HIGHWAYS AGENCY

Safe roads, reliable journeys, informed travellers

# A14 Cambridge to Huntingdon improvement scheme

# Environmental Statement

# Appendices

# Appendix 13.2: Carbon assessment

**Date: December 2014**

**6.3**

Page left intentionally blank.

# Executive summary

This report is an appendix of the *A14 Cambridge to Huntingdon improvement scheme Environmental Statement (ES).* It presents the carbon footprint baseline and makes recommendations for intervention to reduce carbon emissions.

The Highways Agency is committed to contributing to the UK's reduction of greenhouse gas (GHG) emissions and seeks to calculate the carbon footprint of its activities.

The construction of the A14 Cambridge to Huntingdon improvement scheme (the scheme) is a major project, with considerable volumes of construction materials required. This type of scheme inevitably results in carbon emissions associated with the use of materials and energy expended in construction. In addition, the scheme seeks to increase road capacity, while making journeys quicker, safer and less congested. The additional capacity is predicted to increase numbers of vehicles using the road, which is likely to increase $CO_2$ emissions from traffic compared to the situation in the absence of the scheme.

Calculations indicate that the footprint of the construction phase of the scheme would be approximately 981,432 tonnes of $CO_2e$ ($tCO_2e$) and that this is primarily due to materials and excavation (75%) and transport and logistics (24%).

During the operational phase of the scheme, it is expected that the fully utilised scheme would result in the emission of an additional 68,238 $tCO_2$ per year from traffic. Energy use due to the scheme, such as lighting and Intelligent Transportation System (ITS) equipment, would begin at approximately 135 $tCO_2e$ per year and reduce over the years due to decarbonisation of the electricity grid; over a 60 year assessment period the operational emissions are thought to result in an increase of 4,386,445 $tCO_2$ from traffic and 2,350 $tCO_2e$ from energy use in the scheme.

Several general ways to reduce the carbon footprint are suggested, using the principles of avoid and/or eliminate, reduce, substitute or replace, and compensate.

**Carbon footprint of the scheme**

| $CO_2e$ source | Tonnes $CO_2e$ |
|---|---|
| Waste | 281 |
| Transport | 235,979 |
| Materials | 740,062 |
| Energy (site offices and other fuel use) | 5,110 |
| **Construction total** | **981,432** |

| $CO_2e$ source | Tonnes $CO_2e$ |
|---|---|
| Energy use in the scheme | 2,350 |
| Operational additional emissions | 4,386,445 |
| **Operational (traffic and energy) 60 year total** | **4,388,794** |

# 1 Introduction

## 1.1 Background

1.1.1 This report is an appendix of the *A14 Cambridge to Huntingdon improvement scheme Environmental Statement (ES)*. It presents the carbon footprint baseline and makes recommendations for intervention to reduce carbon emissions.

1.1.2 The Highways Agency is committed to contributing to the Government's goal of reducing greenhouse gas (GHG) emissions, as enshrined in UK legislation by the *Climate Change Act 2008*. To this end, one of the performance measures stated in the *Highways Agency Business Plan* (Highways Agency, 2013) is to *"Minimise Highways Agency $CO_2$ Emissions"*. In order to measure the progress against this target the Highways Agency reports the carbon footprint of its activities within its *Annual Report and Accounts 2012-2013* (Highways Agency, 2013).

1.1.3 The Highways Agency acknowledges that it is a leader in the UK construction sector, and as such needs to lead by example, providing its supply chain with the tools necessary to measure GHG emissions, and provide the incentives to actively manage (and wherever possible reduce) them. The Highways Agency has developed a carbon calculation methodology, which covers maintenance, construction and operationally derived carbon emissions. This supports the measurement and enables the consequent management of GHG emissions from activities associated with the Highways Agency's function.

## 1.2 Definitions

1.2.1 Reporting for this scheme GHG impact is carried out using mass of carbon dioxide equivalent ($CO_2e$) emissions, which allows for the emissions of the six key GHG: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride ($SF_6$); to be expressed in terms of their equivalent global warming potential in mass of $CO_2$. *The Greenhouse Gas Protocol* (Greenhouse Gas Protocol, 2004), the most widely used accounting tool for GHG emissions and the basis for the reporting boundaries within the *Highways Agency Carbon Calculation for Major Projects* (*CCMP*) (Highways Agency, 2013), makes use of key definitions in order to determine the boundary of ownership for the emissions, including:

- direct emissions: originating from sources that are owned or controlled by the reporter; and
- indirect emissions: emissions that are a consequence of the activities of the reporting entity, but occur at sources owned or controlled by another entity.

1.2.2 Further to this, the *GHG Protocol* (2004) categorises these direct and indirect emissions into three broad scopes, including:

- scope 1: All direct GHG emissions;
- scope 2: Indirect GHG emissions from consumption of purchased electricity, heat or steam; and
- scope 3: Other indirect emissions, e.g. extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. transmission and distribution losses from supply) not covered in scope 2, outsourced activities, waste disposal.

1.2.3 The *Carbon Calculation Tool Instruction Manual for Major Projects* (Highways Agency, 2009) describes the following reporting boundaries:

- Direct, including:
  - Highways Agency utilities use;
  - Highways Agency fuel use; and
  - Highways Agency business transport.
- Indirect, including:
  - Electricity;
  - Other transport;
  - Waste removal;
  - Highways Agency material consumption and transport;
  - Subcontractor material consumption; and
  - Subcontractor fuel consumption.

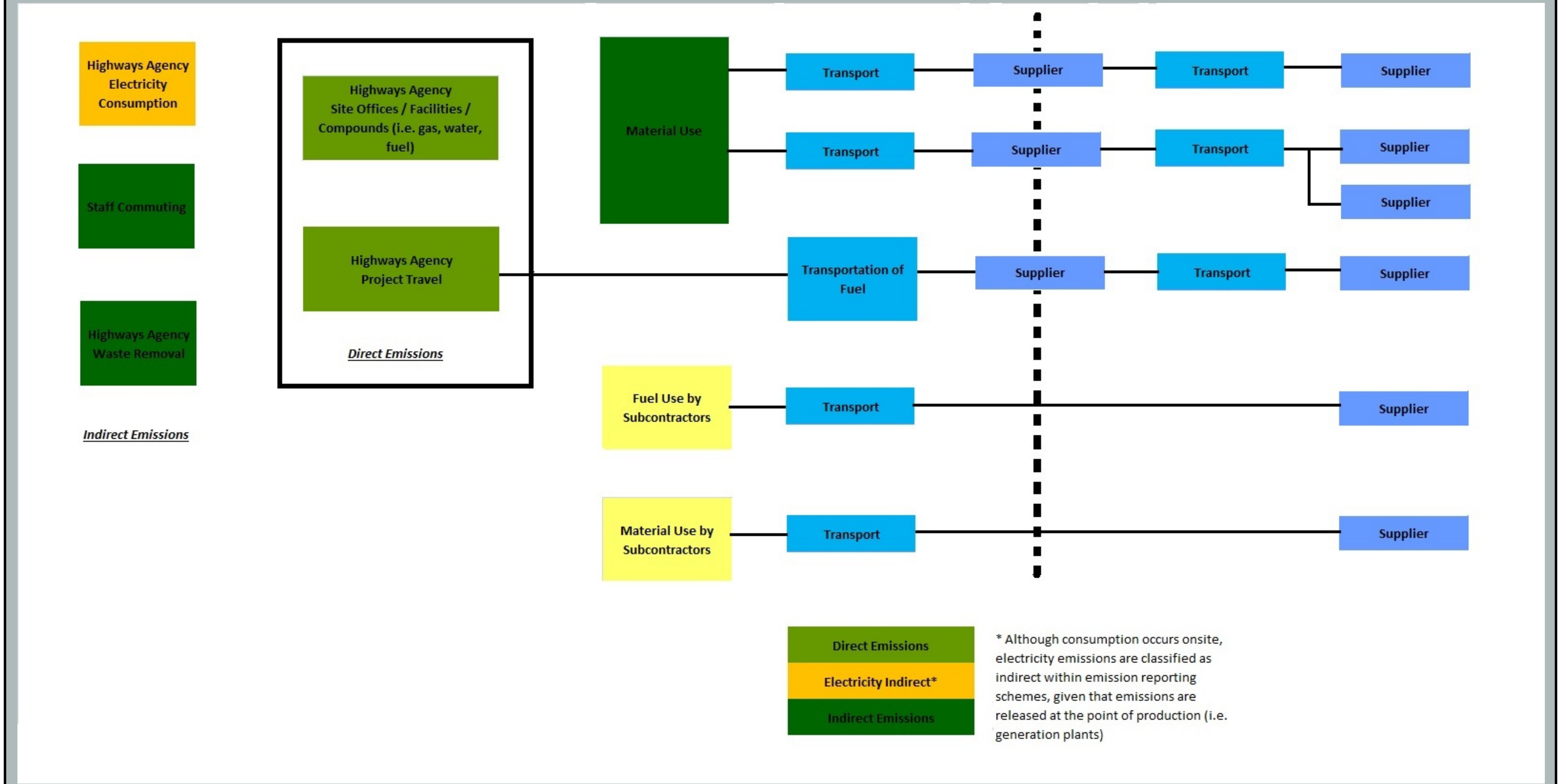
1.2.4 In the *Carbon Calculation Tool Instruction Manual for Major Projects* (Highways Agency, 2009) document it is stated that the Highways Agency has no control over the transportation element of subcontractor procurements and consumption.

