5). Indeed, hazardous waste is reported under all EWC chapters in Table 4.5 with the most significant tonnages coming from Chapters 19, 16, 13 and 12 (e.g. chapter 19 wastes are those from waste water treatment whereas chapter 16 are those wastes which are otherwise not specified).

Looking at waste tonnages within the indicator categories and across waste streams it is clear to see from Table 4.11 that certain materials are worthy of greater effort to capture from specific waste streams. For example; paper and card mainly arises within the C&I waste stream (e.g. from packaging and paper processing operations) and is potentially easier to capture as the quantities involved are more economically viable; less prone to contamination with other materials; and visible within the work environment. Initiatives at the company level have produced case studies of large private enterprises achieving zero waste to landfill status (RICOH, 2009; EMF, 2012) thus representing empirical evidence to support estimations of the potential benefit from resource efficiency within the economy (OH, 2009; 2011; BIS, 2012). Such case studies are from diverse industrial and commercial sectors (e.g. electronic printing & copying and flooring) illustrating the applicability of such approaches across economic sectors as previous research had suggested (Phillips et al. 2006).

8.2.2.4 Capturing materials

In order to realise benefits associated with compositional characteristics an evaluation is required of the efficacy of current systems at capturing materials (e.g. for recycling, composting or energy recovery). As raised in section 4.3.2, overall reported diversion of all controlled wastes in the case study area is 66.8% (recycling and composting at 57.7% and recovery 9.2% shown in Table 4.12). There is, however, significant variation between waste streams with only 43.8% of hazardous waste captured. In addition, LACW averages at 51.6% overall recovery at the WPA level with marked variation at the district level (DEFRA, 2013d). Both C&D and C&I wastes have higher than 50% recycling (63.8 and 57.3% respectively) with overall material capture rates being above the national 2020 target of 70% for C&D wastes (74.4% in 2012) and capture rates for C&I reported as 64.2% in 2012.

However, a very significant amount of these materials; primarily inert materials from construction and demolition operations used as aggregate or classified as exempt from permitting requirements (e.g. materials used for landfill engineering); are captured outside of the environmental permitting regime (NCC, 2012). It also suggests that overall capacity for treatment and recovery may not be enough to meet longer-term goals in line with national and European targets. Table 4.13 shows that according to waste returns data (EA, 2012a; 2012b) only 713kt of materials were sent to permitted treatment and recovery facilities in the county with another 644kt of materials passing through transfer operations. This suggests that recycling and recovery from LACW, hazardous, most C&I and a small amount of C&D wastes are passing through treatment and recovery facilities within the permitting regime as active wastes with larger quantities (1.02Mt overall) being sent for disposal via landfill.

According to these results the actual recycling and recovery rate for active wastes (e.g. those within the environmental permitting regime) were as low as 41.1% (34.3 and 6.8% respectively) in 2012. But this also suggests the maximum amount of infrastructure capacity required to meet current needs is 1.74Mt proven capacity (see Table 4.13), excluding transfer operations. This is at odds with projections within the planning literature which specifies a need for 1.93Mt of capacity in 2010/11 and 2.21Mt of capacity required by 2031 (NCC, 2012). The principal reason for this discrepancy relates to the projection methodology used in the WPA calculations which forecast arisings for LACW and C&I waste to increase significantly (from 354kt to 468kt per annum for LACW and from 1.06Mt to 1.12Mt per annum for C&I wastes) over this period (NCC, 2012). As such, the WPA is planning for a worst case scenario which may see them either investing in facilities which they cannot run at optimal capacity or putting contracts out to tender which may incur additional costs for the WPA if they cannot meet contractual arrangements for feedstock (this would be most pertinent to large EfW facilities which have historically been contracted over 25 year periods).

8.2.2.5 Evaluating the potential gap in capacity

In order to determine any potential capacity gap it is necessary to start by assuming current levels of arisings will remain unchanged (a so-called base case scenario). In terms of the capacity gap derived from baseline calculations and targets set out in the planning literature (NCC, 2012; DEFRA, 2013a) Figures 4.6a-d showed that if 2012 levels of waste generation and rates for recycling, recovery and disposal were maintained then LACW targets would not be met from as early as 2015. Baseline C&I performance would achieve target rates until 2020 with hazardous performance missing targets for recycling and disposal throughout the period (2012-2030). Performance for C&D wastes is the only stream which would meet all targets (when recycling and recovery are considered together) across the entire period.

Two considerations must be addressed from these findings in order to achieve the requirements of objective 1 (see section 1.4). Firstly, are waste arisings likely to remain static throughout the planning period? Secondly, is the amount of residual material sent for recovery via diversion from landfill likely to change? To address waste arisings, these have been in a state of flux for many years but the most recent data available would suggest these are declining across all waste streams in the case study area and for England since at least 2008 (see Figure 4.2 – LACW trends; Table 4.1 – C&I waste returns trends; and Table 4.4 – C&D returns and estimation trends). In terms of recovery rates and diversion of wastes from landfill, this too has been changing since the 1990's (Curran and Williams, 2011; Phillips et al. 2011). For example; recycling rates for LACW wastes in England have changed from around 9% in 1990 to an average of 43.2% in 2013 (Eunomia, 2012; DEFRA, 2014a).

Given initiatives from government on specific waste streams (e.g. halving waste to landfill – C&D sector) (WRAP, 2013a) as well as the policy emphasis on resource efficiency (BIS, 2012), industry initiatives around the circular economy (EMF, 2012) and European level emphasis on materials security issues (EC, 2011c; EEA, 2012) there is little doubt that recycling and recovery through specialised treatment operations is likely to continue for the foreseeable future (e.g. until at least 2020).

It must therefore be concluded that planning policy which uses a worst case scenario approach is flawed and the resulting planning has the potential to leave a significant cost burden on LAs unless new models are considered which can offer a range of plausible options for waste planning in order to assist decision-makers and inform stakeholders. Indeed, the waste industry has started (in late 2014) to recognise the problem of over-capacity for residual waste treatment (Eunomia, 2014) suggesting that by 2020 England would have excess incineration capacity and would face similar issues to European countries with significant over-capacity in this area.

As previously raised, planning for sustainable wastes management faces a complex, dynamic and non-linear system open to the influences highlighted within chaos and systems theories (e.g. balancing and reinforcing feedbacks) (Gleick, 2008,p61; Meadows, 2008,p30). As such, investment in large scale incineration may lack the flexibility to respond to radical changes around waste. Indeed, top-down approaches which seek to protect a waste management business model may produce a bifurcation point where radical change emerges (Capra, 1996, p136) and the resulting system is considerably altered with the potential to make some business models untenable.

8.2.3 Visioning

So how does an individual, group, organisation, sector or government deal with such complexity and potentially radical changes? Chapter 5 presents results on the use of a backcasting approach developed from Robinson's generic framework (1990). Such a futures method is considered to have considerable advantages over traditional forecasting approaches in terms of considering complex sustainability issues (Dreborg, 1996); such as those around planning for sustainable waste management (SERI, 2010b). This is further expanded within this study in terms of applying backcasting from a systems theory perspective; particularly in relation to testing the impact of each scenario within a QM which utilises three recognisable metrics, namely: tonnages of waste produced; economic implications of specific policy packages impacting on waste generation; and the environmental impacts in terms of carbon emissions (direct and avoided) and these may produce synergies between sectors within a resource paradigm.

The backcasting approach taken (Figure 5.1) was preceded by defining the goal, scope, temporal extent and key variables (both endogenous and exogenous) to be considered. In addition, the baseline analysis forms an integral part of the backcasting approach with specific applications across the visioning, scenario development and feasibility testing stages. The overarching goal of the backcasting was to assess the feasibility of zero waste as a strategic policy approach within England. The scope of the study was a high growth area (Northamptonshire) within England which represents a two-tier WMS. The county council (which acts as the WPA) is under pressure to reduce costs across all services (including waste management) and respond more effectively to the problem of waste with particular regard to a number of variables, such as: a rapidly growing population; increasing numbers of households; diversifying economy and competing land use demands.

The temporal extent of the backcast was out to 2050 from a 2012 baseline (as the last full year of data available for the analytical phases of the research) representing a 38 year time horizon. This extended period went significantly beyond the short-term EU targets (e.g. to 2020) and medium-term targets of the Review of Waste Policy (DEFRA, 2011a); Waste Management Plan for England (DEFRA, 2013a); and Waste Prevention Plan for England

(DEFRA, 2013b). Such an extended period is considered as it allows a generational perspective to influence thoughts on norms, values and beliefs (Kok et al. 2011) and for capital stocks to turn over (Robinson, 1990; 2003). These are significant considerations as individuals are considered more likely to perceive future changes which have some connection to their lives (or those of their children). In addition, the drive in England towards the rapid introduction of incineration capacity; as a means of delivering on targets and thus dealing with the residual waste problem; is likely to entail a minimum 20-25 years for those stocks to turn over (e.g. for contracts to end with LAs).

8.2.3.1 Results of the visioning exercise

The visioning exercise comprised 3 elements: stakeholder identification and questionnaire development; stakeholder and experts workshop; analysis and continued stakeholder participation.

8.2.3.1.1 Stakeholder identification and questionnaire development

Figure 5.2 shows 17 key stakeholder groups were identified and approached based on the roles considered key within that group (e.g. Environmental Officer within a case study company or Regional Planning within the former East Midlands WTAB). Following a trial of the questionnaire with members of the supervisory team and external advisors which identified wording and structuring issues for amendment; a total of 115 questionnaires were sent to stakeholders from the 17 original groups, refined into 7 categories in Table 5.1. A high response rate was achieved (54.8%) with most (n=5) categories being well represented (a response rate above 40%). Three categories were identified as being essential to continuing stakeholder dialogue (private sector; local government; and the general public) with these categories accounting for 60.9% of all questionnaires sent out and 58.7% of those returned. In terms of the general public an equal selection was made between male and female (50:50) with a broad range of ages between 18 and 70 being represented.

Significant time and effort was required in dealing with queries relating to the questionnaire mainly around questions relating to future perceptions; these were addressed in a number of ways including: asking individuals to imagine themselves in similar role but 20-30 years from now; or imagining their children's perceptions of current practices in light of hypothetical solutions to waste or environmental issues. However, reflecting on this stage of the process would suggest that engagement in this way paid dividends when approaching the same individuals for further research purposes in terms of their familiarity with the type of questions being asked; or when assigning scores to factor choice within variable categories for plausibility results (see section 5.3.1).

8.2.3.1.2 Backcasting workshop

The backcasting workshop was held in September 2011 with 15 attendees from a range of disciplines and fields. The workshop was designed around three sessions (Figure 5.3) each designed to initiate discussion on arrange of issues around waste and resource management with an overarching theme of zero waste; based on the release in June of the Review of Waste in England (DEFRA, 2011a) and associated documents as well as earlier publications from The Scottish Executive ('Zero Waste Plan' - TSE, 2010) and Welsh Assembly Government ('Towards a Zero Waste Wales' – WAG, 2010).

The sessions were captured through a range of media (audio recording; notation and photographic evidence) as an accurate record and evidence base for subsequent analysis. The sessions were held across a 5 hour period: 1.5 hours for open discussion forum; 1.5 hours for brainstorming and 2 hours for identification of potential pathways and capturing individual visions of the future. All recordings were transcribed and sent to participants (n=25; 15 participants on the day and a further 10 whom submitted their views for inclusion within the discussion) for validation along with a request for further feedback based on reflections (see section 5.2.3). Feedback was received from 11 participants (a response rate of 44%) which was utilised in the later analytical phases. Based on the feedback a series of semi-structured interviews (n=16) were undertaken in two blocks (October 2011 to February 2012 and September 2012 to February 2013) with participants from the workshop session (n=6) as well as stakeholders recruited after the workshop (n=10) to evaluate the plausibility of scenarios developed.

8.2.3.1.3 Analytical phases 1 to 3

Thematic analyses of the outputs from the questionnaires; workshop; feedback; and follow-up interviews were undertaken using mind mapping software (Mind Genius 4©). Figure 5.4 showed 77 key factors and characteristics identified within the first two sessions of the workshop, reduced from 168 when overlap, language, specificity and relevance to the topic were taken into account. The software allowed refinement of factors and speeded up the process of thematic categorisation through visual prompting and the ability to colour code individual factors or groups thereof. Such tools are especially effective when analysis is drawn out across an extended period as additional data is gathered and new outputs are generated (e.g. from interviews or through plausibility matrices).

The third phase of analysis applied the STEEP method in order to group specific factors in order to identify contrasting characteristics to be embedded within different scenario narratives. Figure 5.5 showed the results of applying a STEEP method but also indicated the need for other groupings (e.g. monitoring and statements) as the individual factors and characteristics (e.g. realizing value at all stages of the life-cycle) were considered as either guiding principles to be reflected within a specific scenario or as a means of quantifying the impacts of all scenarios (e.g. the use of a carbon metric). In terms of analysing the input questionnaires and combing these with discussions from the potential pathway workshop session (Figure 5.6), applying the STEEP method was more straightforward as questions were framed to elicit more structured responses. For example; the six factors within the environmental section were able to put detail to the previous monitoring section (Figure 5.5) allowing quantifiable characteristics to be attached to specific scenarios (e.g. high levels of waste prevention for the deep sustainability scenario – ecological citizenship). However, certain contradictions were also raised around the types of factors which were beginning to form around outline scenarios. This problem has been addressed previously (DEFRA, 2011b) by means of stakeholder feedback on scenario drafts. This approach was utilised with stakeholders involved as well as through feedback from the supervisory team. Nevertheless, certain stakeholders insisted on contradictory factors being included within their visions as they felt this reflected a realistic take on government policy formation, both currently and in the future (Anonymous, 2011 - personal communications).

8.2.3.1.4 Developing a futures table

Personal visions of the future for waste and resource management (n=15) were a key objective of the workshop session. These visions based on individual values and beliefs as well as reflecting their professional and expert backgrounds were a cornerstone of the backcasting process. Detailed accounts were given by a number of stakeholders on the day with further details provided *ex-post* through feedback on transcripts or within interviews. The development of the futures table (Table 5.2) represented the first bringing together of variables (drivers and trends) with broad themes (although Table 5.2 shows the actual names of the scenarios these were inserted as the final output) – more descriptive themes used for stakeholder feedback (e.g. deep sustainability; hierarchic power structures; blue/green circularity; policy drift). Table 5.2 shows the main drivers of change which broadly capture the exogenous variables previously identified (see section 8.2.1). The three key trends identified (economic, policy and social) encompass a further 11 factors (3, 4 and

4 respectively) which were considered to have the greatest potential impact on the WMS within the case study region and England.

Development of the futures table is probably the most significant contribution towards Objective 2 as from this point forwards more structured analysis takes place of the actual themed scenarios as well as the process of testing these scenario frameworks with the first elements of the QM starting to take shape. In particular, the high level factors (Figure 5.7) represent direction for each individual scenario in terms of the policy/value matrix and thus represent the divergence points between the scenarios. One can argue, it is this step within the backcasting process which differentiates the scenarios as representing radical system changes or incremental changes (Robinson, 2003) which are likely to fall short of the zero waste aspiration.

8.2.3.1.5 Triangulation: stakeholder evaluation and sector views

Validation of the visioning outputs is a critical means of triangulating the qualitative results from the workshop, interviews, questionnaires, thematic analysis and futures table. Before these results could be taken forwards for the detailed scenario development and feasibility testing, it was necessary to collect and evaluate the thoughts of stakeholders involved in the visioning process and to reflect on areas of weakness or strengths. In addition, capturing the views of other waste professionals would be a good indicator as to the plausibility of the outputs generated.

A short questionnaire survey was tested and trialled with the supervisory team before sending out. Stakeholders were asked to rate the process on a percentage scale (0-100) through the survey questions (questions n=3) with seven evaluation criteria. Figure 5.8 showed the evaluation of visions produced with 6 of the 7 criteria scoring between 66 and 90% with only one criterion (committed) scoring below 60%. Interestingly, the creative and communicative natures of the visioning process were identified as key strengths.

Stakeholders were then asked to rate the visioning process from the perspective of key decision-makers in their organisations. Figure 5.9 showed that respondents scored all aspects of the question between 65 and 82%. The weakest criterion was 'concrete' suggesting stakeholders felt there was a need to address the link between desirable futures and recognisable metrics. Similar issues have been found in the UK with backcasting studies undertaken on climate change (Anderson et al. 2008) and for transport networks (Banister and Hickman, 2006). The final question asked stakeholders to rate visioning (and backcasting) as a strategic foresight tool. Figure 5.10 showed the lowest scoring criterion (consensus) achieved a 67% rating while the highest scoring criterion was 'creativity' at more than 90%.

Overall, stakeholders were very positive (75.0%; 76.1% and 78.2% aggregated responses to questions) about the use of visioning methods as part of a backcasting approach from the perspective of being: creative (rated as 1, 2 and 1) – most participants had never heard of backcasting but were familiar with forecasting and predictive methodologies with comments made on the flexibility of the approach compared to these. Many saw a real strength in the clarity of the method in terms of visualisation through the use of a wall with notes which built up through debate, discussion and their own interactions. This approach in terms of group interaction is commonly applied in The Natural Step (TNS) studies with diverse groups of participants (Holmberg, 1998; Hojer and Mattson, 2000).

8.2.4 Scenario development and pathway formation

The scenario development process within this research has two distinct phases: using plausibility matrices to capture stakeholder preferences numerically and iteratively formulating the scenario narratives based on visioning results (in particular, drawing on the futures table and high level factor matrix).

8.2.4.1 Plausibility matrices results

Stakeholders were recruited from the pool of identified experts with technical knowledge of the waste sector (n=25) as well as an equal number of stakeholders with no direct involvement with the waste sector (n=25) in order to determine preferences for systems variables. Table 5.7 shows how individual stakeholder responses were recorded with descriptive statistics captured for analytical purposes. A likert scale was utilised, as this formed a simplistic range of choices for stakeholders (1-5) where a score of 1 represented the most favoured choice. This method of scoring was chosen for its simplicity for all stakeholders involved above more complex approaches such as general morphological analysis (GMA) (Ritchey, 1998). Although GMA is a powerful mathematically based tool for dealing with very large variable sets (Zwicky, 1969; Ritchey, 1991) it produces a predictive output and this is not in keeping with a normative/transformative scenario approach (Borjesson et al. 2006). Even though the plausibility matrix used contains a morphological field (14 variables x 5 choices) of 5^{14} or in excess of 610m combinations, the purpose of the exercise is to capture a fixed number of responses (n=50) and for these to provide a relative weighting to each variable based on that limited number of inputs. However, a far larger set of stakeholder inputs (as seen with some of the large-scale backcasting studies using the Quest participatory backcasting software – Robinson et al. 2011) may necessitate a more robust mathematical tool such as GMA.

Table 5.8 presented the combined results of the plausibility matrices using the preference scale discussed. Individual scores (weightings) are given for each parameter impacting upon the group variable for technical stakeholders (TS), non-technical stakeholders (NTS) and a mean weighting which can be used to differentiate between parameters when making the final choice of parameter to include within each scenario. In total, each variable had 15 alternative weightings from which to select the narrative detail. For example; the variable demographics produced three weightings for ‘stable population growth’, the TS and mean scores represented the second highest weightings whereas the NTS weighting was the highest within that result set. Such results and combinations of results are useful for fine tuning the qualitative narratives and tended to generate debate among stakeholders when iterations were sent out for feedback. In total, 3 iterations were undertaken with feedback from stakeholders progressively diminishing as the choices became more focused (see Table 5.9 for indicative scenarios sent to stakeholders). Earlier work in analysing the workshop outputs, questionnaires and interviews (see Figures 5.5; 5.6; and 5.7) allowed the number of iterations to be minimised and thus speeded the process of finalising the scenario narratives and refinement of the futures table (see Table 5.2).

8.2.4.1.1 Problems encountered and solutions found

Scenario development was very time consuming and could have been improved with a more structured approach utilising dates for meeting multiple stakeholders (as seen with Delphi studies – Schmelev and Powell, 2006). However, this process of arranging large scale meetings invariably leads to delays and extends the time horizon within the data generation and collection phases. This would inevitably impact the staggered analytical phases required to capture and iteratively build on stakeholder perspectives and feedback on process results (e.g. workshop questionnaires or transcript sign-off). Large scale backcasting projects are able to absorb these delays within the research planning process (Hickman and Banister, 2007; van Vliet, 2011) but this can call into question the outcomes if the original data is far-removed from the results release date. It may thus be suggested that smaller scale projects (e.g. looking at a specific geographically limited area) can make use of a flexible approach to scheduling which allows overlap with non-critical pathways. The importance of identifying critical points and pathways within the research thus increases and should be considered at the earliest possible stage.

8.2.4.2 Narrative formation

The results from the earlier stages of the scenario development process were captured by means of a morphological field (Figure 5.11) which allowed the first visualisation of the proposed scenarios. This was a key point in the research as it allowed ideas and disparate comments and suggestions from multiple stakeholders to crystalize and start to become a coherent storyline. Indeed, this was the point from which the scenarios were assigned their names (e.g. Circular Economy and Ecological Citizenship). Although not designed to elicit a perception as to the content, the names are indicative of a concept or general theme (e.g. circularity; valorisation; and destabilisation). More specifically, the name of the sustainability scenario was given a name ‘ecological citizenship’ which linked the concept of responsibility from society with a fundamental reconnecting with the environment from a deep-seated change in social, political and economic attitudes. The scenario narratives were thus collated and presented as a brief storyline with recognition of some of the key drivers.

The storylines essentially draw on the 14 key variables and link these with insights on potential policy directions which could be taken given certain stimuli. For example; scenario CE raises the issue of policy alignment between energy and waste (at the time of writing this debate has focused on the growth in AD and how this can address part of the waste problem while providing a ‘renewable’ energy source for grid usage – ADBA, 2012). Table 5.10 also suggests how policies may take time to change, particularly within the EU target dominated time-horizon to 2020 (NCC, 2012) and suggests areas (time periods between milestones) where the main policy approach may transition within the backcast period (e.g. the waste system achieves a long-term downwards trend in waste generation partly as a result of shifting to a materials-based policy approach). Table 8.1 is provided to show the levels of impact on waste generation rates by 2050.

Table 8.1: Impact of waste prevention, reuse and systems variables changes (%) on overall waste generation derived from QM for 2050

Change factor (%)	CE	VM	EC	ED
Systems Variables	5.74	7.29	3.59	-9.01
Prevention	4.26	4.13	11.66	0.00
Reuse	14.34	8.68	8.79	1.71
Overall change	24.34	20.11	24.04	-7.31

Scenario CE fundamentally changes waste to a resource management approach through integrated policy approaches (Table 5.10). Under CE, innovation takes place in terms of design for products and services to use fewer materials and remove built-in obsolescence but relies in the main on resource efficiency gains and levels of reuse (14.34% see Table 8.1) to impact on levels of waste generation. Scenario CE is most closely linked with policy drivers: resource efficiency, design, secondary materials markets and resource management focus. These policy drivers impact on systems variables and cause a 5.74% reduction in waste generation by 2050. Waste prevention has the lowest impact on generation (4.26%) by 2050.

This contrasts with the focus on recycling and recovery under scenario VM (Table 5.11) which was influenced by considerations around materials security; drawing on the Security First scenario within the GEO-4 Europe research programme (UNEP, 2007). Similar to scenario CE the materials scenario (VM) is a top-down approach relying on technological developments utilised and developed incrementally in response to changing waste governance shaped partly in consultation with the traditional waste sector. The focus on materials stifles efforts to prevent and reduce waste (4.13% prevention and 8.68% reuse) but does lead to much higher levels of recycling and recovery which exceed targets in the early period of the backcast. Scenario VM is most closely linked to economic drivers: economic growth, commodity prices and landfill tax levels. The impact of these drivers and other variables has the largest impact on waste generation of the four scenarios (7.29% reduction).

Scenario EC is the most optimistic scenario in terms of the degree of behaviour change which might be achieved (e.g. for individuals, business and organisations). The scenario narrative is influenced by the GEO-4 'sustainability scenario' (UNEP, 2007); 'Vision 2050' (WBCSD, 2010); and the 'sustainability turn' scenario within DEFRAs foresight study (DEFRA, 2011b). Waste prevention is most significant within scenario EC (including reuse) accounting for a reduction in all wastes by 20.45% (see Table 8.1) while systems variables changes account for a further reduction of 3.59%. Scenario EC is the only vision to include widespread use of landfill bans (e.g. on all recyclable materials) which is supported with a detailed Zero Waste Strategy from 2020 with similar goals to those for Wales and Scotland (WAG, 2010; TSE, 2010).

In contrast to the other three scenarios, ED is the most pessimistic and is used as a reference scenario (Robinson, 1990; Dreborg, 1996; Quist and Vergragt, 2011; DEFRA, 2011b). This vision of the future does not produce reduced waste generation.

8.2.5 Quantitative model results

The quantitative model (QM) (Figure 8.2) represents the mechanism used for measuring the different impacts of each scenario and ultimately whether or not a proposed scenario required any further iteration (Robinson, 1990; Robinson et al. 2011; Quist, 2006). These impacts are measured against 3 key metrics: tonnages (waste generation profiles for all controlled wastes as well as avoided tonnages from prevention and systems variables changes); economics (costs from sending residual tonnages to landfill as well as from gate fees charged at facilities for accepting wastes and savings from avoiding gate fees and landfill tax); and carbon (as savings versus landfill for materials sent for treatment and recovery and as avoided emissions from prevention and systems variables changes).

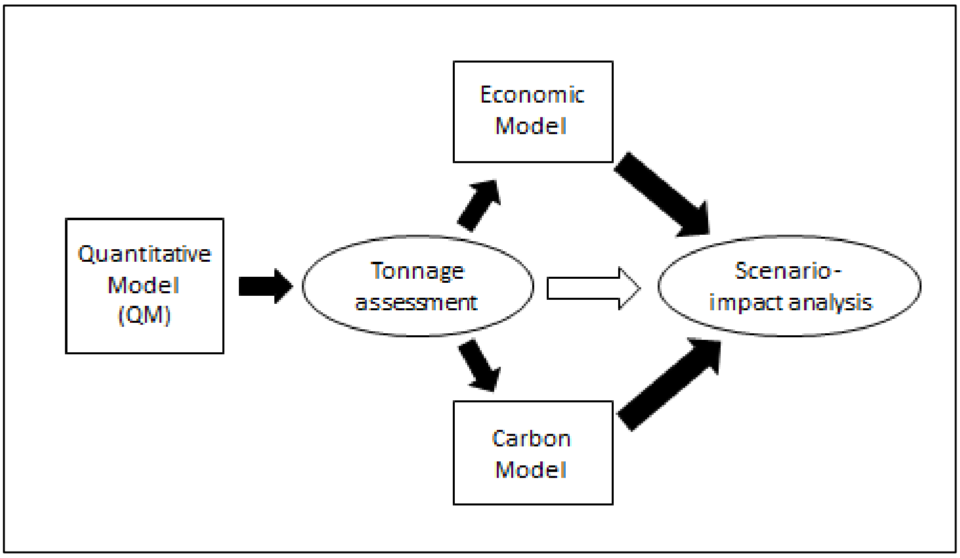


Figure 8.2: Quantitative Model (QM) structure and functions.

8.2.5.1 Impact analysis – waste tonnages

In determining the impact of each vision and scenario pathway Table 5.10 reaffirms the baseline levels of waste tonnages in the study area (2.70Mt) as well as the materials from each waste stream being managed by waste management method (e.g. recycling). The baseline values show 66.9% of all wastes were being recycled or recovered in 2012 with 33.1% (896kt) being sent to landfill disposal. This level of overall performance masks the differences by waste stream but represents a holistic perspective on the WMS (see Seadon, 2010). When LACW and C&I wastes are considered (e.g. the main waste streams containing active wastes specified in the landfill directive diversion targets), recycling accounted for 45.8 and 57.3% of the totals with recovery operations accounting for a further 5.81 and 6.88% respectively. In order to reach the specified ZW criteria (recycling or recovering at least 90% of all wastes – ZWIA, 2009) this would require LACW recycling and recovery to increase by a further 38.4% (equivalent to 130kt) and C&I wastes by a minimum of 25.8% (equivalent to 246kt).

Such large scale change may be achieved through significant annual increases in recycling and recovery of materials (as envisaged and being delivered through the Welsh zero waste plan - WAG, 2010; DEFRA, 2014a); or via reductions in overall generation (primarily through policy initiatives on prevention and reuse) coupled with sustained recycling and recovery. In addition, the impact of wider exogenous variables has the potential to significantly alter levels of waste generation (e.g. population change; economic growth and adopting new economic models). As outlined previously, scenarios CE and EC seek to significantly reduce generation of waste whereas scenario VM has a greater focus on maximising recycling and recovery in order to achieve the zero waste goal. Scenario ED provides an indication of what could happen with a set of factors negatively impacting on waste generation coupled with little change to current policy approaches.

8.2.5.1.1 The impact of systems variables

Systems variables have the potential to impact on levels of waste generation on a considerable scale. For example; an economy which is in recession will suppress consumer demand and the production of good and services thus resulting in a downwards pressure on levels of waste generation. This pressure comes from the change to the physical production system (i.e. lower levels of production) and from the attitudes and behaviours of consumers (i.e. reduced demand for goods and services). Figure 5.12 showed that three scenarios (CE, VM and EC) all had profiles showing an overall reduction across the period which contrasted with the upwards profile of increasing generation compared when assessed against the index value (1.000 = no change). The cumulative change for systems variables across all scenarios was modest. Of the reducing scenarios; VM produced the largest cumulative impact (7.29%) with scenario EC producing the least cumulative impact (3.59%). In contrast, scenario ED had an increasing impact of 9.01% across the backcast period (2012-2050).

Assigning values to exogenous and endogenous variables (+ or -) was achieved through the interview process (n=8) and in consultation with the supervisory team with the range of values aggregated to produce a weighting for each scenario. The subjectivity of the interviewees and team members was overcome with aggregation as the goal was not to predict but to give an indicative value to be used in the QM as a means of testing the results. There were fourteen variables (7 exogenous and 7 endogenous) which produced a considerable variation (non-linearity) in systems variables values. In contrast, the values for prevention and reuse produced somewhat linear profiles (as seen in Figures 5.13 to 5.15). For example; all scenarios were first calculated in terms of individual controlled waste streams where an individual target for prevention and reuse of 25% for C&D (see Table A12.9 in Appendices 12) wastes could be calculated across the period with consideration given to specific policy impacts.

8.2.5.1.2 Problems encountered and solutions found

A somewhat unexpected outcome occurred when final calculations were made within the QM in terms of applying the changes for systems variables and those for prevention initiatives. The decision was made to deduct the impacts of systems variables before prevention as these would impact at different magnitudes within a single year, whereas prevention impacts would be measured as a final year impact (determined by the relative change in overall arisings not attributable to recycling, recovery or disposal). The effect of this process saw a marginal reduction in the anticipated impact of combined variables changes and prevention. This variation was attributed to an issue with aggregation and it was discovered that a further step was required to account for the relative weightings of each controlled waste stream after aggregation. The full QM results for each scenario shown in Tables 5.12-5.15 have had the required adjustment accounted for.

8.2.5.1.3 Assessing the impacts against zero waste criteria

Table 8.2 shows the results for variables changes, waste prevention and reuse initiatives across the four scenarios.

Table 8.2: Summary of change factors (cumulative %) for systems variables, prevention and reuse as well as the total changes to waste generation across all scenarios by 2050

Change factor	CE	VM	EC	ED
Systems Variables	5.74%	7.29%	3.59%	-9.01%
Prevention	4.26%	4.13%	11.66%	0.00%
Reuse	14.34%	8.68%	8.79%	1.71%
Totals	24.34%	20.11%	24.04%	-7.31%

Table 8.2 summarises the overall change experienced under each scenario in waste generation (indicated in Figure 5.16 and Table 5.13). The three reducing scenarios show a very significant reduction in excess of 20% (with a maximum under CE of 24.3%), contrasting with a modest increase of 7.31% in waste generation under ED. However, the means of achieving the reductions vary considerably.

Scenario CE achieves most of its reduction through reuse in keeping with the cradle-to-cradle (C2C) principles (see Braungart and McDonough, 2002) which underpin the concept of developing circular economic model (EMF, 2011; 2012). Indeed, Table 5.13 shows that high levels of recycling (78.2%) and recovery (13.3%) are a central feature of the scenario which ultimately succeeds in achieving the ZWIA definition, with 91.5% of all controlled wastes diverted from landfill and incineration without energy recovery compared with a baseline of 66.9% (recycling 57.7% and recovery 9.16%) of overall recovery with 33.2% of all wastes sent for disposal.

Scenario VM achieves the majority of its reductions from a combination of reuse (8.68%) and systems variables changes (7.29%) as the emphasis is on capturing and realising a value from materials rather than prevention. This ‘valorisation’ approach shows an increase in recycling from the baseline (57.7%) to 79.2% by 2050. The scenario reaches the ZWIA definition through increasing overall recovery to 13.5% resulting in a total of 92.7% of all controlled wastes diversion from final disposal.

Scenario EC emphasises sustainability and the reduction of environmental impacts from waste management with a significant emphasis of resource rather than waste. Most of the overall reduction is achieved through prevention initiatives (11.7%) as policies are focused around considerations of design, extending product lives, leasing models and changing consumption patterns. Reuse is also a significant factor as materials are circulated within the economy with a new Resource Strategy (Zero Waste England) introduced from 2020, incorporating many of the C2C principles, resource efficiency approaches and circular business models supported by government, industry and consumer choices. The 'sustainability approach' replaces waste with resource as a definition for secondary materials with those materials requiring disposal being placed in cells designed and engineered for future accessibility as technologies come on stream. Under scenario EC recycling increases to 85.4% (the highest level of all scenarios) but sees recovery reduce to 8.04% (the lowest level of all scenarios) reflecting the emphasis on diversion from incineration (even with energy recovery as this is a one-off final gain rather than the multiple benefit of recirculating materials through recycling). These performance figures mean that scenario EC achieves the ZWIA definition with the highest percentage of remaining controlled wastes (93.4%) being diverted from final disposal.

The reference scenario ED witnesses an increase in waste generation linked to systems variables changes (9.01%) but is also impacted by a continuation of policies which maintain a role for reuse (1.71% reduction). This means there is an increase in generation of controlled wastes by 7.3%. During the backcast period recycling rates decline to 51.8% (an overall reduction of 5.9%) which is accompanied by a diversion from landfill of 29.7%. The increase in waste generation and diversion from landfill are managed by means of recovery operations (including incineration via EfW) with a greater than threefold (310%) increase in materials destined for this management route. AD plays a significant role within this scenario as there is a continued emphasis on energy security and alignment with waste policy (see DEFRA, 2011d; ADBA, 2012). This is the only scenario not to achieve the ZWIA definition, reaching 78.3% overall recovery of controlled wastes with a significant emphasis on incineration as a waste management method into the future.

In terms of tonnages Figure 5.16 gives and overall comparison of the four scenarios showing the marginal difference between the three reducing scenarios with the increasing trend under the reference scenario (ED). The overall changes are attributable to either systems variables or waste prevention (prevention and reuse initiatives). Table 5.14 compares these changes and shows scenarios CE and EC accounting for 657kt and 649kt reductions respectively with VM totalling 543kt reduction across the period (2012-2050). In contrast, scenario ED sees an overall increase of 270kt reaching an overall controlled wastes total of 2.90Mt. Thus overall performance for waste tonnages is comparable under scenarios CE and EC with scenario VM marginally above these (~110kt).

8.2.5.1.4 Evaluating the tonnage results with the research objectives

In this research objective 2 aimed to identify future zero waste scenarios utilising a backcasting approach. In addition, objective 5 was to propose a ‘fit-for-purpose’ model for holistic and sustainable waste management. In terms of objective 2; the policy packages (see Table 5.2 and Tables 5.7 to 5.10) developed for each scenario produced different outcomes when tested for impact within the QM (see Tables 5.13). These outcomes have been assessed against the ZWIA definition of zero waste (to achieve a 90% diversion of all wastes from landfill and incineration) (ZWIA, 2009). Three of the scenarios exceeded this level (achieving between 91.5 and 93.4% diversion of remaining controlled wastes compared with a 2012 baseline). The remaining scenario (ED) failed to achieve the defined level and also showed an overall increase in generation of controlled wastes, thus illustrating the capability of the QM to identify negative outcomes as well as positive.

In terms of objective 5; the QM was developed in spreadsheet format to make it an accessible tool for stakeholders and potential decision-makers and can be utilised as a model to test multiple scenarios and multiple variations and permutations. The model is also capable of scrutinising wastes/resources at the individual waste stream level as well as for metrics other than tonnages (e.g. carbon and economics). This degree of flexibility can account for subtle or more radical changes to variables capable of impacting WMS in England or elsewhere.

8.2.5.2 Impact analysis – economics of waste/resource management

Economic impacts associated with policy approaches in each scenario were calculated in terms of the monetary value for each factor as either incurred or avoided costs:

- Gate fees (charged by all facilities for acceptance of materials)
- Landfill tax (charged at different rates for active and inert wastes)[1]
- Infrastructure provision (new facilities or expanding existing sites)

8.2.5.2.1 Gate fees calculations and results

It was necessary to produce a range of mean values for gate fees charged as the scale of facility and type of operation has implications for charging. WRAP have produced a guide since 2008 (WRAP, 2013c) which were used to produce the estimated values (see Table 5.16) which were then applied to specific waste streams (see Table 5.17) reflecting the nature of that waste (e.g. active or inert). These figures were incorporated within the QM as an economic model which could be linked to tonnage data through factor values (£/tonne or £/kg where appropriate).

In order to determine levels of gate fees across the backcast the focus of the scenario (e.g. sustainability focus within EC was represented as higher fees in order to incentivise

[1] To simplify the model tax exempt materials (e.g. inert materials used for daily cover and road construction) are not estimated in order to provide an indicative value

diversion from landfill as a cost mechanism) and the system variables changes (see section 8.2.5.1.1) were used to give an indication of where these should be set (Figure 5.17). Waste tonnage data (generated and avoided) is then used to produce an overall gate fee costs and savings value for each scenario across the backcast period (see Figures 5.18 and 5.19). This approach allows a baseline to be determined (£52.1m) as well as final values in 2050. Figure 5.18 shows an increase for three scenarios (CE, EC and ED) with a significant reduction (£5.6m) for scenario VM. The economic model is used to determine absolute values rather than relative values as the concern is with the amount of incurred costs (or level of potential savings) rather than the proportion of change which would merely reflect underlying tonnage calculations.

These absolute values produce linear profiles for both costs (Figure 5.18) and savings (Figure 5.19) reinforcing the results from Table 5.20. Indeed, Figure 5.19 is useful to compare the cumulative savings (as the area between the series line and the *x-axis*) of scenarios. These 'potential' savings represent the avoidance of sending 'prevented' tonnages to landfill; these figures could therefore have been more significant if the calculation had been in relation to gate fees for specific facility types. The cumulative savings performance shows that scenario EC has the largest savings across the period (£40.2m) compared with CE (£35.6m). Scenarios ED and VM have the lowest savings with £30.4m and £30.3m respectively (see Table 5.20).

8.2.5.2.2 Landfill tax calculations and results

Landfill tax is relatively predictable as the historic record has shown (see Figure 4.7) and the degree of certainty provided to the waste sector through announcements on changes to the landfill tax escalator. However, scenarios which incorporate this variable have to recognise the previous success attributed to the fiscal instrument as the main driver of diversion from landfill in England (DEFRA, 2013a) at the time of writing (late 2014) and over recent years. As part of this recognition, landfill tax must be viewed as being applicable for the duration of the backcast. Notwithstanding, the levels are liable to change according to the emphasis placed on diversion within future waste policy. Table 5.18 summarises rates across scenarios for the milestone years of the backcast; with a number of factors are of note. The standard rate increases substantially under CE, VM and EC but decreases under ED after an initial period of increase (2012-2020). The low rate is a fraction of the standard rate, increasing marginally under CE and VM; remaining constant under ED and increasing more than sevenfold under EC.

Estimations for hazardous waste are more difficult as no specific rate is set under the landfill tax regime. However, a baseline estimation (set at 3x the average gate fee to reflect the far higher cost of disposal associated with hazardous materials) was made to provide a comparison point for future costs. As can be seen, the rate remains constant under ED but increases in varying proportions under the remaining three; with scenario EC having the highest rate by 2050 (£420.50/tonne).

Determining the overall costs and savings associated with landfill tax requires calculating the rates (Table 5.18) with the tonnages (see section 8.2.5.1.1) to provide a comparison. The profiles for costs (Figure 5.20) and savings (Figure 5.21) shows scenario EC with the worst overall cost performance across the period countered by the best overall savings performance. In cost terms, scenario ED has the lowest mean (£30.0m) compared with the highest mean under scenario EC (£47.0m). In contrast, these rankings are reversed for cumulative savings with EC having the highest (£59.6m) and ED the lowest (£7.7m).

8.2.5.2.3 Additional infrastructure assessment: calculations and results

It is only possible to provide estimation for costs of infrastructure as there are few reports and sources of data available given the commercially sensitive nature of the subject materials. However, a 2011 report ‘Rubbish to Resource’ (APSRG, 2011) as well as a number of case studies on the WRAP website (WRAP, 2013c) were utilised to provide an indicative range of values. The number of facilities required by each scenario (Table 5.19) was calculated based on the change in tonnages sent to recycling or recovery operations by 2050. Estimated costs are derived from calculations in Table 5.20 with the mean cost of recycling investment being £6.15m and mean residual investment being £201.5m (which produced a figure of ~£20bn for 150 facilities additional capacity for England by 2020). Additional infrastructure has a bearing on the spatial patterns proposed in Chapter 6 and will be revisited in section 8.3.

8.2.5.2.4 Evaluating the economic results with the research objectives

The overall economic performance of the scenarios is thus measured in terms of costs and savings derived from the three factors: gate fees; landfill tax and additional infrastructure. Table 5.21 shows that when all three factors are combined the total economic cost of each scenario can be calculated. By 2050, scenario VM has the lowest annual costs (£67.9m) compared with the highest annual costs under EC (£123.3m). Total costs for additional infrastructure are averaged across the period in order to spatially represent these as a mapping layer in GIS. Results for cumulative savings are also presented (as GIS map layers for milestone years) as annual savings; with performance assessed in Table 5.21 over the entire period. In terms of potential savings scenario EC is the best performer as a result of the far higher levels of gate fees and landfill tax across the backcast period.

The use of economic metrics (costs and savings) addresses the requirements of objective 5 for the model to be ‘fit-for-purpose’ as there is considerable debate within the sector and across government (national and local) about the future costs of waste management (APSRG, 2011; DEFRA, 2013a; Eunomia, 2014). This scenario based approach allows potential policy choices (e.g. an extensive programme of EfW construction for England or an AD strategy which seeks to commission and build hundreds of new facilities) to be assessed in order to determine if other approaches are more cost-effective in realising the same overarching goal of sustainable waste management. Indeed, the economic model can evaluate many multiples of scenarios (rather than 4) and could be combined with approaches such as CBA or LCA to make a business case for a specific policy approach.

8.2.5.3 Impact analysis – carbon emissions from waste management

Determining the carbon emissions from all controlled waste streams is undertaken in order to address objective 5 (see section 1.4) and is achieved through developing a carbon model within the overall QM (see Figure 8.2). The importance of compositional analysis comes to the fore with this assessment as carbon factors are calculated in terms of the individual fractions of waste streams (Turner et al. 2011; ZWS, 2012; DEFRA, 2013e). The carbon metrics applied in England (DEFRA, 2013_{carb}) are used in the calculations in order to align results specifically with the study area; but other footprinting tools may be appropriate for different locations. Indeed, the Zero Waste Index (Zaman and Lehman, 2013) incorporates carbon emissions as one of the factors for calculating zero waste within city locations. The carbon factors ($kgCO_2/t$) of the 15 compositional categories area shown in Table 5.22 with controlled waste streams broken down to indicate where emissions reductions policies can be targeted (e.g. for metals and textiles with the highest carbon factors). This theme of targeting policies continues in table 5.23 in terms of theoretical maximums for both avoidance and residuals which help identify the relative importance of waste streams. In this way, emissions from the C&I waste stream are most significant under both avoidance and residual considerations.

8.2.5.3.1 Direct emissions calculations and results

The direct emissions used in the carbon model assess those emissions from landfill of residual wastes. The performance profiles for direct emissions (Figure 5.22) show a consistent downwards trend for scenarios (CE, VM and EC) with a similar performance over the period 2012-2030 for ED before marginally increasing to the end of the backcast period. This performance is measured from the baseline (2012). Scenario EC achieves the lowest direct emissions by 2050 (39ktCO_2e) with ED having the highest (188ktCO_2e). This pattern is repeated for cumulative emissions (Figure 5.23). The impact on direct emissions is predictable given the connection with landfill diversion policies for all scenarios and the impact this had on tonnages (see section 8.2.5.1).

8.2.5.3.2 Savings versus landfill: emissions avoided by diversion

Avoided emissions in this research context are those which are avoided through diverting materials from landfill and from the avoidance of emissions produced in replacing discarded items and services within the economy (including those from energy and water consumption). The next section will look at avoidance in terms of preventing the generation of waste or from reuse of materials.

The key factor in terms of 'savings versus landfill' (DEFRA, 2013e) relates to the amount of materials which have been sent for recycling or recovery under each scenario. Consequently, the performance of each scenario moves relative to changes in recycling and recovery of materials with scenario CE seeing the least increase in avoided emissions as this scenario also witnessed the lowest increase in materials being recycled or recovered above the baseline (see Table 5.13). This logic holds in terms of scenario ED having the highest avoided emissions because of the significant increase (more than threefold) in materials being sent to recovery operations. This logic is also witnessed with emissions profiles (Figure 5.24) and through calculating the cumulative savings versus landfill (Figure 5.25); which shows avoidance through recycling significantly higher under scenarios EC, VM and CE compared with ED countered by almost double the avoided quantity (19.3MtCO_2e) from recovery under ED over EC.

8.2.5.3.3 Avoided emissions: variables changes and prevention

To finalise the determination of carbon impacts, avoidance of emissions through systems variables changes and/or prevention initiatives are accounted for in terms of the reuse values within the carbon metrics calculations (DEFRA, 2013e). The profiles for waste prevention (Figure 5.26) and variables changes (Figure 5.27) show emissions avoidance under both categories for scenarios CE, EC and VM. In contrast, scenario ED shows small amounts of avoidance from prevention initiatives (e.g. reuse) but a reversed impact for systems variables, in other words increased emissions from this category. These changes are shown with greater clarity in terms of cumulative savings (Figure 5.28). The results indicate the carbon model is capable of differentiating factors which impact emissions negatively and positively and may be useful in identifying types of feedback loops (e.g. balancing or reinforcing) under specific scenario conditions.

8.2.5.3.4 Evaluating the carbon results with the research objectives

Carbon impact is calculated as the final means of delivering objective 5 in relation to the policy connection between waste management and decarbonising the economy (CAT, 2010). In so doing, decision-makers have a model which can generate results applicable across research disciplines (e.g. waste planning, economic development and climate change). In terms of overall carbon impacts for each scenario; savings versus landfill are summed with avoidance from prevention and systems variables before deducting direct emissions (Table 5.24). This shows that scenario EC is the best overall performer compared with the worst performing scenario (CE). These calculations do not include carbon impacts from new infrastructure provision as the absence of reliable data precludes adding this to Equation 5.1 at the time of writing. However, as Table 5.25 shows the calculations taken forwards (from Table 5.24) can be considered indicative of the performance which might be anticipated if these were included.

8.2.5.4 Evaluating impact: comparing scenario performances

In order to test the scenarios produced and to make the QM developed as robust as possible, three separate metrics were utilised which are readily recognisable to decision-makers and stakeholders within the waste and resource management fields (i.e. tonnages; economic costs and savings; and carbon emissions). Table 5.26 showed the final comparison of these three metrics coupled with a performance matrix to indicate where scenarios had advantages or disadvantages compared with the others. Although the results are reported as an overall ranking this does not necessarily make any one scenario the best choice for the future. Indeed, the purpose of backcasting is to show a range of possible future states (Robinson, 1990). This may seem non-committal *prima facie* but through the process of outlining policy packages (as scenario narratives) to testing the impact of these packages (via metrics) and ultimately determining if a scenario can meet the recognised definition of zero waste (ZWIA, 2009) under these conditions; the backcasting process is providing stakeholders and decision-makers with options. The purpose of these options is to illustrate the potential for the future of ‘waste’ to be considerably different from the current pathway, often considered as unsustainable.

It is possible to say that three scenarios meet the ZWIA definition of zero waste and that by doing so waste generation will reduce considerably under a range of different circumstances. However, some of these circumstances (such as making the disposal of waste prohibitively expensive under scenario EC) can be counter-productive and the reference scenario can be a more economically appealing option. On the other hand, a scenario based on principles of the circular economy may not deliver the levels of emissions savings expected.

8.2.5.5 Problems encountered and solutions developed

The availability of data was a profound problem in terms of waste streams (e.g. C&I and C&D wastes) and for determining the accuracy of economic & carbon calculations (e.g. infrastructure costs and embedded carbon as factor values). However, indicative results serve the requirements of the scenario process in terms of being non-predictive which ultimately reduces the need to rely on the quantitative output. Notwithstanding, the scenarios produced should be credible to audiences and to potential users (e.g. decision-makers and key stakeholders within the resource management field). In addressing, the data gaps every effort was made to obtain data sets identified (e.g. waste returns data from the Environment Agency) which could be used as the basis for robust estimations methodologies (see sections 4.1.3 and section 4.3 for examples). As such, refinement of the QM with more accurate data as it becomes available can only to serve to increase the level of acceptability and robustness. This emphasis on data should also be tempered with the value of producing radical visions which challenge current ways of thinking and policy development about waste. To that extent, the indicative nature of some of the outputs based on estimated data, does not detract from the overall package produced in terms of visioning; baseline assessment of the system; scenario development and impact assessment. Indeed, these outputs are further enhanced through the use of GIS techniques as discussed in section 8.3.

8.3 GIS modelling results

The GIS methodology developed within the research was designed to meet the requirement s of objective 3 ‘future infrastructure capacity needs at the sub-regional level’ and objective 4 ‘embedding the backcasting output within a GIS environment’. Chapter 6 speaks to the first of these in terms of spatially assessing the baseline conditions of the WMS before applying a GIS-AHP site-evaluation process to future infrastructure assessment before running the opportunities and constraints models to determine the overall suitability of sites within the MWDF local plan for the study area.

8.3.1 Baseline system mapping

The baseline mapping of the WMS looks at the spatial distribution of arisings (by waste stream) and infrastructure (by facility type and capacity). Waste management facilities cover a range of operations from sorting through crushing and shredding to incineration and deposit in landfill. The scope of this study covers all facility types but recognises that diversion from landfill has been and remains a key policy focus in England (DETR, 2000; DEFRA, 2007a; 2013a). Section 4.7 contains a number of baseline maps for exogenous variables which have been discussed previously.

8.3.1.1 Mapping arisings by waste stream

In order to present the tonnage data (as well as data for economic and carbon metrics) these must be converted into spatially relevant formats (i.e. calculated and then geo-referenced). Arisings data were calculated for individual LSOAs (n=422) in the study area through the application of Equation 6.1. LSOA data layers were obtained from Ordnance Survey (OS) Open Source data sets with the geo-referenced data exported to excel spreadsheet format. Population data (Figure 4.9) was then extracted and entered into the spreadsheet so that resident numbers and density could be used to calculate per capita tonnages (t/cap) and waste densities (t/ha). The overall tonnage data for each waste stream could then be calculated for each LSOA and the relevant column for each output calculated using excels formulas function. Figure 6.2 shows the spatial distribution of arisings by waste stream in 2012.

The baseline was calculated according to waste streams in order to provide the opportunity to differentiate impacts over the backcast period. However, the assessment tonnage metric of using 'all wastes' (all controlled wastes) was comparable to the economic and carbon metrics for visualising outputs (example output maps by waste stream are included as Figure A12.7 to A12.12 in Appendix 12 for indicative purposes).

8.3.1.2 Spatial distribution of facilities in the study area

Understanding where waste facilities are located as well as the scale and type of operation is a fundamental requirement to determine if a system can perform optimally. If this is found to be inadequate, the spatial data can be utilised to assess where additional capacity may be needed or whether a new spatial pattern may be more effective (e.g. for maximising throughput; minimising costs; and minimising environmental impacts). Figure 6.3 showed the spatial distribution of all facilities which were operational (receiving wastes) in 2012. The proportional symbols used gave a good indication of the overall permitted capacity this was supported with subsequent analysis first by district (Table 6.1) showing the permitted annual capacity as well as number of facilities and actual throughput (received and removed wastes). A total of 101 operational facilities were spread across the 7 WCAs with an operational capacity of 2.38Mt in 2012.

Operational capacity is then reported by facility type (see Tables 6.2 to 6.5) in order to identify gaps in overall capacity as well as for specific WCAs (e.g. no organic waste facilities in CBC). In terms of recycling (organic and other treatment) and recovery facilities Table 6.6 showed only 595kt operational capacity for recycling (55 sites) and 118kt capacity for recovery (5 sites). Allowing for additional materials diverted from transfer facilities and the use of secondary permits at a number of landfill facilities the 713kt capacity (29.9% of all wastes received) would only be adequate to meet a 50% recycling target for LACW and C&I wastes (~640kt) within the study area. This suggests a significant need exists to enhance future operational capacities and/or provide additional sites with integrated facilities capable of managing large quantities of different materials. These findings indicate that scenarios with additional capacity are required to meet a zero waste target of 90% recycling and recovery of all remaining wastes. Section 5.4.1 indicated that the lowest tonnage scenario would require 1.87Mt recycling and recovery capacity in 2050 for all waste types. The baseline assessment indicated that an additional 860kt of inert wastes were recovered at exempt sites and as aggregates (Table 4.3) which would equate to 1.57Mt recycled or recovered leaving a minimum additional requirement of 300kt capacity by 2050 to achieve the zero waste definition (ZWIA, 2009). Notwithstanding the shortfall in capacity, the proposed MWDF local plan recommends reducing the number of operational facilities to 98 from 101 (NCC, 2012) and does not give any detailed indication as to how the operational capacities of the remaining sites will be expanded to meet the increased waste generation forecasts contained therein.

8.3.2 Addressing the problem: applying GIS based AHP

To begin to address the problem of the identified future infrastructure capacity gap, there first was a need to evaluate the proposed facilities within the MWDF. Previous research at the regional scale has highlighted the problem of inadequate infrastructure and the need for a robust modelling approach which can be applied at different scales (DTZ/LR, 2009a). The tool developed previously used an MCDA approach to identify areas of search by means of producing opportunities and constraints maps of a geographic area utilising LSOAs as the unit of analysis. It was decided to use Saaty's AHP as a relatively intuitive method with outputs readily recognisable to stakeholders involved.

