Appendix A

TOPIC BASED SCHEMES ASSESSMENT: DRAFT AOS FOR AIRPORTS NPS

A-9 CARBON

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9 CARBON

9.1 INTRODUCTION

9.1.1 This topic based assessment considers each airport expansion scheme under the Carbon topic. These are London Heathrow Extended Northern Runway (LHR-ENR), London Heathrow Northwest Runway (LHR-NWR) and London Gatwick Second Runway (LGW-2R) (together the shortlisted schemes).

9.1.2 By law, before designating an Airports National Policy Statement (NPS) an Appraisal of Sustainability (AoS) must be carried out. This AoS is a strategic level assessment. It is based on the contents of the draft Airports NPS. The AoS considers alternatives to the Government's preferred scheme as set out in the draft Airports NPS, including the outline masterplans supplied to the Airports Commission (AC) for the three shortlisted schemes. This AoS considers the impacts of expansion without the benefits of the mitigation package put forward by scheme promoters, unless stated otherwise. The Government has outlined that it expects a significant mitigation package to be put in place by the promoter of its preferred scheme to ensure that, wherever possible, significant effects are avoided, reduced or offset.

9.1.3 Further project-level design will be required which will inform an Environmental Impact Assessment carried out by the promoter. This would include an assessment, which is likely to include effects identified in the AoS, as well as more detailed mitigation developed as detailed design progresses. This will also be developed through consultation with both affected communities and other stakeholders.

9.1.4 This assessment builds on the previous assessment undertaken as part of the AC's Appraisal Framework but also responds to the AoS Appraisal Framework. This assessment focuses on responding directly to the requirements of the Strategic Environmental Assessment (SEA) Directive, and to addressing issues which have been identified through scoping (a review of plans, policies and programmes and also the national baseline).

9.1.5 The assessment focuses on the central case considered by the AC (assessment of need), but also includes a "high demand" sensitivity test to examine the implications for carbon emissions in a "worst case" scenario (see Annex presented in Section 9.13).

9.1.6 The Climate Change Act 2008 ("the Act'') established a legally binding target to reduce the UK's 'net' greenhouse gas emissions[1] by at least 80% below base year (1990[2]) levels by 2050 (the '2050 target'). The UK has also set five "carbon budgets" under the Act. These set interim five-year caps on emissions, currently up to 2032.

9.1.7 While domestic aviation emissions are included within the 2050 target and UK carbon budgets, international aviation emissions are not currently in the 2050 target as defined by the Act, nor within the five carbon budgets that have been set. However, the Act requires that the Government take into account international aviation emissions when setting carbon budgets.

[1] The UK's 'net' greenhouse gas emissions are the UK's total greenhouse gas emissions after any adjustments are made to account for the trade in carbon credits in accordance with any rules established by the Government.

[2] Base year is 1990 for emissions of carbon dioxide, nitrous oxide and methane, but 1995 for emissions of hydrofluorocarbons (HFCs), perfluorocarbons and sulphur hexafluoride.

9.1.8 The independent Committee on Climate Change (CCC) has interpreted the requirement to take international aviation emissions into account as requiring the UK to aim to meet a 2050 target which includes these emissions, and has made its recommendations for the levels of the existing carbon budgets on this basis.

9.1.9 Specifically, in their recommendation for the fifth carbon budget[3], the CCC advised that international aviation emissions "should continue to be allowed for by setting the budget on the path to meeting the 2050 target with international aviation emissions included" but that these emissions "should not be formally included in the fifth carbon budget". The Government set the fifth carbon budget in line with the CCC's advice, and did not include international aviation emissions, consistent with the CCC's advice that their inclusion remains impractical at this time.

9.1.10 The CCC has stated[4] that an appropriate planning assumption for 2050 aviation emissions is around 2005 levels (i.e. 37.5 $MtCO_2$).

9.1.11 To reflect the uncertainty over future aviation carbon policy, the AC developed two carbon policy scenarios – carbon-capped and carbon-traded – and used both to assess the carbon impacts of expansion. It concluded that any of the three shortlisted schemes could be delivered within the UK's climate change commitments.[5]

9.1.12 In this document, each expansion scheme is considered against the AoS Appraisal Framework Objectives, and Questions. The Objective and Questions which are addressed within this assessment are as follows:

- **AoS Objective 14:** To minimise carbon emissions in airport construction and operation.
  - **AoS Question 27:** Will the approach to the development be consistent with overall carbon requirements?
  - **AoS Question 28:** Will the approach minimise carbon emissions associated with surface transportation?