1.2.5 The *Carbon data analysis and verification: Findings Report* (Highways Agency, 2013), noted that the boundaries set out in the *Carbon Calculation Tool Instruction Manual for Major Projects* (Highways Agency, 2009) were not in line with the Highways Agency objective to:

*"Reduce GHG emissions across all activities we can influence. No activity is too large or too small"* (*Sustainable development plan 2012–2015*, Highways Agency, 2012).

1.2.6 It has therefore been considered appropriate to adjust the reporting boundaries to include the emissions resulting from the transport of materials consumed by subcontractors. The adjusted reporting boundaries are shown in *Box 1.1*.

## Box 1.1: A14 construction carbon footprint reporting boundary



# 2 Carbon footprint management

## 2.1 The Highways Agency Carbon Calculation for Major Projects

2.1.1 The *CCMP* (Highways Agency, 2013) is the most applicable tool for this assessment. It has been designed to meet Highways Agency specifications, contains carbon factors related to the types of materials commonly used in highway construction, and comes with thorough documentation allowing for use by non-specialists. This means that it can be embedded in the scheme and utilised as appropriate in the monitoring and updating of the scheme's carbon footprint. It was most recently updated in January 2013, to bring carbon factors in line with the latest guidance.

2.1.2 The *CCMP* (Highways Agency, 2013) is part of a toolkit designed to enable the Highways Agency to identify the emissions baseline of Highways Agency activities. The *CCMP* (Highways Agency, 2013) is designed to be completed quarterly to report on the carbon footprint of a major project in the previous quarter. The tool provides a means of estimating the volume of carbon produced through construction, maintenance and operational activities undertaken by the Highways Agency and its main contractors.

## 2.2 Methodology

2.2.1 The methodology used is that described within the *Carbon Calculation Tool Instruction Manual for Major Projects* (Highways Agency, 2009); the Highways Agency Major Projects Data Collection Pro-forma was used as a guide to inform the collection of information from key data holders.

2.2.2 The collected data comprised estimates of materials, fuel, electricity use and consumables use. These data are used as inputs to the *CCMP* (Highways Agency, 2013) in order to generate an initial estimate of the carbon footprint of the scheme. The input data included:

- materials quantities, as described in *Chapter 13 of the ES;*
- on-site heavy goods vehicle (HGV) movements, as described in *Appendix 3.2 of the ES*;
- labour force information, as described in *Appendix 3.2 of the ES* and *Chapter 16 of the ES;*
- information on the quantities, and dispositions, of construction and demolition waste, as described in *Chapter 13 of the ES*; and
- assumptions regarding material transport to site, based on information from *Appendix 3.2 of the ES* and reasonable likely worst-case estimates.

2.2.3 Information for on-site traffic movements was available in the format of HGV vehicle kilometres, rather than the input required by the tool, which calls for litres of diesel. As the required functionality to convert average-laden HGV vehicle kilometres to $tCO_2e$ was not available within the *CCMP* (Highways Agency, 2013), this was calculated in an additional sheet. This calculation was performed by multiplying the total number of kilometres travelled on-site by HGVs by the carbon factor of an average-laden Average Diesel HGV, as sourced from the *Greenhouse Gas Conversion Factor Repository* (Defra, 2014). Planned output metrics from the carbon calculations comprise a total project footprint, expressed in the following terms:

- total tonnes of $CO_2e$[1]; and
- a breakdown of tonnes of $CO_2e$ by material type.

[1] The CCMP produces results primarily in $tCO_2e$, however some items only return $tCO_2$. The labelling used within the tool has been amended to indicate $tCO_2e$ throughout this report.

# 3 Embodied carbon and emissions associated with construction

## 3.1 Materials use and waste disposal

### Data gathering and key assumptions

3.1.1 The information on materials used within the scheme is derived from the information in *Chapter 13 of the ES*. This includes the information shown in *Table 13.5* in *Chapter 13 of the ES*, which is repeated here as *Table 3.1*. The information on waste that has been collected for *Chapter 13 of the ES* is also used in the *CCMP* (Highways Agency, 2013).

3.1.2 The material requirements include a 10% contingency which is in line with the information provided within *Chapter 13 and Appendix 3.2 of the ES.* This has been taken as a likely worst case for material construction impacts.

3.1.3 In interpreting *Chapter 13 of the ES* for input into the *CCMP* the assumptions that were made regarding material selection are shown in *Table 3.1*.

**Table 3.1: Summary of construction materials resource use**

| Construction material required | Type of material selected within *CCMP* | Estimated quantities of materials ($m^3$) | Additional information on materials resource |
|---|---|---|---|
| Blacktop | Asphalt | 516,701 | Material used to pave the road and bridges surfaces. |
| Sub base | Quarried aggregate | 273,041 | Layer of aggregate material, sourced from quarries off site. |
| Capping | Aggregates for capping are planned to be won from the borrow pits, these have not been included as quarry-sourced aggregate | 383,701 | Layer of usually relatively low quality aggregate, derived from on-site excavation. |
| Concrete | Ready-mix concrete: general road and pavement | 606,373 | Concrete in bridges, structures, roads, headwalls, culverts, chambers. Where it was required to convert $m^3$ to tonnage, a density of 2.4 tonnes per $m^3$ was used[2]. |

[2] This is the density of compacted cast concrete, *Inventory of Carbon and Energy (Version 2.0)* (University of Bath, 2011). This was considered to be the most reasonable worst case for potential concrete density.

| Construction material required | Type of material selected within *CCMP* | Estimated quantities of materials ($m^3$) | Additional information on materials resource |
|---|---|---|---|
| Steel | Steel: general | 12,358 | Steel used in bridges, structures, roads. |
| Plastics | Plastic | 2,764 | Plastics used for ducting and carrier drains. |
| Excavation | All material excavation is inputted as quarry-sourced soil | 8,356,700 | Excavated material, from cuttings, borrow pits and flood compensation areas |

## 3.2 Logistics

### Data gathering and key assumptions

3.2.1 At the preliminary design stage, no location is indicated for materials sourced from locations outside the scheme footprint, unless specified below. It is intended that required material from outside the scheme footprint would be imported onto the scheme via the existing strategic road network or via the existing rail network to the Cambridge railhead and then transferred by road.