The literature states the need to identify locally specific criteria which can be grouped as opportunities or constraints for the siting of waste management sites (Sumathi et al. 2008; DTZ/SLR, 2009a; De Feo and De Gisi, 2010). In total 5 groups of opportunities and 4 groups of constraints were identified (Table 6.7) these contained 19 individual opportunities criterion and 22 constraints. In order to refine the suitability model a typology approach was utilised drawing on previous findings with stakeholder groups (De Feo and De Gisi, 2010). Of the opportunities criterion, 11 were preferential and 8 penalizing while the constraints produced 6 which were excluding and 16 penalizing (see Tables 6.8 and 6.9). This meant that extra weight could be given to preferential criterion but any analysis which registered an excluding criterion would be rejected. The reasons for assigning a criterion as penalizing related to economic considerations in terms of minimising costs (e.g. connecting to electricity and gas grids); suitability for certain waste management operations (e.g. types of facility capable of providing jobs to local community); and potential for provisioning of facilities tailored to addressing gaps in capacity. It can also be seen that the criterion identified as preferential are related to the existence of either physical capacity (e.g. existing waste sites or the presence of railway/waterway infrastructure) or specific localised conditions (e.g. areas of new development being favourable for certain technology types) acting as potentially facilitating factors for waste management infrastructure. At this stage a problem formation hierarchy (PFH) was drawn up which breaks down the goal/objective before reducing the problem in terms of scale (i.e. from groups to individual criteria) (see Figure 6.4 and 6.5).

8.3.2.1 Capturing the data and analysing the results

Stakeholders (n=40) completed priority scale forms (Figure 6.6) for macro-scale (group) criteria and micro-scale (individual) criterion. The AHP software developed by Goepel (2013) was an intuitive AHP tool in spreadsheet format which produced pairwise comparison matrices and provided results in terms of Eigenvectors (percentage weights) as well as undertaking consistency testing to validate outputs (see Figures 6.7 and 6.8). The normalized principal Eigenvector values (weights) are taken forwards for final evaluation of all TS and NTS responses with a view to producing a final set of aggregated weights.

8.3.2.1.1 Group criteria weighting

Tables 6.10 and 6.11 report the results of TS and NTS with the consistency ratio (CR) shown for all stakeholders which should be less than 0.1 to satisfy the Saaty requirements (Saaty, 1980). Only one stakeholder (T20) did not meet the required CR but the consolidated CR was unaffected and thus the results were still counted. In terms of group criteria TS prioritised socio-economic factors within opportunities (16.48) and environmental receptors within constraints (14.80). In contrast, NTS prioritised existing waste sites (17.82) within opportunities but matched TS in prioritising environmental receptors (19.47) albeit with a greater weighting value.

8.3.2.1.2 Individual criteria weighting

The same pairwise comparison approach was utilised for individual criteria as with groups with one difference. Because the ordered weighted average (OWA) had already been established with groups there was no requirement to repeat this for individual criterion. Instead a random sample of TS and NTS were used to assign weightings (see Tables 6.12 and 6.13) with consistency tested for each grouping.

8.3.2.1.3 Aggregating weights

To avoid bias in the final OWA weights for TS and NTS are averaged to produce a mean weighting which is taken forwards (Table 6.14). This produces a change in rankings for socio-economic factors compared with TS results but doesn’t appear to be produced by the ‘rank reversal phenomena’ (see Tung et al. 2012). These aggregated weightings are then applied to individual criterion for use in the GIS models (overall suitability; opportunities and constraints) (see Tables 6.15 and 6.16). The development and use of these weightings avoids the use of heuristic values within the suitability analysis and are readily repeatable with the steps outlined. The only alteration which is required comes when entering the values within the GIS software as the numbers must be rounded to whole numbers (see Table 6.19).

8.3.3 GIS model development

The results from the baseline mapping and AHP site evaluation process are the basis for the development of thematic maps and the final application of the models. The last remaining steps are: to define buffer distances from receptors and facilities; produce thematic layers; run the models to identify areas of search; and produce the final suitability maps.

Site selection criteria for waste facilities are defined within waste planning literature and guidance from the Environment Agency (in England) (DCC, 2011; EA, 2012c). Considerations include: land take (ha); land use; access; vehicle types using sites; common features; and distances to receptors (Table 6.17). It can be seen that buffering distance recommended in terms of facility proximity to receptors typically ranges from 100-250m depending on adjacent land uses or the potential for nuisance (noise and visual intrusion). This contrasts with a range of 200-500m for constraints buffers (Table 6.18).

8.3.3.1 Thematic map development and analysis

A total of 39 thematic layer maps were produced as part of the analysis; 18 opportunities and 21 constraints. Data sources were available from a number of sources when the collection phase was undertaken (Feb 2011 to October 2011) but a number of layers had to be developed as bespoke. Since the end of the data collection and analysis stages (mid-2012) a range of sources have increasingly become available which would have considerably reduced development and analytical timescales particularly under the Geo Portal introduced in 2013 and bringing together a range of sources formatted for direct loading into GIS software packages. All maps produced were at a raster resolution of 25m meaning that each pixel within the frame was a square of 25x25m and all are projected using OSGB1936 (British National Grid).

8.3.3.1.1 Constraints maps

The purpose of producing thematic maps is to group recognisable land uses to confer as much information as possible when the actual data is presented in abstract. Land use maps are very accurate as they are often generated from satellite imagery which allows high resolution mapping. However, they can also be out-of-date as the CEH data (Figure 6.16) dates from 2007 being the last available dataset during the data collection phase (CEH, 2010). It does provide a very good reference source for testing other data sets, particularly those of a bespoke nature.

Constraints layers are shown thematically in four maps (Figures 6.10 to 6.13). The first thematic map is surface water; showing 3 layers (canals are part of the rivers layer) (Figure 6.10). The spatial pattern of rivers is extensive throughout the study area with the River Nene as the major river, forming most of the drainage basin for the study area. A number of large bodies of water (e.g. Pitsford Reservoir) are in evidence, particularly within the upper Nene Valley. Derived from the BGS geological maps Source Protection Zones (SPZs) are shown to illustrate areas of significant potable water abstraction. The climatic conditions of the study area and proximity to wider East of England as well as presence of extensive aquifers means that future demand for potable water sources may increase and thus impact on potential siting of waste facilities as all three layers are exclusionary.

Environmental receptors (Figure 6.11) are spread throughout the county and often exhibit multiple categorisations for the same site (e.g. SSSI and RAMSAR). A number of the sites correspond with surface water features and as such would be picked up as excluded through the application of the constraints model. However, these layers are considered to be penalizing in nature and would be reconciled against individual sites in the final suitability assessment.

Conservation receptors (Figure 6.12) are distributed throughout the study area and range from large areas (battlefields) to small plots (listed buildings). The 250m buffers are included in the map to illustrate the disproportionate impact some types of receptors exert on the assessment. Of further note, the study area does not contain any agricultural land classified as Grade 1 but does contain extensive areas of Grade 2 which is exclusionary. The rest of the receptors in this grouping are penalizing.

The final category is flood risk (Figure 6.13) showing flood zones and historic flood event layers. Areas of significant risk are considered exclusionary with medium and low risk zones as well as historic extent areas (defined as a 1 in 100 year event) considered penalizing. These definitions are subjective and would depend on a particular policy focus. The debate around flooding in England has been subject to much debate after the winter floods of 2013/14 and so there is the scope within the modelling to alter weightings to reflect such concerns or to run the model in isolation (e.g. to consider riparian areas only in terms of flooding risk).

8.3.3.1.2 The constraints model

Essentially this is a restrictions model which finds the product of all restrictions (see Equation 6.4) to produce individual layer constraints maps (Figure 6.14a-d and Appendix 11a) as well as a final combined constraint map (Figure 6.15). The constraint model is included in Appendix 11 to illustrate the specific steps taken.

The output maps generate a Boolean score (either scoring 0 = constrained; or 1 = unconstrained) for each pixel (raster resolution 25m). The outputs are simple to interpret (Figure 6.14 and 6.15) as the outcomes are deliberately categorical. The individual maps illustrate the difference between each individual layer in terms of coverage. Some layers are very extensive in their coverage (e.g. rivers) whereas others are isolated and confined (e.g. parks and gardens). The final combined layer provides a very stark comparison, showing that 51% of all land within the study area is constrained (excluded or penalizing to waste facility siting).

8.3.3.1.3 Opportunities maps

A total of 16 layers were created for the spatial assessment and suitability modelling with these presented as 9 maps. These layers included bespoke maps developed from discrete data (non-spatial) which had to be geo-referenced as previously described for constraints. A number (n=10) of these layers were identified as preferential (e.g. existing sites and navigable waterways) while the remainder (n=6) are classified as penalizing thus impacting on the final suitability assessment.

Sources of waste included urban residential; workplaces; and SEL and accounted for 22% of the final weightings for opportunities (Table 6.19). These locations were considered to have the largest population densities; numbers of businesses on industrial estates and business parks; and areas of future development (which would generate multiple waste streams depending on the phase of construction). Facilities in close proximity to these locations (particularly large integrated sites) would benefit from reduced transportation requirements (costs and carbon emissions) including the potential exploitation of other modal transport networks (such as Greta Billing being close to the navigable section of the River Nene or the former Corby sewage works site being adjacent to railway sidings). The bulk of the locations identified as sources of waste are concentrated around the urban centres of Northampton, Corby, Kettering and Wellingborough (Figure 6.16) making these locations strategically important and prime opportunity areas for major investment.

The number of existing waste sites (Figure 6.17) includes 108 active sites accepting waste in the baseline year as well as in excess of 125 historic landfill sites distributed throughout the county but with concentrations around Corby (former steelworks sites) and the upper Nene Valley (gravel and limestone extraction sites).

Socio-economic factors (Figure 6.18a-d) are presented as bespoke layers as these are generated from datasets produced as spreadsheets (HCA, 2009; DCLG, 2011). Employment and regeneration locations are considered preferential as areas accepting waste sites are likely to receive a financial benefit through employment and potentially as host communities. Deprivation is a more complicated factor and has been considered penalizing as perceptions of waste sites can be negative among the public and siting facilities in such areas can be perceived as negatively reflecting the location. However, the spatial distribution of regeneration sites (Figures 6.18c-d) is heavily focused around Corby which also has some of the worst IMD scores within the study area (Figure 6.18a). In addition, LSOAs around Corby can be seen to have low levels of employment and would thus benefit from any opportunity to create more jobs and generate growth. Socio-economic factors account for 24% of final weights (Table 6.19).

Proximity to transport networks is a critical factor in terms of minimising costs and carbon emissions which is reflected in the penalizing nature of road connections in terms of distances away from these (Figure 6.19a). On the other hand, other modal transport networks are considered preferential as the policy focus in England and within the EU has been to move waste away from road transportation wherever possible. The major urban centres benefit from multiple road connections (including 3 motorway junctions in close proximity to Northampton) as well as rail connections and potential for developing navigable waterways (excluding Corby). Transport networks account for 13% of final weights within the suitability model.

Proximity to energy grids (Figures 6.20a-b) is a key consideration for any scenario making extensive use of either EfW or AD. Coupled with this was an assessment by LSOA of the numbers of households without grid connection (both electricity and gas) which may act as potential end users of locally generated energy. For the strategic assessment only major gas and electricity lines were considered as this would minimise connectivity costs through avoiding the need for conversion equipment (i.e. pressurisation equipment for gas grid injection). A number of rural LSOAs were identified (in darker colours) as being potential hosting locations for such facility types. Distance from main lines was considered penalizing in terms of cost and was reflected in the opportunities modelling. Using such considerations and developing the bespoke layers provided some very useful data and insights for potential stand-alone assessments (which is raised in Chapter 9). Proximity to energy networks account for 15% of final weights.

8.3.3.1.4 Opportunities model

The opportunities model uses equation 6.5 and the weighted overlay tool within ArcGIS 10.1 to calculate the final values for opportunities layers. The output in this case was not Boolean, but produced a 5 step valuation with 5 being most suitable and 1 being least. Figure 6.21a-d show the typical style of output maps for individual criteria with ringed 'buffers' clearly visible in each delineating the suitability of each criteria. It is clear that the tool works equally well for layers utilising polylines and polygons (it worked for point source data which was also tested). The full set of maps is contained within Appendix 11b.

The final step was to run the opportunities model for all variables to produce a combined opportunities map (Figure 6.22). A total of 5.40% of land within the study areas was found to be of high suitability with the bulk of this located around the eastern towns from Corby in the north to Wellingborough in the south. The available land was also subdivided in terms of the size of parcels (1-10ha; 10-65ha and >65ha) in order to determine whether parcels could support single sites or larger integrated sites with multiple facilities (Figure 6.23). A total of 14 parcels were >65ha with 19 further parcels ranging between 10-65ha. For land parcels of 1-10ha only 23 parcels were found which met this specified size. This meant that 56 locations covering 3,338ha met the criteria of highest suitability and were of the specified dimensions. The model is very restrictive for land around the PUA of Northampton reflecting the high demand for development land and the proximity of residential areas to any future waste sites. This issue could be addressed through locating operations on new build industrial parks (most likely in proximity to the major communication hubs along the M1). Such sites would benefit from on-site AD and EfW which have the potential to act as anchor tenants for high energy demand logistics operations (a feature of the M1 corridor close to junctions).

8.3.4 Suitability analysis of MWDF sites

The key criteria for undertaking the GIS assessment was to evaluate the MWDF local plan in order to determine if the sites chosen were fit for purpose and met the criteria of being located in areas of highest suitability. The results showed that of the 39 main sites and 59 non-main sites within the plan only 12 met the criteria of highest suitability (see Table 6.20 and 6.21). A total of 6 sites were from the main sites list and the same number was from the list of non-main sites (Figure 6.24). Of these sites, 6 had penalizing factors (2 main and 4 non-main) in relation to proximity to urban residential locations. These were mitigated by already being located in established industrial estate locations. As a result, the 12 sites were considered unsuitable to deliver any meaningful system of facilities capable of managing future need in terms of waste/resource management.

The assessment was undertaken again with the model set to include areas of moderate suitability. This assessment produced a further 32 sites which met the moderate suitability threshold; a total of 16 from each list (see tables 6.22 and 6.23). These sites are dispersed throughout the study area with at least one in proximity to an urban centre (Figure 6.25). The assessment of the MWDF local plan for facilities to meet future waste management needs (NCC, 2012) has shown the majority of sites (n=54) are located in areas of low suitability. This would indicate these sites as being capable of continuing operations under current permits but when this spatial assessment approach is applied, would be unable to expand their operational capacities to meet the need for further diversion of wastes to treatment and recovery.

The research thus proposes a range of spatial patterns which fit with the scenario narratives (see section 5.3) and the policy packages which they contain. Such spatial patterns have been proposed in the literature (Bates et al. 2008) but have not been described at the local scale addressing the system and materials holistically. A total of three spatial patterns are proposed: centralised; central core with outliers; and dispersed (see Figures 6.26 to 6.28).

The centralised pattern is applied to scenarios CE and EC and represents a radical change from the current approach to management and planning based on the WPA administrative boundaries. This pattern assumes a similar approach is adopted by all WPAs within England based on geographical capture zones around large integrated facilities (n=4 for the study area). These are supported with incentive schemes for residents in outlying areas (through council tax and reward schemes) as well as extensive use of bring sites delivered by the private sector (as seen with many retail chains currently). This approach goes hand-in-hand with prevention schemes and the impact of system changes which drive down generation rates. The focus of the pattern is thus capturing the maximum population (residents and businesses) in order to minimise transportation and costs through economies-of scale. Although, based on assumptions, these are reflected in the scenarios which are centred on circularity and sustainability across society which generates significant behaviour change in terms of viewing wastes as resource.

The central core with outlier's pattern is applied to scenario VM and is an incremental change in keeping with policy measures emphasising recycling and recovery. The focus on capturing value is critical to this pattern but is restricted by having to deliver a service based on WPA boundaries. This requires more facilities but does allow larger sites to be located close to large urban centres to realise economies-of-scale. There is also a need to minimise transportation costs and emissions as the number of journeys is likely to be significantly higher than with scenarios CE and EC under a centralised pattern, as more materials are recycling and recovered under VM (see section 5.4.1).

The dispersed pattern is used with scenario ED as a reference scenario as it uses those MWDF sites which meet the high and moderate suitability criteria (n=44). This pattern reflects the WPA boundaries and is an inefficient system producing higher costs than CE and VM as well as the highest levels of emissions. These spatial patterns are assessed further in Chapter 7 and are discussed subsequently (see section 8.4.3).

8.4 Synthesising the results

There were three stages covered in the chapter: mapping the visions; policy impacts; and impact analysis, which fulfilled the remaining requirements of the spatial analysis methodology (Figure 7.1).

8.4.1 Visualising the scenarios

To effectively evaluate the future visions the baseline values are revisited in order to produce overall values; LSOA values and per capita values (see equations 7.1 and 7.3). Figure 7.2a and 7.2b show the spatial distribution and frequency distribution of tonnages by LSOA under equation 7.1. Assigning tonnage values to LSOAs is an effective means of identifying where tonnages are being generated without applying density considerations. They do not show a particular pattern but provide a platform to visually compare temporal changes. This data is supported within the software via geo-spatial analysis tools to statistically illustrate any temporal change (Figure 7.2b). Finally, per capita calculations (equation 7.3) provide a further means of assessing change across the period of the backcast, with results showing a baseline per capita value for all wastes as 3.91tpa.

8.4.1.1 Developing a metric to evaluate the MWDF

A means of providing visual comparison is required in order to assess spatial distribution of facilities using geo-processing tools (e.g. buffering). A metric which shows the density of wastes (as tonnes per hectare) was decided on and was calculated via equation 7.2. The frequency distribution (Figure 7.3) of these values differed considerably from LSOA calculations as these are a function of area rather than population. When presented as a mapping layer (Figure 7.4a) the results are striking. This visualisation allows tonnage (or other metrics) to be geographically defined within a specific location (e.g. densities are highest around major urban centres). By using the GIS environment the statistical summary can be extracted (Figure 7.4b) to illustrate where change occurs rather than relying solely on the visual representations.

8.4.1.2 Population change

The variable with most impact on 'all wastes' tonnage within these equations are therefore population as the area of the LSOAs is fixed. The QM modelled population change for all scenarios (Table 7.1) showing all scenarios increasing in population over the backcast period but at different rates and with different profiles (for example; population increase rapidly under VM until 2040 after which it reduces until 2050).

8.4.2 Policy impacts

8.4.2.1 Future waste tonnage results

The QM produced detailed tonnage figures for each controlled waste stream which were consolidated to produce 'all waste' values (Table 7.2). These results showed change against the baseline (2.70Mt) for each scenario with summary values being produced for milestone years to compare performances and the degree of impact each policy package (based on the narrative) had on waste tonnages. Three scenarios saw significant reductions in tonnages attributable to waste prevention initiatives and non-linear impacts from system variables changes. The reference case (ED) was the only scenario to witness an increase in tonnages attributable to systems variables changes. These performances were visually represented (Figure 5.5a-d) with the statistical summaries used to differentiate the detail of relative performances (Table 7.3). The consistency of tabular and visual results allowed comparison of performance across the backcast period (2012-2050) through applying equations 7.1 and 7.3 using mean values (see Tables 7.4 and 7.5). This process showed nuances within the performance of each scenario across the period rather than just comparing baseline and end-points making the results more robust and revealing significant detail which may have been missed with linear modelling approaches.

8.4.2.2 Future economic impact results

Economic impacts are first calculated within the QM with the results then geo-referenced (by LSOA) within the economic model before the final costs and relative savings are calculated for comparative purposes through mapping each scenario.

Table 7.6 summarised the results from the economic model which presented results at the LSOA level. These were divided by population values (Table 7.1) to calculate the per capita costs and savings. Baseline economic values varied according to the amount of additional investment required (which was averaged and added to each year of the period). This approach ultimately showed scenario VM as the best performer on costs and scenario EC as the best performer for potential savings. However, across the milestone years positons changed frequently between scenarios with the profiles for a number of the scenarios showing a rapid increase in costs for a short period followed by a sustained decline towards the end-point.

8.4.2.3 Mapping the economic impacts

8.4.2.3.1 Scenario comparison: costs

Scenario CE had the lowest relative increase in costs between the baseline and 2050, the costs profiles (Figure 7.6a) show moderate increase to 2030 followed by steady decline to 2050. In contrast, the savings profiles show an increasingly rapid increase across the entire period. Visually, the change between 2012 and 2050 (Figures 7.6b-c) are only discernible by a slight darkening in the overall spatial pattern. Indeed, comparing the frequency distributions (Figures 7.6d-e) shows modest movement of numbers towards the right hand side of the histogram (increase in values) with 173 LSOAs remaining in the lowest two categories.

In contrast to scenario CE, the cost profiles (Figure 7.7a) of scenario VM show a short sharp rise to 2030 before a pronounced and steep decrease sets in and endures to the end-point. The savings profiles show a sustained upwards trend rather than an exponential trend (for CE), achieving comparable levels with scenario CE in 2050. The visual change between the baseline and 2050 (Figures 7.7b-c) are the most striking of all scenarios with a significant shift towards uniformity across LSOAs occurring (e.g. with values of <175k). This change is vividly demonstrated in the frequency distribution of LSOAs (Figure 7.7d-e) which shows a dramatic shift towards the left of the histogram (indicating a reduction in values).

Scenario EC has cost profiles (Figure 7.8a) very similar to scenario CE but very different from VM. These increase to 2030 then slightly decline to the end-point where they are considerably above VM and modestly above CE. Savings profiles are again more similar to CE over VM but end with values modestly above both. Visually, by 2050 scenario EC is very different from the baseline (much darker shading and the inclusion of a higher value category (Figures 7.8b-c). This is reinforced with the frequency distribution which has shifted considerably towards the right of the histogram (Figures 7.8d-e).

Finally, the reference scenario (ED) has an increasing cost profile overall (Figure 7.9a) and a savings profile showing initial increases to 2030 before levelling off to 2050. Visually, there has been a significant darkening in the spatial pattern (Figures 7.9b-c) although there has not been the addition of a higher category as seen with scenario EC. There has been a strong shift to the right of the histogram (Figures 7.9d-e) in terms of frequency distribution.

The economic cost performances of the scenarios therefore shows scenario VM to have outperformed all other scenarios with a very significant reduction in costs by the end of the period (some £69.5k/LSOA and £39.59/capita) lower than the next best performer (scenario CE).

8.4.2.3.2 Scenario comparison: savings

Comparing the savings performance relates to the tonnages avoided and therefore represents potential savings. The overall assessment does not include this category in comparing performance but it is another visual indicator of overall performance between scenarios. Table 7.7 showed a comparison between savings as overall, LSOA and per capita values for the end point and milestone years. The largest savings were in scenario VM in 2020 but this was overtaken in 2030 by scenario EC. By 2050, scenario EC has the largest savings followed by scenario CE. Visually, in 2050 the differences are stark in terms of the low levels of savings in scenario ED (Figure 7.10d) compared with the much darker shading (Figure 7.10c) and higher value categories of scenario EC. When the frequency distributions are compared (Figure 7.11) the skewness of the histograms and different categories used indicates the movement (increase) since 2020.

8.4.2.4 Mapping the carbon emissions impacts

8.4.2.4.1 Scenario comparison: overall performance

In terms of metrics used avoided emissions (savings versus landfill) and prevented emissions are used alongside carbon density calculations (Table 7.8). The baseline avoided emissions were 1.53MtCO_2e and the baseline carbon density value was 66.7tCO_2e/ha. Scenario CE is consistent in having the lowest avoided emissions across the backcast period. In contrast, scenario VM goes from highest avoided emissions in 2020 to second lowest in 2050. All scenarios maintain their relative emissions performance for the years 2030 and 2040. In 2050, scenario EC has the highest avoided emissions overtaking scenario ED. This is an unusual outcome as scenario ED from 2030 onwards does not prevent emissions but adds to them and yet the density results demonstrate that scenario EC is significantly higher than all other scenarios. These results suggest emphasis on reducing emissions within EC considerably outperforms that of scenario CE which has the same spatial pattern of large integrated facilities.

8.4.2.4.2 Scenario comparison: emissions and prevention

Performance for mapping purposes is disaggregated to the LSOA and per capita levels in terms of emissions and prevention. Change relative to the baseline (Table 7.9) across the backcast period shows emissions increases in 2050 ranged from 794-1,455tCO_2e/LSOA. Increases for emissions at the per capita level were in the range 0.28-0.74tCO_2e.

In detail, scenario CE emissions profiles (Figure 7.12a) show a moderate rate of increase across the period. Prevention profiles show a much more significant increase which becomes exponential after 2030. Visually, the change from baseline to 2050 (Figure 7.12b-c) is demonstrated through darkening of the LSOAs in the study area. This is supported by the change in frequency distributions (Figure 7.12d-e) showing a dramatic shift to the right of the histogram (indicative of increasing values).

Scenario VM emissions profiles (Figure 7.13a) have a similar increasing trend to scenario CE albeit with emissions starting and finishing at much higher levels than those in CE. Prevention profiles show an overall increase but rather than exponential growth from 2030 there is evidence of slowing after 2040. Visually, emissions in 2050 (Figure 7.13b-c) are significantly increased which is demonstrated by the numbers of LSOAs within the highest banding and the overall darkening of the shading. Comparing the frequency distributions (Figure 7.13d-e) confirms the increase with a very significant shift to the right of the histogram with 320 LSOAs in the two highest bands compared with 227 under CE.

The emissions profiles under scenario EC (Figure 7.14a) are similar to CE but with a steeper rate of increase and higher levels in 2050 than CE. Visually, the spatial distribution in 2050 (Figure 7.14b-c) are very similar to scenario VM but with still more LSOAs in the higher band than VM and significantly more than scenario CE. In terms of frequency distribution (Figure 7.14d-e) scenario EC sees nearly 85% of LSOAs shifted to the right of the histogram within the two highest bands. This is greater than VM and considerably more than seen for CE.

The reference scenario (ED) has an emissions profile (Figure 7.15a) which begins with a relatively strong upwards trend before levelling off in 2040. The prevention profile moves into the negative part of the y-axis from 2020 indicating a further increase in emissions rather than preventing emissions. Visually, the output map (Figure 7.15b-c) has a very similar pattern to scenarios VM and EC. The frequency distribution (Figure 7.15d-e) shows a strong shift to the right of the histogram indicating an increase for most LSOAs with 337 within the two highest bands in 2050.

The emissions performance shows scenario EC has outperformed the other scenarios by 2050. In addition, it has outperformed all scenarios with the amount of emissions prevented as a consequence of waste prevention initiatives and system variables changes.

8.4.2.4.3 Scenario comparison: carbon densities

Carbon densities are distributed in a similar manner to waste tonnages as a function of area (Figure 7.16) with values ranging from 0.46-313.12tCO_2e/ha. The mean LSOA value in 2012 was 66.74tCO_2e/ha (Table 7.10). Compared with the baseline all values in 2050 have increased. As an initial assessment scenario CE was considered to have performed better than the other scenarios as it had the lowest value. However, in terms of impact from waste operations under the spatial patterns proposed the higher the value the greater the opportunity to maximise reductions and avoidance through policy packages proposed in each scenario.

The frequency distributions for the scenarios in 2050 are compared with the baseline (Figure 7.17a) to compare levels of change. Scenario EC has the greatest number of LSOAs increasing their density values (Figure 7.17b) with these changes being spread throughout the 5 density ranges. The numbers of LSOAs in the two highest ranges increased from 68 to 134 under scenario EC compared with a change from 68 to 104 under CE. This means that higher densities of emissions are concentrated around urban centres under scenarios EC, ED and VM which would be expected to increase the opportunity for achieving long-term savings under scenario EC which is focused on sustainability and thus minimising environmental impacts.

8.4.3 Assessing the overall scenario impacts

In terms of addressing objective 4 and objective 5 (see section 1.3), the production of synthesised maps of waste tonnages, economic impacts and carbon emissions impacts has allowed the quantifiable results from the QM; which are shaped by the policy packages proposed by stakeholders throughout the backcasting process; to be expressed visually and the data analysed within a GIS environment to produce meaningful results on the feasibility of each scenario. These outputs demonstrate how backcasting can be embedded effectively with GIS to produce a model, thus achieving objective 4. However, to fully address objective 5, in terms of the model being fit-for-purpose, the proposed spatial patterns of facilities (see section 6.4.3) are evaluated against tonnage and carbon densities as well as cost implications which are based on the proposed spatial evaluation methodology for future infrastructure provision. These outputs, illustrated that current approaches to siting waste facilities may be out-of-date in England and thus do not produce a robust assessment when based on predictive modelling outputs.

8.4.3.1 Spatial patterns and policy focus of scenarios

8.4.3.1.1 Centralised pattern

Scenario CE has a resource management focus which suggests a considerable degree of policy integration. The scenario extends policy approaches aimed at delivering a zero waste; green and decarbonised economy with significant scope for job creation within a ‘green’ resource management sector. Energy policy alignment is also a key factor with large scale uptake of AD. In light of these diverse policy approaches a location centred approach to facility siting and capacity has been introduced for scenario CE. This pattern sees four large sites with integrated facilities at each managing upwards of 500kt per annum. By 2050, the scenario achieves the definition of zero waste (e.g. managing more than 90% of the remaining wastes via recycling and recovery operations).

In contrast, scenario EC is focused on sustainability and the protection of the environment. This is driven by perspectives, attitudes and behaviours changing around ‘waste’. This definition all but disappears from 2020 with the introduction of a Resource Management Strategy for England. A long-term approach has been taken in terms of education and awareness of sustainability principles which has fed through the educational system including at the business level (graduate driven) where design has a very high priority in terms of preventing wastage of valuable materials. There are similarities with CE in terms of cradle-to-cradle thinking but scenario EC goes further in terms of community ownership and representation in resource management facilities. This also pays dividends with supporting factors such as bring sites as individuals have a sense of responsibility to change their individual behaviours with recycling overall reaching 85% but for individual streams such as metals and paper/card packaging this is nearer to 97%.

The integrated approach is rolled out across England with all WPAs agreeing to cooperate on a geographic catchment for resource management facilities thus taking a strategic approach. This is slightly different under EC as community ownership becomes an embedded policy which is reflected in a percentage share being set aside for community dividends particularly for host communities. The definitions of waste and end-of-waste criteria are overhauled to allow more far greater resource circulation which accelerates the transition to a circular model. In terms of waste tonnages and carbon emissions the centralised pattern (see Figure 7.18a and 7.18b) utilises a 20km catchment as standard which can be expanded or contracted depending on the urbanised or rural nature of these catchments in England. The study area is a good mix of rural and urban and thus indicative of the degree of coverage the ‘old’ WPA boundaries receive. In terms of waste and carbon densities the four catchments cover >88% of the land area; around 92% of the population; and >95% of the highest density LSOAs.

From a cost perspective, the economies of scale from these types of operations are significant. Initial investment is partly funded through the sale of land from former waste sites for redevelopment. Collection costs are kept to a minimum with urban collection systems the norm and the extensive financial benefits of bring schemes allows further roll-out of incentive schemes to boost recycling and recovery. The reduced numbers of vehicle movement's places downwards pressure on direct emissions which is emphasised under scenario EC with financial savings being invested in alternate fuels to power collection fleets.

8.4.3.1.2 Central core with outliers pattern

Scenario VM focuses on maximum capture of resource as valuable materials or energy as a last resort as a response to the materials security agenda. Landfill diversion is paramount as well as provision for future technologies within landfill operations by separating fractions within cells. In the early part of the period an additional EfW facility is utilised to increase recovery rates while other facilities are developed (including a large integrated facility close to Northampton). The spatial pattern tries to minimise distances materials travel (see Figures 7.19a and 7.19b). This scenario has the lowest overall economic costs which suggests this spatial pattern is both efficient and cost saving.

A maximum buffer of 15km is applied around sites to cover the geographic extent of the WPA (~95% achieved at 15km) there is scope for cooperation between WPAs but this requires a complex formula for sharing the economic costs and benefits from mutual coverage. The outlying facilities have a bulking and sorting role where materials are transferred to the larger sites around the main urban centres. This scenario achieves the zero waste definition with 92.7% of remaining materials recycled or recovered by 2050.

8.4.3.1.3 Dispersed pattern

The reference scenario (ED) does not achieve the zero waste definition (attaining a recycling and recovery rate of 78.3%. This is still well beyond the current targets of national and international legislation. The spatial pattern is inefficient and requires significant additional movements to cover the entire geographic extent of the study area putting pressure on emissions (see Figures 7.20a and 7.20b). Significant investment is also required to boost recovery (as the policy of moving towards large-scale ATT is continued) but there is still a significant reliance on landfill and large amounts of valuable materials are lost. This scenario is the closest to the MWDF local plan with many diverse facility types; no plan to integrate sites; increasing levels of waste generation; and no alignment of policies. In this scenario (ED) and for the MWDF local plan as it sands; under this spatial pattern; a zero waste future is not achievable.

In the future a more ambitious and joined up approach is required which could focus on: materials and maximising the recovery of value (VM); resource management towards greening/decarbonising the economy (CE); or embedded sustainability with maximising emissions reduction and taking a strategic approach with community buy-in (EC).

8.5 Summary

This chapter has explored and discussed the research findings of the four results chapters: baseline analysis; backcasting – visions to pathways; waste system spatial analysis; and synthesis results – the G-BFM model. It has done this with a view to the identified gaps in the research (Chapter 2) and in order to address the research objectives and overall aim of the research. The scope of the study is Northamptonshire as a case study area of England with a temporal extent from 2012 to 2050 (backcast period). The goal was to envisage zero waste futures and explore these as a fit-for-purpose model within a GIS environment. This summary will briefly outline how each section addresses the different objectives.

The baseline analysis is a fundamental part of any backcasting exercise, but it can be argued, may also be a valuable stand-alone piece of research which can then be used to undertake a manner of different types of analyses (e.g. material flows or gap analysis). Within this research, objective 1 sought to 'determine likely causes of variations in waste arisings' within England using a case study approach. This baseline ascertained: the levels of 'all wastes' generated (2.70Mt); and the types of movements into, out of and within the WMS which can mask the true quantity of materials requiring management (net importing 340kt). In addition, compositional analysis identified C&I wastes as an area to target approaches which could maximise capture rates for specific material fractions. Required capacity (all facility types) was estimated at considerably below that in the planning literature within the case study area (1.74Mt as opposed to 1.93Mt per annum). Finally, potential gaps were identified in capacity only if waste generation increased over the long-term (as was the case under forecast modelling applied in planning literature) which is at odds with trends across all waste streams examined. For these reasons the key causes of waste variations were considered and identified to be taken forwards for consultation with stakeholders.

The backcasting framework was applied to address objective 2 'identify potential future scenarios for zero waste'. This objective was addressed through stakeholder participation in the visioning exercise which included continuous stakeholder dialogue (input questionnaires, workshop, interviews, feedback and survey questionnaire) to produce a futures table which could be utilised and iterated within the scenario development stage. Scenario development and impact analysis are iterative processes which required stakeholder input alongside the development and testing of a QM. Mixed methodologies (narratives and plausibility matrices on morphological fields) were undertaken to triangulate results with continued stakeholder dialogue. The final narratives and impact assessments found that three scenarios were able to achieve the recognised definition of zero waste (ZWIA, 2009) while the reference scenario was not; thus fulfilling objective 2.

Objective 3 required the 'future infrastructure capacity to be determined with GIS modelling'. This was the most technically challenging part of the research. It was undertaken via a GIS-AHP approach (recommended in the literature and refined here) with stakeholder participation (n=40) to produce weights for geographically relevant criteria for the WMS. Thematic layers were developed from available data sources or as bespoke layers with the final weights, developed in the AHP process, being applied to these layers to produce opportunities and constraints maps. These were combined to determine areas of suitability onto which the existing spatial plan for future infrastructure provision in the study area was tested as being fit-for-purpose. This proved not to be the case and a range of alternative spatial patterns were proposed to meet the requirements of the four scenarios developed.

The model (G-BFM) was then finalised through synthesising the backcast results as GIS outputs and statistically analysed using the spatial-analyst tools available in ArcGIS 10.1. This included testing the impacts of policy packages in terms three metrics: tonnages; economic costs; and carbon emissions. Backcast results were tested against baseline values to determine trends; make visual comparisons; and produce spatial statistics to confirm the findings. These findings were then assessed for their applicability to the proposed spatial patterns in order to put forwards coherent visions of the zero waste futures which may be utilised by decision-makers and stakeholders as well as practitioners in the future as a modelling approach or as indicative visions of what the future WMS could be. In doing so it can be seen that objective 4 had been met in terms of embedding backcasting within a

GIS environment as a functioning model and that objective 5 was met in producing a fit-for-purpose holistic model of zero waste in 2050.

Chapter 9: Concluding remarks

The purpose of chapter 9 is to draw conclusions in terms of how far the research methodology and results have gone towards achieving the objectives and overall aim of the research (section 1.3). In addition, it explores the extent to which these findings address the research gaps identified (section 2.6). It will go on to draw conclusions as to the efficacy of sustainable waste management modelling; using a GIS-based backcasting approach; in terms of the research aim, based on results presented in Chapters 4 through 7. It will then make recommendations (see section 9.2) for policy development around zero waste futures before identifying areas for further research which have been raised throughout the research process (see section 9.3).

The chapter concludes with a section on where future research may be explored based on the potential applications for the G-BFM model as well as in terms of potential methodological and theoretical developments around backcasting and the use of GIS as a visual support package for strategic foresight and stakeholder engagement through participation within the decision-making process on waste and resource planning in England.

9.1 Conclusions

9.1.1 The backcasting methodology

Waste management, or more appropriately, resource management is a complex system which requires understanding from a range of perspectives (individuals, public sector organisations, NGOs, private sector enterprises and governance structures) and disciplines (science, social science and design) in order to identify and explore relationships, networks and connections which have the potential to reshape the economy and society at large. The production of a synthesised model (G-BFM) has the potential to be applied across disciplines with the backcasting framework allowing detailed analysis and evaluation of a complex issue which can be enhanced through visualisation and spatial analysis utilising GIS tools and applications.

It is something of an understatement to say waste is a human system failure. Indeed, the concept of waste is itself a social construct, as in nature wastes from one process (excretions from flora and fauna) are themselves feedstocks for another animal, plant or ecosystem. The question is: how do we go about changing perspectives? Do we continue to apply methods which are based on past situations and make predictions of the future based on this limited range of options? Prosaically; the answer is no.

Then what are the alternatives? That too can be answered prosaically: ‘we do more of the same and make small adjustments to tweak the system’ or more poetically: ‘we offer radically new options based on a range of plausible choices’. Backcasting is one such method (Figure 3.2) which utilises stakeholder participation and feedback to help form narratives of future system conditions which offer a more desirable future state than currently exists. The process starts with a goal: how can we achieve zero waste by 2050 within a geographically defined location? (Figure 3.3). Compare this with a predictive method which would say something like: from where we are today is it possible to attain zero waste in a 38 year time period with current policy considerations? The point is; the framing of the question determines the scale of the problem and as seen with the second question; can restrict the choices available, producing a state of ‘policy lock-in’ (Meadows, 2008). Suck lock-in is reinforced through individual or collective mental models of a ‘waste paradigm’.

Current thinking in England (as well as a lot of other locations) is framed too often within the second mind-set; a waste paradigm (McDonough and Braungart, 2013). But why waste? Why not an inefficient economic activity that underutilises our capital investment?

Put simply, because the law and continued legislation makes one think of it as a waste problem. One of the issues with putting waste into the legislative arena is that it becomes politicised or in other words it takes on a 4-5 year shelf-life. Approaches developed are short-term; in keeping with the duration of a parliament (in England) and yet this becomes a point of considerable contention when arbitrary targets are imposed (at the European level) which require political will to deliver over an extended time horizon. Any delay causes uncertainty within the sector. This can cause investors to perceive greater risk and thus delay the delivery of scientifically sound infrastructure or even impact other economic sectors as they are forced to operate within the 'waste paradigm'. However, a backcasting approach doesn't require consideration of any of these issues (not in the first instance). It addresses uncertainty through its long-term nature and bases choices on values, beliefs and ideals (Robinson, 1990; Quist et al. 2011) which make it a normative approach based on desirability not expediency.

So what does backcasting do and how can it offer anything new? Put simply; backcasting provides a clear vision of waste (resource) management in the future; requiring stakeholders to put forwards their ideas of the future based on **their** values, beliefs and ideals to produce desirable visions for zero waste. Backcasting for waste management is new to England; indeed it has seldom been utilised for waste elsewhere in the world (SERI, 2010). The essence of backcasting in the researchers opinion is not only "the desirability of the future visions" (Dreborg, 1996) but also "the systemic and holistic approach it allows one to follow around a complex issue" rather than undertaking a study which excludes large parts of the overall problem (e.g. focusing on municipal waste which is only one symptom of the 'waste' problem). In this way, it can be concluded that backcasting sits most closely with systems thinking approaches, concerned as it is with the interactions, relationships and causal networks rather than the end problem.

One significant limitation had to be overcome to reach the research goal; as the method, over the last decade, is widely recognised to have shifted towards a participatory approach, so-called second order backcasting (Quist and Vergragt, 2011). This participatory approach utilises large numbers of stakeholders and researchers, as well as extending across longer time horizons than a PhD could accommodate (Davies et al. 2012). For this reason, Robinson's original backcasting framework (Robinson, 1990), first-order backcasting, was revisited and revised (Figure 3.3) to fit with the limited available time via a limited but broad range of expert and non-expert stakeholders used for the various participatory elements (i.e. workshop, questionnaire and plausibility survey).

9.1.2 Applying the backcasting method to waste

As has been discussed, the backcasting method is one which lends itself to viewing problems over the long-term as well as having the ability to account for uncertainty over such timescales by means of producing a range of possible future scenarios (Quist, 2010). Importantly, for waste management, this allows full consideration to be given to all stages of the Waste Hierarchy, but in particular to accounting for the effects of waste prevention over the long-term. The four scenarios produced in this research (circular economy - CE, valorisation and materials - VM, ecological citizenship – EC and economic destabilisation - ED) offer different perspectives on the future WMS within a case study area of England (Table 5.2). It was found that three of the scenarios achieved the ZWIA definition of zero waste: achieving greater than 90% recycling and recovery of all wastes (e.g. that fraction which remained after waste prevention was accounted for). The fourth scenario (ED), generally termed a reference scenario, most closely resembles what is currently happening in terms of the continuation of policy packages. But an important conclusion can be drawn here, when the reference scenario (ED) was run alongside the other scenarios it achieved considerable improvements in recycling and recovery rates, well in excess of the targets outlined in the most recent WMPE (DEFRA, 2013a)[2]. Thus, by framing a policy package around a specific scenario, even a reference case, this can have unintended consequences as the non-linear nature of the model is not predictable.

The baseline analysis (Figure 4.1) proved to be a critical aspect of the research; as it was the data collected here, from primary and secondary sources, as well as the generation of new data through validated calculations methodologies (e.g. for C&D wastes) to address data gaps, which allowed a comprehensive quantitative model (QM) to be developed (see Chapter 5). It can thus be concluded that time spent on collecting baseline data and addressing existing data gaps is a fundamental requirement in order to reflect the system holistically (i.e. for all controlled wastes rather than making assumptions based on data for a single waste stream). In addition, the collation of materials requires a robust database which when linked to spreadsheet based formulae can generate new outputs as new data becomes available. This also allows the outputs to be updated which would be beneficial to decision-makers and practitioners alike. The baseline results also addressed objective 1 in terms of identifying likely causes of variation in waste generation, these included: downwards trends in all waste streams examined; the significant movements of waste materials with the study area being a net importer; concentrations of material types within waste streams; overestimation of required capacity in planning literature; and a capacity gap only if wastes are predicted to increase (Chapter 4).

The visioning exercise (see section 5.2) was a stakeholder driven process which was framed around zero waste and how this future might come about. A two-tier strategy was developed to make the visioning workshop effective. Firstly, identified stakeholders were sent input questionnaires which allowed a wide range of views and ideas to be captured prior to the workshop event. Secondly, the workshop format used meant numbers could be

[2] The reference scenario achieved a combined recovery rate of 78.3% equating to 2.27Mt of materials

restricted to enable all participants to express their thoughts and ideas with a high degree of facilitation. It may be concluded from the approach taken; that a series of workshops would have negated the need for input questionnaires and the use of more facilitation would have allowed greater numbers of participants. These are valid points, however, the single workshop was time consuming to organise and potential participants requested information on the backcasting method prior to the event as most were unaware of the method. Organising and undertaking follow-up work (i.e. transcribing and validation work) would have extended the time horizon of the data collection phase beyond a manageable duration. In brief, the results from input questionnaires, workshop, stakeholder survey, interviews and continued dialogue produced more than enough materials to develop futures tables (Table 5.2), a critical point within the research plan. These futures table and policy/value matrix (Figure 5.7) bring together the various elements to produce a first view of the scenarios and act as an iteration point between scenario development and previously collected data.

The scenario development stage (section 5.3) is undertaken iteratively with considerations over feasibility of the produced scenarios (tested through impact assessments). At this point, policy packages derived from the stakeholders are put forwards to form narratives. It was decided to add a further quantitative dimension to the research through asking stakeholders (participants from the workshop and those stakeholders previously identified) to score variables within a morphological field in order to determine plausibility of policy packages (see Figure 5.11). Having recently been applied in England, a number of the stakeholders were familiar with morphological fields and the process. This produced greater engagement with the process and offered insights which may not otherwise have been garnered.

The proposed policy packages are tested within the QM (section 5.4) in terms of three metrics: waste tonnages; economics of waste management; and carbon emissions from waste management. While the results in Chapter 5 show the final outputs in terms of testing the fully formed scenarios; the testing of scenarios allowed stakeholders to feedback on proposed scenarios (see Table 5.5) which were invaluable for QM development. Ultimately, a final set of four complete scenarios (see Tables 5.6 to 5.9) were produced around four visions of the future (focussing on 3 different approaches and with a reference scenario). The production of the visions addressed objective 2; showing that the backcasting approach applied could produce a range of plausible future visions of zero waste by 2050.

Backcasting is thus an overarching framework allowing a mixed methodology approach to a complex problem which is versatile enough to be streamlined in places and added to in others in order to produce the overarching goal; plausible visions of the future. However, the methodology is inherently visual which has seldom been considered in the literature (Haslauer et al. 2012). The second stage of the research was structured around visualising the results (scenarios) through addressing the issue of waste infrastructure provisioning in England using the case study areas standing plan and an adaptation of a regional infrastructure assessment tool to test the validity of the results. The outcome of this approach was designed to address objective 3, to which end it was successful; which also went some way towards addressing the requirements of objective 4 as backcasting outputs were presented and spatially analysed using a GIS environment. It was discovered that a synergy existed between objectives (3 and 5) which resulted in these being met in their entirety after evaluating optimal site patterns with scenario requirements (see section 7.4).

9.1.2 Embedding backcasting with a GIS environment

In 2009, responding to long-standing concerns over finding an effective means of planning for waste infrastructure, a regional scale assessment tool was launched (DTZ/SLR, 2009a) which produced visualisations (GIS based thematic layer maps) of areas of opportunity and constraint for the potential siting of waste infrastructure to meet future needs (assessed to be greater numbers of recycling and recovery facilities for residual waste fractions). This model was based on an MCA approach assigning relative weights to LSOA units of assessment, applicable to England because of the stability of census data associated with LSOAs. This methodology was evaluated for application to a single WPA (the case study area). The MCA approach used in this research was GIS-AHP with stakeholder participation to assign weights to variables used in the site appraisal approach. These utilised thematic layers based on opportunities and constraints criteria developed in the AHP process, with these assigned weights to produce opportunity and constraint maps which when combined produced a suitability assessment of potential locations which could be used for waste facilities. Applying these results to the local plan found that most proposed sites did not meet the suitability criteria. This meant the plan was not fit-for-purpose and alternative patterns were put forwards for testing against the policy packages and narratives of the four scenarios. This approach meant that objective 3 had only partially been met through the modelling approach. However, it can be concluded that current plans are subject to challenge if the data used is not kept up-to-date. Indeed, the suitability appraisals found only 13% of proposed sites were in areas of high suitability. This suggests a different approach may be required to producing waste planning data in line with planning guidance from government.

To fully address objective 3, and test whether backcasting could be effectively embedded within a GIS environment (objective 4) in order to produce a fit-for-purpose holistic model of zero waste by 2050 (objective 5 and overarching research aim), the backcasting output had to be converted to an appropriate format to be projected with GIS software packages (in this case ArcGIS 10.1). The QM was once again a useful and versatile tool in this process as there was a need to convert metric results to a geo-referenced format (spatial identification data for projecting with British National Grid OSGB1936). LSOAs have this data embedded within them so the conversion was achieved through calculating the metrics at LSOA and per capita levels. It also became apparent that adding a 'density' value would be the most useful value for completing objective 3. Results were presented for baseline, milestone years and end-point (2050) with visualisations (GIS thematic layers) for baseline and end-point comparisons (Appendix 12 contains mapping outputs for milestone years). These results ultimately allowed scenarios to be ranked in terms of their performances on the three metrics. This is done to show where strengths and weaknesses lie rather than choosing any one scenario over another. By using this multiple metric approach it was possible to demonstrate the effectiveness of the visualisations at communicating results but also to ascertain where the changes had occurred through the generation of spatial statistics (at the LSOA level). Effectively; through the production of the visualisations and spatial statistical data; objective 4 was demonstrated as being met; as the results from this stage came from the GIS calculations and were thus an extension of the backcasting results.

The spatial patterns proposed in the spatial appraisal approach were then evaluated with the scenario narratives and policy packages to determine which could deliver these. These results were assessed against density calculations and potential cost implications. It was found that scenario ED under the dispersed pattern was closest to the local plan and that this pattern was the most inefficient in terms of producing highest carbon emissions and the second highest economic costs. This was coupled with scenario ED not meeting the zero waste definition and producing higher waste tonnages (increase over the baseline) than any other scenario. This meant objective 3 was met with the assessment that all three visions of the future were capable of outperforming the WMS conditions set out in the local plan.

Overall, the production of the backcasting methodology and embedding this within a GIS environment, created a model which was versatile enough to realise the research objectives proposed. Also, through assessing the incumbent planning approach to future infrastructure provisioning, the model proved to be fit-for-purpose as it could be used by practitioners to keep such planning considerations up-to-date in line with planning guidance (DCLG, 2012) and offer a range of visions of the future WMS at a local scale which has not been proposed previously; thus meeting objective 5 and offering real value in terms of flexibility across geographic scales. There are areas of the model which would benefit from revision particularly in terms of the functions within GIS which could be used to produce a more detailed assessment of local and wider resource management considerations (e.g. scaling up to the regional and national levels).

The aim of the research was to use a case study area within the East Midlands of England; namely Northamptonshire; to: "produce a holistic multi-criteria model for moving towards zero waste, by 2050". It has achieved this overall aim through applying methods designed to achieve specific objectives capable of delivering this overarching goal. Specifically, a backcasting approach with its systems thinking focus has allowed multiple variables, factors and criteria (e.g. waste generation; materials movements; population; economic growth; emissions from management practices; and fiscal approaches) to be brought together within a mixed methodology model (i.e. the iterative nature of the scenario narrative development and QM feasibility assessments). This model was framed around the concept of zero waste with a defined end-point of 2050 within which the future visions had to perform and ultimately deliver on the zero waste ambition (i.e. greater than 90% recycling and recovery of remaining wastes). Importantly, the model has gone further than merely assessing future desired states by means of producing visualisations of the changes to the WMS between the baseline and end-point within a GIS environment. The additional layer of spatial analysis allows robust findings based on a defined unit of assessment (LSOA) as well as in terms of relevant metrics (tonnages, economics and carbon) and through an evaluation of the proposed physical structure of the WMS with those put forwards to optimally deliver the future scenarios (CE, VM, EC and ED). The overarching GIS based backcasting framework model (G-BFM) can thus be said to deliver the aim as it can deliver on objectives and produce coherent, supported and validated outputs defining different zero waste visions.

Of particular value for stakeholders, practitioners and researchers are the assessed visions in terms of the different policy approaches available to drive down waste generation in England (particularly impacted by waste prevention and changes to behaviour within society which have a downwards pressure on waste generation rates). The flexibility of the QM provides an additional capacity to change the magnitude of impacts from single or multiple variables, thus allowing more radical visions to be tested (e.g. a theoretical impact of 50% waste prevention through changes to the definition and criteria for end-of-waste). In addition, these visions can be projected in a manner readily recognisable to a broad range of stakeholders (e.g. thematic layer maps; opportunities and constraints maps; and overall suitability maps) as well as providing a robust means of evaluating systems changes and planning considerations for the future (e.g. under a circular economy model; a focus on materials and their value; or a deep sustainability model of development).

9.2 Recommendations

Based on the outcomes form the modelling process, a set of recommendations for decision-makers; based on the range of options outlined in the scenarios and potential impacts identified for the policy packages contained therein; are proposed.

There are three main considerations which must be addressed when developing new projects and strategies to deliver zero waste based on circular economy, materials value chain and sustainability models in the future.

1. Such models must be able to embed the waste hierarchy and thus consider prevention as a critical tool in:
    a. changing definitions of waste – fundamentally shifting to a materials specific approach where 'clean' materials meeting specified protocols do not come under the scope of waste legislation (e.g. secondary raw materials, by-products or non-toxicity)
    b. designing out obsolescence – design components for multiple uses (upcycling) and extending the operational life before allowing ease of disassembly for maximum value recovery
    c. being more resource efficient - extending beyond materials to include water, energy and hidden wastes (in the workplace and as individuals; and
    d. raising awareness of choices which produce waste - lifestyles, physical capacity, and willingness of participants (see ISB model – Timlett and Williams, 2011)
2. There must be greater focus on the business models which will drive any resource management futures such as circular economy (Greyson, 2007); materials value chains (Deloitte, 2011) or sustainability (Robinson et al. 2011).
3. A significant need exists to address the psychology of 'waste' in terms of altering mental models which approaches such as backcasting are able to deliver via 'social learning' (Robinson, 2003); which can be facilitated through the visualisation of outcomes.

9.2.1 Recommendations to implement G-BFM model

Drawing on these considerations and conclusions from the previous section, a number of recommendations can be made in terms of applying the methodology produced in order to move towards zero waste futures, at the regional scale building towards the country level.

1. There is an overarching need to introduce the G-BFM model at the regional scale (East Midlands) in order to bring together a range of appropriate stakeholders to form partnerships; similar to the REC model of the 1990's and early 2000's or through facilitation by bodies which replaced EMDA and GOEM (e.g. East Midlands Councils). These stakeholders could include:
    a. WPAs – current legal responsibility for their geographic areas with scope to shift towards collaboration based on facility location with catchment (see logistics)
    b. resource companies – traditional waste companies embedding new business models
    c. logistics – expertise in efficient movement of 'secondary' materials
    d. champions – high profile individuals with recognised track record (e.g. Dame Ellen MacArthur)
    e. academia/researchers – undertake research requirements in line with research agenda
    f. steering group – to deliver the overarching goal

    This could be achieved over a 1-3 year timescale at minimal cost - £2k per meeting (50 delegates), with 2 meetings per year (3 years), with a maximum cost of £12k.

