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Planning for waste minimisation and resource efficiency in HS2

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High Speed 2 (HS2) will be the new backbone of Britain's rail network. Phase 1 will be Europe's biggest construction project, creating 230 km of new railway, and will provide significant challenges in waste management, not least the production of approximately 130 Mt of excavated material. HS2 Ltd has developed an *Environmental Policy* which includes a commitment to 'Source and make efficient use of sustainable materials, maximise the proportion of material diverted from landfill and reduce waste'. HS2 Ltd has acted to deliver on these commitments through a number of initiatives which are described, including: exemplary contractual waste-diversion targets; resource efficiency workshops; pre-demolition audits, including salvage audits for affected heritage assets; optimising on-site and off-site reuse of excavated material; development of contractor guidance on maximising the reuse of felled timber and development of a material-efficiency metric. This paper provides a synopsis of the approach taken by HS2 Ltd to date.

Notation

ME_{asset}	material-efficiency metric for asset
M_{rec}	mass of recycled material (t)
M_{ren}	mass of renewable material (t)
$M_{ren+rec}$	mass of recycled renewable material (t)
$M_{ren+reu}$	mass of reused renewable material (t)
M_{reu}	mass of reused material (t)
M_v	mass of virgin material (t)

1. Introduction

High Speed 2 (HS2) will be the new backbone of the UK's rail network, directly connecting the city centres of London, Birmingham, Manchester and Leeds. Once fully completed, the railway will comprise around 553 km of new high-speed track and will crucially release capacity on the existing railway network. HS2 will also be integrated into the East and West Coast Main Lines, with trains crossing over to the existing network and serving towns and cities in the north of England and Scotland. This will open up access to the high-speed network to around half the population of the UK and significantly cut journey times between the north and the south. The proposed HS2 network and destinations served are shown in Figure 1.

Phase 1 between London and Birmingham is scheduled for completion in 2026, with phase 2a extending the network to Crewe by 2027. The remainder of phase 2 will create a Y-shaped network extending to Manchester in the west and Leeds in the east, with scheduled completion by 2033. When fully operational, up to 48 HS2 trains will be running every hour on the UK rail network, each with up to 1100 seats (HS2, 2017a).

The HS2 programme is a huge undertaking; Britain's first new intercity railway north of London in 100 years. As Europe's largest infrastructure project, it will provide significant challenges in all aspects of construction logistics including waste and resource management.

Phase 1 will comprise four new stations and 230 km of new railway, including approximately 46 km in tunnel, 74 km in cutting and the remainder either on embankments, viaducts or at the surface level.

HS2 Ltd has developed an *Environmental Policy* (HS2, 2017b) which includes a commitment to 'Source and make efficient use of sustainable materials, maximise the proportion of material diverted from landfill and reduce waste'. This high-level commitment has been used as a foundation to develop a waste-management policy which enshrines the waste hierarchy and also a set of core requirements which span across all contracts and are designed to incentivise an exemplary level of performance in relation to waste management and resource efficiency.

Based on the reference design developed for the phase 1 hybrid bill, approximately 130 Mt of excavated material will be

