LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

Summary carbon calculation outputs (CL-002-000)

Climate

November 2013

VOL 5

ES 3.5.0.3.2

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Department for Transport

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1 Summary of construction carbon calculation outputs

1.1.1 Table 1, Table 2 and Table 3 summarise the construction footprint of Phase One HS2 for the 'Worst-case', 'Central' and 'Stretch' cases by:

- scope (embedded, transport and labour and plant); and
- design element (viaducts, roads, tunnels etc.).

1.1.2 It should be noted that figures in this and subsequent tables have been rounded. Totals are calculated from the un-rounded data and therefore may not appear to be the sum of the component parts.

Table 1: The Proposed Scheme's construction carbon footprint by scope and element (Worst-case)

Element	Embedded (tCO_2e)	Transport (tCO_2e)	Labour and plant (tCO_2e)	Total (tCO_2e)
Earthworks	0	390,000	200,000	590,000
Construction and demolition waste	0	40,000	0	40,000
Land use, land use change and forestry	100,000	0	0	100,000
Bridges and viaducts	660,000	30,000	220,000	910,000
Roads	150,000	10,000	20,000	170,000
Retaining walls, cuttings and embankments	190,000	10,000	110,000	310,000
Tunnels, portals and dive-unders	1,420,000	80,000	20,000	1,520,000
Tunnel boring machine	30,000	500	250,000	280,000
Stations and depots	570,000	10,000	130,000	710,000
Track	1,170,000	30,000	190,000	1,390,000
Rolling stock	230,000	0	0	230,000
Other	160,000	20,000	30,000	210,000
Total	4,680,000	610,000	1,180,000	6,460,000

Table 2: The Proposed Scheme's construction carbon footprint by scope and element (Central case)

Element	Embedded (tCO_2e)	Transport (tCO_2e)	Labour and plant (tCO_2e)	Total (tCO_2e)
Earthworks	0	390,000	200,000	590,000
Construction and demolition waste	0	40,000	0	40,000
Land use, land use change and forestry	100,000	0	0	100,000
Bridges and viaducts	520,000	30,000	180,000	730,000

Element	Embedded (tCO2e)	Transport (tCO2e)	Labour and plant (tCO2e)	Total (tCO2e)
Roads	100,000	10,000	10,000	120,000
Retaining walls, cuttings and embankments	140,000	10,000	90,000	240,000
Tunnels, portals and dive-unders	1,170,000	80,000	10,000	1,260,000
Tunnel boring machine	30,000	500	250,000	280,000
Stations and depots	520,000	10,000	120,000	650,000
Track	970,000	30,000	160,000	1,160,000
Rolling stock	230,000	0	0	230,000
Other	140,000	20,000	20,000	190,000
Total	3,920,000	610,000	1,060,000	5,590,000

Table 3: The Proposed Scheme's construction carbon footprint by scope and element (Stretch case)

Element	Embedded (tCO2e)	Transport (tCO2e)	Labour and plant (tCO2e)	Total (tCO2e)
Earthworks	0	390,000	200,000	590,000
Construction and demolition waste	0	40,000	0	40,000
Land use, land use change and forestry	100,000	0	0	100,000
Bridges and viaducts	480,000	30,000	170,000	670,000
Roads	90,000	10,000	10,000	110,000
Retaining walls, cuttings and embankments	130,000	10,000	80,000	220,000
Tunnels, portals and dive-unders	1,080,000	80,000	10,000	1,170,000
Tunnel boring machine	30,000	500	250,000	280,000
Stations and depots	510,000	10,000	120,000	640,000
Track	880,000	30,000	150,000	1,060,000
Rolling stock	230,000	0	0	230,000
Other	130,000	20,000	20,000	180,000
Total	3,670,000	610,000	1,020,000	5,300,000

2 Summary of operation carbon calculation outputs

2.1.1 Table 4 summarises the operational footprint of HS2 Phase One by:

- 'Scenario A' and 'Scenario B'[1]; and
- operational aspect (train operation, train maintenance, station operation, tunnel fans, tree planting, mode shift and released capacity for freight).

Table 4: The Proposed Scheme's operational carbon footprint by scenario and operational aspect

	Scenario A (tCO2e)	**Scenario B (tCO2e)**
Train operation	1,980,000	1,040,000
Train maintenance	290,000	280,000
Station operation	530,000	420,000
Tunnel fans	5,000	3,000
Tree planting	-500,000	-500,000
Mode shift[2]	-3,200,000	-2,340,000
Freight uptake of released capacity	-2,070,000	-2,070,000
Total	-2,970,000	-3,160,000

[1] Scenario A uses many of the same assumptions that are used by, and reflected in, the Economic Case for HS2. It is based on grid emission factors and electric car penetration projections from DECC/IAG and WebTAG; Scenario B is based on grid emission factor and electric car penetration projections from the CoCC.

[2] The surface access component of the mode shift operation footprint is 372,000 tCO_2e for Scenario A and 74,000 tCO_2e for Scenario B.

3 Carbon calculation inputs

3.1.1 Figure 1 presents the projection of how the carbon intensity of electricity is predicted to reduce in the future based on the Committee on Climate Change (CoCC) Fourth Carbon Budget[3] and DECC/IAG[4] data.

Figure 2 shows the projected CO2e emissions for the production of steel in the European Union (EU) based on data from Eurofer, The European Steel Association[5].

[3] Committee on Climate Change (2010), *The Fourth Carbon Budget: Reducing Emissions through the 2020s*.
[4] Department for Transport (2013), *WebTAG unit 3.3.5, Transport Analysis Guidance*, http://www.dft.gov.uk/webtag/; Accessed 1 October 2013.
[5] Eurofer The European Steel Association (2013), *A Steel Roadmap for a Low Carbon Europe 2050.*

3.1.2 Figure 3 shows the projected CO_2 emissions for the production of concrete in the UK based on data from MPA, The Concrete Centre[6].