2. At a practical level, backcasting may be used to drive LAs towards a circular economy/zero waste future, through:

a. Capacity building (up to 6 months depending on numbers of stakeholders). Costs would be around £25 per attendee with additional costs covered by organisation, envisaged as 4 sessions of 25-50 delegates, with costs between £2.5 and £5k.
b. Structural training on the methodology (delivered as a package to LAs and stakeholder organisations in-house for setting a goal [e.g. continuing previous work with Derbyshire on zero waste plans] and using the G-BFM techniques and methods – over 6 months). Costs would be for 1 week intensive sessions at stakeholder sites at a fixed cost of £1k per facilitator (1 facilitator per 25 delegates). Estimated costs would range from: £26k (1 facilitator) to a maximum of £78k (3 facilitators).
c. Delivering participatory workshops and follow-up work (either single workshops or a series which builds numbers of participants – over 12 months). These would be organised with local stakeholders invited by hosting organisation with costs charged per workshop (max 18 in 12 months) rather than number of attendees (£500/facilitator). Total estimated cost £9k.
d. Setting out the scenarios and producing visualisations with a GIS environment (over 6 months). Desk based work with a fixed cost of £10k for reports and presentations.
e. Proposing new regional zero waste strategies and waste management frameworks for LAs to meet the requirements of new Local Waste Plans and keeping these updated (at 3 year point then ongoing monitoring every 12 months with new data added to QM). Costs of strategy launches covered by LA with additional retention costs until trained staff come on-stream £2k.

3. In order to monitor progress, it is recommended to utilise the GIS outputs and to a review procedure in place (every 12 months at the LA scale for low-level review and every 3 years for high-level review with regional stakeholders). This can be delivered at a resource stream or sector level (e.g. C&I sectors which have implemented resource efficiency approaches). The cost implications of continuous monitoring are minimal if rolled in to duties of an existing planning officer (one each at local and regional scales) and is estimated as an additional £10k per year.
4. Once consolidated at a regional scale a move towards developing the model at the national scale. For example; by undertaking a feasibility assessment using scenarios of implementing a zero waste/circular economy strategy for England. This may be achieved over the medium-term, 3-7 years with a view to introducing such a strategy in 2025 (e.g. Scotland's interim target for Zero Waste Plan). The costs of undertaking a zero waste strategy feasibility assessment could be minimised through joint tripartite research collaborations between universities; government departments/regulators; and private 'resource' sector entities (perhaps including funded PhDs) on a matched funding basis with bids for EU funding streams (e.g. Horizon 2020). The total estimated cost over 6 years would be £250-300k.

Through undertaking such an approach it would be possible to build capacity and expand the case study approach to a regional scale for a cost of between £61.5k and £126k. To produce the national scale assessment would cost between £250k and £300k on a tripartite basis, which gives an overall delivery cost of between £311.5k and £426k over a 7 year period. Training key stakeholders at the LA level (or organisational scale if utilising groups of companies such as the CE 100) would allow scaling up with a view towards implementing new regionalised zero waste strategies. These strategies can be monitored and reviewed through up-to-date performance outputs allowing adaption for implementation according to the pace of progress towards the overall goal; such as transitional stages from county to region to national.

9.3 Further research

As part of the requirements under Article 28 of the WFD (2008/98/EC) the government in England had to produce a plan for future waste management and for waste prevention. These set out a number of a number of priority areas for future action:

- Business – emphasis on prevention and efficiency to reduce costs, embed behaviour change and reduce pressure on scarce resources
- Consumers and communities – lifestyle choices to drive demand-side behaviour change
- Government and the public sector – providing a long-term clear policy framework

To achieve such change new business models are recommended (Figure 9.1) which focus on the dynamics of the system (reinforcing and balancing feedback loops).

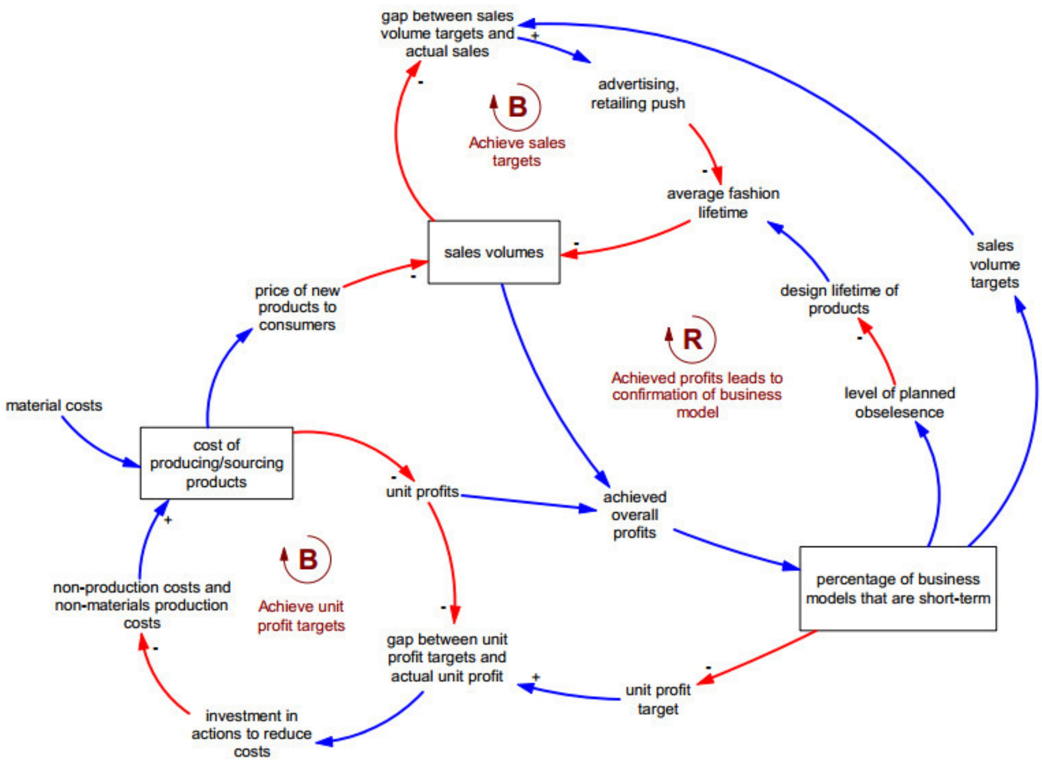


Figure 9.1: Business model formed around waste prevention (Source: DEFRA, 2013e).

In order to deliver the recommendations in section 9.2, an approach adopting the 4E's of behaviour change (DEFRA, 2013e) is required in order to develop partnerships of universities, LAs, LEPs, businesses, local stakeholders and government bodies, bringing together the three main stakeholder groups identified. These partnerships would have:

1. Access to funding streams from European development mechanisms (e.g. European Development Fund; Horizon 2020); and
2. The potential to bid for research council funding; government delivery body funding (such as Innovate UK) or other funding streams which may become available in the future.

In doing so, these funds would be used to deliver the G-BFM model in the manner described (section 9.2). The structure of the approach would also reflect the priority materials (food waste, textiles, paper & card, WEEE and bulky items) and sectors (construction & demolition and chemical & healthcare wastes). To deliver projects focused on these priority areas and the overarching goal of prevention within the zero waste agenda, specific proposal to facilitate change include:

1. WRAP support: promote transition through locally specific models such as Business Improvement Districts (BIDs) or REC's to deliver a framework of monitoring and review.
2. Resource management sector companies: actively transforming operations and business models could provide funds and training facilities.
3. Recruitment of 'champions' and figureheads: for compelling message delivery on business, economic and social benefits of transitioning to more sustainable futures.
4. Initiatives in research extended to include doctoral and post-doctoral researchers: funded through a mix of company stipends; scholarship awards; research council programmes; or direct university funding for inter-disciplinary research.

By utilising a broad range of stakeholders and addressing multiple research areas a number of examples of spin-off projects are identified to look at:

1. Heat-demand mapping with GIS: supporting modelling for infrastructure provisioning;
2. Multi-sector backcasts (waste, energy and water): exploring complex overlapping policy areas with systems thinking approaches;
3. Multi-disciplinary backcasts: potentially bringing large organisations (e.g. NHS) together with subject specialists (resources) to address social, economic and environmental impacts of large organisations.

Indeed, the UK has a history of applying scenario based approaches to such complex problems (as seen with climate change modelling and long-term transport policy formation). Thus, bringing together interdisciplinary teams to address such issues may offer considerable inhibiting barriers but the potential for catalysing change through open-minded discourse provides scope for real optimism for the future.

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Footnotes

Volume 1:

[1] The devolved administrations also include Gibraltar but this is beyond the scope of the research which focuses on England in relation to the United Kingdom geographic area (DEFRA, 2013a).

[2] Article 28 of the revised Waste Framework Directive requires that Member States ensure that their competent authorities establish one or more waste management plans covering all of their territory.

[3] Reporting to the EU is for the UK as a whole under the Eurostat data reporting scheme (see Eurostat, 2012).

[4] This MWDF is to be replaced with a Minerals and Waste Local Plan (MWLP) to meet the requirements under the WMPE (DEFRA, 2013a) and NPPF (DCLG, 2012)

[5] See Chapter 4 for a more detailed macro-scale baseline assessment of waste arisings.

[6] Waste Planning Authorities have a statutory requirement to show how a minimum of 10 years waste management capacity can be delivered within their administrative area under PPS10 (DCLG, 2013). Under the duty-to-cooperate brought in with the NPPF (DCLG, 2012) WPAs must have consideration for all areas which they interact with (import/export of wastes) which means Local Plans typically run from 2012 to 2026/31 and must also be kept up-to-date.

[7] The MWDF is proposed to be replaced with a Minerals and Waste Local Plan (MWLP) which at the time of writing had just finished its consultation process and was being schedule for introduction in 2015. However, delays have held this back and so the MWDF is still the applicable document set.

[8] According to waste returns data hazardous waste primarily originates from industrial processes (EA, 2012b). Thus modelling this waste stream has been aligned with C&I waste in this research.

[9] C&D waste is shown as recycling only but this merely reflects the link between estimations methodologies previously used for aggregates and exempt sites

[10] C&D recycling and recovery performance is shown ‘stacked’ in order to make a visual comparison with the C&D recycling/recovery target

[11] Standard rate landfill tax is applied to ‘active’ waste. This comprises heterogeneous wastes from municipal, commercial and some industrial sources

[12] LSOAs are a robust unit of assessment as change between Census taking is limited (prior to the 2011 census the last changes were in 2004) whereas using ‘wards’ is more subjective given the frequent political boundary changes

[13] Codes are defined as: B1 – Office and Light Industry; B2 – General Industry; B8 – Storage and Distribution (see NCC, 2009)

[14] IMD was calculated for 2010 based on 2004 LSOA classification and covered 407 LSOAs (see DCLG, 2011). In contrast the 2011 census had 422 LSOAs within Northamptonshire.

[15] District abbreviations are: CBC - Corby Borough Council; KBC - Kettering Borough Council; BCW – Borough Council of Wellingborough; NBC – Northampton Borough Council

[16] The horizontal axis represents values/behaviour; and the vertical axis represents waste policy

[17] Stages 4,5 and 6 are covered in Chapter 7
[18] The 7 WCAs are: shown as CBC, DDC, ENC, KBC, NBC, SNC and WBC in Figure 6.8 (Corby, Kettering, Northampton & Wellingborough Borough Councils; and Daventry, East Northamptonshire & South Northamptonshire District Councils).

[19] Total number of facilities is higher than the operational figure here as it includes 7 facilities which were in closure stage of their permit and were removing waste only (4 MRS; 2 ELV and 1 Vehicle depollution – see EA, 2012a).

[20] Pairwise comparison matrices are shown in Appendix 10

[21] RRPs are generally associated with logistics and distribution activities in the UK. Such sites have been utilised internationally and designated as Eco-Industrial Parks (EIPs) (see Tudor et al. 2007 or Chertow, 2008 for detailed discussion of EIPs and underlying Industrial Symbiosis principles).

[22] ESA = Environmentally Sensitive Area; SSSI = Sites of Special Scientific Interest

[23] WAP: working age population; EcA: economically active; Em: employed; UEm: unemployed

Volume 2:

[1] To simplify the model tax exempt materials (e.g. inert materials used for daily cover and road construction) are not estimated in order to provide an indicative value

[2] The reference scenario achieved a combined recovery rate of 78.3% equating to 2.27Mt of materials

Appendices

Appendix 1: Composition of waste streams and calculations

Compositional analyses are carried out infrequently as a consequence of the cost and time involved in undertaking such studies. To overcome this limitation a number of sources were utilised to address identified gaps within the data. Table A1.1 to A1.3 provide breakdowns for LACW, C&I and C&D waste arisings by tonnage, percentage and indicator category.

Table A1.1: LACW compositional analysis for Northamptonshire derived from national and localised studies (2012)

LACW fractions	LACW Indicator category	Indicator %	Fractions %	Category (t)	Fraction (t)	Conversion Factor
Food waste	Organics	33.65%	17.84%	114,318	60,607	0.530
Garden waste			14.08%	-	47,834	0.418
Other organic			1.73%	-	5,877	0.514
Paper	Paper/Card	22.69%	16.65%	77,084	56,565	0.734
Card			6.04%	-	20,520	0.266
Glass	Glass	6.64%	6.64%	22,558	22,558	
Metals	Metals	4.30%	4.30%	14,608	14,608	
Plastics	Plastics	9.99%	9.99%	33,939	33,939	
Textiles	Textiles	2.83%	2.83%	9,614	9,614	
Wood	Wood	3.73%	3.73%	12,672	12,672	
WEEE	WEEE	2.19%	2.19%	7,440	7,440	
Hazardous	Hazardous waste	3.04%	0.53%	10,328	1,801	0.174
Sanitary			2.51%	-	8,527	0.826
Furniture	Bulky waste	1.59%	1.34%	5,402	4,552	0.843
Mattresses			0.25%	-	849	0.157
Non-combustible	Non-recyclables	9.35%	2.82%	31,764	9,580	0.302
Other wastes			2.32%	-	7,882	0.248
Fines			1.66%	-	5,639	0.178
Combustible			2.37%	-	8,052	0.254
Soil			0.18%	-	612	0.193
Totals		100.00%	100.00%	339,727	339,727	

Sources: (after DEFRA, 2009; NCC, 2007a; 2007b; EA, 2012a; 2012b)

The data sources for LACW included: Municipal Waste Composition – Review of Municipal Waste Component Analyses undertaken for DEFRA by Resource Futures (DEFRA, 2009); the last compositional analyses of municipal waste undertaken for

Northamptonshire County Council by Entec UK (NCC, 2007a; 2007b); and the waste returns databases held by the Environment Agency (EA, 2012a; 2012b).

Table A1.2: C&I compositional analysis for Northamptonshire derived from SOC classification with pro-rata LACW composition applied for mixed ordinary wastes (2012)

C&I national reporting categories (SOC)	C&I Indicator category	Indicator %	Fractions %	Category (t)
Animal & Vegetable wastes	Organics	14.31%	14.31%	136,639
Mixed ordinary wastes (non-metallic)		65.52%	65.52%	625,663
Pro rata MSW (100% of 65.52%)	Paper/Card	49.46%	49.46	309,453
	Glass	14.47%	14.47	90,533
	Plastics	21.77%	21.77	136,207
	Wood	6.17%	6.17	38,603
	Textiles	8.13%	8.13	50,866
Metallic wastes	Metals	10.38%	10.38%	99,156
Discarded equipment	WEEE	1.03%	1.03%	9,789
Chemical wastes	Hazardous waste	3.44%	3.44%	32,889
Common sludge's				-
Mineral wastes	Non-recyclables	5.31%	4.46%	50,723
None Wastes			0.01%	-
Healthcare wastes			0.85%	-
Totals			100.00%	954,850

Sources: (DEFRA, 2010; DEFRA, 2009; EA, 2012a; 2012b)

Key data sources for C&I waste composition included the last national scale survey carried out for DEFRA by Jacobs Engineering Ltd (DEFRA, 2010) and waste returns databases held by the Environment Agency (EA, 2012a; 2012b).

Table A1.3: C&D compositional analysis for Northamptonshire derived from national and local studies (2012)

C&D national reporting categories	C&D Indicator category	Fractions %	Category (t)
Concrete	Inert (Concrete)	59.00%	776,076
Inert	Inert	21.00%	276,230
Metals	Metals	10.00%	131,538
Timber	Wood	7.00%	92,077
Plasterboard	Inert (Plasterboard)	1.40%	18,415
Insulation	Textiles	0.80%	10,523
Plastics	Plastics	0.80%	10,523
Totals		100.00%	1,315,382

Sources: (BRE, 2009; WRAP, 2010; EA, 2012a; Monier et al. 2011)

Given the low level of risk attached to most C&D wastes studies are relatively scarce when compared with other waste streams (e.g. municipal waste). To address this data gap a number of regional (BRE, 2009); national (WRAP, 2010); and international (Monier et al. 2011) studies were collated with waste returns data (EA, 2012a) to provide an indication of key categories and significant waste fractions.

The main issue addressed through collating the available data sources, related to defining indicator categories in order to determine the types of facilities most applicable for each category. Hence, the compositional analyses (for each controlled waste) were used as part of the subsequent infrastructure assessment to identify areas of under or over-capacity. Table A1.4 summarises the tonnage data by controlled waste stream and overall values for indicator categories.

Table A1.4: Summary of tonnages by controlled waste stream and overall indicator category for Northamptonshire (2012)

(tonnes)	**Controlled waste streams**				
Indicator category	MSW	C&I	C&D	Hazardous	Sub-totals
Organics	114,318	136,639	-	-	250,957
Paper/Card	77,084	309,453	-	-	386,537
Glass	22,558	90,533	-	-	113,091
Metals	14,608	136,207	131,538	-	282,353
Plastics	33,939	38,603	10,523	-	83,065
Textiles	9,614	50,866	10,523	-	71,004
Wood	12,672	99,156	92,077	-	203,904
WEEE	7,440	9,789	-	-	17,229
Hazardous	10,328	32,889	-	94,243	137,460
Bulky	5,402	-	-	-	5,402
Non-recyclable	31,764	50,723	-	-	82,488
Inert	-	-	276,230	-	276,230
Concrete	-	-	776,076	-	776,076
Plasterboard	-	-	18,415	-	18,415
Baseline tonnages	339,727	954,859	1,315,382	94,243	2,704,212

Sources: (after NCC, 2007a; 2007b; BRE, 2009; WRAP, 2010; Monier et al. 2011; DEFRA, 2009; 2010; EA, 2012a; 2012b)

Appendix 2: Infrastructure provision for Northamptonshire in 2012

The following tables are provided to indicate the overall throughput of facilities within Northamptonshire for the baseline year of 2012. Tables A2.1 to A2.4 show the breakdown of large facility types while

Table A2.5 gives a breakdown of operational bring sites within the county.

The final sets of tables (A2.6 to A2.9) are presented to show the performance and type of collection system in operation within the seven WCAs and the WDA.

The policy focus in England on diversion from landfill over the last decade has seen most Local Authority areas in England significantly increase provision (whether LA owned or merchant operated) of alternative treatment facilities. These are typically more specialised and are suitable for specific waste fractions (e.g. green garden waste to open-windrow composting).

Table A9.1: Treatment capacity by facility type for Northamptonshire in 2012

Treatment type	Facility type	# facilities	Throughput	Permitted
Anaerobic Digestion	SR2010 No16: On-farm anaerobic digestion	1	2,600	75,000
	A23 : Biological Treatment Facility	2	61,860	75,000
Biological Treatment	S0819 : Sewage sludge treatment	1	54,228	250,000
Car Breaker	A19a : ELV Facility	3	133	5,000
	A19 : Metal Recycling Site (Vehicle Dismantler)	1	0	5,000
Chemical Treatment	A21 : Chemical Treatment Facility	1	1	5,000
Composting	A22 : Composting Facility	6	107,055	164,998
	S0817 : Composting in closed vessels	1	24,707	75,000
MRF	A15 : Material Recycling Treatment Facility	3	60,611	99,999
	S0814 : Materials Recycling Facility	1	36,737	73,080
Metal Recycling	A20 : Metal Recycling Site (mixed MRS's)	7	38,110	145,000
	S0821 : Metal recycling site	1	1,878	5,000
Physical Treatment	A16 : Physical Treatment Facility	8	71,976	489,998
Physico-Chemical Treatment	A17 : Physico-Chemical Treatment	6	69,891	479,997
WEEE Treatment	S0823 : WEEE treatment	6	65,634	150,000
Totals		48	595,421	2,098,072

Source: (EA, 2012a; 2012b)

Northamptonshire is typical of this trend and in addition to the facilities listed in Table A2.1 a number of applications are transiting through planning within the county which will potentially see an additional 0.36Mt of permitted treatment capacity by 2015.

Table A2.2: Transfer capacity by facility type for Northamptonshire in 2012

Transfer (WTS)	Facility type	# facilities	Throughput	Permitted
Non-Hazardous WTS & Treatment	S0803 : HCI Waste TS + treatment	3	33,563	90,000
Non-Hazardous WTS	A11 : HCI Waste TS	17	308,072	649,994
Hazardous WTS	A9 : Hazardous WTS	4	244,818	307,665
Clinical WTS	A12 : Clinical Waste Transfer Station	2	600	30,000
CA Site	S0813 : Non-hazardous & hazardous HWA Site	10	56,878	229,000
Totals		36	643,931	1,306,659

Source: (EA, 2012a; 2012b)

Overall throughput to operational capacity is significant at 0.64Mt and is largely directed to sites licensed for non-hazardous and hazardous transfer operations. Such licensing is not prescriptive and sites licensed for hazardous waste will mainly handle non-hazardous wastes. Permitted transfer capacity has reduced by around 0.50Mt since 2010. This has largely been as a result of 9 non-hazardous WTS closing or being relicensed as hazardous WTS (n=2).

Table A2.3: Recovery capacity by operation and permit type for Northamptonshire in 2012

Recovery operation	Permit type	# facilities	Throughput	Permitted
Deposit of waste to land (recovery)	A25 : Deposit of waste to land as a recovery operation	1	22,441	n/a
Construction	SR2010 No7: Use of waste in construction <50,000 tpa	1	5,098	n/a
Construction	SR2010 No8: Use of waste in construction <100,000 tpa	2	58,799	n/a
Reclamation	SR2010 No9: Use of waste for reclamation etc. <50,000 tpa	1	31,421	n/a
Totals		5	117,759	n/a

Source: (EA, 2012a; 2012b)

These recovery operations have been licensed since 2010 and do not come under the environmental permitting regulations. These operations are dealt with by means of exemptions licensing and are often absent from other reporting regimes which indicates that a significant quantity of inert materials are likely to be treated via this route and thus significantly under-reported.

Table A2.4: Landfill capacity by facility type for Northamptonshire in 2012

Landfill	Facility type	# facilities	Throughput	Permitted
Non-Hazardous (SNRHW) Landfill	L02 : Non Hazardous (SNRHW) LF	1	67,866	800,000
Non-Hazardous Landfill	L04 : Non Hazardous LF	3	357,947	880,000
Inert Landfill	L05 : Inert LF	7	597,098	1,339,000
Hazardous Restricted	L06 : Hazardous Restricted LF	1	1,338	249,999
Totals		12	1,024,250	3,268,999

Source: (EA, 2012a; 2012b)

Landfill capacity has reduced significantly since 2010 when there were a further 3 operational landfill sites in the county (1 inert and 2 non-hazardous) with a combined permitted capacity of 0.80Mt.

Performance of Local Authorities (collection of waste)

While the bulk of waste materials pass through the facilities shown previously the waste system also includes other assets which reflect policy priorities of individual WCAs.

Table A2.5: Tonnes of material collected at bring sites in Northamptonshire (2011/12)

Period of reporting	Bring site Recycling (tonnes)	Bring site Reuse (tonnes)	Total bring site recycling and reuse (tonnes)
Apr 11 to Jun 11	1,654	1	1,655
Jul 11 to Sep 11	1,366	1	1,367
Oct 11 to Dec 11	759	-	759
Jan 12 to Mar 12	735	0	735
Total for year	4,513	2	4,515

Source: (WDF, 2013)

Table A2.5 shows the total tonnages of materials collected at bring across Northamptonshire in the reporting year 2011/12. While the overall tonnage is low this still represents a material fraction which may otherwise have been sent for final disposal to landfill or for energy recovery outside the county. Material fractions which pass through such sites are often more valuable materials such as textiles, plastics, cans, batteries and glass which are readily recyclable and are potentially less prone to contaminants as receptacles are typically segregated.

The following tables show the structure of the LACW collection system in Northamptonshire for the baseline year (2012) as well as illustrating the performance of those systems in terms of material fractions collected and fate of residual wastes.

Table A2.6: Summary of LACW collection systems and services offered for dry recyclables by district

WCA	**Co-mingled**	**Frequency**			**Number of households**			**4 or > recyclables (households)[2]**
		Kb Box	**Wheeled**	**Other**	**Kb Box**	**Wheeled**	**Other**	
CBC	Yes	n/a	2 weekly	n/a	-	26,692	-	26,692
DDC	No	Weekly	n/a	n/a	32,970	-	-	32,970
ENC	Yes	n/a	n/a	n/a	-	35,732	1,498	37,230
KBC	Yes	2 weekly	2 weekly	n/a	41,038	432	-	41,470
NBC[1]	Yes	Weekly	n/a	2 weekly	80,000	-	12,310	92,310
SNC	Yes	Weekly	Weekly	n/a	35,530	920	-	36,070
WBC[1]	Yes	n/a	2 weekly	n/a	-	33,350	-	33,350
Totals					189,538	97,126	13,808	300,092

Source: (WDF, 2013) Notes: [1]NBC and WBC send 100% of collected materials to MRFs [2]Total dwelling stock is 300,990

Table A2.7: Summary of LACW organic waste collection frequency and service with number of households serviced by district

WCA	**Households**	**Kitchen Waste with Garden Waste**	**Frequency**
CBC	26,692	No	2 weekly
DDC	32,970	No	2 weekly
ENC	37,230	No	2 weekly
KBC	41,470	No	2 weekly
NBC	66,153	Yes	Weekly
SNC	33,770	Yes	Weekly
WBC	33,350	No	2 weekly
Total	271,635		

Source: (WDF, 2013)

Table A2.8: Performance summary of material collected (tonnes) through kerbside schemes for Northamptonshire in 2012 (Source: WDF, 2013)

Material collection class	SNC	KBC	ENC	DDC	BCW	CBC	NBC	NCC	Total waste sent for recycling (tonnes)
Aerosols	-	-	-	-	-	-	-	11	11
Aluminium cans	276	-	129	-	174	18	163	-	759
Automotive batteries	4	-	-	-	-	-	-	144	148
Bric-a-brac	-	-	-	-	-	-	0	-	0
Brown glass	-	-	29	-	34	-	-	-	63
Card	53	-	1,387	-	760	-	-	2,288	4,488
Cardboard beverage packaging	3	2	-	-	2	-	2	6	15
Clear glass	-	-	81	-	88	-	-	-	169
Green garden waste only	460	-	2,288	4,630	4,454	4,052	13,802	13,686	43,372
Green glass	-	-	110	-	85	-	-	-	195
HDPE [2]	-	-	206	-	-	-	-	-	206
Mattresses	-	6	-	-	-	-	-	-	6
Mineral Oil	12	-	2	-	-	-	-	109	123
Mixed cans	-	562	91	620	-	204	-	1	1,477
Mixed glass	2,460	2,414	1,390	2,146	457	1,350	1,591	451	12,259
Mixed paper and card	-	-	1,158	2,593	3,637	933	3,176	49	11,547
Mixed plastic bottles	-	10	95	-	-	88	19	54	266
Mixed tyres	-	-	-	-	-	-	-	96	96
Other compostable waste	10,822	10,083	-	2,977	-	-	-	-	23,882
Other materials	-	-	-	-	-	-	13,095	3	13,098
OTHER PLASTICS [7]	-	-	-	-	-	16	-	60	75
Other scrap metal	111	-	20	16	-	-	28	3,771	3,947
Paint	-	-	-	-	-	-	-	289	289
Paper	2,663	2,862	2,720	667	167	2,810	-	557	12,447
PET [1]	-	-	-	-	-	-	-	219	219

Table A2.8: (continued) (Source: WDF, 2013)

Material collection class	SNC	KBC	ENC	DDC	BCW	CBC	NBC	NCC	Total waste sent for recycling (tonnes)
Plasterboard	-	-	-	-	-	-	-	862	862
Plastics	551	643	318	414	1,132	276	321	728	4,383
Post-consumer, non-automotive batteries	-	-	0	-	-	-	-	-	0
Rubble	418	-	-	-	-	-	-	11,588	12,006
Soil	151	-	-	-	-	-	-	-	151
Steel cans	276	-	295	-	275	54	162	-	1,061
Textiles & footwear	195	130	42	28	144	-	296	551	1,386
Video tapes, DVDs and CDs	15	-	-	-	-	-	-	13	28
Waste food only	-	-	-	320	-	-	642	-	961
WEEE - Cathode Ray Tubes	-	-	25	-	-	-	-	1,639	1,664
WEEE - Fluorescent tubes and other light bulbs	-	-	0	-	-	-	-	5	5
WEEE - Fridges & Freezers	-	-	19	-	-	-	20	575	615
WEEE - Large Domestic App	56	-	15	-	-	-	18	574	662
WEEE - Small Domestic App	-	-	18	-	-	-	-	1,574	1,592
Wood	-	-	-	-	-	81	-	-	81
Wood for composting	-	-	-	-	-	-	-	919	919
Total by LA	18,528	16,712	10,437	14,410	11,407	9,883	33,335	40,820	155,532

Table A2.9: Performance summary of residual waste collection for Northamptonshire in 2012 (Source: WDF, 2013)

Collection method specified	**SNC**	**KBC**	**ENC**	**DDC**	**BCW**	**CBC**	**NBC**	**Total residual waste (tonnes)**	**WDA collected residual (tonnes)**
Asbestos Waste separately collected	-	-	-	-	-	-	0	3	3
Civic amenity sites waste : Household	-	-	-	-	-	-	-	28,432	28,432
Civic amenity sites waste : Non Household	-	-	-	-	-	-	-	504	504
Collected household waste : Bulky Waste	100	-	-	48	113	143	126	529	-
Collected household waste : Other	44	48	2,215	39	41	32	110	2,529	0
Collected household waste : Regular Collection	17,179	18,738	12,572	15,871	15,263	12,999	42,055	134,682	5
Collected household waste : Street Cleaning	848	183	926	2,189	988	431	3,028	8,594	-
Collected non-household waste : C&I	1,454	1,186	427	1,089	-	400	1,772	6,329	0
Separately collected healthcare waste	4	96	107	9	-	5	14	234	-
Clearance of fly-tipped materials	106	138	131	130	503	278	703	1,988	0
Total by collection method	19,735	20,389	16,378	19,375	16,908	14,288	47,807	183,825	28,944

Appendix 3: Example input questionnaire for backcasting workshop

Input questionnaire:

Backcasting workshop on desirable future states for the UK waste sector in 2050; from a zero waste perspective.

1. Please give an indication of your thoughts on potential and/or desirable states for the UK waste sector in 2050. For example; should England follow the targets set by Scotland with a recycling rate of 70%?

2. What level of impact (in percentage terms) do you ascribe to waste prevention and reuse, on waste arisings and composition, in your vision?

3. In what ways do you feel a zero waste vision should inform policy during the period 2011 – 2050?

4. What are the key barriers to achieving your vision?

5. Can you suggest ways of overcoming identified barriers?

6. What are the potential drivers for delivering your vision?

7. How may potential drivers be facilitated by policy development? And in what ways may these translate into practice?

8. In what ways do you perceive a need for radical change or an incremental approach to achieving sustainable waste/resource management?

9. What implications are there in your vision for the UK waste/resource sector, as it currently exists, in terms of infrastructure and policy requirements?

10. Are there any wider implications for the UK economy as a whole as a result of your vision?

Thank you for your time. All ideas and thoughts will be collated to produce a scoping report to be utilised in the actual workshop event. A copy of both this scoping report and key findings of the event will be supplied in due course; while your thoughts, ideas and opinions may be further sought during follow-up interviews. Individuals will be contacted directly and permission requested, alternatively willingness to be interviewed latterly and permission for this may be provided by signing below.

I hereby give my consent to be approached in order to participate in an interview process as follow-up to this workshop.

Signed:

My contact details are:

E-mail:

Phone:

Thank you for your participation.

Nicholas Head (Researcher).

<u>Consent Form</u>

<u>For participation in the study of:</u>

Backcasting workshop on determining desirable future states for the waste sector in progressing towards zero waste by 2050

(Details of the workshop are contained within the attached information documentation)

Please initial the boxes

I have read the information documentation sheet and understand what is involved	☐
I understand that the information I give will remain confidential and that my data will be destroyed after the study has finished	☐
I understand that I can withdraw from the workshop at any time	☐
I am willing for the workshop to be recorded by agreed means (i.e. audio tape)	☐
I am willing to participate in this project	☐

Signed: …………………………………………… Date: ………………………………….

Alternatively consent may be given over the telephone (on the contact details provided previously)

Appendix 4: CIWM survey data for waste professionals

Survey questions were sent out to waste professionals (n=500) with two questions included relating to zero waste for the CIWM 2012 annual survey. The results of the primary category coding to Question 1 "*What is 'zero waste'?*" are presented in Figure A4.1.

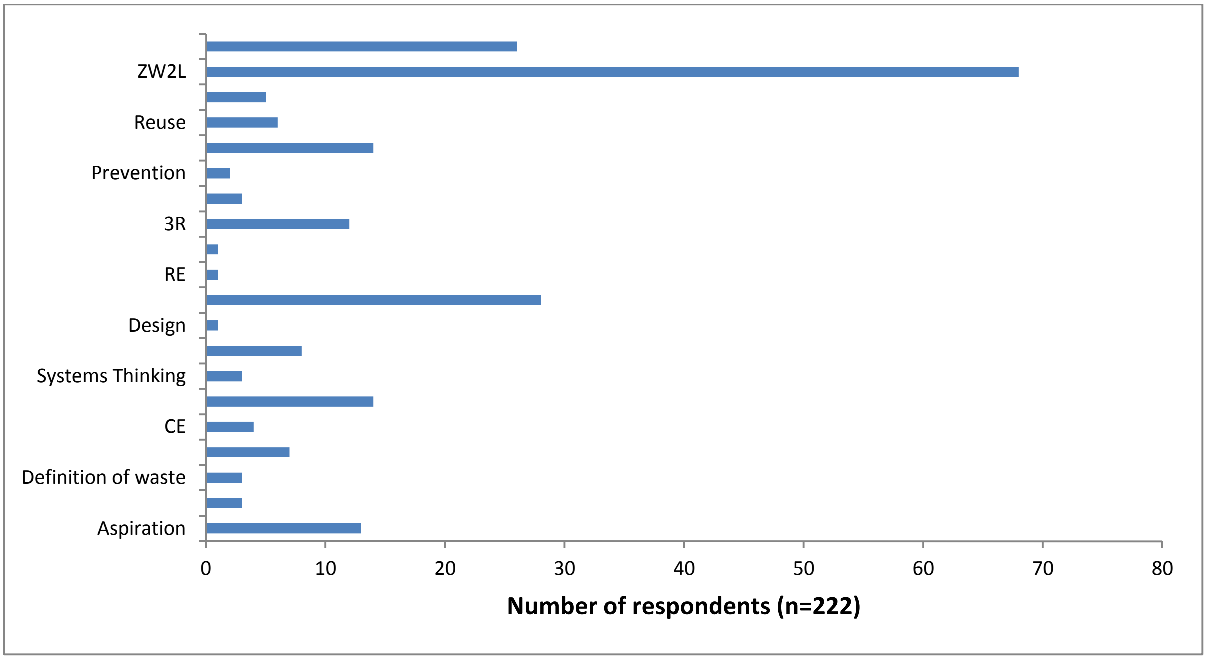


Figure A4.1: Number of survey respondents to Question 1 by primary category coding (Source: CIWM, 2012)

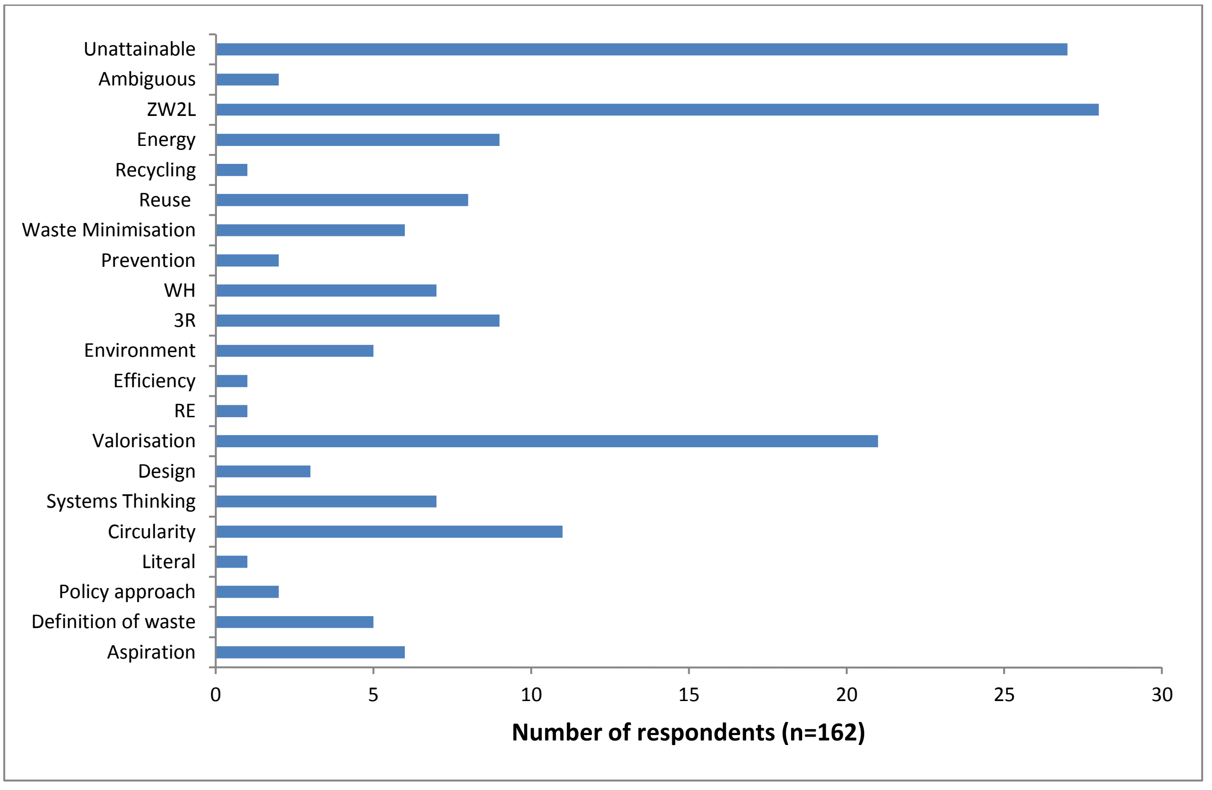


Figure A4.2: Number of survey respondents to Question 1 by secondary category coding (Source: CIWM, 2012).

This question was sub-divided into Parts A and B requiring respondents to indicate whether or not in their opinion the sector was capable of delivering a zero waste concept, followed by asking respondents to explain their choices. Table A4.1 summarises the answers to Part A.

Table A4.1: Summary of responses to Part A of the secondary survey question: "Is the sector capable of delivering such a concept as 'zero waste'?"

Response	Number of responses	Percentage (%)
No	124	55.86
Yes	98	44.14
Total	222	100.00

Source: (CIWM, 2012)

To gain a comprehensive assessment of views from the waste sector Part B of question 2 was analysed to qualitatively determine reasoning behind the answer given in Part A.

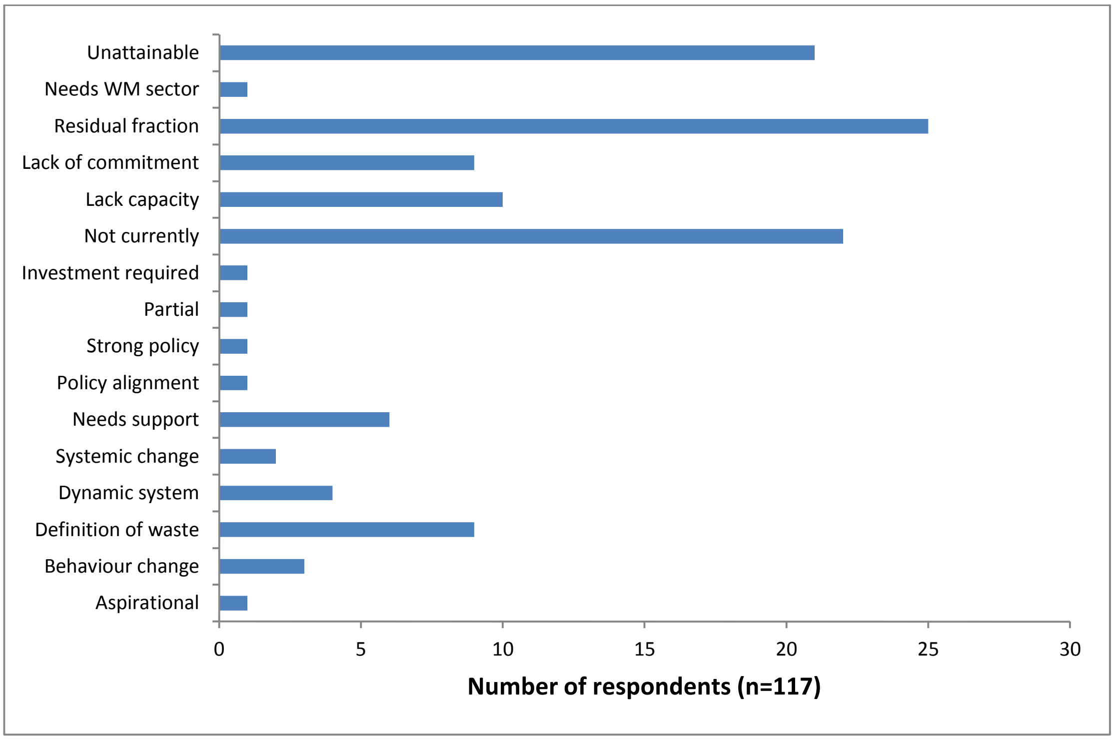


Figure A4.3: Number of survey respondents answering No by primary category coding (Source: CIWM, 2012)

As with answers to question 1, responses to Part B were coded as primary and secondary categories, however this coding was undertaken in terms of whether respondents answered Yes or No. Figure A4.3 illustrates the primary category coding.

Appendix 5: Example of individual response to plausibility matrix within morphological field

Table A5.1: Stakeholder response matrix showing individual responses

Option	Demographics	Socio-Economic Situation	Consumption patterns + environmental behaviour	Economic output	Economy structure	Corporate Eco-Behaviour	Commodity Markets	Energy System	Waste System	EfW Capacities / Technologies	Sytsem Support + Intervention	Development of Landfill Tax (environmental taxes)	Voluntary Improvements	Recycle & Reuse Capoacities / Technology
1	Stable Population Growth	Growing affluence	Good attitudes, wasteful behaviour	Steady growth	Continued shift to services	Diverse approaches	Closed markets and protectionis	Slow shift to renewables	Slow increase in recycling and	Small-scale EfW	Stable legislation	Gradual tax increases	Stable support and participation	MSW dominates development
2	Population boom	Income distribution	Strong increase in sustainable consumption	Rapid per capita growth	Resurgence of British manufacturing	Low level of concern and efficiency	Open markets and stable supplies	Increase in AD and associated EfW	Decreasing trend in waste arisings	Large scale EfW	Push for deregulation	Hammering of landfill	Increase in policy driven measures	Coordinated expansion
3	Rapidly ageing population, stagnation	Inequality reigns	Steady buying power, conscious choices	Bust-boom cycle	Centre of excellence (quality based	Sustainability / resource efficiency drive	High prices and strong volatility	Large increase in ATT (centralised	Low impact of waste prevention policies	De-coupled fuel production and	More legislation, more standardisa	Landfill reduction and Incineration tax	Decrease in policy measures / industry	High-Tech focus on C&I wastes
4	Increasing population balances ageing,	Poor society	Low consumption and environmentally	Double dip	Balancing (diversify - growth of green	Economic competitiveness depends on CE	Steadily increasing prices	Mergers between energy and waste	High impact of waste prevention policies	Large % increase in centralised AD (energy	Zero Waste England (Resource Manageme	Sophisticated materials based approach	No policy but strong industry response to	Low-Tech uncoordinated and diverse
5	Decreasing population growth (EU migrants	Income squeeze	High consumption and low environmentally	Triple dip	Product design and stewardship focus	Economic competitiveness depends on CE (curve)	Reversal of super-cycle	Market reform for smaller producer	Shift to materials based approach	Large % increase in on-farm AD (decentralis	Secondary materials markets flourish	Decrease in landfill tax	Industry lead on C&I and C&D	Holistic and integrated approach RM
1	3	2	4	2	1	4	1	5	5	1	4	4	4	4
2	4	1	2	4	5	5	3	3	3	5	1	2	3	3
3	5	3	3	3	4	2	4	1	4	2	5	3	5	1
4	1	5	1	1	2	3	2	4	2	4	3	1	2	5
5	2	4	5	5	3	1	5	2	1	3	2	5	1	2

Appendix 6: Scenario narratives in morphological fields

Table A6.1: Qualitative scenario choices for Circular Economy

Option	Demographics	Socio-Economic Situation	Consumption patterns + EB	Economic output	Economy structure	Corporate Eco-Behaviour	Commodity Markets	Energy System	Waste System	EfW Capacities / Technologies	Sytsem Support + Intervention	Development of Landfill Tax	Voluntary Improvements	Recycle & Reuse Capacity
1	Stable Population Growth	Growing affluence	Good attitudes, wasteful behaviour	Steady growth	Continued shift to services	Uncoordinated approaches	Closed markets and protectionism	Slow shift to renewables	Slow increase in recycling and recovery rates	Small-scale EfW	Stable legislation	Gradual tax increases	Stable support and participation	MSW dominates development
2	Population boom	Income re-distribution	Strong increase in sustainable consumption	Rapid per capita growth	Resurgence of British manufacturing	Low level of concern and efficiency	Open markets and stable supplies	Increase in AD and associated EfW	Decreasing trend in waste arisings over long-term	Large scale EfW	Push for deregulation	Hammering of landfill	Increase in policy driven measures	Coordinated expansion
3	Rapidly ageing population, stagnation	Inequality reigns	Steady buying power, conscious choices	Bust-boom cycle	Centre of excellence (quality based production)	Sustainability / resource efficiency drive	High prices and strong volatility	Large increase in ATT (centralised)	Low impact of waste prevention policies	De-coupled fuel production and consumption	More legislation, more standardisation	Landfill reduction and Incineration tax	Decrease in policy measures / industry responses	High-Tech focus on C&I wastes
4	Increasing population balances ageing	Poorer society	Low consumption and high environmental consciousness	Double dip recession (cycle)	Balancing (growth of green economy)	Economic competitiveness depends on CE approach (behind curve)	Steadily increasing prices	Mergers between energy and waste companies	High impact of waste prevention policies	Large % increase in centralised AD (biogas production)	Zero Waste England (Resource Management Strategy, 2020)	Sophisticated materials based approach	No policy but strong industry response to consumer demands	Low-Tech uncoordinated and diverse
5	Decreasing population growth	Income squeeze continues	High consumption and low environmentally conscious behaviour	Triple dip recession (cycle)	Product design and stewardship focus	Economic competitiveness depends on CE approach (ahead of curve)	Reversal of super-cycle	Market reform for smaller producer entry	Shift to materials based approach	Large % increase in on-farm AD (decentralised)	Secondary materials markets flourish (replace virgin materials)	Decrease in landfill tax	Industry lead on C&I and C&D	Holistic and integrated approach to resource management

Table A6.2: Qualitative scenario choices for Valorisation and Materials

Option	Demographics	Socio-Economic Situation	Consumption patterns + EB	Economic output	Economy structure	Corporate Eco-Behaviour	Commodity Markets	Energy System	Waste System	EfW Capacities / Technologies	Sytsem Support + Intervention	Development of Landfill Tax	Voluntary Improvements	Recycle & Reuse Capacity
1	Stable Population Growth	Growing affluence	Good attitudes, wasteful behaviour	Steady growth	Continued shift to services	Uncoordinated approaches	Closed markets and protectionism	Slow shift to renewables	Slow increase in recycling and recovery rates	Small-scale EfW	Stable legislation	Gradual tax increases	Stable support and participation	MSW dominates development
2	Population boom	Income re-distribution	Strong increase in sustainable consumption	Rapid per capita growth	Resurgence of British manufacturing	Low level of concern and efficiency	Open markets and stable supplies	Increase in AD and associated EfW	Decreasing trend in waste arisings over long-term	Large scale EfW	Push for deregulation	Hammering of landfill	Increase in policy driven measures	Coordinated expansion
3	Rapidly ageing population, stagnation	Inequality reigns	Steady buying power, conscious choices	Bust-boom cycle	Centre of excellence (quality based production)	Sustainability / resource efficiency drive	High prices and strong volatility	Large increase in ATT (centralised)	Low impact of waste prevention policies	De-coupled fuel production and consumption	More legislation, more standardisation	Landfill reduction and Incineration tax	Decrease in policy measures / industry responses	High-Tech focus on C&I wastes
4	Increasing population balances ageing	Poorer society	Low consumption and high environmental consciousness	Double dip recession (cycle)	Balancing (growth of green economy)	Economic competitiveness depends on CE approach (behind curve)	Steadily increasing prices	Mergers between energy and waste companies	High impact of waste prevention policies	Large % increase in centralised AD (biogas production)	Zero Waste England (Resource Management Strategy, 2020)	Sophisticated materials based approach	No policy but strong industry response to consumer demands	Low-Tech uncoordinated and diverse
5	Decreasing population growth	Income squeeze continues	High consumption and low environmentally conscious behaviour	Triple dip recession (cycle)	Product design and stewardship focus	Economic competitiveness depends on CE approach (ahead of curve)	Reversal of super-cycle	Market reform for smaller producer entry	Shift to materials based approach	Large % increase in on-farm AD (decentralised)	Secondary materials markets flourish (replace virgin materials)	Decrease in landfill tax	Industry lead on C&I and C&D	Holistic and integrated approach to resource management

Table A6.3: Qualitative scenario choices for Ecological Citizenship

Option	Demographics	Socio-Economic Situation	Consumption patterns + EB	Economic output	Economy structure	Corporate Eco-Behaviour	Commodity Markets	Energy System	Waste System	EfW Capacities / Technologies	Sytsem Support + Intervention	Development of Landfill Tax	Voluntary Improvements	Recycle & Reuse Capacity
1	Stable Population Growth	Growing affluence	Good attitudes, wasteful behaviour	Steady growth	Continued shift to services	Uncoordinated approaches	Closed markets and protectionism	Slow shift to renewables	Slow increase in recycling and recovery rates	Small-scale EfW	Stable legislation	Gradual tax increases	Stable support and participation	MSW dominates development
2	Population boom	Income re-distribution	Strong increase in sustainable consumption	Rapid per capita growth	Resurgence of British manufacturing	Low level of concern and efficiency	Open markets and stable supplies	Increase in AD and associated EfW	Decreasing trend in waste arisings over long-term	Large scale EfW	Push for deregulation	Hammering of landfill	Increase in policy driven measures	Coordinated expansion
3	Rapidly ageing population, stagnation	Inequality reigns	Steady buying power, conscious choices	Bust-boom cycle	Centre of excellence (quality based production)	Sustainability / resource efficiency drive	High prices and strong volatility	Large increase in ATT (centralised)	Low impact of waste prevention policies	De-coupled fuel production and consumption	More legislation, more standardisation	Landfill reduction and Incineration tax	Decrease in policy measures / industry responses	High-Tech focus on C&I wastes
4	Increasing population balances ageing	Poorer society	Low consumption and high environmental consciousness	Double dip recession (cycle)	Balancing (growth of green economy)	Economic competitiveness depends on CE approach (behind curve)	Steadily increasing prices	Mergers between energy and waste companies	High impact of waste prevention policies	Large % increase in centralised AD (biogas production)	Zero Waste England (Resource Management Strategy, 2020)	Sophisticated materials based approach	No policy but strong industry response to consumer demands	Low-Tech uncoordinated and diverse
5	Decreasing population growth	Income squeeze continues	High consumption and low environmentally conscious behaviour	Triple dip recession (cycle)	Product design and stewardship focus	Economic competitiveness depends on CE approach (ahead of curve)	Reversal of super-cycle	Market reform for smaller producer entry	Shift to materials based approach	Large % increase in on-farm AD (decentralised)	Secondary materials markets flourish (replace virgin materials)	Decrease in landfill tax	Industry lead on C&I and C&D	Holistic and integrated approach to resource management

Table A6.4: Qualitative scenario choices for Economic Destabilisation

Option	Demographics	Socio-Economic Situation	Consumption patterns + EB	Economic output	Economy structure	Corporate Eco-Behaviour	Commodity Markets	Energy System	Waste System	EfW Capacities / Technologies	Sytsem Support + Intervention	Development of Landfill Tax	Voluntary Improvements	Recycle & Reuse Capacity
1	Stable Population Growth	Growing affluence	Good attitudes, wasteful behaviour	Steady growth	Continued shift to services	Uncoordinated approaches	Closed markets and protectionism	Slow shift to renewables	Slow increase in recycling and recovery rates	Small-scale EfW	Stable legislation	Gradual tax increases	Stable support and participation	MSW dominates development
2	Population boom	Income re-distribution	Strong increase in sustainable consumption	Rapid per capita growth	Resurgence of British manufacturing	Low level of concern and efficiency	Open markets and stable supplies	Increase in AD and associated EfW	Decreasing trend in waste arisings over long-term	Large scale EfW	Push for deregulation	Hammering of landfill	Increase in policy driven measures	Coordinated expansion
3	Rapidly ageing population, stagnation	Inequality reigns	Steady buying power, conscious choices	Bust-boom cycle	Centre of excellence quality based production)	Sustainability / resource efficiency drive	High prices and strong volatility	Large increase in ATT (centralised)	Low impact of waste prevention policies	De-coupled fuel production and consumption	More legislation, more standardisation	Landfill reduction and Incineration tax	Decrease in policy measures / industry responses	High-Tech focus on C&I wastes
4	Increasing population balances ageing	Poorer society	Low consumption and high environmental consciousness	Double dip recession (cycle)	Balancing (growth of green economy)	Economic competitiveness depends on CE approach (behind curve)	Steadily increasing prices	Mergers between energy and waste companies	High impact of waste prevention policies	Large % increase in centralised AD (biogas production)	Zero Waste England (Resource Management Strategy, 2020)	Sophisticated materials based approach	No policy but strong industry response to consumer demands	Low-Tech uncoordinated and diverse
5	Decreasing population growth	Income squeeze continues	High consumption and low environmentally conscious behaviour	Triple dip recession (cycle)	Product design and stewardship focus	Economic competitiveness depends on CE approach (ahead of curve)	Reversal of super-cycle	Market reform for smaller producer entry	Shift to materials based approach	Large % increase in on-farm AD (decentralised)	Secondary materials markets flourish (replace virgin materials)	Decrease in landfill tax	Industry lead on C&I and C&D	Holistic and integrated approach to resource management