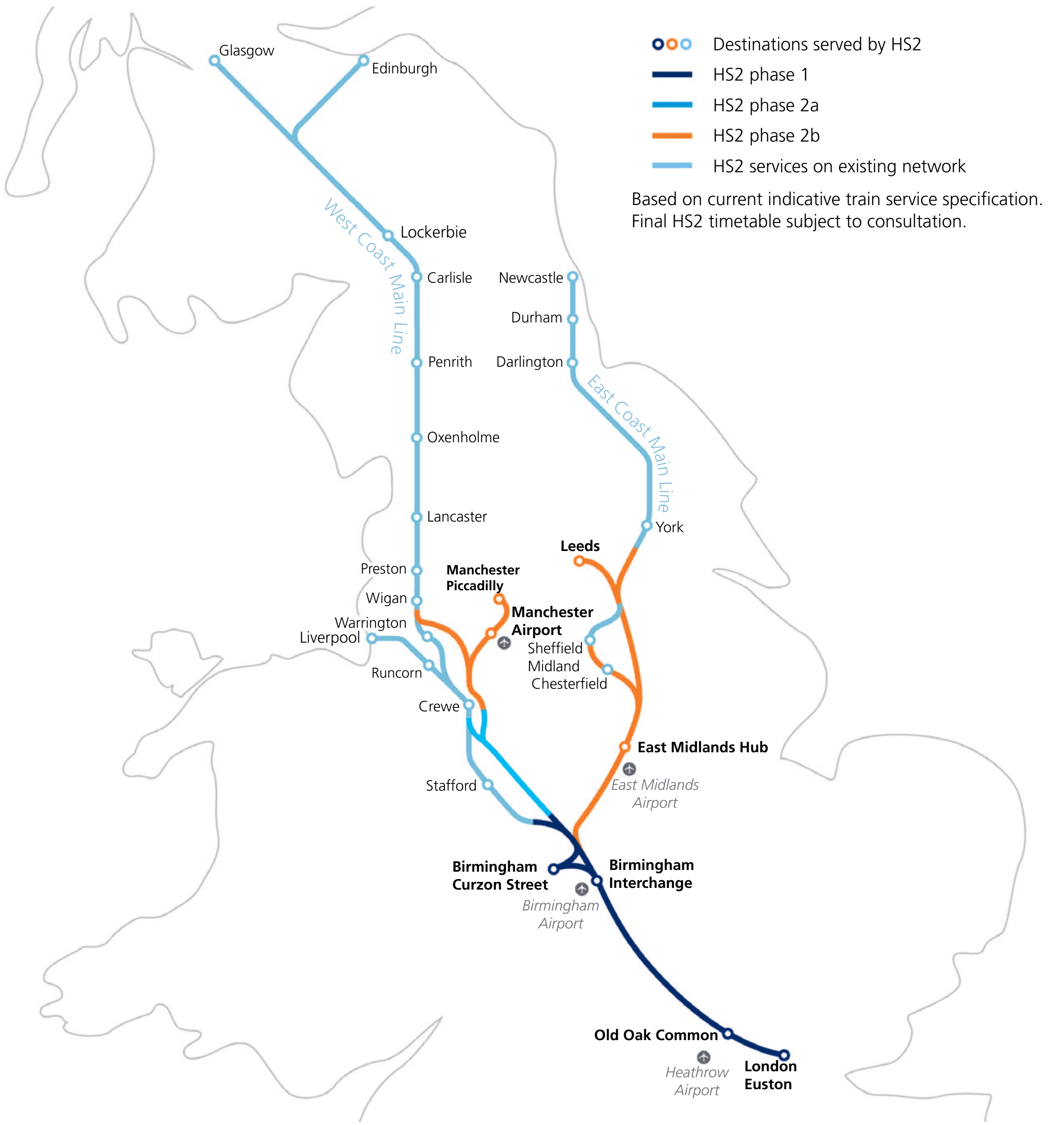

Figure 1. Proposed HS2 network and destinations served

produced during construction. It is also estimated that construction of phase 1 will require approximately 1·4 Mt of concrete and 0·22 Mt of steel (BCaTG, 2011).

The principal aim of this paper is to set the scene in terms of the programme's aspirations with respect to waste minimisation and resource efficiency and how these have been translated into requirements for HS2's supply chain partners. This is addressed through six key areas of focus

- setting performance targets
- resource-efficiency workshops
- pre-demolition audits of buildings
- excavated material

- maximising the reuse of timber from site clearance and
- developing a material-efficiency metric.

In addition to the above, HS2 Ltd has undertaken work in relation to the circular economy, including establishing and embedding a set of principles and measures to coordinate the realisation of opportunities (Charlson and Dunwoody, 2019).

2. Performance targets

It is widely acknowledged that setting clear performance targets is an important component in delivering reduced wastage and the associated savings in construction cost (Wrap, 2018a). HS2 Ltd undertook a review of performance benchmarks from various sources to assist in establishing achievable but challenging targets. These were

- the benchmark performance rates in both relevant Building Research Establishment Environmental Assessment Method (Breeam) manuals to which HS2 is assessing – that is, *Breeam UK New Construction: Infrastructure* (BRE, 2016) and *Breeam UK New Construction: Non-domestic Buildings* (BRE, 2014)
- published construction industry data extracted from the Building Research Establishment (BRE) SmartWaste tool and
- targets and performance data from other current and completed large-scale infrastructure projects.

2.1 Breeam infrastructure requirements

The Breeam infrastructure assessment includes a single category in relation to construction waste management (Wst 01). This enables the project to score credits by promoting resource efficiency and through effective reduction and management of construction waste.

The waste-management section provides credits in relation to both the quantity of waste produced and in relation to the diversion of waste from landfill, as shown in Tables 1 and 2.

2.2 Breeam non-domestic building requirements

For non-domestic buildings, the BRE manual provides a tiered approach to the assessment of waste generation performance based on a metric of tonnes of waste per 100 m^2 of gross internal floor area. HS2 has agreed a tailored assessment criterion for its stations which is based on a metric of tonnes of waste per £100 000 of project value, as shown in Table 3. This departure from the metric in the *Non-domestic Buildings Technical Manual* (BRE, 2014), which is based on tonnes of waste per 100 m^2 of gross internal floor area, is consistent with that agreed for other major station developments including Crossrail.