9.2 POLICY AND LEGISLATION

9.2.1 Airports in the UK are covered by a number of pieces of National and European legislation. The following policy and legislation relevant to this assessment are summarised below.

UK Climate Change Act 2008 ("the Act")

9.2.2 The Act established a legally binding target to reduce the UK's greenhouse gas emissions by at least 80% below base year (1990) levels by 2050. The UK's carbon budgets as described within the Act set interim five-year caps for UK emissions, currently up to 2032. However, while domestic aviation emissions are included within UK carbon budgets, international aviation emissions are excluded.

[3] Committee on Climate Change, 2015. *The Fifth Carbon Budget: The next step towards a low-carbon economy*. [online] Accessed 02/08/2016.
[4] Committee on Climate Change, 2013. *Factsheet: Aviation*. [online] Accessed 04/01/2016.
[5] See section 9.3 for an explanation of the AC's approach.

European Union Emissions Trading System (EU ETS) as applied to aviation

9.2.3 The EU ETS is a carbon 'cap and trade' system launched in 2005 aimed at reducing greenhouse gas emissions from the 'traded sector' to a given level (cap) in the most cost-effective way (trade) amongst its participants. Aviation was initially included in the system from 2012, with emissions from all flights originating from or arriving at aerodromes situated in the European Economic Area (EEA) initially included in the system. However, the 'Aviation EU ETS' met with strong international opposition, due to perceived infringements on sovereignty. In parallel, progress was made at the UN's International Civil Aviation Organisation (ICAO) to address international aviation emissions, with an agreement to develop a Global Market-based Measure (GMBM), for decision at the 2016 ICAO Assembly. In order to promote progress on the GMBM, the EU agreed to a temporary derogation - to reduce the scope of the Aviation EU ETS for 2012 - 2016 to cover emissions from flights between EEA States only. Following the 2016 ICAO Assembly, the European Commission will review the Aviation EU ETS and put forward proposals on the future of the system, taking into account the agreement at ICAO. The EU ETS is enacted in UK legislation through the Greenhouse Gas Emissions Trading Scheme Regulations 2012.

European Union Emissions Trading System (EU ETS) as applied to large combustion plant (>20MW_{th})

9.2.4 As with aviation, the EU ETS as applied to large combustion plant also works on the 'cap and trade' principle. A cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The cap is reduced over time so that total emissions fall. Within the cap, companies receive or buy emission allowances which they can trade with one another as needed. The limit on the total number of allowances available ensures that they have a value. Both Heathrow and Gatwick feature large boiler plant and/or power generation (CHP) plant that falls under the remit of the EU-ETS.

Carbon Reduction Commitment (CRC) Energy Efficiency Scheme

9.2.5 The CRC is a requirement to buy allowances based on qualifying carbon emissions, alongside other reporting and documentation requirements. The qualifying criteria is to use at least 6,000 MWh of electricity supplied through a half-hourly meter. This affects the majority of UK airports.

Climate Change Levy (CCL)

9.2.6 The CCL is a levy on supplies of electricity and certain fossil fuels, designed to encourage affected bodies to put in place energy saving measures. Certain energy-intensive industrial sectors are able to negotiate discounts on CCL in return for signing up to energy targets known as Climate Change Agreements (CCAs), however, this option is not open to the aviation sector.

Mandatory Carbon Reporting

9.2.7 This requires all UK listed companies to report on their greenhouse gas emissions as part of their annual Directors' Report. The requirement affects all UK incorporated companies listed on the main market of the London Stock Exchange, a EEA market or whose shares are dealing on the New York Stock Exchange or NASDAQ, and will affect many of the larger publicly-held airports. Currently, Gatwick Airport Limited is listed on the London Stock Exchange and is required to participate in Mandatory Carbon Reporting; whereas Heathrow Airport is privately held by a consortium headed by Ferrovial, and is therefore not compelled to report in this way.

