HIGHWAYS AGENCY

Safe roads, reliable journeys, informed travellers

Highways Agency Carbon Routemap

Opportunities for a national low carbon transportation system

ARUP

Working on behalf of the Highways Agency

An executive agency of the Department for Transport

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Executive Summary

The Highways Agency is proud of the steps it has taken in making sustainability an important consideration across the organisation. The Agency's sustainable development plan supports the organisation's strategic vision to be the world's leading road operator. Within the principle of being a sustainable Highways Agency, is the performance aspect to *"be a low footprint organisation, both in the services we deliver and in our workplace behaviours."*

Central to this principle is the agenda of climate change and the defining environmental challenge that it represents. In 2013 the Highways Agency (HA) commissioned Arup to carry out an independent review of their 'Carbon data analysis and verification' framework. The review contributed to the on-going efforts by the Agency to make the most meaningful contribution to the UK Government target of 80% reduction in greenhouse gas emissions vs. 1990 levels by 2050. Within this context the study found the scope of the Agency's on-going carbon accounting to be in line with industry guidance, and exceeding the Government's minimum requirements. In conclusion it recommended that to strengthen these achievements and manage its position with regard to climate change risk, the Agency must move from greenhouse gas (GHG) emissions measurement to the challenge/opportunity of emissions management.

Such a complex objective needs detailed consideration and in particular, how the Highways Agency can most meaningfully contribute to the development of a nationwide low carbon transportation system. The purpose of this project has been to meet this ambition and develop a strategic carbon model to 2050 and a Highways Agency low carbon Routemap to aid the Agency with its forward planning on GHG emissions management and reduction.

The outcome of this work provides the Highways Agency with a bespoke and detailed tool to create scenarios of estimated GHG emissions trajectories to 2050, and the ability to explore the priorities, decisions, and actions that will be necessary for the Agency to manage its GHG emissions and work to reduce these out to 2050. In this regard the Routemap has been developed to complement the Highways Agency's existing framework of carbon tools, guidance and processes already in place.

The deliverables of the work forming the Highways Agency carbon Routemap are this report, a carbon calculation model and a supporting infographic. It is anticipated that these will be used:

- as tools to enable the HA to move beyond the measurement of GHGs to the opportunity of planned carbon management that is aligned with industry best practice
- as evidence to support the strategic planning and decision-making necessary for carbon emissions reductions
- to identify carbon hot spots, enabling the prioritisation of issues and bringing focus to actions
- as an aid to unlock the synergy between climate change mitigation and opportunities for cost reduction, energy and material efficiency and help the Agency respond to the Treasury's Infrastructure Carbon Review

- as a reference source and visual aid for stakeholder dialogue within the HA, to its professional peers, and to network users/customers

This Routemap is unique in modelling the climate change impacts and risks of a national infrastructure provider in the breadth and depth it provides.

Scope of the Highways Agency carbon Routemap

The Routemap covers the direct and indirect GHG emissions associated with the Agency's organisational activity, the highway asset base and associated supply chain, and those arising from the use of the network by customers. To aid with communicating this scope, three emissions categories are used throughout the report:

- Corporate (Organisational) carbon emissions: the direct and indirect emissions associated with the operation of the strategic road network (SRN) by the Highways Agency.
- Asset base carbon emissions: the emissions arising as a result of construction and maintenance activity of the strategic road network and the supply chain that exists to deliver this (i.e. those emissions effectively embodied within the SRN).
- Road user carbon emissions: the emissions arising from the use of the SRN by parties other than the Highways Agency and its partners, i.e. the public / the Agency's customer base.

The Highways Agency carbon Routemap covers the period 2013 to 2050 and takes as its baseline position in 2013 carbon emissions based on historically measured or calculated data gathered over the period 2009 to 2013.

In projecting forward, three future scenarios to 2050 are created from a combination of historic trends, published forecasts and benchmarks, modelled dependencies and expert knowledge of key drivers of carbon emissions. These scenarios are:

1. Baseline: a reference scenario with low technology take up and when the HA is not proactive in its efforts to meet the low carbon agenda.
2. HA's current trajectory: intended to represent as closely as possible the Agency's current trajectory where by technology take up is low, although the Agency is proactive within the low carbon agenda.
3. An intelligent[1] low carbon transport system: this scenario combines high technology take up with a transformation of the SRN into an intelligent, low carbon transport system, and where the HA is proactive in meeting the low carbon agenda.

The Routemap carbon calculation model also allows the user to change variables within scenarios (for example: the proportion of electric cars on the SRN network; or the reduction in carbon intensity of asphalt production). The model has over 360 control levers that a user can adjust to create their own bespoke scenarios out to 2050.

[1] See Section 4.3 for fuller description of "intelligent".

Key findings

The 2013 GHG emissions arising from construction and maintenance of the SRN and its associated supply chain are over double that of the Highways Agency as an organisation itself. Taken together both are small when considering SRN use which accounts for emissions some 90 times greater than the combined asset and organisational emissions.

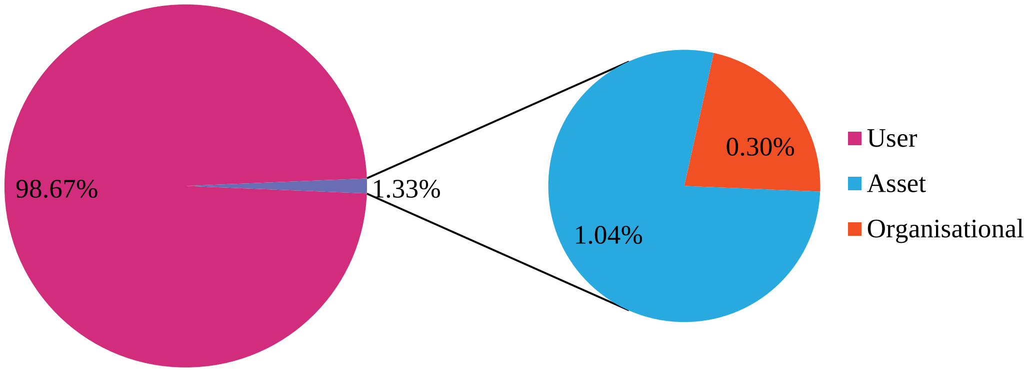


Figure 1. Relative scaling of organisational (0.09 $MtCO_2e$), asset base (0.33 $MtCO_2e$) and road user carbon emissions (31.41 $MtCO_2e$) in 2013. Note that the pie chart percentage splits represent a sum total 100% of these emission contributions in 2013.

Further analysis of the Routemap suggests:

Corporate /organisational carbon emissions: are made up of a range of component parts (estate buildings, water use, office procurement, business travel, etc.) but are largely weighted by network energy demand particularly lighting. They therefore see a marked reduction in all scenarios due to assumed energy grid decarbonisation. Set against this context is the likelihood that electricity bills will increase in order to fund the electricity grid’s decarbonisation. This makes it a priority that the Highways Agency should continue its efforts towards reducing electrical demand in order to minimise its exposure to energy price increases. Additionally, demand reduction is a key contribution to national grid decarbonisation in itself, making it less expensive to install the necessary infrastructure.

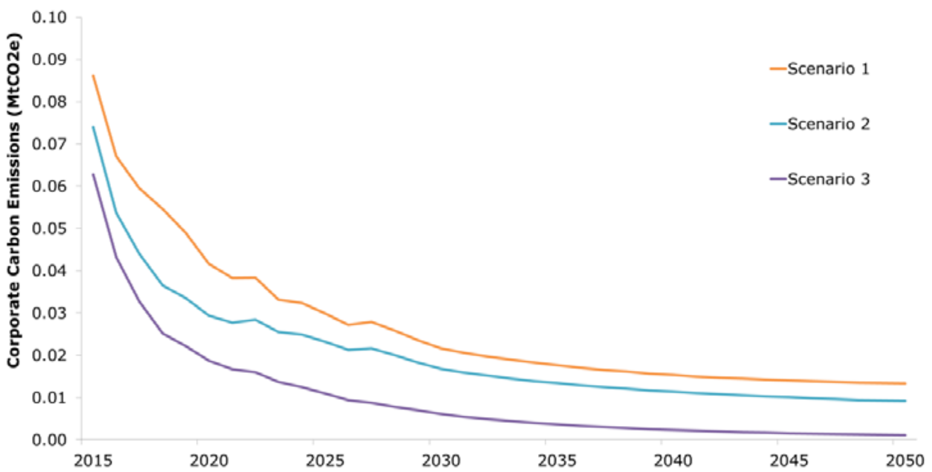


Figure 2. Corporate/organisational carbon emissions profiles for the Highways Agency.

Asset base carbon emissions: in 2013 are some three times higher than corporate emissions and show a marked increase in the short term in line with the Highway Agency's planned budget. This means emissions from construction are projected to almost double over the next five years from 0.5 $MtCO_2e$ in 2014 to over 1.2 $MtCO_2e$ by 2020. Thereafter expenditure is assumed to level off and run steady to 2050. Overall the trend is of slow decline and the construction supply chain remains a significant carbon emitter for the Highways Agency out to 2050. This anticipated short term sharp increase is of particular concern when set against the priority of keeping atmospheric carbon dioxide concentrations within a global budget of less than 450ppm. This pending climate change risk is an issue that the Highways Agency should move to manage and address directly through taking mitigating efforts in the short term.

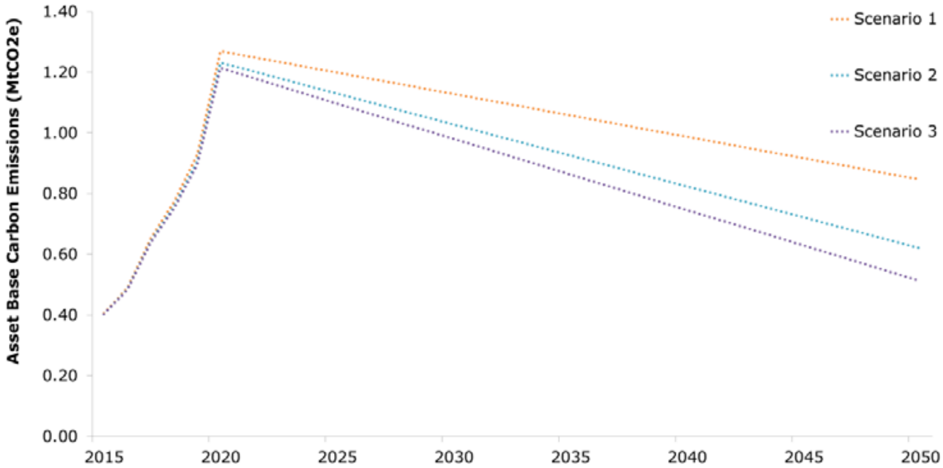


Figure 3. Asset base carbon emissions profiles for the SRN.

Road user carbon emissions: are an order of magnitude greater than those arising from asset base /supply chain carbon emissions. In scenario 1 trends in travel demand overwhelm the Agency's efforts to manage speed and congestion, and vehicle drive trains see only modest improvements in carbon efficiency through to 2030. Under the assumptions of this scenario, there is almost no net reduction in road user emissions by 2050.

Scenario 2 takes into account improvements that the Highways Agency can implement through a degree of roll out of smart motorway technology and improvements to congested links leading to a significant 2.9 $MtCO_2e$ emissions saving.

Scenario 3 sees substantial change in drivetrain mix of vehicle stock on the road together with efficiency improvements to current technology norms. Smart motorways would be rolled out to most of the network and 'mile a minute' average speeds are realised for all links on the motorway and trunk A-road network. This aspect in particular will require a proactive approach by the Highways Agency enabling the transition to smart motorways with focus on construction initiatives alleviating congestion and adapting the base infrastructure system, together with shifts in operational approaches to traffic management. Overall, this results in an 83% reduction (some 25.5 $MtCO_2e$) by 2050. The conclusion is that with targeted action on the roll–out of smart motorways and works to ease bottlenecks, the Highways Agency can deliver significant impact to the creation of a national low carbon transportation system.

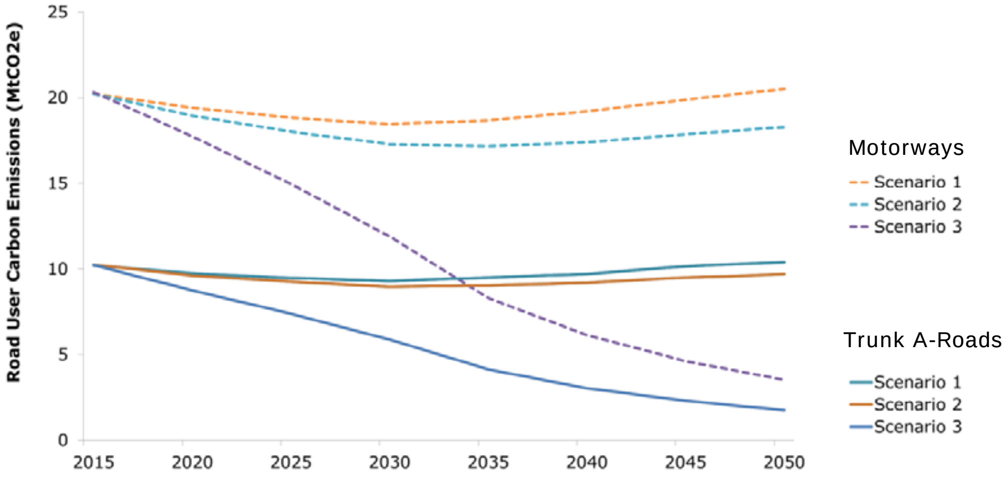


Figure 4. Road user carbon emissions split between motorway and trunk A-road allocations.

Next steps

The publication of this low carbon Routemap positions the Highways Agency as a leader in understanding the climate change impacts of the national highway system. Although the Highways Agency may have less influence within this sphere than it might like, the work has broken new ground in measuring the scale of emissions, identifying where they reside, and determining what will need to happen if we are to meet national reduction commitments.

As a major infrastructure provider the Highways Agency is entering an exciting new phase that will radically change the way strategic roads are funded and managed. The opportunity of this transition is to use the low carbon Routemap to bring about change to the way climate change is dealt with when delivering critical national infrastructure.

In this way the challenge of climate change can be met head on. Aspirations should be set high for the Highways Agency has a solid base of evidence and a functional carbon framework from which to build. By extending its remit to emissions management, and harnessing existing relationships and partnerships, the short term opportunity is to:

- Continue the drive to reduce electrical demand across the HA estate and the SRN mitigating carbon emissions and reducing the risk of increased electricity bills
- Move to engage and manage carbon emissions from the construction value chain /supply base as expenditure on projects increases in the next period
- Use the carbon Routemap as a means to inform action towards a national low carbon transportation system

As the Treasury Infrastructure Carbon Review (2013) shows, the right approach will deliver efficiencies and cost savings at the same time.

Glossary of terms

Agency	Highways Agency
Capital carbon	All GHG emissions associated with construction and demolition activities in the United Kingdom, including those embodied within imported construction materials and products, and those associated with the provision of professional support services (e.g. architecture and engineering).
CCC	Committee on Climate Change
CRC	CRC Energy Efficiency Scheme (formerly known as the Carbon Reduction Commitment)
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CDF	Collaborative Delivery Framework
DCLG	UK Department for Communities and Local Government
DECC	UK Department for Energy and Climate Change
Defra	UK Department for the Environment, Food, and Rural Affairs
DfT	Department for Transport
Direct emissions	GHG emissions resulting from on-site combustion of hydrocarbons for the purposes of space heating and hot water
DBFO	Design, Build, Finance and Operate
GCB	Green Construction Board
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
HA	Highways Agency
HGV	Heavy Goods Vehicle
ICT	Information Communications Technology
Indirect emissions	GHG emissions resulting from the off-site combustion of fossil fuels to provide for energy demands (electricity) in buildings
LED	Light Emitting Diode
LGV	Large Goods Vehicle
MtCO2e	Mega (million) Tonnes of Carbon Dioxide Equivalent, a standard measure of GHG emissions
MRIO	Multi-Region Input-Output
MP	Major Project
MAC	Managing Agent Contractor
ONS	Office for National Statistics
OGV	Other Goods Vehicle

Operational carbon	All direct and indirect GHG emissions arising from consumption of energy for the uses and sectors defined as being part of the built environment for the purposes of this study.
SIC	Standard Industrial Classification (code)
Scope I, II, III	This refers to the three classes of GHG emissions as reported under the Greenhouse Gas Protocol. Scope I emissions are direct GHG emissions. Scope II emissions are indirect GHG emissions resulting from purchased electricity, heat or steam. Scope III emissions are other indirect GHG emissions such as those associated with the extraction and production of purchased materials and fuels, and other activities not directly controlled by the reporting entity.
SRN	Strategic Road Network (SRN) in England
SON	High pressure Sodium lamps
SOX	Low pressure Sodium lamps
TO	Traffic Officer
TSGB	Transport Statistics Great Britain (TSGB)
TW	Terawatts; a unit of power equal to 1,000GW or 1,000,000MW
TWh	Terawatt hours; a unit of energy

1 Project introduction

The Highways Agency is proud of the steps it has taken in making sustainability an important consideration across the organisation. The Agency's sustainable development plan supports the organisation's strategic vision to be the world's leading road operator. Within the principle of being a sustainable Highways Agency, is the performance aspect to *"be a low footprint organisation, both in the services we deliver and in our workplace behaviours."*

Central to this principle is the agenda of climate change and the defining environmental challenge that it represents. The Agency is working to address this challenge and make the most meaningful contribution to the UK Government target of 80% reduction in greenhouse gas (GHG) emissions vs. 1990 levels by 2050, a target which is backstopped in legislation by the Climate Change Act (2008).