3.1.3 Figure 4 details the electric vehicle penetration rate based on the Committee on Climate Change Fourth Carbon Budget and percentage of electric car and light goods vehicle (LGV) vehicle kilometres based on DECC/IAG guidance[7].

[6] MPA The Concrete Centre, (2012) *Concrete Industry Sustainability Performance Report 5th report: 2011 performance data.*
[7] Department for Transport (2012), *WebTAG unit 3.5.6, Transport Analysis Guidance*; http://www.dft.gov.uk/webtag/; Accessed 1 October 2013.

Figure 1: Electricity grid decarbonisation factors applied from DECC/IAG and the Committee on Climate change

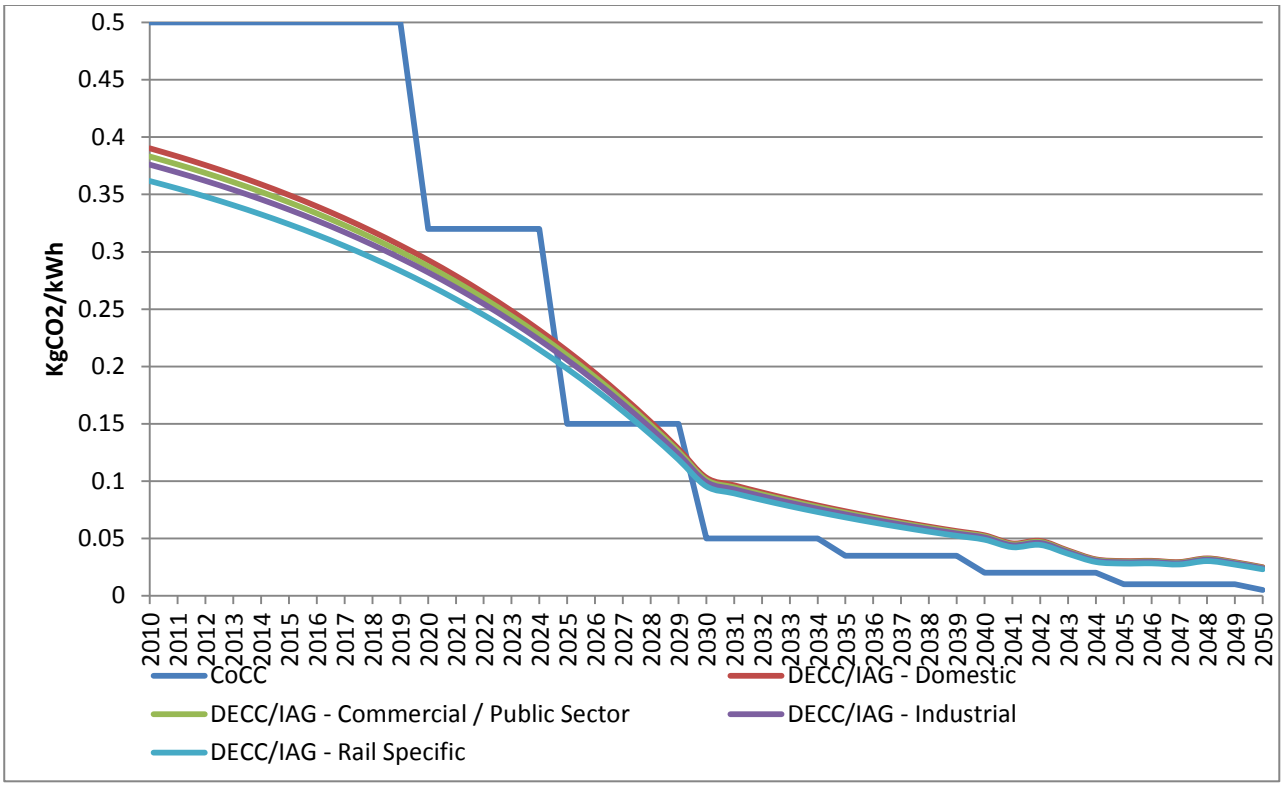


Figure 2: Projected CO_2e emissions for the production of steel in the EU

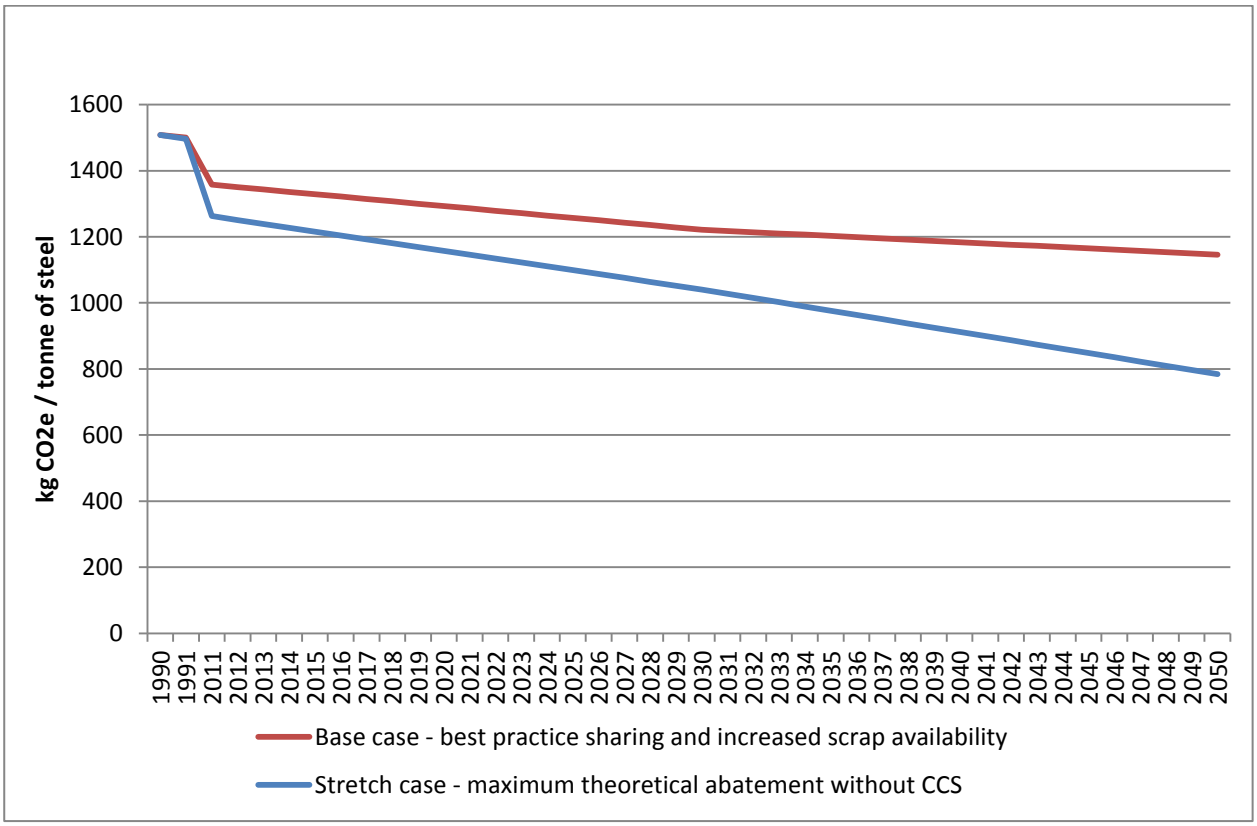


Figure 3: Projected CO_2 emissions for the production of concrete in the UK

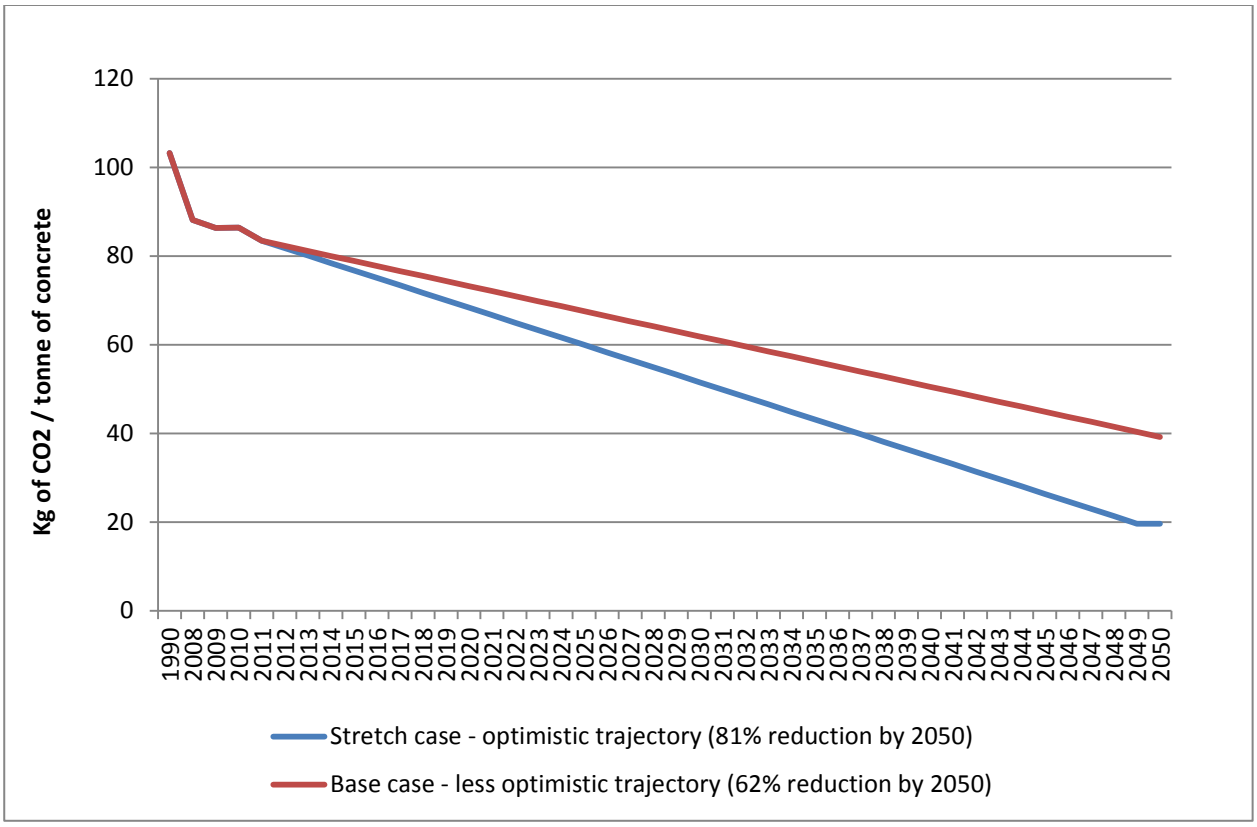
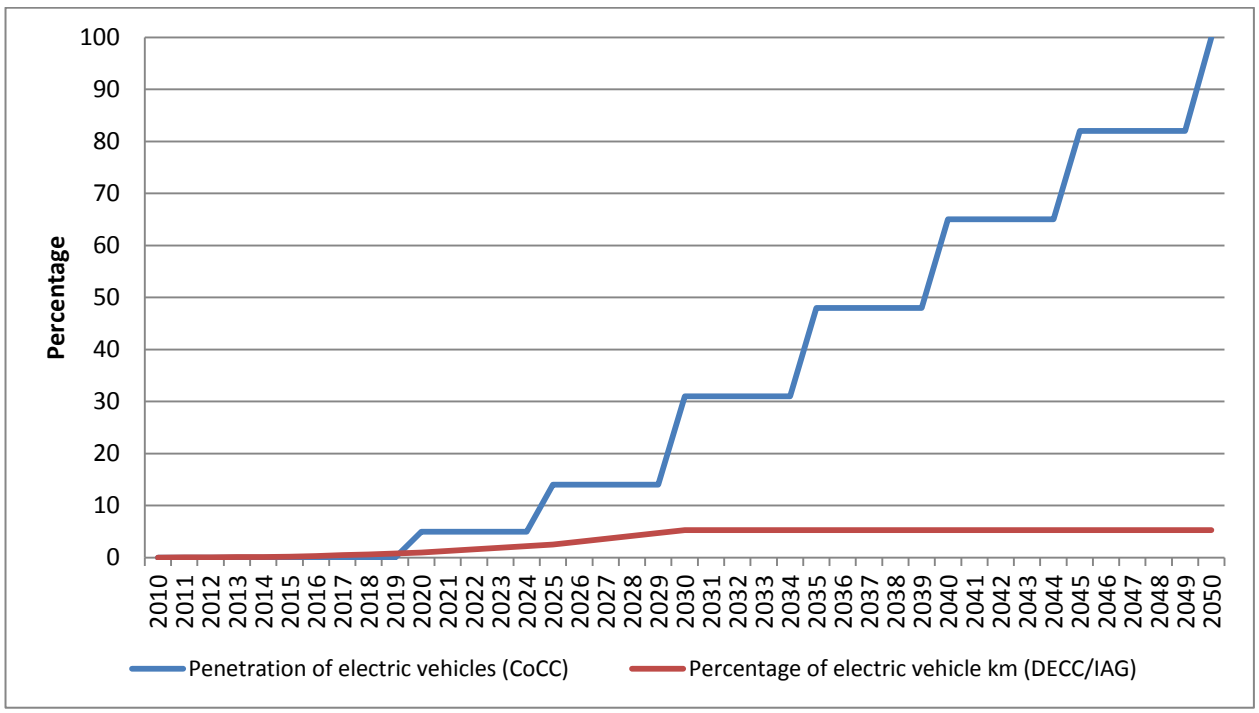