9.2.8 In addition to the mandatory regulatory schemes listed above, airports may choose to participate in voluntary carbon measurement and reporting schemes, such as:

ACI's Airport Carbon Accreditation Scheme

9.2.9 A voluntary programme that enables airports to measure and certify their carbon footprint. Airports must have their carbon footprints independently verified in accordance with ISO14064 (Greenhouse Gas Accounting) to gain certification. There are four levels of certification available from basic carbon footprinting (Level 1 - "Mapping"), putting in place a carbon management plan (Level 2 – "Reduction"), achieving reductions (Level 3 – "Optimisation"), to full carbon neutrality (Level 4 – "Neutrality"). Both Heathrow and Gatwick are currently accredited to Level 3 – Optimisation.

Various non-airport specific energy and carbon management accreditation schemes

9.2.10 This could include schemes such as the Carbon Trust Standard, Carbon Saver Standard, CEMARS and BSi Kitemark. These are voluntary accreditation schemes which seek to recognise the efforts made by organisations to reduce their carbon emissions. Currently, both Heathrow and Gatwick hold certification to the Carbon Trust Standard.

9.3 BACKGROUND TO THE ASSESSMENT

9.3.1 The assessment is based on the AC's Final Report of July 2015, and the supporting material drawn from the following reports prepared by Jacobs:

- Jacobs, 2014. *8. Carbon: Baseline*[6] - representing the forecast carbon emissions for each of the three schemes under consideration, based on the "do minimum" scenario;
- Jacobs, 2014. *8. Carbon: Assessment*[7] - representing the forecast carbon emissions for each of the three schemes under consideration, based on the "do something", whilst operating in a carbon-capped environment; and
- Jacobs, 2015. *Module 8: Carbon, Carbon Further Assessment*[8] - representing the forecast carbon emissions for each of the three schemes under consideration, based on both the "do minimum"[9] and the "do something"[10] scenarios, whilst operating in a carbon traded environment.

9.3.2 Carbon emissions relating to air travel, passenger surface access and the operation of airport buildings and fuel use have been forecast by the AC for both Heathrow and Gatwick for a "do minimum" scenario, without new runway expansion over a 60-year period from 2025/2026 to 2085/2086. Emissions from construction of the new runways and associated facilities have also been assessed. Furthermore, the same emissions have been modelled for the new LHR–NWR, the LHR-ENR and the LGW-2R over the same period under two climate change policy scenarios: carbon-capped and carbon-traded. In the carbon-capped scenario, it has been assumed that aviation emissions will be capped in line with the CCC's planning assumption of 37.5 $MtCO_2$ in 2050. Under the carbon-traded scenario, UK aviation carbon emissions could continue to grow, with compensatory reductions being made elsewhere via a mechanism under which UK aviation emissions would be offset by purchases of carbon credits across the global economy.

[6] Jacobs, 2014. *8. Carbon: Baseline*. [online] Accessed 04/01/2016.
[7] Jacobs, 2014. *8. Carbon: Assessment.* [online] Accessed 04/01/2016.
[8] Jacobs, 2015. *Module 8: Carbon, Carbon Further Assessment*. [online] Accessed 04/01/2016.
[9] Represents the conditions which would exist if the scheme did not go ahead and the airport developed in the absence of the scheme.
[10] Represents the conditions which would exist if the scheme did go ahead.

9.3.3 In all three expansion schemes and under both climate change policy scenarios, the most significant volume of emissions is related to air travel. The modelling shows that in the baseline case without expansion, under both the carbon-capped and carbon-traded scenarios, at airport level these are expected to decrease slightly over the period due to assumed improvements in the fuel efficiency of aircraft, together with a shift in airline fleets to larger aircraft on long haul routes.

9.3.4 Surface access emissions remain the second largest source of operational CO_2 emissions over the assessment period. These will increase under both the carbon-capped and carbon-traded scenarios, with fluctuations linked to annual passenger numbers. However, the rise is not in line with increased passenger numbers due to increases in vehicle efficiency and decarbonisation of road transport in line with Government policy[11].

9.3.5 Emissions from staff surface access and freight handling are also likely to increase. These were not assessed by the AC. This is discussed further under Section 9.12, Assumptions and Limitations.

9.3.6 The modelling shows that emissions from buildings and airport operations also reduce over time, most significantly due to the expected decarbonisation of grid electricity, but also due to expected efficiency increases on the part of the operators.

9.3.7 The AC's assessment focussed on the emissions of carbon (as carbon dioxide, CO_2) associated with the combustion of fuels, either directly in aircraft, surface vehicles or boilers or other plant at the airport, or indirectly, such as in large scale boiler plant used in the generation of electricity. The AC also looked at carbon dioxide equivalent (CO_2e) emissions associated with construction of new airport infrastructure and facilities. These are also significant, particularly in the case of the two Heathrow schemes, where they form the second largest overall source of emissions after air travel over the assessment period.

