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An exploration of the resource sector's greenhouse gas emissions in the UK, and its potential to reduce the carbon shortfall in the UK 4th and 5th carbon budgets

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Foreword

Over 190 countries have signed the Paris Agreement and re-committed to the low-carbon economy. The UK alongside China, India and the EU will need to meet set targets for reducing greenhouse gas (GHG) emissions in order to achieve the United Nation's goal of limiting global warming to below 2 degrees. Considering the UK is expected to miss these targets by almost 180 million tonnes in the 4th and 5th budgets (between 2023 - 2032), this presents a huge challenge for the country.

We have just five years to drastically change the way we produce, travel and expend energy. The waste and resource sector is already diversifying, modifying and innovating its services - resulting in a projected saving of 23 million tonnes of emissions during the 4th and 5th budgets, equating to over 10% of the UK's total carbon shortfall.

While the UK waste and resource sector currently accounts for around 4% of the UK GHG emissions, its potential for driving further reductions calls for an approach that goes beyond waste treatment and disposal. Energy supply, transport and industrial processes collectively account for 51% of GHG emissions, and in this report we estimate the contribution that the waste and resource sector can make across these broader areas which will close the gap in emissions.

While considerable changes in current waste management, energy supply and transport infrastructure might be required for these reductions, they offer the opportunity for the UK to become a green, zero waste economy and take a leadership role in reducing greenhouse gas emissions.

This report highlights the potential for the waste and resource industry to close the emissions gap, but it is paramount other sectors engage and become equally carbon conscious in order to achieve emissions targets and for the UK to transition to a low carbon economy.

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Abbreviations

AD	Anaerobic Digestion
BEIS	Department for Business, Energy and Industrial Strategy
CCC	Committee on Climate Change
DH	District Heating
EfW	Energy from Waste
ERF	Energy Recovering Facilities
EU ETS	European Union emissions trading system
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land use, land-use change, and forestry
UNFCCC	United Nations Framework Convention on Climate Change
WWTW	Wastewater Treatment Works

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Abstract

Currently in its 3rd carbon budget, the UK is at risk of under-delivering the greenhouse gas (GHG) emission targets set out in the 4th and 5th carbon budgets (2023-2032). The latest government projections, based on both existing policies and new plans proposed in the Clean Growth strategy, identify a total shortfall of almost 180 Mt CO_2e emissions across the period. More ambitious plans are needed to deliver further emission reductions if the carbon budgets are to be met.

The UK Waste Management sector has great potential for driving the needed reductions, however, realising the opportunities that it presents calls for an approach that goes beyond the traditional view of it as a waste disposal and treatment mechanism. It is also important to consider its interconnectedness with other economic activities as a result of its ability to retain energy and resources in the economy.

Accounting for almost 4% of the UK GHG emissions in the last carbon budget (2013-2017), the sector's total five-year emissions are projected to drop by 38 Mt CO_2e in the 5th carbon budget, making up 3% of the UK total. However, taking into account the contributions that the sector can make to Energy Supply, Transport and Industrial Processes demonstrates that its total contribution to tackling climate change can be considerably greater than what is portrayed in the current policies and projections. Thus, the total GHG emission reductions estimated for 2023-2032 that the Waste and Resource sector can drive range between 227 Mt CO_2e and 358 Mt CO_2e emissions, which is equivalent to 6% and 9% of the total projected UK GHG emissions respectively. The identified reductions are not only greater than the total emissions projected for the Waste Management sector but also the total projected gap in emissions.

The greatest opportunities for emission reductions are associated with sector-wide changes such as the replacement of a portion of fossil fuels as a source of energy with waste-derived energy that can be generated at Energy Recovery Facilities, as well as the diversion of waste from landfill sites to alternative treatments that can recover the embedded energy and materials. Achieving these GHG emission reductions would require considerable changes in the current infrastructure but they would benefit the UK economy by aiding the transition to becoming a green, zero waste economy.

Introduction

Through the Climate Change Act, the UK government has committed to reduce emissions by at least 80% of 1990 levels by 2050, and contribute to global emission reductions, to limit global temperature rise to as little as possible above 2°C. To meet these targets, the government has set five-yearly carbon budgets which currently run until 2032. They restrict the amount of greenhouse gas the UK can legally emit in a five-year period.

Between 1990 and 2016, the UK greenhouse gas (GHG) emissions have dropped by 42%, outperforming the target emission reductions set out by the government in the first two carbon budgets spanning from 2008 to 2017. The UK is currently also on target to deliver the third carbon budget ending in 2022, however, significant further reductions will need to be made across sectors if the targets set out in the 4th and 5th carbon budgets are to be met (CCC, 2017).

Although good progress has been made to date, that progress is stalling. Since 2012, emissions reductions have been largely confined to the power sector, whilst emissions from transport and building stock are rising. Based on the currently proposed plans and without new and stronger policies, the UK will fail to meet its commitments for GHG reductions with a total shortfall currently projected to be almost 180 Mt CO_2e emissions between the years 2023 and 2032 (BEIS, 2018a).

Opportunities exist for closing the gap in emissions across all economic sectors, from transport and industry to agriculture and waste, and effective new strategies and policies are urgently needed to ensure emissions continue to fall.