Figure 4: Electric vehicle penetration and percentage of electric vehicle kilometres



4 Carbon conversion factors and assumptions

4.1.1 Table 5: lists all the carbon conversion factors used for the assessment. Carbon conversion factors convert a unit of either material (i.e. tonnes of steel) or distance travelled (km by car) into the associated carbon emissions (tCO2e) for this activity.

4.1.2 Table 6 summarises other related assumptions, such as assumed densities of construction materials (tonnes per cubic metre of concrete) or the types of modes used by construction workers in their commute to site.

4.1.3 Table 7 summarises the key underlying assumptions made throughout the carbon assessment. These range from train speeds, to number of working days for construction workers, down to the type of vehicles used.

4.1.4 Table 8 summarises the known data gaps and extent of missing data associated with key construction elements for which a carbon footprint could not be effectively calculated.

Table 5: Carbon factors applied by aspect of the assessment and material

Aspect	**Material**	**Unit**	**Emission factor**		**Detail**	Source
			kgCO2/unit	**kgCO2e/unit**		
Construction materials	Concrete (2013 no change)	kg		0.110	Concrete, normal, at plant/CH U (262.7251kgCO2e/m3, density 2380kg/m3)	SimaPro 7.3.3 software
Construction materials	Concrete (2020 Central)	kg	0.073			MPA The Concrete Centre, (2012)
Construction materials	Concrete (2020 Stretching)	kg	0.068			MPA The Concrete Centre, (2012)
Construction materials	Steel (2013 no change)	kg		1.460	Reinforcing steel, at plant/RER U	SimaPro 7.3.3 software
Construction materials	Steel (2020 Central)	kg		1.293		Eurofer The European Steel Association, (2013)
Construction materials	Steel (2020 Stretching)	kg		1.157		Eurofer The European Steel Association, (2013)
Construction materials	Concrete with reinforcement (2013 No change)	kg		0.107	Concrete (reinforced) I	SimaPro 7.3.3 software
Construction materials	Concrete with reinforcement (2020 Central)	kg	0.081			MPA The Concrete Centre, (2012)
Construction materials	Concrete with reinforcement (2020 Stretching)	kg	0.075			MPA The Concrete Centre, (2012)
Construction materials	Aggregate (road stone) (fine)	kg		0.004	Gravel, crushed, at mine/CH U	SimaPro 7.3.3 software
Construction materials	Cement	kg		0.762	Cement, unspecified, at plant/CH U	SimaPro 7.3.3 software
Construction	Cement mortar (grout)	kg		0.190	Cement mortar, at plant/CH U	SimaPro 7.3.3 software