Within this context the scope of the Agency's current carbon accounting is in line with industry guidance, and exceeds the Government's minimum requirements. But to strengthen these achievements and manage its position with regard to climate change risk, the Agency must move from GHG emissions measurement to the challenge/opportunity of emissions management.

However, such a complex objective needs detailed thought as it would be easy to set counterproductive goals focused on direct responsibilities, when in reality the goal must be towards how the Highways Agency can most meaningful contribute to the development of a UK wide low carbon transportation system.

This project has been undertaken in support of meeting this ambition and developing a strategic carbon model to 2050 and a Highways Agency low carbon Routemap to aid the Agency with its forward planning on GHG emissions management and reduction.

1.1 The purpose and opportunity of the Highways Agency carbon Routemap

In 2013 the Highways Agency commissioned Arup to carry out an independent review of their 'Carbon data analysis and verification' framework. The review formed part of a wider study by the Agency to strategically plan to make the most meaningful contribution to the UK Government target of 80% reduction in greenhouse gas emissions vs. 1990 levels by 2050.

The initiative presented here in has been conducted to further support this goal. It is complementary to the framework of tools, guidance and processes the Agency has already put in place.

The goal has been to add another dimension to the Agency's carbon narrative by proactively forecasting how the Agency's emissions will change over time, incorporating and bringing together an understanding of GHG emissions arising from the organisation, the highway asset base, and the use of the Strategic Road Network (SRN). The benefits this brings are many and include:

- A tool to move beyond the measurement of GHG to the opportunity of planned carbon management that is aligned with industry best practice

- An evidence base to support strategic planned decisions for carbon emissions reductions
- The identification of carbon hot spots, enabling the prioritisation of issues and bringing focus to actions
- An aid to unlock the synergy between climate change mitigation and opportunities for cost reduction, energy and material efficiency and help the Agency respond to the Treasury's Infrastructure Carbon Review
- A reference source and visual aid for stakeholder dialogue within the Highways Agency, to its professional peers, and to network users/customers

1.2 How to read this report

This report has been prepared as a final output providing a supporting factual report to accompany the Highways Agency carbon Routemap model. These two project components (technical report and carbon Routemap model) together with a presentational infographic form the deliverables of the project. This report is organised into seven technical sections covering:

Project approach: an overview of how the study has been conducted and key working steps (see Section 2).

Study scope and boundaries: a description of the boundaries of the 'Highways Agency carbon Routemap' as applied by the model and of how the scope of organisation, asset base and road user emission are organised to Scope 1, 2 and 3 GHG emission categories (see Section 3).

Future scenario descriptions: the model is primed with three scenarios to 2050 including a strategy for a low carbon transport system. This section provides a narrative of the scenarios (see Section 4).

Findings: a detailed review and summary of results for each of the Highways Agency low carbon Routemap reporting modules is provided (see Section 5).

Overall perspectives: a summary narrative of headline perspectives from the Highways Agency low carbon Routemap is provided (see Section 6).

Recommendations: for further work to improve the quality, reliability and use of the model. The section focuses on technical data and modelling approaches (see Section 7).

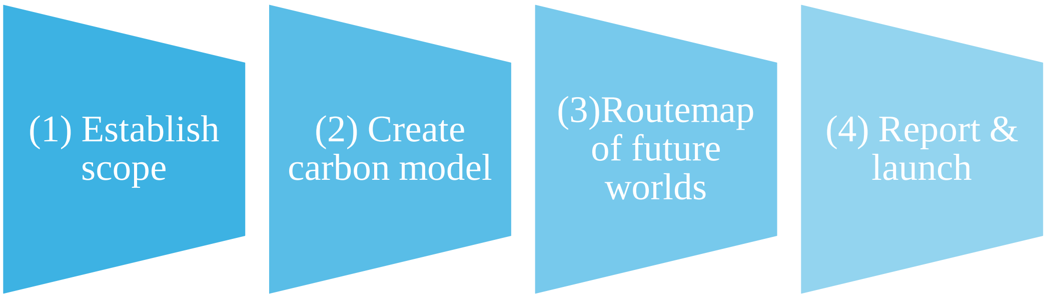
Carbon model approach: provided in the report Appendix is a detailed description of the method applied to create the carbon model, including underlying assumptions, justifications, and evidence and source data references. This section also provides a complete listing of the variables that a user can apply to control the model and run scenarios. Default values that describe each scenario are also noted (see Appendix A).

2 Project approach

The project has been developed over four sequential steps each building on the next in creating the strategic carbon model and a Highways Agency low carbon Routemap.

The working approach has required intense cooperation between Arup and the Highways Agency with true multidisciplinary input from highways engineers, strategic network planners, climate change /carbon analysts, traffic modellers, organisational accountants, major project specialists, intelligent transport system expertise and sustainability specialists.

Significant effort has gone into providing the Routemap model and its calculation approach with data and information that has come from the Highways Agency, and which is consistent with its outlook.



Once the study boundaries had been defined (1), the team could then set about establishing the carbon Routemap model based on best available data (2). A horizon scanning workshop was then held to explore with the Highways Agency what the future might entail, and how this would impact on their operations and the use of the SRN (3). This was used to define default future scenarios, and therefore generate within the scope of the Routemap model, estimated carbon emissions which form the basis of the report (4).

3 Study scope and system boundaries

The Highways Agency reports its organisational emissions in line with Kyoto Greenhouse Gas Protocol scopes, assigning Scope 1, Scope 2, or Scope 3 to the emissions sources. This reporting focusses on the direct and indirect emissions associated with the Agency's buildings stock and asset base, as well as the embodied emissions associated with material use in construction and maintenance activity to the SRN. The Routemap takes this as a start point but also includes the emissions arising from the use of the SRN by customers.

To aid with communicating this scope, three emissions categories are defined as follows:

- Corporate (Organisational) carbon emissions: the direct and indirect emissions associated with the operation of the SRN by the Highways Agency.
- Asset base carbon emissions: the emissions arising as a result of construction and maintenance activity of the SRN and the supply chain that exists to deliver this (i.e. those emissions effectively embodied within the SRN).
- Road user carbon emissions: the emissions arising from the use of the SRN by parties other than the Highways Agency and its partners, i.e. the public / the Agency's customer base.

Table 1 overleaf presents an overview of the scope of carbon emissions sources within the Routemap and their classification.

Table 1. Scope of carbon emissions sources for the Highways Agency carbon Routemap / model

Scope	Organisational (Corporate) Carbon Emission Sources	Asset Base Carbon Emission Sources	Road User Carbon Emission Sources
1	**Estates:** Gas and oil on-site combustion in HA offices, National Traffic Operations Centre and Regional Control Centres for space heating, hot water, and catering. **Traffic Officers:** Fuel consumption of TO fleet.		
2	**Estates:** Electricity for heating, lighting, cooling & ventilation, catering, appliances in HA offices and Control Centres. **Network:** Electricity for highway lighting, signage and other roadside electrical infrastructure such as ICT equipment associated with operation of the network.		
3	**Water:** Water demand for Estates. **Travel:** Highways Agency business travel and commuting. **Waste:** Estates waste production, transport and final disposal*. **Office expenditure*:** Including aspects such as stationary, computers, food, etc.	**Highway & Network Construction:** Embodied emissions from new construction activity (such as major projects and DBFO) and associated emissions from material supply chains. **Highway & Network Maintenance:** Embodied emissions from maintenance/refurbishment activity and associated emissions from material supply chains.	**Private vehicles*:** Direct and indirect (in the case of electric vehicles) emissions from users of the strategic road network.

* These are in addition to the Highway Agency reported corporate carbon footprint.

* These are in addition to the Agency's reported corporate carbon footprint.

4 Future scenarios

Three scenarios have been modelled as default in the HA Carbon Routemap. These represent different levels of technology take up (in terms of efficient/low carbon vehicles, energy generation, intelligent transport systems and production efficiency) and different levels of low carbon leadership by the Agency.

4.1 Scenario 1: Baseline

Low technology take-up; HA not proactive on the low carbon agenda

This hypothetical scenario has been generated for comparison purposes.

Within this scenario, the number of journeys made, mode of transport and energy efficiency of the modes of transport follow Department for Transport (DfT) projections. This represents a low take-up of the available technology (such as electric vehicles) in the wider industry.

Factors outside of the Agency's control (such as material production) are assumed to have minimal carbon reductions.

The Agency does not progressively implement any low carbon activities or initiatives.

4.2 Scenario 2: HA's current trajectory

Low technology take-up; HA is proactive within the low carbon agenda

This scenario was developed in a collaborative workshop between the Arup project team and Agency experts and is intended to represent as closely as possible the Agency's current trajectory.

Within this scenario, all external factors (such as mode of transport and material production efficiency) are the same as in the baseline scenario. This represents a low take-up of the available technology in the wider industry.

However, the Agency continues to be a leader in sustainable transport. There are moves to streamline the operations of the Agency with various initiatives taken to improve the energy efficiency of their Estate including making all offices zero carbon, some moves towards home working and telecommuting and implementing on-site renewables where applicable.

The Traffic Officer (TO) fleet is transformed with the majority of vehicles being electric.

The impact of the operation of the network has been minimised through intelligent lighting controls decreasing the hours of illumination required, and the mostly LED bases lighting and signage systems being powered through renewable energy generated along the SRN.

Resource efficiency and carbon reductions activities have been embedded into design and procurement processes to the existing asset base and these are much less carbon intensive per £ invested.

4.3 Scenario 3: An intelligent[3] low carbon transport system

High technology take-up; HA is proactive within the low carbon agenda

This scenario combines a high technology take up, transforming the SRN to an intelligent low carbon transport system, with the proactive approach of the Highways Agency. It has been created to illustrate the impact this could have on the emissions controlled and influenced by the Agency. However in reality many of these aspects may be outside the Agency's direct control.

In this scenario the predominant mode of travel is in electric or hybrid vehicles. Demand is managed through provision of real-time information and incentivising users to make journeys at less busy times or using less congested routes. Automated driverless cars are the norm with routes being purely for these vehicles. This has further eased congestion and on these roads and improved reliability as well as eliminating the need for lighting and signage.

After initially requiring more TO support to assist with the transition to these systems, accidents are now practically eliminated and TO support is negligible.

Resource efficiency and carbon reductions have been embedded into the design and procurement of new construction and maintenance to the existing asset base and these are much less carbon intensive per £ invested.

In addition, factors outside of the Agency's control (such as material production) are assumed to have significant carbon reductions.

[3] "Intelligent" in this context means a highway system that incorporates the latest technological innovation including systems within vehicles and infrastructure that facilitate low carbon efficient transportation.

5 Highways Agency carbon Routemap summary findings

The following section presents summary findings for the HA carbon Routemap for the period 2014-2050. Findings are organised within the scope categories of organisational, asset base and SRN use. Headline trends of the Routemap scenarios are initially set out to provide an overview.

In reviewing findings the reader must remember that results are presented within the context of the three future scenarios representing different levels of technology take up and the low carbon leadership adopted by the Highways Agency:

- Scenario 1: Low technology take-up; HA not proactive on the low carbon agenda
- Scenario 2: Low technology take-up; HA is proactive within the low carbon agenda
- Scenario 3: High technology take-up; HA is proactive within the low carbon agenda

The other aspect that it is important to recognise whilst reviewing the findings is the significant differences in scale between the different sources of emissions (organisational/corporate, asset and road user). This is illustrated in Figure 5 which shows that in 2013 the asset emissions were over double the organisational emissions and that the user emissions were over 90 times larger than the combined asset and organisational emissions. Due to these differences varying scales are used in the reporting of the findings, with results being presented in tonnes, ktonnes or Mtonnes of CO_2e, as appropriate.

Note that where appropriate all time-series graphics presenting results have been baselined from 2009. This aligns with the Highways Agency corporate reporting strategy. In some cases where data has not been available within the scope of the study this has resulted in an initial blank before the measured/calculated, or forward projected data is available.

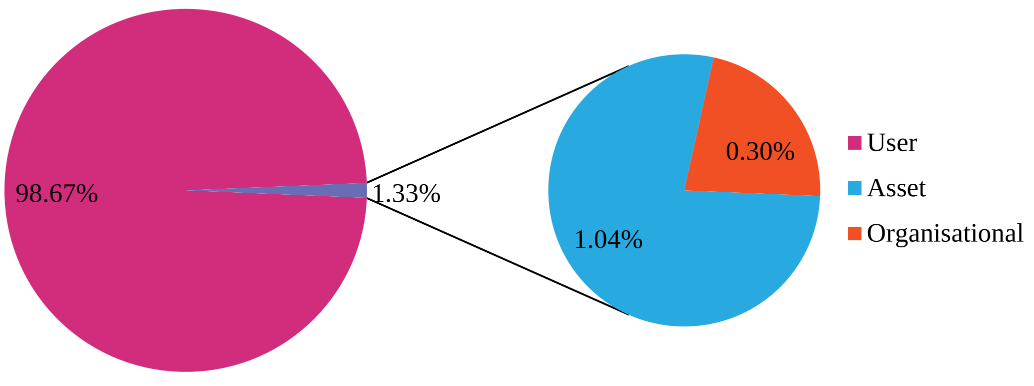


Figure 5: Relative scaling of organisational (0.09 $MtCO_2e$), asset base (0.33 $MtCO_2e$) and road user carbon emissions (31 $MtCO_2e$) in 2013. Note that the pie chart percentage splits represent a sum total 100% of these emission contributions.

5.1 Headline trends

Figure 6 brings together the Highways Agency carbon Routemap of corporate and asset base emissions set against the baseline year 2015 and projected to 2050 for all three study scenarios.

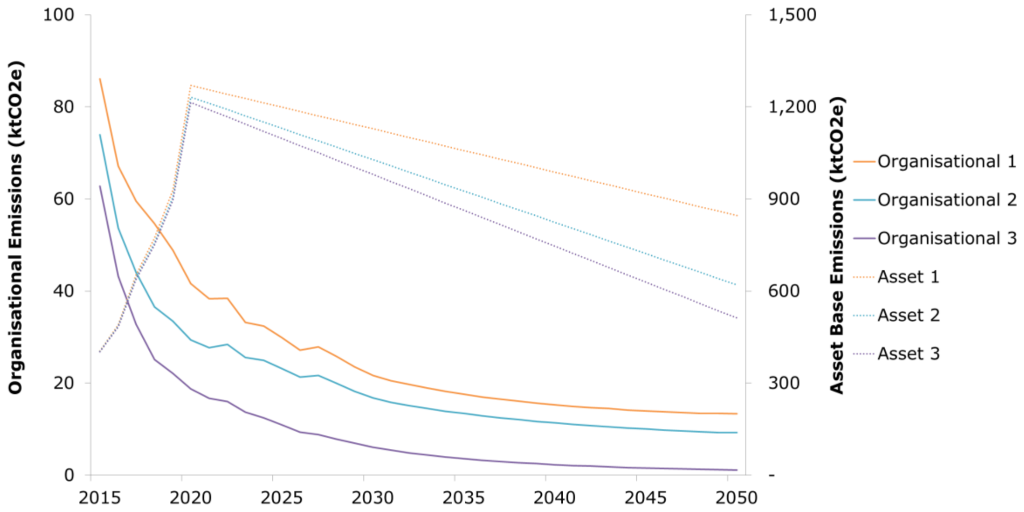


Figure 6. Organisational and asset base carbon emissions profiles for the HA. Number allocations 1, 2 and 3 reference to the appropriate scenario.

Organisational emissions although made up of a range of component parts (estate buildings, water use, business travel, etc.) are largely weighted by network lighting. They therefore see a marked reduction in all scenarios due to assumed energy grid decarbonisation.

Asset base emissions are some three times higher than corporate emissions and show a marked increase in the short term in line with the Highway Agency's planned budget. This means emissions from construction are projected to almost double over the next 5 years from 0.5 $MtCO_2e$ in 2014 to over 1.2 $MtCO_2e$ by 2020. Thereafter expenditure is anticipated to level off and run steady to 2050. Here the scenarios diverge over time, but with all showing emissions coming down as efficiencies in materials and construction techniques take effect adept at different rates. Over all, the trend is slow and the construction supply chain remains a significant carbon liability for the Highways Agency out to 2050.

Figure 7 presents the over view of road user carbon emissions across all scenarios. The carbon emissions levels from use of the SRN are an order of magnitude greater than those arising from the network asset base construction and maintenance.

Scenario 1 shows the results of the Agency taking an inactive approach to carbon mitigation. Trends in travel demand overwhelm the Agency's efforts to manage speed and congestion, and vehicle drive trains see only modest improvements in carbon efficiency through to 2030. Under the assumptions of this scenario, there is almost no net reduction in road user emissions by 2050, with only a negligible 1.5% decrease versus 2013.

Scenario 2 follows a similar profile retaining the DfT forecast vehicle mix, fuel efficiency, traffic growth and speed projections, but takes into account improvements that the Highways Agency can implement. The reductions seen here although seeming minor on the chart (Figure 7) are significant in terms of the tonnage of savings they generate. This indicates towards the role the Agency could play, and the opportunity for its contribution to the objective of creating a low carbon national transport infrastructure system.