This report focused on the waste sector, exploring its current GHG contribution and the possible emission reduction options for the future. However, it goes beyond the conventional definition of it as waste treatment or disposal activities and also considers its links to resource management, therefore calling it the “Waste and Resource sector” or simply “Resource sector” to distinguish it from the “Waste Management sector” that is limited to waste treatment. The report then summarises the reporting methodology used by the UK government in its national GHG emission inventories as it is key to understanding the emission sources and reduction options linked to the sector. To identify the emission reduction opportunities in the Waste and Resource sector, an overview of its current and projected share of the UK’s GHG account as well as the sources of those emissions follows. The report closes with the evaluation of possible potential reductions.

UK Waste and Resource Sector

The UK Waste Management sector has seen one of the greatest drops in emissions since 1990 with an overall reduction of over 70% and an average annual abatement of 10% between 2012 and 2016 (BEIS, 2018b). This notable progress is largely a result of policies that facilitated reductions in biodegradable waste going to landfill, improved methane capture technology and management of landfill sites (CCC, 2017). These and other existing policies, including the EU Waste Framework Directive, are expected to continue driving down the GHG emissions in the waste sector (BEIS, 2018c).

Further reductions of the sector's emissions are possible, which can both help the UK meet its carbon budgets by easing the burden of abatement targets in other economic activities and achieve the long-term ambition of becoming a zero avoidable waste economy by 2050 as set out in the government's Clean Growth Strategy (HM Government, 2017). However, realising the full potential of the sector's ability to contribute to tackling climate change will require more ambitious plans beyond the options already recognised and, importantly, considering its interconnectedness with other economic activities, including Energy Supply and Transport, through its ability to retain energy and resources in the economy.

Understanding GHG Emission Reporting

To assess the resource sector's contribution and, indeed, the opportunities that it presents for reducing the GHG emissions in the UK, it is crucial to, first of all, understand how these emissions are calculated and reported in the UK Government Carbon Budgets.

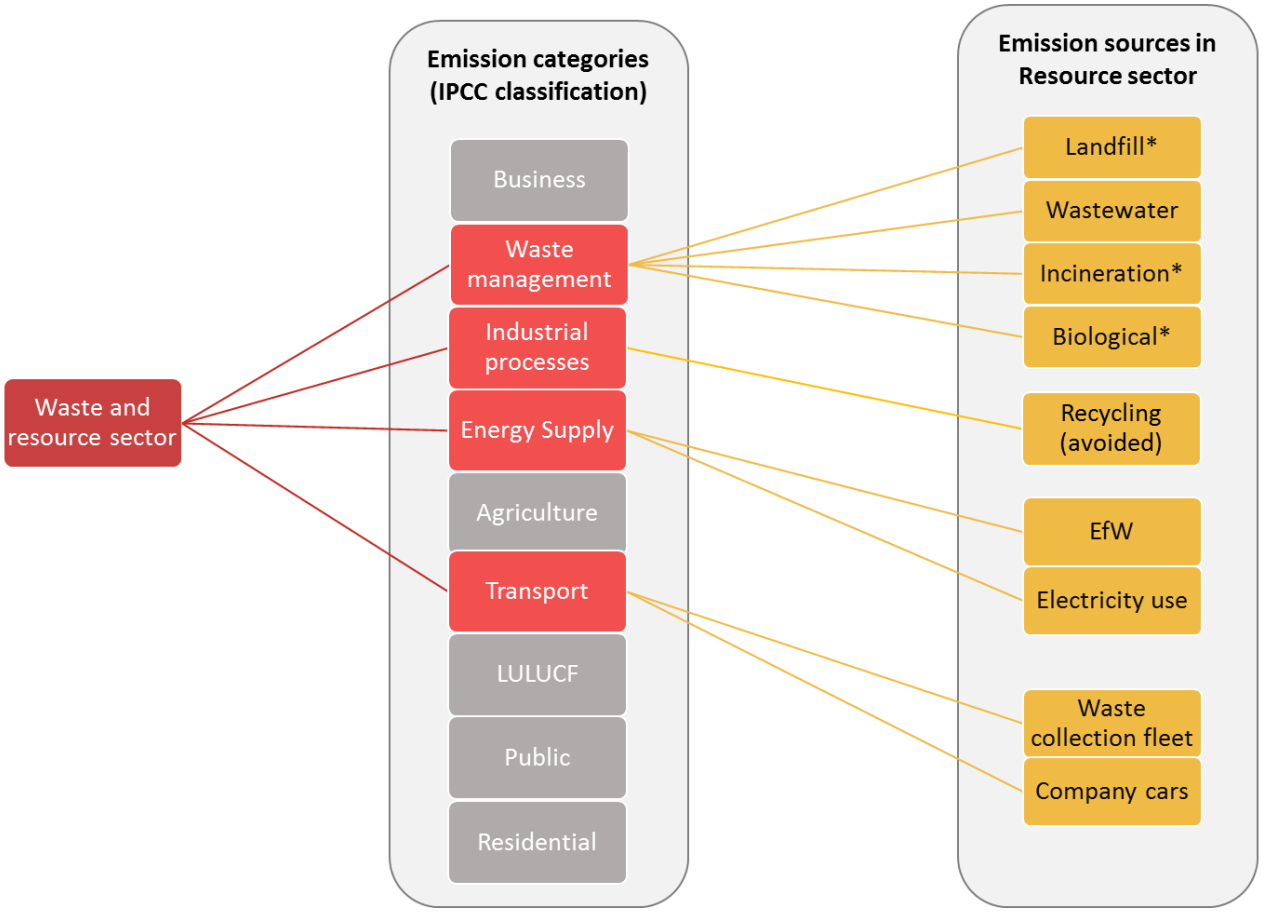
Under the IPCC guidelines (2006), the impacts reported in the "waste" section of the UNFCCC inventory are limited to direct emissions from the disposal and treatment of waste, excluding treatments where energy is recovered. Therefore, they only include emissions associated with waste treatment at the lowest levels of the waste hierarchy, i.e. landfilling, incineration, organic waste treatment and mechanical biological treatment.