With respect to landfill diversion the non-domestic building assessment adopts a similar approach to infrastructure, with benchmark levels as shown in Table 4.

Table 1. Breeam infrastructure benchmarks for waste generation

Quantity of waste/£100 000 project value (construction waste related to on-site construction and dedicated off-site manufacture or fabrication)	
m^3	t
5·3	7·1

Table 2. Breeam infrastructure benchmarks for diversion of non-hazardous waste from landfill

Breeam project assessment criteria reference	Type of waste	Volume: %	Tonnage: %
16	Construction	92	95
16	Demolition	80	90
20 – exemplary	Construction	98	98
20 – exemplary	Demolition	85	95

Table 3. Breeam non-domestic buildings waste generation target levels

	Quantity of waste/£100 000 (project value)	
Breeam credits	m^3	t
One credit	≤21·8	≤21·1
Two credits	≤16·1	≤15·6
Three credits	≤8·1	≤7·9
Exemplary level	≤8·1	≤7·9

Table 4. Breeam non-domestic buildings landfill diversion target levels

Breeam credits	Type of waste	Volume: %	Tonnage: %
One credit	Non-demolition	70	80
	Demolition	80	90
	Excavation	N/A	N/A
Exemplary level	Non-demolition	85	90
	Demolition	85	95
	Excavation	95	95

2.3 Review of BRE SmartWaste data

BRE has collated waste data from the construction industry using its SmartWaste tool. BRE and the Waste and Resources Action Programme (Wrap) published these data (Wrap, 2014) to assist the industry in waste planning, forecasting and management. The SmartWaste database includes data on a range of civil engineering project categories including 'railways'. The information included below is based on data which were available at the time of HS2's review in March 2015 (the time at which the phase 1 performance targets were initially developed).

Table 5. BRE SmartWaste railway projects waste generation data

Waste product	Railways: m^3 per £100 000	All projects: m^3 per £100 000	Railways: t per £100 000	All projects: t per £100 000
Total (excluding soils)	16·6	10·3	9·7	9·6
Number of projects	20·0	251·0	85·0	137·0

Table 6. BRE SmartWaste waste performance for railway projects and civil engineering projects

Waste management route	Railway projects	All civil engineering projects
Average % reused	3·4	10·4
Average % recycled	23·9	21·5
Average % recovered	30·7	35·2
Average % landfilled	42·1	33·0
Average % diverted from landfill	57·9	67·0

Tables 5–7 show a variety of data extracted from SmartWaste which were used to provide a view on construction industry waste performance.

2.4 Review of data from other major projects

As part of its target-setting process, HS2 undertook a review of the construction, demolition and excavation waste targets which were set by other large-scale infrastructure projects being implemented or planned in the UK. These were considered to provide suitable performance benchmarks.

2.4.1 Network Rail

Network Rail's reported waste-management performance (NR, 2015) is shown in Table 8.

2.4.2 Channel tunnel rail link

During construction of the Channel Tunnel Rail Link (High Speed 1) an extensive effort was made to reuse and recycle approximately 15·7 million m^3 of surplus excavation material, which were produced from the tunnelling and excavation works. Approximately 12 million m^3 were generated in section 1 of which 5 million m^3 were reused as structural fill and 7 million m^3 as mitigation fill. In section 2, about 3·7 million m^3 were generated of which approximately 2·5 million m^3 were reused at Stratford in London. Overall, more than 92% of excavated material was reused and recycled across the project.

The surplus excavated material strategy adopted involved providing materials for generating development platforms for major industrial and residential/commercial development coupled with the reuse of excavation materials for other infrastructure projects, and within the structural and mitigation earthworks of the new railway and associated highway works.

2.5 Adopted HS2 targets

HS2 Ltd's adopted contractual performance targets for waste generation and the diversion from landfill are shown in Tables 9 and 10. These are part of a suite of contract technical requirements which applies across all contracts.

HS2 has adopted separate waste-generation targets for buildings and infrastructure based on the relevant Breeam

Table 7. BRE SmartWaste new building project construction waste management methods

Performance	Average: %	Standard: %	Good: %	Best: %
Reuse	14	0	0	4
Recycling	22	0	3	34
Recovery	34	1	21	62
Landfill	30	50	16	4
Diverted from landfill	70	50	84	96

Table 8. Network Rail waste-management performance

Waste metric	Unit	2013/2014	2014/2015
Amount of waste produced by network rail and its contractors	t	3 231 691	4 145 090
Proportion of waste reused	%	86·6	11·0
Proportion of waste recycled	%		76·8
Proportion of waste recovered	%	0	0·6
Proportion of waste diverted from landfill	%	86·6	88·4
Total amount of waste produced from infrastructure projects normalised to amount of spend	t/£100 000	49·5	75·6