Note: EB = Environmental Behaviour

Appendix 7: Factor values for system variables impacts

Table A7.1: Cumulative impact calculations used in the quantitative model for CE scenario

Year	Cumulative impact of exogenous variables			Cumulative impact of endogenous variables			Year	Aggregated cumulative impact of variables		
	LACW	C&I	C&D	LACW	C&I	C&D		LACW	C&I	C&D
2012	0.9954	0.9970	0.9950	0.9996	0.9996	0.9995	2012	0.9975	0.9983	0.9973
2013	0.9954	0.9970	0.9950	0.9996	0.9996	0.9995	2013	0.9975	0.9983	0.9973
2014	0.9968	0.9991	0.9964	0.9996	0.9996	0.9995	2014	0.9982	0.9993	0.9980
2015	0.9984	1.0007	0.9980	0.9996	0.9996	0.9995	2015	0.9990	1.0001	0.9988
2016	0.9984	1.0007	0.9980	0.9996	0.9996	0.9994	2016	0.9990	1.0001	0.9987
2017	0.9984	1.0007	0.9980	0.9996	0.9996	0.9994	2017	0.9990	1.0001	0.9987
2018	1.0020	1.0043	1.0016	0.9994	0.9994	0.9994	2018	1.0007	1.0019	1.0005
2019	1.0020	1.0043	1.0016	0.9994	0.9994	0.9994	2019	1.0007	1.0019	1.0005
2020	1.0009	1.0032	1.0009	0.9994	0.9994	0.9994	2020	1.0002	1.0013	1.0002
2021	0.9988	1.0007	0.9992	0.9994	0.9994	0.9994	2021	0.9991	1.0001	0.9993
2022	0.9983	1.0001	0.9987	0.9994	0.9994	0.9994	2022	0.9988	0.9998	0.9991
2023	0.9977	0.9996	0.9981	0.9994	0.9994	0.9994	2023	0.9986	0.9995	0.9988
2024	0.9974	0.9993	0.9978	0.9994	0.9994	0.9994	2024	0.9984	0.9993	0.9986
2025	0.9966	0.9976	0.9974	0.9994	0.9994	0.9994	2025	0.9980	0.9985	0.9984
2026	0.9970	0.9980	0.9978	0.9991	0.9991	0.9989	2026	0.9980	0.9985	0.9984
2027	0.9966	0.9976	0.9974	0.9991	0.9991	0.9989	2027	0.9979	0.9984	0.9982
2028	0.9972	0.9982	0.9980	0.9991	0.9991	0.9989	2028	0.9981	0.9986	0.9984
2029	0.9974	0.9984	0.9981	0.9991	0.9991	0.9989	2029	0.9982	0.9987	0.9985
2030	0.9977	0.9987	0.9985	0.9991	0.9991	0.9989	2030	0.9984	0.9989	0.9987
2031	0.9980	0.9988	0.9984	0.9981	0.9981	0.9979	2031	0.9981	0.9984	0.9982
2032	0.9980	0.9988	0.9984	0.9978	0.9978	0.9976	2032	0.9979	0.9983	0.9980
2033	0.9977	0.9984	0.9980	0.9978	0.9978	0.9976	2033	0.9977	0.9981	0.9978
2034	0.9982	0.9989	0.9986	0.9978	0.9978	0.9976	2034	0.9980	0.9983	0.9981
2035	0.9977	0.9984	0.9980	0.9974	0.9974	0.9972	2035	0.9975	0.9979	0.9976
2036	0.9973	0.9980	0.9977	0.9974	0.9974	0.9972	2036	0.9974	0.9977	0.9974
2037	0.9970	0.9977	0.9973	0.9974	0.9974	0.9972	2037	0.9972	0.9975	0.9973
2038	0.9968	0.9975	0.9971	0.9974	0.9974	0.9972	2038	0.9971	0.9974	0.9972
2039	0.9970	0.9977	0.9973	0.9974	0.9974	0.9972	2039	0.9972	0.9975	0.9973
2040	0.9973	0.9980	0.9977	0.9974	0.9974	0.9972	2040	0.9974	0.9977	0.9974
2041	0.9963	0.9970	0.9968	0.9970	0.9970	0.9969	2041	0.9966	0.9970	0.9968
2042	0.9968	0.9975	0.9973	0.9970	0.9970	0.9969	2042	0.9969	0.9973	0.9971
2043	0.9970	0.9977	0.9975	0.9970	0.9970	0.9969	2043	0.9970	0.9974	0.9972
2044	0.9973	0.9980	0.9979	0.9970	0.9970	0.9969	2044	0.9972	0.9975	0.9974
2045	0.9977	0.9984	0.9982	0.9970	0.9970	0.9969	2045	0.9974	0.9977	0.9975
2046	0.9973	0.9980	0.9979	0.9967	0.9967	0.9965	2046	0.9970	0.9974	0.9972
2047	0.9970	0.9977	0.9975	0.9967	0.9967	0.9965	2047	0.9968	0.9972	0.9970
2048	0.9968	0.9975	0.9973	0.9967	0.9967	0.9965	2048	0.9967	0.9971	0.9969
2049	0.9963	0.9970	0.9968	0.9967	0.9967	0.9965	2049	0.9965	0.9968	0.9966
2050	0.9959	0.9966	0.9964	0.9967	0.9967	0.9965	2050	0.9963	0.9966	0.9965

Table A7.2: Cumulative impact calculations used in the quantitative model for VM scenario

Year	Cumulative impact of exogenous variables			Cumulative impact of endogenous variables			Year	Aggregated cumulative impact of variables		
	MSW	C&I	C&D	MSW	C&I	C&D		MSW	C&I	C&D
2012	0.9954	0.9970	0.9950	0.9994	0.9995	0.9994	2012	0.9974	0.9982	0.9972
2013	0.9954	0.9970	0.9950	0.9994	0.9995	0.9994	2013	0.9974	0.9982	0.9972
2014	0.9968	0.9991	0.9964	0.9994	0.9995	0.9994	2014	0.9981	0.9993	0.9979
2015	0.9984	1.0007	0.9980	0.9994	0.9995	0.9994	2015	0.9989	1.0001	0.9987
2016	0.9984	1.0007	0.9980	0.9996	0.9996	0.9994	2016	0.9990	1.0002	0.9987
2017	0.9984	1.0007	0.9980	0.9992	0.9993	0.9989	2017	0.9988	1.0000	0.9984
2018	1.0020	1.0043	1.0016	0.9992	0.9993	0.9989	2018	1.0006	1.0018	1.0002
2019	1.0020	1.0043	1.0016	0.9992	0.9993	0.9989	2019	1.0006	1.0018	1.0002
2020	1.0009	1.0032	1.0009	0.9983	0.9980	0.9961	2020	0.9996	1.0006	0.9985
2021	0.9988	1.0007	0.9992	0.9983	0.9980	0.9961	2021	0.9985	0.9994	0.9976
2022	0.9983	1.0001	0.9987	0.9983	0.9980	0.9961	2022	0.9983	0.9991	0.9974
2023	0.9977	0.9996	0.9981	0.9983	0.9980	0.9961	2023	0.9980	0.9988	0.9971
2024	0.9974	0.9993	0.9978	0.9983	0.9980	0.9961	2024	0.9978	0.9986	0.9969
2025	0.9966	0.9976	0.9974	0.9983	0.9980	0.9961	2025	0.9975	0.9978	0.9968
2026	0.9970	0.9980	0.9978	0.9983	0.9980	0.9961	2026	0.9976	0.9980	0.9969
2027	0.9966	0.9976	0.9974	0.9983	0.9980	0.9961	2027	0.9975	0.9978	0.9968
2028	0.9972	0.9982	0.9980	0.9983	0.9980	0.9961	2028	0.9977	0.9981	0.9970
2029	0.9974	0.9984	0.9981	0.9983	0.9980	0.9961	2029	0.9978	0.9982	0.9971
2030	0.9977	0.9987	0.9985	0.9983	0.9980	0.9961	2030	0.9980	0.9984	0.9973
2031	0.9980	0.9988	0.9984	0.9981	0.9979	0.9959	2031	0.9981	0.9983	0.9971
2032	0.9980	0.9988	0.9984	0.9981	0.9979	0.9959	2032	0.9981	0.9983	0.9971
2033	0.9977	0.9984	0.9980	0.9981	0.9979	0.9959	2033	0.9979	0.9981	0.9970
2034	0.9982	0.9989	0.9986	0.9981	0.9979	0.9959	2034	0.9982	0.9984	0.9972
2035	0.9977	0.9984	0.9980	0.9981	0.9979	0.9959	2035	0.9979	0.9981	0.9970
2036	0.9973	0.9980	0.9977	0.9981	0.9979	0.9959	2036	0.9977	0.9979	0.9968
2037	0.9970	0.9977	0.9973	0.9981	0.9979	0.9959	2037	0.9975	0.9978	0.9966
2038	0.9968	0.9975	0.9971	0.9981	0.9979	0.9959	2038	0.9974	0.9977	0.9965
2039	0.9970	0.9977	0.9973	0.9981	0.9979	0.9959	2039	0.9975	0.9978	0.9966
2040	0.9973	0.9980	0.9977	0.9981	0.9979	0.9959	2040	0.9977	0.9979	0.9968
2041	0.9963	0.9970	0.9968	0.9979	0.9977	0.9957	2041	0.9971	0.9973	0.9963
2042	0.9968	0.9975	0.9973	0.9979	0.9977	0.9957	2042	0.9974	0.9976	0.9965
2043	0.9970	0.9977	0.9975	0.9979	0.9977	0.9957	2043	0.9974	0.9977	0.9966
2044	0.9973	0.9980	0.9979	0.9979	0.9977	0.9957	2044	0.9976	0.9979	0.9968
2045	0.9977	0.9984	0.9982	0.9979	0.9977	0.9957	2045	0.9978	0.9980	0.9970
2046	0.9973	0.9980	0.9979	0.9979	0.9977	0.9957	2046	0.9976	0.9979	0.9968
2047	0.9970	0.9977	0.9975	0.9979	0.9977	0.9957	2047	0.9974	0.9977	0.9966
2048	0.9968	0.9975	0.9973	0.9979	0.9977	0.9957	2048	0.9974	0.9976	0.9965
2049	0.9963	0.9970	0.9968	0.9979	0.9977	0.9957	2049	0.9971	0.9973	0.9963
2050	0.9959	0.9966	0.9964	0.9979	0.9977	0.9957	2050	0.9969	0.9971	0.9961

Table A7.3: Cumulative impact calculations used in the quantitative model for EC scenario

Year	Cumulative impact of exogenous variables			Cumulative impact of endogenous variables			Year	Aggregated cumulative impact of variables		
	MSW	C&I	C&D	MSW	C&I	C&D		MSW	C&I	C&D
2012	0.9954	0.9970	0.9950	0.9998	0.9998	0.9997	2012	0.9976	0.9984	0.9973
2013	0.9954	0.9970	0.9950	0.9998	0.9998	0.9997	2013	0.9976	0.9984	0.9973
2014	0.9968	0.9991	0.9964	0.9998	0.9998	0.9997	2014	0.9983	0.9995	0.9980
2015	0.9984	1.0007	0.9980	0.9998	0.9998	0.9997	2015	0.9991	1.0003	0.9988
2016	0.9984	1.0007	0.9980	0.9998	0.9998	0.9997	2016	0.9991	1.0003	0.9988
2017	0.9984	1.0007	0.9980	0.9998	0.9998	0.9997	2017	0.9991	1.0003	0.9988
2018	1.0020	1.0043	1.0016	0.9998	0.9998	0.9997	2018	1.0009	1.0020	1.0006
2019	1.0020	1.0043	1.0016	0.9998	0.9998	0.9997	2019	1.0009	1.0020	1.0006
2020	1.0009	1.0032	1.0009	0.9998	0.9998	0.9997	2020	1.0003	1.0015	1.0003
2021	0.9988	1.0007	0.9992	0.9997	0.9996	0.9996	2021	0.9993	1.0002	0.9994
2022	0.9983	1.0001	0.9987	0.9997	0.9996	0.9996	2022	0.9990	0.9999	0.9991
2023	0.9977	0.9996	0.9981	0.9997	0.9996	0.9996	2023	0.9987	0.9996	0.9989
2024	0.9974	0.9993	0.9978	0.9997	0.9996	0.9996	2024	0.9985	0.9994	0.9987
2025	0.9966	0.9976	0.9974	0.9995	0.9994	0.9996	2025	0.9981	0.9985	0.9985
2026	0.9970	0.9980	0.9978	0.9995	0.9994	0.9996	2026	0.9982	0.9987	0.9987
2027	0.9966	0.9976	0.9974	0.9995	0.9994	0.9996	2027	0.9981	0.9985	0.9985
2028	0.9972	0.9982	0.9980	0.9995	0.9994	0.9996	2028	0.9983	0.9988	0.9988
2029	0.9974	0.9984	0.9981	0.9995	0.9994	0.9996	2029	0.9984	0.9989	0.9989
2030	0.9977	0.9987	0.9985	0.9995	0.9994	0.9996	2030	0.9986	0.9991	0.9990
2031	0.9980	0.9988	0.9984	0.9995	0.9994	0.9996	2031	0.9988	0.9991	0.9990
2032	0.9980	0.9988	0.9984	0.9995	0.9994	0.9996	2032	0.9988	0.9991	0.9990
2033	0.9977	0.9984	0.9980	0.9995	0.9994	0.9996	2033	0.9986	0.9989	0.9988
2034	0.9982	0.9989	0.9986	0.9995	0.9994	0.9996	2034	0.9988	0.9992	0.9991
2035	0.9977	0.9984	0.9980	0.9995	0.9994	0.9996	2035	0.9986	0.9989	0.9988
2036	0.9973	0.9980	0.9977	0.9995	0.9994	0.9996	2036	0.9984	0.9987	0.9986
2037	0.9970	0.9977	0.9973	0.9995	0.9994	0.9996	2037	0.9982	0.9985	0.9985
2038	0.9968	0.9975	0.9971	0.9995	0.9994	0.9996	2038	0.9981	0.9984	0.9984
2039	0.9970	0.9977	0.9973	0.9995	0.9994	0.9996	2039	0.9982	0.9985	0.9985
2040	0.9973	0.9980	0.9977	0.9995	0.9994	0.9996	2040	0.9984	0.9987	0.9986
2041	0.9963	0.9970	0.9968	0.9995	0.9994	0.9996	2041	0.9979	0.9982	0.9982
2042	0.9968	0.9975	0.9973	0.9995	0.9994	0.9996	2042	0.9981	0.9984	0.9985
2043	0.9970	0.9977	0.9975	0.9995	0.9994	0.9996	2043	0.9982	0.9985	0.9985
2044	0.9973	0.9980	0.9979	0.9995	0.9994	0.9996	2044	0.9984	0.9987	0.9987
2045	0.9977	0.9984	0.9982	0.9995	0.9994	0.9996	2045	0.9986	0.9989	0.9989
2046	0.9973	0.9980	0.9979	0.9995	0.9994	0.9996	2046	0.9984	0.9987	0.9987
2047	0.9970	0.9977	0.9975	0.9995	0.9994	0.9996	2047	0.9982	0.9985	0.9985
2048	0.9968	0.9975	0.9973	0.9995	0.9994	0.9996	2048	0.9981	0.9984	0.9985
2049	0.9963	0.9970	0.9968	0.9995	0.9994	0.9996	2049	0.9979	0.9982	0.9982
2050	0.9959	0.9966	0.9964	0.9995	0.9994	0.9996	2050	0.9977	0.9980	0.9980

Table A7.4: Cumulative impact calculations used in the quantitative model for ED scenario

Year	Cumulative impact of exogenous variables			Cumulative impact of endogenous variables			Year	Aggregated cumulative impact of variables		
	MSW	C&I	C&D	MSW	C&I	C&D		MSW	C&I	C&D
2012	0.9990	1.0009	0.9990	1.0001	1.0001	1.0002	2012	0.9995	1.0005	0.9996
2013	0.9990	1.0009	0.9990	1.0001	1.0001	1.0002	2013	0.9995	1.0005	0.9996
2014	1.0004	1.0030	1.0005	1.0001	1.0001	1.0002	2014	1.0003	1.0016	1.0003
2015	1.0020	1.0046	1.0021	1.0003	1.0003	1.0002	2015	1.0011	1.0024	1.0011
2016	1.0020	1.0046	1.0021	1.0003	1.0003	1.0002	2016	1.0011	1.0024	1.0011
2017	1.0020	1.0046	1.0021	1.0003	1.0003	1.0002	2017	1.0011	1.0024	1.0011
2018	1.0020	1.0046	1.0021	1.0003	1.0003	1.0002	2018	1.0011	1.0024	1.0011
2019	1.0020	1.0046	1.0021	1.0003	1.0003	1.0002	2019	1.0011	1.0024	1.0011
2020	1.0020	1.0046	1.0021	1.0005	1.0005	1.0005	2020	1.0013	1.0026	1.0013
2021	1.0034	1.0060	1.0035	1.0005	1.0005	1.0005	2021	1.0020	1.0033	1.0020
2022	1.0034	1.0060	1.0035	1.0005	1.0005	1.0005	2022	1.0020	1.0033	1.0020
2023	1.0034	1.0060	1.0035	1.0005	1.0005	1.0005	2023	1.0020	1.0033	1.0020
2024	1.0034	1.0060	1.0035	1.0005	1.0005	1.0005	2024	1.0020	1.0033	1.0020
2025	1.0034	1.0064	1.0035	1.0005	1.0005	1.0005	2025	1.0020	1.0035	1.0020
2026	1.0045	1.0075	1.0049	1.0005	1.0005	1.0005	2026	1.0025	1.0040	1.0027
2027	1.0045	1.0075	1.0049	1.0005	1.0005	1.0005	2027	1.0025	1.0040	1.0027
2028	1.0045	1.0075	1.0049	1.0005	1.0005	1.0005	2028	1.0025	1.0040	1.0027
2029	1.0045	1.0075	1.0049	1.0005	1.0005	1.0005	2029	1.0025	1.0040	1.0027
2030	1.0045	1.0075	1.0049	1.0005	1.0005	1.0005	2030	1.0025	1.0040	1.0027
2031	1.0061	1.0088	1.0061	1.0005	1.0005	1.0005	2031	1.0033	1.0046	1.0033
2032	1.0061	1.0088	1.0061	1.0005	1.0005	1.0005	2032	1.0033	1.0046	1.0033
2033	1.0061	1.0088	1.0061	1.0006	1.0006	1.0005	2033	1.0033	1.0047	1.0033
2034	1.0061	1.0088	1.0061	1.0006	1.0006	1.0005	2034	1.0033	1.0047	1.0033
2035	1.0070	1.0096	1.0070	1.0006	1.0006	1.0005	2035	1.0038	1.0051	1.0038
2036	1.0070	1.0096	1.0070	1.0006	1.0006	1.0005	2036	1.0038	1.0051	1.0038
2037	1.0070	1.0096	1.0070	1.0006	1.0006	1.0005	2037	1.0038	1.0051	1.0038
2038	1.0070	1.0096	1.0070	1.0006	1.0006	1.0005	2038	1.0038	1.0051	1.0038
2039	1.0070	1.0096	1.0070	1.0006	1.0006	1.0005	2039	1.0038	1.0051	1.0038
2040	1.0070	1.0096	1.0070	1.0006	1.0006	1.0005	2040	1.0038	1.0051	1.0038
2041	1.0055	1.0075	1.0055	1.0006	1.0006	1.0005	2041	1.0031	1.0041	1.0030
2042	1.0055	1.0075	1.0055	1.0006	1.0006	1.0005	2042	1.0031	1.0041	1.0030
2043	1.0055	1.0075	1.0055	1.0006	1.0006	1.0005	2043	1.0031	1.0041	1.0030
2044	1.0055	1.0075	1.0055	1.0006	1.0006	1.0005	2044	1.0031	1.0041	1.0030
2045	1.0055	1.0075	1.0055	1.0006	1.0006	1.0005	2045	1.0031	1.0041	1.0030
2046	1.0055	1.0075	1.0055	1.0006	1.0006	1.0005	2046	1.0031	1.0041	1.0030
2047	1.0055	1.0075	1.0055	1.0006	1.0006	1.0005	2047	1.0031	1.0041	1.0030
2048	1.0055	1.0075	1.0055	1.0006	1.0006	1.0005	2048	1.0031	1.0041	1.0030
2049	1.0055	1.0075	1.0055	1.0006	1.0006	1.0005	2049	1.0031	1.0041	1.0030
2050	1.0055	1.0075	1.0055	1.0006	1.0006	1.0005	2050	1.0031	1.0041	1.0030

Note: Highlighted rows are those shown in Table 5.11 (page 199)

Appendix 8: Waste stream calculations for gate fees

Table A8.1: LACW gate fees costs and savings calculations

Year	CE costs (£M)	CE savings (£M)	VM costs (£M)	VM savings (£M)	EC costs (£M)	EC savings (£M)	ED costs (£M)	ED savings (£M)
2012	9.44	-	9.44	-	9.44	-	9.44	-
2013	9.45	0.07	9.44	0.13	9.44	0.04	9.60	0.29
2014	9.48	0.15	9.45	0.15	9.47	0.09	9.70	0.19
2015	9.52	0.16	9.47	0.17	9.53	0.21	9.92	0.39
2016	9.64	0.15	9.60	0.28	9.66	0.10	10.12	0.46
2017	9.79	0.18	9.72	0.21	9.80	0.18	10.31	0.43
2018	9.93	0.16	9.86	0.23	9.96	0.16	10.53	0.49
2019	10.08	0.19	10.02	0.34	10.14	0.17	10.82	0.61
2020	10.24	0.21	10.02	0.21	10.40	0.14	11.14	0.67
2021	10.39	0.21	10.03	0.22	10.63	0.19	11.39	0.17
2022	10.54	0.21	10.04	0.22	10.87	0.19	11.65	0.17
2023	10.69	0.21	10.04	0.22	11.12	0.19	11.90	0.18
2024	10.83	0.21	10.05	0.21	11.36	0.20	12.17	0.18
2025	10.97	0.21	10.05	0.21	11.61	0.20	12.44	0.18
2026	11.12	0.21	10.05	0.21	11.86	0.20	12.72	0.19
2027	11.26	0.21	10.05	0.21	12.12	0.20	13.00	0.19
2028	11.41	0.21	10.05	0.21	12.38	0.21	13.29	0.19
2029	11.57	0.22	10.05	0.20	12.65	0.21	13.59	0.20
2030	11.72	0.22	10.05	0.20	12.93	0.22	13.68	0.20
2031	11.89	0.26	10.01	0.15	13.18	0.17	13.73	0.13
2032	12.06	0.26	9.97	0.15	13.44	0.17	13.78	0.13
2033	12.22	0.26	9.93	0.15	13.70	0.17	13.83	0.13
2034	12.40	0.26	9.90	0.15	13.97	0.18	13.89	0.13
2035	12.56	0.26	9.86	0.14	14.24	0.18	13.94	0.14
2036	12.73	0.26	9.82	0.14	14.52	0.18	14.00	0.14
2037	12.90	0.26	9.78	0.14	14.80	0.18	14.05	0.14
2038	13.07	0.26	9.73	0.14	15.08	0.18	14.11	0.14
2039	13.24	0.26	9.69	0.13	15.36	0.19	14.17	0.14
2040	13.41	0.26	9.65	0.13	15.66	0.19	14.44	0.14
2041	13.64	0.36	9.60	0.13	15.87	0.04	14.68	0.12
2042	13.87	0.36	9.56	0.13	16.08	0.04	14.93	0.12
2043	14.10	0.36	9.52	0.13	16.30	0.04	15.19	0.12
2044	14.34	0.37	9.48	0.13	16.52	0.05	15.45	0.12
2045	14.58	0.37	9.44	0.13	16.75	0.05	15.71	0.13
2046	14.83	0.37	9.40	0.13	16.98	0.05	15.98	0.13
2047	15.07	0.37	9.35	0.12	17.21	0.05	16.25	0.13
2048	15.31	0.37	9.31	0.12	17.44	0.05	16.53	0.13
2049	15.55	0.36	9.26	0.12	17.67	0.04	16.81	0.13
2050	15.79	0.36	9.22	0.11	17.89	0.04	17.10	0.14

Table A8.2: C&I gate fees costs and savings calculations

Year	CE costs (£M)	CE savings (£M)	VM costs (£M)	VM savings (£M)	EC costs (£M)	EC savings (£M)	ED costs (£M)	ED savings (£M)
2012	27.98	-	27.98	-	27.98	-	27.98	-
2013	28.03	0.31	27.99	0.32	27.96	0.13	28.29	0.42
2014	28.14	0.36	28.27	0.73	28.07	0.32	28.65	0.43
2015	28.24	0.33	28.48	0.56	28.17	0.33	29.11	0.58
2016	28.64	0.28	28.92	0.52	28.60	0.43	29.36	0.49
2017	29.01	0.24	29.38	0.58	29.04	0.43	29.74	0.77
2018	29.43	0.27	29.90	0.61	29.48	0.37	30.11	0.77
2019	29.90	0.32	30.47	0.69	29.99	0.50	30.53	0.90
2020	30.32	0.27	30.61	0.76	30.74	0.40	31.21	1.31
2021	30.68	0.20	30.63	0.49	31.47	0.49	31.99	0.71
2022	31.03	0.20	30.65	0.48	32.22	0.50	32.78	0.72
2023	31.38	0.20	30.65	0.48	32.98	0.50	33.59	0.73
2024	31.72	0.20	30.65	0.47	33.74	0.51	34.42	0.74
2025	32.05	0.18	30.62	0.45	34.49	0.50	35.26	0.76
2026	32.38	0.18	30.59	0.45	35.27	0.51	36.15	0.78
2027	32.70	0.18	30.56	0.44	36.05	0.51	37.05	0.80
2028	33.04	0.19	30.54	0.44	36.86	0.53	37.97	0.81
2029	33.38	0.19	30.51	0.44	37.70	0.54	38.90	0.83
2030	33.73	0.20	30.50	0.44	38.56	0.55	39.27	0.83
2031	34.11	0.30	30.33	0.22	39.49	0.62	39.47	0.44
2032	34.49	0.29	30.17	0.21	40.45	0.63	39.67	0.44
2033	34.86	0.29	30.00	0.21	41.42	0.64	39.87	0.44
2034	35.25	0.30	29.85	0.21	42.42	0.66	40.07	0.44
2035	35.63	0.29	29.68	0.20	43.44	0.66	40.28	0.45
2036	36.00	0.29	29.51	0.20	44.47	0.67	40.50	0.46
2037	36.37	0.29	29.34	0.19	45.52	0.67	40.72	0.46
2038	36.74	0.28	29.16	0.19	46.59	0.68	40.94	0.46
2039	37.12	0.29	28.99	0.19	47.68	0.70	41.15	0.46
2040	37.51	0.29	28.82	0.19	48.81	0.72	41.99	0.47
2041	38.19	0.98	28.86	0.52	49.90	0.82	42.66	0.07
2042	38.90	0.99	28.90	0.52	51.02	0.85	43.34	0.07
2043	39.61	0.99	28.95	0.52	52.18	0.87	44.03	0.07
2044	40.34	1.00	28.99	0.52	53.37	0.89	44.72	0.07
2045	41.09	1.01	29.05	0.52	54.59	0.92	45.43	0.07
2046	41.83	1.01	29.09	0.51	55.83	0.92	46.15	0.07
2047	42.57	1.01	29.12	0.50	57.09	0.93	46.89	0.07
2048	43.32	1.01	29.15	0.49	58.37	0.94	47.63	0.07
2049	44.06	1.00	29.18	0.48	59.67	0.94	48.38	0.07
2050	44.80	1.00	29.19	0.47	60.98	0.94	49.15	0.07

Table A8.3: C&D gate fees costs and savings calculations

Year	CE costs (£M)	CE savings (£M)	VM costs (£M)	VM savings (£M)	EC costs (£M)	EC savings (£M)	ED costs (£M)	ED savings (£M)
2012	9.46	-	9.46	-	9.46	-	9.46	-
2013	9.18	0.33	9.35	0.12	9.38	0.09	9.37	0.10
2014	8.89	0.34	9.18	0.19	9.33	0.04	9.27	0.12
2015	8.61	0.34	9.00	0.22	9.25	0.10	9.16	0.15
2016	8.41	0.34	8.93	0.19	9.26	0.10	9.00	0.15
2017	8.31	0.22	8.81	0.25	9.27	0.10	8.84	0.14
2018	8.25	0.19	8.65	0.31	9.30	0.09	8.68	0.14
2019	8.19	0.19	8.49	0.32	9.35	0.06	8.52	0.14
2020	8.17	0.13	8.16	0.35	9.56	-0.03	8.39	0.11
2021	8.06	0.23	7.96	0.18	9.55	0.25	8.39	0.11
2022	7.95	0.23	7.76	0.18	9.54	0.26	8.39	0.11
2023	7.84	0.23	7.57	0.18	9.51	0.26	8.39	0.12
2024	7.72	0.24	7.37	0.18	9.49	0.27	8.39	0.12
2025	7.60	0.24	7.18	0.17	9.45	0.28	8.38	0.12
2026	7.47	0.24	6.99	0.17	9.41	0.28	8.38	0.12
2027	7.34	0.24	6.81	0.17	9.37	0.28	8.38	0.12
2028	7.21	0.24	6.62	0.17	9.32	0.29	8.38	0.12
2029	7.08	0.24	6.44	0.17	9.27	0.29	8.37	0.12
2030	6.95	0.25	6.27	0.16	9.22	0.30	8.24	0.12
2031	6.87	0.18	6.10	0.15	9.22	0.22	8.18	0.06
2032	6.78	0.18	5.94	0.15	9.22	0.23	8.11	0.06
2033	6.70	0.18	5.78	0.15	9.21	0.23	8.04	0.06
2034	6.61	0.18	5.62	0.14	9.21	0.24	7.97	0.06
2035	6.52	0.18	5.47	0.14	9.20	0.24	7.90	0.06
2036	6.42	0.19	5.31	0.14	9.18	0.25	7.84	0.06
2037	6.33	0.19	5.16	0.14	9.16	0.25	7.77	0.06
2038	6.23	0.19	5.01	0.14	9.13	0.25	7.71	0.06
2039	6.13	0.19	4.86	0.14	9.10	0.26	7.64	0.06
2040	6.02	0.19	4.71	0.13	9.06	0.26	7.69	0.06
2041	5.98	0.11	4.59	0.11	9.00	0.29	7.77	0.03
2042	5.93	0.11	4.47	0.11	8.94	0.30	7.84	0.03
2043	5.88	0.11	4.35	0.10	8.87	0.30	7.91	0.03
2044	5.84	0.11	4.23	0.10	8.80	0.31	7.99	0.03
2045	5.79	0.12	4.12	0.10	8.72	0.31	8.06	0.03
2046	5.74	0.11	4.00	0.10	8.64	0.32	8.14	0.03
2047	5.69	0.11	3.89	0.10	8.54	0.32	8.21	0.03
2048	5.63	0.12	3.78	0.10	8.45	0.33	8.29	0.03
2049	5.58	0.11	3.67	0.10	8.34	0.33	8.36	0.03
2050	5.52	0.11	3.56	0.10	8.22	0.34	8.44	0.03

Table A8.4: Hazardous waste gate fees costs and savings calculations

Year	CE costs (£M)	CE savings (£M)	VM costs (£M)	VM savings (£M)	EC costs (£M)	EC savings (£M)	ED costs (£M)	ED savings (£M)
2012	5.26	-	5.26	-	5.26	-	5.26	-
2013	5.25	0.03	5.25	0.02	5.25	0.02	5.26	0.01
2014	5.24	0.04	5.26	0.05	5.26	0.03	5.27	0.02
2015	5.24	0.04	5.27	0.04	5.26	0.03	5.29	0.02
2016	5.29	0.05	5.33	0.05	5.32	0.03	5.28	0.02
2017	5.35	0.04	5.39	0.05	5.38	0.03	5.26	0.02
2018	5.41	0.05	5.46	0.04	5.45	0.03	5.25	0.02
2019	5.47	0.03	5.53	0.02	5.51	0.00	5.24	0.02
2020	5.53	0.03	5.51	0.03	5.63	0.01	5.23	0.01
2021	5.59	0.04	5.48	0.01	5.75	0.04	5.30	0.01
2022	5.65	0.04	5.44	0.01	5.86	0.04	5.37	0.01
2023	5.71	0.04	5.41	0.01	5.98	0.04	5.45	0.01
2024	5.77	0.04	5.38	0.01	6.10	0.04	5.52	0.01
2025	5.82	0.04	5.34	0.01	6.21	0.04	5.60	0.01
2026	5.87	0.04	5.30	0.01	6.33	0.04	5.68	0.01
2027	5.93	0.04	5.26	0.01	6.45	0.04	5.76	0.01
2028	5.98	0.04	5.23	0.01	6.57	0.04	5.85	0.01
2029	6.04	0.04	5.19	0.01	6.70	0.04	5.93	0.01
2030	6.10	0.04	5.16	0.01	6.83	0.05	5.93	0.01
2031	6.15	0.02	5.12	0.02	6.96	0.07	5.93	0.01
2032	6.20	0.02	5.09	0.02	7.09	0.07	5.93	0.01
2033	6.25	0.02	5.06	0.02	7.23	0.07	5.93	0.01
2034	6.31	0.02	5.03	0.02	7.37	0.07	5.93	0.01
2035	6.36	0.02	4.99	0.01	7.51	0.07	5.93	0.01
2036	6.41	0.02	4.96	0.01	7.65	0.07	5.94	0.01
2037	6.46	0.02	4.93	0.01	7.80	0.07	5.94	0.01
2038	6.51	0.02	4.89	0.01	7.94	0.07	5.94	0.01
2039	6.56	0.02	4.86	0.01	8.09	0.07	5.95	0.01
2040	6.61	0.02	4.83	0.01	8.24	0.08	6.04	0.01
2041	6.66	0.04	4.80	0.07	8.41	0.25	6.13	0.02
2042	6.71	0.04	4.77	0.07	8.57	0.26	6.21	0.03
2043	6.77	0.04	4.75	0.07	8.74	0.26	6.30	0.03
2044	6.82	0.04	4.72	0.07	8.92	0.27	6.39	0.03
2045	6.88	0.04	4.70	0.07	9.10	0.27	6.49	0.03
2046	6.94	0.04	4.67	0.07	9.28	0.28	6.58	0.03
2047	6.99	0.04	4.65	0.07	9.46	0.28	6.67	0.03
2048	7.05	0.04	4.62	0.06	9.65	0.29	6.77	0.03
2049	7.10	0.04	4.60	0.06	9.84	0.29	6.87	0.03
2050	7.15	0.04	4.57	0.06	10.03	0.29	6.97	0.03

Appendix 9: Carbon emissions for system variables & waste prevention

Table A9.1: Carbon emissions savings from waste prevention (tCO_2e)

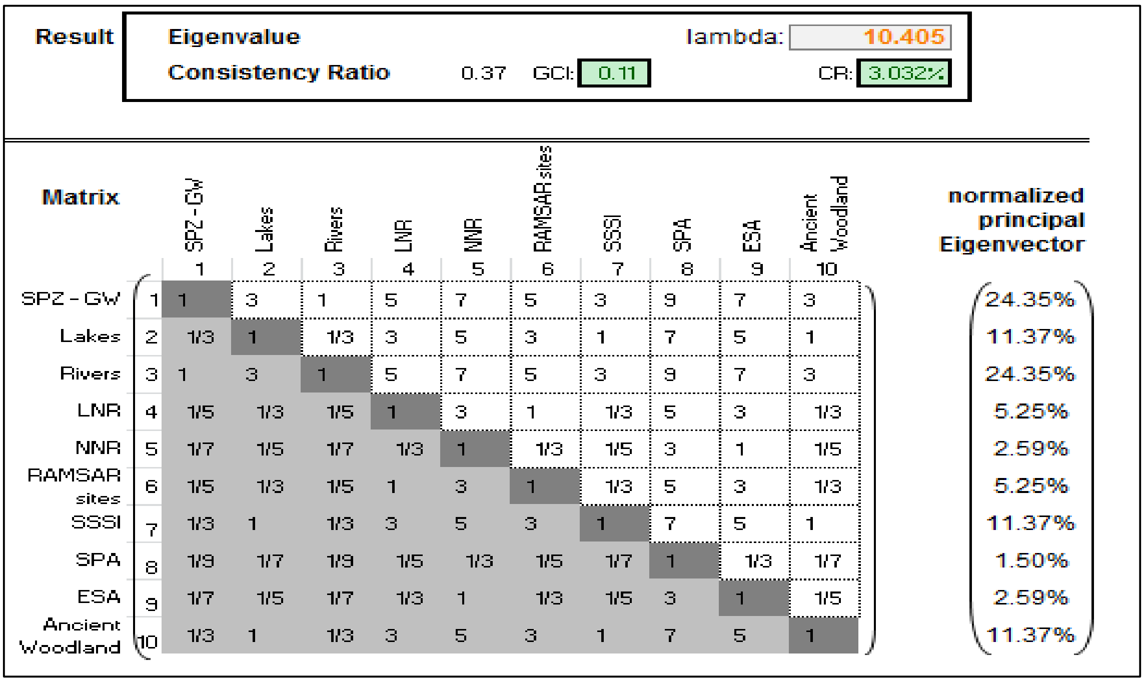
Year	CE Prevention (tCO_2)	VM Prevention (tCO_2)	EC Prevention (tCO_2)	ED Prevention (tCO_2)
2012	-	-	-	-
2013	21,593	12,315	13,465	3,745
2014	18,737	12,258	14,410	3,745
2015	20,181	13,211	13,349	3,748
2016	26,525	19,079	15,497	7,502
2017	24,159	18,969	14,881	6,943
2018	19,263	14,112	10,051	4,310
2019	19,167	15,649	13,739	3,754
2020	19,059	15,579	16,112	3,758
2021	14,219	11,462	14,459	-
2022	14,128	11,408	14,388	-
2023	14,033	11,352	14,314	-
2024	13,937	11,294	14,238	-
2025	13,837	11,230	14,154	-
2026	13,736	11,169	14,073	-
2027	13,634	11,105	13,990	-
2028	13,536	11,045	13,911	-
2029	13,441	10,987	13,835	-
2030	13,348	10,930	13,761	-
2031	19,586	17,217	29,598	3,887
2032	19,432	17,093	29,314	3,899
2033	19,276	16,968	29,028	3,911
2034	19,126	16,848	28,753	3,924
2035	18,969	16,724	28,472	3,938
2036	18,810	16,599	28,189	3,952
2037	18,649	16,471	27,904	3,966
2038	18,488	16,343	27,620	3,980
2039	18,330	16,218	27,341	3,994
2040	18,177	16,096	27,070	4,008
2041	18,335	7,731	21,497	-
2042	18,171	7,679	21,236	-
2043	18,011	7,629	20,981	-
2044	17,855	7,581	20,733	-
2045	17,704	7,534	20,493	-
2046	17,548	7,486	20,254	-
2047	17,391	7,437	20,014	-
2048	17,233	7,388	19,777	-
2049	17,072	7,337	19,538	-
2050	16,910	7,285	19,300	-
Cumulative	671,609	474,819	739,739	76,962

Table A9.2: Carbon emissions savings from systems variables changes (tCO_2e)

Year	CE Variables (tCO_2)	VM Variables (tCO_2)	EC Variables (tCO_2)	ED Variables (tCO_2)
2012	-	-	-	-
2013	8,147	8,322	7,747	- 436
2014	17,531	11,226	12,817	- 1,823
2015	12,218	8,118	9,697	- 5,132
2016	12,191	7,889	9,661	- 5,137
2017	14,244	12,903	9,622	- 2,958
2018	7,712	6,134	2,870	- 2,959
2019	3,467	1,861	-1,391	- 5,143
2020	5,266	8,804	4,700	- 5,681
2021	9,385	12,951	9,116	- 8,444
2022	6,151	11,775	7,965	- 10,660
2023	7,105	12,710	8,928	- 10,691
2024	7,724	13,305	9,550	- 10,722
2025	9,784	15,346	11,966	- 11,167
2026	9,804	14,614	11,255	- 13,479
2027	10,396	15,181	11,850	- 13,528
2028	9,394	14,138	10,825	- 13,576
2029	9,036	13,746	10,454	- 13,624
2030	8,369	13,042	9,769	- 13,673
2031	9,966	13,223	9,655	- 16,288
2032	16,596	16,157	19,730	- 14,066
2033	17,094	16,673	20,175	- 14,253
2034	16,054	15,634	19,064	- 14,299
2035	17,457	16,453	19,811	- 16,143
2036	17,928	16,950	20,233	- 16,202
2037	18,387	17,437	20,642	- 16,261
2038	18,539	17,613	20,741	- 16,320
2039	18,099	17,187	20,247	- 16,380
2040	17,376	16,474	19,471	- 16,439
2041	19,479	18,338	20,942	- 12,676
2042	18,465	10,763	12,502	- 15,090
2043	18,031	10,419	12,133	- 15,146
2044	17,324	9,791	11,490	- 15,202
2045	16,630	9,170	10,859	- 15,259
2046	17,609	9,702	11,344	- 15,316
2047	18,016	10,227	11,819	- 15,373
2048	18,140	10,461	12,011	- 15,430
2049	18,798	11,256	12,737	- 15,487
2050	19,171	11,759	13,180	- 15,545
Cumulative	517,080	477,753	476,190	- 456,010

Appendix 10: Pairwise comparison matrices and calculations

This section provides examples of data generation using pairwise comparisons. Weights were calculated with feedback from 5 stakeholders (randomly selected). The mean was taken of 5 results and multiplied by group criteria weighting to give an individual value for each criterion in the group. A value of greater than 0.1 in the CI calculations (alternatively >10% as CR in the software) requires the criterion to be revisited.



		SPZ - GW 1	Lakes 2	Rivers 3	LNR 4	NNR 5	RAMSAR sites 6	SSSI 7	SPA 8	ESA 9	Ancient Woodland 10	normalized principal Eigenvector
SPZ - GW	1	1	3	1	5	7	5	3	9	7	3	24.35%
Lakes	2	1/3	1	1/3	3	5	3	1	7	5	1	11.37%
Rivers	3	1	3	1	5	7	5	3	9	7	3	24.35%
LNR	4	1/5	1/3	1/5	1	3	1	1/3	5	3	1/3	5.25%
NNR	5	1/7	1/5	1/7	1/3	1	1/3	1/5	3	1	1/5	2.59%
RAMSAR sites	6	1/5	1/3	1/5	1	3	1	1/3	5	3	1/3	5.25%
SSSI	7	1/3	1	1/3	3	5	3	1	7	5	1	11.37%
SPA	8	1/9	1/7	1/9	1/5	1/3	1/5	1/7	1	1/3	1/7	1.50%
ESA	9	1/7	1/5	1/7	1/3	1	1/3	1/5	3	1	1/5	2.59%
Ancient Woodland	10	1/3	1	1/3	3	5	3	1	7	5	1	11.37%

Figure A10.1: Example pairwise comparison matrix and CR for Environmental Receptors criterion

Table A5.1: Calculations for the individual Environmental Receptor criterion

Criterion	T1	T2	T3	NT1	NT2	Mean	Weight
SPZ - GW	0.2939	0.2505	0.2125	0.2407	0.2421	0.2480	3.6697
Lakes	0.1469	0.0519	0.1001	0.0436	0.1151	0.0915	1.3543
Rivers	0.1469	0.1230	0.2125	0.1095	0.2421	0.1668	2.4689
LNR	0.0619	0.0227	0.0224	0.0436	0.0524	0.0406	0.6006
NNR	0.0619	0.0519	0.0475	0.0436	0.0257	0.0461	0.6825
RAMSAR sites	0.0266	0.0519	0.0224	0.0436	0.0524	0.0394	0.5824
SSSI	0.0619	0.2505	0.2125	0.1041	0.1151	0.1488	2.2027
SPA	0.0266	0.0519	0.0475	0.0212	0.0144	0.0323	0.4782
ESA	0.0266	0.0227	0.1001	0.1095	0.0257	0.0569	0.8425
Ancient Woodland	0.1469	0.1230	0.0224	0.2407	0.1151	0.1296	1.9183
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	14.80
CI	0.0220	0.0215	0.0216	0.0172	0.0283	0.0221	

The output in Figure A10.1 shows the results box and pairwise matrix used to generate the relevant weights for individual criterion (represented by the normalized principal Eigenvector). The calculations for all weights in the Environmental Receptors group are shown in Table A10.1. All criteria including the Mean were found to be below 0.1.

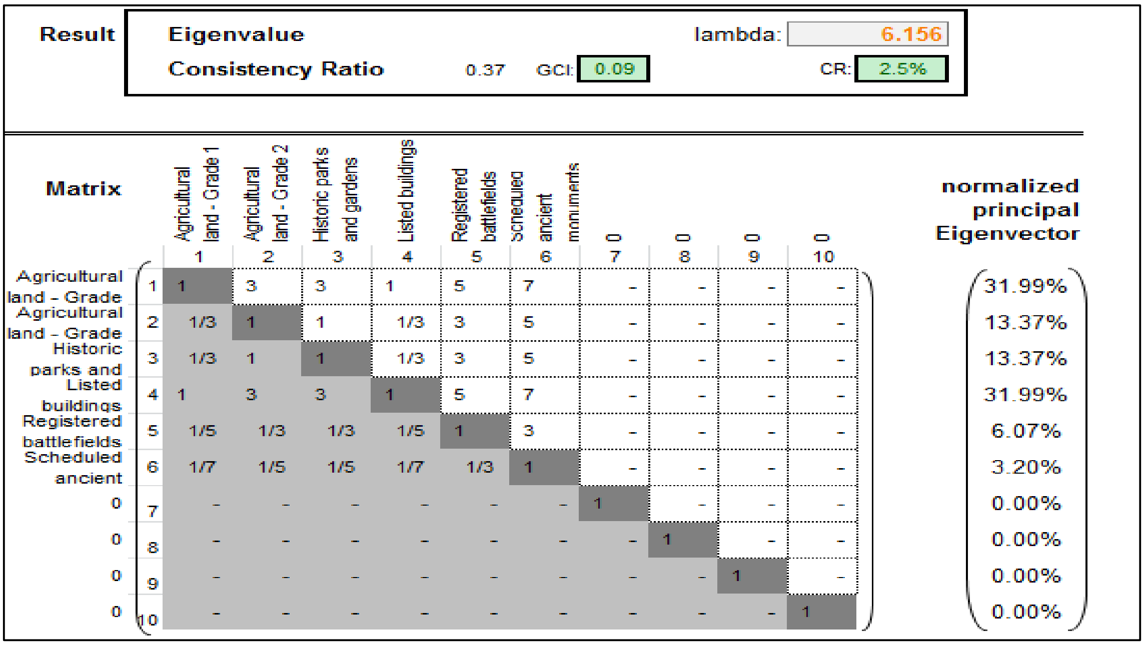


Figure A10.2: Example pairwise comparison matrix and CR for Conservation Receptors criterion

Table A10.2: Calculations for the individual Conservation Receptor criterion

Criterion	T4	T5	NT3	NT4	NT5	Mean	Weight
Agricultural land - Grade 1	0.4576	0.3206	0.1131	0.3185	0.0943	0.2608	0.9050
Agricultural land - Grade 2	0.2392	0.1338	0.1131	0.1291	0.0943	0.1419	0.4924
Historic parks and gardens	0.1070	0.1338	0.3075	0.1291	0.2564	0.1868	0.6481
Listed buildings	0.1070	0.3206	0.3075	0.3185	0.2564	0.2620	0.9091
Registered battlefields	0.0447	0.0599	0.1131	0.0524	0.2564	0.1053	0.3653
Ancient monuments	0.0447	0.0313	0.0458	0.0524	0.0422	0.0433	0.1501
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3.47
CR	0.0325	0.0203	0.0080	0.0123	0.0062	0.0159	

The output in Figure A10.2 shows the results box and pairwise matrix used to generate the relevant weights for individual Conservation Receptor criterion. The calculations for all weights in the Conservation Receptors group are shown in Table A10.2. All criteria including the Mean were found to be well below the CR threshold.

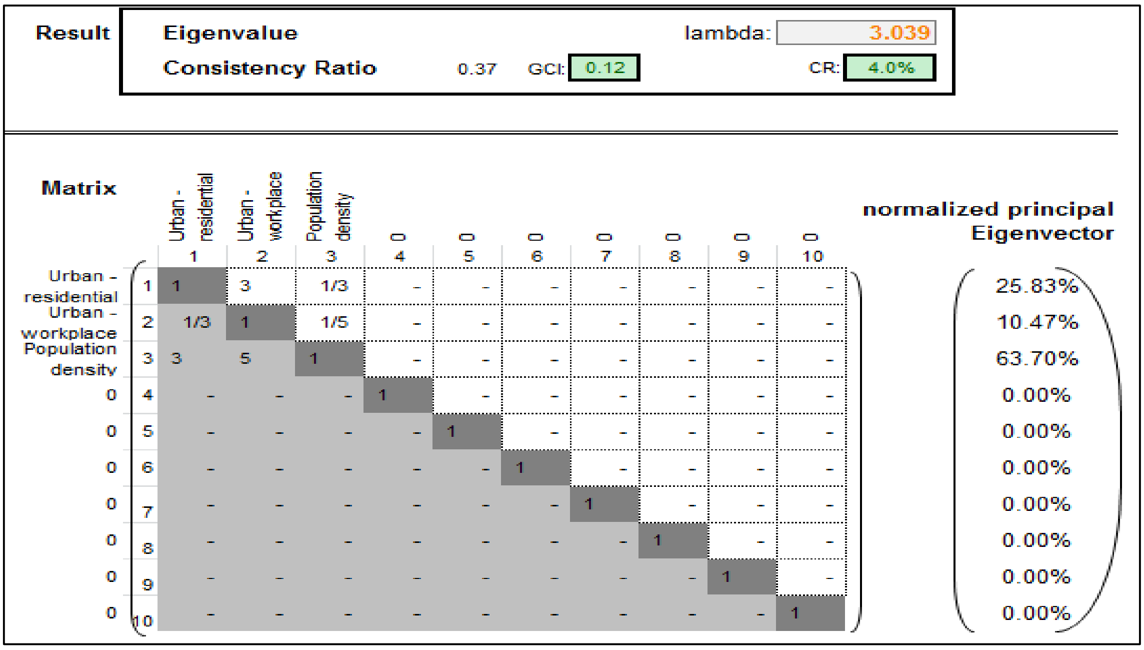


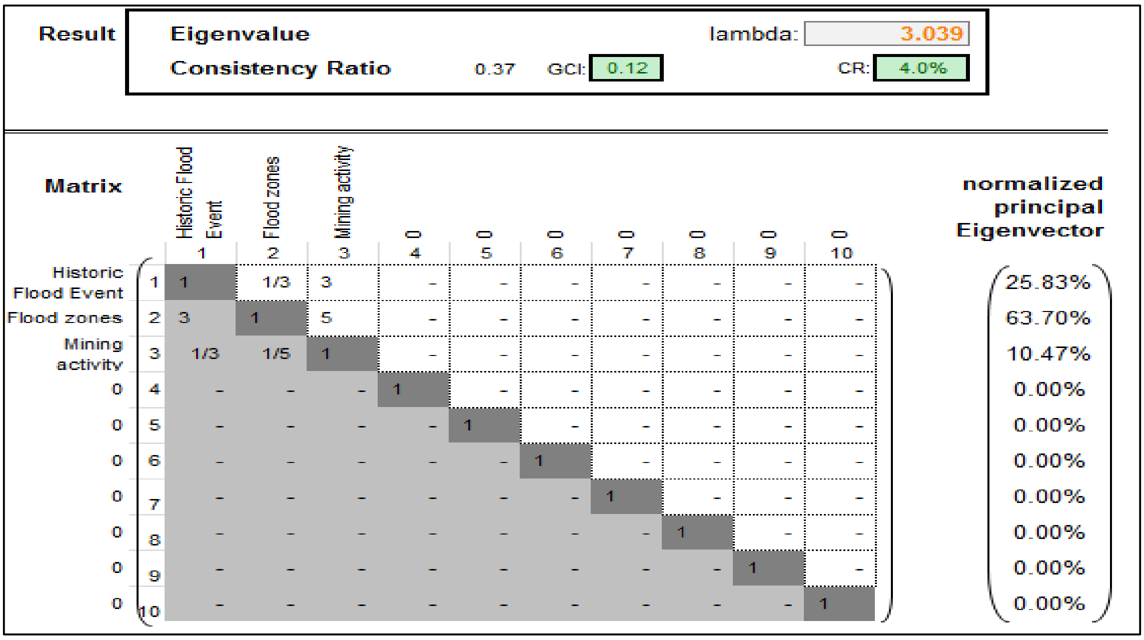
Figure A10.3: Example pairwise comparison matrix and CR for Human & Social Capital Receptors criterion

Table A10.3: Calculations for the individual Human & Social Capital Receptor criterion

Criterion	T6	T7	T8	NT6	NT7	Mean	Weight
Urban - residential	0.2583	0.2000	0.2583	0.4286	0.4286	0.3147	3.0121
Urban - workplace	0.1047	0.2000	0.1047	0.1429	0.1429	0.1390	1.3306
Population density	0.6370	0.6000	0.6370	0.4286	0.4286	0.5462	5.2274
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	9.57
CI	0.0402	0.0000	0.0402	0.0000	0.0000	0.0160	

The output in Figure A10.3 shows the results box and pairwise matrix used to generate the relevant weights for individual Human & Social Capital Receptor criterion. The calculations for all weights in the Human & Social Capital Receptor group are shown in Table A10.3. All criteria including the Mean were found to be well below this threshold.

The output in Figure A10.4 shows the results box and pairwise matrix used to generate the relevant weights for individual Flood Risk & Ground Stability criterion. The calculations for all weights in the Flood Risk & Ground Stability group are shown in Table A5.4. All criteria including the Mean were found to be well below this threshold.