All other activities and impacts related to waste management (i.e. the activities that make it the "resource sector") are recorded under other sections of the inventory (Hogg & Ballinger, 2015). Thus, for instance, the impacts of waste incineration and anaerobic digestion with energy recovery are recorded under Energy Supply, the benefits of avoided emissions from recycling materials appear under Industrial Processes, and the emissions resulting from the transportation of waste are part of the Transport section (BEIS, 2018b; Hogg & Ballinger, 2015) (Figure 1).

Furthermore, the methodology adopted in estimating these emissions plays an important role in the results reported in the UK GHG inventory and the level of uncertainty associated with them. In the Waste Management sector, the main source of uncertainty is the difficulty of accurately estimating the methane emissions from landfill sites. Currently estimated using the MELMod model, these results are highly sensitive to a number of values, including the biogenic content assumed to be present in waste, its methane generation potential and the amount of methane collected (Brown et al, 2018) (See Table A1 in Appendix A for the summary of methodologies and uncertainty sources in estimating the direct GHG emissions linked to the resource sector).

To address the inaccuracies and inconsistencies in the MELMod approach, the UK government had commissioned work to update the activity data and emission factors for landfill methane (Eunomia Consulting and Research, 2011), and has consequently made changes in the source of data used to quantify the amount of waste landfilled and the waste decomposition rates (Brown et al, 2017). In 2015, the methodology changes lead to an additional 0.88 Mt CO_2e emissions reported from landfill sites, leading to an increase of 0.18% of the total UK emissions that year (BEIS, 2018d). Despite the recent methodological improvements, however, the uncertainty in the waste sector emissions remains high. At about ±39% in 2016 (at the 95% confidence level) compared to less than ±3% for the entire economy, the sector' uncertainty is among the highest of all sectors (CCC, 2017) (Table 1).

The above methodological issues associated with the calculation and reporting of GHG emissions result in a distorted picture of the resource sector’s total contribution to the UK’s carbon budgets, making it difficult to see the mitigation opportunities that the sector presents beyond the direct emissions of waste management, and the vital role that it can play in combating climate change (Hogg & Ballinger, 2015). In this report, all of the key activities related to the Waste and Resource sector are considered.



**excluding emissions of waste treatment with energy recovery*

Figure 1. Resource sector's GHG emission reporting in the UK carbon accounts

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories; Brown et al, 2018.

Resource Sector Emissions

Current GHG emissions

The majority of all emissions (over 90%) associated with waste management is methane, which arises as a result of decomposition of biodegradable waste (BEIS, 2018c; CCC, 2017). Landfill sites have been historically and remain the main source of these emissions, although the latter have fallen by over 70% since 2001 following the introduction of the EU Landfill Directive and the associated policies that facilitated a reduction in the amount of biodegradable waste sent to landfills and improvements in methane capture and landfill sites management (Figure 2). Today, the GHG emissions from waste management make up just under 4% of the UK's total greenhouse gas emissions with solid waste disposal on landfill sites accounting for a 67% share of the sector's total emissions, followed by waste-water handling at 22%, biological treatment at 9% and waste incineration at 2% (excluding that with energy recovery) (based on data for 2015, Figure 3).