3.2.2 The material requirements include a 10% contingency which is in line with the information provided within *Chapter 13* and *Appendix 3.2 of the ES* in order to cover a likely worst case for construction impacts. Further, it has been assumed that the on-site HGV movements are as detailed within *Appendix 3.2 of the ES.*

3.2.3 The requirements for the transport of material to the site have been assessed by material type, and appropriate assumptions have been made using information in *Appendix 3.2 of the ES*, *Chapter 13 of the ES,* and other sources where necessary.

3.2.4 With regard to structural and reinforcement steel, steel used in the scheme is expected to be from non-local sources, as no appropriate local supplier has been identified. It is likely that the steel would be supplied through regional ports that have the capability and capacity for construction material. While the details of the procurement are currently unspecified, ports with capability for suitable materials import include Tilbury, Chatham and Ipswich[3]. The distance from these docks to Huntingdon was determined and the average distance of 130km was used as the distance for road transport from an import from dockside to scheme.

[3] Tilbury is the major Port for London, is situated on the northern bank of the Thames and provides good road/rail transport links to the scheme site. Chatham Docks and rail link were re-purposed for construction steel (rebar) import in association with the Heathrow Terminal 5 project. Ipswich Kings Lynn and Lowestoft docks are indicated for suitable East Anglian ports. The average distance of these ports to Huntingdon is 126km.

3.2.5 With regard to concrete, the use of batching plants is noted in *Appendix 3.2 of the ES*. To inform a likely worst case scenario, it is estimated that 43% of the concrete could be mixed at an existing batching site in Cambridge and that the development of an additional, project specific local batching plant could allow for a total of 70% of concrete requirements to be serviced within a 15km radius of point of use. It has been assumed that the remainder of the concrete would most likely be supplied from within 120km of the scheme (based on an estimate of the distance that could be travelled within the workable time for ready-mix concrete from batching plant to site discharge[4]). As further details of procurement are not currently specified, a sample review construction material suppliers was undertaken within this distance. The results of this study identified a number of suitable sites, with an estimated average distance of 95km. Therefore, 70% of the concrete requirements are presumed to travel 15km while the remaining 30% is assumed to be delivered 95km by road.

3.2.6 With regard to asphalt (black top), a significant volume of asphalt is required for the scheme and appropriate material cannot be sourced within the site boundaries. A similar methodology to that used for concrete was used to identify an approximate distance for estimating the transport impact of this material. As further details of procurement are not currently specified, a sample review of construction material suppliers was undertaken, assuming a similar maximum distance to concrete[5]. The results of this study identified a number of suitable sites, resultant in an estimated average distance of approximately 85 km has been estimated (*Appendix 3.2 of the ES*) that 13% of the asphalt requirements could be sourced via rail, through Cambridge railhead. Therefore, 13% of the asphalt requirements are presumed to travel 15km by road, and 70km by rail, while the remaining 87% is assumed to be delivered 85km by road.

3.2.7 Aggregates used for the sub-base of the road cannot be sourced within the site boundaries. The same assumptions that have been applied for asphalt have been applied for this material.

3.2.8 Plastics used within the scheme, for ducting, drains and other unspecified purposes, has been assumed to be as available for construction use from suppliers within a similar maximum distance to asphalt and concrete. It is modelled as being transported a maximum distance of 85km by road from materials depots to the scheme sites.

3.2.9 HGV movements around the site, for uses which include the movement of soil and aggregates, were calculated using information from *Appendix 3.2 of the ES*.

[4] This is dependent on concrete temperature, but is typically between 90 minutes and 120 minutes.

[5] The time and distance for the movement of asphalt has been inferred from *The Specification for Low Temperature Asphalt Mixtures* (Transport Research Laboratory, 2014) which states, for BS EN 13108-5 for half-warm mix stone mastic asphalt and BS EN 13108-7 for half-warm mix porous asphalt, that the *"… time between the completion of mixing and the start of compaction of samples shall be (120 ± 10) min".*

## 3.3 Plant use, travel and waste

### Data gathering and key assumptions

3.3.1 The use of consumables, such as fuel for mobile plant, was not available at this stage of the design. Therefore, the methodology used to generate a footprint for this was the "work time" method available in the *CCMP* (Highways Agency, 2013), which required the input of the length of work, in weeks, by site size.

3.3.2 The scheme is broken down into six sections, as described in *Chapter 3 of the ES*. Each of these sections is categorised as a "very large" construction site, with more than 25 people working on-site and spending of more than £10 million. The cumulative length of work from these six sites would be approximately 680 weeks as described in *Appendix 3.2 of the ES*; these durations can be seen in *Table 3.2*.

3.3.3 Values for GHG emissions that would result from the energy consumption of site offices and fixed plant (including electricity, gas, petrol, and diesel use on site offices, compounds, and at temporary traffic management areas) were derived from *UK Construction Industry Benchmarks* (*KPIZone 2009*). The figures are presented as kg$CO_{2e}$/ £100,000, so the construction project value is utilised in order to produce $CO_2$ estimates. At this stage of design detailed forecast data on electricity, gas, petrol, and diesel consumption would not be expected.

3.3.4 It has been assumed that the travel requirements are for a labour force of approximately 2,750, which is in line with the information provided in *Appendix 3.2 of the ES.*

3.3.5 Construction employee commuting has been estimated by multiplying the peak employment of 2,750, number of days worked on site, and an estimate of the average commuting distance. Employment estimates for the project range from between 2,000 and 2,750 peak employment on the site, with a likely worst case peak labour force of about 2,750 (*Appendix 3.2* and *Chapter 16 of the ES*). In order to provide an estimate for the scheme, the estimate of 2,750 employees was used.

3.3.6 The commuting calculation is based on up to 500 staff being located at the main construction site in temporary accommodation, with others commuting from within the local Cambridgeshire area. The average Cambridgeshire commuting was determined using population-weighted distances of each Cambridgeshire ward. This involved determining the distance of the main settlement of each ward to the boundary of the scheme and multiplying by the proportion of the Cambridgeshire population that the ward represents. This resulted in an estimate of 12.51km, for a 25.02km round trip. The staff that are to be accommodated within the scheme's worker accommodation are assumed to make commutes of 128km, 256km for the round trip, every four weeks[6]. The distance travelled by staff that commute from outside of Cambridgeshire, but are not staying in worker accommodation has been informed by the *Working Rule Agreement for the Construction Industry* (Construction Industry Joint Council, 2013); the average distance for this group has been taken to be 74km (148km round trip), as beyond this distance workers can be entitled to additional welfare payments. These distances are high level estimates at this time, as information on local job uptake and employee commuting practices for the scheme cannot be accurately defined at this stage.

3.3.7 Water use within the construction sites would have associated carbon emissions; this is addressed in the *CCMP* (Highways Agency, 2013) through the indirect impact of using mains water, or the direct impact of the road transport of water. Within the *Code of construction practice (CoCP) in Appendix 20.2 of the ES* the management of foul water and sewage is addressed through either connection to the local sewage system, if available and appropriate, or through temporary storage facilities and off-site disposal. Given that many of the construction sites of the scheme are in close proximity to water utilities, it is considered likely that the majority of potable water needs would be met through a mains water connection. Non-potable water needs can be partially supplied through the use of rainwater capture and water from excavation dewatering; however a likely worst case assumes that these substitutions are not significant.

3.3.8 Industry benchmarks for fresh water used in construction are published by WRAP. For Highways the benchmark ranges between 1.3 and 9.2m$^3$ fresh water per £100k project value. Applying the middle of this range to a project value of £1.24 billion gives an estimate of 65,500m$^3$. It is noted that there are only a small number of observations for Highways; however, this range accords with observed construction industry key performance indicators (KPIs) (Office of National Statistics, 2011).