9.3.8 In addition, there are other emissions of greenhouse gases associated with the operation of an airport, and with aviation, which were not assessed. These are discussed further under Section 9.12, Assumptions and Limitations.

9.4 INTERACTION WITH OTHER TOPICS

9.4.1 The Carbon topic is closely related to other topic-based assessments in this report. Where the Carbon topic interacts with topics and associated impacts are understood to be direct and potentially significant, they have been listed in the below table. A description of the interaction is provided.

Table 9.1. Interaction of the Carbon topic with other topics.

TOPIC	INTERACTION
Economy	There is a potential interaction between the financial benefits associated with expansion of airport capacity, the potential effect that the airport expansion will have on carbon emissions, and the contribution that the expanded airport will make to carbon budgets.
Soils/Biodiversity/ Landscape	Soils and vegetation absorb and store carbon. Loss of land and vegetation linked to airport expansion will reduce the capacity of the landscape to absorb carbon emissions, and may result in the release of stored carbon into the atmosphere. This has not been quantified as part of this assessment, as there is insufficient data available to enable a robust assessment to be made. It is recommended that this be assessed by an applicant at the time of detailed scheme design.

[11] Department for Transport, 2013. *Driving the Future Today: A strategy for ultra-low emission vehicles in the UK*, Office for Low Emission Vehicles. [online] Accessed 04/01/2016.

Topic	Interaction
Water	Carbon emissions make a significant contribution to greenhouse gases which cause climate change. Impacts of climate change include changes in weather patterns and sea level rise which increase flood risk and changes water availability.
Air Quality	Most air quality issues stem from the combustion of fuels associated with Air Transport Movements (ATMs), surface access and operation of the airport infrastructure. Some of the proposed mitigation measures for both air quality and carbon emissions will have the effect of reducing both aspects.
Materials and Waste	Materials used have embodied carbon emissions due to manufacture and transport, particularly during construction when large quantities of natural resources are used. Transport and processing/ disposal of waste gives rise to carbon emissions as well as other greenhouse gases. A resource efficient approach is a carbon efficient approach.
Noise	Modern turbofan aircraft engines are quieter and more efficient than earlier generations, however, changes to engine design in the pursuit of greater efficiency may result in increased noise, at least in the short term, for example through adoption of turboprop or open rotor engine designs. Furthermore, changes to aircraft operating patterns intended to reduce fuel burn on take-off and landing may result in increased risk of noise exposure to surrounding communities, and, conversely, measures intended to reduce the numbers of residents exposed to noise may have the effect of increasing fuel burn and consequent emissions.

9.5 ASSESSMENT CRITERIA

9.5.1 The general criteria used for assessing the significance of effects within the AoS are set out in the methodology in Section 3 of the AoS Report, to which this appendix is attached, and are applied to this topic. It should be noted that schemes are assessed individually against the requirements of the SEA Regulations and presented together for comparison. Identification of significance is set out in Table 9.2 below.

Table 9.2. Identification of Significant Effects in the AoS

++	*Significant positive effect*
+	*Positive effect*
-	*Negative effect*
--	*Significant negative effect*
+/-, ++/--	*Mixed positive and negative effect*
?	*Uncertain effect*
0	*No relationship / neutral effect*

9.5.2 No further assessment criteria specific to this topic have been applied to the assessment.

9.6 SUMMARY OF BASELINE AND ISSUES

NATIONAL BASELINE

9.6.1 In 2014, UK greenhouse gas emissions amounted to 514.4 $MtCO_2e$ (million tonnes carbon dioxide equivalent). This measure includes carbon dioxide emissions, and also emissions of other known greenhouse gases such as methane, nitrous oxide and HFCs. These are related back to an equivalent carbon dioxide figure by means of their known Global Warming Potential (GWP) factor, to give an equivalent measure expressed in terms of carbon dioxide or CO_2e. This is a 35.4% reduction from 1990 when 796.6$MtCO_2e$ was released. Between 2000 and 2014, greenhouse gas emissions reduced by 27.6%.