Aspect	Material	Unit	Emission factor		Detail	Source
			kgCO2/unit	kgCO2e/unit		
materials						
Construction materials	Timber	kg		0.110	Sawn timber, hardwood, raw, kiln dried, u=10%, at plant/RER U	SimaPro 7.3.3 software
Construction materials	Asphalt	kg		0.066	Hot rolled asphalt , asphalt, 4% (bitumen binder content (by mass) data - 1.68MJ/kg feedstock energy (included)	University of Bath, (2011)
Construction materials	Sand	kg		0.002	Sand, at mine/CH U	SimaPro 7.3.3 software
Construction materials	Clay (bentonite)	kg		0.240	General simple baked clay products (including terracotta and bricks)	University of Bath, (2011)
Construction materials	Glass (fibre)	kg		1.495	Glass wool mat, at plant/CH U	SimaPro 7.3.3 software
Construction materials	Rubber (gaskets)	kg		2.675	Synthetic rubber, at plant/RER U	SimaPro 7.3.3 software
Rolling stock	Aluminium	kg		9.160	General aluminium - typical (assumed a UK ratio of 25.6% extrusions, 55.7% rolled and 18.7% castings and a worldwide recycled content of 33%.	University of Bath, (2011)
Rolling stock	Steel (rolling stock)	kg		1.950	General steel - world typical - world 39% recycled content	University of Bath, (2011)
Rolling stock	High density polyethylene (HDPE)	kg		1.930		University of Bath, (2011)
Rolling stock	Copper	kg		2.170	Tube and sheet - typical - EU production data, estimated from Kupfer Institut LCI data. 37% recycled content (the 3 year world average).	University of Bath, (2011)
Rolling stock	Iron	kg		2.030	(Virgin) Iron - statistical average	University of Bath, (2011)
Rolling stock	Glass	kg		1.350	Toughened glass	University of Bath,

Aspect	Material	Unit	Emission factor		Detail	Source
			kgCO2/unit	kgCO2e/unit		
						(2011)
Rolling stock - maintenance and cleaning	Water	m3		0.344	Water supply	Defra DECC, (2013)
Rolling stock - maintenance and cleaning	Waste water	m3		0.709	Water treatment	Defra DECC, (2013)
Rolling stock - maintenance and cleaning	Waste transport (rigid >17t truck average laden)	tonne.km		0.233	Including well to tank (WTT)	Defra DECC, (2013)
Rolling stock - maintenance and cleaning	Heating (Gas oil - energy - net CV)	kWh		0.346	Including WTT	Defra DECC, (2013)
Material transport	Heavy goods vehicle (HGV) (all diesel) (all HGV)	tonne.km		0.150	Including WTT	Defra DECC, (2013)
Material transport	Artic >33t 100% laden	tonne.km		0.075	Including WTT	Defra DECC, (2013)
Material transport	Artic >33t average laden	tonne.km		0.103	Including WTT	Defra DECC, (2013)
Material transport	Rail (freight train)	tonne.km		0.033	Including WTT	Defra DECC, (2013)
Waste emissions from landfill	Landfill - inert waste, 5% water	kg		0.007	The factor for disposal, inert waste, 5% water, to inert material landfill	SimaPro 7.3.3 software
Movements of excavated material	Diesel (average biofuel blend)	l		3.178	Including WTT	Defra DECC, (2013)
Movements of excavated material	Rigid (>17 tonnes) 0% laden	km		0.958	Including WTT	Defra DECC, (2013)
Movements of	Rigid (>17 tonnes) 100% laden	km		1.373	Including WTT	Defra DECC, (2013)

Aspect	Material	Unit	Emission factor		Detail	Source
			kgCO2/unit	kgCO2e/unit		
excavated material						
Movements of excavated material	Artic >33t 0% laden	km		0.859	Including WTT	Defra DECC, (2013)
Movements of excavated material	Artic >33t 100% laden	km		1.424	Including WTT	Defra DECC, (2013)
Movements of excavated material	Artic >33t 100% average laden	km		1.209	Including WTT	Defra DECC, (2013)
Tunnel boring machine	Grease and hydraulic oil	kg		1.071	Lubricating oil at plant/RER U	SimaPro 7.3.3 software
Tunnel boring machine	Paint	kg		2.540	'Waterborne' value applied due to 70% market share. Includes energy feedstock.	University of Bath, (2011)
Released capacity for freight	Gas oil	l		3.512	Including WTT	Defra DECC, (2013)
	Gas oil	l		2.783		WebTAG Unit, (2013)
Route-wide track	Rails	kg		As per steel factors presented above	Double-headed conventional track	
Route-wide track	Sleeper	kg	0.214		Standard sleeper (Cemex). The factor excludes sleeper transport to final destination from Washwood Heath.	Cemex UK Operations
Route-wide track	Sleeper	kg	0.189		Green sleeper (Cemex). The factor excludes sleeper transport to final destination from Washwood Heath.	Cemex UK Operations
Route-wide track	Fastenings	kg		As per steel factors presented above		
Route-wide track	Baseplates	kg		As per steel factors presented above		

Aspect	**Material**	**Unit**	**Emission factor**		**Detail**	Source
			kgCO2/unit	**kgCO2e/unit**		
Route-wide track	Polyurethane, flexible foam, at plant/RER U	kg		4.758	Flexible foam, at plant/RER U	SimaPro 7.3.3 software
Worker commute	Car commuting	day		5.150	25km return journey by car (park and ride, 75% car and 25% bus)	Defra DECC, (2013)
Worker commute	Public transport commuting (50% rail; 50% bus)	day		2.411	25km return journey by public transport (50% rail:50% bus)	Defra DECC, (2013)

Table 6: Assumptions associated with materials densities, worker commuting and transport distances

Aspect	Name	Unit	Factor	Detail	Source
Material densities	Sand (soft sand and Gravel)	kg/m3	2240		University of Bath, (2011)
Material densities	Sand (sharp sand and gravel)	kg/m3	2240		University of Bath, (2011)
Material densities	Asphalt pavement	kg/m3	2000	Density range 1700-2300 kg/m3, average used	University of Bath, (2011)
Material densities	Concrete cast (compacted)	kg/m3	2380	Concrete, normal, at plant/CH U	SimaPro 7.3.3 software
Material densities	Aggregate	kg/m3	2240		University of Bath, (2011)
Material densities	Timber	kg/m3	720		University of Bath, (2011)
Material densities	Steel	kg/m3	7800		University of Bath, (2011)
Material densities	Neoprene gasket	kg/m3	1500		University of Bath, (2011)
Material densities	Polyurethane	kg/m3	30		University of Bath, (2011)
Material densities	Glass (soda-lime)	kg/m3	2500		University of Bath, (2011)
Material transport	Trip transport distance of DRY construction materials to site include 10% uplift	km	55		
Material transport	Round trip transport distance of WET materials to site	km	100		

