

Nexus of construction waste management & carbon emissions

*Cases from the UK student accommodation
refurbishment projects*

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waste & carbon



Setting the scene



Carbon: *Emissions & Calculations*



Waste: *Management & Calculations*



Bringing it together

climate change

Greenhouse gas (GHG) emissions from buildings will be a significant portion of the overall emission profile of any given country.

How buildings are constructed, materials used, energy consumed and building management and eventually demolished, ultimately determines the whole life cycle environmental footprint of any given building.



The UK built
environment
contributes around

40%

of total carbon
footprint.



student accommodation

The student accommodation sector is now the best-performing asset in the UK and US property markets and this is projected to further accelerate.

Building refurbishment of existing student accommodations being the preferred method to satisfy growing demand.

Student
Accommodation Sector
has grown by a net
increase of

2.6%

in 2020 with more than

25,000

new beds coming to
the UK market.



environmental assessment systems

Schemes	Country	Year first published	Developer	Assessment scheme	References
Building Research Establishment Environmental Assessment Methodology (BREEAM)	UK	1990	Building Research Establishment	BREEAM UK Refurbishment and Fit-out 2014	BREEAM (2015a)
Leadership in Energy and Environmental Design (LEED)	USA	1998	US Green Building Council, CNU (Congress for the new urbanism), NRDC	New construction and major renovations (v4)	USGBC (2011)
Comprehensive Assessment System for Built Environment Efficiency (CASBEE)	Japan	2001	Japan Sustainable Building Consortium, Japan Green Building Council	CASBEE-renovation	CASBEE (2015)
Building Environmental Assessment Method (BEAM) Plus	Hong Kong	1996	Hong Kong Green Building Council	New Building Version 1.2	HKGBC (2012)
Green Building Labelling System (GBLS)	Taiwan	1999	Taiwan Architecture and Building Research Institute	GBLS; EEWII-renovation	GBL (2013)
Haute Qualité Environnementale (HQE)	France	1996	HQE Association	Environmental performance non-residential buildings	HQE (2013)
Green Star	Australia	2003	Green Building Council of Australia	Design and As Built	GBCA (2014)
Green Mark	Singapore	2005	Building and Construction Authority	Non-residential existing building	BCA (2012)
Green Building Index (GBI)	Malaysia	2010	Malaysian Institute of Architects and the Association of Consulting Engineers Malaysia	Non-residential existing building	GBI (2011)
Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCrest)	Malaysia	2013	Public Work Department Malaysia and Construction Industry Development Board	New Construction	CIDB (2013)





environmental assessment systems

BREEAM Refurbishment and Fit-Out Technical Standard

Wst 01 Project waste management

BREEAM[®]
delivered by **bre**

Number of credits available	Minimum standards	Applicability			
		Part 1	Part 2	Part 3	Part 4
6	Yes	Yes	Yes	Yes	Yes

To promote resource efficiency via the effective management and reduction of refurbishment and fit-out waste and the reuse and direct recycling of materials.



environmental assessment



DESIGN REFERENCE GUIDE

Residential Building & Landed Home

Version 3.2

February 2021

RES 4-3 Waste Disposal (1)

RES 6-1 Carbon Emission (3)

Credit Allocation:

Category		Credits Allocations	
(I)	Energy Related Requirements	High- Rise	Landed
Minimum 30 credits	Part 1: Energy Efficiency		
	RES 1-1 Thermal Performance of Building Envelope -RETV	15	22
	RES 1-2 Naturally Ventilated Design and Energy Efficient Cooling	22	22
	RES 1-3 Daylighting	6	6
	RES 1-4 Artificial Lighting	8	4
	RES 1-5 Ventilation in Carparks	6	2
	RES 1-6 Domestic Hot Water System	3	3
	RES 1-7 Lifts	1	1
	RES 1-8 Cool Hardscaped Areas	2	2
	RES 1-9 Energy Efficient Features	7	7
	RES 1-10 Renewable Energy	15	15
	Category Score for Part 1 – Energy Efficiency	85 (Max)	84 (Max)
(II)	Other Green Requirements		
Minimum 20 credits	Part 2: Water Efficiency		
	RES 2-1 Water Efficient Fittings	8	8
	RES 2-2 Water Usage Monitoring	1	1
	RES 2-3 Irrigation System and Landscaping	3	3
	Category Score for Part 2 – Water Efficiency	12	12
	Part 3: Environmental Protection		
	RES 3-1 Sustainable Construction	10	10
	RES 3-2 Sustainable Products	8	8
	RES 3-3 Greenery Provision	8	8
	RES 3-4 Environmental Management Practice	10	10
	RES 3-5 Green Transport	5	5
	RES 3-6 Stormwater Management	3	3
	RES 3-7 Internet Connectivity	1	1
	RES 3-8 Community Connectivity	1	1
	Category Score for Part 3 – Environmental Protection	47	47
	Part 4: Indoor Environmental Quality		
	RES 4-1 Noise Level	1	1
	RES 4-2 Indoor Air Pollutants	2	2
	RES 4-3 Waste Disposal	1	1
	RES 4-4 Indoor Air Quality in Wet Areas	2	2
	Category Score for Part 4 – Environmental Quality	6	6
Part 5: Other Green Features			
RES 5-1 Green Features & Innovations	7	7	
	Category Score for Part 5 – Other Green Features	7	7
Part 6: Carbon Emission of Development			
RES 6-1 Carbon Emission of Development	3	3	
	Category Score for Part 6 – Carbon Emission of Development	3	3
GreenRE Score:		160 (Max)	159 (Max)