Scenario 3 anticipates the development of a national low carbon transport system including significant change in vehicle drive trains mix and significant efficiency improvements to current technology norms. Smart motorways would be rolled out to most of the motorway network, resulting in higher average speeds and the rollout of autonomous vehicles. Overall, this results in a 83% reduction in CO_2e emissions by 2050 compared to Scenario 1, a reduction of 25.5 MtCO_2e.

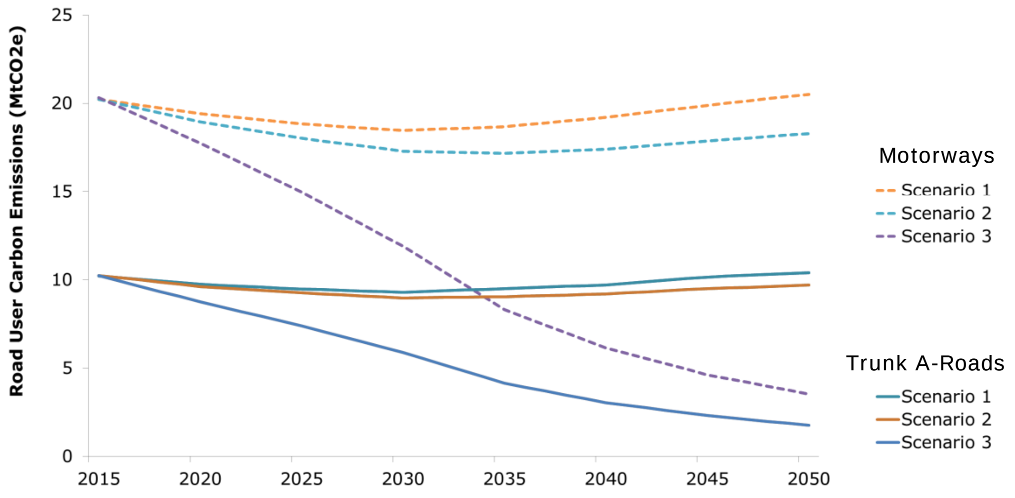


Figure 7. Road user carbon emissions split between motorway and trunk A-road allocations and presented for each of the three study scenarios.

5.2 Corporate (Organisation) carbon emissions

Organisational carbon emissions are the most disparate and cover the HA estate, the TO fleet, network energy needs, business travel, water, and office expenditure amongst others. For description and explanation of the Routemap model behind each of the calculations on corporate/organisation emissions the reader should consult Appendix A2.

5.2.1 HA estate carbon emissions

The expected decarbonisation of the electricity grid renders any electrical consumption negligible by 2050. This is not to say that there need not be any effort on this agenda, as electricity bills are expected to increase to fund the decarbonisation of the energy grid. Therefore, there should be further drive in the future to reduce electrical demand, regardless of scenario. Scenario 1 shows that if the Agency continues to supply its buildings with fossil-fuelled heat, that by 2050 its gas boilers will be the primary source of emissions. Figure 8, Figure 9 and Figure 10 present these perspectives with Figure 11 showing the relative emission split between the direct (Scope 1) emissions from offices and the indirect (Scope 2) of purchased energy.

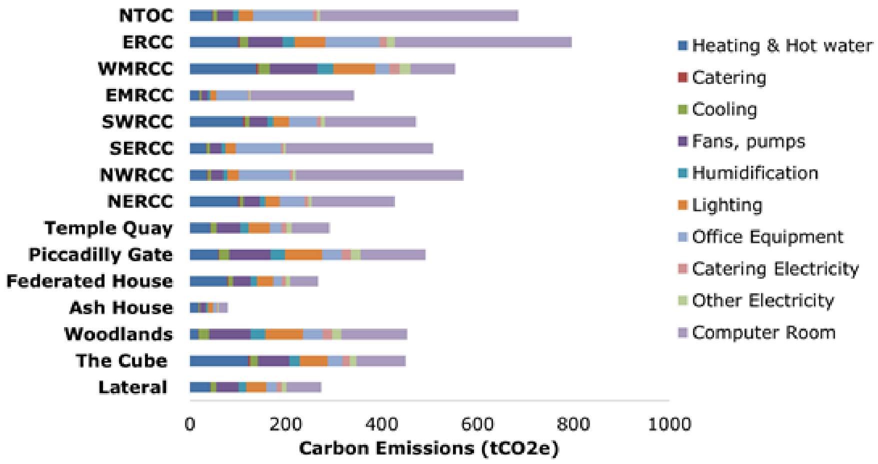


Figure 8. Estate CO_2e emissions by demand type, 2013 (common to all scenarios).

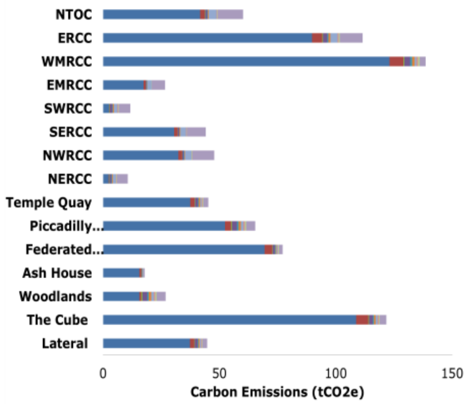


Figure 9. Modelled estate CO_2e emissions by demand type and for 2050 presented for Scenario 1, baseline. Note the difference in scale on the x-axis between Figure 8 and this image; both are presented in tCO_2e.

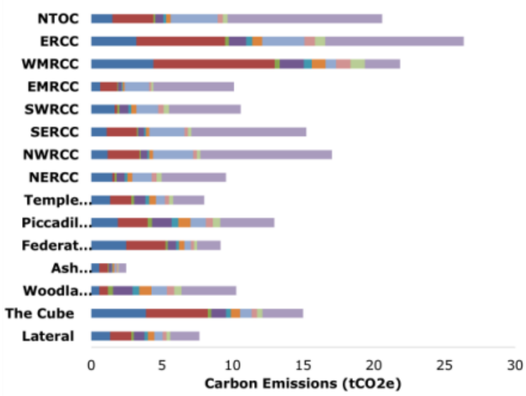


Figure 10. Modelled estate CO_2e emissions by demand type and for 2050 presented for Scenario 3. Note the difference in scale on the x-axis between Figure 8 and this image; both are presented in tCO_2e.

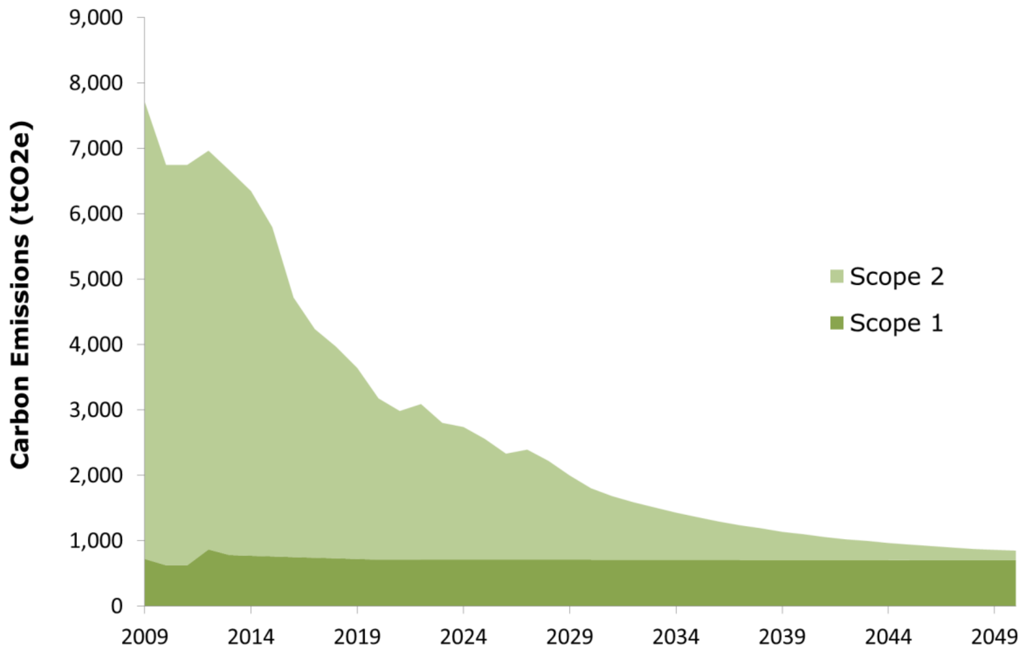


Figure 11. Overall estate emissions trajectory to 2050 (excluding TO Fleet and Network emissions i.e. lighting and equipment) / baseline scenario 1.

5.2.2 Network carbon emissions

Network emissions arise from the electricity consumption of highways illumination (luminaires, signage etc.) and other electrical equipment (cameras, weather sensors etc.). Decline of emissions in all scenarios is seen largely driven by decarbonisation of the UK grid; see Figure 12.

Scenarios 2 and 3 have sharper decline because of faster action to reduce primary energy demand by the Agency. This reduction is slightly higher in Scenario 3 as the HA is driven to be more ambitious.

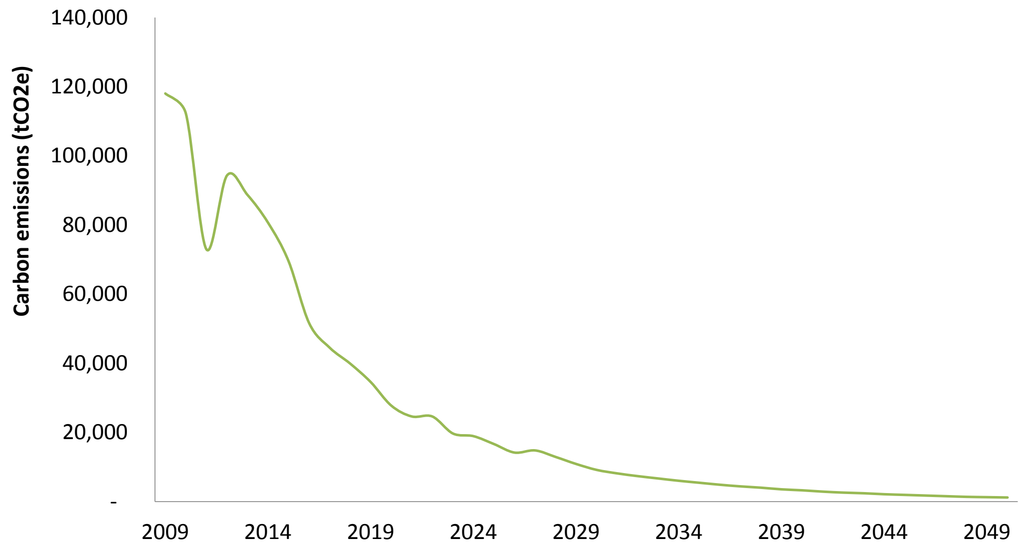


Figure 12. Projection of network carbon emissions, baseline scenario 1.

Figure 13 shows the split of emissions the network is responsible for between its lighting and its electrical equipment requirements. Lighting is responsible for the greater majority and the make-up of this is presented further in Figure 14.

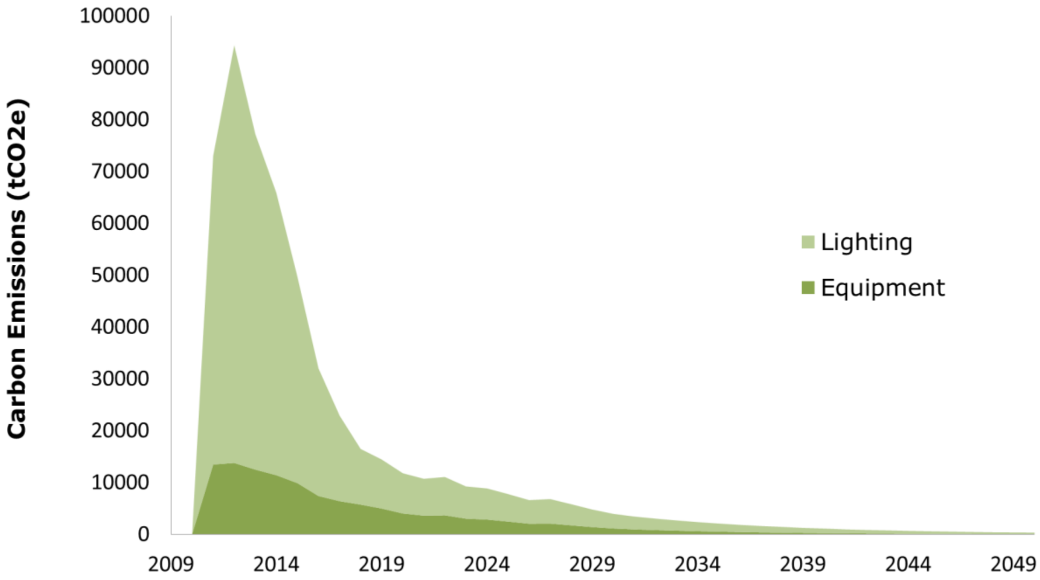


Figure 13. The split of carbon emissions for highway lighting and equipment for baseline scenario. 1.

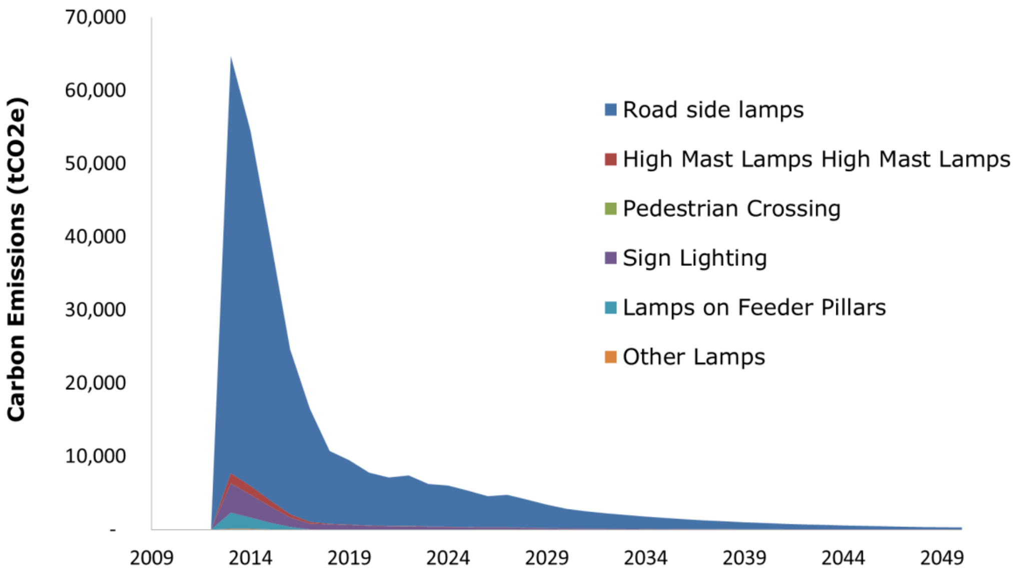


Figure 14. The carbon emissions associated with network lighting demand shown for baseline scenario 1.

5.2.3 Traffic Officer fleet carbon emissions

Only modest reduction in carbon emissions in the baseline scenario 1 occur as the only driver of any influence is the 5% efficiency improvement in diesel vehicles; see Figure 15. In scenario 2, significant efficiency improvements and electrification of the vehicle fleet are slightly offset by increased usage of fleet.

Scenario 3 envisages a future in which highways are used by automated cars only. As a consequence highway incidents are few but severe when they do occur. The entire TO fleet operates electric vehicles and emissions are negligible. The outcome of this scenario is presented in Figure 15.

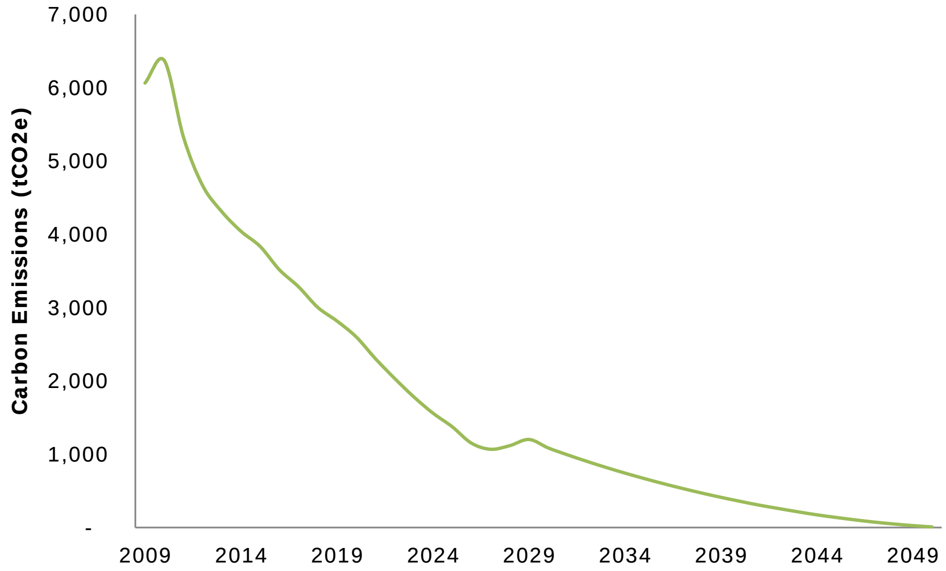


Figure 15. Traffic Officer fleet carbon emissions, presented for scenario 3. This scenario is shown because it illustrates the impact reduction potential of decarbonising the TO vehicle fleet; a saving of some 6,000 tCO_2e.