3.3.9 The fuel required at the site was estimated through analysis of the potential requirements from the soil excavation and from the on-site HGV use. This estimate of fuel requirements is inputted into the tool in order to output an estimate of the GHG emissions that result from the required transportation of fuel to the site, however the emissions associated with the fuel itself has been accounted for separately in the relevant sections of this analysis.

[6] This distance is informed by the entitlement rules for periodic leave for home residence to workplace stated within the Construction Industry Joint Council's May 2013 revision of the Working Rule Agreement for the Construction Industry.

3.3.10 Construction waste was estimated using the waste arisings presented in *Table 13.7 in Chapter 13 of the ES*, converting $m^3$ into tonnage where necessary, using material densities from within the *CCMP* (Highways Agency, 2013). This required an assumption of how far the waste would be transported. Again, the "regional" option was selected, in order to represent the waste remaining within the Cambridgeshire area in accordance with the proximity principle of waste management. In addition, based on the assessment in *Chapter 13 of the ES* it was also assumed that the concrete, aggregate, and black top construction waste would be reused on site, while the waste steel and plastic would be recycled regionally. The concrete and steel waste that would result from demolition works in section 6 of the scheme was considered to have the potential to be fully recycled.

3.3.11 Office waste (a category which includes waste that arises within on-site construction offices), was estimated using the *CCMP* method 4b. This requires the inputs of project duration as seen in *Table 3.2*, the level of employment and an estimate of how far the waste will travel. For this, the "regional" option was selected, in order to represent the waste remaining within the Cambridgeshire area in accordance with the proximity principle of waste management.

**Table 3.2: Scheme duration**

| Scheme section | Estimated construction duration (months) | Estimated construction duration (weeks) |
|---|---|---|
| **1 – A1 Alconbury to Brampton Hut** | 20 | 86.6 |
| **2 – A1/A14 Brampton Hut to ECML** | 36 | 156 |
| **3 – A14 ECML to Swavesey** | 34 | 147.3 |
| **4 – A14 Swavesey to Girton** | 36 | 156 |
| **5 – A14 Cambridge Northern Bypass** | 16 | 69.3 |
| **6 – Old A14 Huntingdon** | 15 | 65 |
| **Total** | 157 | 680 |

## 3.4 Results

3.4.1 In order to illustrate the process that was undertaken using the *CCMP* (Highways Agency, 2013), *Table 3.3* represents an example of the *CCMP* tool. *Table 3.3* shows the inputs and the outputs for the material types of asphalt and steel, with the outputs calculated by the tool shown in the table in bold text. It can be seen that material densities, which were derived from background spreadsheets, are used to convert the material from $m^3$ to tonnage. This is then multiplied by embodied carbon factors, which are also derived from background spreadsheets, to produce the embodied emissions in $tCO_2e$.

**Table 3.3: Example of the *CCMP* (Highways Agency, 2013)**

| Type of material | Asphalt | Steel: general |
|---|---|---|
| **Unit** | $m^3$ | $m^3$ |
| **Total material purchased** | 516,701 | 12,358 |
| **Quantity (Tonnes)** | **878,391.36** | **98,864** |
| **Total shipping Tonne-km** | 0 | 0 |
| **Total rail Tonne-km** | 7,993,361 | 0 |
| **Total road Tonne-km** | 66,669,904 | 0 |
| **Average road transport (km)** | 0 | 129 |
| **Embodied ($tCO_2e$)** | **57,973.83** | **144,342.14** |
| **Transport ($tCO_2e$)** | **8,489.24** | **0** |
| **Estimated road transport ($tCO_2e$)** | **0.00** | **1,574.0** |

3.4.2 The outputs of the *CCMP* (Highways Agency, 2013) are presented in the rest of this section, with commentary.

3.4.3 The estimates for site energy and mobile plant are presented in *Table 3.4*, using the work time method described above. The carbon emissions listed for the site office are the median result of the benchmark methodology, combined with the output from the water consumption estimates. The results shown in *Table 3.4* are the top quartile result, the median result and the lower quartile result, as follows:

- top quartile: 27.2 $tCO_2$;
- median: 835.3 $tCO_2$; and
- lower quartile: 4,838.6 $tCO_2$.

**Table 3.4: Carbon due to energy use**

| Energy | Tonnes $CO_2e$ |
|---|---|
| **Site offices and fixed plant** | 857.88 |
| **Mobile plant** | 4,252.08 |
| **Total** | 5,110 |

3.4.4 *Table 3.5* shows that the largest proportion of embodied emissions associated with the scheme result from quarry sourced materials. This refers to emissions resultant from excavation, and the production of asphalt and sub-base aggregates.

3.4.5 The next largest contributor to the embodied footprint is concrete, which is used in structures across the scheme.

3.4.6 Metals also contribute to the footprint with a similar emissions level to concrete. Due to the higher embodied emissions factor per tonne of steel, the overall emissions impact is broadly similar to that of concrete despite the substantial difference in the volumes and masses of the materials involved. This steel is reinforcement used in many concrete structures throughout the project and the structural sections used in e.g. signage gantries and lighting columns. Some of this information was not available in discrete categories at this time. As such, the lighting and intelligent transport systems (ITS) category, which features items such as lighting columns and guardrails, reports a low value so as to avoid double counting these items as far as possible. Included in that total are the closed circuit television (CCTV) masts and roadside cabinets.

**Table 3.5: Carbon embodied in materials**

| Materials (excluding transport) | Tonnes $CO_2$e |
|---|---|
| **Metals** | 144,342.14 |
| **Plastics** | 8,783.14 |
| **Quarry-sourced materials** | 401,766.82 |
| **Ready-mixed concrete** | 184,822.43 |
| **Lighting and ITS** | 347.19 |
| **Total** | 740,061 |

3.4.7 As seen in *Table 3.6*, the employee commuting estimate is the largest component of transport and logistics associated carbon. This is partially due to the conservative inputs and assumptions used to generate this result, but primarily due to the high level of manpower that would be required, both within and from outside of Cambridgeshire, for the construction of the scheme. This estimate of staff travel places the emissions level at almost ten times more than the transport of material to, and around, the site.

3.4.8 The haulage of materials, both within the scheme boundaries and to reach site, makes up the next largest component of carbon emissions from transport.

3.4.9 The impact of the usage of fuel used for mobile plant and HGVs is split between the categories of materials (excavation) and transport (on-site HGV use). Additionally, emissions associated with the transportation of fuels have been estimated according to the methodology described above. This resulted in estimates of fuel transport of up to 132 million litres; inputting this value into the tool gave the output of 518 t$CO_2$e as shown in *Table 3.6*.

**Table 3.6: Carbon due to transport**

| Transport | Tonnes $CO_2$e |
|---|---|
| **Employee commuting** | 210,277.97 |
| **Transportation of fuel to site** | 518.04 |
| **Materials transport** | 22,390.55 |
| *- Of which rail* | 397.05 |
| *- Of which road* | 20,388.32 |
| *-Of which average (road)* | 1,605.19 |
| **HGV movements on-site** | 2,792.47 |
| **Total** | 235,979 |

3.4.10 It can be seen in *Table 3.7*, even with a large workforce expected to be involved that would be expected to result in significant site office waste, the emissions associated with the transport of construction waste makes up the larger proportion of carbon due to waste removal.

**Table 3.7: Carbon due to waste removal**

| Waste removal | Tonnes $CO_2$e |
|---|---|
| **Maintenance / construction waste transport** | 206.57 |
| **Office waste transport** | 74.25 |
| **Total** | 280.83 |

3.4.11 Across the entire scheme, the estimates shown in *Table 3.8* indicate that carbon embodied in materials would make up the largest proportion of the construction stage carbon footprint.