Result	Eigenvalue		lambda: 3.039
	Consistency Ratio	0.37 GCI: 0.12	CR: 4.0%

Matrix		Historic Flood Event 1	Flood zones 2	Mining activity 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
Historic Flood Event	1	1	1/3	3	-	-	-	-	-	-	-	25.83%
Flood zones	2	3	1	5	-	-	-	-	-	-	-	63.70%
Mining activity	3	1/3	1/5	1	-	-	-	-	-	-	-	10.47%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%
0	6	-	-	-	-	-	1	-	-	-	-	0.00%
0	7	-	-	-	-	-	-	1	-	-	-	0.00%
0	8	-	-	-	-	-	-	-	1	-	-	0.00%
0	9	-	-	-	-	-	-	-	-	1	-	0.00%
0	10	-	-	-	-	-	-	-	-	-	1	0.00%

Figure A10.4: Example pairwise comparison matrix and CR for Flood Risk & Ground Stability criterion

Table A10.4: Calculations for the individual Flood Risk & Ground Stability criterion

Criterion	T9	T10	NT8	NT9	NT10	Mean	Weight
Historic flood event	0.2583	0.2583	0.2583	0.2583	0.6370	0.3340	2.37
Flood zones	0.6370	0.6370	0.6370	0.6370	0.2583	0.5612	3.99
Mining activity	0.1047	0.1047	0.1047	0.1047	0.1047	0.1047	0.74
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	7.11
CI	0.0402	0.0402	0.0402	0.0402	0.0402	0.0402	

Appendix 11: Constraints and Opportunities layer maps

Individual constraints map layers are presented as Boolean results (0 = constraining pixel 25m raster resolution 1 = non-constraining pixel). These layer maps represent Appendix 11a (constraints) and use the constraints model:

$$\prod_{j=1}^{m} r_j$$

There are a total of 16 individual layer maps which are presented on Disc 1.

Individual opportunities map layers are presented as a scale classification 1-5 where 5 is the highest suitability. These layers represent Appendix 11b (page 288) opportunities and use the opportunities model:

$$\sum_{i=1}^{n} w_i \, C_j$$

There are a total of 17 individual layer maps which are presented on Disc 1.

These maps are then combined using the suitability model:

$$S = \sum_{i=1}^{n} w_i \, C_j \prod_{j=1}^{m} r_j$$

This identifies areas of suitability according to the criteria set out within the AHP process which are subsequently reclassified to identify areas of search by land parcel size.

The models are illustrated in Figures A11.1 to 11.4.

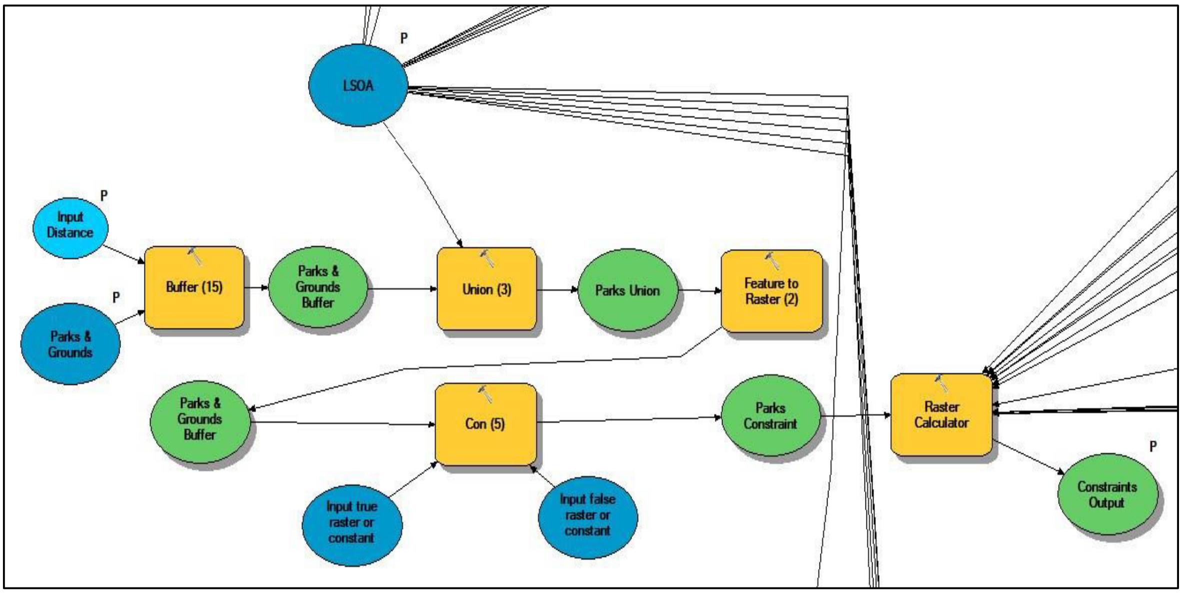


Figure A11.1: Individual variable calculations using Model Builder

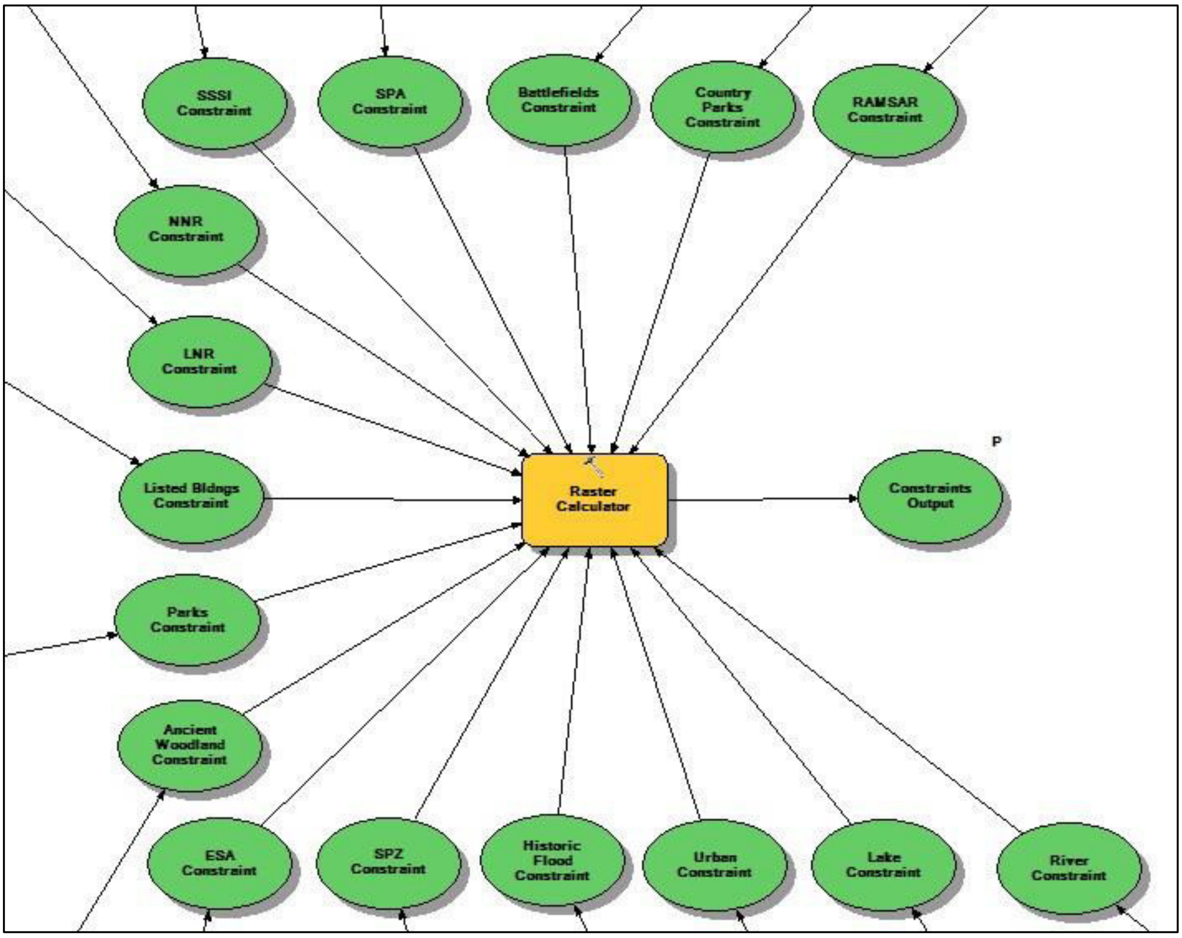


Figure A11.2: Final raster calculations for constraints variables in Model Builder

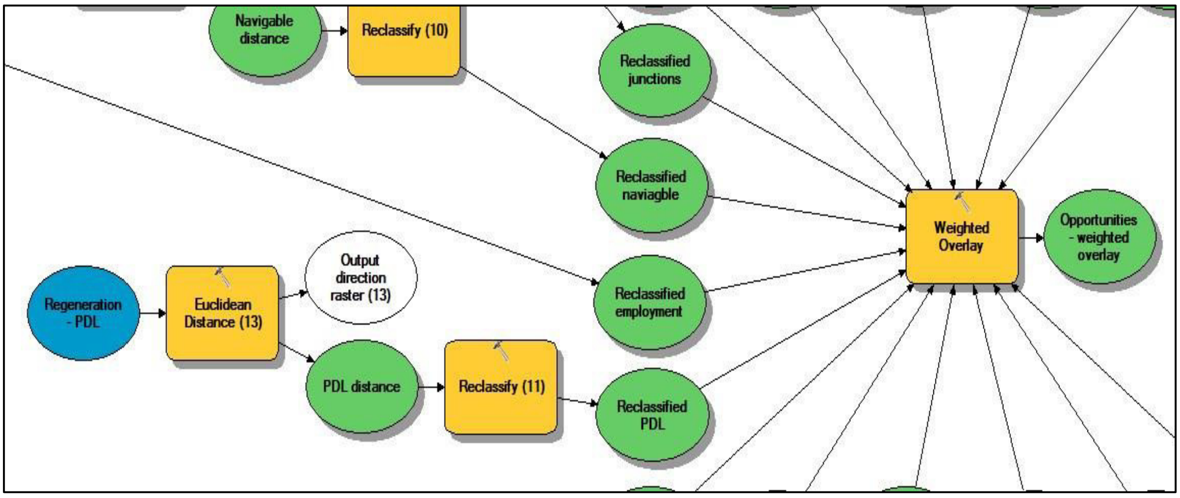


Figure A11.3: Individual opportunities variables calculation in Model Builder

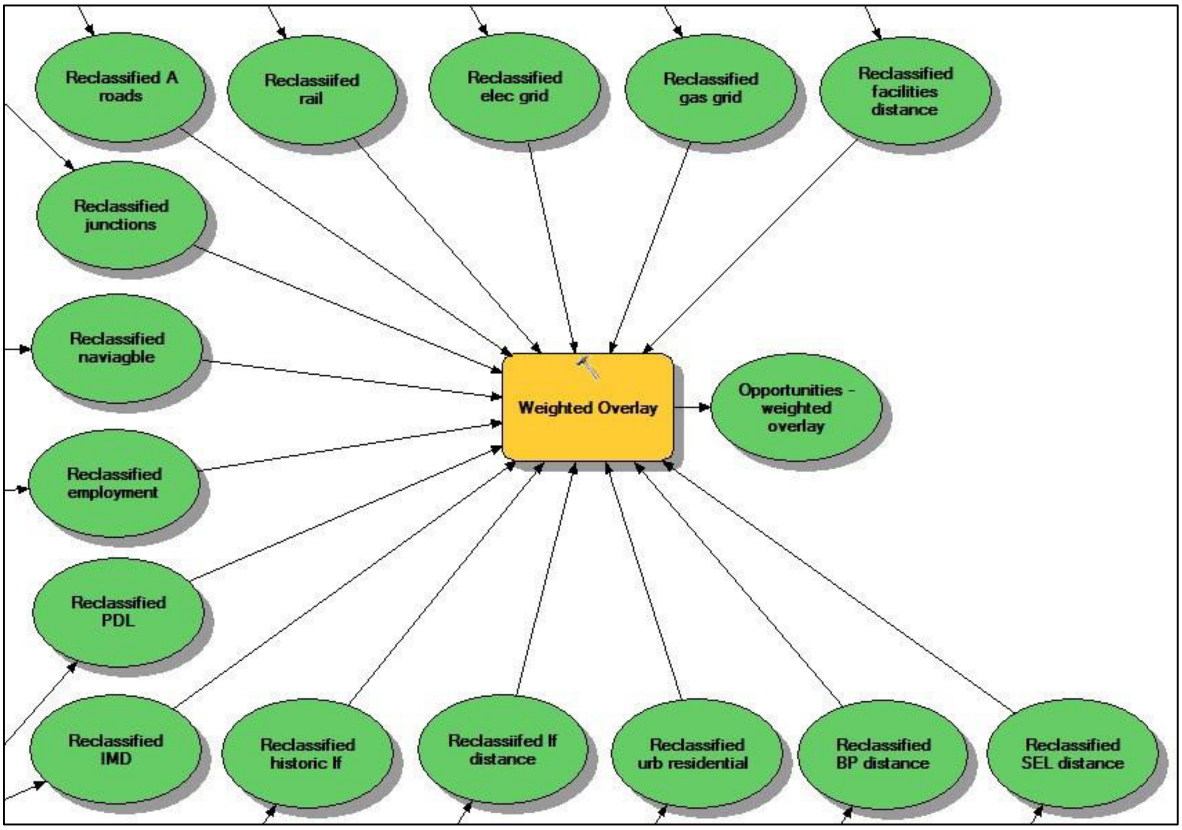


Figure A11.4: Final opportunities weighted overlay calculations in Model Builder

Appendix 12: Backcasting maps through GIS analysis

Appendix 12 is contained entirely on Disc 1 and encompasses:

- Waste tonnages maps – all scenarios
    - Figures A12.1 to A12.12
- Economic costs and savings for milestone years – all scenarios
    - Figures A12.13 to A12.18
- Carbon emissions performance maps – all scenarios
    - Figures A12.19 to A12.21

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Appendix 11a: Constraints layers (Figures A11.1 to A11.16)

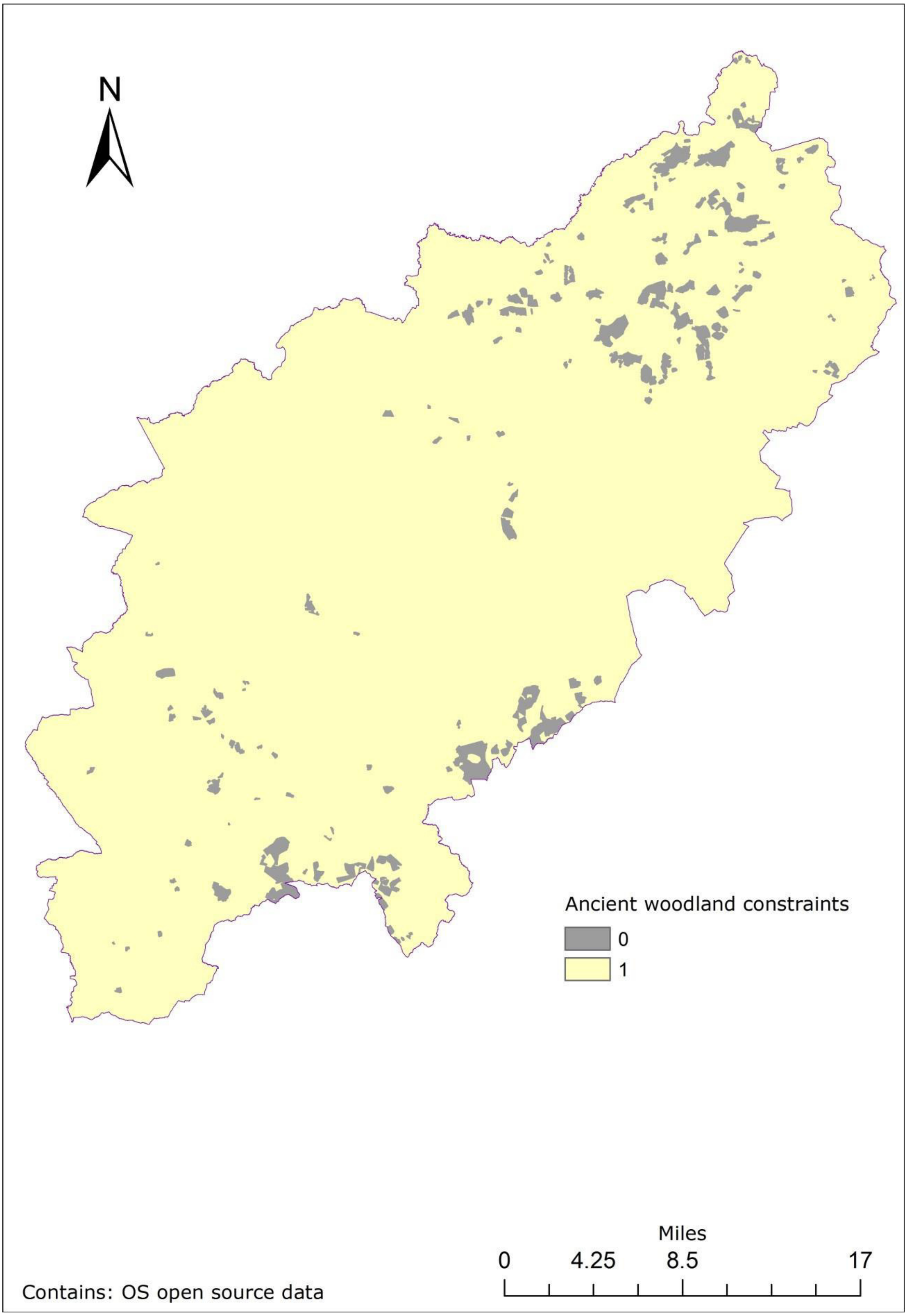

Figure A11.1: Ancient woodland Boolean raster constraints layer

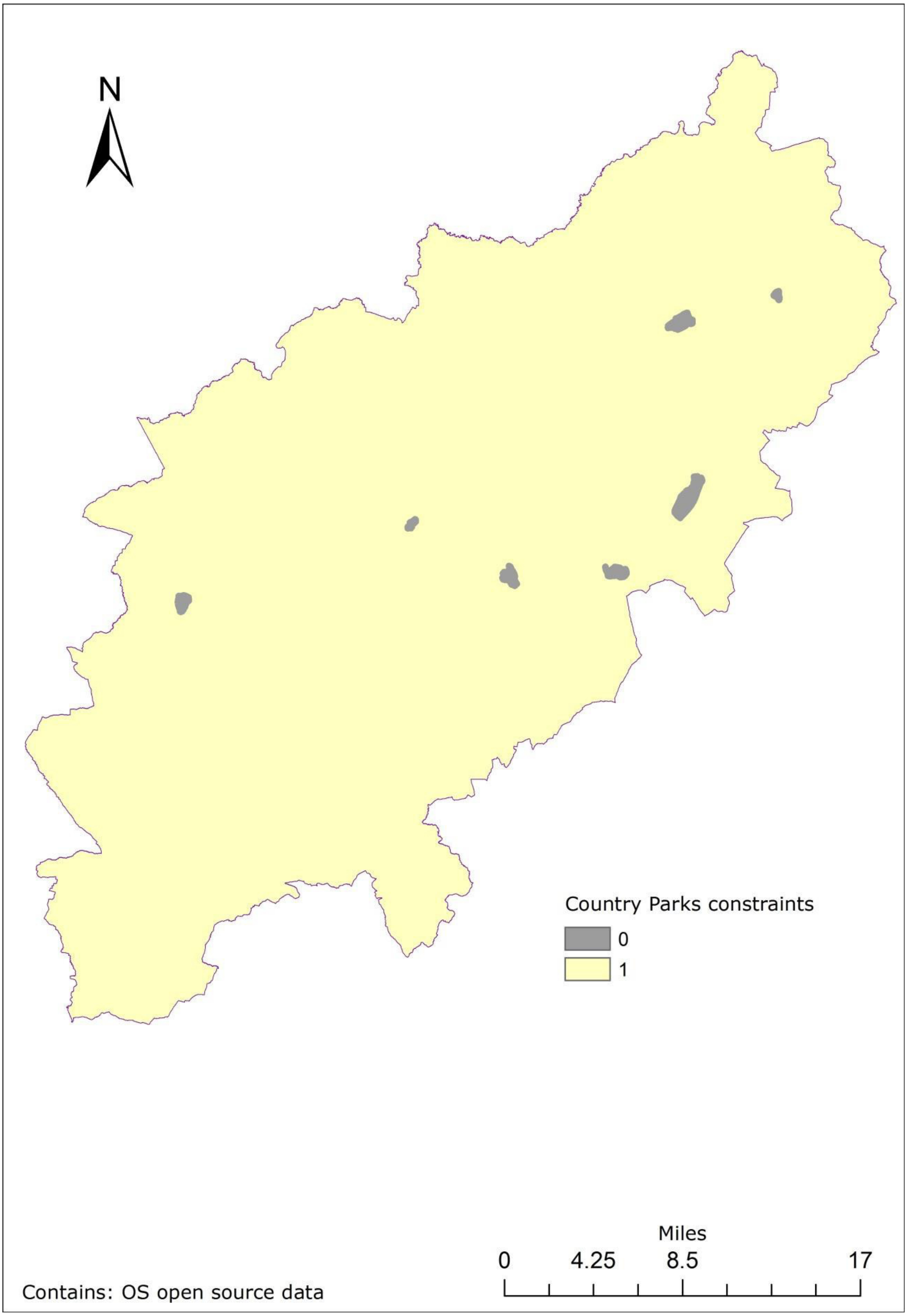

Figure A11.2: Country parks Boolean raster constraints layer

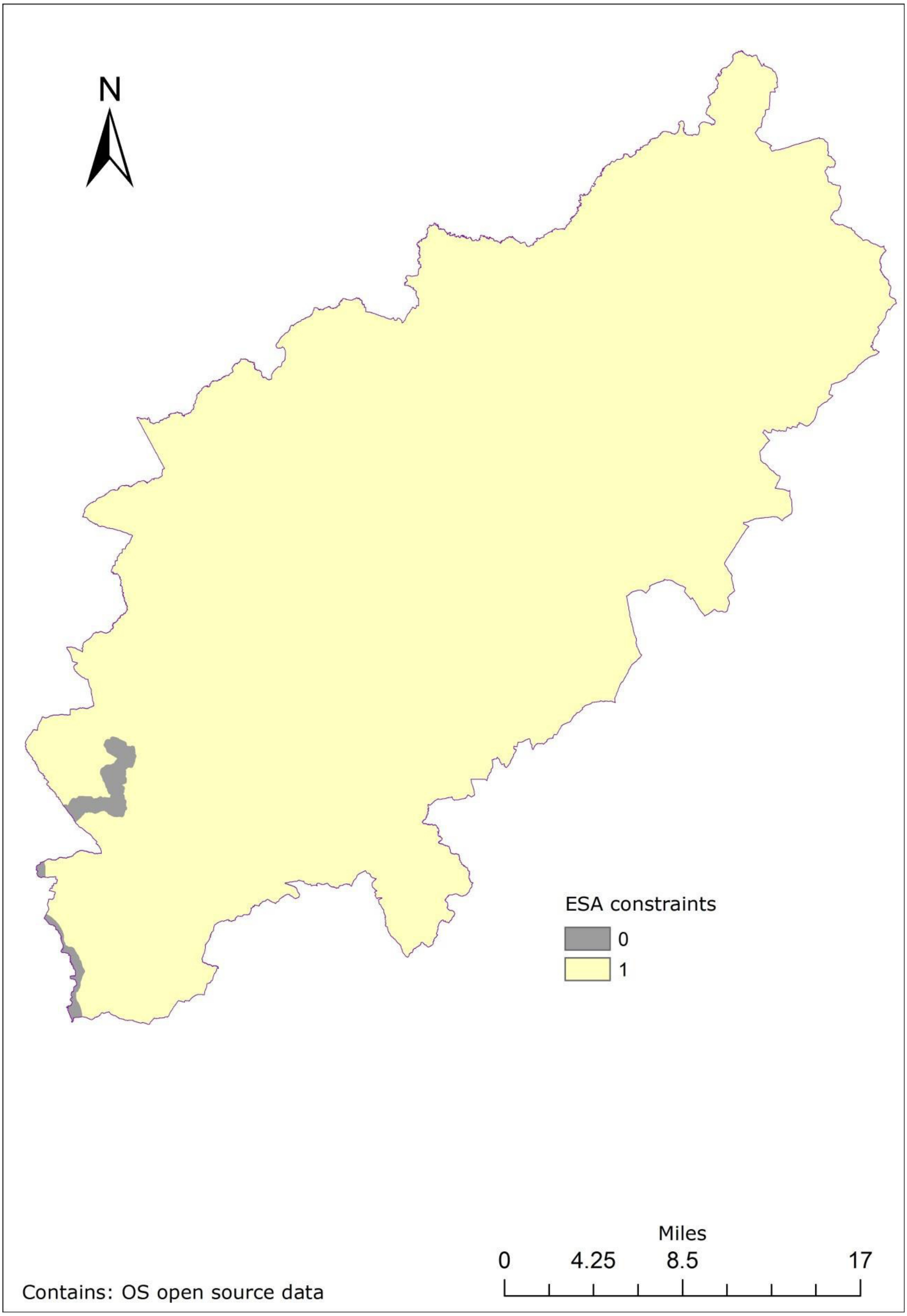

Figure A11.3: Environmentally Sensitive Areas (ESA) Boolean raster constraints layer