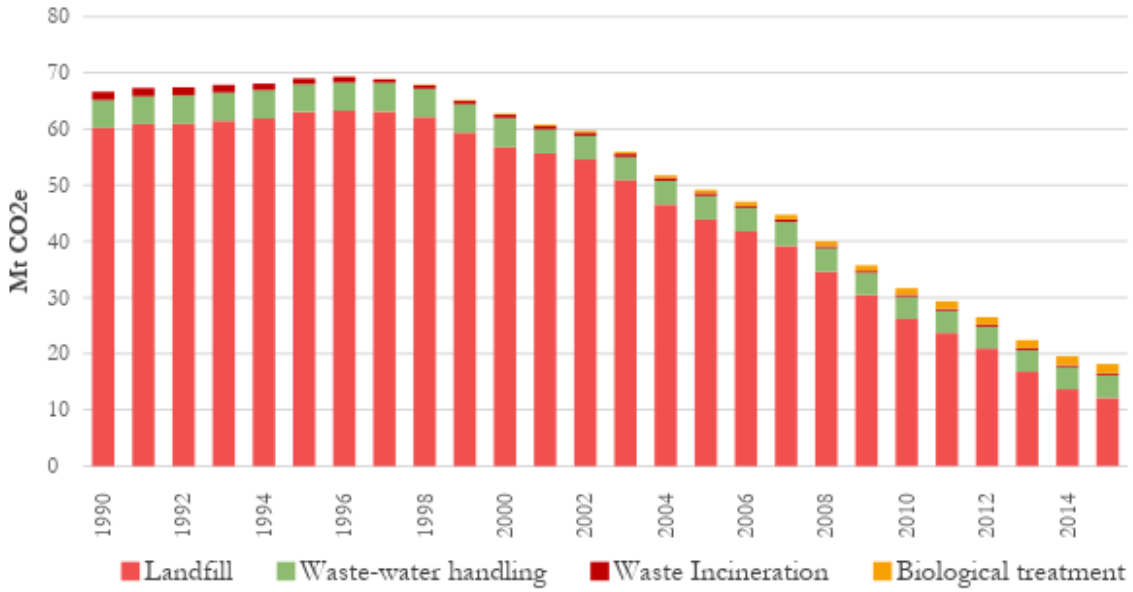


Figure 2. GHG emissions from waste by source, 1990-2015

Source: BEIS, 2017

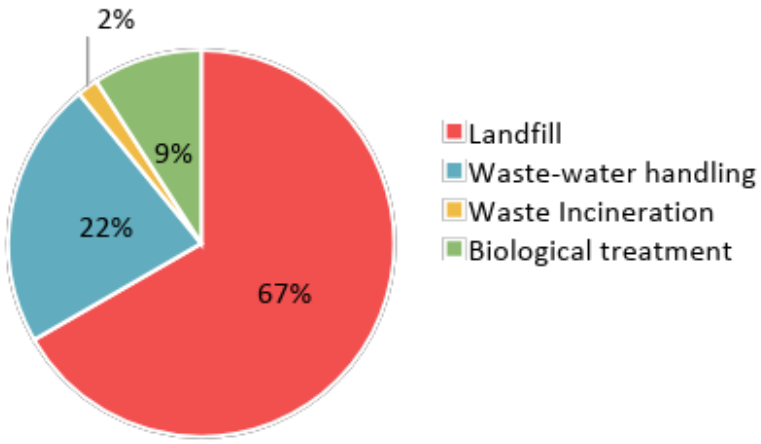


Figure 3. GHG emissions by source in the Waste Management sector, based on data for 2015

Source: BEIS, 2017

As a result of the particularity of the GHG emission reporting methodology discussed above, there is a lack of clarity on the resource sector's contribution to the emissions in the Energy Supply, Industrial Processes, and Transport sectors (from energy-from-waste (EfW) facilities, material recycling, collection fleet, etc.). In this report, these emissions were extrapolated for the whole of the economy based on the emissions provided by Veolia UK (2016). Thus, the annual carbon emissions of energy-from-waste recovery activities, as well as the emissions associated with the electricity and fuel use at various facilities and buildings of the Waste Management sector, are estimated to be almost 1.7 Mt CO_2e. The direct annual emissions associated with the fuel use for the waste collection fleet and business vehicles are estimated to be 0.2 Mt CO_2e (Table 1).

The avoided emissions of material recycling in the UK are only partly accounted for in the UK carbon inventory because it is the producer country of the associated primary materials that benefits from the avoided emissions and therefore includes those in its carbon inventory. For example, the avoided emissions associated with using recycled plastic in China (sent in the form of sorted plastic waste from the UK) as opposed to using virgin plastic in the latter's industrial processes, are reported in China's carbon inventory and not UK's. Given the lack of specific data on the current avoided emissions in the UK and the fact that these are not direct emissions, they are not provided in this report, however the avoided emissions are considered as part of the opportunities for future reductions.

Table 1. Resource sector GHG emissions, 2015

Sector & Source of emissions	Amount of waste handled, Mt	GHG emissions 2015, Mt CO_2e	Share of UK GHG emissions, %
Waste Management		**19**	**3.8**
Landfill	*11.4*	*13*	*2.6*
Biological treatment	*6.4*	*1.6*	*0.3*
Incineration & open burning	*0.5*	*0.3*	*0.1*
Wastewater Treatment	*2.2*	*4.1*	*0.8*
Energy Supply (UK total)		**120**	**24.2**
*EfW, Electricity and fuel use at facilities**	-	*1.69*	*0.3*
Transport (UK total)		**125**	**25.2**
*Waste sector's fleet & other fuel use**	-	*0.20*	*0.04*
Total UK GHG emissions**		**496**	

*Rough estimate based on Veolia UK data for 2013-2016 and the company's 5% share of UK waste handling.

** Excluding EU ETS Allowance

Hyphen – no waste-specific data available

Sources: IPCC, 2006; BEIS, 2017; Veolia UK, 2016

Projected GHG emissions

The UK Clean Growth Strategy, published last year (HM Government, 2017), sets out a broad vision for waste management and is largely based on existing policies such as the EU Waste Framework Directive aimed at increasing recycling and reuse and reducing harmful disposal (BEIS, 2018e; European Commission, 2016). Based on these measures, the GHG emissions in the Waste Management sector are expected to fall just below 11 Mt CO_2e annual emissions by 2032, down from about 19 Mt CO_2e in 2015 (BEIS, 2018b; BEIS, 2017). Across the five-year carbon budgets the projected drop is from 93 Mt CO_2e in the period of 2013-2017 to 55 Mt CO_2e emissions in 2028 - 2032, that is a 38 Mt CO_2e reduction in emissions in the 5th carbon budget, bringing the sector's share of UK total emissions to 3%. The main drivers of this projected drop include limiting emissions from landfill sites to 7 Mt CO_2e in 2032 by minimising the amount of biodegradable waste disposal, a 20% reduction in the amount of food and drink waste arising and recycling at least 50% of household waste by 2020 (HM Government, 2017). In total, the waste management emissions are projected to drop from about 93 Mt CO_2e emissions in the last carbon budget (2013-2017) to 55 Mt CO_2e in the 5th (2028-2032), or from 3.5% of the UK Net GHG emissions to 3% respectively (Table 2).