9.6.2 The most recent data published by the former Department of Energy and Climate Change (now BEIS) indicates that, in 2014, emissions from UK road transport (by source) were 109.3 $MtCO_2e$. The aviation sector (by source) contributed 1.5 $MtCO_2e$ from domestic flights plus a further estimated 32.9 $MtCO_2e$ from flights departing the UK.[12]

9.6.3 Between 2000 and 2014, the level of emissions from domestic flights decreased from 2.1 $MtCO_2e$ in 2000, to 1.5 $MtCO_2e$ in 2014. Emissions from flights leaving the UK increased by around 6% between 2000 and 2014, from 30.4 $MtCO_2e$ to 32.9 $MtCO_2e$.

9.6.4 At airport level, emissions from flights departing Gatwick and Heathrow are currently around 3.9 $MtCO_2$/year and 18.8 $MtCO_2$/year respectively[13]. This represents around 12% of emissions from UK departing flights in Gatwick's case, and 57% in Heathrow's.

FUTURE BASELINE AND ISSUES

9.6.5 Aviation is a relatively small contributor to total greenhouse gas emissions (both at the UK and global levels) contributing 2% of man-made CO_2 emissions globally.[14] However, as is described below, emissions are projected to grow and aviation is likely to be a significant contributor in coming decades. According to the Department for Transport's (DfT's) own forecasts, demand for air travel is forecast to increase within the range of 1% to 3% a year, up to 2050, compared with historical growth rates of 5% a year over the last 40 years. Without expansion, emissions from flights departing the UK are forecast to increase from 33.3 $MtCO_2$ in 2011 to 47 $MtCO_2$ by 2050[15]. Note that the baseline and future projection figures referred to in this report are consistent with those used by the AC in their analysis.

9.6.6 To determine the baseline for future carbon emissions, the AC needed to address uncertainty over future aviation carbon policy as described in the Introduction to this Appendix. To reflect this, the AC considered the demand for aviation under two future climate change policy scenarios, each of which represented a different approach to managing CO_2 emissions from aviation in the future.

9.6.7 In the first climate change policy scenario, the AC integrated the CCC's planning assumption into its approach to forecasting aviation demand by assuming that 'gross' UK aviation emissions in 2050 were capped in line with the CCC planning assumption under a carbon emissions-constrained scenario ("carbon-capped").

9.6.8 In the second climate change policy scenario, the AC considered a case in which UK aviation carbon emissions were allowed to continue to grow, with compensatory reductions being made elsewhere via a mechanism under which UK aviation emissions would be offset by purchases of carbon credits across the global economy ("carbon-traded").

[12] Department of Energy and Climate Change (now BEIS), 2015. *2014 UK greenhouse gas emissions: final figures* – date tables. [online] Accessed: 14/05/2016.
[13] Department for Transport, 2013. UK Aviation Forecasts, Table 6.3. [online] Accessed 26/01/2017.
[14] http://www.icao.int/environmental-protection/Documents/ICAO%20Environmental%20Report%202016.pdf
[15] Department for Transport, 2013. *UK Aviation Forecasts*. [online] Accessed 04/01/2016.

9.6.9 The construction, operation and maintenance of additional capacity will generate emissions associated with materials (embodied), transportation and energy use. These higher emissions, where under the non-traded sector (those sectors not covered by the EU ETS), will affect performance against the UK's carbon budgets.

9.6.10 There are currently a range of policies and measures in place or planned, designed to promote the decarbonisation of surface transportation, and in particular road transport. These have not been included in the predicted baseline without expansion.

9.6.11 The Ecosystem Services Assessment undertaken on behalf of the AC[16] identifies the importance of ecosystems in relation to climate regulation, providing a carbon store, for instance in woodland and undisturbed soils. However, this has not been quantified in the assessment due to lack of robust data. It is recommended that this be assessed by an applicant at the time of detailed scheme design when more robust data is expected to be available.

9.7 MITIGATION INCLUDED IN ASSESSMENT

9.7.1 The assessment of carbon undertaken by the AC uses information taken from the three reports prepared by Jacobs[17,18,19] which in themselves drew information and data from a range of sources provided by each of the respective scheme promoters.

9.7.2 The AC's observations on the respective features of the three shortlisted schemes and their associated carbon impacts are contained in its Final Report[20] .

9.7.3 The scheme promoters also produced a number of documents covering potential mitigation measures that could be included in the final design of each respective scheme. However, it should be noted that these were not included in the assessment below but are documented in Section 9.10.