*Total score will be rounded to the nearest whole number

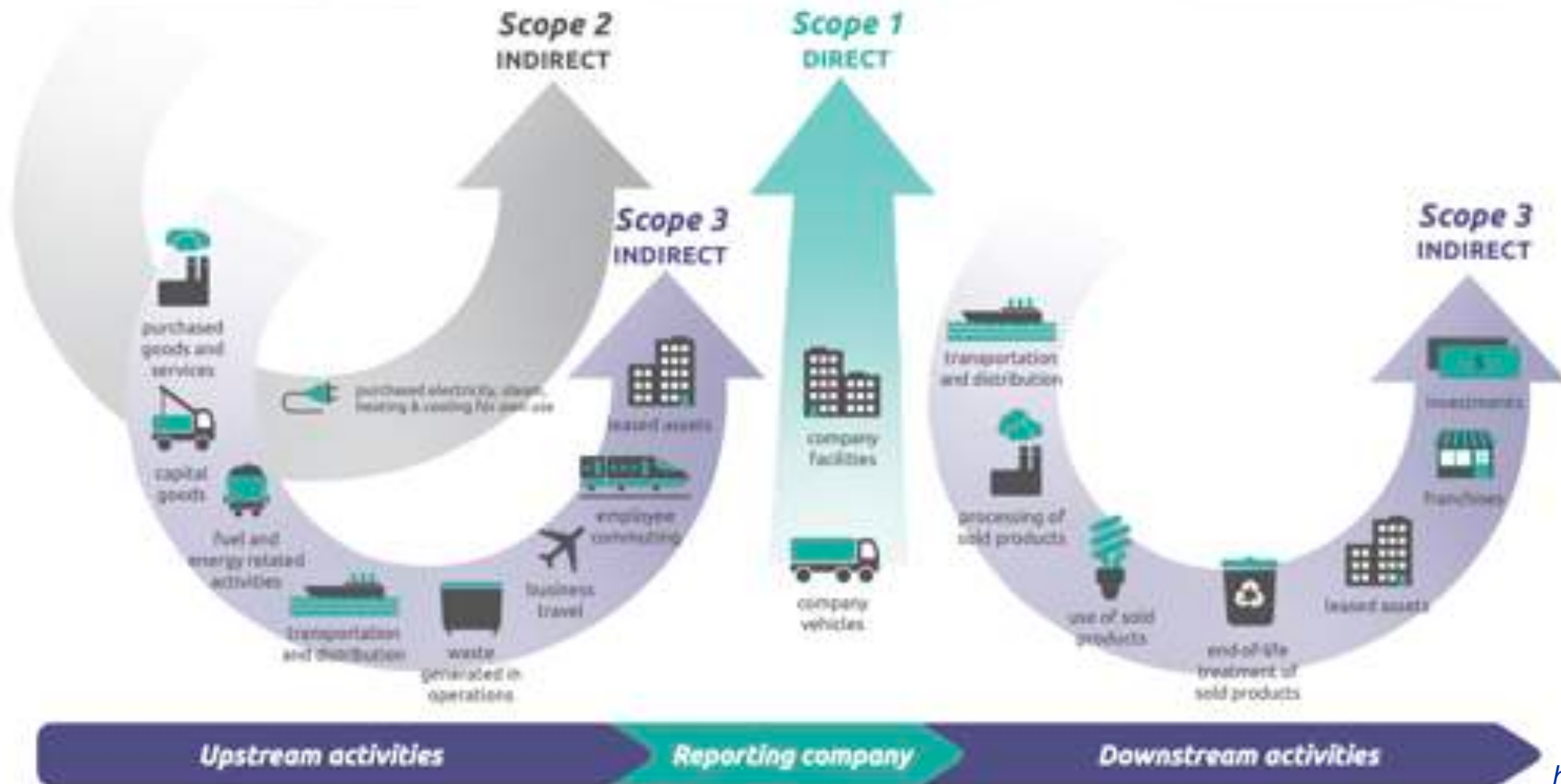
carbon calculation



In 2016,

92%

of Fortune 500
companies used
GHG Protocol
directly or
indirectly through
a program based
on GHG Protocol.





carbon calculation



Calculator example

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Research and analysis

Greenhouse gas reporting: conversion factors 2020

The conversion factors are for use by UK and international
organisations to report on 2020 greenhouse gas emissions.

<https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020>

Scope 1 Direct Emissions (Fuel used)

Business Travel

Person	Type	Distance [return] (km)	Emmission factor (kgCO ₂ e/unit)
Managing Director	Car-petrol	168	0.2095
Operations Manager	Car-petrol	168	0.2095
Quantity Surveyor	Car-petrol	168	0.2095
Project Administrator	Car-diesel	168	0.1987
Environmental Manager	Car-diesel	80	0.1987
Site Manager	4x4 diesel	4	0.2635
Assitant Site Manager	Car-petrol	65	0.2095
Assitant Site Manager	Car-petrol	50	0.2095
Labourer	Motorcycle	20	0.1067

Site visit frequency

M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
2	2	2	2	2	2	2	2	2	2	2	2	1
3	10	10	11	13	10	12	11	12	13	14	13	5
3	12	13	10	12	9	10	12	11	13	12	10	0
1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
15	21	22	23	22	17	23	20	21	22	23	20	10
6	3											
	21	22	22	22	17	23	20	20	21	23	20	8
	21	21	23	22	17	23	18	21	22	22	20	9