The total GHG emission projections that take into account the newly proposed plans and policies indicate that there still remains a gap in achieving the set carbon budgets for 2023-2032, which comes to nearly 180 Mt CO_2e emissions, that is 64 and 116 Mt CO_2e emissions in the 4th and 5th carbon budgets respectively (Table 2). It is therefore important to consider the additional emission reduction opportunities that the Waste and Resource management sector presents as it can help reduce the shortfall in reaching the carbon emission targets.

Table 2. The UK projected GHG emissions, focus on Waste

UK CARBON BUDGET	2nd (2013-2017)	3rd (2018-2022)	4th (2023-2027)	5th (2028-2032)
Carbon budget level, Mt CO_2e	2,782	2,544	1,950	1,725
Projected Net GHG emissions, Mt CO_2e*	2,657	2,401	2,014	1,841
Performance Vs. budget, Mt CO_2e	125	143	-64	-116
Shortfall Vs. budget, %			-3.3%	-6.7%
Projected GHG emissions in waste-related sectors				
WASTE MANAGEMENT EMISSIONS, Mt CO_2e	93	69	60	55
Share of Net UK projected emissions, %	*3.5%*	*2.9%*	*3.0%*	*3.0%*
ENERGY SUPPLY EMISSIONS, Mt CO_2e	701	428	332	294
Share of Net UK projected emissions, %	*26%*	*18%*	*16%*	*16%*
Est. waste-related emissions**	8.3			
Share of Net UK projected emission, %	*0.3%*	-	-	-
TRANSPORT EMISSIONS, Mt CO_2e	591	560	536	520
Share of Net UK projected emissions, %	*22%*	*23%*	*27%*	*28%*
Est. waste-related emissions**	1.1			
Share of Net UK projected emission, %	*0.04%*	-	-	-

*Projections include the EU ETS Allowances and are based on existing and a subset of new policies and proposals from the UK Clean Growth Strategy

**Rough estimate based on Veolia UK data for 2013-2016 and the company's 5% share of UK waste handling.

Hyphen – no waste-specific data available

Source: BEIS, 2018b; Veolia UK, 2016

Uncertainty in the GHG emission results

The complexity associated with calculating GHG emissions across the economy means that the reported emission results are subject to uncertainty. The latter is particularly great in the Waste Management sector, where the difficulty of estimating the methane emissions from landfill sites is at source. At about ±39% uncertainty and compared to less than ±3% for the entire economy

(data for 2015 at the 95% confidence level), the uncertainty in the GHG emissions driven by waste management activities is among the highest of all sectors (CCC, 2017) (Table 3).

Table 3. Uncertainty in the reported UK GHG emissions, 2015

Sector & Source	GHG emissions 2015, Mt CO_2e	Share of total UK GHG emissions, %	Uncertainty, %
Waste Management	**19.0**	**3.9%**	**± 39%**
Landfill	*13.0*	*2.6%*	*± 53%*
Biological treatment	*1.6*	*0.3%*	*± 49%*
Incineration & open burning	*0.3*	*0.1%*	*± 97%*
Wastewater Treatment	*4.1*	*0.8%*	*± 51%*
Energy Supply (UK total)	**120**	**24%**	**± 3%**
*EfW and Electricity use at facilities***	*1.69*	*0.3%*	-
Transport (UK total)	**125**	**25%**	**± 3%**
*Waste sector's fleet & other fuel use***	*0.2*	*0.04%*	-
Total UK economy	**492**		**± 3%**

* Excluding EU ETS Allowance

**Rough estimate based on Veolia data for 2013-2016 and the company's 5% share of UK waste handling.

Hyphen – no waste-specific data available

Sources: IPCC, 2006; BEIS, 2017; Veolia UK, 2016

There is also a large degree of uncertainty in emission projections and the estimated shortfall for the 4th and 5th carbon budgets due to a number of variables including the state of the world (e.g. GDP, population and fossil fuel prices), government policies and the calculation methods (BEIS, 2018a). Based on the uncertainties modelled by the government (only considering a number of key variables and therefore, most likely underestimating the full scale of uncertainty) the projected GHG emissions for the 4th and 5th carbon budgets could vary by ±6% and ±7% respectively (BEIS, 2018a). Consequently, the Waste and Resource sector's contribution to reducing the GHG emissions and the carbon budget gap may be considerably greater or lower than estimated in this project.

Opportunities for GHG Emission Reduction

Methodology

This report identifies multiple opportunities for the Waste and Resource sector to reduce its GHG emissions and drive further reductions across other sectors. These comprise three types of reductions – those that are Veolia-specific, Sector-wide (referring to the whole of the UK Waste and Resource sector), and UK-wide (referring to reduction opportunities of a wider scope and which are currently new to the sector) (Table 4). The opportunities presented were identified using current trends and either realistic infrastructural changes that would be required for the proposed changes to take place across the 4th and 5th carbon budgets, or more ambitious plans in selected cases. Thus, two scenarios have been produced identifying a range of the possible reductions: low-end and high-end emission reduction projections. Some of the options identified, to a degree, feature in the policies and plans proposed in the Clean Growth Strategy. In most cases, however, they present additional reduction opportunities.