5.2.4 Water use carbon emissions

In all scenarios, emission reduction occurs on a unit basis, but in fact these are seen to rise for scenarios 1 and 2 due to greater gross demand (i.e. due to higher staff numbers). Unit reductions are driven by modest efficiencies in water consumption per employee in scenario 1 and 2, and a slightly larger reduction in scenario 3 as employees are assumed more engaged and change behaviour accordingly.

Added to this are modest reductions in the carbon intensity factor of water for scenario 1 and 2 with slightly larger reductions occurring in scenario 3 as water suppliers are assumed to be taking action to reducing the footprint of their activities. These findings are presented in Figure 16.

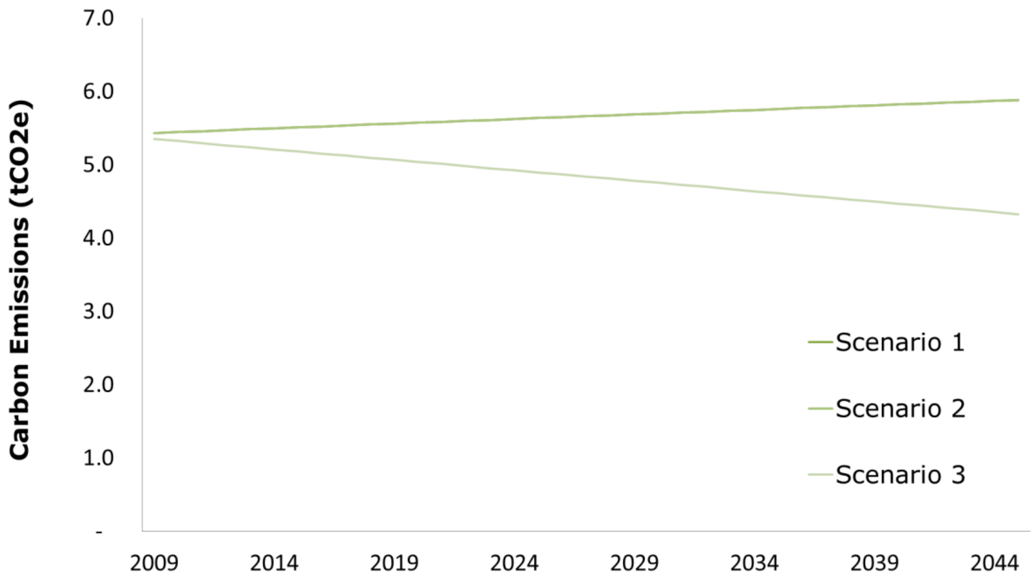


Figure 16. Emissions arising from estate water requirements shown for all scenarios. Scenarios 1 and 2 follow the same trend and therefore appear together.

5.2.5 Employee travel carbon emissions

Scenario 1 shows a slight improvement in emissions due to modest energy efficiency improvement in transport modes; whilst scenario 2 shows a higher reduction in emissions as the Highways Agency actively encourages low carbon travel and reduced business travel.

Within Scenario 3, the emissions are reduced due to video conferencing becoming the norm (as an alternative to traveling to meetings) and achievement of greater energy efficiency improvements and low carbon transportation. This scenario represents the most compelling carbon mitigation strategy for the Agency as shown in Figure 17.

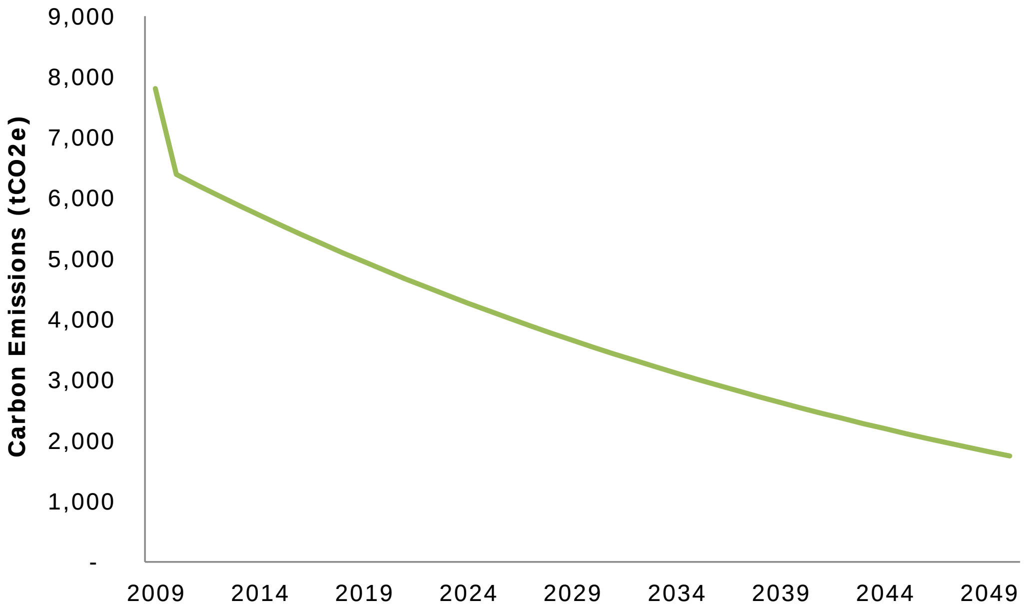


Figure 17. Emissions associated with employee travel, presented for scenario 3.

5.2.6 Office expenditure carbon emissions

Office expenditure emissions cover aspects such as office equipment and stationery together with other administration and service requirements of corporate operation (a fuller description of these categories and the applied methodology can be found in Appendix A2.4). These emissions were calculated at 12,700 tCO_2e for the 2013/14 year; see Figure 18. In isolation this represents a significant footprint when set against other corporate emissions. A forward projection to 2050 was not undertaken due to uncertainties of what to align the emission category with. Looking ahead this scope 3 emissions liability represents an agenda the Agency should consider in further detail particularly because it has a degree of control on its spend and supply chain.

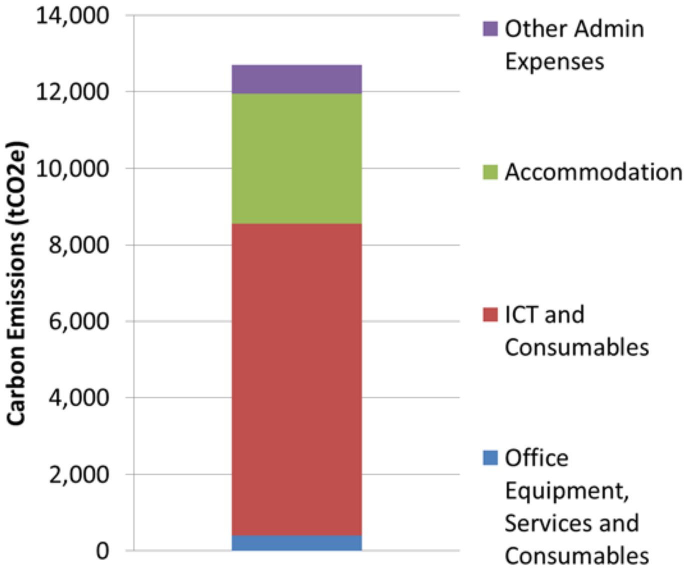


Figure 18. Scope 3 office expenditure emissions for 2013/14. Each category has been built up from more granular expenditure functions. For example accommodation includes various building administrative costs, security, removals, and cleaning services (see Appendix A2.4).

5.3 Asset base carbon emissions

The asset base carbon Routemap model covers those emissions arising as a result of the construction and maintenance activity to the SRN and the supply chain that exists to deliver this. For description and explanation of the calculations models that support this section the reader should consult Appendix A3.

Asset base construction emissions are expected to increase in line with the Highway Agency's budget and future spending reviews. Construction emissions are projected to more than double over the next 5 years from 0.5 $MtCO_2e$ in 2014 to over 1.2 $MtCO_2e$ by 2020. Thereafter expenditure is anticipated to level off and run steady to 2050. Over time emissions come down as efficiencies in materials and construction techniques take effect; but this trend is slow and the supply chains remain a significant carbon liability for the Highways Agency out to 2050.

Reductions in construction emissions depend on the level of improvements achieved by the construction and supply sector itself. But they are also a function of how much influence/action the Highway Agency applies to carbon mitigation measures and at what rate; for example:

- Scenario 1 as baseline represents almost a business as usual world where efficiency improvements in the construction sector take place at a slow pace. The Highway Agency under this scenario has little control and simply adheres to normal practice. Scenario 1 construction emissions are calculated as 0.85 $MtCO_2e$ in 2050.
- Scenario 2 does not differ significantly from Scenario 1. Of the twelve levers used to influence construction emissions, the Highway Agency has more direct control on only three: site offices, plant equipment and design efficiency. The remaining levers touch on materials such as cement, plastics and timber, areas the Highway Agency does not directly influence. It is expected the construction and manufacturing sector itself will drive efficiency improvements in these areas; whereas the Highway Agency will be left with procurement choices. Scenario 2 achieves a 27% reduction in construction emissions in relation to Scenario 1 by 2050.

Scenario 3 represents a world where climate change becomes a priority and action for efficiency improvement is the norm. Similar to Scenario 2, the Highway Agency will benefit from this irrespective of the degree of control it has over its supply chain. Scenario 3 achieves a 39% reduction in construction emissions in relation to Scenario 1 by 2050. The outcome of this scenario is presented in Figure 19.

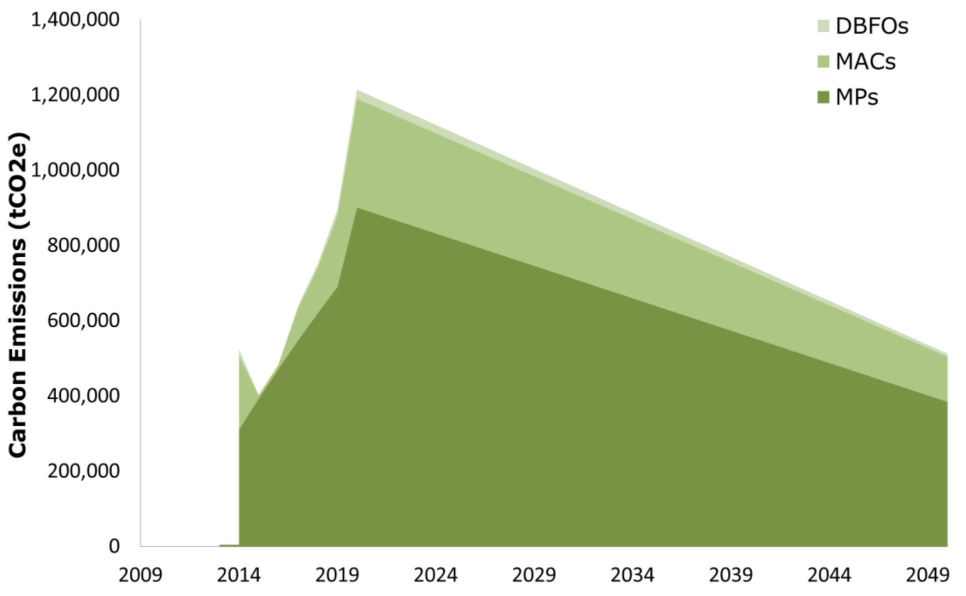


Figure 19. Agency asset base construction emissions profile by project type for scenario 3.

Figure 20 has been created to provide an illustration of hotspots occurring within the Agency's asset based construction activity. The model is able to be interrogated not only by project type, but also by material usage and activity type.

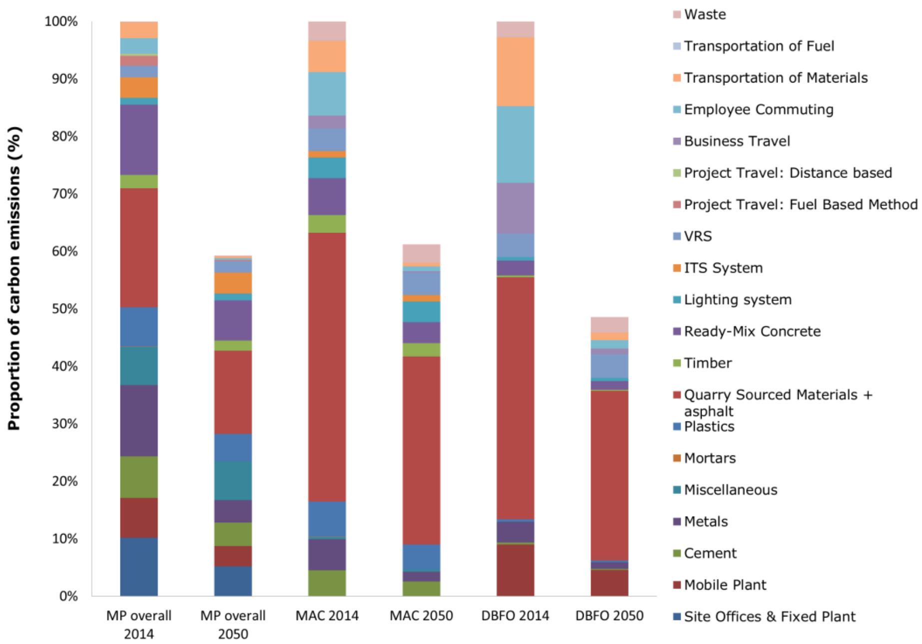


Figure 20. Breakdown of asset base construction emissions by activity and material type for scenario 3. Profiles for year 2014 and 2050 are shown side by side.

5.4 Road user carbon emissions

The road user carbon model covers those emissions arising from the use of the SRN by the general public (customer base). For description and explanation of the calculations models that support this section the reader should consult Appendix A4.

The results for road user carbon emissions are summarised in Table 2 and shown graphically for each scenario though the following section including the split between vehicle type and road type.

Table 2. Scenario results summary ($MtCO_2e$).

Year	Value		
	Scenario 1	Scenario 2	Scenario 3
2013	31.4	31.4	31.4
2030	27.8	26.3	17.8
2050	30.9	28.0	5.4

5.4.1 Scenario 1: baseline

Low technology take-up; HA not proactive on the low carbon agenda

Scenario 1 shows the results of the Agency taking a back seat in setting the carbon agenda. Trends in travel demand overwhelm the Agency's efforts to manage speed and congestion, and vehicle drive trains see only modest improvements in carbon efficiency through to 2030. Under the assumptions of this scenario, there is almost no net reduction in road user carbon emissions by 2050, with only a negligible 1.5% decrease versus 2013; see Figure 21. While vehicle efficiency improvements to 2030 are enough to reduce emissions by this date somewhat, the continued trends in demand growth more than offset these gains in later years.

Scenario 1 represents the DfT forecast vehicle mix, fuel efficiency, traffic growth and speed projections and is used as a baseline to compare the other scenarios against. Under this scenario the CO_2e emissions from the vehicles on the HA network would reduce until 2030 due to improvements in vehicle efficiency, but then are forecast to increase to 2050 as traffic volumes increase to a similar level as the 2013 emissions.

The Scenario 1 output from the model closely matches the DfT CO_2e emissions forecasts set out in Road Transport Forecasts 2013, thus serving to validate the output from the model; see Figure 21.

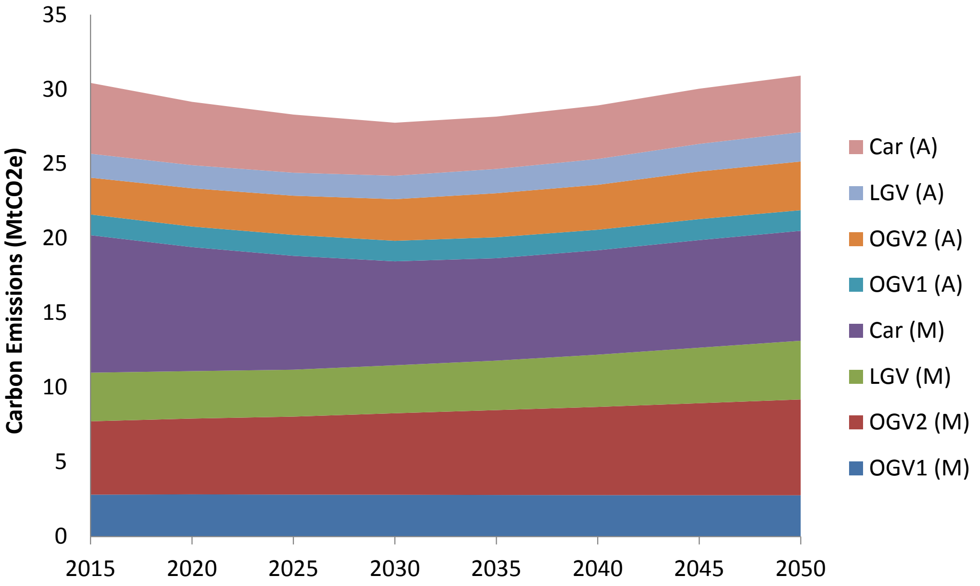


Figure 21. Road user carbon emissions for Scenario 1 baseline.