Table 9. HS2 resource-efficiency and waste minimisation targets

Development	Target	Stretch target
	t of waste/£100 000 (project value)	t of waste/£100 000 (project value)
Buildings	≤15·6	≤7·9
Infrastructure	≤7·1	N/A

Table 10. HS2 landfill diversion targets

Work stage	Target
Demolition	95% diversion from landfill
Excavation	95% beneficial reuse
Construction	95% diversion from landfill

assessment methodology. In the case of buildings, HS2 has adopted the BRE exemplary level as a 'stretch target'.

The waste-generation and landfill diversion performance targets adopted are considered by HS2 Ltd to be challenging but achievable.

3. Resource-efficiency workshops

In line with guidance developed by Wrap (2018b) which acknowledges that the best opportunities for improving resource efficiency occur during the design stage, HS2 adopted a designing-out-waste approach early in the development of the phase 1 scheme, during the development of the reference design for the hybrid bill. This led to the development of a set of designing-out-waste opportunities recommended for consideration during the design and construction phases.

To recognise the synergy between waste reduction and material efficiency, as the design process progressed, HS2 Ltd decided to expand this designing-out-waste approach to a more holistic resource-efficiency approach. This approach was built around the concept of resource-efficiency workshops. These workshops aim to identify opportunities in both material efficiency and waste reduction, making the process more efficient and effective by allowing these topics to support one another and to focus on the wider topic of resource efficiency in a single workshop when the project specialists are brought together. It is intended that these resource-efficiency workshops will be undertaken as an integral part of the ongoing design development process and be held not less than once during each project design stage.

Resource-efficiency workshops are arranged to review and build on opportunities already identified, highlighting which actions are most applicable to the current project phase and what needs to be done next to explore the opportunities further. They are also seen as an opportunity to record resource-efficiency actions that have already been completed and to identify further opportunities.

The workshops include all stakeholders relevant to the project stage. These could include, but are not limited to, HS2 technical staff, cost consultants, architects, structural/civil engineers, service engineers, contractors, demolition contractors, manufacturers, environmental consultants and project managers. In all instances, the workshop facilitator will have an understanding of resource-efficiency and experience of successfully facilitating other similar workshops.

Opportunities identified through workshops are managed through the HS2 environmental sustainability opportunities realisation process, which provides a structured approach through which opportunities that may lead to enhanced whole-life environmental-sustainability outcomes can be explored throughout the delivery of the programme. It leads project teams through an identify–prioritise–investigate–implement process, which is integrated into a plan–do–check–act approach throughout the design and construction/manufacturing stages to drive continual improvement.

4. Pre-demolition audits

The development of HS2 will require the demolition of many structures ranging from industrial units to buildings of historical significance such as the National Temperance Hospital in the vicinity of Euston station in central London.

To maximise the reuse of material from demolition works, HS2 has included a number of requirements, as follows

- follow the Institution of Civil Engineers' (ICE) *Demolition Protocol* (ICE, 2008) and use best practicable means to recover material at its highest value
- undertake pre-demolition surveys on all buildings to identify the presence of any hazardous materials (including asbestos-containing materials) that may be present
- undertake a pre-demolition audit for all buildings to be demolished and prepare a demolition bill of quantities to categorise and quantify the materials that will be available for potential reuse, thus enabling the design team to identify opportunities for on-site recovery
- undertake salvage audit on all buildings to identify potential fixtures, fittings and equipment with sufficient value for reuse; this may include items or materials with basic reuse value or heritage or architectural value.

The salvage audits are a key step in facilitating the reuse of equipment, fixtures and fittings left in buildings to be demolished. This could include items such as discarded furniture, carpet tiles, light fittings and so on The salvage audit identifies how these items will be reused, such as other local building projects and charitable organisations or, in the case of items with heritage or architectural value, museums or other academic collections. This will ensure that, where possible, materials are reused rather than recycled or recovered, thus managing them in compliance with the waste hierarchy.

Designated heritage assets to be demolished or substantially affected have been identified and will each be the subject of individual heritage agreements with the relevant local planning authority and Historic England. In some instances, the heritage agreements and the method statements to be submitted under these agreements will include specific requirements in relation to the identification and salvage of fixtures and fittings of historic and or/architectural significance. In the case of other historic buildings and structures (non-designated built heritage assets) to be demolished or partially demolished, specific requirements for the salvage of fixtures and fittings of historic and/or architectural significance will be set out in the relevant project plans and location-specific written schemes of investigations which form part of a suite of heritage-related requirements.