The CO_2 equivalent emissions were calculated using the 2018 GHG conversion factors (BEIS and DEFRA, 2018), except in the case of recycling where the 2011 life-cycle conversion factors for waste disposal (DEFRA and DECC, 2011) were used because they account for the benefits of avoided emissions associated with the virgin material production. To estimate the total emission reductions in each case, the benefits of each option were compared to inaction (i.e. current activities and conditions) across the whole ten-year period between 2023 and 2032.

Table 4. Description of the GHG emission reduction opportunities in the UK Waste and Resource sector

Scope	#	Opportunities for GHG emission reduction	Opportunity description	Is reduction covered by current policies?*
Veolia-specific	1	District heating on all Veolia ERFs	Replacing a portion of UK energy use for heating purposes with the heating generated at Veolia UK Energy Recovery Facilities (ERFs), considering only the currently unexploited capacity to generate heat	No
	2	EfW through AD at 100% of Veolia WWTW	Replacing a portion of UK energy supply from the UK grid with the biogas that can be generated at Veolia's Waste Water treatment works (WWTW) through Anaerobic Digestion (AD)	No
Sector-wide	3	District heating on all UK ERFs (incl. Veolia)	As option 1 but based on the total additional capacity of all UK ERFs to produce district heating	No
	4.1/ 4.2	50%/ 100% UK collection fleet to electric	Replacing 50%/ 100% of all diesel waste collection fleet in the UK with electric vehicles	Partly
	5.1/ 5.2	50% / 100% of cars and vans of the waste sector to electric	Replacing 50%/ 100% of all diesel company fleet (cars and vans) with electric vehicles	Partly
	6	Recycling 500kt of plastics instead of ERF	Diverting 500,000 tonnes of recyclable plastic waste (in the form of packaging) from ERFs to recycling. The avoided emissions of producing virgin materials are also accounted for (assuming recycling and production takes place in the UK)	Partly
	7	Divert undercapacity waste from LF to ERF/AD/Recycling	Diverting waste that is currently landfilled but that has energy or material value to alternative treatments, including recycling, ERFs, Anaerobic Digestion	Yes
	8.1/ 8.2	One/ Ten 20MW biomass burner(s)	Replacing a portion of electricity supply from the UK grid with that generated at one/ ten new biomass burner(s). Biomass is assumed to be waste wood such as wood pellets and not virgin material	No
	9.1/ 9.2	Replace 10%/ 20% gas use with biomass	Replacing 10%/ 20% of the energy derived from natural gas use with that from biomass burning	Partly
	10.1/ 10.2	Replace 10%/ 20% gas use with district heating	Replacing 10%/ 20% of natural gas use for heating with the District Heating (DH) supplied by UK ERFs	Partly
UK-wide	11.1/ 11.2	Biofuel for 10%/ 20% of public transport trips (buses)	Replacing 10%/ 20% of UK diesel bus trips (based on the fuel consumption) with biofuel-based buses	Partly
	12	Battery storage to support the grid at peak times	Increasing renewable energy storage and thereby reducing the use of energy directly from the UK grid	Partly

*In many cases, the extent to which the above initiatives are covered by the UK Clean Growth Strategy is unclear, in such instances author judgement was used.

Results

The total GHG emission reductions estimated for 2023-2032 range between 227 Mt CO_2e emissions (low-end scenario) and 358 Mt CO_2e emissions (high-end scenario), equivalent to 6% and 9% of the total projected UK GHG emissions respectively (Table 5). Furthermore, the contribution to the carbon shortfall in the 4th and 5th carbon budgets equates to over 10% and 23 Mt CO_2e emissions considering the additional initiatives which reduce the overall carbon emissions in the UK.

The greatest opportunities for reductions are associated with sector-wide changes including the replacement of a share of natural gas as a source of heat generation with biomass burning and also with district heating generated at ERF facilities. In addition, diverting the waste currently sent to landfill sites to alternative treatments such as recycling, ERFs and anaerobic digestion in order to maximise the value of that waste as a source of energy and materials presents significant emission reduction possibilities. Together, the reduction associated with these initiatives would make up between 4% and 7% of the total UK GHG emissions, that is 168 and 291 Mt CO_2e emissions respectively. Additionally, a UK-wide initiative of increasing battery storage to support the electricity grid at peak times would help reduce the GHG emissions by almost 34 Mt CO_2e (or by 1%) (Table 5).