5.4.2 Scenario 2: HA's current trajectory

Low technology take-up; HA is proactive within the low carbon agenda

Scenario 2 retains the DfT forecast vehicle mix, fuel efficiency, traffic growth and speed projections, but takes into account improvements that the Highways Agency can implement. In particular this includes increased introduction of smart motorways, such that vehicles travel at more consistent speeds minimising periods of heavy congestions, and improvements to the most congested links so that a 'mile a minute' 60mph average speeds are realised for all links on the motorway network.

These assumptions also include reduced traffic growth for goods vehicles as a proportion of freight is moved off the network. It should be noted that this still represents growth in HGV traffic compared to current levels, but a smaller increase than is forecast. This results in a 9.4% reduction in CO_2e emissions by 2050 compared to Scenario 1, a reduction of 2.9 $MtCO_2e$; see Figure 22.

The reductions seen here are a direct result of the Highways Agency's influence and response to the carbon agenda. This highlights the role the Agency has in the wider carbon story of national transport infrastructure (by focussing only on its own emissions limits, the Highways Agency would lose the opportunity of contributing to a wider benefit). This scenario shows the level of influence the Agency has over a wider, more significant body of emissions.

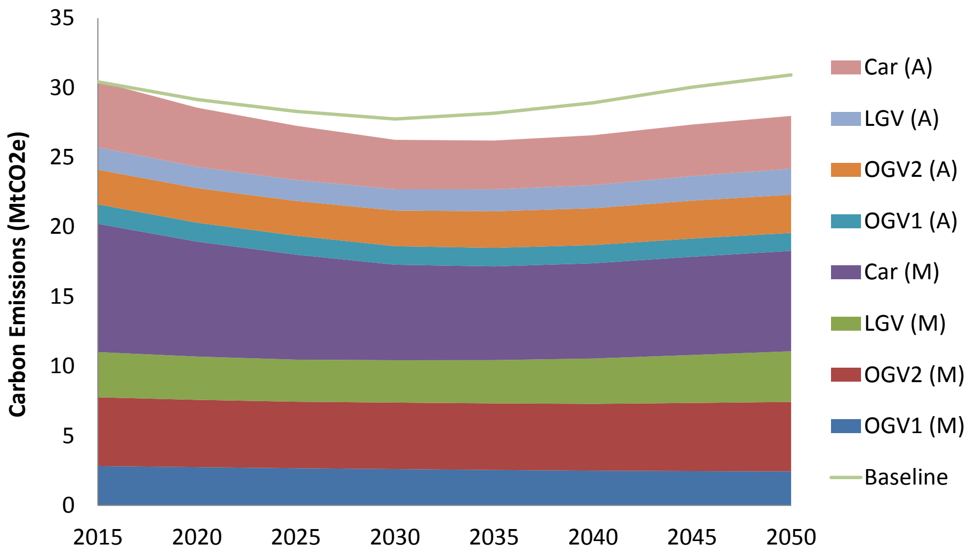


Figure 22. Road user carbon emissions for Scenario 2, HA's current trajectory.

5.4.3 Scenario 3: An intelligent low carbon transport system

High technology take-up; HA is proactive within the low carbon agenda

Scenario 3 considers an alternative future where a conscious decision has been made to curb the country's carbon emissions. This scenario includes a significant switch to electric vehicles, including a high proportion of electric cars, but also that a proportion of goods vehicles would be electrically powered. The remaining non-electric vehicles are forecast to have significant efficiency improvements including hybrid propulsion and other technological advances. The outcome is a fundamental change in vehicle drivetrains from today's norms.

Smart motorways would be rolled out to most of the motorway network, resulting in more consistent speeds, and 'mile a minute' 60mph average speeds are realised for all links on the motorway and trunk A-road network.

As with Scenario 2, these assumptions also include reduced traffic growth for goods vehicles, but that improved comfort and reliability would increase traffic growth for cars.

But whereas in other scenarios this leads to growth in emissions after 2030, the conditions achieved in this scenario are enough to maintain a steep downward trajectory in carbon emissions.

The rollout of autonomous vehicles would also reduce congestion and increase capacity, and the reduced headway between vehicles would decrease aerodynamic drag, improving efficiency by as much as 15% on sections of the network were they have exclusive lanes.

Overall, this results in a 83% reduction in CO_2 emissions by 2050 compared to Scenario 1, a reduction of 25.5 $MtCO_2e$; see Figure 23.

A large part of the savings in CO_2e emissions in Scenario 3 are related to changes in the national vehicle fleet rather than the highway network itself. However the results from Scenario 2 and 3 show that the Highways Agency can impact on the CO_2e emissions of the vehicles even without changes to the mix of vehicles.

Although the current government has no plans for road user charging, should it become an established mechanism, it would likely form a powerful tool for influencing driver behaviour and end user vehicle purchasing decisions by varying the charges incurred by the road user/customer depending on their vehicle choice, route, and travel timing decisions.

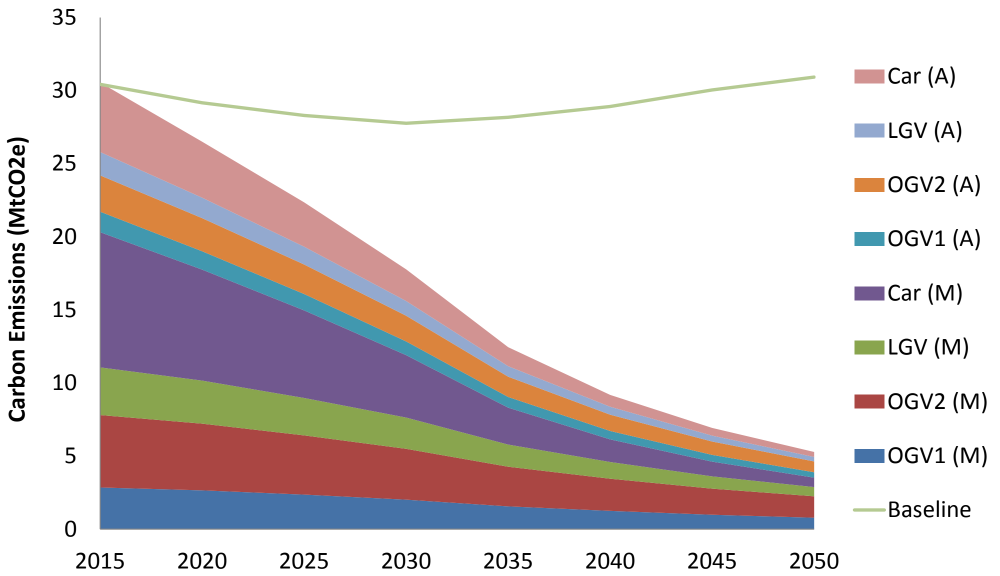


Figure 23. Road user carbon emissions for Scenario 3 an intelligent low carbon transport system.

6 Overall perspectives and opportunities arising

Through this project the Highways Agency and its consulting partner Arup have aimed to develop a tailored and specific carbon Routemap model for the Highways Agency out to 2050. In working to understand what it would mean to deliver meaningful reductions in emissions over this time horizon, many challenges and opportunities have been identified. This section of the report presents a series of key messages brought together to provide an overall perspective on the work and the headline messages it conveys.

Corporate vs Asset base vs Road user carbon emissions: Figure 24 shows that the 2013 GHG emissions arising from construction and maintenance of the SRN are over double that of the HA organisation itself. Taken together both are small when considering SRN use accounts for emissions some 90 times greater than the combined corporate and asset emissions.

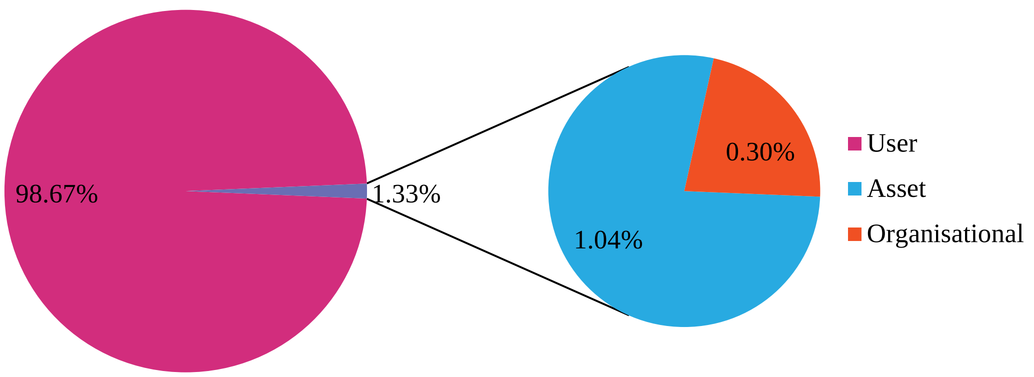


Figure 24. Relative scaling of organisational (0.09 $MtCO_2e$), asset base (0.33 $MtCO_2e$) and road user carbon emissions (31 $MtCO_2e$) in 2013. Note that the pie chart percentage splits represent a sum total 100% of these emission contributions.

The Highways Agency must bring focus with its carbon management plan to all three parts of this agenda and develop response strategies accordingly. With asset and organisation it has greater influence and some control and can make significant reductions against these responsibilities.

The Highway Agency's contribution to a national low carbon transportation system: When considering emissions from SRN use the Highways Agency has less influence. Notwithstanding this as scenario 2 and 3 demonstrate, targeted action around the role out of smart motorways are estimated to bring some 9% improvements against this much larger emission liability of 31$MtCO_2e$; the impact therefore can be significant. By embracing smart motorways such that vehicles can travel more consistently minimising periods of heavy congestion and with works to ease bottlenecks the Highways Agency can deliver significant impact to a national low carbon transportation system.

Manage the short term expenditure increase and its climate change impact: The Highways Agency investment in road enhancements is expected to triple by 2021 to over £3billion, creating a sharp increase in carbon emissions in the next six year period. This should be seen as particularly relevant as set against the priority of keeping atmospheric carbon dioxide concentrations within a global budget of 450ppm.

In this regard the objective for the Highways Agency must be to manage the trajectory of its decarbonisation profile. The objective to achieve significant cuts by 2050 is important, but the '*area underneath the curve*' and the emissions tonnage this represents will be critical to its role in mitigating climate change risk.

The Highways Agency has a strong track record of GHG emissions measurement. As expenditure increases come into play the challenge/opportunity must be to move to active emissions management. In delivering this there is an important role for the construction value chain (i.e. the designer, constructor, supplier, demolition contractor). Improvement in their practice to reduce emissions intensity should be incentivised or required (be it in design, during construction or with supply of materials). The timing is right to reinvigorate the Highways Agency carbon framework and associated toolbox and apply it to the opportunities of the forward business plan.

HA estate carbon emissions: The direct and indirect carbon emissions from the estate building stock are expected to see significant reductions in line with the decarbonisation of the electricity grid by 2050. Notwithstanding this differences transpire between the three scenarios where by in scenario 1 the Agency continues to supply its buildings with fossil-fuelled heat which means that by 2050 its gas boilers will be the primary source of emissions. By contrast in scenario 3 gross estate emissions are some four times less and arise from functions such as catering and trace emissions from the grid to power ICT equipment, in this case all heating must be provided by 100% renewables.

Traffic Officer fleet carbon emissions: This aspect is driven primarily by the drive chain choice of vehicles which make up the TO fleet, together with highway incident occurrences. The third scenario is the most interesting for it envisages a future in which the entire TO fleet operates with electric vehicles and highways are used by automated cars which in consequence leads to 80% fewer incidents. Taken together this means emissions of the TO fleet become negligible by 2050.

Network carbon emissions: These arise from the electricity consumption of highways illumination (luminaires, signage etc.) and other electrical equipment (cameras, weather sensors etc.). Significant decline of emissions in all scenarios is seen largely due to the decarbonisation of the electricity grid. With lighting being responsible for the greater majority, efficiencies are further driven by 40% fewer lamps, 50% dimming across all the stock, and widespread energy saving through switch off during darkness.

Organisational consumption: Scope 3 emissions from corporate procurement were determined at over 12,000 tCO_2e in 2013 being second only to network lighting and equipment. Nor are they expected to benefit from the same energy grid decarbonisation profile. Further and more detailed understanding of emissions from organisational consumption is needed including understanding where hotspots exist (in the purchase of ICT hardware for example), and how these might be addressed in the future.

Energy grid: The importance of a fully decarbonised electricity grid cannot be overstated. The energy grid model assumes a reduction in carbon intensity of 97% of 2010 levels by 2050, which leads to any electrical demands in that year producing near-zero carbon emissions. This aspect represents a risk to the

Highways Agency low carbon Routemap if it fails to materialise. Of further importance is the likelihood that electricity bills are expected to increase in order to fund the electricity grid decarbonisation. This makes it a priority that the Highways Agency should continue its focus towards reducing electrical demand in order to minimise its exposure to energy price increases.

Leadership: The publication of this low carbon Routemap has positioned the Highways Agency as a leader in understanding the climate change impacts of the national highway system. Although the Highways Agency may have less influence within this sphere than it would like, the work has broken new ground in measuring the scale of emissions, identifying where they reside, and determining what will need to happen if we are to meet national reduction commitments.

As a major infrastructure provider the Highways Agency is entering an exciting new phase that will radically change the way strategic roads are funded and managed. The opportunity of this transition is to use the low carbon Routemap to bring about change to the way climate change is dealt with when delivering critical national infrastructure.

In this way the challenge of climate change can be meet head on. Aspirations should be set high for the Highways Agency has a solid base of evidence and a functional carbon framework from which to build. By extending its remit to emissions management, and harnessing existing relationships and partnerships, the short term opportunity is to more constructively engage with the construction value chain and supplier base to reduce emissions. As the Treasury Infrastructure Carbon Review (2013) shows, the right approach will deliver efficiencies and cost savings at the same time.

The Highways Agency carbon Routemap can be used to forward cast, identify future reduction targets, and set strategies to achieve them. It can also be a campaigning tool to lead and drive cultural change within the Agency and its stakeholders supporting the shift to low carbon economy, accelerating growth and creating an optimal outcome for the Highways Agency's long term future.

7 Recommendations for improving the quality, reliability and use of the model

This section considers improvements that might be made to the Highways Agency low carbon Routemap and focuses on technical data and modelling approaches.

7.1 Corporate (Organisation) carbon emissions

Estates carbon emissions: While estate emissions are based on actual energy consumption data, benchmarks have been used to convert this total energy consumption into consumption by various office demands. A high-level building stock audit would allow for more reliable granularity to the energy and emissions figures, and, crucially, give a much clearer picture of the achievable reductions in energy demand and emissions across the different buildings in the Agency's estate. This could be informed by discussions with building energy managers and landlords.

Network carbon emissions: Although some network emissions have been disaggregated by spatial area/geography, others such as equipment and certain lighting assets were not. This information is available and the model could be extended to contain this granularity across the 2500 highway links it contains. This would enable the Highways Agency to have a detailed picture of the spatial energy usage across the network and where priority action should be directed to reduce emissions from this.

Traffic Officer carbon fleet: Future changes in average UK fuel feedstock, such as biodiesel blending or sourcing from tar sands mean that it is likely the diesel emissions factor will change from year to year (although not to the same degree that is expected from the electricity grid). A lever to reflect different diesel supply types for the TO fleet would enable the investigation of significant emissions reduction potential.

Office expenditure carbon emissions: Scope 3 office procurement emissions have been measured but not fully integrated into the Routemap model. A time series profile requires development. Further understanding of specific procurement categories would be useful to strengthen the calculation. The calculated carbon footprint represents a significant proportion of the Agency's 2013 organisational emissions, on this basis it is an aspect that should be investigated further.

Waste carbon emissions: The office waste emissions have been measured and reported but not integrated to the time series Routemap model. Data availability and robustness were the constraining factors. This aspect could be more successfully incorporated with access to the right information from the Highways Agency from which to make forward projections.

7.2 Asset base carbon emissions

Efficiency improvements in highway works activities: There are a number of activities where there was little data on which to base future efficiency improvements (i.e. ITS system, VRS, waste etc.). As such they were modelled as flat into the future. All could be addressed and a more satisfactory trend identified with further research.

Project carbon intensity: Best available data was applied to determine the carbon intensity of MP, DBFO, and MAC. However, this did demand a simplified approach and the model would be strengthened if a more granular understanding were available within these categories and of the carbon intensity of the specific work functions being delivered. This particularly applies to the DBFO and the MAC categories.

Future expenditure projections: The model is driven by future expenditure predictions and the short term profile for the Highways Agency is striking. Post 2020 a flat line of expenditure has been applied. Is this high level of investment likely to continue or is a cyclical profile more realistic? The longer term profile warrants further consideration together with its relative allocation to MP, DBFO, and MAC.

Understanding regional variation: Regional works expenditure plans exist but have not been applied in the Routemap. If this were undertaken the works carbon emissions (MP, DBFO, and MAC) could be spatially related enabling carbon to be a variable within regional works plans. The Routemap model contains the spatial capacity to present this.