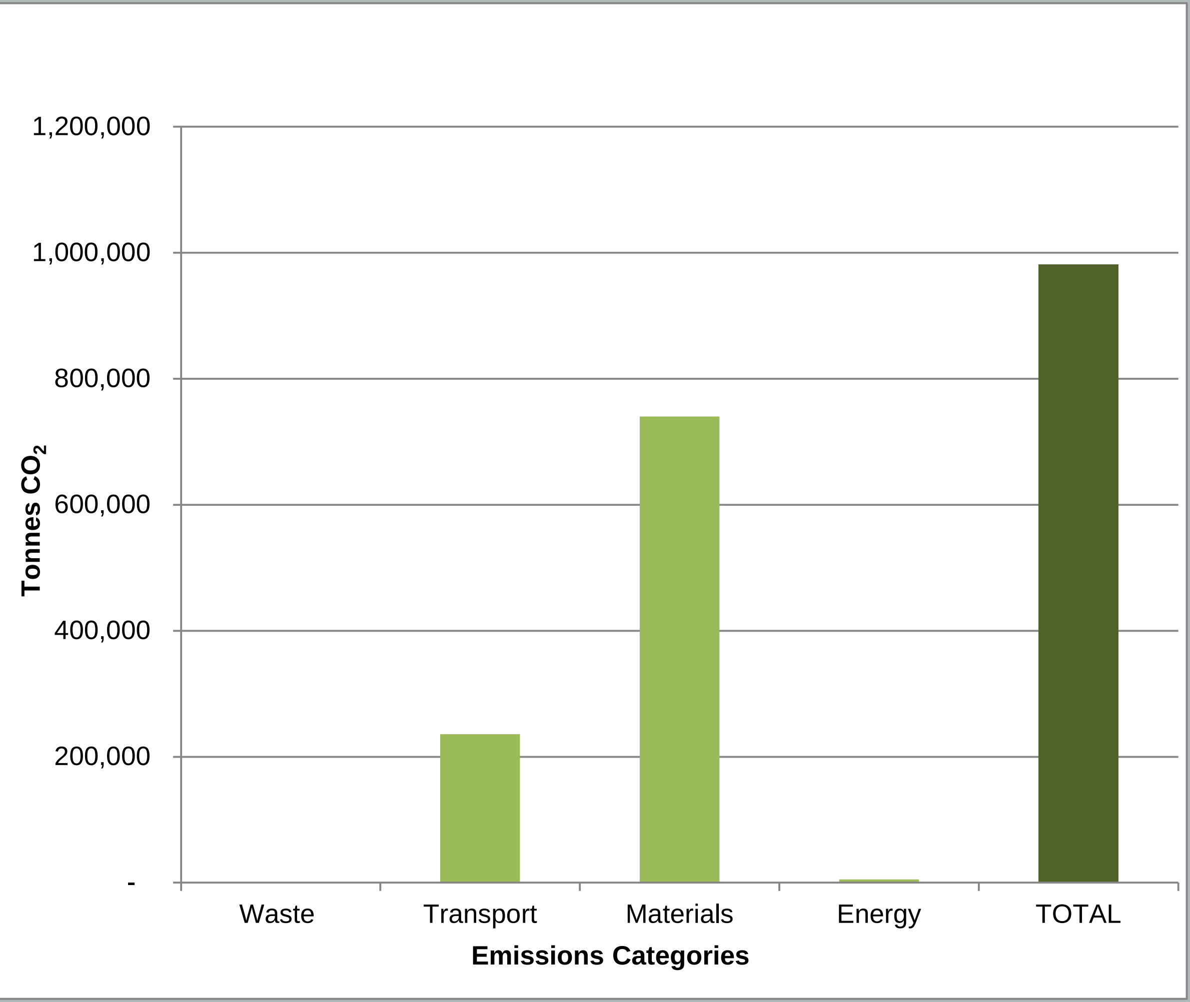
3.4.12 As shown in *Table 3.8* both energy and waste make up a very small proportion of the total project footprint.

3.4.13 These breakdowns can be seen in *Table 3.8* and *Box 3.1*.

**Table 3.8: Carbon footprint summary table**

| $CO_2$ category | Tonnes $CO_2$e | % proportion |
|---|---|---|
| **Waste** | 281 | 0% |
| **Transport** | 235,979 | 24% |
| **Materials** | 740,062 | 75% |
| **Energy** | 5,110 | 1% |
| **Total** | 981,432 | 100% |

**Box 3.1: Project carbon footprint**



# 4 Suggested interventions for construction

## 4.1 Introduction

4.1.1 Reporting and guidance, such as the *Infrastructure Carbon Review* (HM Treasury, 2013) and *Building a Sustainable Future* (ICE, 2011) indicate that the potential to influence carbon emissions decreases as a project progresses, from the most during the planning stage, to more modest reductions during design and construction. With this in mind, the key early intervention procedure, as identified in the *Infrastructure Carbon Review* (HM Treasury, 2013), can be considered to be:

- avoid and/or eliminate or 'build nothing': challenge the need; explore alternative approaches to achieve the desired outcome;
- reduce or 'build less': maximise the use of existing assets, optimise asset operation and management to reduce the extent of new construction required;
- substitute or replace or 'build clever': design in the use of low carbon materials, streamline the delivery process, minimise resource consumption;
- compensate or 'build efficiently': embrace new construction technologies, eliminate waste.

4.1.2 These principles can be applied both towards the scheme as a whole and also to individual design components.

4.1.3 In the first instance, use of significant quantities of high impact materials, (e.g. steel and aluminium), or processes (e.g. large amounts of excavation), should be avoided where practicable through alternative design specification. If this cannot be done, the amount of material or the length/intensity of the process should be reduced where functional specifications allow. Materials or processes should be substituted with lower intensity replacements, if possible within design standards for strength and safety. Finally, compensatory measures, such as carbon offsetting, should be considered where it is felt they would be cost effective.

## 4.2 Design and materials

4.2.1 Using the principle of avoidance and reduction, minimisation of material use should be sought. This would have the benefits of reducing the required construction materials, reducing the transport required for the construction, and potentially reducing the length of operation of plant. While this has informed the design at this stage, reductions in resource use should be secured where possible at the detailed design stage. This could be through the application of lean construction methods, which involves applying processes that reduce waste such as those described in *Lean Construction* (Constructing Excellence, 2004), or through application of sustainability principles through involvement with assessment schemes such as CEEQUAL, which considers physical material use and management.

4.2.2 Where it would not significantly impact upon engineering, safety and maintenance characteristics, the principle of substitution requires that low carbon alternatives for materials be considered.

4.2.3 At this stage of the design quantities of timber to be used on the scheme is not fully known. It is anticipated that timber would be reused to the full extent on-site, and that all non-reusable timber would be recycled. As such, no permanent embodied carbon impact would result.

4.2.4 No compensatory interventions have been identified at this stage, however the following Highways Agency case studies are presented:

- M25 widening: use of the "King sheet pile" profile reduced embodied carbon associated with the piling by 80%. Other savings were from reduced pavement thicknesses and from use of recycled aggregates;
- A21 Stocks Green Bypass embankment: use of electro-osmosis stabilisation technique, resulting in emissions 70% lower than granular fill and 40% lower than soil nail solutions; and
- A421 improvement scheme: heavy use of recycled materials, including 400,000 car tyres, 400,000 tonnes of pulverised fuel ash, and 450,000 tonnes of recycled aggregates, which were all used as embankment fill material. 30,000 tonnes of glass sand from recycled bottles was used for drainage bedding media.

4.2.5 Where water has been obtained as a result of excavation dewatering or rainwater capture, and there is no requirement to return such water (free of contaminants) to ground or watercourse (e.g. in sensitive environments or drought conditions), there is an opportunity to reduce mains potable water use. This is through the substitution of this water for appropriate construction uses (e.g. dust suppression, concrete batching or vehicle washing).