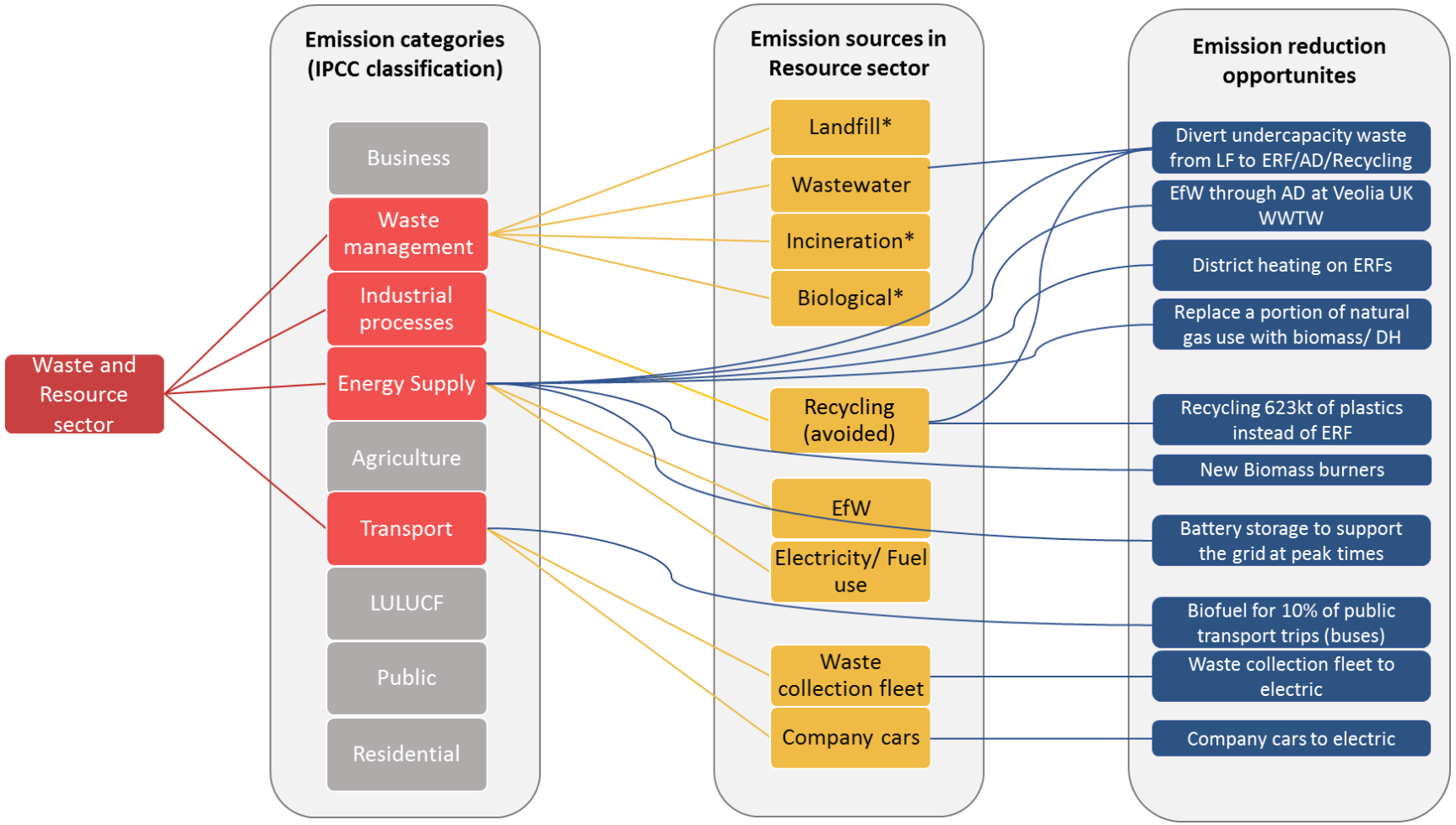
Other opportunities include the avoidance in GHG emissions as a result of diverting 500,000 tonnes of recyclable plastic packaging waste from incineration facilities to recycling (thereby avoiding 11 Mt CO_2e emissions associated with the production of virgin materials and the combustion of the waste), and utilising the full capacity for district heating production at all UK energy recovery facilities (6 Mt CO_2e). Moreover, switching 50% of the UK waste collection fleet from diesel to electric vehicles can help reduce emissions by 4 Mt CO_2e, while substituting 10% of passenger trips made by diesel buses with biofuel-based alternatives would reduce the public transport emissions by 2 Mt CO_2e (Table 5).

The opportunities presented in this report are not exhaustive, but they address many direct sources of emissions in the sector, with at least one (the diversion of waste from landfill to recycling, ERFs and anaerobic digestions) clearly delivering benefits across several emission categories, including Energy Supply and Industrial Processes (Figure 4).

Table 5. GHG emission reduction opportunities in the UK Resource sector in the 4th and 5th carbon budgets (2023-2032)

Scope	Option #	Option (low/ high - end or both)	Opportunities for GHG emission reduction	Est. GHG emission reduction, Mt CO_2e	Share of total UK GHG emissions, %*	Share of shortfall, %*
Veolia-specific	1	both	District heating on all Veolia ERFs	*2.3*	0.06	1.3
	2	both	EfW through AD at 100% of Veolia WWTW	*1.0*	0.03	0.6
Sector-wide	3	both	District heating on all UK ERFs (incl. Veolia)	5.7	0.14	3.2
	4.1	low-end	50% UK collection fleet to electric	4.1	0.10	2.3
	4.2	high-end	100% UK collection fleet to electric	8.1	0.21	4.5
	5.1	low-end	50% of Cars and vans of the waste sector to electric	1.4	0.03	0.8
	5.2	high-end	100% of Cars and vans of the waste sector to electric	2.8	0.07	1.5
	6	both	Recycling 500kt of plastics instead of ERF	11.1	0.28	6.2
	7	both	Divert undercapacity waste from LF to ERF/AD/Recycling	45.4	1.15	25.3
	8.1	low-end	One 20MW biomass burner	0.1	0.00	0.1
	8.2	high-end	Ten 20MW biomass burners	1.2	0.03	0.6
	9.1	low-end	Replace 10% gas use with biomass	87.7	2.21	48.8
	9.2	high-end	Replace 20% gas use with biomass	175.3	4.42	97.5
	10.1	low-end	Replace 10% gas use with district heating	34.9	0.88	19.4
	10.2	high-end	Replace 20% gas use with district heating	69.8	1.76	38.8
UK-wide	11.1	low-end	Biofuel for 10% of public transport trips (buses)	2.1	0.05%	1.1
	11.2	high-end	Biofuel for 20% of public transport trips (buses)	4.1	0.10%	2.3
	12	both	Battery storage to support the grid at peak times	33.7	0.85%	18.8
TOTAL- low end				**227.2**	**5.7%**	**141.5%**
TOTAL- high end				**358.3**	**9.0%**	**216.4%**