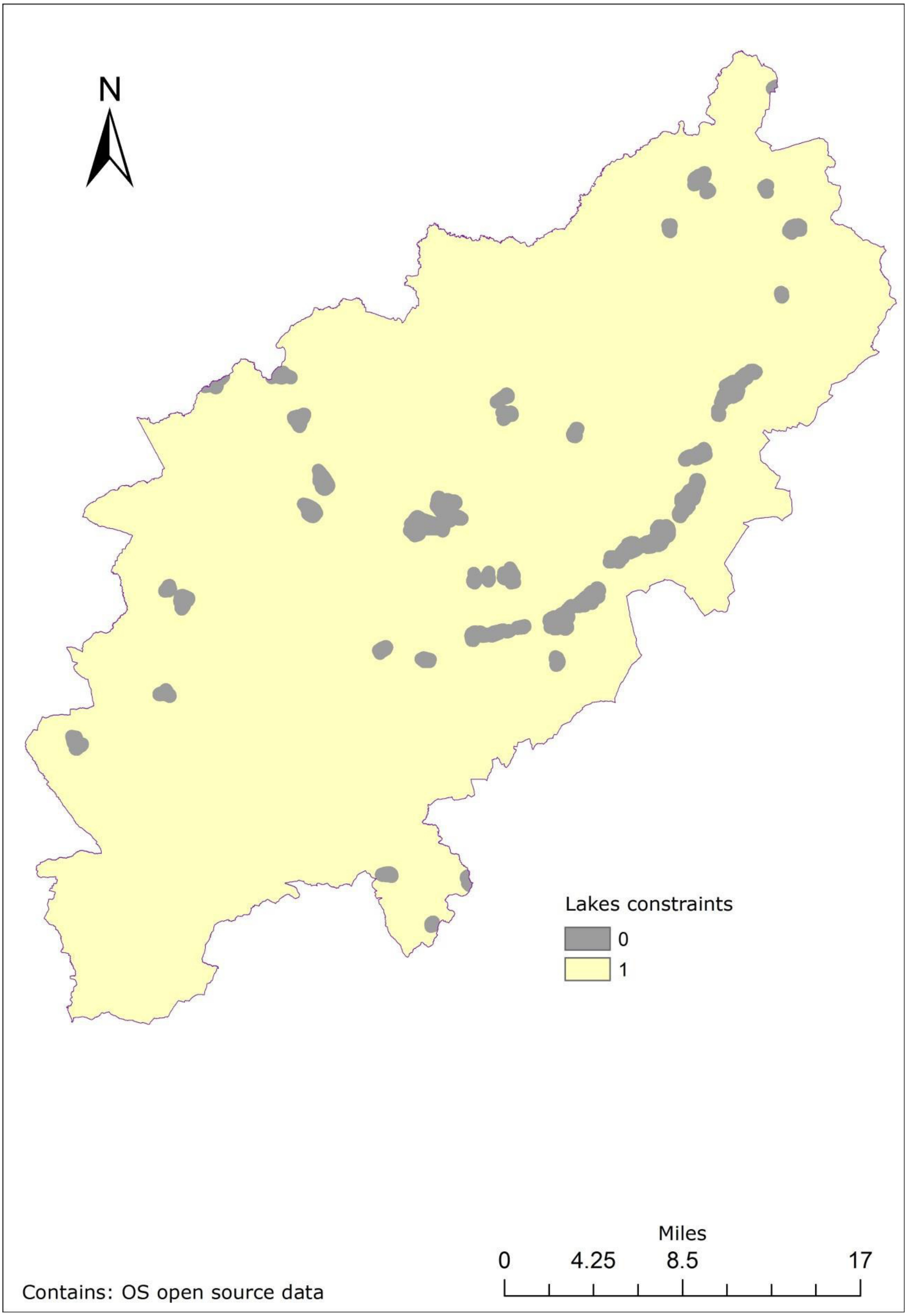

Figure A11.4: Lakes Boolean raster constraints layer

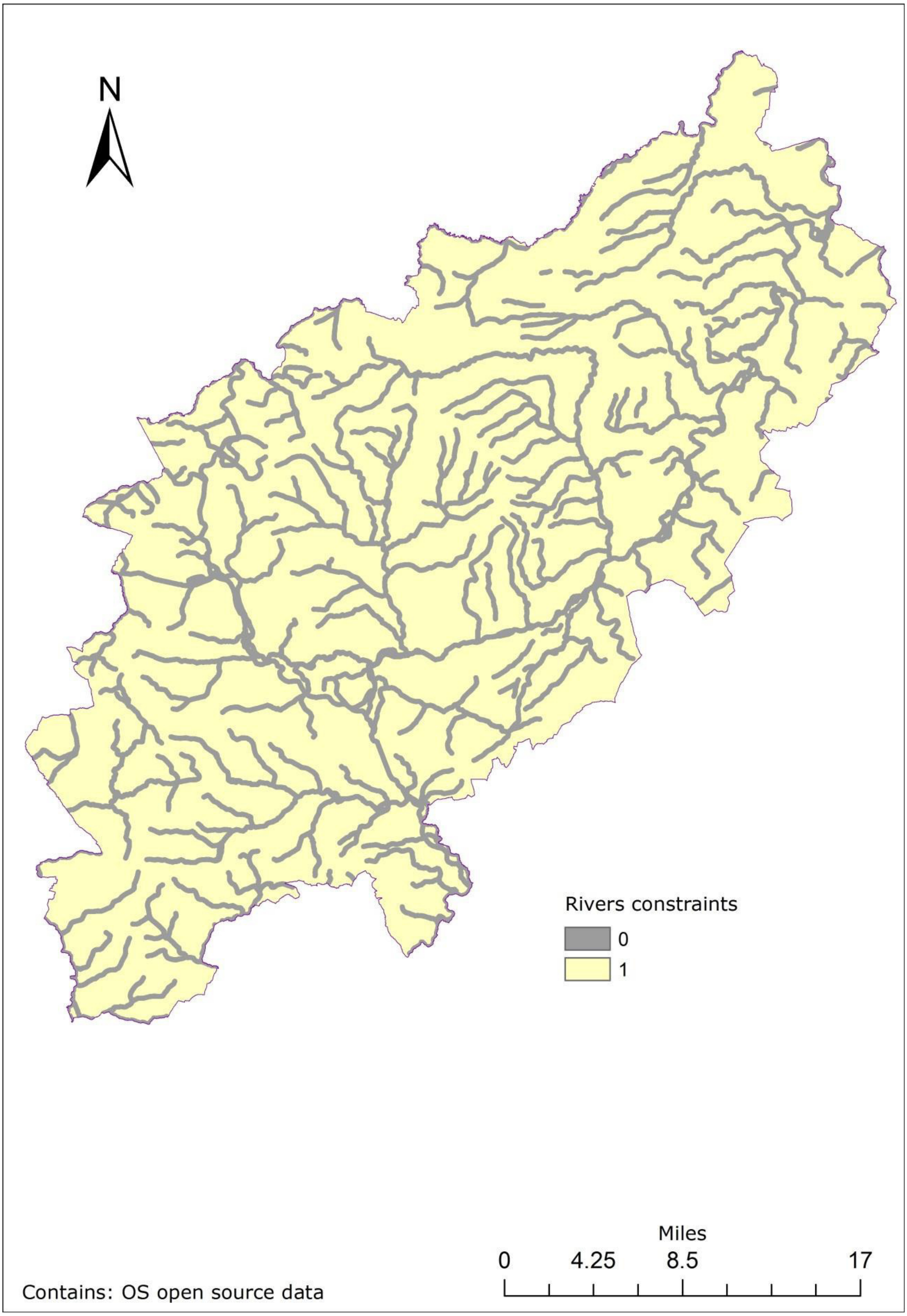

Figure A11.5: Rivers Boolean raster constraints layer

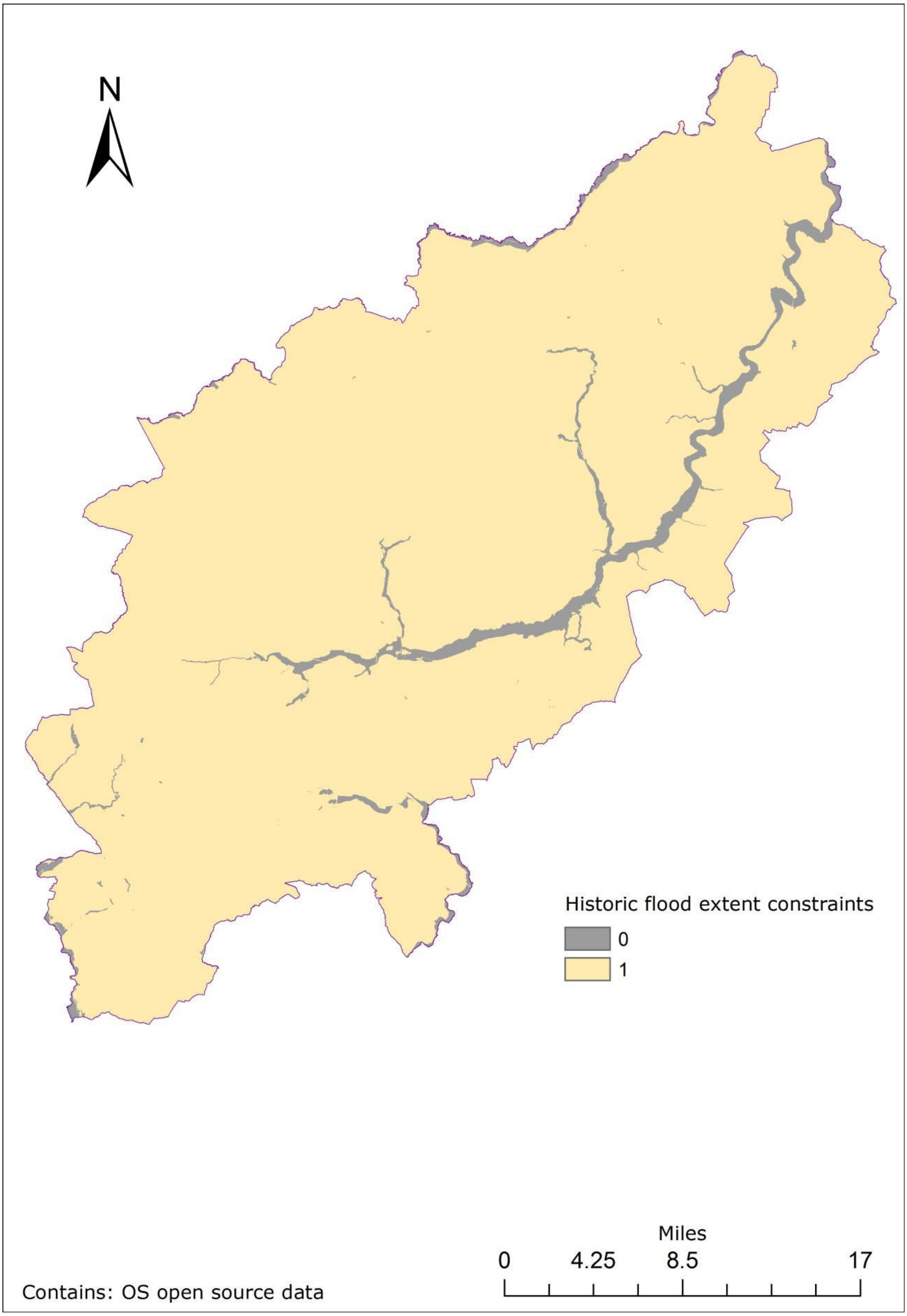

Figure A11.6: Historic flood extent Boolean raster constraints layer

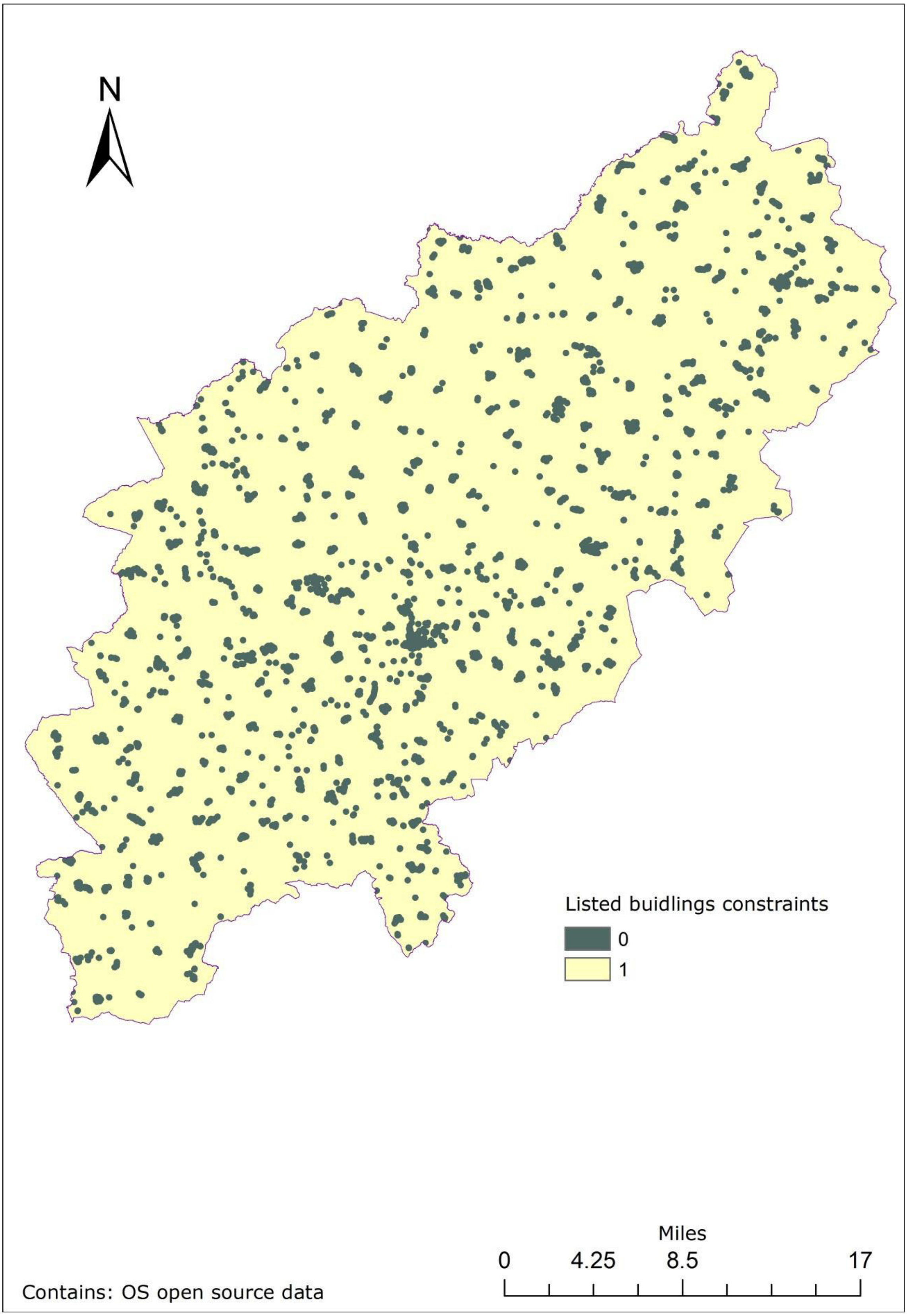

Figure A11.7: Listed buildings Boolean raster constraints layer

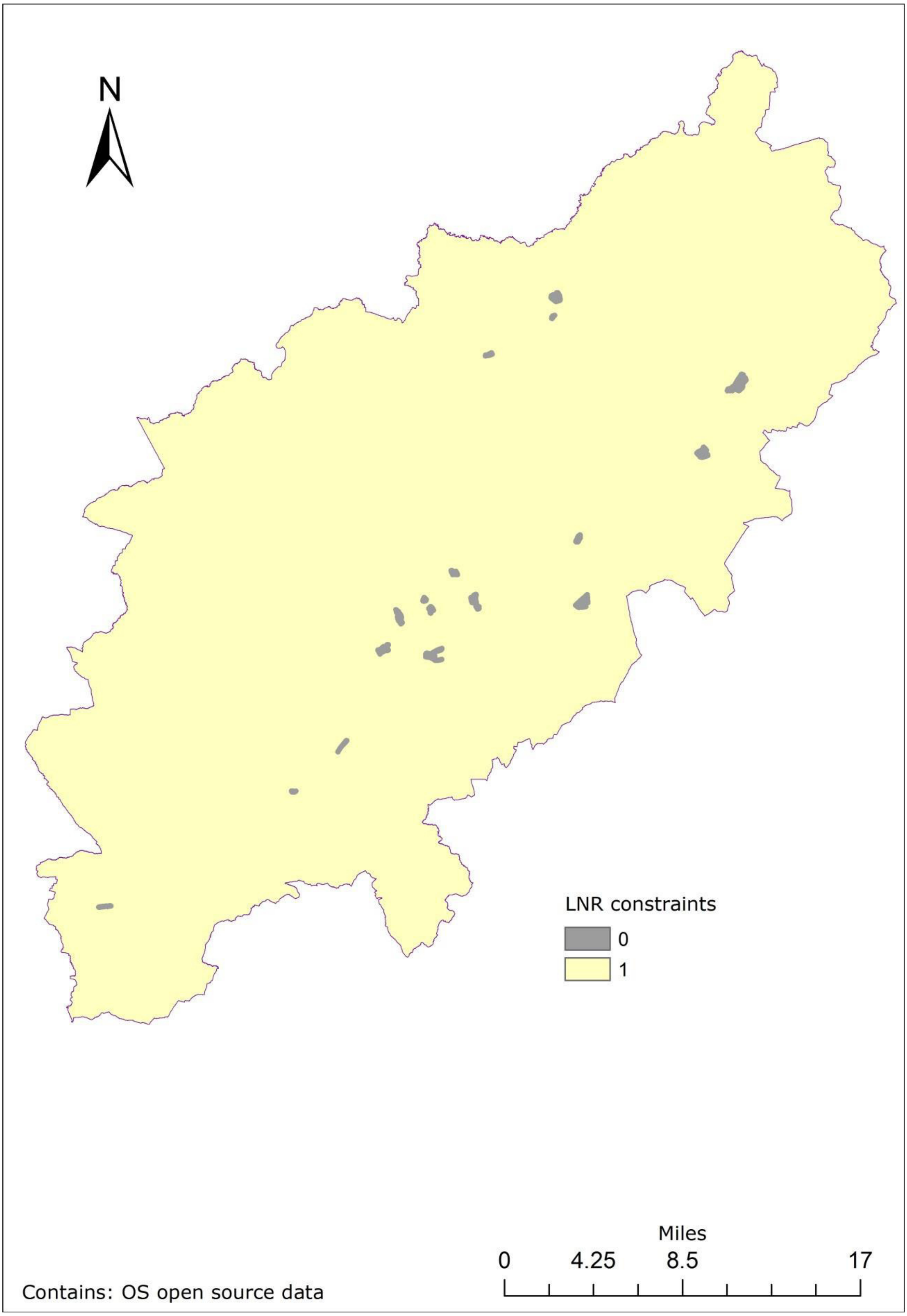

Figure A11.8: Local Nature Reserve (LNR) Boolean raster constraints layer

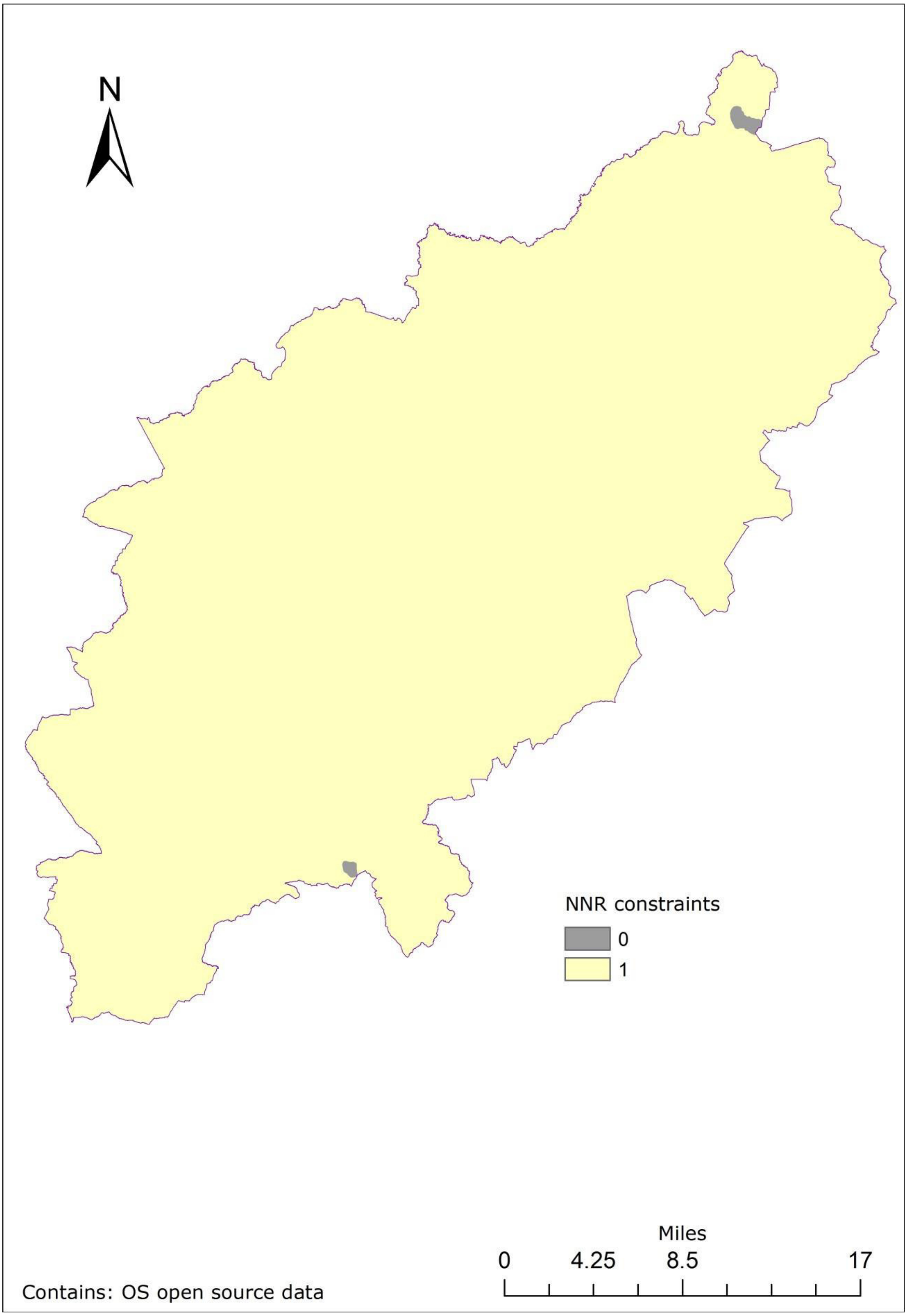

Figure A11.9: National Nature Reserve (NNR) Boolean raster constraints layer

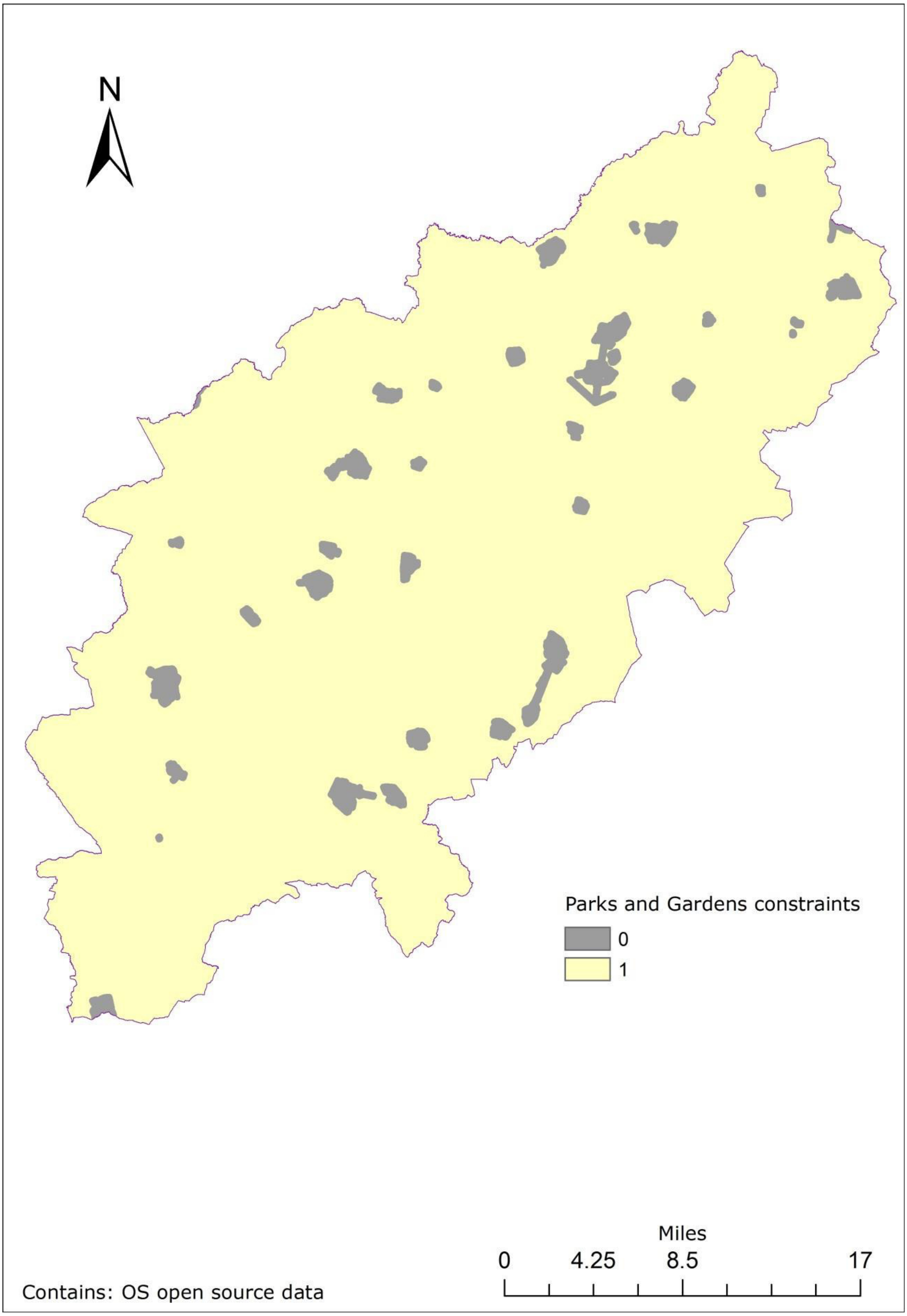

Figure A11.10: Parks and gardens Boolean raster constraints layer

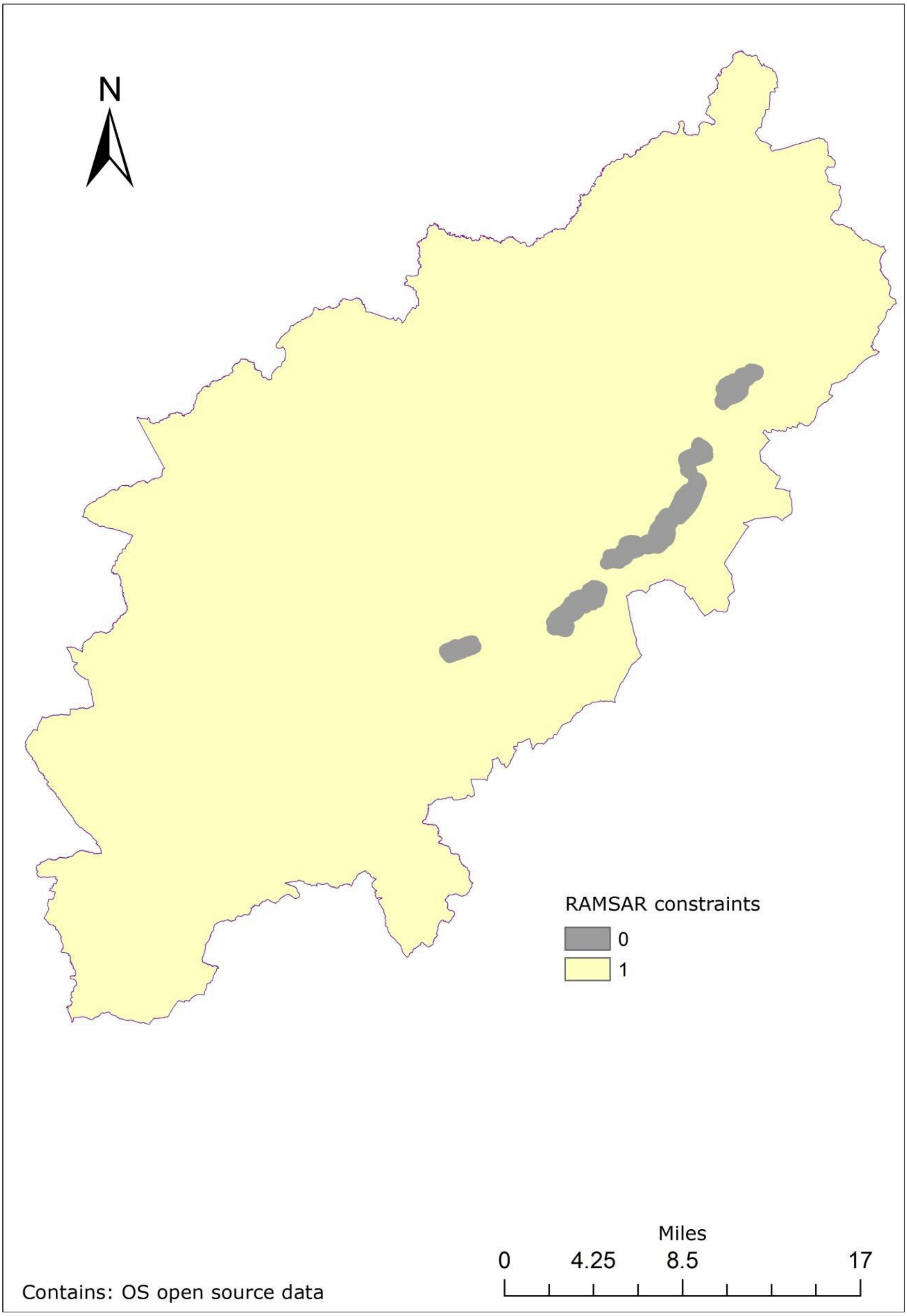

Figure A11.11: RAMSAR sites Boolean raster constraints layer

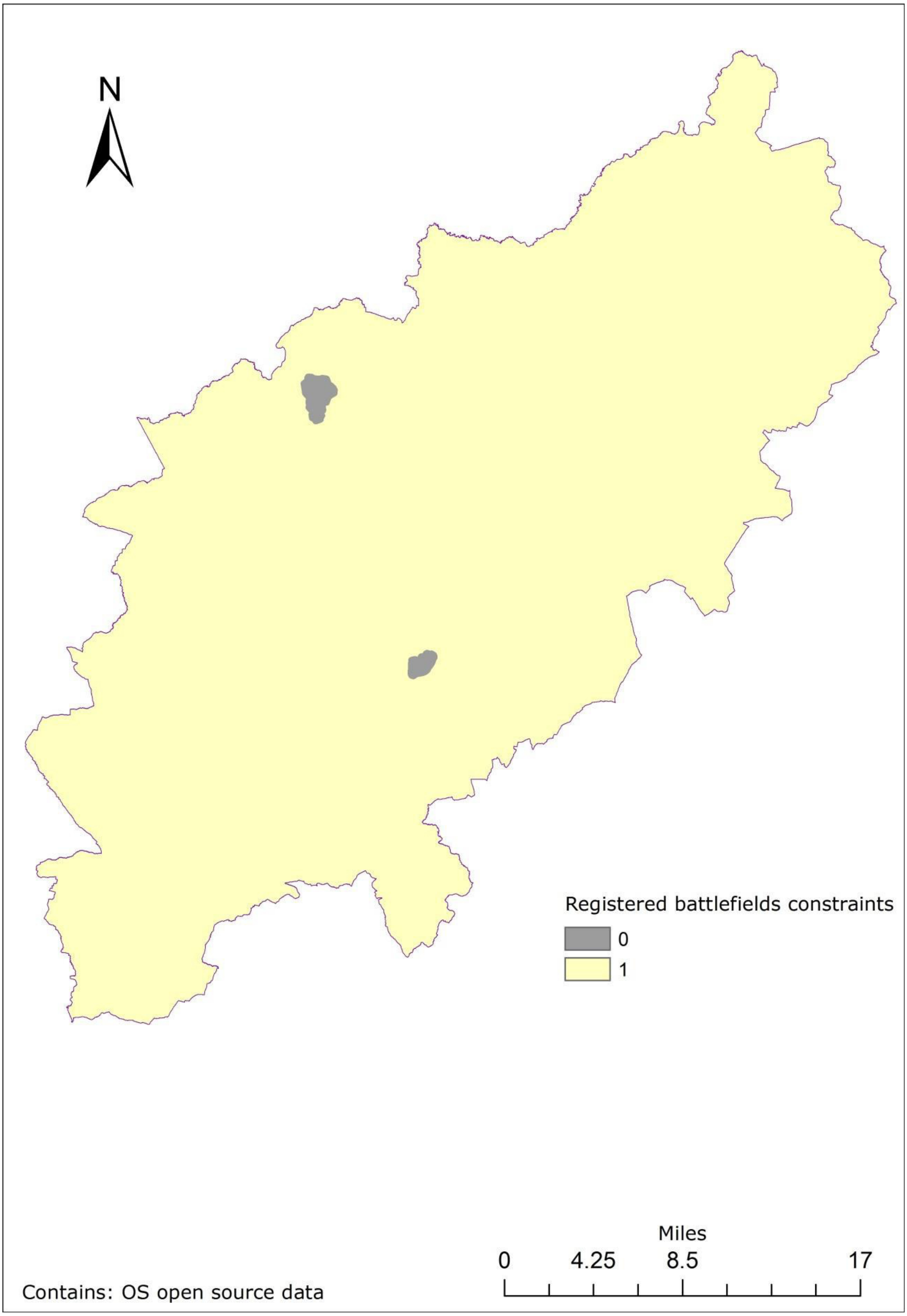

Figure A11.12: Registered battlefields Boolean raster constraints layer

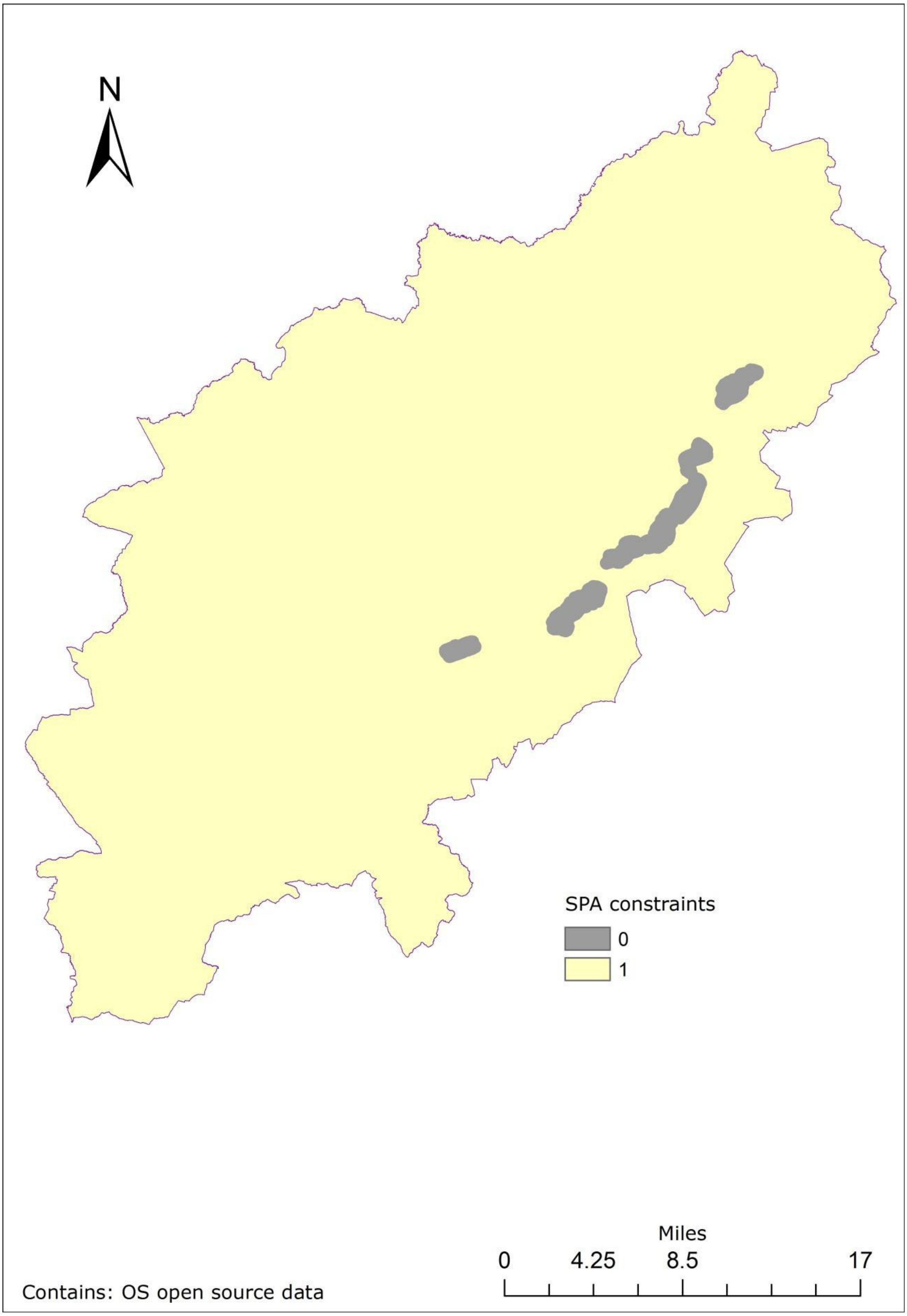

Figure A11.13: Special Protection Area (SPA) Boolean raster constraints layer

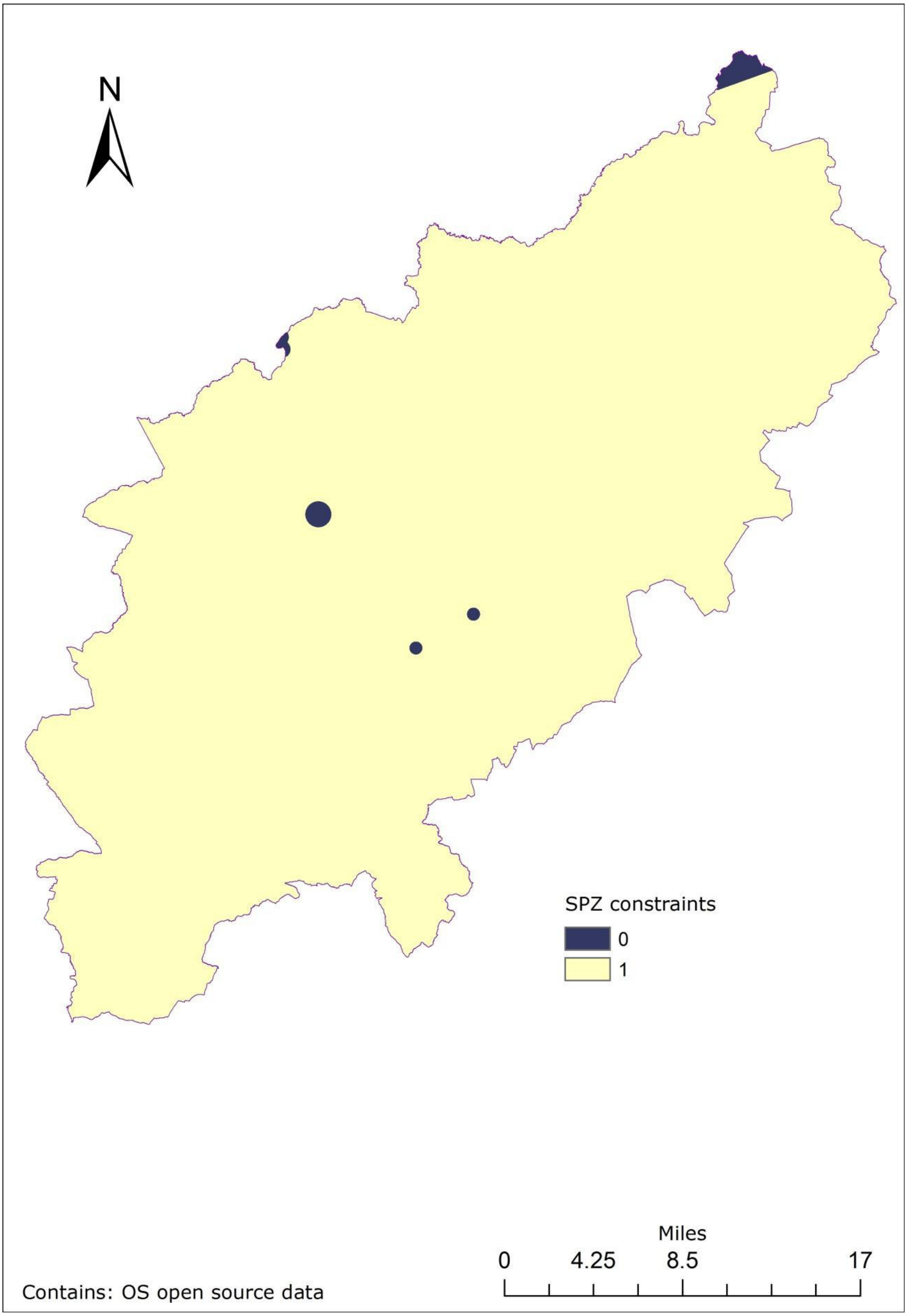

Figure A11.14: Source Protection Zones (SPZ) Boolean raster constraints layer

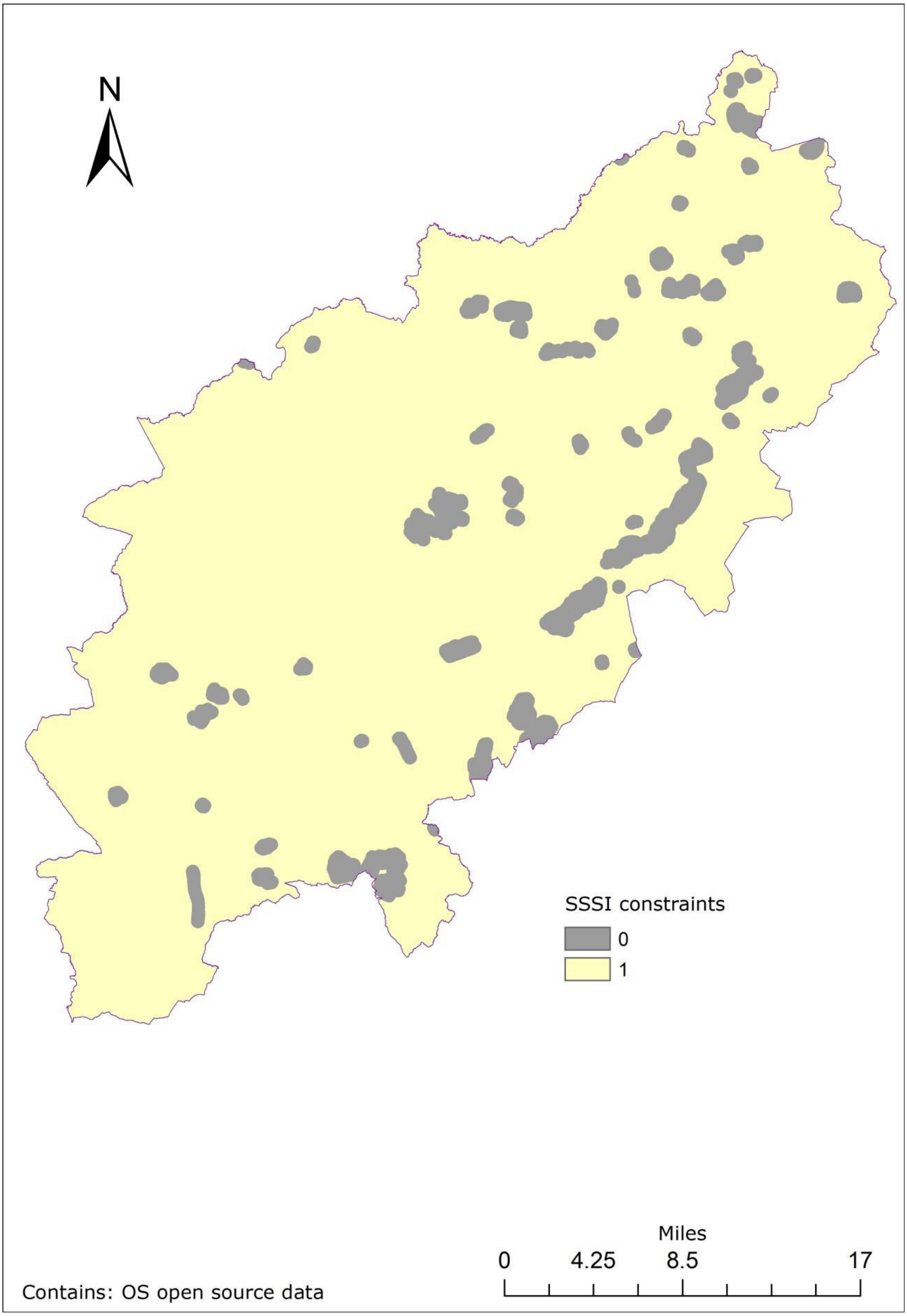

Figure A11.15: Sites of Special Scientific Interest (SSSI) Boolean raster constraints layer

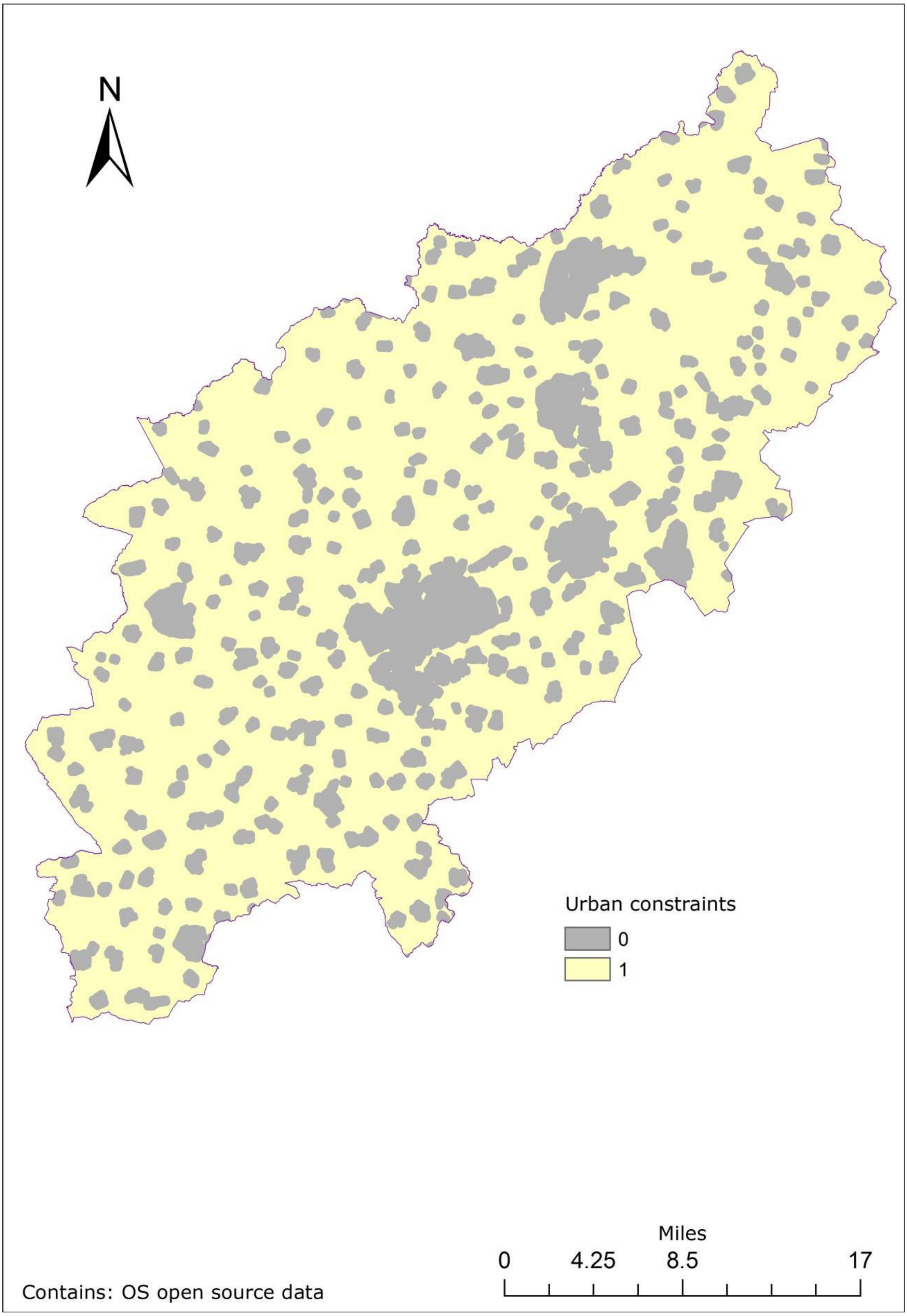

Figure A11.16: Urban centres Boolean raster constraints layer

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Appendix 11b: Opportunities layers (Figures A11.17 to A11.33)

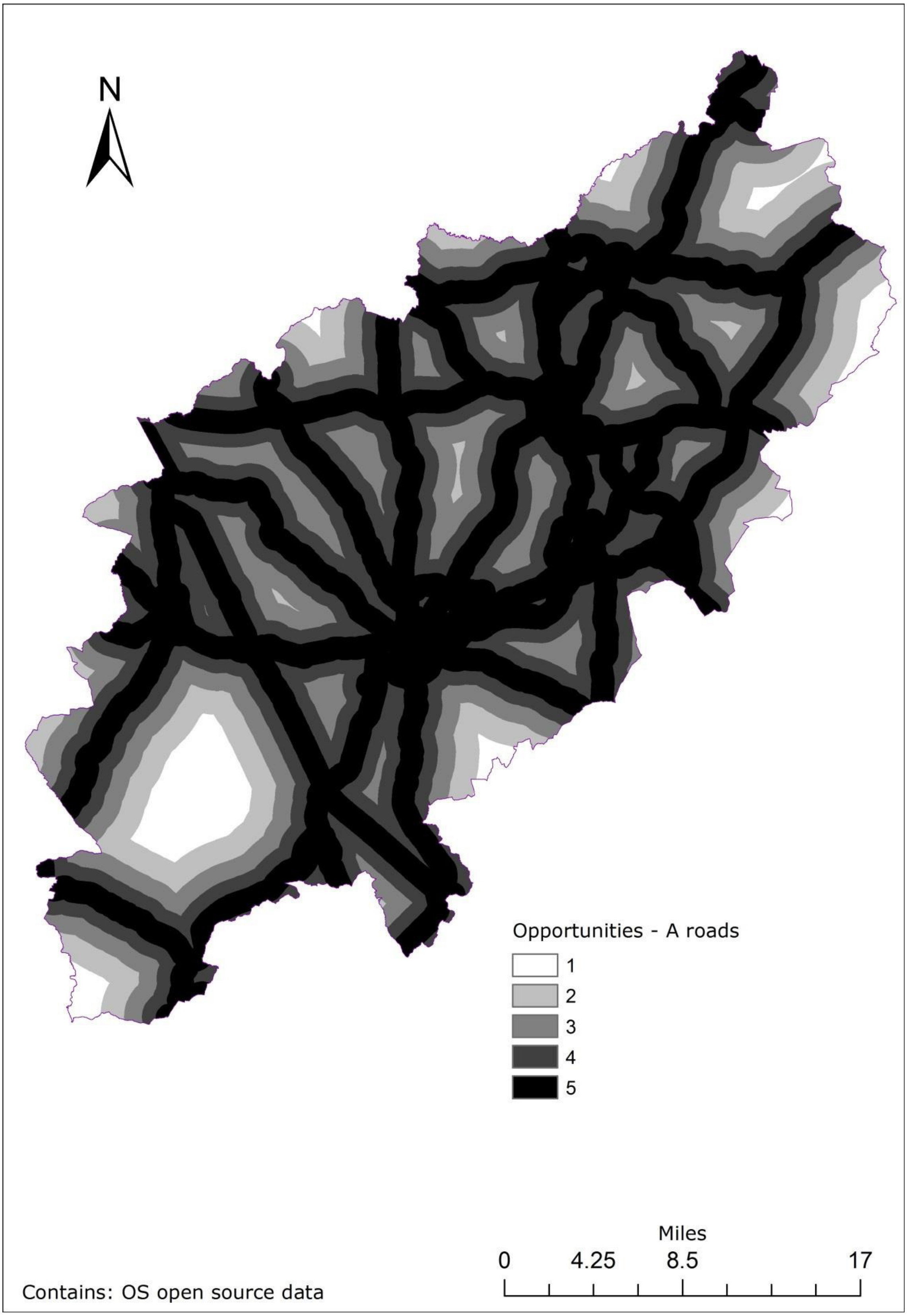

Figure A11.17: A road proximity (distance to minimise) opportunities layer

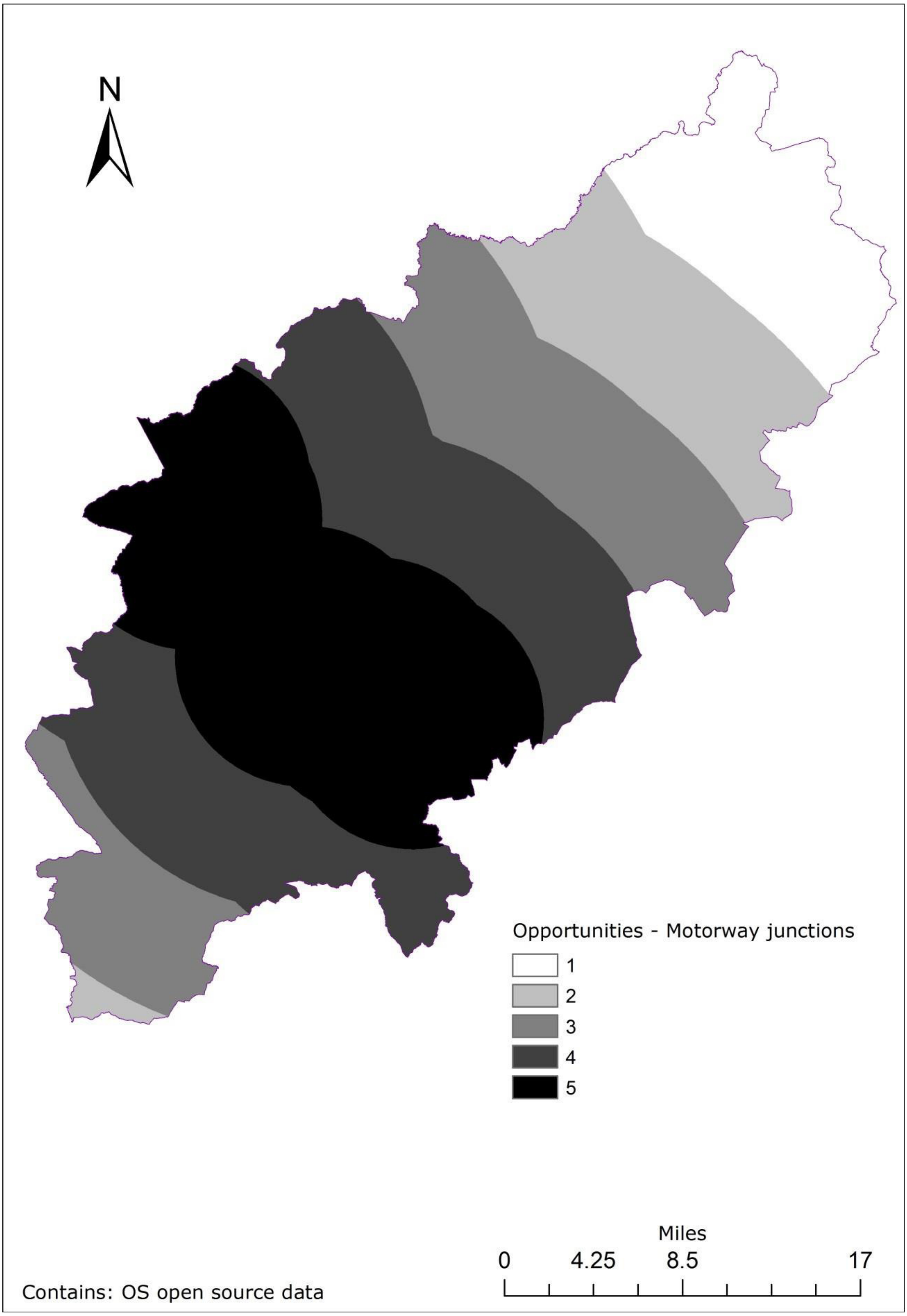

Figure A11.18: Motorway junctions proximity (distance to minimise) opportunities layer

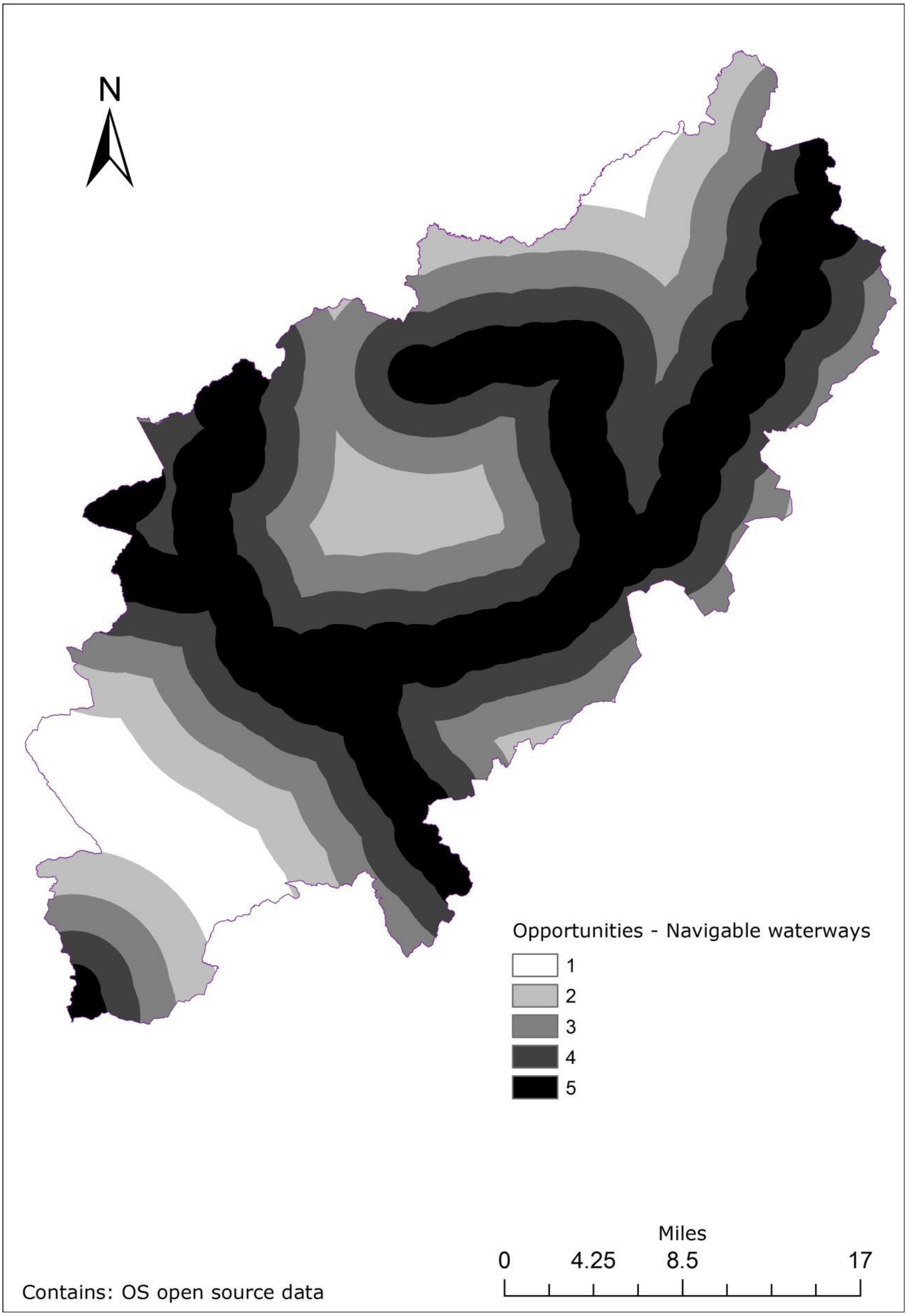

Figure A11.19: Navigable waterways proximity (distance to minimise) opportunities layer

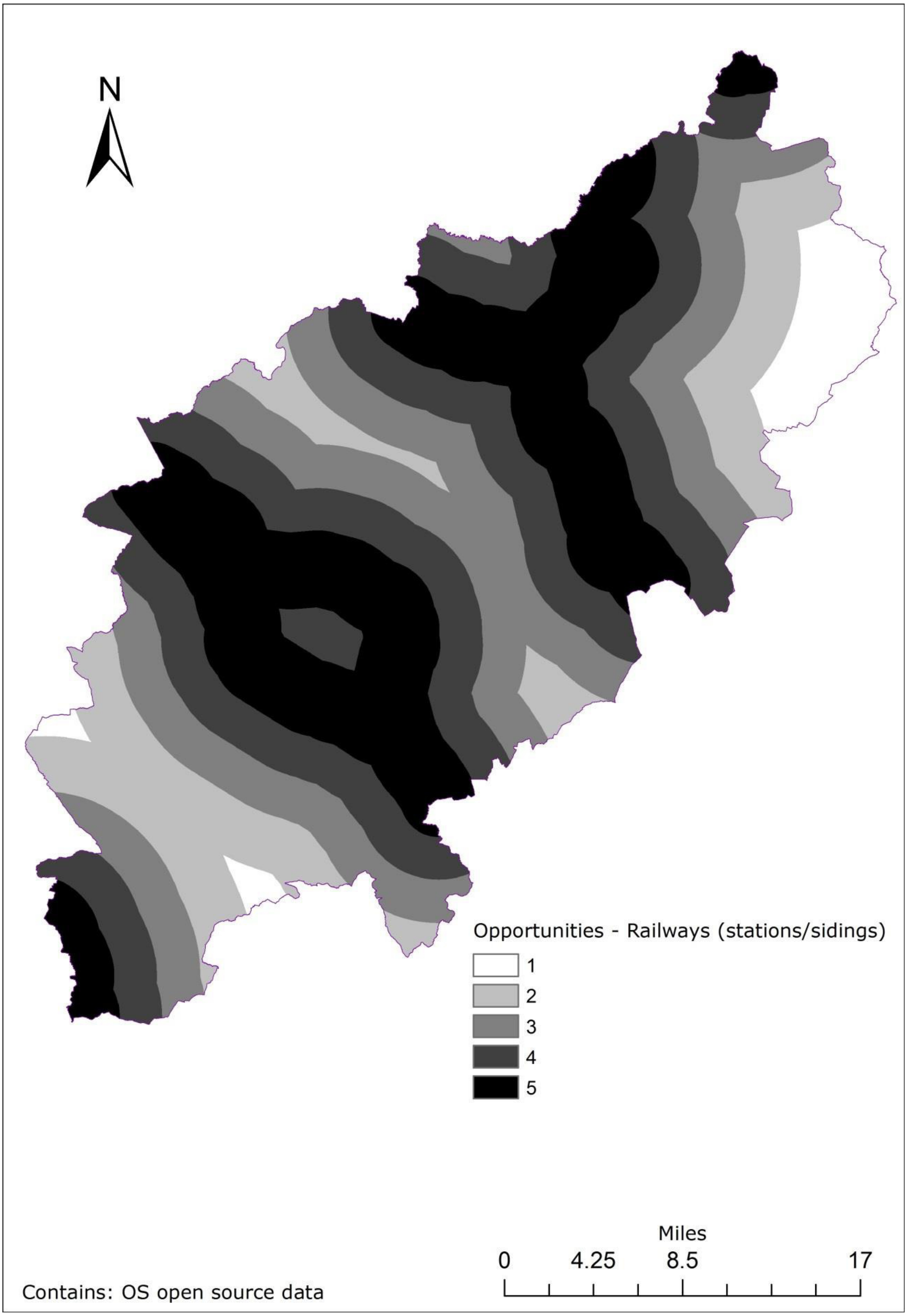

Figure A11.20: Rail proximity (distance to minimise) opportunities layer

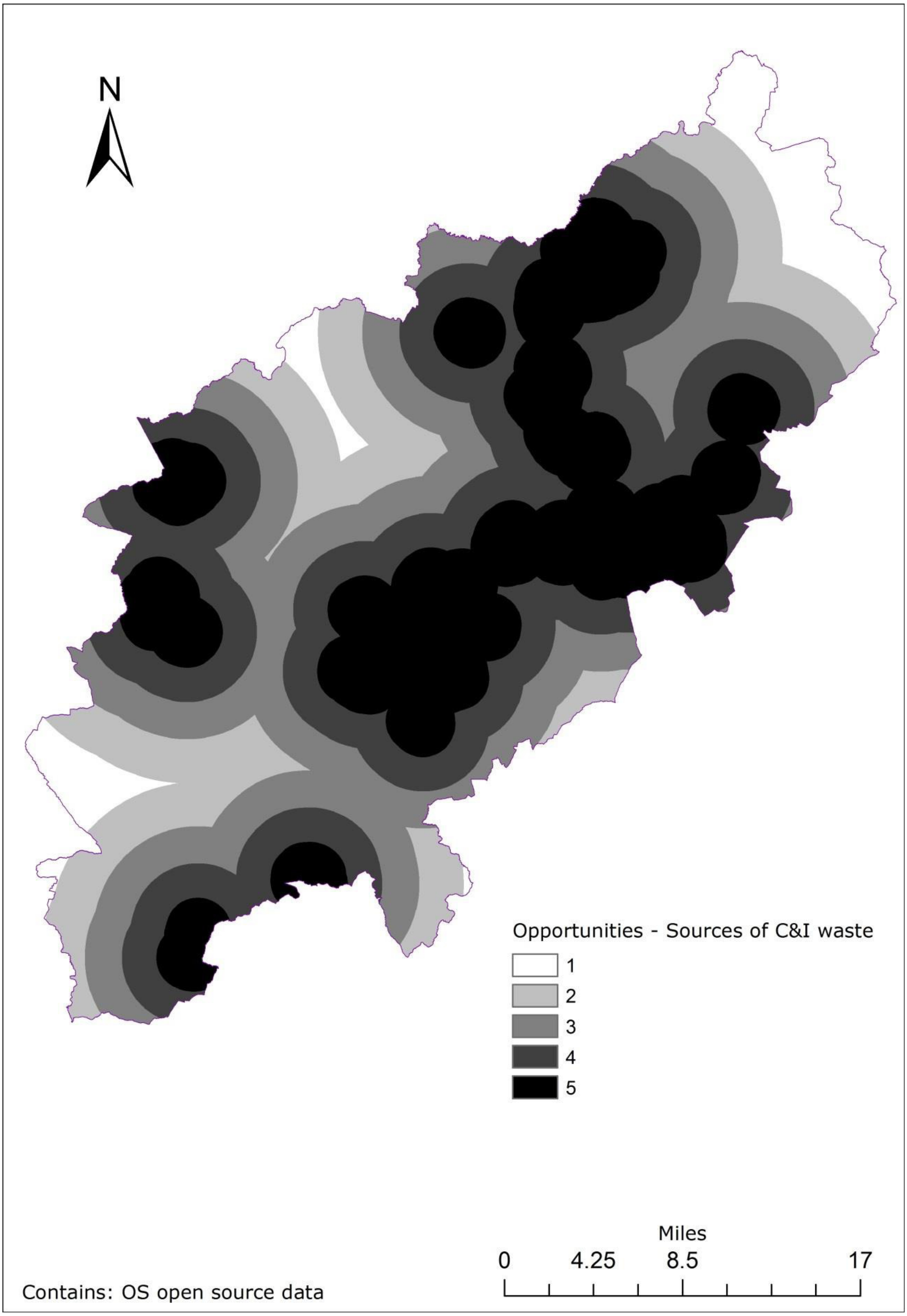

Figure A11.21: Sources of C&I waste (business parks) opportunities layer

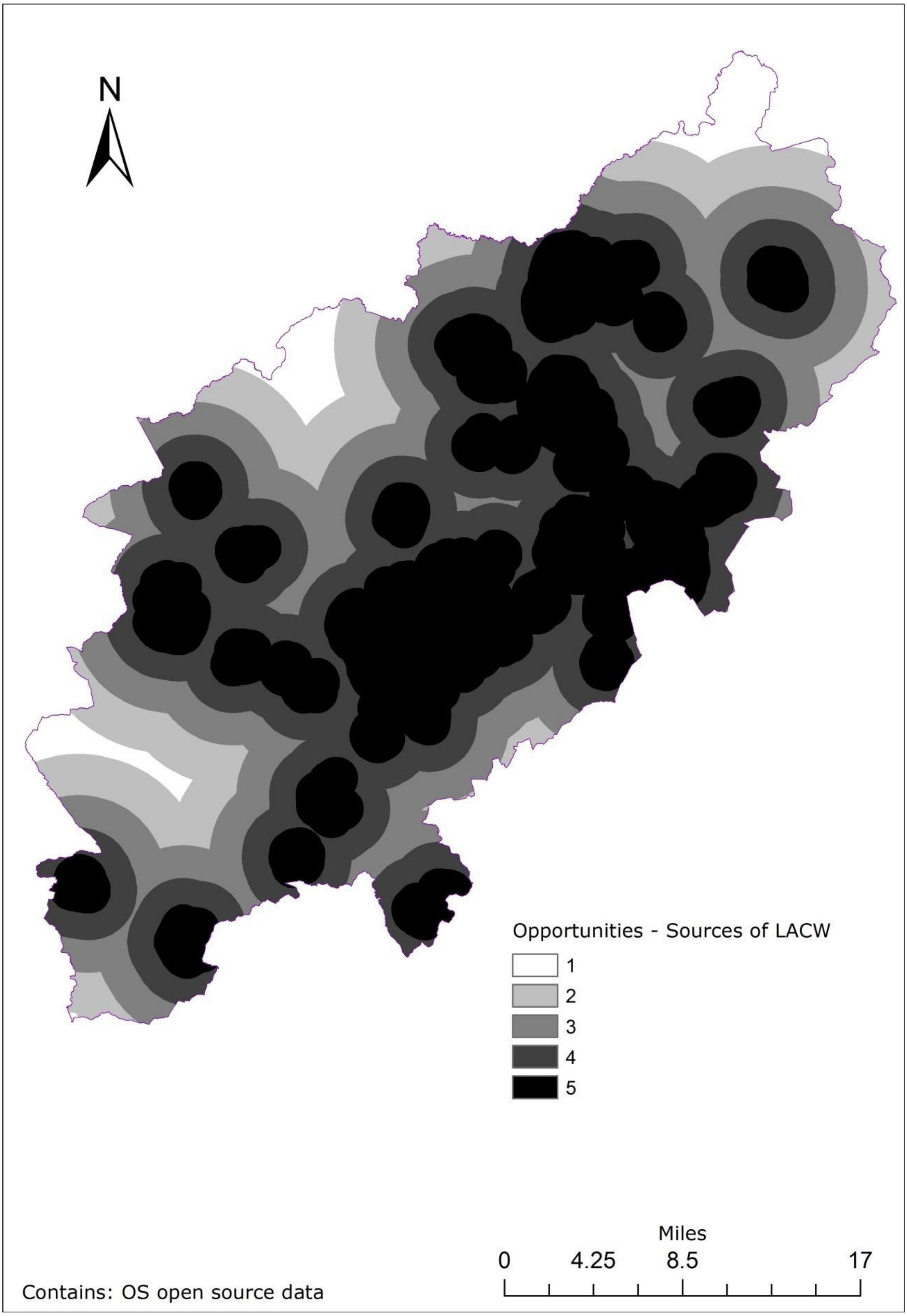

Figure A11.22: Sources of LACW (e.g. domestic dwellings) opportunities layer

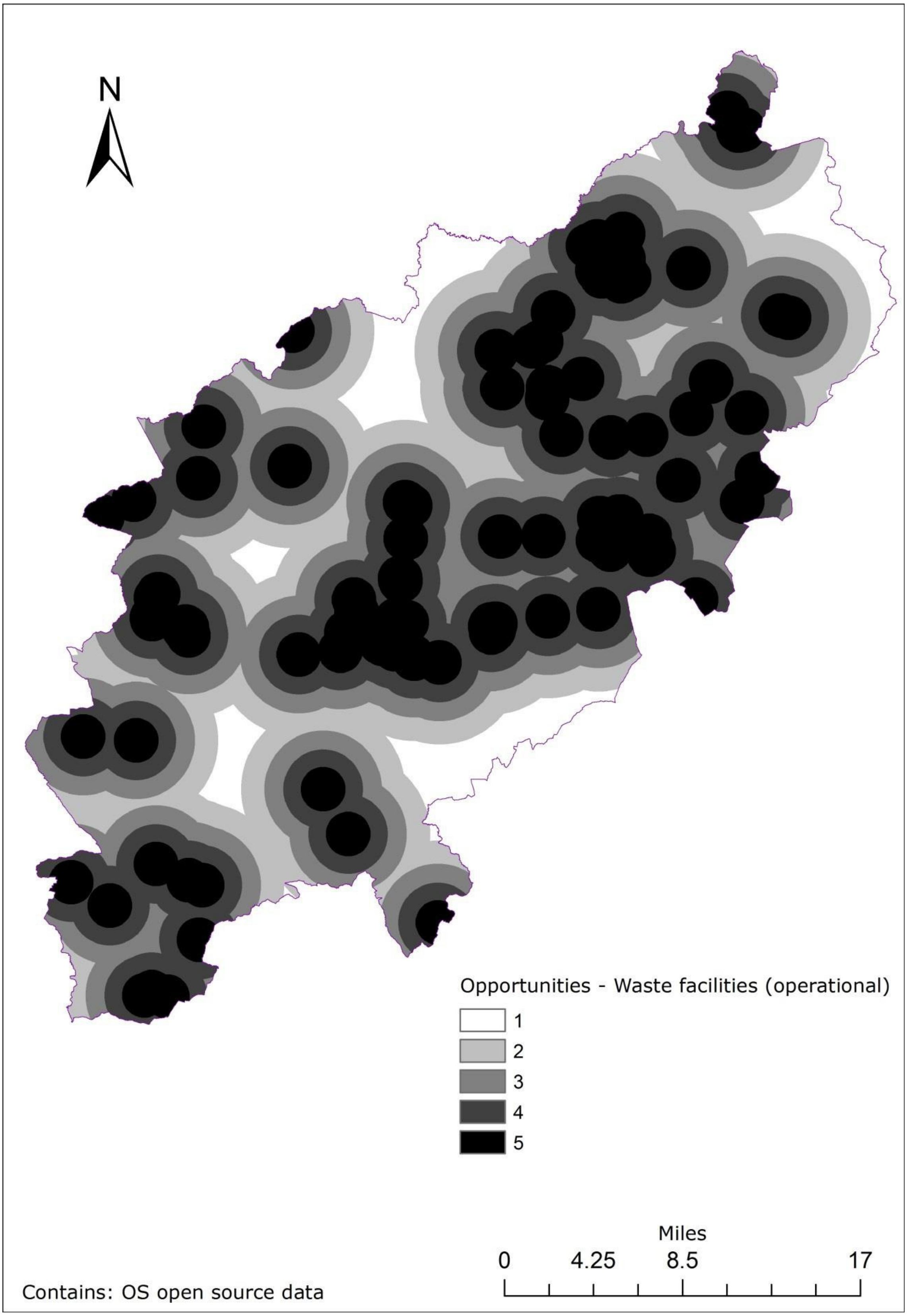

Figure A11.23: Operational waste facility proximity (distance to minimise) opportunities layer

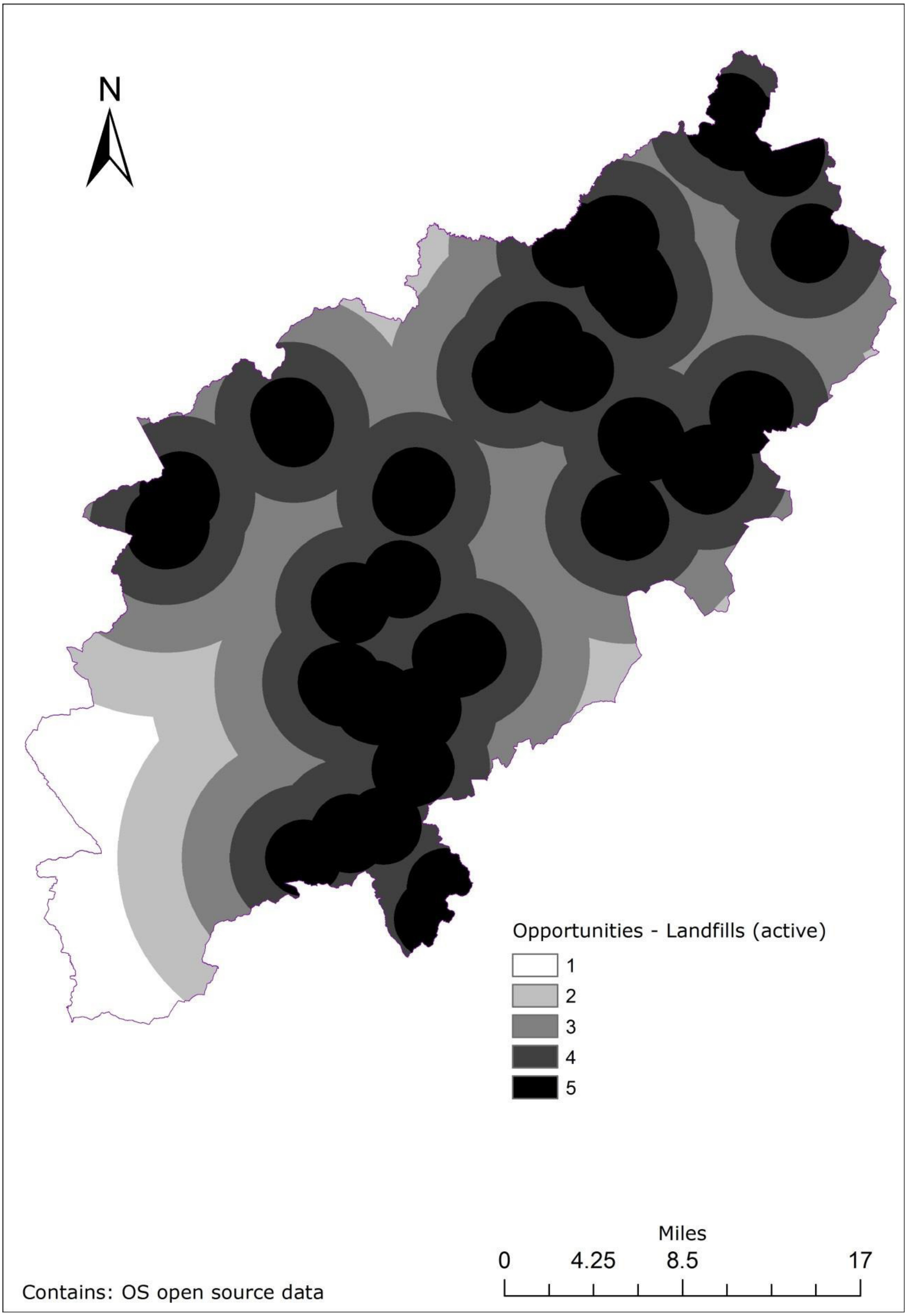

Figure A11.24: Operational landfill proximity (distance to minimise) opportunities layer

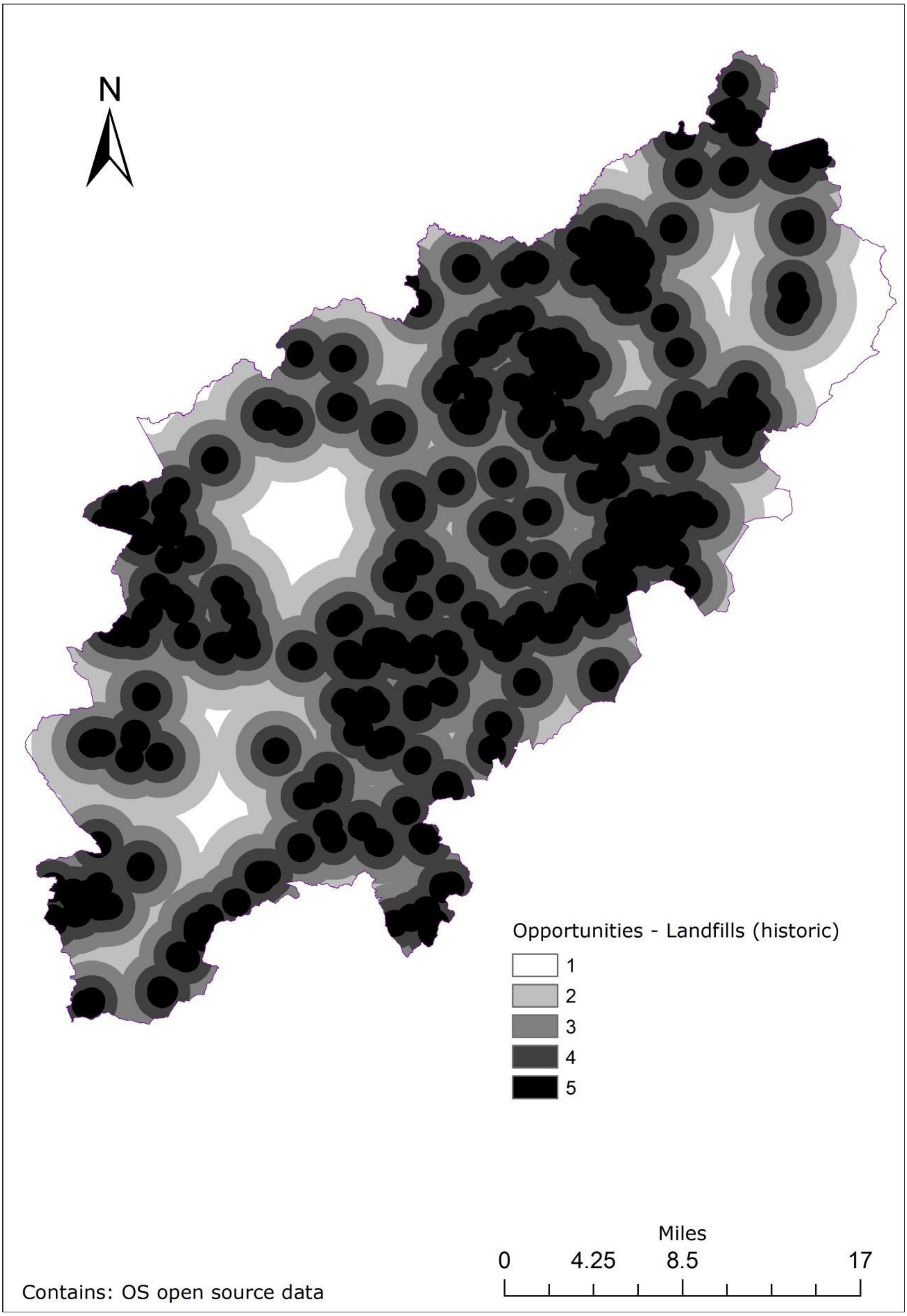

Figure A11.25: Historic landfill proximity (distance to minimise) opportunities layer