## 4.3 Transport and logistics

4.3.1 Using the principles of avoidance and reduction, where practicable, material use and the generation of waste should be avoided. This would reduce the transport required for construction and waste and spoil removal. A particularly large proportion of transport emissions are associated with staff commuting. With this in mind, measures to reduce the environmental impact of staff travel are included in a staff travel plan, which are a requirement in the *Code of Construction Practice (CoCP) (Appendix 20.2 of the ES)*. As referred to in the *CoCP*, sustainable staff travel plans would be put into place in order to lessen and reduce this impact. Measures to reduce independent driving mileage may include car sharing schemes, staff buses, and expansion of on-site accommodation may be appropriate, although the environmental impact of any measures should be considered as part of the travel plan. No assessment has been made of the impact this would have at this time.

4.3.2 Using the principal of substitution, alternative options should be explored for getting material to site and removing waste from site. The reduction of the required material transport distance should be a priority, for example through local sourcing. Another substitution that can be explored at an early stage is the use of biofuels in logistics. An investigation of the implications of requiring biofuel use in a contracted material transport road fleet should be undertaken in terms of the cost, air quality, and noise implications compared with the potential carbon emissions reductions.

4.3.3 No compensatory interventions have been identified at this stage.

## 4.4 Efficient use of plant

4.4.1 Using the principles of avoidance and reduction, the efficient use of plant and machinery should be maximised. This can be aided by requiring minimal idling of on-site equipment. This would reduce on-site fuel and electricity use, and the use of consumables associated with the equipment.

4.4.2 Using the principal of substitution, the use of biofuels for diesel plant should be investigated, in terms of the cost and resilience implications compared with the potential carbon emissions reductions.

4.4.3 No compensatory interventions have been identified at this stage.

## 4.5 General interventions

4.5.1 To add to the proposed carbon metrics it is recommended that decision points at which a carbon reducing action would be taken should be developed. This could be in the form of the two following metrics:

- $CO_2$e/£ change in cost; and
- $CO_2$e/operational lifespan of the completed road.

4.5.2 These metrics could allow decision makers to make consistent choices regarding interventions to be enacted.

# 5 Change in emissions in the operational phase

## 5.1 Emissions from traffic

### Data gathering and key assumptions

5.1.1 The mass emissions that are likely to result from the change in traffic due to the implementation of the scheme have been calculated as part of the regional air quality assessment, reported in *Chapter 8 of the ES*.

5.1.2 This assessment uses a standard approach to address the difference between the air quality that would be likely with the scheme (the 'do-something' scenario) and without the scheme (the 'do-minimum' scenario, in which changes such as growth in traffic, standard maintenance regimes, or known future changes in regulations or policy that are entirely independent of the scheme are predicted for the 'opening year' and the 'forecast year') for both the anticipated year of opening (2020) and 15 years after opening (2035). This air quality analysis includes $CO_2$ emissions, though other GHG, such as $CH_4$ and $N_2O$ were not outputs of the modelling.

5.1.3 To assess the potential impact of accounting for $CO_2e$ an analysis of the emissions factors for average cars as reported in the *Defra Conversion Factors Repository* was undertaken. It was found that for diesel cars the contribution of $CH_4$ and $N_2O$ to the total emissions is 0.98%, and for petrol cars the contribution is 0.36%. As there is no sufficient information on how this contribution would change over the lifetime of the scheme, it has been considered appropriate not to progress this analysis further.

5.1.4 The regional assessment in the *ES* presents total $CO_2$ emissions for the road network covered in the affected road network (ARN), in both do-minimum and do-something scenarios, and is based on modelled changes in number of vehicles, speed of vehicles and altered routes. It should be noted, however, that the methodology used only considers emissions within the ARN and so emissions due to the use of electric vehicles are not considered in either the do-minimum or the do-something scenarios.

5.1.5 The use of the traffic model has the advantage of wide network coverage, so all of the network effects of the proposed scheme are encompassed by the assessment. The methodology used to calculate emissions is consistent with many other road projects and it is recognised as the current best practice, and is described in more detail in *Chapter 8 of the ES*. In order to establish a total footprint over a 60 year period, the annual growth in emissions was extrapolated out to 2041, from when it was considered to remain static.

5.1.6 It is possible that the carbon intensity of road transport may reduce in the future, however the forecast fuel efficiency improvements and forecast proportions of electric vehicles, are not available beyond 2035 (Department for Transport, 2014). There is potential for ultra-low emission vehicles such as electric vehicles, plug-in hybrids and fuel cell vehicles to play an increasing role in road transport, however as this is not forecast within the inputs used for *Chapter 8 of the ES* this is not considered further in this chapter. The development of the scheme is not in itself considered to have a significant effect on the adoption of low emission vehicles.

### Results

5.1.7 The findings of this assessment indicate an increase of 34,263 tonnes per year of $CO_2$ emissions between the do-minimum and do-something scenarios in 2020. This is estimated to rise to a difference of 68,238 tonnes per year of $CO_2$ in 2035. To put these values into context: the annual road transport emissions for Cambridgeshire, as estimated through traffic levels, were 1,784kt$CO_2$ in 2012 (*DECC, 2014*). Therefore the calculated increases in the do-something scenario for 2035 are roughly equivalent to 3.8% of Cambridgeshire's current road transport emissions.

5.1.8 Key values for the additional carbon are displayed in *Table 5.1*. *Table 5.1* shows that the scheme enables an increase in annual $CO_2$ emissions to the A14 and ARN of approximately 6.9% more than the do-minimum level by 2020 and 12.4% more than the do-minimum level by 2035.

**Table 5.1: Additional annual carbon emissions due to traffic**

| | Additional t$CO_2$ / yr | Additional $CO_2$ per year (%) |
|---|---|---|
| **Opening year (2020)** | 34,263 | 6.9 |
| **Forecast year (2035)** | 68,238 | 12.4 |

5.1.9 The total estimated emissions due to traffic are displayed in *Table 5.2*. If $CH_4$ and $N_2O$ were accounted for it could represent between 15,791 t$CO_2$e and 42,987 t$CO_2$e, depending on the proportion of petrol, diesel and electric vehicles. The estimated total increase represents a change of 13.1% over the baseline emissions.

**Table 5.2: Carbon emissions due to traffic**

| | t$CO_2$ |
|---|---|
| **Do minimum, over 60 year period** | 33,429,610 |
| **Do something, over 60 year period** | 37,816,054 |
| **Total additional t$CO_2$, over 60 year period** | 4,386,445 |

5.1.10 The *Draft National Policy Statement for National Networks* (Department for Transport, 2013) states that:

> *"while, considered in isolation, individual schemes may result in an increase in $CO_2$ emissions, the Government's overarching plan for reducing carbon emissions will ensure that any such increases do not compromise its overall $CO_2$ reduction commitments."*

## 5.2 Emissions due to the use of operational energy

### Data gathering and key assumptions

5.2.1 Emissions would arise from energy required for highway lighting and ITS technology such as signage and CCTV cameras. These emissions would occur at energy generation facilities and would be dependent upon the energy source mix used in generation at the time.

5.2.2 An estimate has been made of the change in energy usage as a result of the do-something scenario, utilising the additional lighting capacity at key sections of the scheme. The estimate also incorporates the removal of a total of 454 existing lighting columns, to be removed from the following locations: Brampton Hut Junction (6), Girton Interchange (213), Milton Junction (15), Swavesey Junction (50), Bar Hill Junction (18), Hatton's Road area (27), A1307 Huntingdon Road (50), Histon Junction (15), and Huntingdon Town Centre (60).

5.2.3 The total increase in lighting energy usage as a result of the proposed scheme is calculated to be 613,256 kilowatt hours per annum under standard operation (on at dusk, off at dawn). Additionally, it is acknowledged that it is an aspiration of the scheme that Highways Agency road lighting is connected to the Motorway Road Lighting Control System (MORLICS) to enable the lighting output to operate only as much as required, referred to as 'variable operation'. An estimate of the energy consumption of operating on this variable basis indicates a reduction of the energy consumption compared to standard operation of 42%.