Scope 2 (Indirect) (Purchased energy)

Stationary source


	Emmission factor (kgCO ₂ e/unit)
Electricity (kWh)	0.5452
Natural Gas (kWh)	0.1852
LPG (kWh)	0.214
Coal (kWh)	0.322
Generator	2.322

Usage quantity

M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
474	764	809	829	912	1132	953	1021	982	972	921	871	542

carbon calcu

Calculator
example


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Scope 3 (Indirect) (Outsourced activities requiring fuel, energy, etc)

Business Travel			
	Type	Distance [return] (km)	Emmision factor (kgCO2e/unit)
Client 1	Car-petrol	114	0.2095
Client 2	Car-petrol	114	0.2095
QS 1	Car-petrol	110	0.2095
QS 2	Car-petrol	110	0.2095
QS 3	Car-petrol	110	0.2095
CDM	Car-petrol	112	0.2095
H&S Consultant	Car-petrol	105	0.2095
H&S Consultant	Car-petrol	26	0.2095
Strip Out - flooring	VAN-petrol	110	0.2405
Mechanical	VAN-petrol	70	0.2405
Electrical	VAN-petrol	70	0.2405
Suspended Ceilings	VAN-petrol	145	0.2405
Hygienic Wall Cladding	VAN-petrol	55	0.2405
Floor Finishes	VAN-petrol	5	0.2405
Painting and Decorating	VAN-petrol	70	0.2405
FF&E	VAN-petrol	140	0.2405
Mastic Sealant	VAN-petrol	120	0.2405
Joinery	VAN-petrol	75	0.2405
Fire Alarm	VAN-petrol	140	0.2405
Cleaning	VAN-petrol	40	0.2405

Site visit frequency													
M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	
1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	
2	5	6	5	5	4	3	2	2	2	1	1	1	
	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	
5	12	17	18	20	15	21	20	23	21	19	16	10	
10	21	22	21	24	21	24	21	24	22	18	15	7	
10	21	29	26	26	20	25	19	24	21	22	16	10	
4	14	31	28	29	20	23	17	20	17	15	12	4	
4	15	21	19	17	10	13	10	11	12	15	13	6	
5	21	29	28	29	21	24	19	17	16	18	15	8	
5	21	28	27	28	21	28	22	25	21	23	18	10	
	21	29	27	27	19	21	17	19	20	19	15	8	
	10	18	17	16	10	14	12	13	14	16	14	6	
	15	19	18	20	11	17	15	19	17	15	12	7	
	6	8	10	9	4	10	8	9	10	6	5	2	
	12	17	10	10	6	11	9	10	8	9	7	3	

Material Transport (deliveries, suppliers)

	Type	Distance [return] (km)	Emmision factor (kgCO2e/unit)
Cabins	HGV	130	0.8952
Consumables	LGV - diesel	40	0.588
Floor Finishes	LGV - diesel	70	0.588

Site visit frequency													
M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	
2												2	
1	2	5	6	6	4	6	5	5	7	6	5	2	
6	11	16	18	17	10	11	11	13	13	10	9	5	

Project Vehicles

	Type	Distance [return] (km)	Emmision factor (kgCO2e/unit)
Skips	LGV - petrol	50	0.5637
Skips	LGV - petrol	70	0.5637
Recycling	HGV	100	0.8952

Site visit frequency													
M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	
4	10							3	4	3	3	3	
		4	2	2	2	2	3				3	3	
		2				1							



carbon calculation



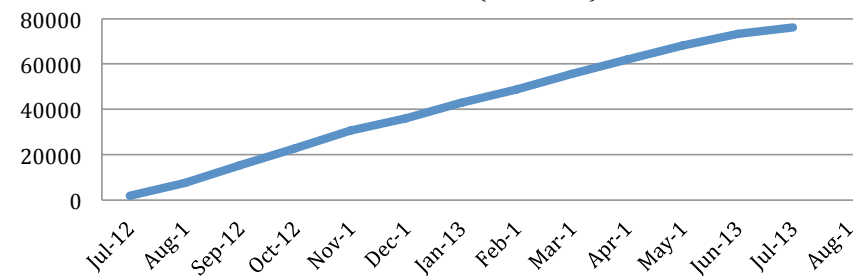
Report & Display
example

CARBON EMISSION REPORT (JULY 2013 [final])

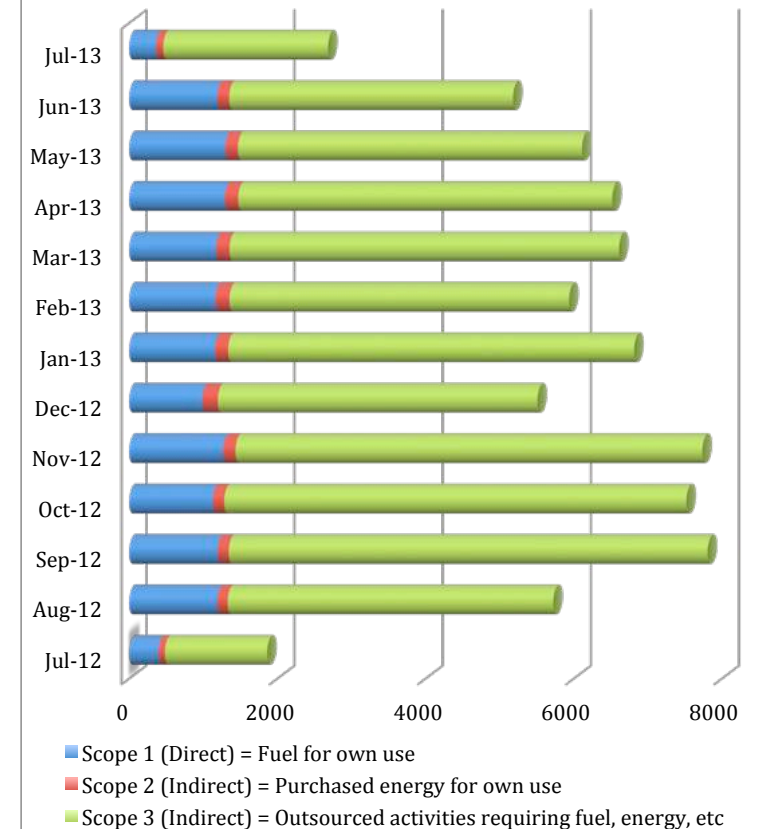
Atlantic Point Carbon footprint : **76,021** kgCO₂e