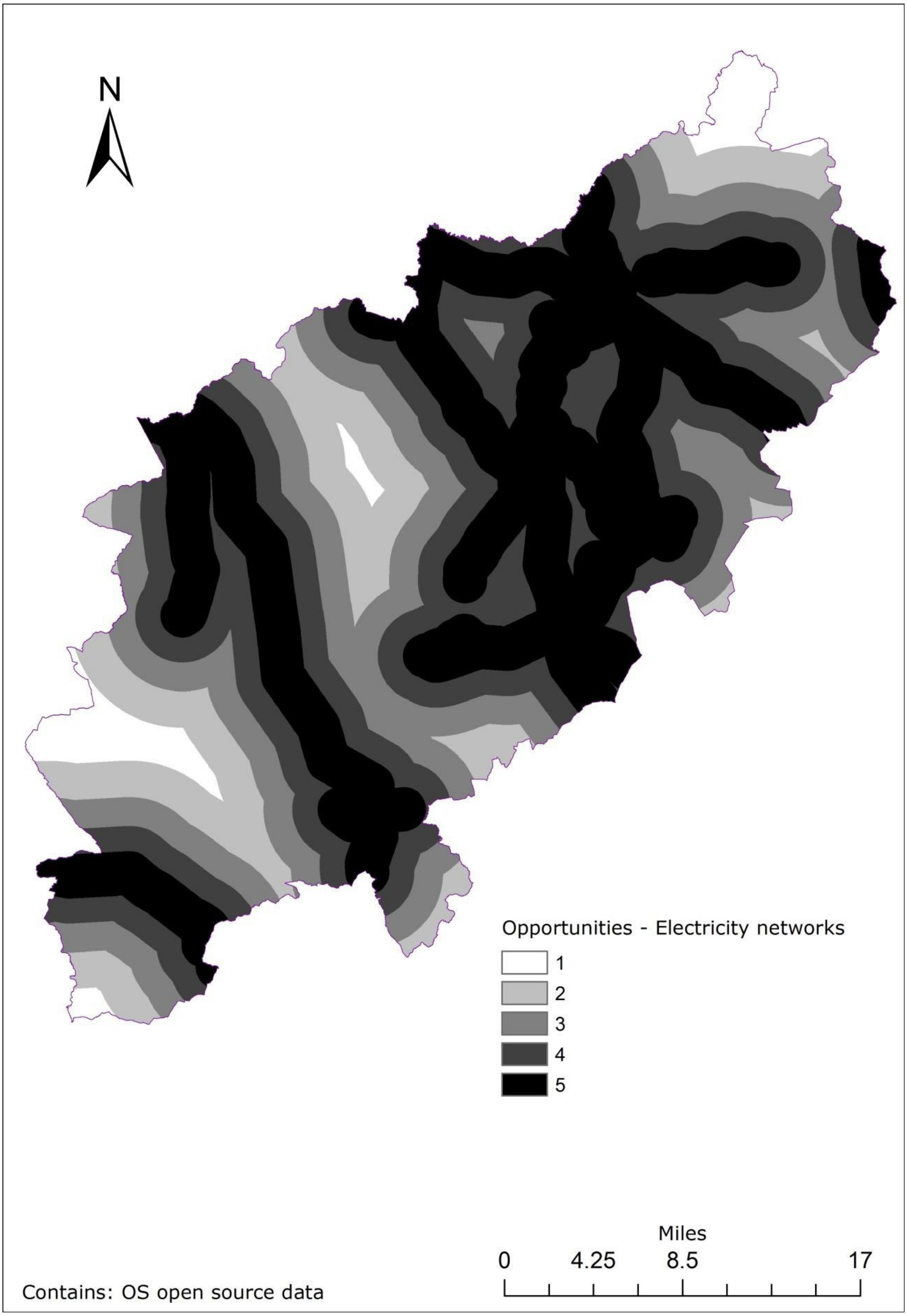

Figure A11.26: Electricity network proximity (distance to minimise) opportunities layer

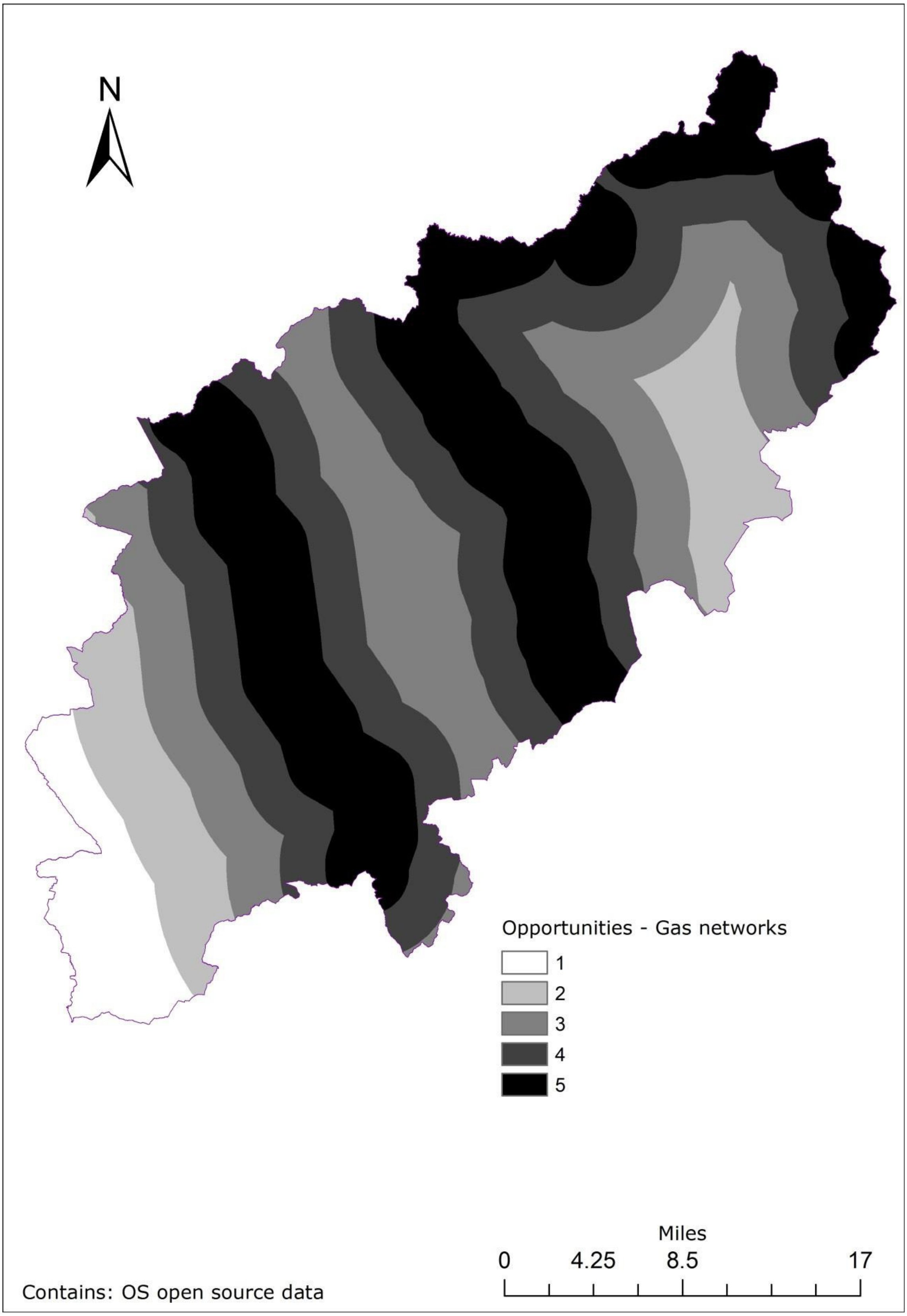

Figure A11.27: Gas network proximity (distance to minimise) opportunities layer

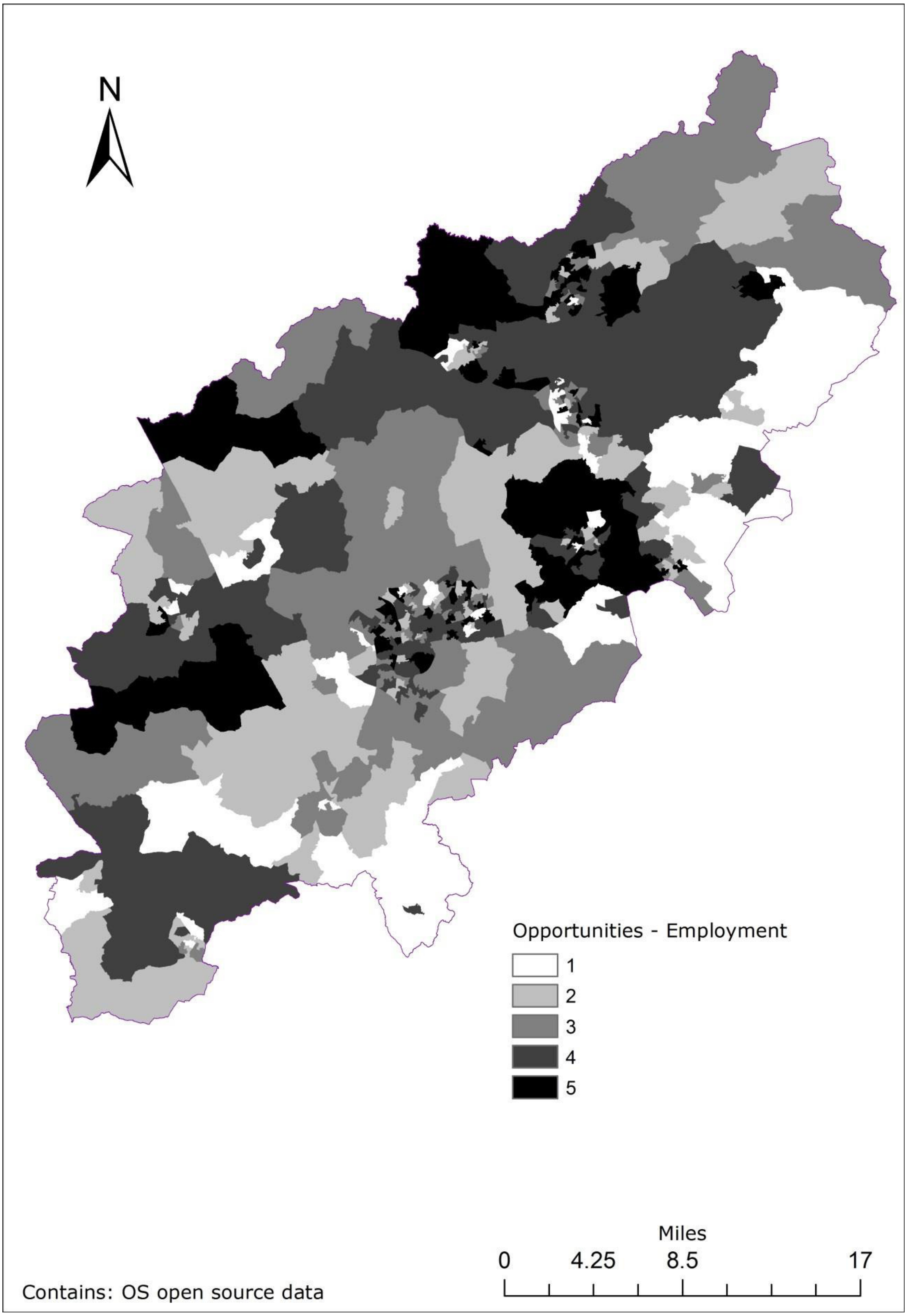

Figure A11.28: LSOA employment (job creation potential) opportunities layer

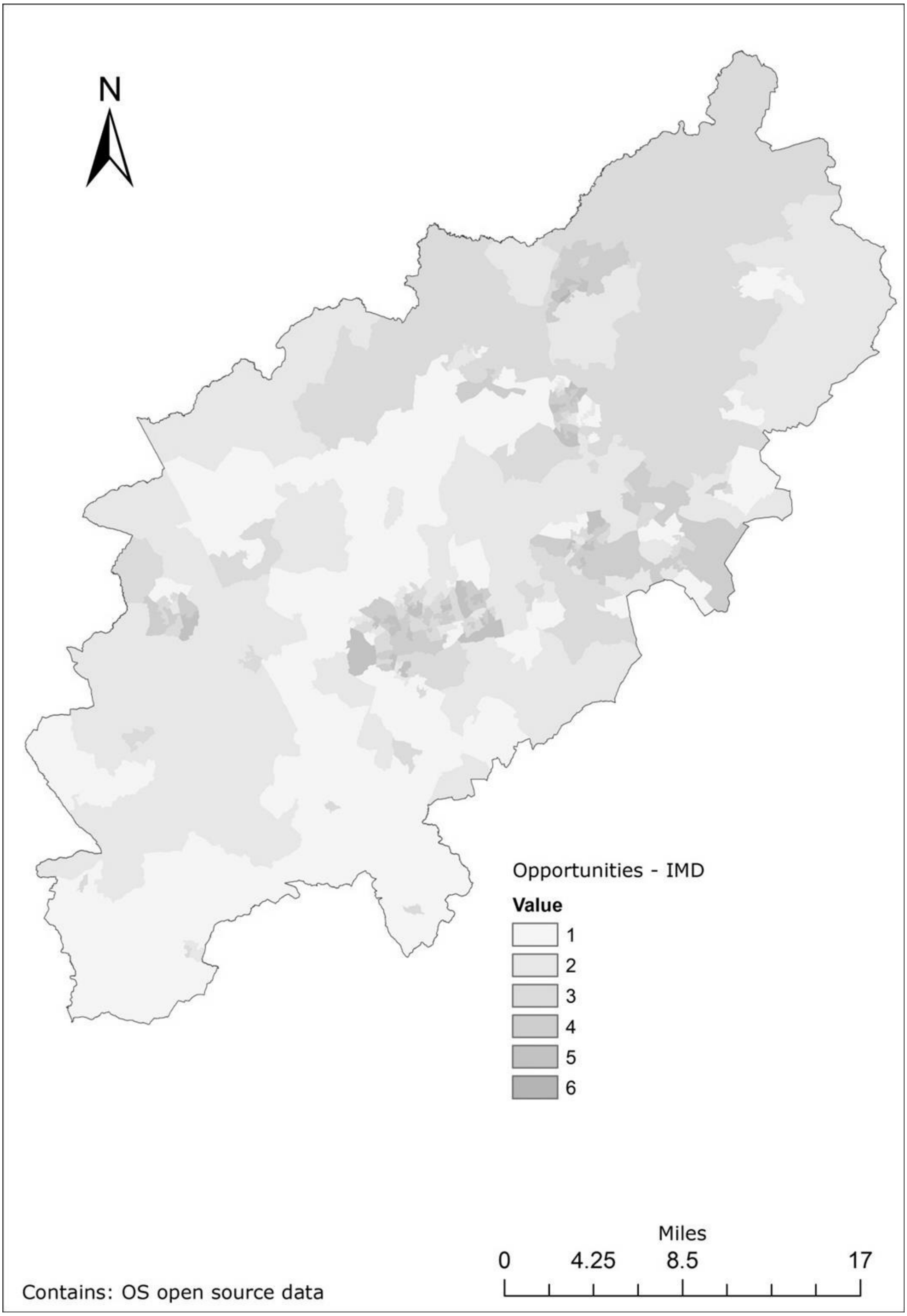

Figure A11.29: Areas of deprivation (potential economic benefit) opportunities layer

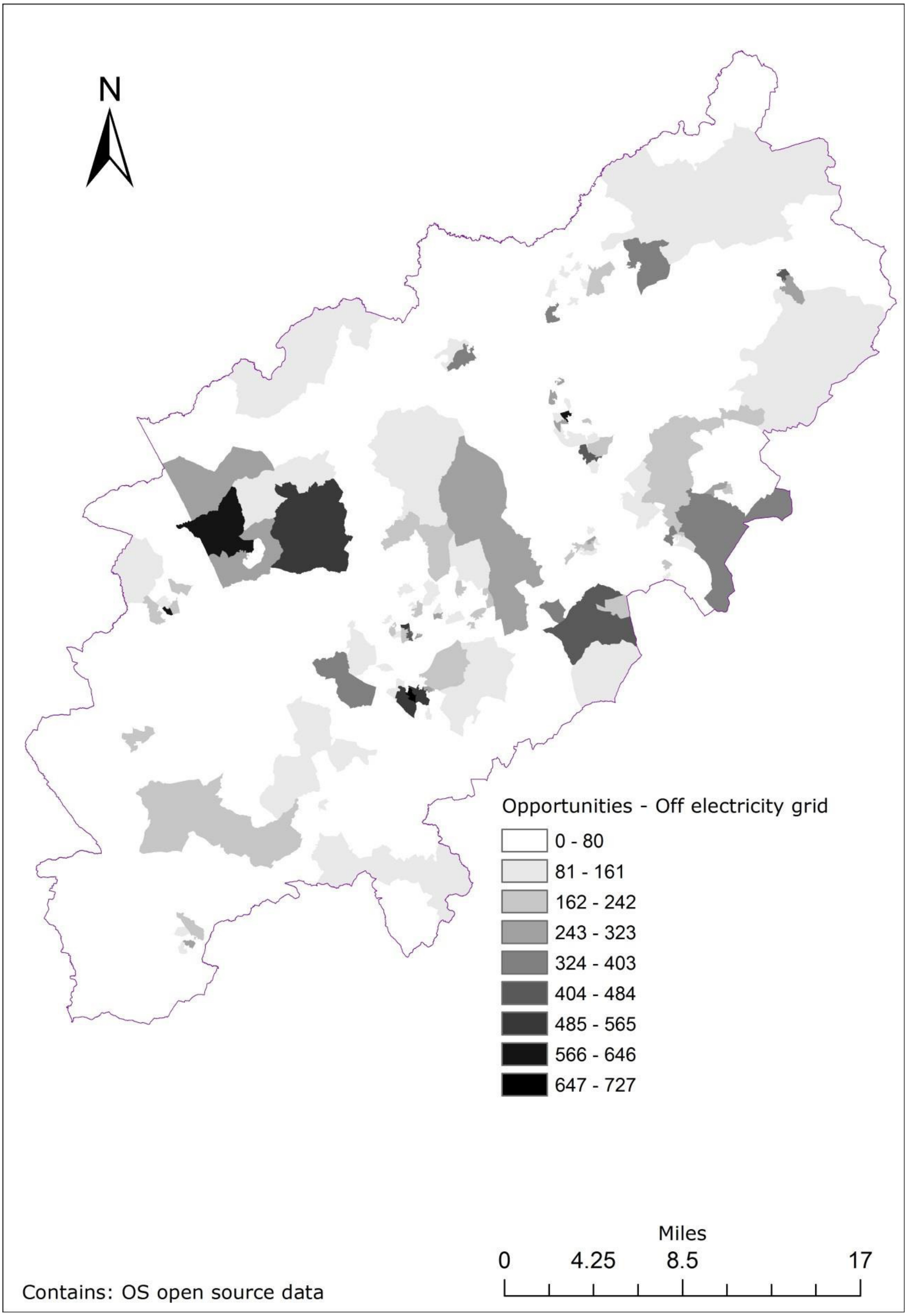

Figure A11.30: Off electricity grid (numbers of households) opportunities layer

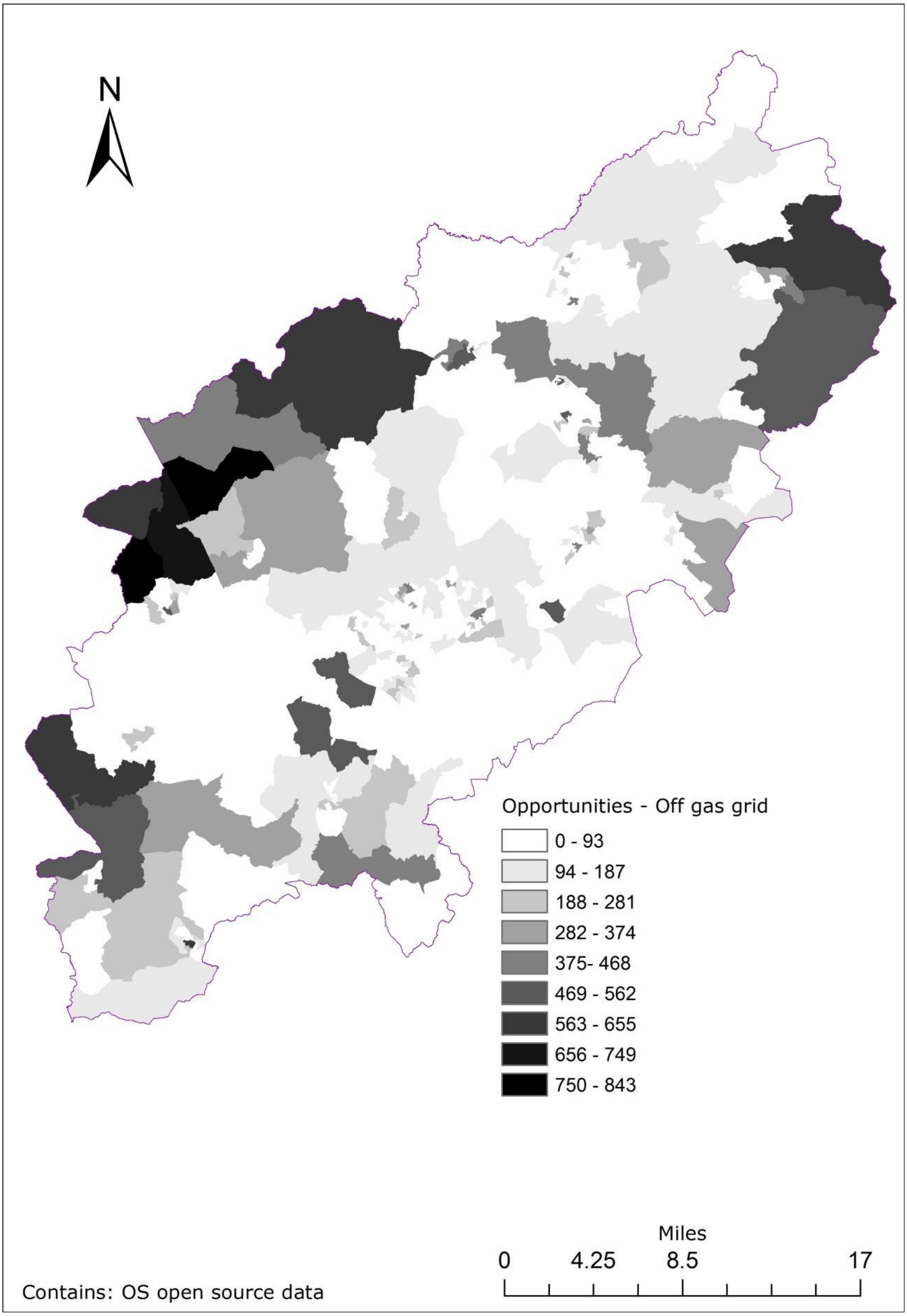

Figure A11.31: Off gas grid (numbers of households) opportunities layer

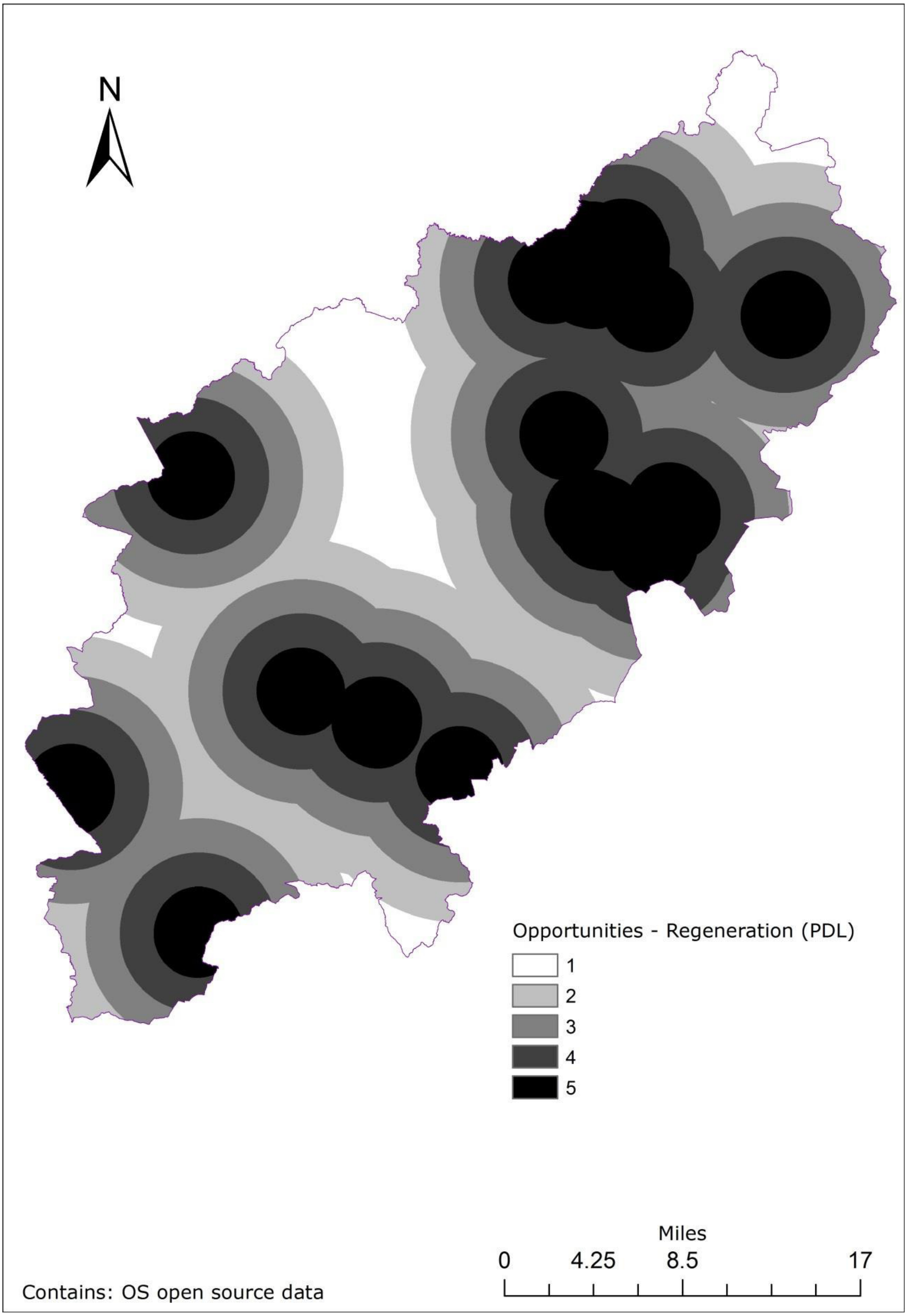

Figure A11.32: Regeneration potential (Previously Developed Land) opportunities layer

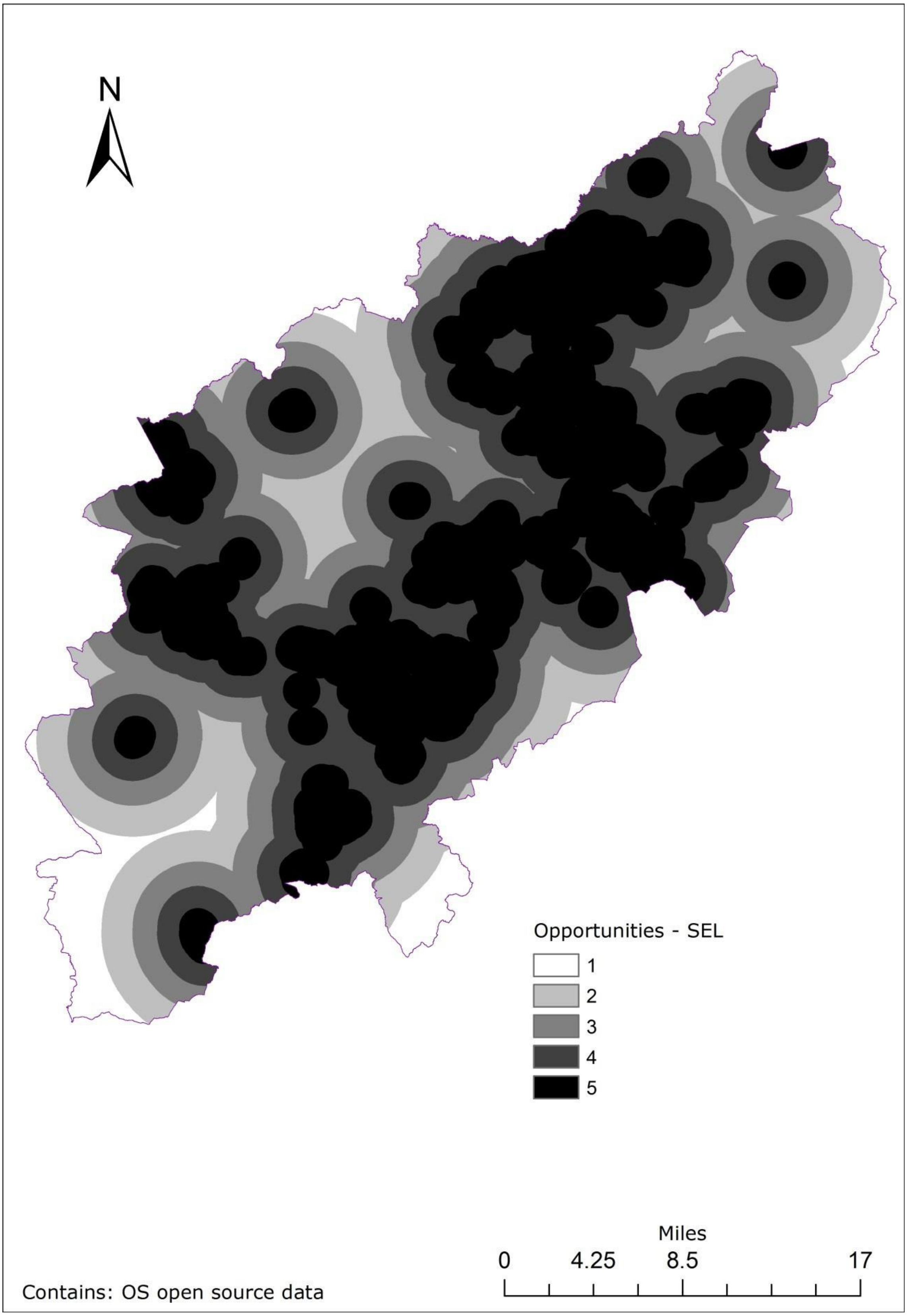

Figure A11.33: Strategic Employment Land proximity (future growth and development) opportunities layer