5.2.4 The additional power usage of the scheme is shown in *Table 5.3*.

**Table 5.3: Additional lighting power usage across the scheme**

| Location | Total location power (kW) | Standard operation | Variable operation |
|---|---|---|---|
| | | Total usage per annum (kW) | Total usage per annum (kW) |
| **Areas under the adoption of the Highways Agency** | | | |
| Ellington Junction | 6.52 | 27,077 | 15,795 |
| Brampton Hut Junction | 1.68 | 6,986 | 4,075 |
| Brampton Interchange | 27.03 | 112,189 | 65,444 |
| A1198 Junction | 0.92 | 3,836 | 2,237 |
| Swavesey Junction | 2.46 | 10,228 | 5,966 |
| Bar Hill Junction | 3.08 | 12,785 | 7,458 |
| Girton Interchange | 54.59 | 226,595 | 132,180 |
| Histon Junction | 4.28 | 17,746 | 10,352 |
| Milton Junction | 1.89 | 7,833 | 4,569 |
| **Subtotal** | **102** | **425,274** | **248,077** |
| **Areas under the adoption of Cambridgeshire County Council** | | | |
| B1514 Buckden Road | 1.68 | 6,961 | 4,061 |
| A1198 Junction | 3.49 | 14,470 | 8,441 |

| Location | Total location power (kW) | Standard operation | Variable operation |
|---|---|---|---|
| | | Total usage per annum (kW) | Total usage per annum (kW) |
| Swavesey Junction | 10.62 | 44,075 | 25,711 |
| Robins Lane | 1.88 | 7,796 | 4,547 |
| Bar Hill Junction | 5.33 | 22,117 | 12,901 |
| Hatton's Road area | 4.84 | 20,091 | 11,720 |
| Dry Drayton Road | 4.15 | 17,227 | 10,049 |
| A1307 Huntingdon Road | 11.31 | 46,944 | 27,384 |
| Histon Junction | 2.00 | 8,302 | 4,843 |
| Milton Junction | 1.79 | 7,439 | 4,339 |
| Huntingdon town centre | 15.94 | 66,146 | 38,585 |
| **Subtotal** | **45** | **187,982** | **109,656** |
| **Total** | **147** | **613,256** | **368,420** |

5.2.5 The scheme has progressed on the basis that a light emitting diode (LED) source would prove most efficient for Highways Agency routes, as increasingly utilised on the strategic road network. This assumption is incorporated into the power usage, which is shown in *Table 5.3*.

5.2.6 Similarly, information on the electricity usage of particular ITS equipment is limited. In order to establish the significance of ITS equipment the energy use of the CCTV equipment was calculated. A conservative value of 20 watts was used as the energy draw of the cameras, as given by *Power Consumption and Environmental Impact of Video Surveillance Systems* (Connexed Technologies; no date), though some cameras can draw as little as five watts.

5.2.7 To estimate the carbon emissions associated with lighting and ITS equipment, the estimated annual energy usage of 623,943 kWh (with standard operation) and 368,420 kWh (with variable operation) has been multiplied by the grid-average, consumption-based, commercial/public sector electricity emissions factors for the respective years, as reported in Table 1 of the *Green Book supplementary guidance, Tables 1-20: supporting the toolkit and the guidance* (DECC, 2014). The assessment was progressed on the assumption that there are no efficiency improvements so as to produce a worst-case assessment; however no consideration has been made for efficiency loss over time; given appropriate maintenance and the use of LEDs this can be considered negligible.

5.2.8 In order to produce a sensitivity representing the worst-case, this calculation was also run with the assumption that the emissions factor does not decrease from 2020 (opening year) levels.

## Results

5.2.9 *Table 5.4* presents the total additional carbon emissions expected due to energy use for lighting and CCTV on the scheme. This is a conservative estimate as it assumes standard operation of the lighting, rather than the variable operation which would reduce energy consumption by 255,523 kWh per year. The emissions due to energy use are low in comparison to emissions due to traffic. This is particularly the case in later years of the scheme, where the decarbonisation of grid electricity lowers the factors applied to the energy used. The worst-case sensitivity, using the 2020 emissions factor, results in far greater emissions associated with the scheme.

5.2.10 CCTV usage accounts for less than 4% of the total energy use of both lighting and CCTV energy usage, which itself is just 0.02% of the annual operational emissions.

**Table 5.4: Additional long term carbon emissions due to energy use**

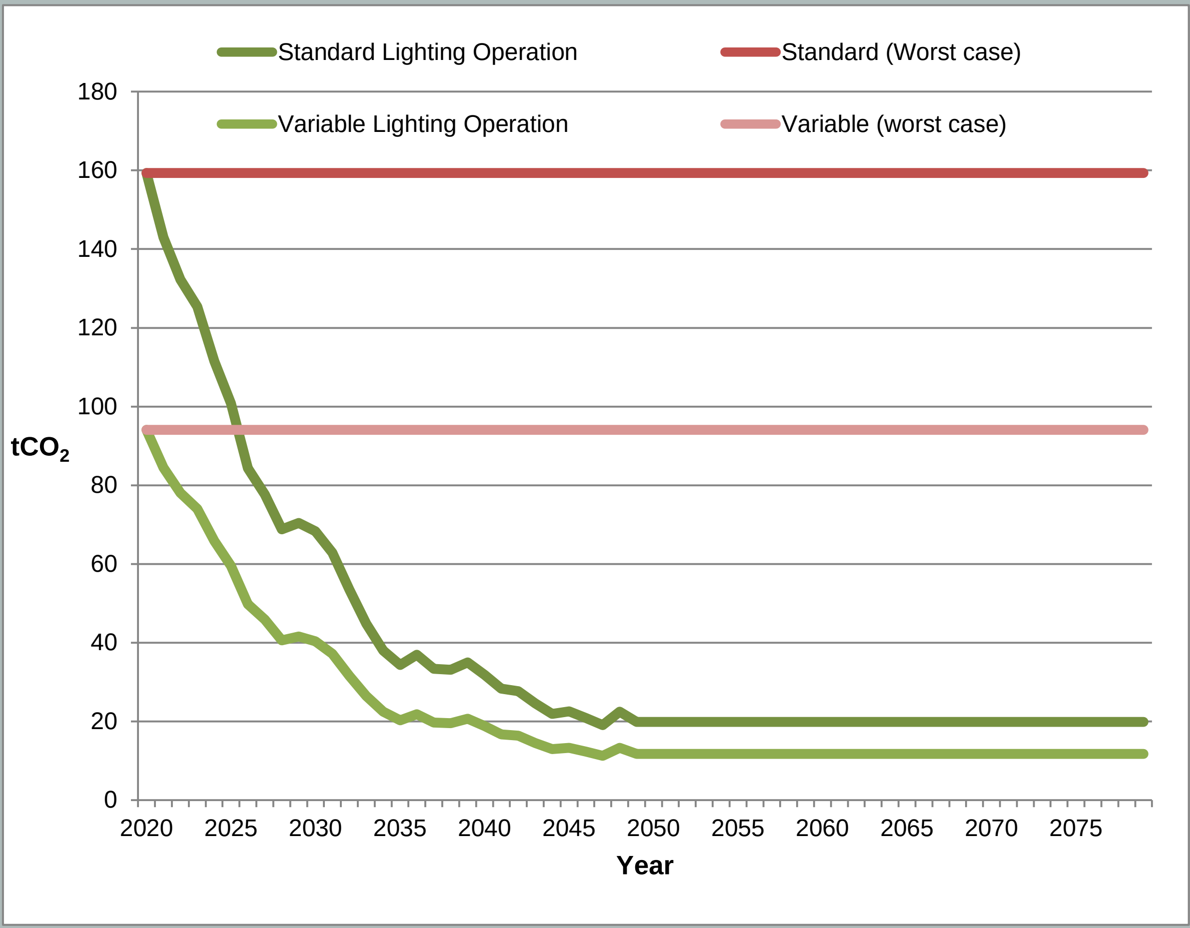
| | Additional $tCO_2e$ over period |
|---|---|
| **30 year period** | 1,752 |
| **60 year period** | 2,350 |
| **30 year period (worst case)** | 4,781 |
| **60 year period (worst case)** | 9,562 |

5.2.11 *Table 5.5* shows that emissions due to energy use are concentrated at the front-end of the scheme lifetime, with the annual emissions dropping by over 70% between the opening year of 2020 and the forecast year of 2035 due to forecast electrical grid decarbonisation. This change over time is also presented in *Box 5.2,* which shows results for both the standard operating mode and with variable operation, under both the forecast emissions factors and the worst-case 2020 emissions factor.