Aspect	Name	Unit	Factor	Detail	Source
Material transport	Transport distance from site of waste to be reused	km	50		
Material transport	Transport distance from site of waste to be landfilled	km	100		
Plant and worker travel emissions based on known material footprint	Underbridge embedded carbon			82% materials, 11% transport, 7% plant and workers travel	ARUP CO2ST tool
Plant and worker travel emissions based on known material footprint	Viaduct embedded carbon			67% materials, 5% transport, 27% plant and workers travel	ARUP CO2ST tool
Plant and worker travel emissions based on known material footprint	Highway bridge embedded carbon			82% materials, 11% transport, 7% plant and workers travel	ARUP CO2ST tool
Plant and worker travel emissions based on known material footprint	Accommodation bridge embedded carbon			82% materials, 11% transport, 7% plant and workers travel	ARUP CO2ST tool
Plant and worker travel emissions based on known material footprint	Maintenance access bridge embedded carbon			82% materials, 11% transport, 7% plant and workers travel	ARUP CO2ST tool
Plant and worker travel emissions based on known material footprint	Replacement bridge embedded carbon			82% materials, 11% transport, 7% plant and workers travel	ARUP CO2ST tool
Plant and worker travel emissions based on known material footprint	Dual carriageway road embedded carbon			79% materials, 10% transport, 11% plant and workers travel	ARUP CO2ST tool
Plant and worker travel emissions based on known material footprint	Single carriageway road embedded carbon			79% materials, 10% transport, 11% plant and workers travel	ARUP CO2ST tool
Plant and worker travel emissions based on known material footprint	Cuttings emissions (0.5m deep)			20% materials, 8% transport, 72% plant and workers travel	ARUP CO2ST tool

Aspect	Name	Unit	Factor	Detail	Source
Plant and worker travel emissions based on known material footprint	Cuttings emissions (0.7m deep)			20% materials, 8% transport, 72% plant and workers travel	ARUP CO2ST tool
Plant and worker travel emissions based on known material footprint	Retaining walls embedded carbon			85% material, 7% transport, 8% plant and workers travel	ARUP CO2ST tool

Table 7: Underlying assumptions by sector and area

Sector	Assumptions
Construction	In the absence of data construction site plant and workers' commuting emissions are calculated based on the relative proportion of construction plant and commuter emissions to materials/transport emissions from the ARUP CO2ST tool.
Construction	In the absence of data for drainage pipe, pre-cast parapets and pre-cast beams an uplift factor of 2.5% has been applied to the total embodied, and transport emissions for those sections of the route where these elements are included.
Construction	In the absence of data, timber formwork is assumed to be 30mm thick.
Construction	Embodied emissions from railway equipment (energy and telecommunication) are based on data from T. Baron, M. Tuchschmid, G. Martinetti and D. Pépion (2011), High Speed Rail and Sustainability. Background Report: Methodology and results of carbon footprint analysis, International Union of Railways (UIC), Paris8.
Construction	In the absence of data for plant, labour and commuting emissions for route wide track construction, emissions are assumed to equal 15% of the total embedded emissions.
Construction	Slab track component lifespan (years). All components are replaced at these intervals. • Concrete - 60 • Rails - 12.5 • Baseplates - 25 • Fastenings - 25
Maintenance	Maintenance and renewal of Network Rail assets associated with HS2 operation will be undertaken by Network Rail.

[8] T. Baron, M. Tuchschmid, G. Martinetti and D. Pépion (2011), *High Speed Rail and Sustainability Background Report: Methodology and results of carbon footprint analysis, International Union of Railways* (UIC), Paris.

Sector	Assumptions
Employees	In the absence of data 233 working days/year based on 5 day week and statutory holidays.
Euston station	In the absence of data retaining walls (contiguous piled) assumed to be cast in place with a 1.2m diameter double wall with a gap and an average depth of 10m.
Euston station	In the absence of data barrette walls assumed to be 4.5m by 1.2m wide with an average depth of 15m.
Euston station	In the absence of data station platforms assumed to be 300mm thick concrete.
Euston station	In the absence of data station concourses, entrances and passageways are all 400mm thick concrete slabs.
Euston station	Due to an absence of detailed design data for Euston station an uplift factor of 2 was applied to the carbon footprint of the known elements.
Euston station	In the absence of data station ticket offices are constructed from concrete.
Euston station	In the absence of data tunnel concrete slabs assumed to be 1m thick with steel reinforcement.
Euston station	Proposed Scheme platforms: • 5 international island platforms (440m long, 10.4m wide) • 2 international side platforms (440m long, 6m wide) • 5 reduced width shaved platform ends (70m long, 3m wide) No changes to classic train platforms.
Carbon factors	Although the design life of the proposed scheme is 120 years, it is noted that the non-carbon GHG emission factors used (sourced from the Intergovernmental Panel on Climate Change second assessment report) are based on a 100 year time horizon. Whilst the IPPC GHG emission factors are generally accepted as 'best practice' and are widely used for this kind of assessment, their use in the context of the current project results in an inconsistent scope of reporting between the stated objective of the assessment and the emissions factors used. GHG emission factors with a longer duration time horizon are not widely available and the impact of this inconsistency is considered unlikely to be significant.