	Scope 1	Scope 2	Scope 3
Estimated emission	41,853	12,431	162,805
Emission reduction target	33,482	11,188	113,964
Actual emission	13,794	2,071	60,156
<i>Report by month</i>			
Jul-13	359.92	100.38	2223.88
Jun-13	1188.36	161.31	3831.66
May-13	1297.60	170.57	4643.81
Apr-13	1291.50	180.01	5048.90
Mar-13	1172.24	181.87	5257.43
Feb-13	1164.79	189.09	4583.48
Jan-13	1158.95	176.50	5456.30
Dec-12	987.28	209.65	4307.56
Nov-12	1266.77	168.902	6300.60
Oct-12	1129.18	153.531	6238.34
Sep-12	1194.25	149.83	6466.64
Aug-12	1188.38	141.49	4393.60
Jul-12	394.98	87.75	1379.40

Carbon Emission (cumulative)



Carbon Emission (monthly report)





carbon calculation



GREENHOUSE
GAS PROTOCOL

Case study project estimated GHG emission data.

Project	GHG Emission Scope	Organisational KPI Data									
		Distance (kgCO ₂ ^{eq} per km)		Duration (kgCO ₂ ^{eq} per week)		GIFA (kgCO ₂ ^{eq} per m ²)		Rooms (kgCO ₂ ^{eq} per room)		Value (kgCO ₂ ^{eq} per £100k)	
		WLC	RP	WLC	RP	WLC	RP	WLC	RP	WLC	RP
CS-1	Scope 1	133.0	111.6	249.6	209.6	0.8	0.7	37.8	31.7	2.6	2.2
	Scope 2	59.3	46.9	111.3	88.1	0.4	0.3	16.8	13.3	1.1	0.9
	Scope 3	639.4	483.7	1200.5	908.1	3.8	2.8	181.6	137.3	12.3	9.3
	Overall	831.6	642.2	1561.5	1205.8	4.9	3.8	236.1	182.4	16.0	12.4
CS-2	Scope 1	82.1	77.6	242.0	228.8	0.8	0.7	27.9	26.3	3.4	3.2
	Scope 2	12.3	11.2	36.3	33.0	0.1	0.1	4.2	3.8	0.5	0.5
	Scope 3	358.1	330.6	1055.4	992.2	3.4	3.2	121.5	114.3	14.7	13.8
	Overall	452.5	425.5	1333.7	1254.0	4.3	4.0	153.6	144.4	18.5	17.4
CS-3	Scope 1	16.3	12.1	431.3	318.8	0.9	0.6	20.5	15.2	3.7	2.8
	Scope 2	1.1	0.8	28.2	20.8	0.1	0.0	1.3	1.0	0.2	0.2
	Scope 3	78.2	56.5	2063.8	1492.6	4.1	2.9	98.3	71.1	17.8	12.9
	Overall	95.6	69.4	2523.3	1832.1	5.0	3.6	120.2	87.2	21.8	15.8
CS-4	Scope 1	52.1	39.3	1529.6	1151.6	2.4	1.8	53.4	40.2	11.8	8.9
	Scope 2	1.3	1.0	38.5	29.7	0.1	0.1	1.3	1.0	0.3	0.2
	Scope 3	53.3	41.5	1562.3	1216.7	2.4	1.9	54.5	42.4	12.0	9.4
	Overall	106.7	81.8	3130.4	2397.9	4.8	3.7	109.2	83.7	24.1	18.5

WLC: Estimated emissions reflecting the whole lifecycle of the case study projects (kgCO₂^{eq}).