7.3 Road user carbon emissions

A spatial model of 2500 highway links: While the calculations are undertaken on a link by link basis for each of the approximately 2500 links in the SRN, the future trends, including traffic growth, changes in vehicles speeds, vehicle mix etc., are assumed to be consistent over the whole network. It was originally assumed that compiled data provided by the Highways Agency would be broken down by vehicle type such that the variation in HGV proportion and HGV speeds could be considered on a link by link basis. While this added detail is unlikely to affect that overall vehicle emissions results estimated by the model, it could affect the results if they were extracted on a regional or sub-regional basis.

In summary the model already runs on a link-by-link basis for the strategic road network, but currently assumptions around improvements to traffic flow and congestion etc. are spread across the entire network. The potential exists to allow users of the Routemap tool a far greater level of control over the improvements made to individual links, to allow the investigation of the carbon and speed impacts of more targeted, specific interventions to be more tailored.

HGV: The provision of more detailed breakdowns for HGV’s would enhance the reliability of results but would not necessarily change overall conclusions. This is unless further evidence about the potential to reduce HGV emissions emerged. The model would benefit from further review of this vehicle category and its potential decarbonisation trajectories.

Linking network improvements and road user emissions: The current model does not directly link planned spatially specific improvements (i.e. the Agency’s works plan) to the highway network with changed traffic conditions; and future versions of the model could incorporate this more detailed input to allow localised impacts and benefit to be considered.

The potential for this is significant and using the Routemap as a works planning and priority tool that considers climate change could be possible. This could be realised if a spatially defined future works plan were overlaid to the 2500 link network road user model. In this way the localised carbon mitigation benefit of changed traffic conditions from works could be determined and analysed through different scenarios assessments.

7.4 Recommendations for using the Highways Agency carbon Routemap

Monitoring annual progress to reducing emissions: This project has delivered a first tool providing a comprehensive and detailed understanding of where emissions liabilities exist across the Highways Agency and the SRN including organisational/corporate, asset base and network user carbon emissions in detail. With the forward projection capability (2013 to 2050) it can also provide a basis for what might be expected from the Highways Agency if it is to set GHG emissions reduction targets.

In this regard the Routemap can serve two functions. In the first instance it can help establish and inform the forward emissions reduction plan covering actions and priorities, informing target levels and identifying time-series points. Then on a periodic basis it can also be used as a database in which outturn data can be recorded. This foundation provides the potential for using the Routemap as a progress monitoring instrument to measure carbon emissions reduction achievements against plan.

Performance monitoring - going beyond carbon and GHG impacts: With the network use model there exists a basic framework of 2500 highway links into which a range of additional variables might be added. Aspects such as average speed are already part of the calculation approach and give insight into time saving potential and reliability. If risk characteristics were defined for the network links (influenced by variables such as speed, carriageway design, vehicle ICT equipment etc.) it would be feasible to consider aspects such as user safety, accident risk or congestion. This could be presented across the user carbon model using its GIS platform. In this way a nexus of issues be they accidents, reliability, congestion, or carbon could be reported and scenarios created to find a balance across them.

Engagement with stakeholders: The Routemap has potential as a powerful stakeholder engagement tool for carbon mitigation. It offers a means to communicate:

- internally within the HA to general staff and organisational leadership
- with the HA supply base including works contractors, material suppliers and engineering and design teams
- to professional peers of strategic importance like the DfT and Network Rail
- to the general public

A campaign around the outcomes of the project could be an influential way of contributing to the discussion of what a national low carbon transportation strategy should look like.

Web user dashboard: Create a Routemap user dashboard accessible or based on the internet. This has the potential to quickly provide in a compelling and very informative way outcomes of scenarios created in the Highways Agency carbon

Routemap. A web dashboard would be dynamic and assist with understanding different relationships between the data as the user adjusts variables though slides or levers that represent interventions that can be taken. In this way it is similar to the Routemap excel.xls but provides for a degree of easier access.

It is a platform that potentially allows wider stakeholder engagement and a means for getting information and understanding from the underlying data more quickly. If developed in tandem with an on-going or cyclical data gathering process it also has the potential to provide the regular reporting of performance as input data is provided. An example of a web dashboard is provided in Figure 25.

Figure 25. Example of a web-enabled dashboard.

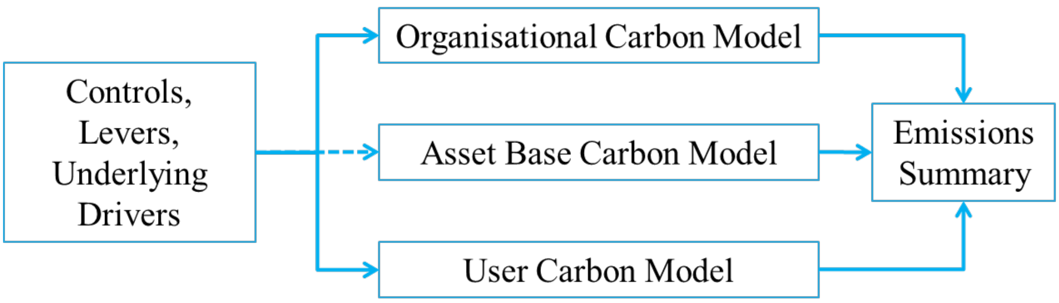
Appendix A

Carbon Routemap model description

A1 Introduction

The Highways Agency carbon Routemap model is a GHG emissions calculation tool covering the Agency's organisational footprint, that arising from its asset base due to construction and maintenance works, and the emissions that arise from vehicles that use the SRN. In this section of the report a description of the model is presented to assist the user by providing a technical reference of how the model works.

The section is split into three parts covering the main modules of the model. For each, the methodological approach is documented, together with a narrative on the data applied and any key assumptions that underpin the model.



A2 Corporate (Organisation) carbon emissions model

The three primary sources of organisational Scope 1 and Scope 2 emissions are Estates, Network, and the TO Fleet activity. Scope 3 organisational emissions as defined by office procurement have also been included in this category. The modelling approaches for these are described in the sections below.

A2.1 Estates emissions

This section summarises the approach of the estates model. The model performs calculations based on the HA estate make up, and the adjustment a use applies to levers that influence this make up and its emissions profile.

A2.1.1 Summary of adopted model approach

The estates model is based on gas and electricity consumption figures provided by the Highways Agency for seven offices and eight control centres (including the National Traffic Operations Centre) for 2013/2014.

Benchmarks and reasoned assumptions have been used to convert the fuel consumption (gas or electricity) into a “service” demand, for example converting 2,500 kWh of gas consumption into 2,000 kWh of heat and hot water demand via an assumed 80% gas boiler efficiency.

Knowing service demands allows for the future variance of these in response to drivers such as staff numbers, equipment replacement and efficiency improvements, and behavioural change to be modelled.

The key assumptions and levers used are outlined below. It should be noted that the range of levers is constrained somewhat due to the Agency only being a tenant in its offices. It cannot exert direct control (as opposed to a building owner) and can only influence energy and carbon saving interventions looking forward. This said, in most cases the Agency is either the sole tenant or the primary tenant, so it is anticipated it does wield a good degree of influence.

A2.1.2 Key assumptions

This section outlines the main assumptions used in the modelling of Estates emissions

- DECC projections for electrical grid decarbonisation: DECC Updated Energy and Emissions Projections[4] up to 2030 are extrapolated out to 2050 and used in the models as appropriate.
- Energy consumption split: typical energy consumption benchmarks published by CIBSE[5] have been adapted to assign demand types to the gas and electricity consumption figures.

[4] https://www.gov.uk/government/collections/energy-and-emissions-projections
[5] CIBSE Guide F: http://www.cibse.org/knowledge/cibse-guide/cibse-guide-f-energy-efficiency-in-buildings

- Existing equipment efficiencies: a gas boiler seasonal efficiency of 80%, and chiller average COP of 2.5 have been assumed. These are currently not modelled to vary with time; however in the time horizon analysed it is likely that all systems will see at least one replacement, which is likely to have superior performance to the incumbent system.

The following assumptions are undergoing further refinement:

- Electricity consumption of control centres: control centres have a significantly different consumption profile from the Agency's offices, and have therefore been assigned different demand properties in the modelling. It is currently assumed that electricity consumption in excess of what would be expected from offices given gas demand is the result of greater IT infrastructure demand. However, it is likely that the 24-hour operational profile of the control centres actually leads to almost all electrical demands (lighting, cooling and ventilation, etc.) being greater than average; hence a more balanced profile will be appropriate.

A2.1.3 Levers and scenario inputs

The following list outlines the most significant levers and controls currently in place to drive the model scenarios. These are currently geared towards generating the business as usual scenario, but once further clarity on the potential additional scenario conditions is available, it may be appropriate to include further drivers and measures.

- Annual changes in staff numbers: separated by office and control centre staff, allowing for an investigation of the effects of, say, more smart motorways leading to increased staff requirements, or increased construction activity requiring more oversight.
- Reductions in heating and cooling demand per person as a result of behavioural change: the effects of changing internal temperature set-points, using less hot water, installing smart building management systems, etc. These can be varied linearly up to 2020, and then between 2021 and 2050.
- Office IT infrastructure: annual energy consumption reduction as a result of the use of more modern equipment. Depending on driver values, the benefits yielded by this driver can be offset by increases in demand from IT infrastructure associated with smart motorway activities.
- Annual lighting replacement rate: depending on tenancy arrangements, this is not necessarily under the control of the Agency, but will have an impact on energy demand, as replaced luminaires will increasingly be of low-energy varieties.
- Uptake of intelligent lighting systems by 2050: depending on the future under investigation, smart lighting systems (daylight sensors, dimming, motion sensors etc.) will be taken up to a greater or lesser extent.
- Annual change in equipment use in control centres as a result of smart motorway activities. Depending on the scenario, control centres are expected to install additional equipment to manage modern motorways. Note that this demand is offset somewhat by increases in technology electrical efficiency.

Lever	Value		
	Scenario 1	Scenario 2	Scenario 3
Heat: per-staff change in demand by 2020 due to demand management	-10%	-10%	-10%
Heat: per-staff change in demand by 2050 due to demand management	-15%	-30%	-40%
Cooling: per-staff change in demand by 2020 due to demand management	-10%	-10%	-10%
Cooling: per-staff change in demand by 2050 due to demand management	-15%	-30%	-40%
Lighting: annual replacement rate of bulbs	20%	20%	10%
Lighting: date when all bulbs replaced are low-energy (CFL or LED)	2020	2015	2015
Lighting: date when all bulbs replaced are LEDs	2025	2020	2020
Uptake of smart lighting technologies by 2050	10%	50%	95%
Offices			
Annual change in staff numbers	0.5%	0.5%	0.0%
Control centres			
Annual change in staff numbers	0.5%	1.5%	1.5%
Annual change in office equipment demand due to smart motorway activities	1%	2%	1%
Annual change in computer room demand due to smart motorway activities	1%	2%	1%

A2.1.4 Scenario results

The figures below present initial results for the indicative business as usual scenario, which will be developed in further detail following the scenario workshop.

The figures show that all emissions associated with electrical consumption reduce to near-zero by 2050. This is driven by the assumed decarbonisation of the national electrical grid. The outcome is that by 2050 the main sources of emissions are those buildings that still use gas boilers. This shows through in Figure 11 where the profile of Scope 2 emissions exactly follows the DECC electrical grid decarbonisation projection after 2013.

A2.2 Network emissions

Network Scope 2 emissions arise from the electricity consumption of highways illumination (luminaires, signage etc.) and other electrical equipment (cameras, weather sensors etc.). Accordingly, the network emissions model is split into Illumination and Equipment sections.

A2.2.1 HA illumination model methodology

The illumination or lighting model was built up from data provided by the Agency for the financial year 2008/09 with data on number of lamps, average wattage of lamps and switch regimes into six categories, as defined in the Agency's baseline equipment report[6]:

1. Roadside lamps
2. High mast lamps
3. Sign lamps
4. Pedestrian crossing lamps
5. Lamps on feeder pillars
6. Other

Where data was available, the stock was disaggregated by Agency network area as shown in the table below.

Table 3. Level of disaggregation of Agency stock data.

Category	Data disaggregated by HA network
Roadside lamps	Yes
High mast lamps	Yes
Sign lighting	Yes
Pedestrian crossing lamps	No
Lamps on feeder pillars	No
Other	No

To project the model to 2050, the luminaire stock was divided into three types of lamps by their suitability for different energy saving measures and external drivers. These are:

- High pressure sodium lamps (SON) making up the majority of HA network luminaires.
- Low pressure sodium lamps, second largest proportion in luminaire stock.
- All other lamps

The methodology adopted allows for greater flexibility in setting controls on the model. The table below summarises the energy saving measures applied to each luminaire type in chronological order.

[6] WSP, 2010. Energy Solutions Programme: HA Roadside Electrical Asset Baseline Report (Baseline Year: FY2008/09)

Table 4. Luminaire energy saving measures applied.

Energy saving measure	Replaced with lower wattage SON (ECG integrated)	Replaced with LEDs	Trimming + Dimming + Midnight Switch-off	Integration of renewable technology
SOX lamps	Yes	Yes	Yes	Yes
SON lamps	Yes	Yes	Yes	Yes
All other types	No	Yes	Yes	Yes

An additional driver is the ability to increase or decrease the luminaire stock into the future.

The user will have the ability to decide whether or not to apply each model driver. The model provides the structure for utilising those measures that are appropriate for the luminaire type. The context (e.g. pedestrian crossing) within which the luminaires are used will factor in the scale of application in different scenarios.

To estimate the GHG emissions, the model calculates the energy consumption of luminaires year by year up to 2050 and multiplies this figure by the DECC grid carbon factor for the respective year.

Integral to the model are the assumptions and constraints resulting from the top down approach, summarised in the table below. The recommendations of this report do not take into account the particulars of each luminaire size, use and operation but illustrate the overall narrative of associated carbon emissions.

Table 5. Lighting assumptions used

Assumption / Constraint	Comment	Source
LED efficacy will improve up to 2030 and plateau thereafter		US, Department of Energy, 2010, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_energy-savings-report_10-30.pdf
All SOX lamps can be replaced with either equivalent or lower wattage SON, leading to a reduction in annual energy consumption of 30%	The reduction of energy consumption is realised due to an upgraded control gear, lower wattage lamp or central management system introduced	Arup industry experience and discussions with Highways Agency
All SON lamps can be replaced to lower wattage SON, leading to a reduction in annual energy consumption of 30%	The figure of 30% was based on a calculation of the average reduction reported by the HA Area 14 for replacement with lower wattage lamps	HA Area 14 Energy Savings spread sheet
All luminaire types can be replaced with LEDs of equivalent light output		Arup industry experience
All luminaire replacements include an upgrade to an electronic control gear		
All luminaires with an electronic control gear can		

Assumption / Constraint	Comment	Source
be subject to trimming or dimming		
All luminaires except those for pedestrian crossings are assumed to be on a dawn till dusk switching regime.	The proportion of luminaires (other than pedestrian crossing lamps) on 24 hour switching regimes was found to be negligible. Some luminaires were already upgraded to smarter switching regimes but their effect would be negligible on overall energy consumption.	HA, HA roadside equipment baseline report – (footnote 6), 2008/09
All pedestrian crossing lamps are on 24 hours switching regime		HA, HA roadside equipment baseline report – (footnote 6), 2008/09
Efficacy of SOX lamps is 113 lm/W		US, Department of Energy, 2010, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_energy-savings-report_10-30.pdf
Efficacy of SON lamps is 100lm/W		
Efficacy of LED lamps is 86 lm/Win 2010, achieving 204 lm/W in 2030.		
Average efficacy of other lamps ranges between 15 and 59 lm/W		Arup industry experience
Light output ratio of SOX is 65%		
Light output ratio of SON lamps is 80%		
Light output ratio of all other lamps is 80%		
Light output ratio of LED lamps is 95%		
Average lamp life of SOX lamps is 3 years		
Circuit wattage of SON lamps due to standard control gear increases lamp wattage by 10%		Arup industry experience
Circuit wattage of SOX lamps due to standard control gear increases lamp wattage by 40%		
Circuit wattage of other lamps due to standard control gear increases lamp wattage by 25%		
Average lamp life of SON lamps is 4 year		US, Department of Energy, 2010, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_energy-savings-report_10-30.pdf
Average lamp life of LED lamps is 10 years		
Average lamp life of all	Average made up of relative	

Assumption / Constraint	Comment	Source
other lamps ranges between 1 and 5 years	proportions of each lamp type within each category.	
Estimates of the annual energy consumption are based on average luminaire wattage for the luminaire categories.	This is a constraint on the accuracy of the model. As a result certain energy measures will not be appropriate, for e.g. lowering wattage of luminaires	HA baseline report – Footnote 6

A2.2.2 Equipment model methodology

This model was based on the 'HA Communication Asset – Electricity Costs and Carbon Emissions' data for the year 2011/12. The data was provided as carbon emissions which were converted into an annual energy consumption figure using the UK grid carbon factor for the given year. The same groupings of equipment as defined in the data records were maintained, namely:

1. Automatic number plate recognition
2. Cabinets
3. Cameras
4. HA Dig enforcement cameras
5. HA weather information system
6. Message signs
7. Outstations Equipment
8. Signal

Data was not available for traffic counting equipment and has not been included, with the Agency currently uncertain of existing energy consumption. Similar to the lighting model, the carbon emissions were calculated from projected energy consumption for the given year.