Sector	Assumptions
Land use change	Embedded carbon in land-use by type • Urban - 0 tCO_2/ha • Neutral grassland - 60 tCO_2/ha • Arable and Horticulture - 45 tCO_2/ha • Coniferous Woodland - 75 tCO_2/ha • Fen Marsh and Swamps - 75 tCO_2/ha • Mixed Broadleaved and Woodlands - 65 tCO_2/ha • Dwarf Shrub Heath - 85 tCO_2/ha • In absence of other data land use change will occur 200m to the right and left of the line.
Operation	2,000,000 trees will be planted. Trees are a mixed of native woodland as defined by the Woodland Carbon Code[9]. All trees are assumed to be planted in 2017.
Rolling stock	• Maximum speed of 330/360 km/hr • Train lengths of 200m and 400m • Energy consumption: o 24.65 kWh/km for the 200m trains and 47.32kWh/km for the 400m trains moving on the HS2 network; and o 15.27 kWh/km for the 200m train moving on the classic network. • Train movements: o 200m trains: Weekdays and Saturdays - 290 movements per day; Sundays - 286 movements per day; and o 400m trains: Weekdays and Saturdays - 40 movements per day; Sundays - 0 movements per day
Station operation	• Old Oak Common – the station is in operation 19 hours per day; assumed a power factor of 0.9 and a diversity factor of 0.7. • Euston station - 320kWh/m2/yr for electricity and 64 kWh/m2/yr for gas. • Curzon Street – all areas of the station (concourse, commercial space, WC etc.) consume both electricity and gas. Curzon Street consumes the same amount of energy as Euston station per sq.m of floor space.
Transport	In the absence of data 80% of all temporary steel structures will be recycled; 20% will be re-used. It is assumed that all temporary steel structures will be transported 50km from site for either reuse or recycling.
Transport	In the absence of data 25% of the haul road/platform granular fill waste will be transported 50km for reuse.

[9] The Forestry Commission (July 2012), *Woodland Carbon CO2de Version 1.4 27.*

Sector	Assumptions
Transport	In the absence of data all 'dry' construction materials to site are transported over a distance of 110km (this includes a 10% uplift factor to account for the additional transport distance the delivery lorry would be required to travel to collect another load).
Transport	• Proportion of petrol, diesel and electric vehicle km from Department for Transport, (2012), WebTAG unit 3.5.6 Transport Analysis Guidance 10, and penetration rates of electric vehicles from Committee on Climate Change, (2010), The Fourth Carbon Budget: Reducing Emissions through the 2020s. For the purposes of the assessment proportion of electric vehicle km corresponds directly to the penetration rate of electric vehicles. • Emissions factors for grid electricity (domestic) for charging electric vehicles from Department for Transport (2013) WebTAG unit 3.3.5, Transport Analysis Guidance11, and Committee on Climate Change, (2010), The Fourth Carbon Budget: Reducing Emissions through the 2020s. • Emission factors for petrol and diesel vehicles from Department for Transport (2013) WebTAG unit 3.3.5, Transport Analysis Guidance, and Committee on Climate Change, (2020), The Fourth Carbon Budget: Reducing Emissions through the 2020s • Emissions factors for grid electricity (rail specific) to operate the electric train sets from - Department for Transport (2013) WebTAG unit 3.3.5, Transport Analysis Guidance, and Committee on Climate Change, (2010), The Fourth Carbon Budget: Reducing Emissions through the 2020s
Transport	• Movements of excavated material transportation emissions based on: o CAT 740 – 17m3 payload, 50 litres of diesel per hour. o Road wagon – 8.5 m3 payload, 34 litres of diesel per hour. o Rail – 740 m3 payload, 360 litres of diesel per hour.
Transport	In the absence of data for worker commuting: • Commuting by Car - 25km return journey by car (park and ride, 75% car and 25% bus). • Commuting by public transport - 25km return journey by public transport (50% rail:50% bus).
Transport	Waste from site for reuse is transported 50km.
Transport	Waste from site to landfill is transported 100km.
Transport	For transport of liquid construction materials, such as concrete, where a laden return/onward journey is not possible, the total transport distance assumed to be 100km (50km to site and 50km return journey).

[10] Department for Transport, (2012), *WebTAG unit 3.5.6, Transport Analysis Guidance*, http://www.dft.gov.uk/webtag/ Accessed on 1st October 2013.
[11] Department for Transport (2013) *WebTAG unit 3.3.5, Transport Analysis Guidance*, http://www.dft.gov.uk/webtag/ Accessed on 1st October 2013.

Sector	Assumptions
Transport	• Up to 20 paths per day are released for use by freight trains. The 20 trains per day is increased linearly from 2 in year 2026 to 20 in 2035 from which point there are 20 freed up paths per day to 2085 • Each freight train carries 36 containers and each HGV carries 1 container • Each container weights 20 tonnes • Rail freight and road haulage is for 300 days per year • Emissions saving are calculated based on a the same distance travelled for both HGVs and trains, i.e. 124km which represents a trip from Wembley to Rugby via Northampton
Transport	Passenger km carbon factors for air travel are based on Department for Transport, (2013), UK Aviation Forecasts12; for London airports to 2050. Due to the lack of any other information beyond 2050 the passenger km carbon factor for 2050 is projected forward unchanged to 2086. The emissions associated with aviation include an uplift factor for radiative forcing, otherwise known as the other non-CO_2 climate change effects of aviation – water vapour, contrails, NOx etc. This approach is consistent with Defra DECC, (2013), UK Government conversion factors for company reporting.
Tunnel fans	Tunnel fans operate 2hrs a week to ensure their effective operation. Emissions factors for grid electricity (industrial) for fan operation from Department for Transport (2013) WebTAG unit 3.3.5, and Committee on Climate Change, (2010), The Fourth Carbon Budget: Reducing Emissions through the 2020s.
Tunnels	In absence of data tunnel gasket material volume is based on the cross section of "Type Tokyo Route 12, M 385 41a groove 26*10mm". Top Width 26mm; Bottom Width 32mm; Total Height 20mm; 50% void space.
Tunnels	• Tunnel Boring Macine (TBM) tunnels are Euston, Northolt corridor, HS1 Link, Chilterns, Long Ichington Wood and Bromford • Euston and HS1 link tunnel TBM progress is 100m/week, and all others tunnels TBM progress is 80m/week • TBM operates 24hrs/day 7 days/week with a utilisation factor of 80%. TBM Apparent power (MVA) is 4.5. TBM Power factor is 0.98. • Emissions factors for grid electricity (industrial) to manufacture and power the TBM from Department for Transport (2013) WebTAG unit 3.3.5, Transport Analysis Guidance, and Committee on Climate Change, (2010), The Fourth Carbon Budget: Reducing Emissions through the 2020s
Waste	In the absence of data the following waste assumptions were applied: • Concrete - 2.5% of bulk material • Roadstone - 25% of bulk material removed from site for recycling • Timber - 5% of bulk material • Demolition - 90% recycled • Grout - 0.05% of bulk material
Waste	90% of construction waste is reused based on HS2 Ltd. Waste Forecast and Assessment Methodology.