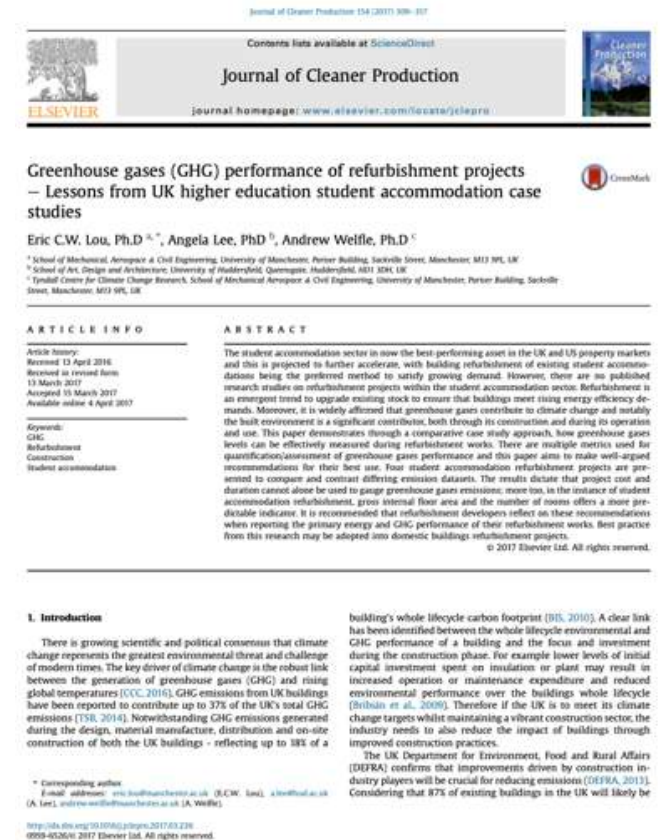
RP: Estimated emissions reflecting the refurbishment phase of the case study project's lifecycles (excluding project start-up and move-out) case study projects GHG levels emissions analysis (kgCO₂^{eq}).

carbon calculation



Positive correlation in GHG performance and its duration, value, gross internal floor area (GIFA) and number of rooms.

Project GIFA was identified as the KPI that provided the most consistent and accurate prediction of the GHG performance of student accommodation refurbishment projects using JCT Design and Build contracts in the UK.

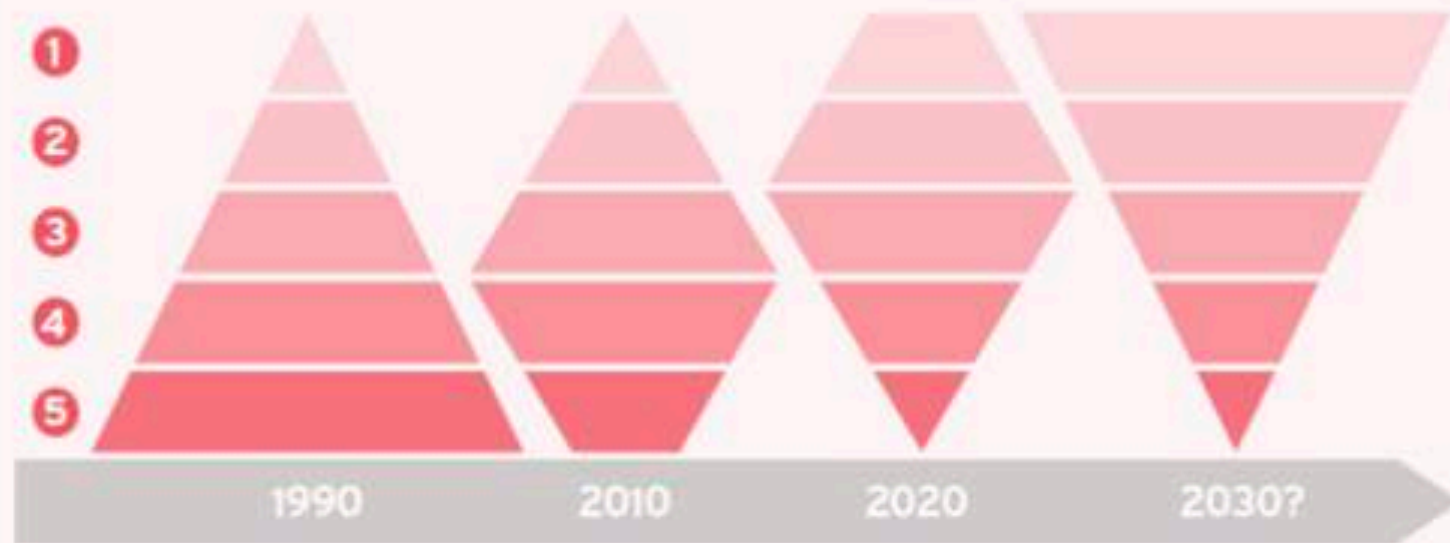


waste



<https://www.constructionleadershipcouncil.co.uk/news/zero-avoidable-waste-report-published-by-the-green-construction-board/>

Evolution of Waste Management Practices: In the past, most waste was dealt with by disposal, but over time that will shift increasingly to recycling, reuse and ultimately prevention.



① Prevention

Using less material in design and manufacture. Keeping products for longer; reuse. Using less hazardous materials.

② Preparing for reuse

Checking, cleaning, repairing, refurbishing, whole items or spare parts.

③ Recycling

Turning waste into a new substance or product. Includes composting if it meets quality protocols.

④ Other recovery

Includes anaerobic digestion, incineration with energy recovery, gasification and pyrolysis which produce energy (fuels, heat and power) and materials from waste; some backfilling.

⑤ Disposal

Landfill and incineration without energy recovery.