**Table 5.5: Additional annual carbon emissions due to energy use**

| | Additional $tCO_2$ / yr |
|---|---|
| **Opening year (2020)** | 159 |
| **Forecast year (2035)** | 34 |

**Box 5.2: Additional $tCO_2$ per year due to energy use**



# 6 Suggested interventions for the operational phase

## 6.1 Introduction

6.1.1 The methodology for identifying operational savings is the same as that described for construction.

## 6.2 Traffic

6.2.1 Interventions related to the emissions generated by traffic should be considered in the light of overall scheme objectives, safety and design standards. Where practicable, interventions should be considered to reduce journey length, optimise speed, and reduce any stop-start impacts that increase emissions per vehicle. Studies show that emissions from vehicles are related to their speed and acceleration, with a smoothing of 'stop-and-go' patterns associated with a reduction of $CO_2$ emissions (Barth, M; and Boriboonsomsin, K., 2009).

6.2.2 The scheme design includes ITS, which would regulate flows, reduce congestion and improve traffic reactions to road incidents. The smoother flows and reduced congestion delivered by such systems reduces emissions per vehicle. Should technological advances in emission-saving features of ITS become available, consideration should be given to upgrading where feasible and economical. If correctly implemented, *The potential of Intelligent Transport Systems for reducing road transport related greenhouse gas emissions* (European Commission, 2009) confirms that ITS has significant potential to reduce GHG emissions.

## 6.3 Energy use

6.3.1 Consideration of whole life costs, including the carbon impact, should be made when selecting lighting solutions for the scheme, and other energy drawing technology. This should be reviewed when the relevant infrastructure reaches the end of its operational life, in order to ensure that the best solution is chosen even as technologies change.

# 7 Bibliography


Barth, M; and Boriboonsomsin K, 2009. Traffic congestion and Greenhouse gases. Access 35. Available at: http://www.uctc.net/access/35/access35_Traffic_Congestion_and_Grenhouse_Gases.pdf Accessed: 17 November 2014

Cambridge Water, 2014. "How much water do you use?" Available at: http://www.cambridge-water.co.uk/customers/how-much-water-do-you-use Accessed: 25 September 2014

Connexed Technologies, (n.d.), Power Consumption and Environmental Impact of Video Surveillance Systems

Constructing Excellence, (2004). Lean Construction Fact Sheet. Available at: http://www.constructingexcellence.org.uk/pdf/fact_sheet/lean.pdf Accessed: November 2014

Construction Industry Joint Council (2013). Working Rule Agreement for the Construction Industry Available at: https://www.ucatt.org.uk/files/publications/2013cijcagreement.pdf Accessed: 17 November 2014

Climate Change Act 2008, Available at: http://www.legislation.gov.uk/ukpga/2008/27/contents Accessed: 23 October 2014

DECC Interdepartmental Analysts Group (2014), Green Book supplementary guidance, Tables 1-20: supporting the toolkit and the guidance.

DECC (2014). Local and regional CO2 emissions estimates for 2005-2012: full dataset. Available at: https://www.gov.uk/government/statistics/local-authority-emissions-estimates Accessed 23 October 2014

Defra (2014). Greenhouse Gas Conversion Factor Repository. Available at: http://www.ukconversionfactorscarbonsmart.co.uk/ Accessed: 17 September 2014

Defra Research and Development (2011) A review of local authority road lighting initiatives aimed at reducing costs, carbon emissions and light pollution.

Department for Transport (2013). Draft National Policy Statement for National Networks. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263720/consultation-document-draft-national-policy-statement.pdf Accessed 13 October 2014

Department for Transport (2014). WebTAG: TAG data book, November 2014. Available at: https://www.gov.uk/government/publications/webtag-tag-data-book-november-2014 Accessed 13 November 2014

European Commission (2009). The potential of Intelligent Transport Systems for reducing road transport related greenhouse gas emissions Available at: http://ec.europa.eu/enterprise/archives/e-business-watch/studies/special_topics/2009/documents/SR02-2009_ITS.pdf Accessed 12 November 2014

GHG Protocol (2004) The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard (Revised Edition), World Business Council for Sustainable Development, World Resources Institute.

GHG Protocol (2012) Construction CO2e Measurement Protocol. Available at: http://www.ghgprotocol.org/files/ghgp/ENCORD-Construction-CO2-Measurement-Protocol-Lo-Res_FINAL.pdf Accessed 12 November 2014

Highways Agency, Parsons Brinkerhoff and WSP Group (2009) Highways Agency Carbon Calculation Tool – Instruction Manual – version v5c December 2009. Available at: http://assets.highways.gov.uk/specialist-information/major-projects-knowledge-sharing-ha-carbon-calculation/CCT-Instruction_Manual-MP-v5c.pdf Accessed 16 September 2014

Highways Agency (2009). Carbon Calculation Methodology. Available at: http://www.highways.gov.uk/about-us/sustainability/carbon-calculation-methodology/ Accessed 17 September 2014

Highways Agency (2009). Major Projects HA Carbon Calculation Instruction Manual. Available at: http://www.highways.gov.uk/publications/major-projects-knowledge-sharing-ha-carbon-calculation/ Accessed 17 September 2014

Highways Agency (2013). Annual Report and Accounts 2012-2013 Available at: https://www.gov.uk/government/publications/the-highways-agency-annual-report-and-accounts-2012-to-2013 Accessed 13 November 2014

Highways Agency (2013). Business Plan 2013 – 14. Available at: http://assets.highways.gov.uk/about-us/corporate-documents-business-plans/S120450_Highways_Agency_Business_Plan_2013-14.pdf Accessed 16 September 2014

Highways Agency (2012). Sustainable development plan 2012 – 2015. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/341242/HA_sustainable_development_plan_2012_2015.pdf Accessed 14 November 2014

Highways Agency (2013) Carbon data analysis and verification: Findings Report. Available at: http://assets.highways.gov.uk/specialist-information/knowledge-compendium/2011-13-knowledge-programme/NPPD_SustED_HA_Arup_Carbon_Review_Findings_Report_Issue_20130916.pdf Accessed 13 November 2014

Highways Agency (2013). Major Projects HA Carbon Calculation Spreadsheet version 5e (January 2013). Available at: http://www.highways.gov.uk/publications/major-projects-knowledge-sharing-ha-carbon-calculation/ Accessed 17 September 2014

KPIZone (2009). UK Construction Industry Benchmarks 2009.

Office of National Statistics (2011). Key Performance Indicators in the Construction Industry, Construction Statistics - Chapter 16 - Key Performance Indicators and Benchmarking, No. 12, 2011 Edition. Available at: http://www.ons.gov.uk/ons/taxonomy/index.html?nscl=Key+Performance+Indicators+in+the+Construction+Industry Accessed 14 November 2014

Transport Research Laboratory, 2014. PPR666 The Specification for Low Temperature Asphalt Mixtures. Available at: http://www.trl.co.uk/umbraco/custom/report_files/PPR666.pdf Accessed 14 November 2014

University of Bath (2011). Inventory of Carbon and Energy (Version 2.0)

WRAP (Waste and Resources Action Plan). Resource efficiency benchmarks for construction projects. Available at: http://www.wrap.org.uk/content/resource-efficiency-benchmarks-construction-projects-0 Accessed 30 October 2014