[12] Department for Transport, (2013), *UK Aviation Forecasts*; https://www.gov.uk/government/publications/uk-aviation-forecasts-2013; Accessed 1 October 2013.

Sector	Assumptions
Waste	In the absence of data 2.5% of construction material is assumed to be sent to landfill.
Road alternative	Construction: • Highway o 214 km long o 3.6m per lane o 3m for central reservation o 6m for hard sholder o Dual highway (assuming 6 lanes in total) • Bridges o Assumed 17 highway bridges o 60m span each o 27m wide o 2 span o Steel use (0.150 tonnes per m3) • Cuttings o 10.3 km of cutttings o Depth of cuttings ranged from 7m to 0.5m • Embankments o 8.1 km of embankments o Height of embankments ranged from 5.5m to 0.5m

Sector	Assumptions
	Operation: Road length - 143 kms Vehicle occupancy - 1.6 Annual vehicle kilometres (cars only) - 5,349,373,686

Table 8: Known data gaps associated with construction elements

Sector	Data gap	Extent of missing data (full or partial)
Construction	Temporary haul roads, pilling crane platforms	Partial
Construction	Temporary roads/road widenings/roundabouts	Partial
Construction	Temporary compounds	Partial
Construction	Drainage materials	Partial
Construction	Precast concrete units / beams	Partial
Construction	Steel bridge girders / beams	Partial
Construction	Auto-transformer substation bases and access roads	Partial
Construction	Railway material laydown areas	Partial
Construction	Footpath/farm track diversions	Partial
Construction	Road construction - hammer heads/turning circles	Partial
Construction	Utility diversions	Partial
Construction	Drainage ponds and access roads	Partial
Construction	Tunnel Boring Machine related labour data including commuting	Full
Construction	Tunnel fan manufacture, maintenance and transport	Full
Construction	Rail track construction ground stability improvement works	Full

Sector	Data gap	Extent of missing data (full or partial)
Construction	Disturbance of businesses that may be displaced	Full
Construction	Maintenance lay-bys	Partial
Maintenance	Maintenance activities	Partial
Movements of excavated material	Excavated material conveyor belt energy consumption	Full
Movements of excavated material	Plant data for unloading and packing/setting of fill material	Full
Operation	Testing, commissioning and trial running of the Proposed Scheme	Full
Rail track construction	Rail weld energy consumption	Full
Stations	Construction waste	Partial
Stations	Retaining walls, bridges, drainage, external walls, bus depot, shafts, pilling, lifts, escalators, ticketing systems	Partial
Stations	Fit-out and mechanical and electrical equipment (such as heating, ventilation and air conditioning and escalators)	Full
Stations	Testing and commissioning	Full
Road alternative	Culverts, underpasses, tunnels, petrol stations, commercial space, road maintenance	Full

5 Phase One AoS/ES carbon reconciliation statement

5.1 Construction summary

5.1.1 The HS2 London to West Midlands Appraisal of Sustainability (AoS)[13] estimated HS2 Phase One construction carbon emissions to be 1.2MtCO2e. The AoS carbon assessment was based on preliminary design stage data. Two years later, and with much more refined and detailed design information, the ES reports construction carbon emissions of HS2 Phase One at 5.6MtCO2e (Central case), an increase of around 4.4MtCO2e.

5.1.2 A reconciliation exercise was undertaken in order to better understand the reasons behind this difference. Two main aspects were explored:

- Scope – different boundaries for what was included and excluded in each of the carbon assessments; and
- Construction material volumes – both assessments are based on estimated volumes of construction materials which depend on the level of design detail.

5.1.3 This reconciliation exercise shows that the differences in scope and construction material volumes account for over 99% of the difference (4.4MtCO2e) in estimated construction emissions between the AoS and the HS2 Phase One carbon assessment reported in this ES.

5.2 Operational summary

5.2.1 It has not been possible to undertake a detailed reconciliation between the predicted footprint of the Phase One AoS and the ES, due to the large range associated with the two scenarios reported in the AoS and the fact that the Phase One AoS operational footprint lies within that range. Nevertheless, there are some significant changes that have occurred to the scheme which help to explain the much narrower range in the HS2 Phase One ES.

5.2.2 Firstly, the use of released slots at Heathrow for long haul flights, due to the modal shift of domestic flights to HS2, is no longer assumed to be attributable to the Proposed Scheme (as described in the ES). This is because reallocation of slots is a commercial matter, primarily for the airlines. Factors that might influence the future use of slots could include passenger demand, airport capacity issues, agreements with airport operators and other local commercial considerations at the time.

5.2.3 Secondly, the assumptions around the extent of the modal shift form air and road travel to HS2 have been altered since the AoS. They are now more conservative and consequently the carbon benefits associated with people switching from more carbon intensive modes to HS2 has reduced.

[13] HS2 Ltd (2011) *HS2 London to West Midlands Appraisal of Sustainability.*

6 References

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