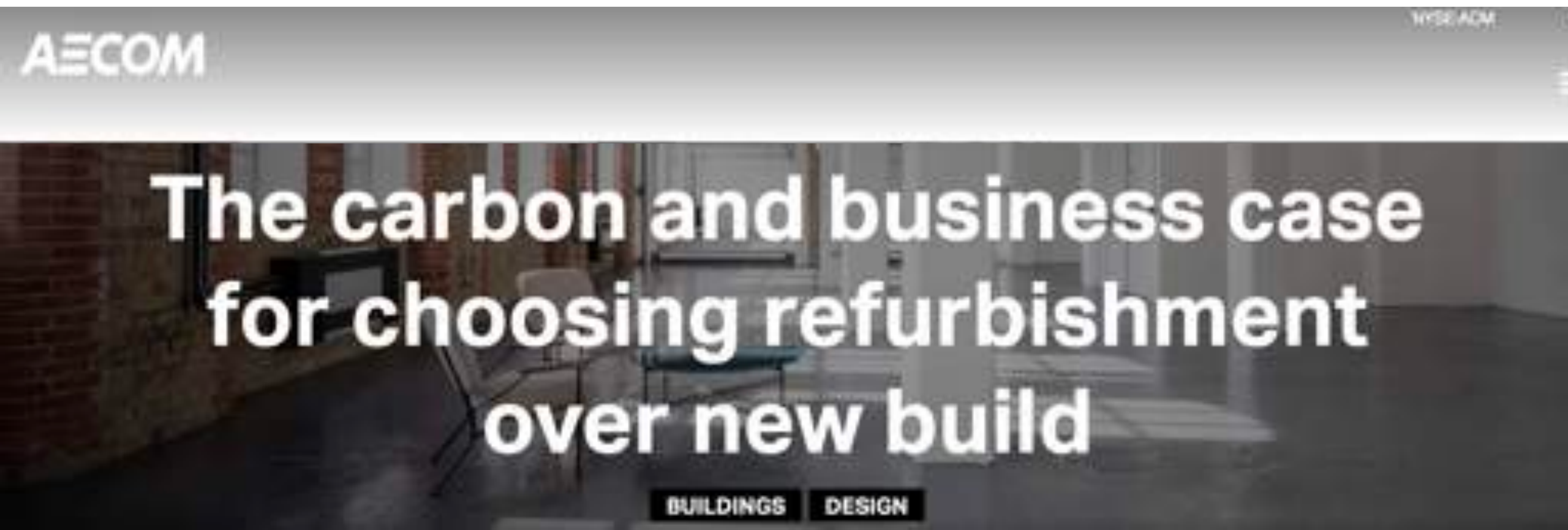


waste



New build vs Refurbishment

<https://aeom.com/without-limits/article/refurbishment-vs-new-build-the-carbon-and-business-case>



waste



waste



1. *Journal of the American Medical Association*, 1997; 277: 1039-1043.

		Diversion of Waste from Landfill (%)				
Waste Resource	Case Study Project A	Case Study Project B	Case Study Project C	Standard Practice	Good Practice	Best Practice
	Project Data	Project Data	Project Data	(WRAP, 2007)	(WRAP, 2007)	(WRAP, 2007)
Bricks	0.84	1	-	0.75	0.85	1
Tiles & Ceramics	0.77	-	0.00	0.75	0.85	1
Glass	-	-	0.00	0.75	0.95	1
Aggregates/Hardcore/Inert	0.82	1	0.00	0.75	0.85	1
Insulation/Fabrics	0.00	-	0.00	0.12	0.5	0.75
Metal	0.84	1	0.00	0.95	1	1
Packaging	0.83	1	0.00	0.6	0.85	0.95
Gypsum/Plasterboard	-	1	0.00	0.3	0.9	0.95
Plastic	0.65	1	0.00	0.6	0.8	0.95
Timber	0.76	1	0.00	0.57	0.9	0.95
Floor Coverings (soft)	0.38	-	-	0.12	0.5	0.75
Electrical & Electronic Equipment	-	1	0.00	0.5	0.7	0.95
Furniture	1	1	0.00	0.1	0.25	0.5
Canteen/Office/Adhoc Waste	-	-	0.78	0.12	0.5	0.75
Other	0.72	0.58	0.00	0.12	0.5	0.75

Proportion of waste diverted to landfill below the WRAP levels for 'standard practice'.

Proportion of waste diverted to landfill achieving WRAP levels for 'standard practice'.

Proportion of waste diverted to landfill achieving WRAP levels for 'good practice'.

Proportion of waste diverted to landfill achieving WRAP levels for 'best practice'.

		Diversion of Waste from Landfill (%)				
Waste Resource	Case Study Project A	Case Study Project B	Case Study Project C	Standard Practice	Good Practice	Best Practice
	Project Data	Project Data	Project Data	(WRAP, 2007)	(WRAP, 2007)	(WRAP, 2007)
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Glass	-	-	0.00	0.75	0.95	1
Aggregates/Hardcore/Inert	0.82	1	0.00	0.75	0.85	1
Insulation/Fabrics	0.00	-	0.00	0.12	0.5	0.75
Metal	0.84	1	0.00	0.95	1	1
Packaging	0.83	1	0.00	0.6	0.85	0.95
Gypsum/Plasterboard	-	1	0.00	0.3	0.9	0.95
Plastic	0.65	1	0.00	0.6	0.8	0.95
Timber	0.76	1	0.00	0.57	0.9	0.95
Floor Coverings (soft)	0.38	-	-	0.12	0.5	0.75
Electrical & Electronic Equipment	-	1	0.00	0.5	0.7	0.95
Furniture	1	1	0.00	0.1	0.25	0.5
Canteen/Office/Adhoc Waste	-	-	0.78	0.12	0.5	0.75
Other	0.72	0.58	0.00	0.12	0.5	0.75

Proportion of waste diverted to landfill below the WRAP levels for 'standard practice'.

Proportion of waste diverted to landfill achieving WRAP levels for 'standard practice'.

Proportion of waste diverted to landfill achieving WRAP levels for 'good practice'.