5. Excavated material

The construction of the phase 1 scheme is forecast to lead to the generation of approximately 130 Mt of excavated material. HS2 Ltd's reference design, prepared for the purposes of the hybrid bill submission, achieved a cut/fill balance that reused over 86% of the excavated material for the construction of railway and highway embankments as well as environmental mitigation earthworks, such as bunds for noise and visual mitigation or landscaping. The actual reuse achieved will be dependent on a number of factors including the final designs developed by main works civil contractors and the actual ground conditions along the proposed route.

HS2 Ltd has developed an excavated materials policy which sets out the key principles that HS2 will follow in relation to the reuse of excavated materials and the disposal of surplus-excavated material, as described below. Excavated material will be used to satisfy the fill material requirements of the HS2 scheme wherever reasonably practicable, thereby reducing the need for imported materials and reducing the amount of excavated material requiring off-site disposal.

The specific steps that should be followed to identify and manage suitable excavated material for use directly as a resource are in line with the Contaminated Land: Applications in Real Environments *Definition of Waste: Code of Practice* (CL:AIRE, 2011). Excavated material will only be considered as surplus if it is either not required, is unsuitable for use, cannot be treated to make it suitable for use or cannot be recovered in the construction of the HS2 scheme. The surplus excavated material will then become eligible for off-site reuse, off-site treatment, recycling or disposal. Contractors are required to apply the waste hierarchy to surplus excavated material.

HS2 Ltd and its supply chain are working together to identify beneficial reuse opportunities for surplus excavated material. These may include

- working with the Environment Agency to provide material for the construction of flood-defence schemes
- habitat-creation schemes
- quarry and land-restoration schemes and
- development platform delivery for major projects.

In addition, HS2 Ltd has identified the opportunity of providing surplus excavated material as a raw material in the manufacture of construction products. Through the Construction Product Association (CPA), HS2 Ltd contacted manufacturers who may be able to utilise surplus excavated material, particularly tunnel arisings which will be produced consistently over a long period of time and have the potential to be very homogeneous in nature. This has the potential to reuse surplus excavated material at a higher value than that of bulk fill applications.

HS2 Ltd has provided several manufacturers with samples from ground investigation works to allow them to test the suitability of the material that will arise from tunnelling operations. This work has been approved for an innovation credit within the HS2 Breeam infrastructure assessment.

6. Maximising reuse of timber from site clearance

The phase 1 environmental statement (HS2, 2015: p. 23) states that an area of approximately 250 ha of forestry land will be permanently removed as a result of the proposed scheme. Although this impact will be offset by the planting of approximately 650 ha of woodland for landscape mitigation and ecological habitat creation or replacement, significant quantities of felled timber will be produced as a result of site clearance activity across the line of route.

Although in volume terms felled timber is not one of the most significant material streams that will be generated during the construction of the proposed scheme, there is the potential for it to be seen as particularly emotive in terms of the perception of the general public and especially local residents.

Typically, trees felled during site clearance would be chipped for reuse on- or off-site as wood fuel or surfacing. HS2 Ltd recognises that although the vast majority of trees to be felled will only be suitable for these uses, a small percentage may have value for other uses such as local community use, construction joinery products and furniture or for the creation of features and habitats. Therefore, this material stream presents an opportunity to seek maximum value from the implementation of the waste hierarchy and application of circular economy principles.

The only industry guidance found in relation to timber reuse was the 'wood use hierarchy' referred to under 'soils and vegetation management' within the Breeam infrastructure technical manual (BRE, 2016). HS2 Ltd has developed guidance for contractors with the intention of maximising its reuse, with specific consideration to ensuring use at the highest value to the local community.

HS2 Ltd's construction demolition and excavation waste strategy provides guidance for contractors on how to identify the most beneficial end use for individual specimen trees or areas of woodland to be cleared and on steps to be taken to achieve the identified use. The guidance is not meant to be prescriptive, or to remove the need for appointment of suitably qualified professionals, rather it is intended to be used at a strategic level to inform the clearance strategy adopted. The guidance has been developed based on research commissioned by HS2 Ltd and carried out by Sustainable Construction Solutions Limited. Figure 2 provides a high level overview of the guidance in the form of a flow chart.

The process includes a number of key questions/decision points as follows.

- Does the tree have cultural or community value?
- Is there a viable community use for the timber?
- Is the timber suitable for use as solid wood?
- Is there an on-site need for the timber?
- Is the timber suitable for wood products or biomass?

Tree and woodland valuation surveys will be carried out and these will assign a quality to each tree, group of trees of woodland to be removed. The following designations will be applied (to stem wood only).

Softwood will be designated as belonging to one of the two following categories

- green logs
- red logs.