The model drivers in this case are commissioning or decommissioning of equipment, energy savings enabled by improvements in the technology or operation of equipment and the proportion of electricity demand generated by renewable energy.

A constraint on this model is the lack of granularity on individual equipment and future energy savings.

A2.2.3 Levers and scenario inputs

The following list outlines the levers and controls currently in place to drive the model scenarios.

Category	Lamp/ equipment type	Lever	Value Scenario 1	Scenario 2	Scenario 3
Road side lamps	SOX lamps	Year that SOX lamps start being replaced with SON lamps	2013	2013	2013
		Year that SON lamps start being replaced with LED lamps	2020	2015	2015
		Change in total lamp stock by 2050	0%	-15%	-40%
	SON lamps	Year that SON lamps start being replaced with lower wattage SON lamps	2013	2013	2013
		Year that SON start being replaced with LED lamps	2020	2015	2015
		Change in total lamp stock	0%	-15%	-40%
	All other lamps	Year that SON lamps start being replaced with LED lamps	2020	2015	2015
		Change in total lamp stock by 2050	0%	-15%	-40%
	All lamps	Delay in upgrade	50%	20%	0%
		Trimming energy reduction	0%	-1%	-2%
		Dimming energy reduction	0%	-32%	-50%
		Midnight Switch Off hours	0	5	6
High Mast Lamps	SON lamps	Year that SON lamps start being replaced with lower wattage SON lamps	2013	2013	2013
		Year that SON lamps start being replaced with LED lamps	2020	2015	2015
		Change in total lamp stock by 2050	0%	-15%	-40%
	All lamps	Delay in upgrade	50%	20%	0%
		Trimming energy reduction	0%	-1%	-2%
		Dimming energy reduction	0%	-32%	-50%
		Midnight Switch Off hours	0	5	6
Pedestrian crossing lamps, sign lighting, lamps on feeder pillars and other lamps	All other lamps	Year that SON lamps start being replaced with lower wattage SON lamps	2020	2013	2013
		Year that SON lamps start being replaced with LED lamps	0%	-15%	-30%
		Change in total lamp stock by 2050	50%	20%	0%
	All lamps	Delay in upgrade	0%	50%	100%
		Trimming energy reduction	0%	0%	0%
		Dimming energy reduction	0%	0%	0%
		Midnight Switch Off hours	0	0	0
Pedestrian Crossing	All lamps	% of lighting demand generated by renewable energy	0%	50%	100%

Category	Lamp/ equipment type	Lever	Value		
			Scenario 1	Scenario 2	Scenario 3
Highway Equipment	ANPR	% change in demand due to installation changes by 2050	10%	30%	-100%
		% change in demand due to to technological / operational changes by 2050	-20%	-50%	-100%
	Cabinets	% change in demand due to installation changes by 2050	10%	30%	-50%
		% change in demand due to technological / operational changes by 2050	-20%	-50%	-60%
	Cameras	% change in demand due to installation changes by 2050	30%	50%	100%
		% change in demand due to technological / operational changes by 2050	-20%	-50%	-60%
	HA DEC	% change in demand due to installation changes by 2050	30%	50%	100%
		% change in demand due to technological / operational changes by 2050	-20%	-50%	-60%
	HAWIS	% change in demand due to installation changes by 2050	10%	20%	50%
		% change in demand due to technological / operational changes by 2050	-20%	-50%	-60%
	Message Signs	% change in demand due to installation changes by 2050	10%	30%	-100%
		% change in demand due to technological / operational changes by 2050	-20%	-50%	-60%
	Meteo	% change in demand due to installation changes by 2050	10%	20%	50%
		% change in demand due to technological / operational changes by 2050	-20%	-50%	-60%
	Outstations	% change in demand due to installation changes by 2050	10%	30%	-100%
	Signal	% change in demand due to technological / operational changes by 2050	-20%	-50%	-60%
		% change in demand due to installation changes by 2050	10%	30%	-100%
	ALL	% change in demand due to technological / operational changes by 2050	-20%	-50%	-60%
		% of equipment demand generated by renewables	0%	0%	0%

A2.3 Traffic Officer fleet emissions

The traffic offer (TO) fleet model was based on data extracted from the 'HA Fleet Master' record for 2013. The model differentiates by network area including training and leased vehicles and by vehicle model. The result is 24 different models personalised to the operation of the vehicle type in each region. Data of average monthly mileage was used, and subsequently converted into an average annual mileage for 2013/14. This figure provided the basis for future projections, which are driven by:

- changes in the number of leased vehicle every 10 years;
- highway incident (including motorway accidents) demand up to 2050; and,
- motor fuel efficiency improvements every 10 years, applied on replaced vehicles with an assumed lease life of 10 years.
- % of fleet that are electric vehicles by 2050 (applied on the total fleet stock, not disaggregated by area)

Key to this model were assumptions on the miles per gallon performance of the TO fleet. The figures summarised in the table below were used.

Table 6. Fleet fuel consumption characteristics

Car Make	Car Model	Modelled miles per gallon
Disco 4 SDV6 GS	Land Rover	35.3
Disco 3 2.7TDV6	Land Rover	27
Vito 116 Dualiner	Mercedes Benz	37.7
L200 Crew cab	Mitsubishi	36.7
Shogun 3.2DI ELGNC	Mitsubishi	36.2
VW T'Porter 1.9D	Volkswagen	33

Similar to the constraints identified in the network modules, the TO fleet model was based on average mileage and average miles per gallon. This averaging created a discrepancy with the reported annual fuel consumption for the year 2014. To ensure the baseline fuel consumption agreed with the reported quantity, a calibration factor was applied to the mile per gallon figures for each vehicle. The resulting fuel consumption per year was multiplied by the latest diesel carbon factor for 2013, as used by the Agency. For this model, it has been assumed that the diesel carbon factor remains constant up to 2050.

A2.3.1 Levers and scenario inputs

The following list outlines the levers and controls currently in place to drive the model scenarios.

Lever	Value		
	Scenario 1	Scenario 2	Scenario 3
Lease life / operating life of TO fleet:			
2013 and 2020	2	2	2
2020 and 2030	2.5	2.5	3
2030 and 2040	4	4	5
200 and 2050	4	4	10
% change in energy efficiency of vehicles impacting the average miles per litre:			
2013 and 2020	10%	22%	25%
2020 and 2030	10%	12%	20%
2030 and 2040	1%	1%	0%
200 and 2050	0%	0%	0%
% change in number of highway incidents by 2050	20%	-10%	-80%
% change in number of vehicles:			
2013 and 2020	0%	15%	15%
2020 and 2030	0%	15%	-15%
2030 and 2040	0%	15%	-20%
200 and 2050	0%	5%	-50%
% of vehicle stock that are electric by 2050	10%	50%	100%

A2.4 General office procurement emissions

The office procurement carbon assessment has been based on office expenditure data, matched against Arup's multi-regional input-output carbon modelling tool and Defra Scope 3 (2012 published data) carbon intensity factors. This means the model reflects true UK consumption and production activity including manufacturing and services industries reflecting both their territorial and non-territorial emissions.

The approach has been based on 2013/14 general office procurement data from the HA. The full listing of expenditure categories is illustrated in the table below. These categories were mapped against industrial specification SIC codes with some aggregation or splitting of expenditure to ensure coverage of all categories. To avoid double counting aspects such as gas, electricity, water and CRC were removed leaving a final list of Scope 3 business/office expenditure. These pound spend values were then multiplied by the appropriate carbon intensities for each category. Note that adjustments for deflation were not applied.

The Highways Agency budget plan did not include office expenditure spend projections for the future. Rather than keeping this expenditure fixed at the 2013/14 level, it was linked to change in-line with construction expenditure. This assumes that office activity reflects the level of investment on construction projects. Expenditure category carbon intensity reductions in the future were not applied because of the high degree of complexity associated with this aspect which was deemed beyond the scope of this phase of work.

Parent Natural Account	Natural Account Name
Office Equipment, Services and Consumables	Couriers & IDS Operating Costs
	File storage and distribution services
	Maintenance of Office Machinery
	Non-capitalised purchases of Office Equipment
	Other office-related equipment and consumables Costs
	Postage
	Printing and Reprographics Operating Costs
	Rentals/Hire of office equipment under operating lease
	Stationery
ICT and Consumables	Consumables - Admin IT
	ICT Consultancy Costs
	ICT Consumables
	ICT Hardware Maintenance
	ICT Hardware Purchase
	ICT Software Maintenance
	ICT Software Purchase
Accommodation	Admin building refurbishment, maintenance, repairs, inspections and advice
	Business rates
	Cleaning / laundry services
	Electricity
	Gas
	Landlord service charges - admin L&B
	Other Accommodation Supplies
	Porterage removals / transport
	Professional advisers - Accommodation
	Rental Charges
	Rental charges - Admin Buildings
	Security costs
	Waste disposal / refuse collection
	Water and sewerage
	Facilities Management Charges
Other Admin Expenses	Bank charges
	Compensation for damaged clothing etc
	Exchange losses
	GPC costs
	Insurance - admin related claims
	Legal advice - admin related

Parent Natural Account	Natural Account Name
	Management consultancies on admin projects
	Nat West Corporate Card
	Payroll service provider charges
	Small Amount Write Offs
	Subscriptions to professional or learned societies
	CRC - Administration Costs
	Remove objects from the Highway
	Non-Executive Director Fees

A2.5 Water emissions

Water consumption associated emissions were based on the HA reported office water consumption in 2012/13. The drivers for this model are:

- Change in water demand per person
- Change in office staff numbers (this is treated as an exogenous driver covered in the estates model)
- Change in the carbon intensity of water supply

A2.5.1 Levers and scenario inputs

The following list outlines the levers and controls currently in place to drive the model scenarios.

Lever	Value		
	Scenario 1	Scenario 2	Scenario 3
% change in water consumption per employee	-10%	-10%	-20%
% change in water carbon conversion factor	-10%	-10%	-20%

A2.6 Waste emissions

The Agency does not report on waste related carbon emissions, although they do have expenditure data on waste disposal / refuse collection (a little over £20,200 in 2013/14). A top-down assessment approach based on expenditure estimated the Agency's waste emissions at 29 tCO_2e, which appeared small when considering the energy intensity of waste treatment facilities. With this in mind waste emissions were excluded pending further investigation. This component of the model could be established if a

A2.7 Emissions from employee business travel

The employee travel emissions were based on the 2010/11 reported HA internal emissions including business travel and employee commuting via all modes of transport. The drivers for this model are:

- Change in total distance travelled

- Change in staff numbers (this is treated as an exogenous driver covered in the estates model)
- Decarbonisation of average carbon intensity of travel. This allows for a change in transport mix of employee travel, decarbonisation of electricity affecting rail emissions and energy efficiency improvements in other modes of transport.

For the latter driver, an average carbon conversion factor (kg/km) of employee travel was calculated based on the 2012/13 total distance travelled and 2010/11 associated carbon emissions. It was assumed that annual total distance travelled has remained constant since 2010.

A2.7.1 Levers and scenario inputs

The following list outlines the levers and controls currently in place to drive the model scenarios.

Lever	Value		
	Scenario 1	Scenario 2	Scenario 3
% change in annual distance travelled by 2050	0%	-15%	-60%
% change in average carbon intensity of business travel by 2050	-5%	-10%	-50%

A2.8 Carbon emissions offset by PV noise barriers

The Highways Agency is considering the installation of photovoltaic panels on noise barriers as a business model to offset the cost of noise barriers and their own carbon emissions. The Highways Agency commissioned a feasibility study[7] and business case assessment[8] which recommended that just over 9km of the highways were suitable for PV noise barriers given orientation of the highway and local area constraints.

The model is based on these studies and driven by the chosen length of highways installed with PV noise barriers by 2050.

Assumptions within the model:

- Solar panels would be installed only where noise barriers were required, therefore not exceeding the estimated maximum eligible length.
- Installed noise barriers would be on average 4m high.
- The power output of solar panels is 300kWp per km (as estimated in the business feasibility study[8] for two rows of panels in landscape format)
- The average capacity factor is 30% (i.e. 30% of the year the solar panels will generate at peak capacity).

[7] Highways Agency, Network Viability Report, 2014
[8] Highways Agnecy, Study of business feasibility of Photovoltaic Enabled Noise Barriers at Communities alongside M40 Motorway Loudwater to Wheatley

A2.8.1 Levers and scenarios inputs

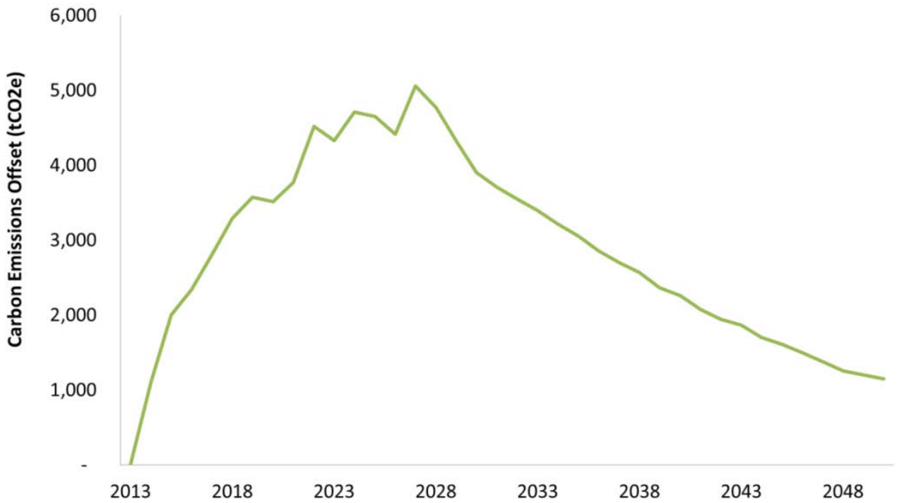
The following list outlines the levers and controls currently in place to drive the model scenarios.

Lever	Value		
	Scenario 1	Scenario 2	Scenario 3
Length of highways with installed PV noise barriers by 2050	0%	30%	100%

A2.8.2 Results of carbon emissions Offset by PV noise barriers

The installation of photovoltaic panels on noise barriers to offset their cost and own carbon emissions is an aspect of interest to the Highways Agency; but it represents only one of many potential interventions that could be made. To this end it does not form a core part of the Routemap and findings are therefore summarised in this section to avoid confusion.

This module with the Routemap model provides a means to consider the opportunities for different strategies of PV installation. The model works on the basis of carbon offset potential. In scenario 1, no noise barriers are installed with solar panels therefore no emissions are offset. Scenario 2 envisages that highways with the best conditions (orientation to sun and local environment) are installed with PV noise barriers by 2050; and scenario 3 envisages the maximum potential length of highways suitable for PV noise barriers are installed. Scenario 3 presents the most interesting outcome and this is summarised in the Figure below.



Potential carbon saving / offset potential of PV noise barriers shown for scenario 3. Offset potential diminishes over time as the energy grid decarbonises.

If the Highways Agency were interested to explore this aspect further an extension of the model would be to consider the length of the Highways network that could have PV installations exclusively (i.e. without the need for noise barriers). Given the Highways Agency's considerable land assets, highway PV installations could be an interesting proposition.

A3 Asset base carbon emissions model

The asset base model is based on two important components including 1) project types and future expenditure profiles for these, and 2) the carbon emissions associated with the supply chain and the materials demanded by the projects. Both these variables are expected to change over time and follow a defined profile.

A3.1 Project types

The model is based on three types of project the Agency delivers: including Major Projects (MP), Design Build Finance Operate project (DBFO) and Managing Agent Contractor projects (MAC). The carbon intensity and expenditure profile for each project type have been established.

A3.1.1 Major projects

Data was provided for ten MP for the period 2012/13. This included the project name, construction duration, construction category type (i.e. widening, smart motorway, renewal, bypass and junction improvement), total carbon emissions (as measured by the Agency supplier carbon assessment framework) and spend (£). This sample of projects enabled a carbon factor for each of the five MP categories types to be established:

1. Widening: 0.632 kgCO_2e / £
2. Smart motorway: 0.196 kgCO_2e/ £
3. Renewal: 0.511 kgCO_2e/ £
4. Bypass: 0.389 kgCO_2e/ £
5. Junction improvement: 0.707 kgCO_2e/ £

A3.1.2 MAC and DBFO

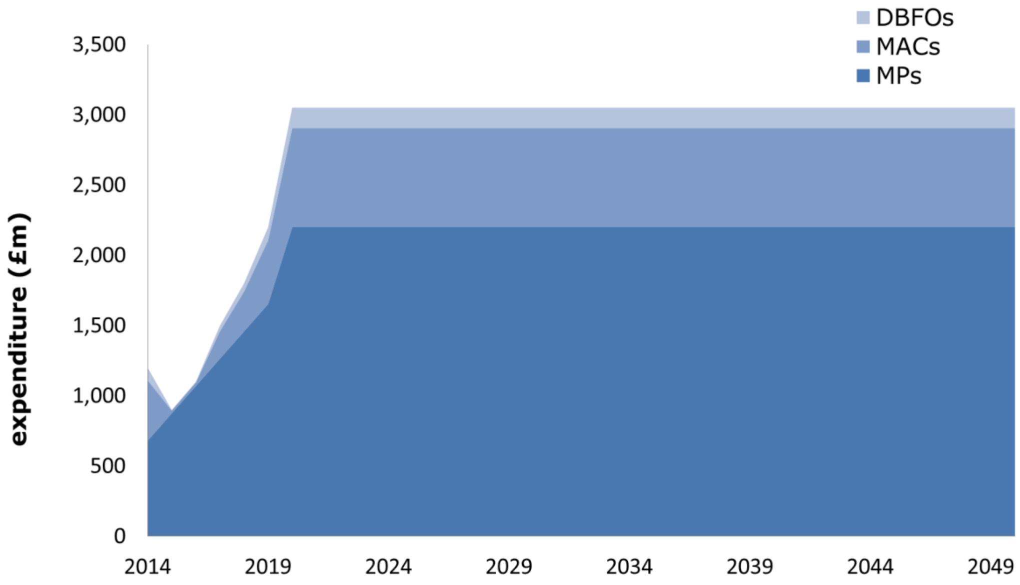
Data for the total MAC and DBFO carbon emissions for the financial year 2012/13 was available. Unfortunately associated expenditure levels for these project types could not be provided. To resolve this an assumed expenditure for each of these projects types was used generating an average carbon factor (CO_2e/ £). This was taken as equivalent to the average carbon factor across the ten MP data set equating to 0.456 kgCO_2e/ £.