Proportion of waste diverted to landfill achieving WRAP levels for 'best practice'.



waste calculation

Waste Resource	Case Study Project A					Case Study Project B					Case Study Project C				
	Waste (t)	Waste Management Strategy				Waste (t)	Waste Management Strategy				Waste (t)	Waste Management Strategy			
		RU	RC	RR	D		RU	RC	RR	D		RU	RC	RR	D
Bricks	1.2	-	0.84	-	0.16	3.3	-	1.0	-	-	-	-	-	-	-
Tiles & Ceramics	1.9	-	0.77	-	0.23	-	-	-	-	-	2.9	-	-	-	1.0
Glass	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	1.0
Aggregates/ hardcore/Inert	21.4	-	0.82	-	0.18	1.8	-	1.0	-	-	49.6	-	-	-	1.0
Insulation/Fabrics	7.3	-	-	-	1.0	-	-	-	-	-	0.4	-	-	-	-
Metal	1.7	-	0.84	-	0.16	0.9	-	1.0	-	-	6.1	-	-	-	1.0
Packaging	34.1	-	0.83	-	0.17	0.9	-	1.0	-	-	0.8	-	-	-	1.0
Gypsum/Plasterboard	-	-	-	-	-	0.5	-	1.0	-	-	2.3	-	-	-	1.0
Plastic	9.9	-	0.65	-	0.35	1.0	-	1.0	-	-	1.1	-	-	-	1.0
Timber	26.4	-	0.76	-	0.24	0.01	-	1.0	-	-	11.0	-	-	-	1.0
Floor Coverings (soft)	51.7	-	0.38	-	0.62	-	-	-	-	-	-	-	-	-	-
Electrical & Electronic Equipment	-	-	-	-	-	2.0	-	1.0	-	-	5.0	-	-	-	1.0
Furniture	61.5	0.41	0.59	-	-	19.0	0.47	0.53	-	-	40.0	-	-	-	1.0
Canteen/Office/Adhoc Waste	-	-	-	-	-	-	-	-	-	-	2.9	-	0.78	-	0.22
Other	41.6	-	0.72	-	0.28	0.8	-	0.58	-	0.42	2.3	-	-	-	1.0
Total Waste (t)	258.6	25.9	160.3	-	72.4	30.1	9.0	11.1	-	0.3	124.8	-	2.5	-	122.3

Waste - Total waste (t) generated by project.

RU - Proportion (%) waste reused.

RC - Proportion (%) waste recycled.

RR - Proportion (%) waste recovered.

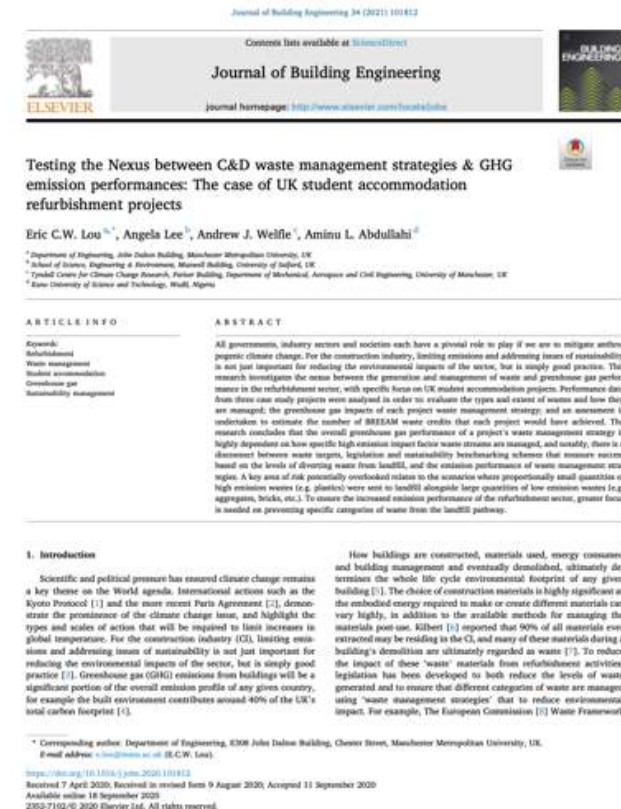
D - Proportion (%) waste disposed through a landfill waste management strategy.



waste calculation

There is a **disconnect** between waste targets, legislation and sustainability benchmarking schemes that measure success based on the levels of diverting waste from landfill, and the emission performance of waste management strategies.