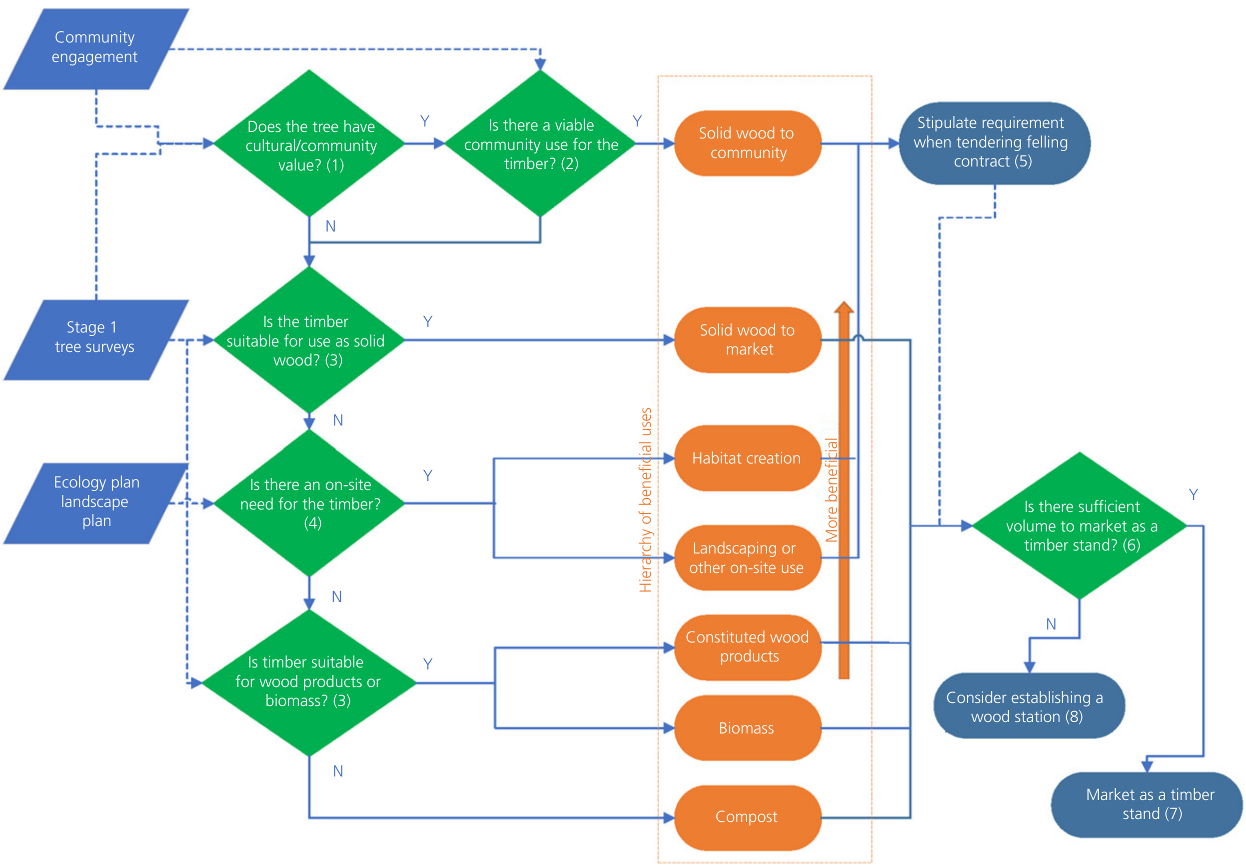

Figure 2. Flow chart of timber reuse guidance

Hardwood will be designated as belonging to one of the three following categories

- sawlog quality
- veneer quality
- biomass quality.

Where a tree that is identified as having community or cultural value requires removal, the following potential uses will be considered

- furniture makers (solid wood)
- arts, crafts and green woodworking groups (logs/solid wood)
- artisans (logs/solid wood)
- schools (solid wood/wood chip)
- wildlife trusts (logs/solid wood/wood chip)
- community woodlands (logs/solid wood/wood chip)
- local residents (wood chip/fire wood logs).

Considerations regarding the viability of community uses will include any additional cost and/or logistical burdens such as drying and sawing. There may be funding available to support community timber initiatives from community investment plans or other sources.

Any requirement for timber in the ecological mitigation works forming part of the proposed scheme design will be determined in an ecology site management plan. This may include the use of brashings as 'dead hedges' to control access or chipped wood for the surfacing of temporary and permanent paths.