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Appendix 12

Waste tonnages maps – all scenarios

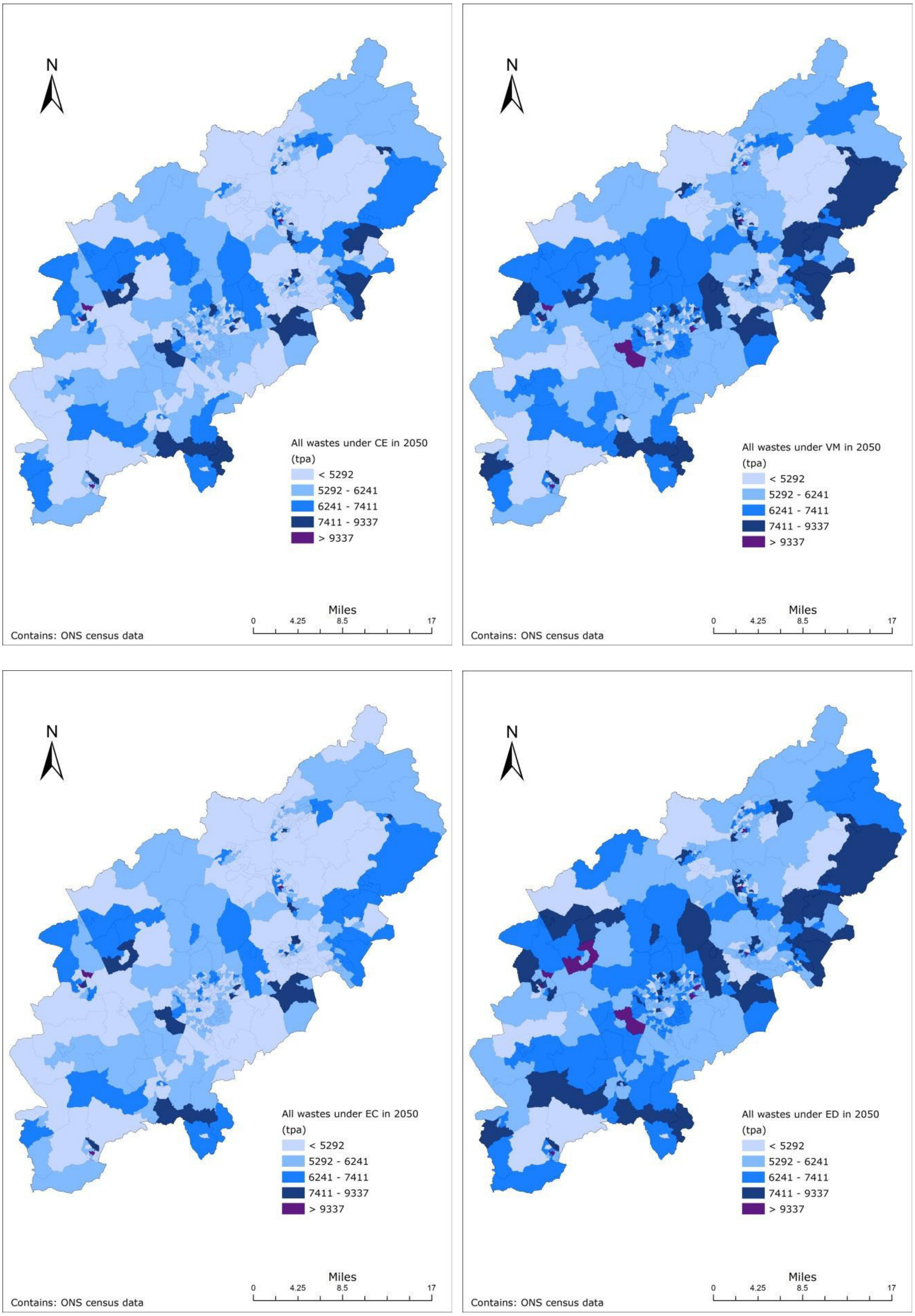

Figure A12.1: All waste tonnages under all scenarios in 2050

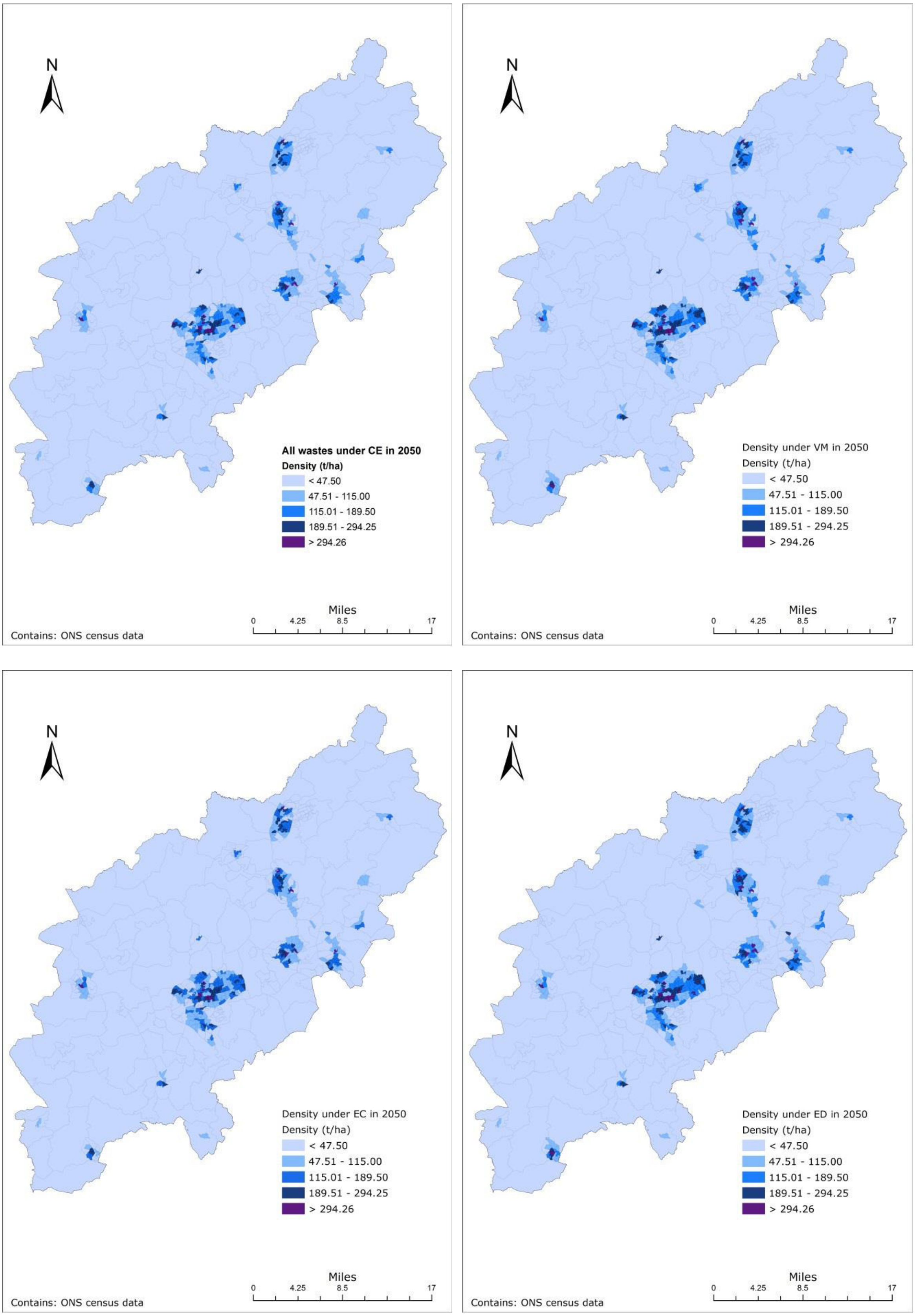

Figure A12.2: All waste tonnages (density) under all scenarios in 2050

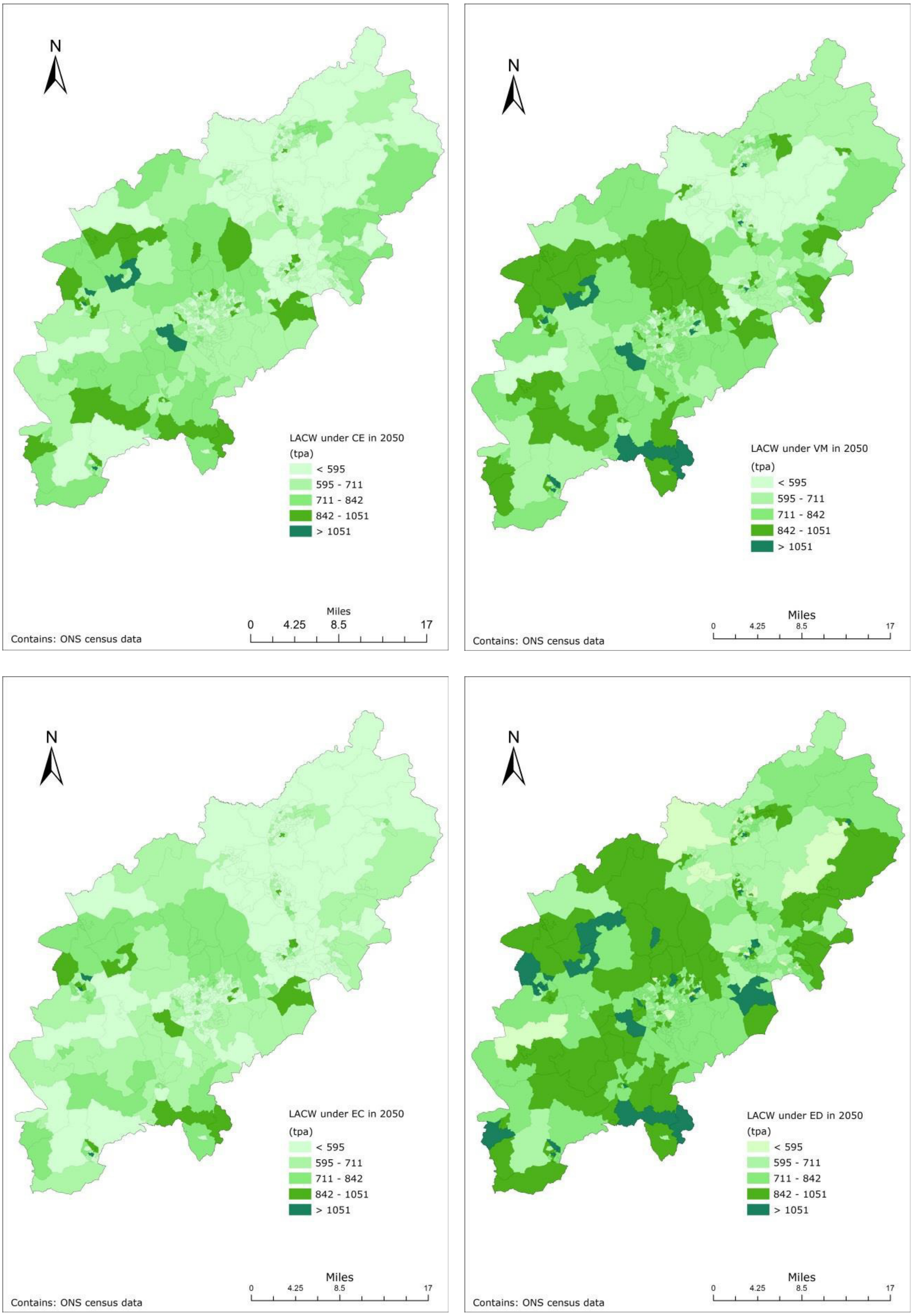

Figure A12.3: LACW tonnages under all scenarios in 2050

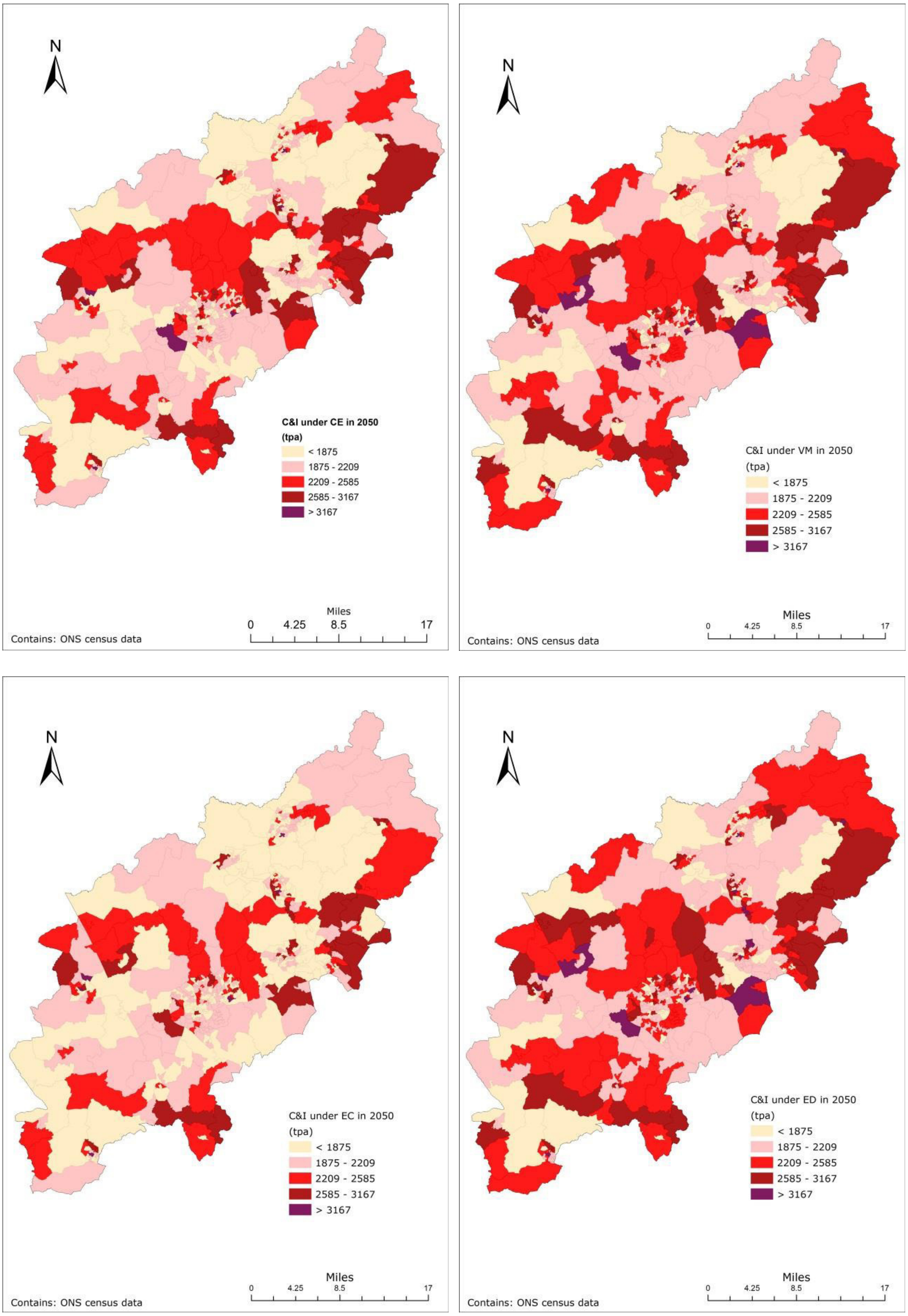

Figure A12.4: C&I waste tonnages under all scenarios in 2050

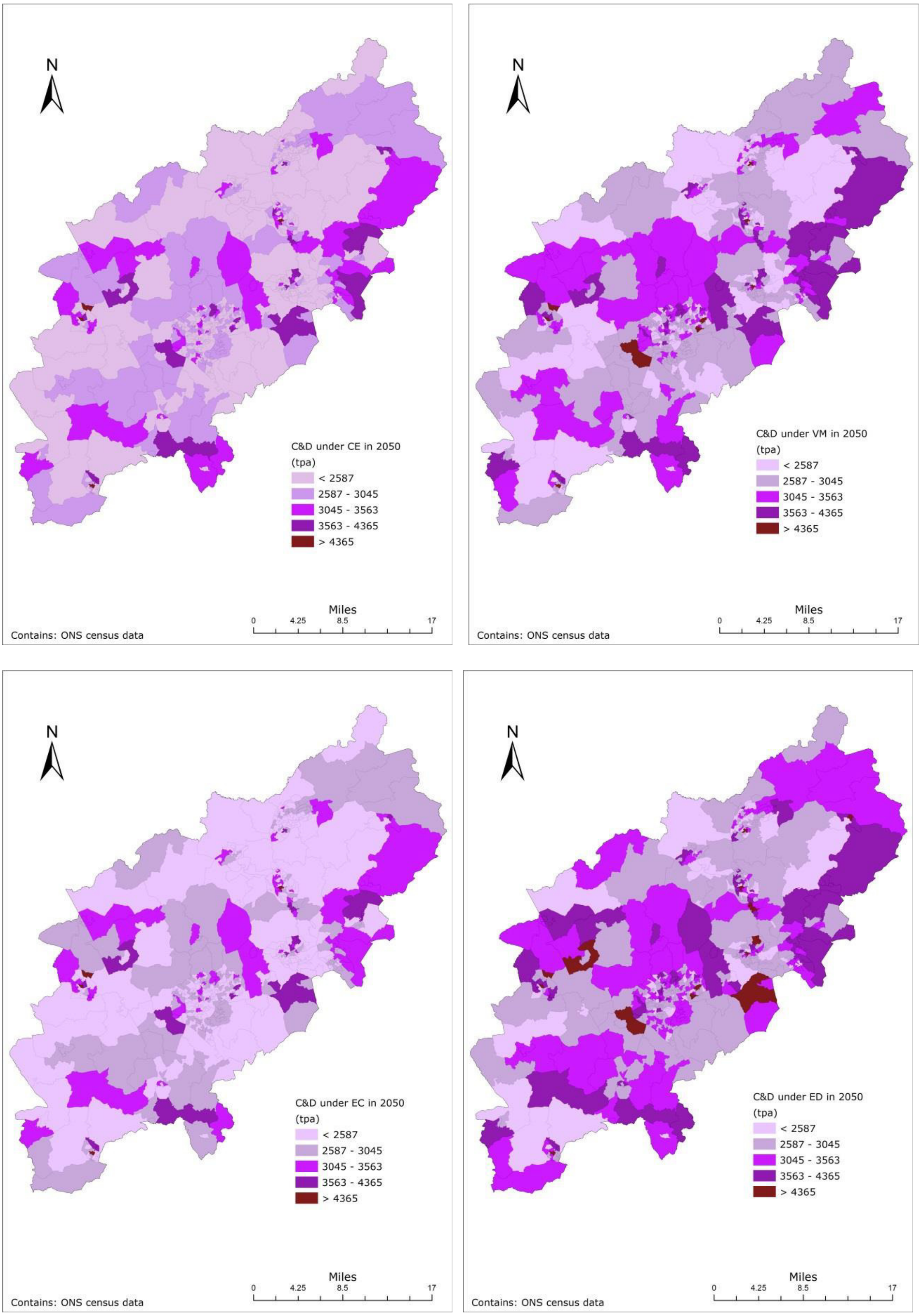

Figure A12.5: C&D waste tonnages under all scenarios in 2050

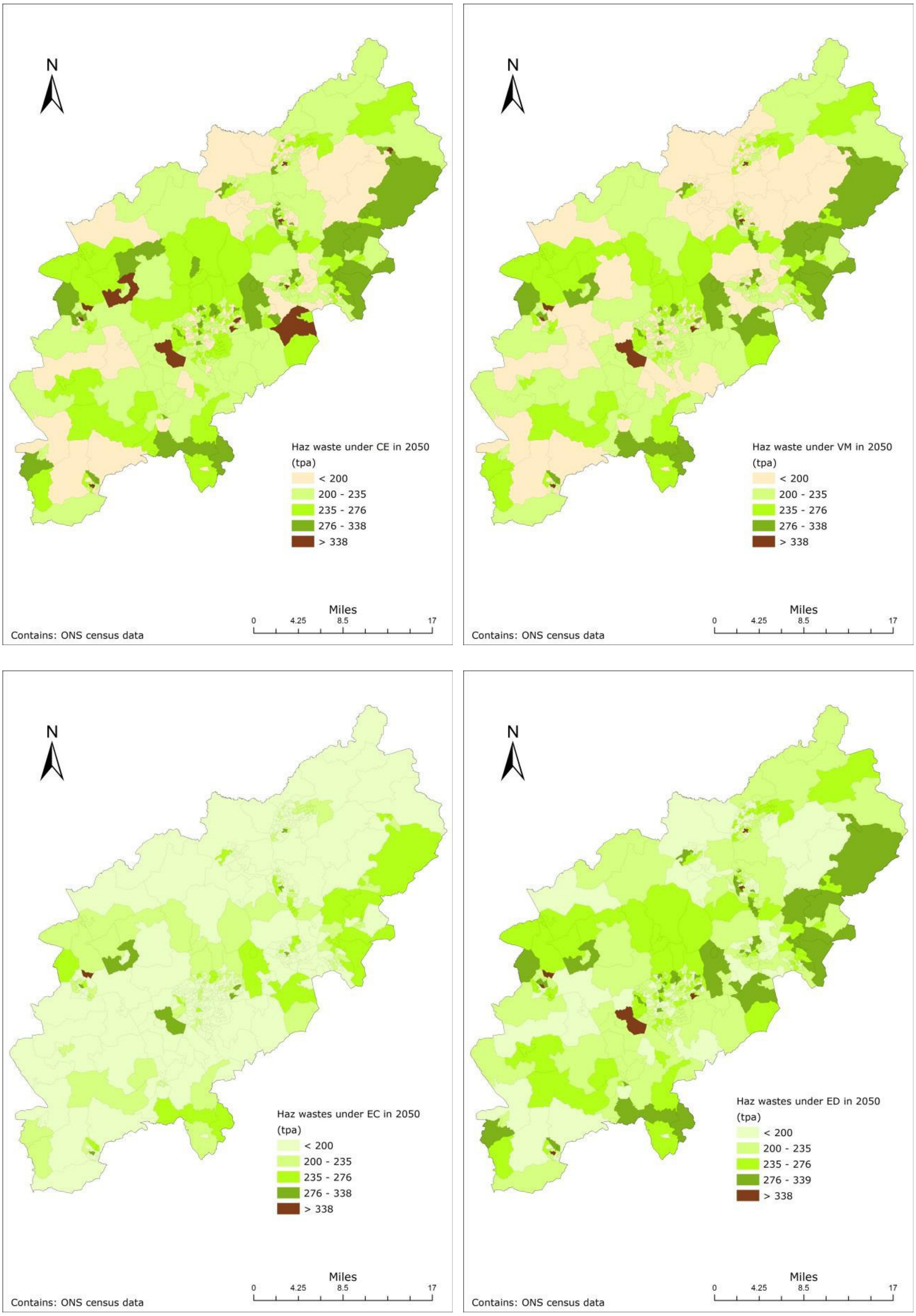

Figure A12.6: Hazardous waste tonnages under all scenarios in 2050

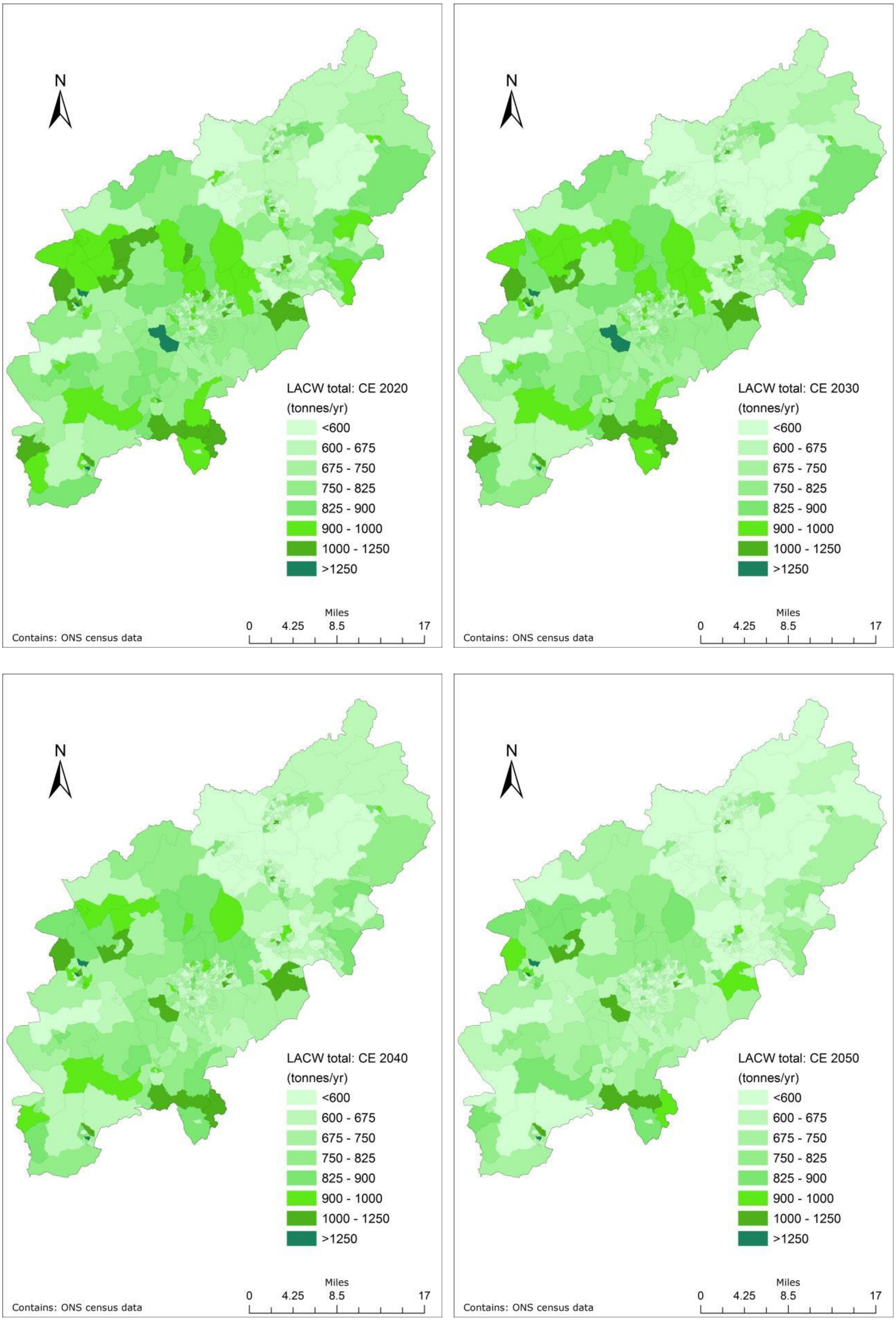

Figure A12.7: LACW tonnages performance under CE for milestone years

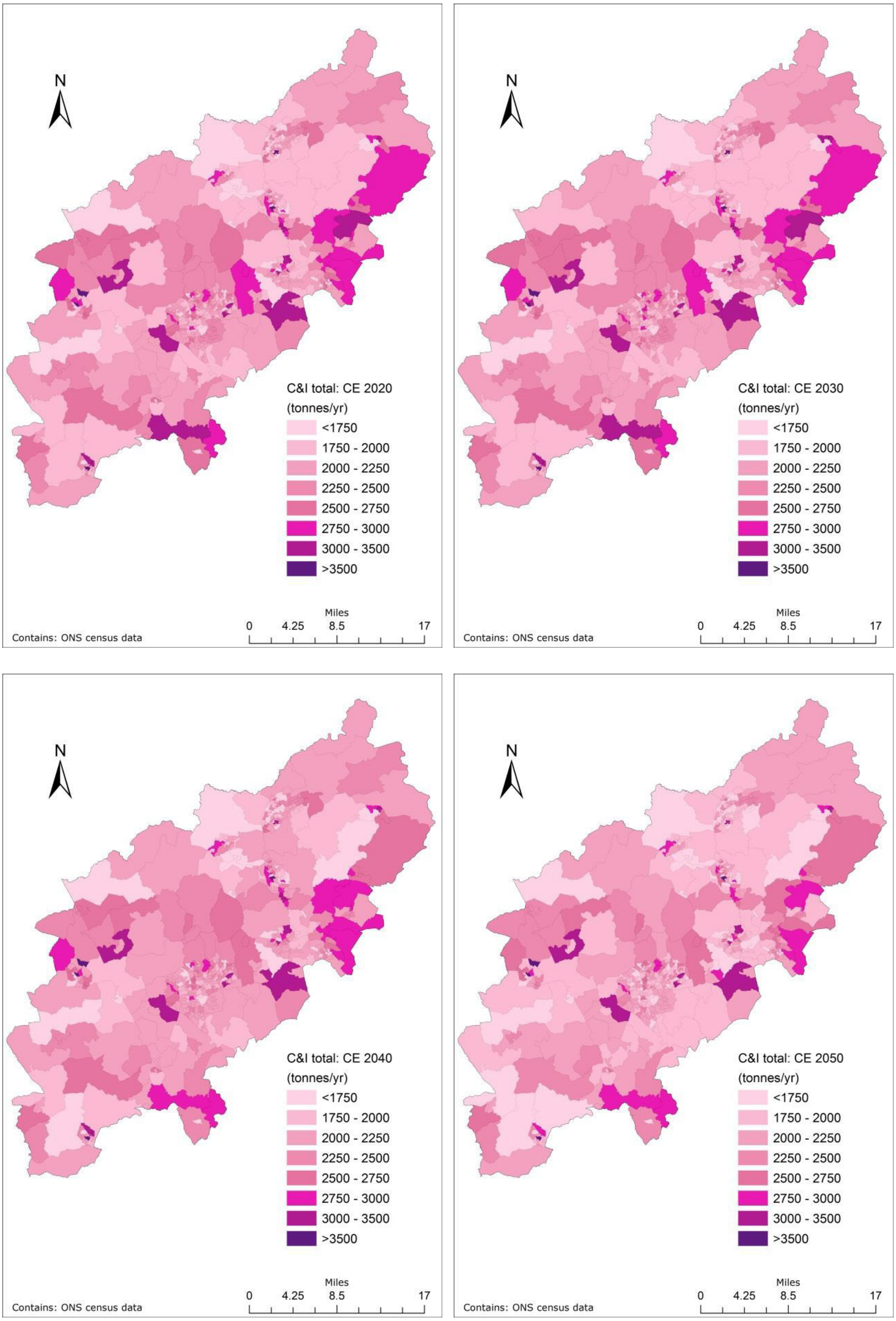

Figure A12.8: C&I tonnages performance under CE for milestone years

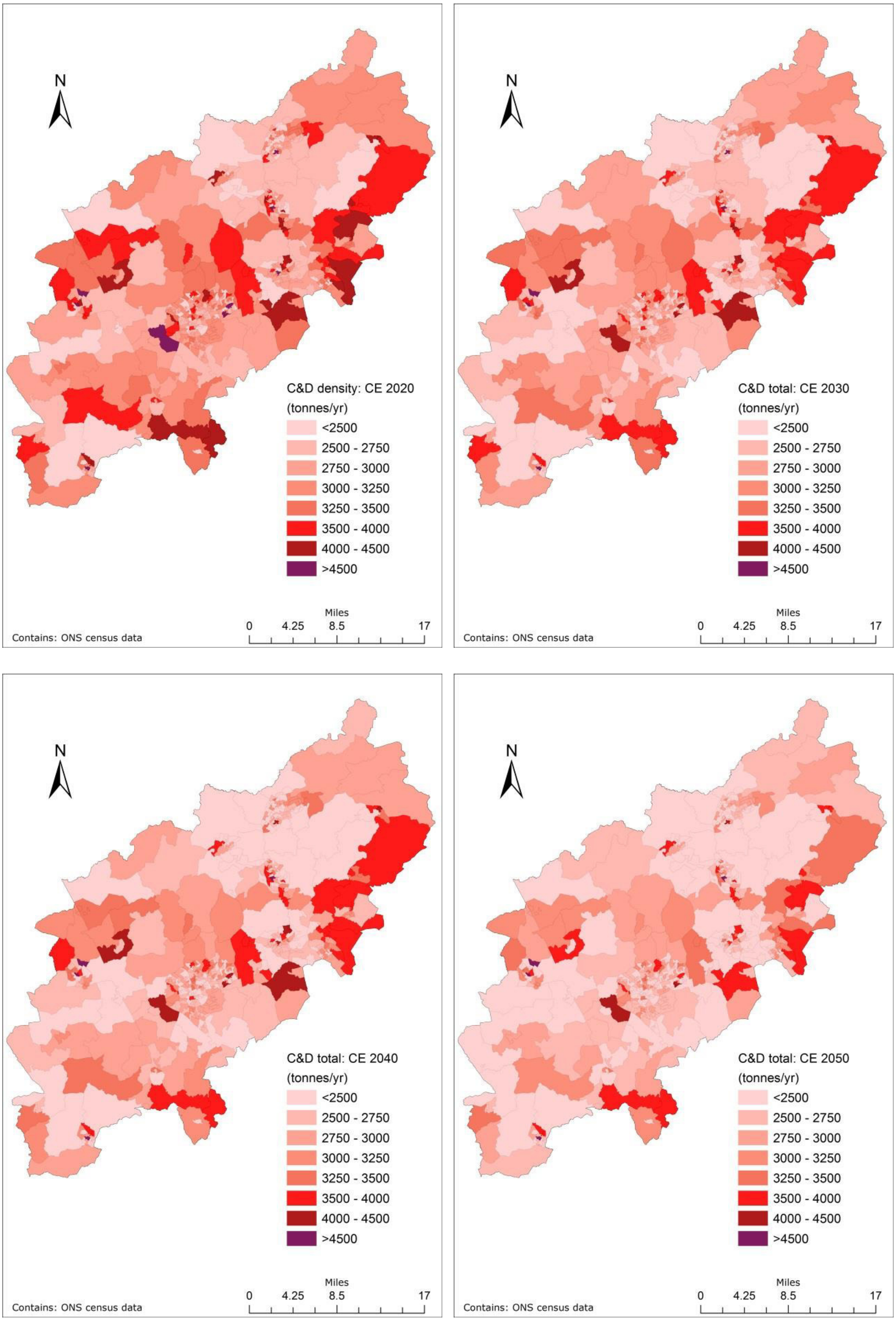

Figure A12.9: C&D tonnages performance under CE for milestone years

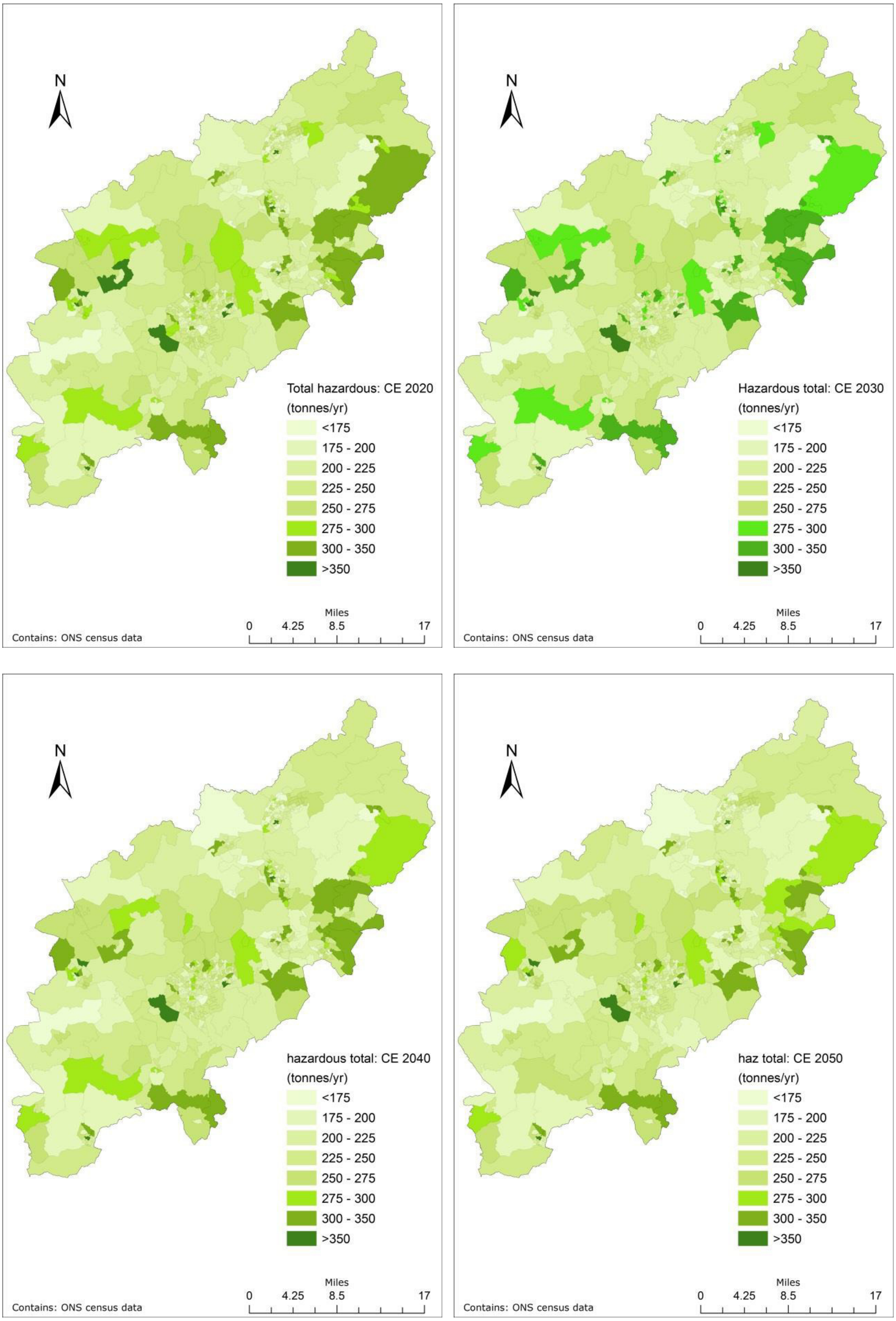

Figure A12.10: Hazardous waste tonnages performance under CE for milestone years

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Appendix 12

Economic costs and savings for milestone years – all scenarios

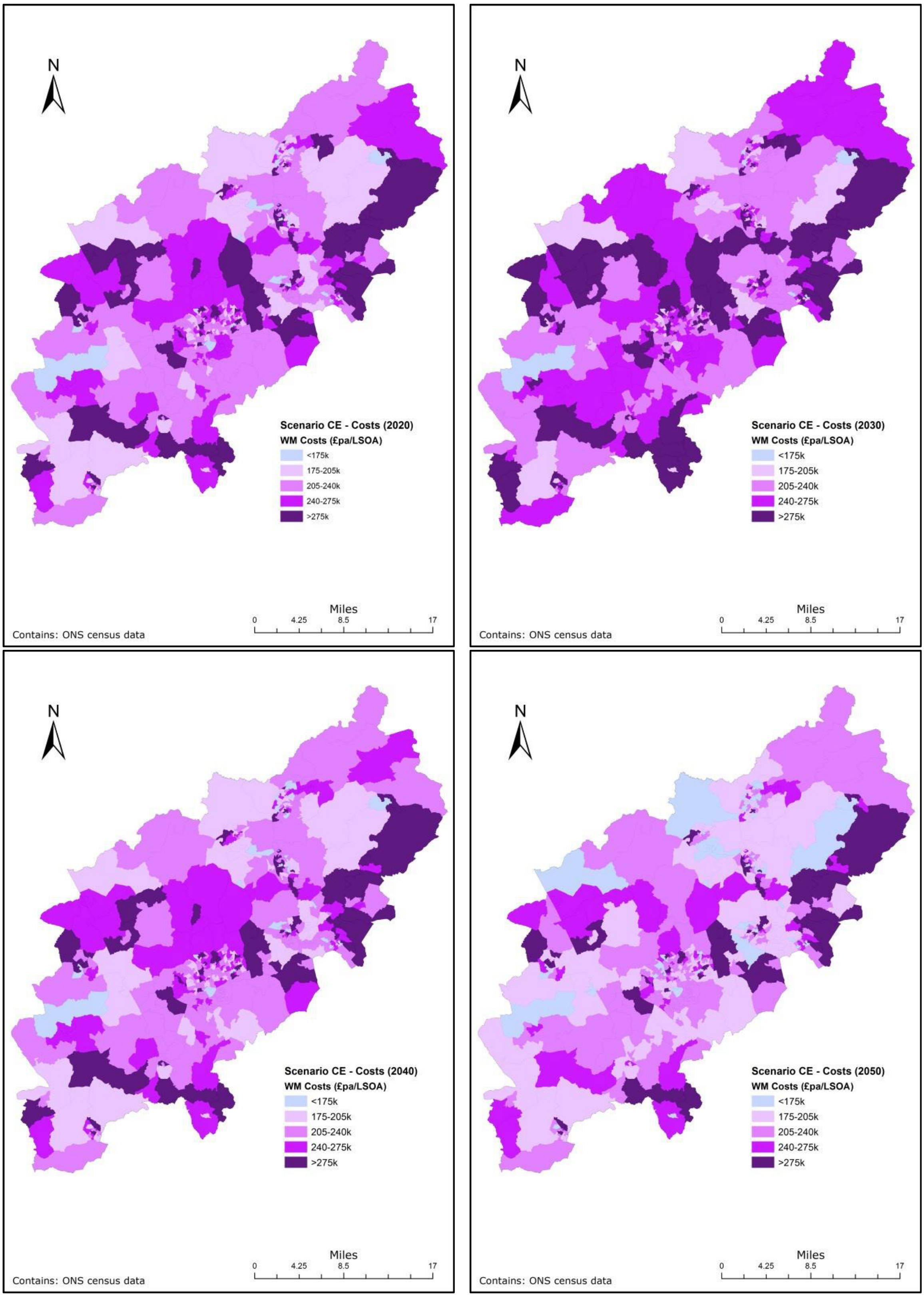

Figure A12.11: Economic costs across the backcast period (2012-2050) under scenario CE in Northamptonshire

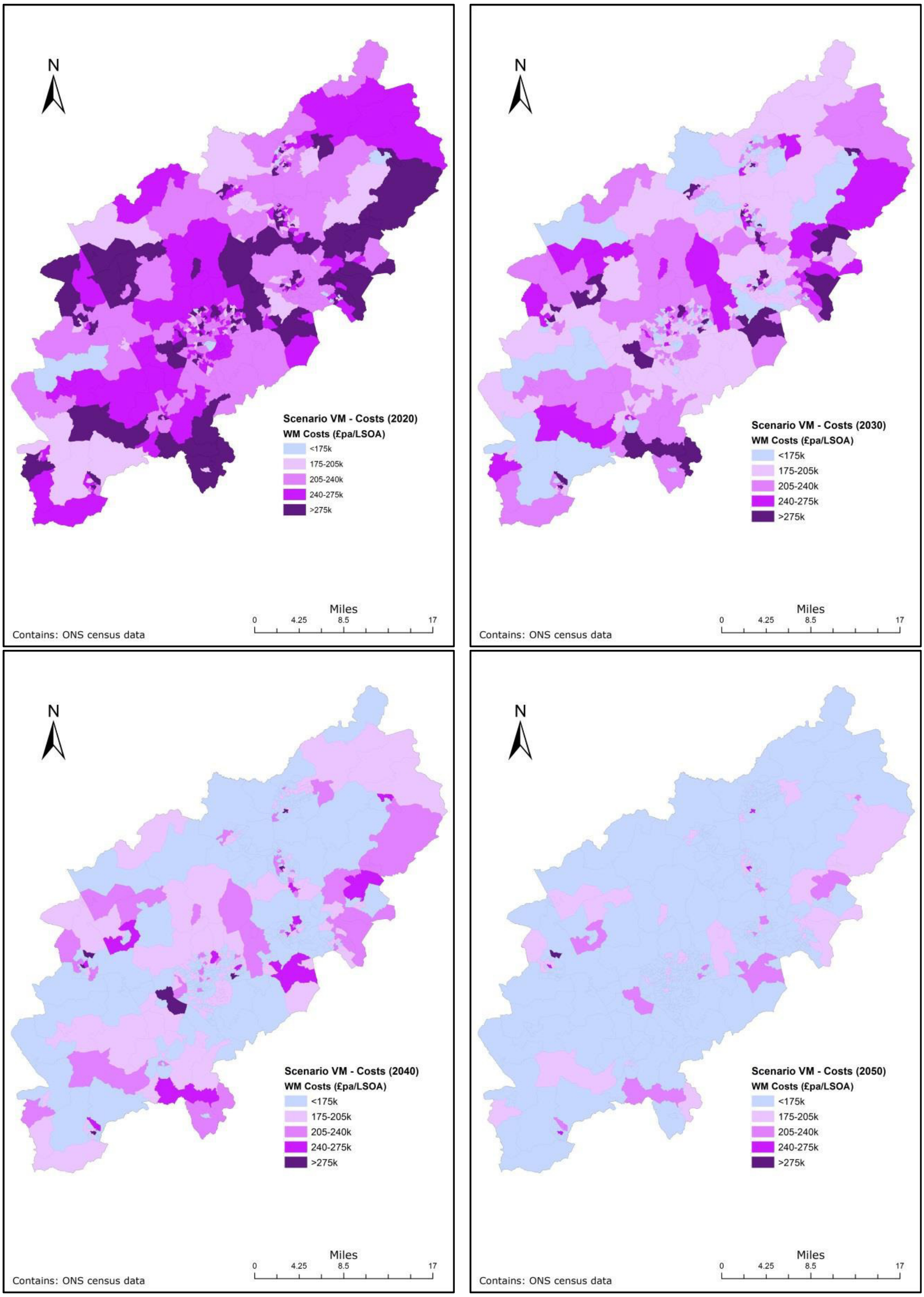

Figure A12.12: Economic costs across the backcast period (2012-2050) under scenario VM in Northamptonshire.

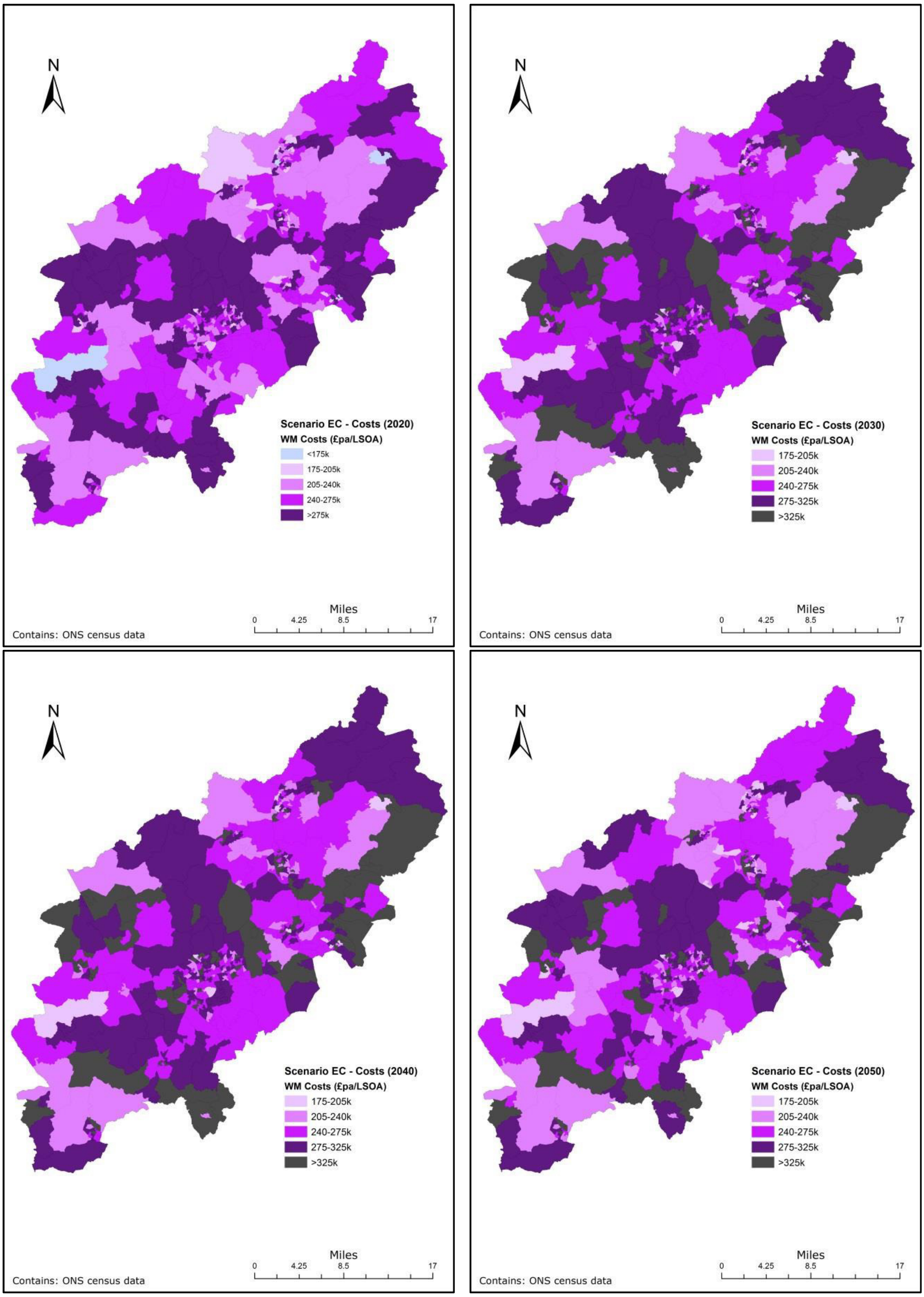

Figure A12.13: Economic costs across the backcast period (2012-2050) under scenario EC in Northamptonshire.

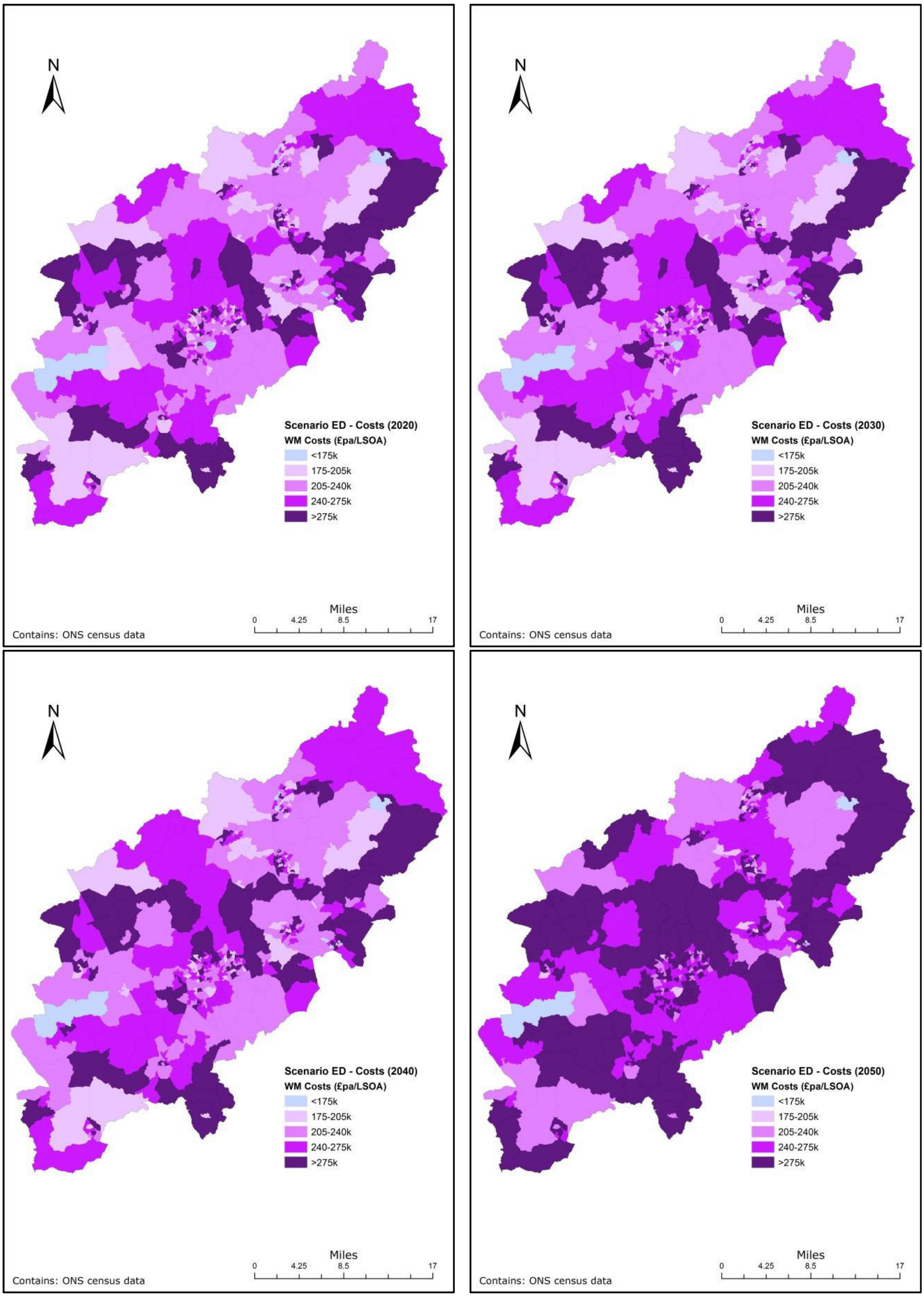

Figure A12.14: Economic costs across the backcast period (2012-2050) under scenario ED in Northamptonshire.

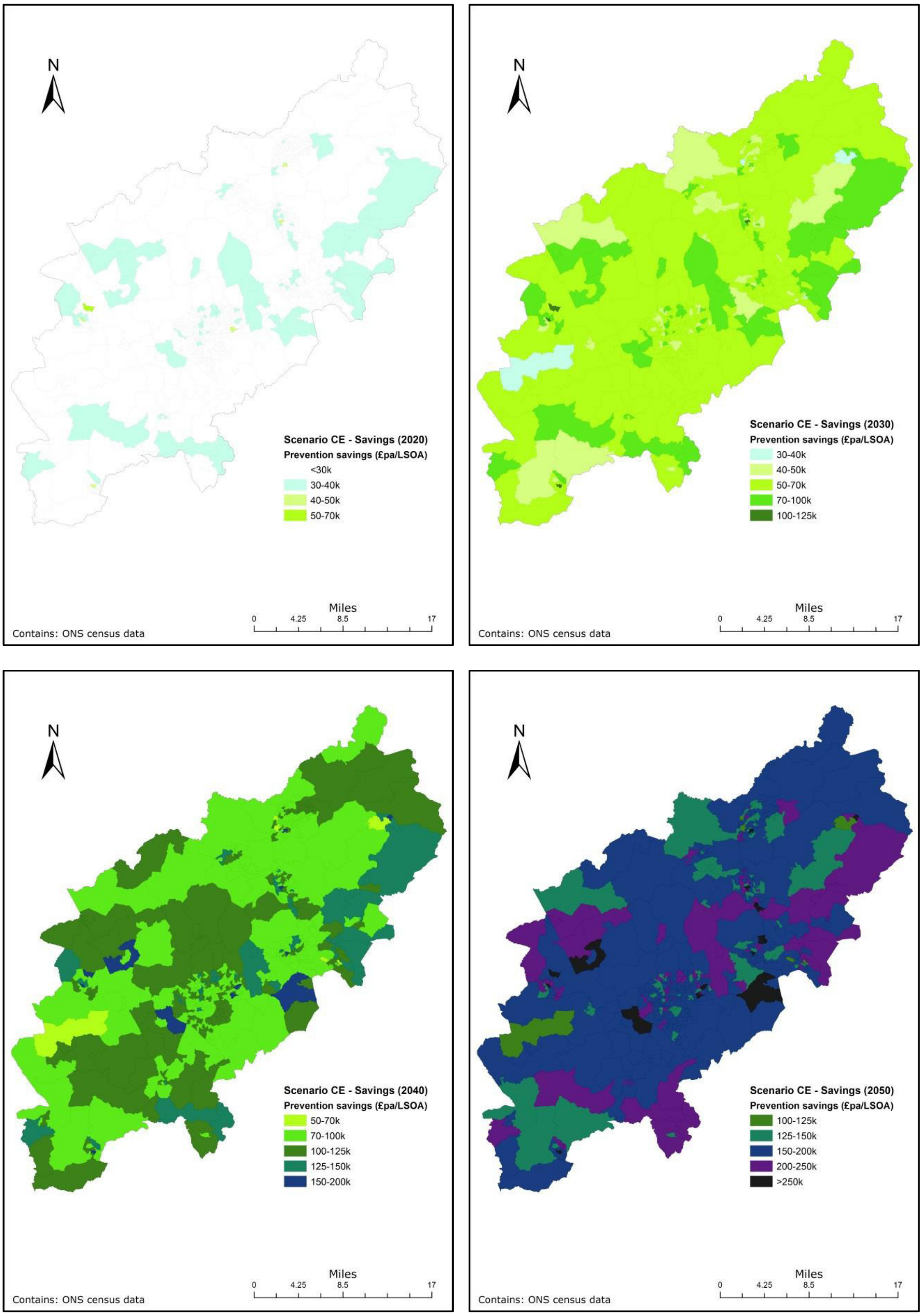

Figure A12.15: Economic savings across the backcast period (2012-2050) under scenario CE in Northamptonshire

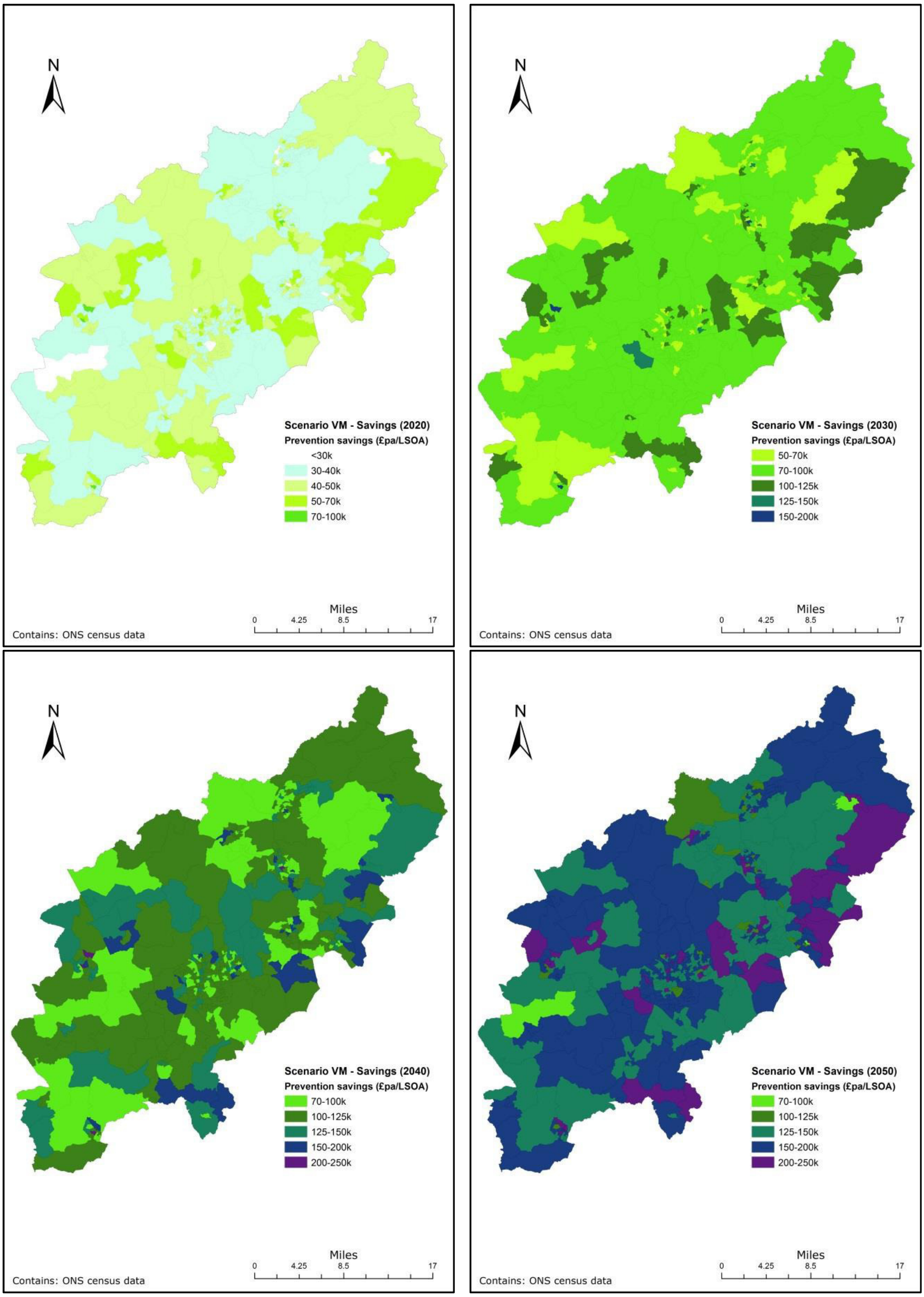

Figure A12.16: Economic savings across the backcast period (2012-2050) under scenario VM in Northamptonshire

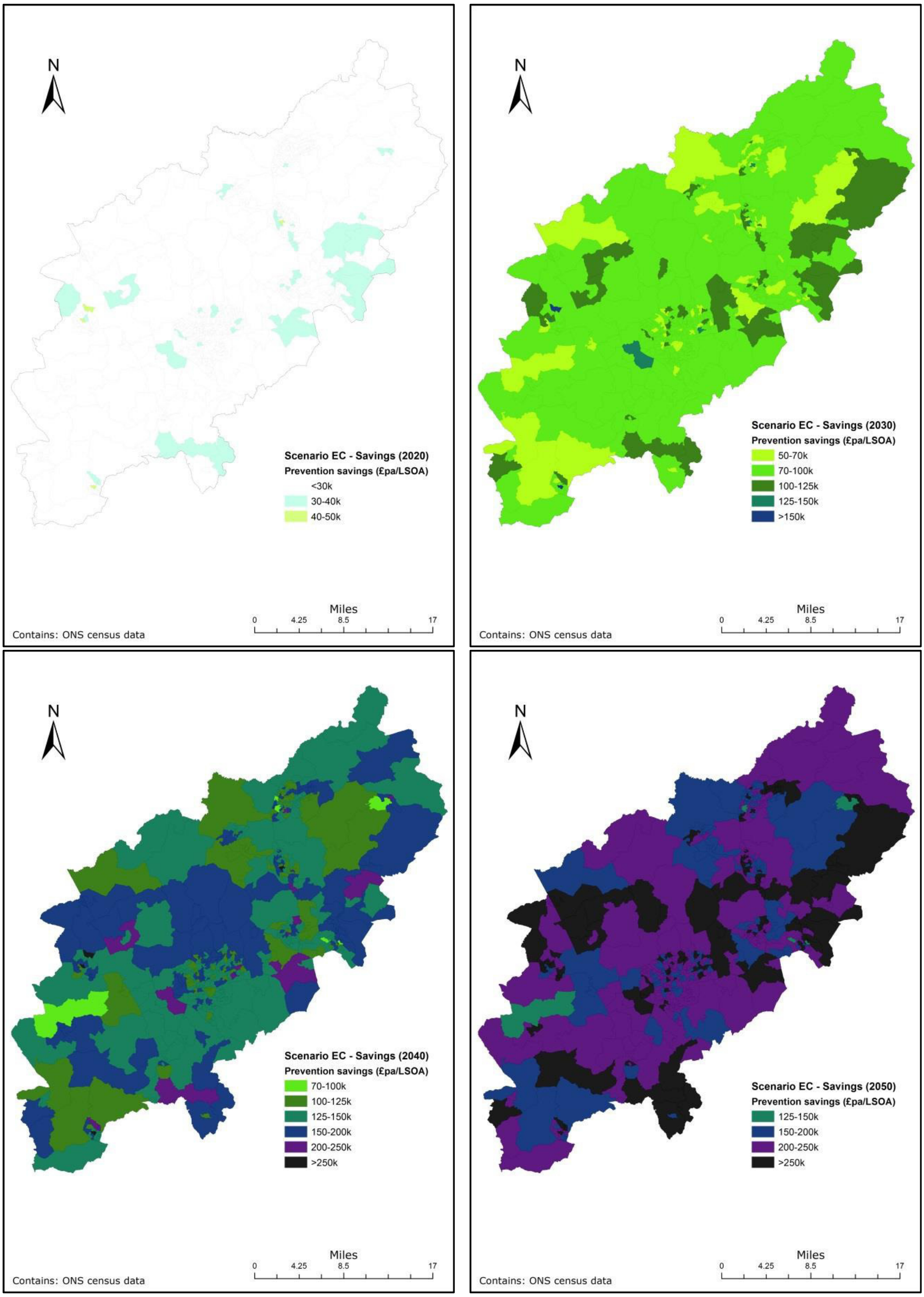

Figure A12.17: Economic savings across the backcast period (2012-2050) under scenario EC in Northamptonshire

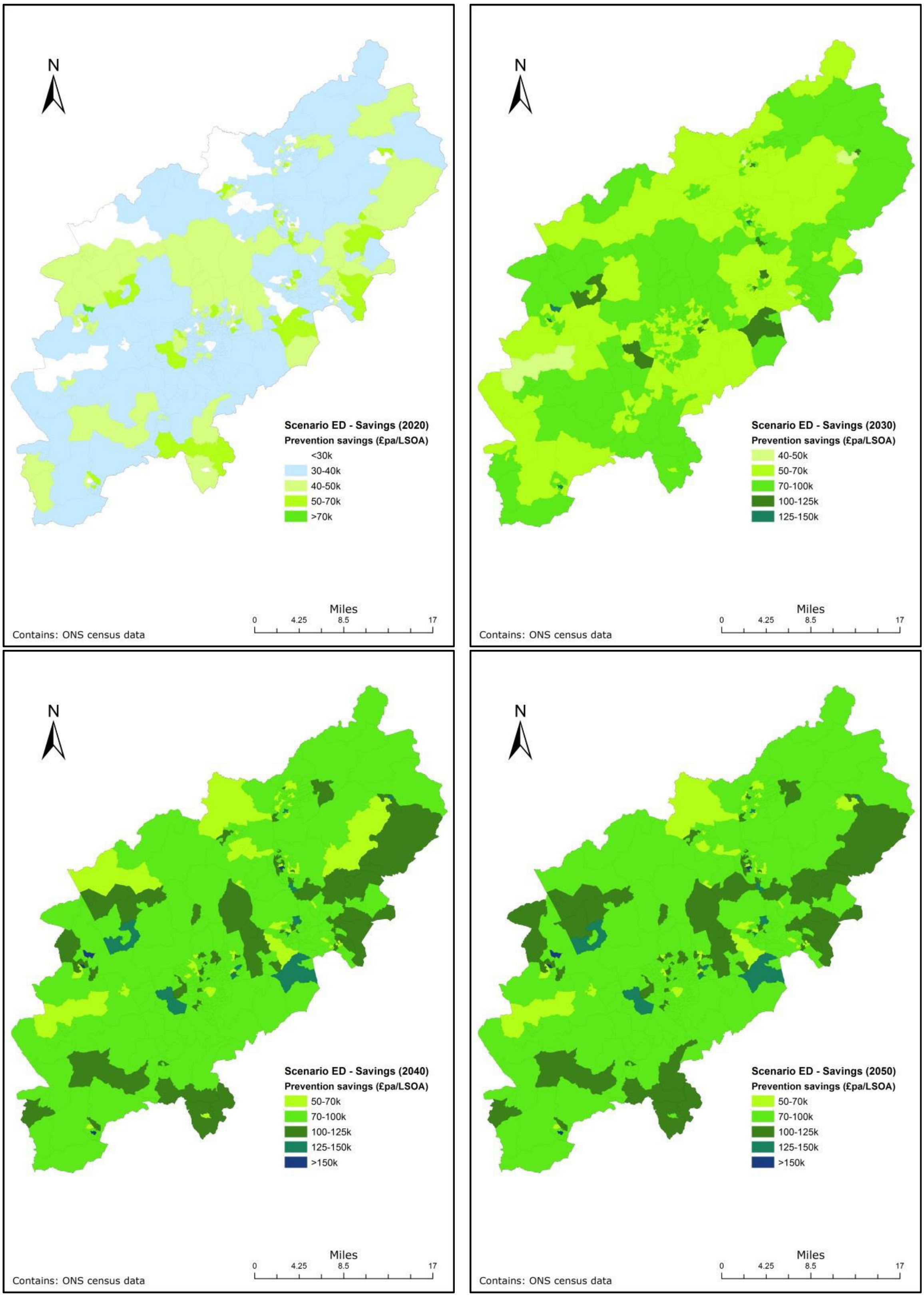

Figure A12.18: Economic savings across the backcast period (2012-2050) under scenario ED in Northamptonshire

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Appendix 12

Carbon emissions maps for milestone years – all scenarios

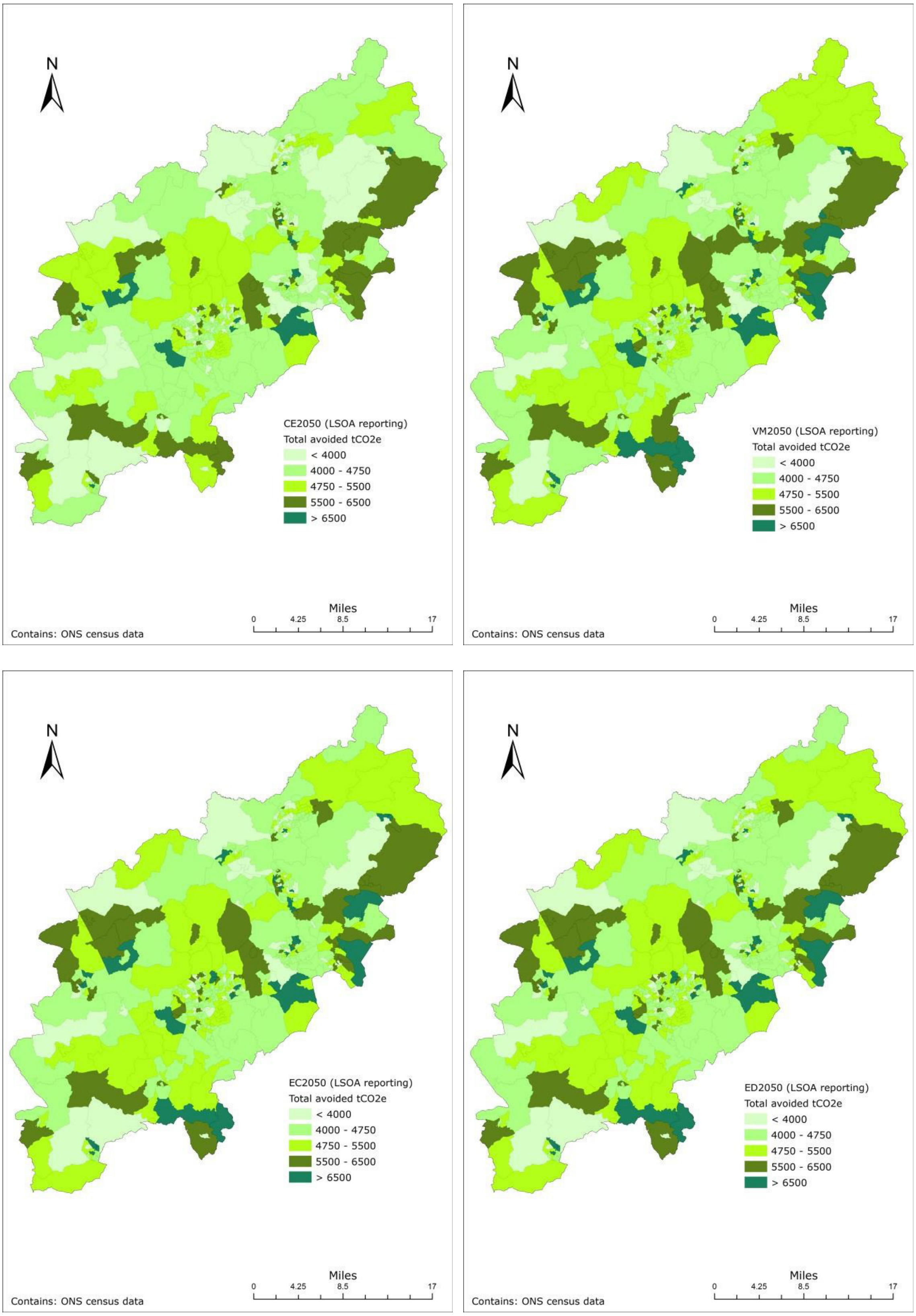

Figure A12.19: Total avoided emissions for all scenarios in 2050

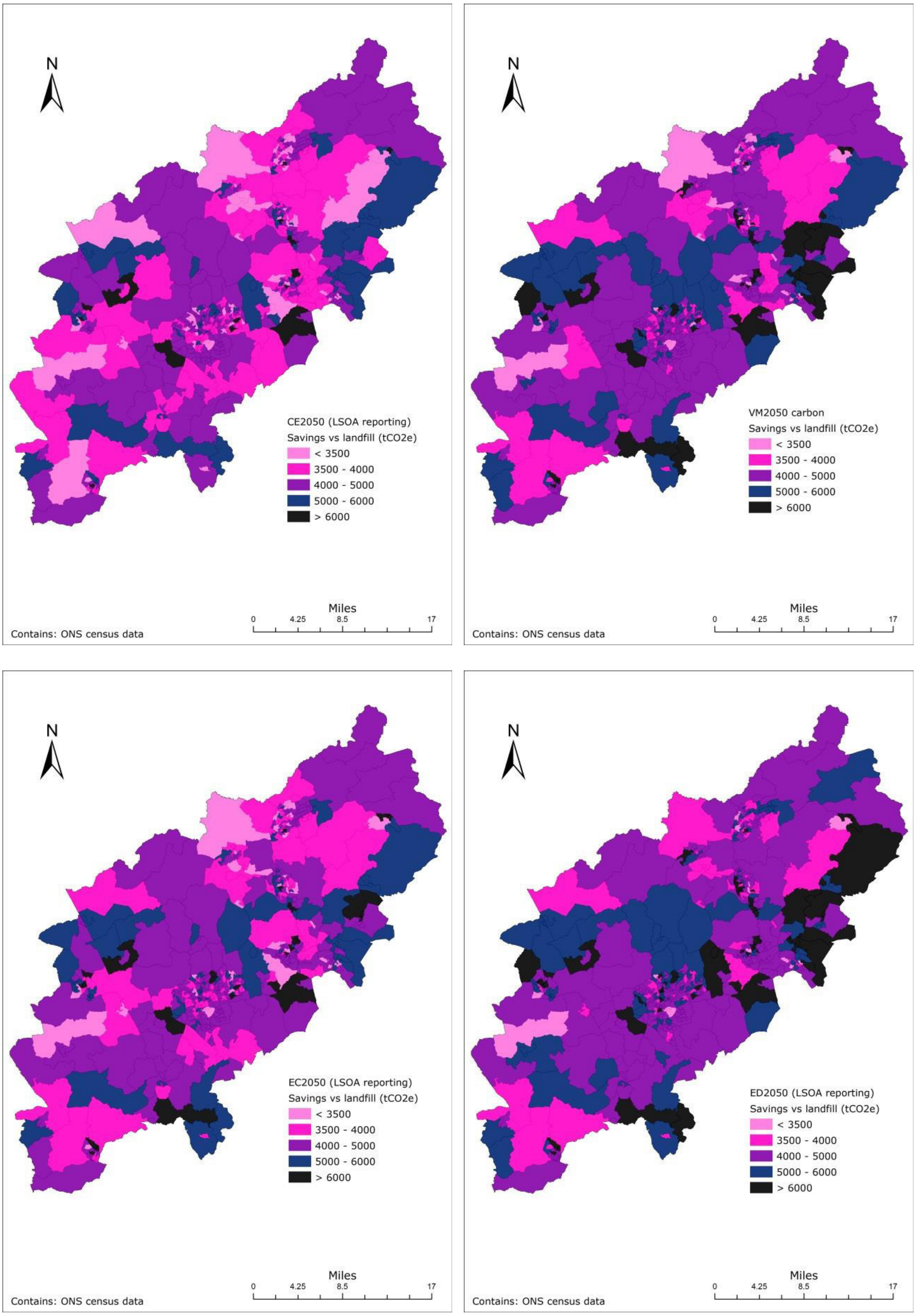

Figure A12.20: Emissions savings versus landfill for all scenarios in 2050

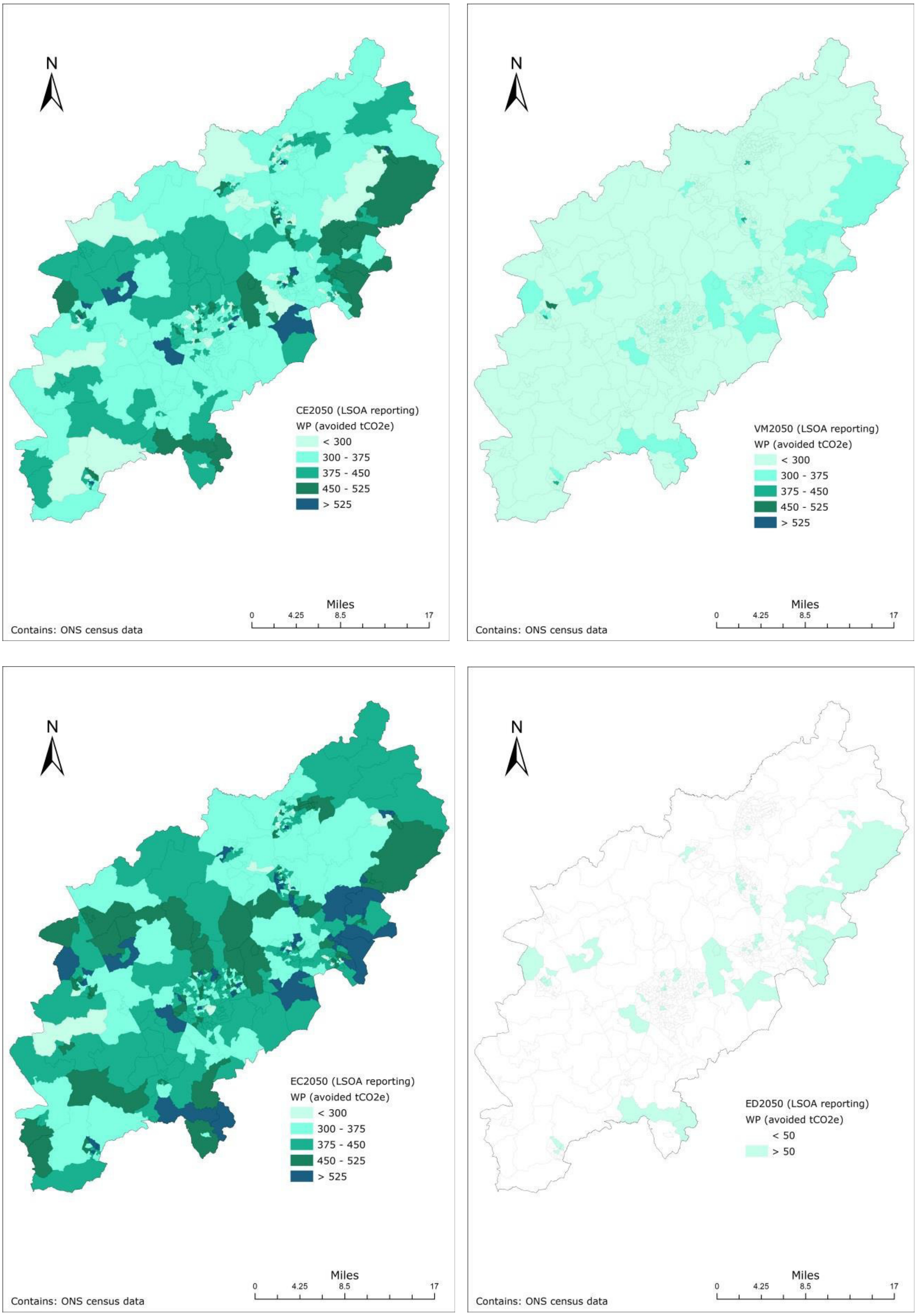

Figure A12.21: Waste prevention avoided emissions for all scenarios in 2050