*Total projected UK Net GHG emissions for 2023-2032 = 3,965 Mt CO_2e; Shortfall projected for 2023-2032 = 179.7 Mt CO_2e (BEIS, 2018b; HM Government, 2017



*excluding emissions of waste treatment with energy recovery

Figure 4. *Waste and Resource sector's GHG emission sources linked to reduction opportuniti*

Discussion

The UK Waste and Resource sector presents several opportunities for reducing the country's GHG emissions and which are incremental to the options already recognised in the government policies. Thus, in addition to the current plans of, for example, reducing biodegradable waste sent to landfills and increasing recycling, the sector can also contribute to ending the economy's dependence on fossil fuels and maximising its resource efficiency by retaining the energy and materials embedded in waste within the economy.

Should all options for GHG emission reductions suggested in this report actualise, the total reduction would be equivalent to at least 6% of the UK's total projected emissions across the 4th and 5th carbon budgets. That is more than the total projected emissions of the Waste and Resource sector. Moreover, these reductions would contribute over 10% to the carbon shortfall in the UK 4th and 5th carbon budgets which equates to carbon savings of 23 Mt CO_2e. Although these estimates are subject to uncertainty, they highlight the significant scale of the contribution that the Waste and Resource sector can make and the important role it can play in greening the UK economy.

Now, due to the specificities of GHG inventory reporting these reductions would appear under other sectors, including Energy Supply, Transport and Industrial Purposes, since from the waste management perspective, the benefits would be mostly in the form of avoided emissions, e.g. avoiding the use of natural gas for heat generation, virgin material production, fossil fuel use in transport, etc. That is why, to make the most of the emission reduction opportunities that the Waste and Resource sector presents, it is important to consider it as an integral part of a systematic approach to decarbonising the economy.

Undoubtedly, carrying out the identified emission reduction initiatives would require a number of changes in the current waste management, energy supply and transport infrastructure. Moreover, the initiatives presented in this report are not exhaustive - future technological and policy developments will reveal new opportunities. Nevertheless, if the UK is to achieve its carbon budget targets and the long-term vision of becoming a zero waste economy with a near-zero emissions electricity system and a low emission road transport, changes like those proposed in this report need to take place without delay.

Conclusion

The Waste and Resource sector can play an important role in reducing the UK's GHG emissions and in combating climate change. It presents opportunities beyond the direct emissions associated with waste and resource management. Maximising the retention of the energy and materials embedded in waste in the economy can facilitate the transition away from the use of fossil fuels and virgin materials and, therefore, make notable contributions to mitigating emissions in the Energy, Transport and Industrial Processes sectors.

By 2032, the sector can help reduce the UK's projected GHG emissions by at least 6% and eliminate the gap in achieving the targets set for the 4th and 5th carbon budgets. Achieving these GHG emission reductions would require considerable changes in the current waste management, energy supply and transport infrastructure, however, they would benefit the UK economy by aiding the transition to becoming a green, zero waste economy.

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Appendix

Table A1. Summary of methods and uncertainties in estimating the direct GHG emissions

Sector (IPCC classification)	Uncertainty in GHG emissions, 2016	Comments on methods	Key sources of uncertainty
Waste Management	±39%	**Solid Waste Disposal**: modelled using *MELmod*, a first order decay model accounting for methane release over time and based on the amount of biodegradable waste disposed in each year and its CH4 generation potential **Biological Treatment:** *UK Waste activity data X IPCC default emission factors* **Incineration**: *Country specific emission factors X Waste Inputs*, and partially based on Pollution Inventory data **Wastewater treatment:** *CH_4 = BOD x Emission Factor* of all wastewater treatment systems *N_2O* calculated based on UK population and protein intake estimates	CH_4 emissions from landfill sites: the model is sensitive to the values assumed for Degradable Organic Carbon present in waste, and the amount of this that is dissimilable, the quantity of methane combusted in engines and flares, the oxidation factor, and the quantity of methane collected.
Energy Supply	±3%	*Emission Factor x Activity Data* (At EfW facilities, only the CO_2 of fossil origin is reported)	Default emission factors for non-CO_2 emissions
Transport	±3%	*Emission Factor x Activity Data* (Emissions from use of biofuels in road transport are included in the emissions reported for petrol and diesel)	The division in CO_2 emissions between vehicle types and the emission factors for non-CO_2 emissions
Total UK economy	**±3%**		
Sources: IPCC, 2006; BEIS 2018			