Where appropriate, contractors may consider marketing a timber stand, whereby complete parcels of woodland are offered for sale as a lot in a 'standing sale'. Prospective buyers are invited to bid on the lot(s) of standing trees, with the winning bidder responsible for clearing all grades of timber and any associated brash or ground vegetation. The buyer will require access to the standing trees to bid, fell, remove and stack the sorted log lengths and other products at a point where they can be collected. This could be a cost-effective method of clearance and resource conservation where there is a significant proportion of timber or biomass available, as the buyer is commercially incentivised to maximise its use and value.

Where there is insufficient quantity of saleable timber in a specific area, it could be beneficial to establish a wood station: an area of land where timber of appropriate quality can be collated and stored until there is a saleable quantity. Wood station collections offer increased flexibility as they allow for the pooling of material to gain an economy of scale. They can also be used to process the timber if required to add value. Potential buyers are then invited to the wood stand to view the available timber prior to purchasing. There are examples of timber station operations which are run as a social enterprise with an ethos of using each piece of timber to its full potential. One such operation is Tree Station which operates in the Greater Manchester area (see TreeStation, 2017).

Contractor's performance with respect to timber reuse will be monitored throughout the site clearance phase. HS2 Ltd's sustainability reporting requirements include the following categories with respect to timber (measured in m^3)

- reused on-site
- provided for community uses
- used for solid wood production
- used for reconstituted board production
- used for biomass
- other reuse
- disposal.

7. Material-efficiency metric

The measures described above in relation to waste generation and diversion from landfill generally follow accepted industry best practice, albeit they are tailored to suit the nature and exceptional scale of the project. The HS2 Ltd team identified, however, that none of the existing available industry metrics would fully address the concept of 'efficient construction material use'. HS2 Ltd therefore developed a material-efficiency metric to incentivise designers and contractors to encourage innovation aimed at achieving exemplary levels of reduction in materials use and the use of reused, renewable and recycled materials in the construction of the scheme.

This metric was developed by initially defining what would need to be quantified to demonstrate efficient use of materials, reviewing existing metrics and then combining aspects of these existing metrics to meet the need. HS2 Ltd appointed the ICE to convene and facilitate a workshop to review the proposed metric. The workshop was chaired by Dr David Greenfield, chair of the ICE Resource Management Panel. A select group of experts with different knowledge specialisms was asked to reach a consensus, through the workshop, on whether the proposed metric will assist in demonstrating the efficient use of construction materials in a quantifiable way for HS2.

The resulting metric (as shown in the equation below) measures the materials used in the final assets to achieve the required design life, weighted between virgin, recycled, reused and renewable materials, and this gives an indication of the effective mass required for the asset per year. The metric is primarily intended for use during the design process to provide a basis on which to evaluate options and to be used, in conjunction with other factors, to inform the selection of the preferred option. It is also intended to be used following the selection of the preferred option to promote materials-efficient design and procurement decisions

$$\mathrm{ME}_{\mathrm{asset}} = \sum_{\mathrm{materials}} \frac{M_{\mathrm{v}} + 0{\cdot}7M_{\mathrm{rec}} + 0{\cdot}35M_{\mathrm{ren}} + 0{\cdot}245M_{\mathrm{ren+rec}} + 0{\cdot}1M_{\mathrm{reu}} + 0{\cdot}035M_{\mathrm{ren+reu}}}{\text{Design life achieved with material (years)}}$$

where $\mathrm{ME}_{\mathrm{asset}}$ is the material-efficiency metric for asset; M_{v}, mass of virgin material (t); M_{rec}, mass of recycled material (t); M_{ren}, mass of renewable material (t); $M_{\mathrm{ren+rec}}$, mass of recycled renewable material (t); M_{reu}, mass of reused material (t) and $M_{\mathrm{ren+reu}}$ is the mass of reused renewable material (t). Although the metric is calculated at an asset level, it can also be aggregated to provide contract- and programme-level metrics.

Contractors are required to demonstrate efficient use of materials by showing a percentage reduction against a baseline, '% improvement in material efficiency'. This would be achieved by each contractor establishing a baseline design on contract commencement and calculating the material-efficiency score for that design. Further scores would then be calculated for each future design iteration, thereby allowing a percentage improvement or deterioration in material efficiency to be reported along with other design updates, as set out in Figure 3.