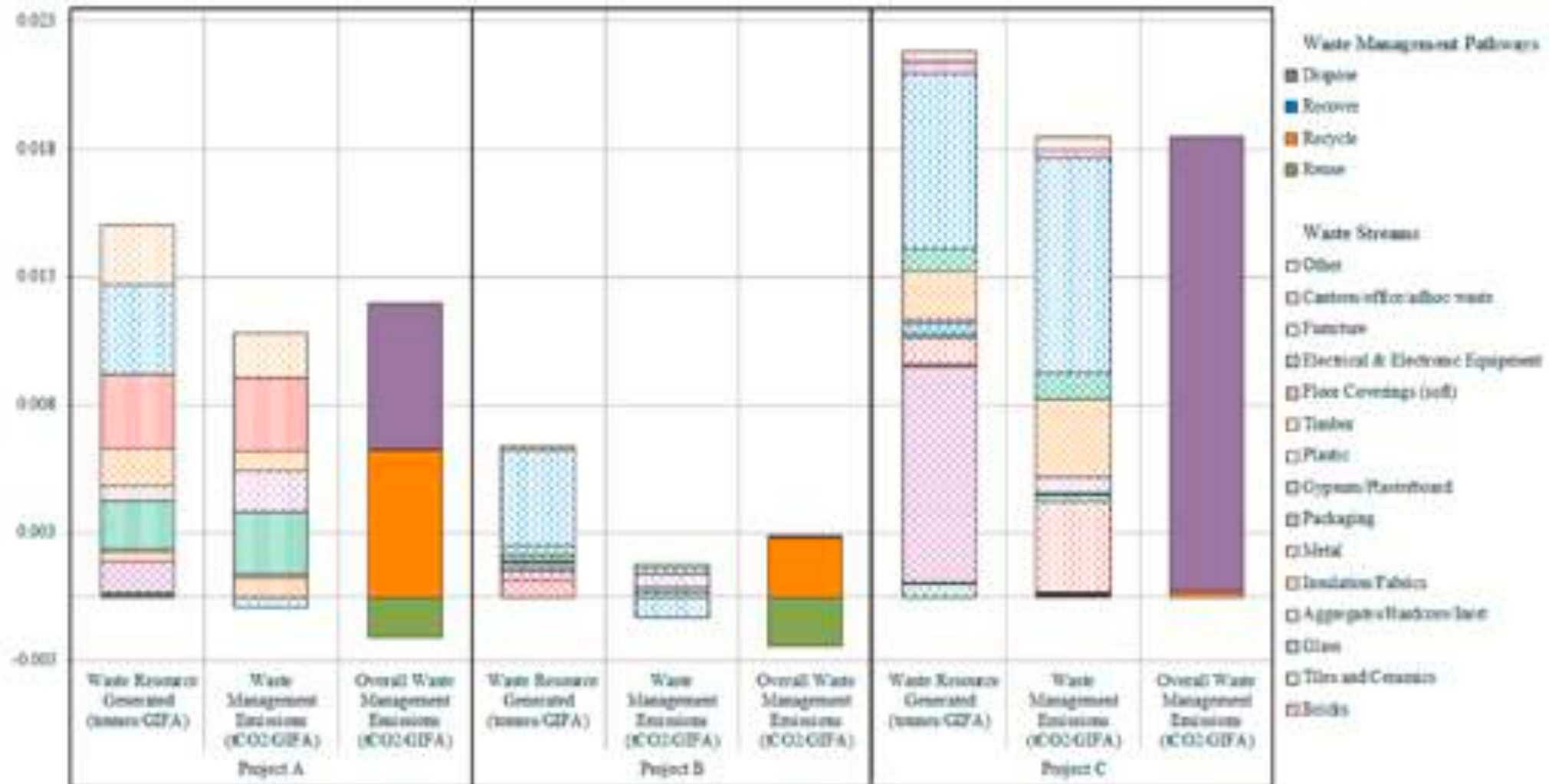
Differentiation in waste management of **reuse, recover and recycle**, which involves a wide degree of effort in reusing existing items, recover as supplementary materials or segregated for recycling.

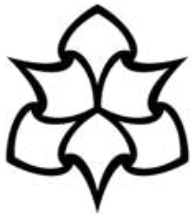


<https://doi.org/10.1016/j.job.2020.101812>



nexus of waste & carbon



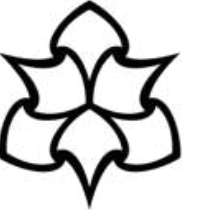


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Calculated project performance for BREEAM credit Wst 01 – project waste management.

Generation of Waste							
BREEAM Credits	Required Performance *	Project Performance					
		Case Study A	Case Study B	Case Study C	Case Study A	Case Study B	Case Study C
		Total Waste Generated (t/100m ² GIFA)			Potential BREEAM Credits Achieved		
1	≤3.5	1.45	0.59	2.13	1	2	1
2	≤1.2						
3	≤0.4						
4	≤0.3						
Diversion of Waste from Landfill							
BREEAM Credits	Required Performance **	Project Performance					
		Case Study A	Case Study B	Case Study C	Case Study A	Case Study B	Case Study C
		Proportion of Waste Diverted from Landfill (%)			Potential BREEAM Credits Achieved		
1	90%	28%	1%	98%	0	2	0
2	97%						



nexus of waste & carbon

- Criteria of BREEAM credits **does not guarantee** a low emission waste management strategy
- Diverting **high emission risk waste** to landfill (*such as plastics*) may offset any benefits gained through reusing and recycling other categories of waste (*such as furniture*)



what's next ?

Moving towards more **digitalisation**
and simulation before moving towards
site activities (Industry 4.0)

Construction 4.0 Strategic Plan
(2021-2025)



Industry 4.0 Facts and Figures



Industry 4.0 could add **\$14.2 trillion** to the global economy **by 2030**



35% of companies adopting Industry 4.0 expect revenue gains in the **next five years**

67%



of UK manufacturers recognise Industry 4.0 as **an opportunity**

The **Made Smarter Review** estimates that the UK industry could achieve **25% increase in productivity** through digital adoption by

2025

Only 25% of manufacturers feel that they have a **sufficient understanding** of Industry 4.0

\$28 billion

The amount of expected **cost reduction** in the automotive sector between 2016 and 2020 due to Industry 4.0



30% increase in productivity could be achieved by the first wave of Internet of Things adopters

3.6%

average cost reduction by 2020



thank you for your time

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