A3.1.3 Future expenditure

To estimate future carbon emissions it was important to establish a future demand profile for Agency works activity. This was based on known or estimated expenditure. It is currently unclear how much the Highways Agency is expected to spend on infrastructure improvements by 2050. According to the Agency's 2014/15 Business Plan, investment in road enhancements is expected to triple by 2021 to over £3 billion. The Highways Agency's 2014/15 total capital budget is £1.28 billion, but not all of it is technically related to construction. By removing investments on items such as '*capitalised staff and office estates costs*', '*capitalised provisions*' and '*maintenance*' the actual investment on Major

Projects was estimated at around £681 million[9]. To this figure the estimated expenditure on MAC and DBFO projects were also added reaching a total of £1,200 million for 2014/15.

Expenditure was then assumed to increase to £3 billion by 2021 following the investment trajectory set out in the Agency's Collaborative Delivery Framework (CDF). MP expenditure was assumed to triple from 2014/15 to 2021 as suggested in the 2014/15 Business Plan. Expenditure on MAC and DBFO projects have been assumed to make up the shortfall between the MP investment and the total CDF projection. Beyond 2021 it is not known what the Agency's investment in road enhancement will be so the model has assumed a flat linear projection to 2050 in all scenarios (see Figure below). Within the carbon Routemap the user is able to adjust this within the scope of the three project types (and the sub-categories of MP) to reflect their own particular outlook.



Highways Agency projected expenditure on construction projects (the anticipated £3 billion investment has been adjusted to reflect that expenditure only on construction works).

A3.2 Supply chain carbon intensity

The model assumes the carbon intensity of project work per pound spent changes over time. The carbon intensity component of this can be adjusted based on a series of parameters incorporated in the model including:

- Industrial processes becoming more efficient and using less energy or less carbon intensive energy to produce the same output.
- The use of carbon capture and storage in the industrial processes producing materials.

[9] This figure is composed of the *major schemes*, *technology improvements* and *smaller schemes*. This figure compares favourably to the ten (completed) MP schemes used for this assessment valued at £1,693 million, equivalent to £564 million per annum assuming a 3–year construction duration per scheme.

- Assets achieving a lower carbon footprint through the design process and choice decisions (this could include more reuse, material substation and technology development of new solutions).
- Improvements in vehicle efficiency.
- Improvements in construction site energy efficiency.

For further evaluation individual levers have been established for discrete material categories based on a historical material supply profile for HA construction works. These are applicable across all project types.

All the levers noted above are incorporated in the model and adjust the carbon intensity factor applied to the project demand forecasts. Default values for each scenario have been selected for each of these variables.

A3.3 Levers and scenario inputs

The following list outlines the levers and controls currently in place to drive the model scenarios. With the exception of CCS, the values shown are those taken in 2050, with linear interpolation applied in the interim period. In the case of CCS, the percentage refers to the take up of the maximum technical potential in 2050 for CCS in the materials sectors. The reference points for these default values are the same as those applied in the UK Green Construction Board built environment low carbon Routemap (2013).

Lever	Value		
	Scenario 1	Scenario 2	Scenario 3
Site office & fixed plant	26%	49%	49%
Mobile plant	26%	49%	49%
Cement	14%	14%	31%
Metals	22%	22%	43%
Mortars	14%	14%	31%
Plastic	7.5%	7.5%	30%
Timber	12.5%	12.5%	25%
Ready-mix concrete	14%	14%	31%
Materials transportation	50%	50%	89%
CCS Steel (after 2020)	45%	45%	45%
CCS Cement (after 2020)	17%	17%	17%
Design efficiency	20%	39%	39%

A4 Road user carbon emissions model

User carbon emissions are those arising from the use of the strategic road network by parties other than the Highways Agency and its partners, i.e. the public.

A4.1 Methodology and data

The user carbon model is based on combining vehicle usage of the network, vehicle-kilometres and speed distributions, with vehicle fleet data and fuel efficiency data.

Following a meeting with the Highways Agency in Birmingham, compiled data was provided in the form of the ‘Network Performance Data Table’ for the 2012-13 financial year. This data included the traffic flow and average speed for every link of the HA managed network (approximately 2500 sections), along with statistics relating to the peak time congestion for these links. ‘Speed Histograms’ were also provided showing the distribution of speeds for typical sections of each road type on the network. Further disaggregation of this data to separate the HGV traffic has been requested but is not yet available, and thus assumptions have been made to produce the results in this report.

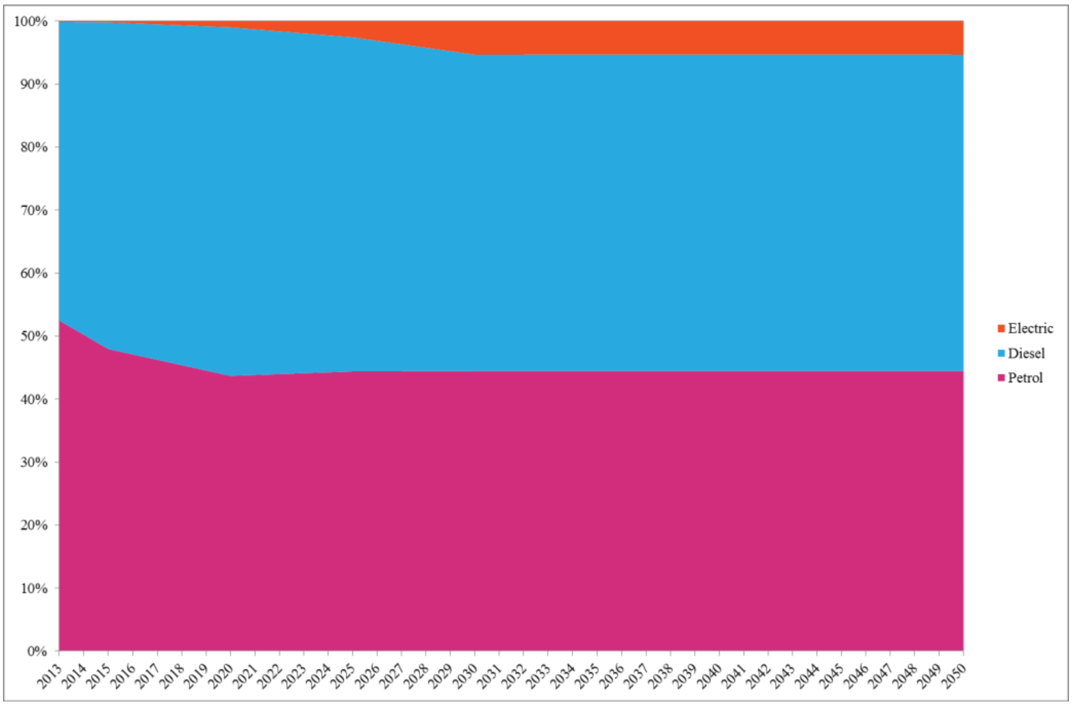
Future forecasts of vehicle-kilometres have been based on Department for Transport (DfT) Road Transport Forecasts.

The vehicle mix has been compiled from historic data from Transport Statistics Great Britain (TSGB) with future forecasts from the DfT’s WebTAG. This includes the historic and forecast proportions of vehicle-type and engine-type, the fuel economy of each type, and the emissions per litre of fuel used (or unit of electricity used).

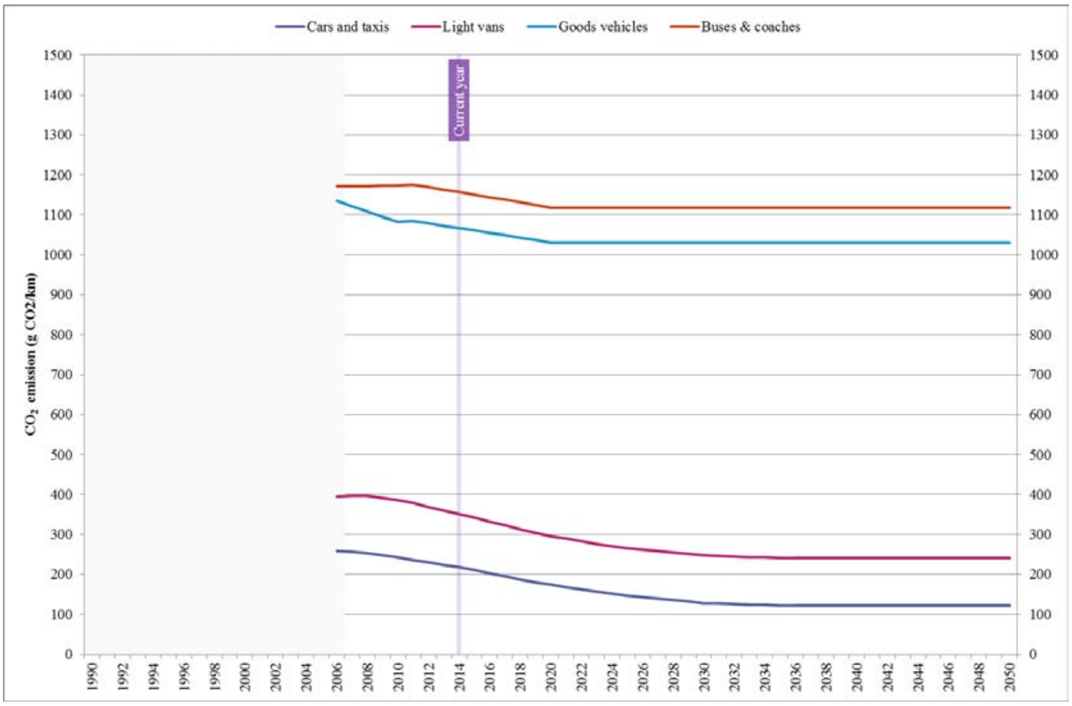
A4.2 Levers and scenario inputs

Controls to adjust the forecasts and assumptions have been built in to the model to allow alternative scenarios to be considered. These ‘levers’ are typically factors to amend the DfT forecasts, such that values of 0%, 0.0 or 1.00 (depending on the lever), represent the ‘default’ DfT forecasts for the future years, rather than no change from the present situation. The levers and values used are described below:

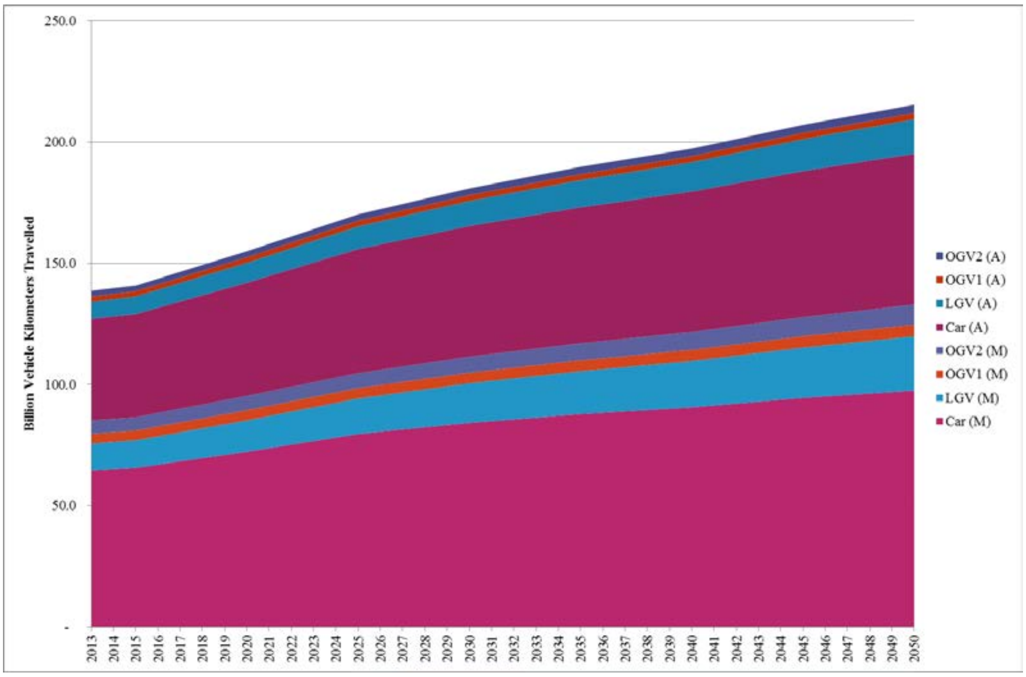
Electric Share: The DfT WebTAG forecasts an increase in the share of electric cars to 5.3% of the total by 2030, and assumes it would remain constant after this. The DfT forecasts assume that goods vehicles would remain powered by combustion engines. The model input allows the proportion of electric cars in 2030 and 2050 to be set by the user, and proportion of electric goods vehicles to be set in relation to the electric car mix.



Fuel Efficiency: The DfT WebTAG forecasts improvements in the fuel efficiency of vehicles. The user input allows further improvements in fuel efficiency to be set as a percentage improvement over and above those assumed by the DfT, disaggregated by vehicle type, fuel type, and the years over which these improvements are assumed to occur.



Traffic Growth: The DfT Road Transport Forecasts predict traffic growth disaggregated by vehicle type and road type. The user inputs allow these traffic growth predictions to be adjusted, disaggregated by vehicle type, road type, and the years over which these changes are assumed to occur.



Average Speed: The DfT Road Transport Forecasts predict variation in average speed by road disaggregated by vehicle type and road type. The changes in average speed are then used by the model to adjust the observed speeds on each link of the HA network. The user inputs allow these average speed predictions to be adjusted, disaggregated by vehicle type, road type, and the years over which these changes are assumed to occur

Speed Profile Normalisation: The distribution of speeds observed on typical links was provided by the Highways Agency, and then adjusted to match the observed average speed on a link by link basis. The Speed Profile Normalisation factor allows the user to adjust this distribution of speeds, where 1.0 assumes a similar range of speeds to those currently observed on each road type, and 0.0 assumes that all vehicles travelling on a link are travelling at the same speed, disaggregated by road type, and the years over which these changes are assumed to occur. This adjustment allows the investigation of the improvements associated with smart motorways.

Improvements to Congested Links: These controls allow the user to improve the average speed on the most congested links on the network by setting the minimum average speed by road type and the year that these are achieved. The user set minimum speed is introduced over time such that the minimum speeds are increased incrementally until the specified target year.

Savings Due to Autonomous Vehicles: The model includes additional controls allow the inclusion of effects that are not directly incorporated into the model. These controls can be used to models the additional efficiencies that Autonomous Vehicles would deliver, in particular the reduction in aerodynamic drag by travelling in platoons which could reduce fuel consumption by 15%

The following list outlines the levers and controls currently in place to drive the model scenarios.

Lever	Value		
	Scenario 1	Scenario 2	Scenario 3
Electric Share: Car: 2030	5.3%	5.3%	25.0%
Electric Share: Car: 2050	5.3%	5.3%	90.0%
Electric Factor: LGV	0.0	0.0	0.8
Electric Factor: OGV1/2	0.0	0.0	0.5
Fuel Efficiency Improvements (above DfT forecast)	0%	0%	50%
Traffic Growth: Car (compared to DfT forecast)	1.00 / 1.00	1.00 / 1.00	1.20 / 1.20
Traffic Growth: LGV (compared to DfT forecast)	1.00 / 1.00	0.90 / 0.90	0.90 / 0.90
Traffic Growth: OGV1/2 (compared to DfT forecast)	1.00 / 1.00	0.50 / 0.50	0.50 / 0.50
Average Speed (compared to DfT forecast)	1.00 / 1.00	1.00 / 1.00	1.20 / 1.10
Speed Profile Normalisation: Motorway	1.00	0.50 by 2050	0.25 by 2040
Speed Profile Normalisation: A Road Dual Carriageway	1.00	1.00	0.50 by 2050
Speed Profile Normalisation: A Road Single Carriageway	1.00	1.00	1.00
Improvements to Congested Links: Motorway	None	60 mph by 2050	60 mph by 2040
Improvements to Congested Links: A Road Dual Carriageway	None	None	60 mph by 2050
Improvements to Congested Links: A Road Single Carriageway	None	None	None
Savings due to Autonomous Vehicles: Motorways	None	None	10%
Savings due to Autonomous Vehicles: A Roads	None	None	5%