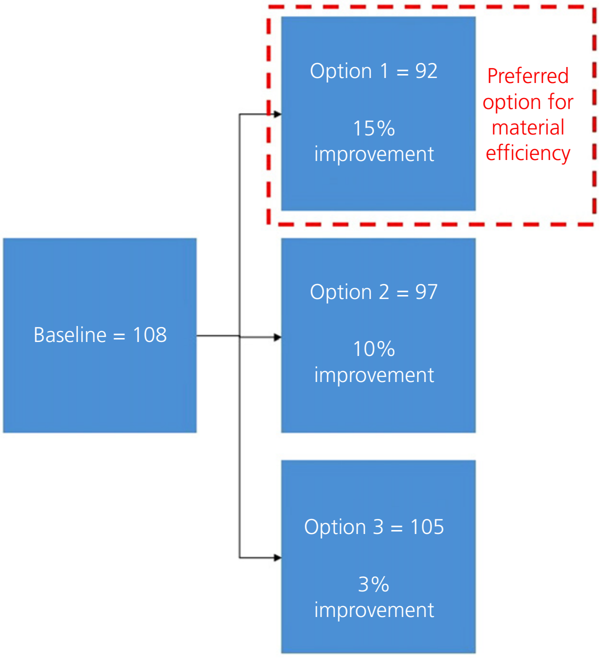

Figure 3. Use of a relative material-efficiency measure during design

8. Estimate of potential savings

An estimate of the potential magnitude of savings which may be achieved by meeting the performance targets that HS2 Ltd has set has been made by calculating the difference between the landfill tax liability arising from the following two scenarios

- waste arisings forecast and assumed landfill diversion and excavated material reuse performance levels from the phase 1 environmental statement, which represent a 'reasonable worst case' scenario with respect to waste to landfill – see Table 11
- waste arisings forecast from the phase 1 environmental statement with landfill diversion performance at HS2 target levels – see Table 12.

The potential landfill tax saving based on these forecasts and assumptions is *c*. £93 million. Other savings would be expected to accrue from the avoided waste-management costs such as collection, haulage and landfill gate fees.

9. Summary

The approach to waste minimisation and resource efficiency described above are considered by HS2 Ltd to combine industry best practices with innovative measures designed to address some gaps in standard practice.

The HS2 programme is at a relatively early stage of development, at least in terms of being able to judge the effectiveness of prescribed measures in terms of achieved outcomes.

HS2 Ltd believes that the set of requirements it has developed in relation to waste management and resource efficiency will provide a springboard for its contractors to deliver an exemplary level of performance befitting a project of this scale to create infrastructure of national significance. Performance against the targets and metrics outlined above will be monitored throughout all construction phases of the programme and will be reported alongside other sustainability metrics. HS2 Ltd looks forward to supporting its supply chain partners in the delivery of excellent levels of performance through innovation and collaboration.

Table 11. Phase 1 landfill tax estimate scenario 1: forecast waste arisings and landfill diversion performance levels as per environmental statement (reasonable worst-case scenario)

	Tonnages						
Landfill class	Surplus excavated material for off-site disposal to landfill (HS2, 2015: table 9)	Surplus excavated material managed by on-site disposal (HS2, 2015: table 8)	Demolition waste for off-site disposal to landfill (HS2, 2015: table 11)	Construction waste for off-site disposal to landfill (HS2, 2015: table 12)	Total forecast landfill tonnage	**Landfill tax rate: £/t (HMRC, 2018)**	**Total landfill tax estimate: £**
Inert	12 573 420	2 737 140	—	—	15 310 560	3·00	45 931 680
Non-hazardous	439 498	—	103 673	308 495	851 666	94·15	80 184 354
Hazardous	470 078	—	69 115	—	539 193	94·15	50 765 021
Total	13 482 996	2 737 140	172 788	308 495	16 701 419		176 881 055

Table 12. Phase 1 landfill tax estimate scenario 2: environmental statement forecast waste arisings with landfill diversion performance at HS2 target levels

	Excavated material				**Demolition waste**				**Construction waste**				
Landfill class	Total tonnage excavated material arising (HS2, 2015: table 8)	Total tonnage excavated material for disposal based on 95% beneficial reuse	Proportion by landfill class (HS2, 2015: table 9): %	Tonnage of excavated material subject to landfill tax	Total tonnage of demolition waste (HS2, 2015: table 10)	Total tonnage to landfill based on 95% landfill diversion	Proportion by landfill class (HS2, 2015: table 11): %	Tonnage of demolition waste to landfill	Total tonnage of construction waste (HS2, 2015: table 12)	Total tonnage of construction waste to non-hazardous landfill based on 95% landfill diversion	**Total forecast tonnage subject to landfill tax**	**Landfill tax rate: £/t (HMRC, 2018)**	**Total landfill tax estimate: £**
Inert			93·00	6 070 046			—				6 070 046	3·00	18 210 137
Non-hazardous			3·00	195 808			60·00	51 836		154 247	401 892	94·15	37 838 095
Hazardous			4·00	261 077			40·00	34 558			295 635	94·15	27 834 012
Total	130 538 618	6 526 931		6 526 931	1 727 876	86 394		86 394	3 084 948	154 247			83 882 244

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