9.7.4 The mitigations considered here relate predominantly to carbon emissions from surface transport, construction and airport operation. In terms of carbon emissions from flights, measures to reduce emissions to be consistent with future carbon obligations such as carbon-pricing, operational efficiencies and biofuels for example, are incorporated into the carbon-traded and carbon-capped scenarios considered by the AC.

LGW-2R

9.7.5 The scheme promoter of the LGW-2R scheme, Gatwick Airport Limited, has carried out a study[21] which examines the carbon emissions associated with the construction and operation of a second runway at Gatwick, and then goes on to identify a range of emissions reduction measures that could be applied.

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[16] Jacobs, 2014, *7. Biodiversity: Ecosystem Services*. [online] Accessed 02/08/2016.
[17] Jacobs, 2014. *8. Carbon: Baseline*. [online] Accessed 04/01/2016.
[18] Jacobs, 2014. *8. Carbon: Assessment*. [online] Accessed 04/01/2016. Jacobs, 2014.
[19] Jacobs, 2015. *Module 8: Carbon, Carbon Further Assessment*. [online] Accessed 04/01/2016.
[20] Airports Commission, 2015. *Final Report*, pp. 203-205. [online] Accessed 04/01/2016.
[21] RSK Environment, 2014. *A Second Runway for Gatwick*, Appendix A11, Carbon. [online] Accessed 04/01/2016.

LHR-NWR

9.7.6 The scheme promoter of the LHR-NWR scheme, Heathrow Airport Limited, has prepared a report[22] which quantifies the expected carbon footprint associated with the building and operation of the proposed LHR-NWR scheme, and covers a range of mitigation measures.

LHR-ENR

9.7.7 The scheme promoter of the LHR-ENR scheme, Heathrow Hub Limited, has prepared a Technical Annex report[23] which covers a range of environmental impacts, including carbon emissions. These are quantified for both construction and operation and a range of mitigation measures are proposed.

9.8 APPROACH TO ASSESSMENT OF CARBON

9.8.1 Impacts at the strategic level have been assessed for both construction and operational phases. For instance, during construction, effects covered under carbon arise from earthworks, lighting and construction activities. During operation, effects would include the emissions from energy used in the operation of new infrastructure and buildings, fuel used by airport vehicles, fuel used during ATMs and fuel used in passenger and staff surface access. This is addressed through the consideration of the duration of the impact (short, medium and long term) within the assessment. For each of the three shortlisted schemes, the AC studied the various carbon impacts across four areas:

- Increased airport capacity leading to a net change in air travel;
- Airside ground movements and airport operations;
- Changes in non-aviation transport patterns brought about by the option's surface access strategy; and
- Construction of new facilities and surface access infrastructure.

9.8.2 The AC used two future climate change policy scenarios to forecast future aviation emissions growth: 'carbon-capped' which assumes that 'gross' UK aviation emissions in 2050 are capped in line with the CCC planning assumption, and 'carbon-traded', which assumes an international trading mechanism which would allow UK aviation emissions to be offset by purchases of carbon credits across the global economy.

9.8.1 The carbon emissions baseline and forecasts under the two scenarios as reported in the AC Final Report are based on work undertaken by Jacobs[24,25,26]. A number of different methods and inputs were used to calculate the emissions.

9.8.2 Emissions from aircraft movements and passenger surface access were estimated by the AC based on the methodology used by the UK DfT Aviation Forecasts[27,28]. Emissions associated with altered flight operations were not calculated because there was judged to be insufficient information on air space routing and management changes for the future runway 'do something' proposals.

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[22] AMEC Environment & Infrastructure UK Limited, 2014. *Heathrow's North-West Runway-Carbon Footprint Assessment*. [online] Accessed 02/08/2016.
[23] URS, 2014. *Heathrow Expansion*, Stage 2 Submission, Attachment 5-1.
[24] Jacobs, 2014. *8. Carbon: Baseline*. [online] Accessed 04/01/2016.
[25] Jacobs, 2014. *8. Carbon: Assessment.* [online] Accessed 04/01/2016.
[26] Jacobs, 2015. *Module 8: Carbon, Carbon Further Assessment*. [online] Accessed 04/01/2016.
[27] Department for Transport, 2011. *Aviation Forecast 2011*. [online] Accessed 06/11/2016.
[28] Department for Transport, 2013. *Aviation Forecast 2013*. [online] Accessed 06/11/2016.

9.8.3 Operational emissions were forecast by the AC based on reported historic energy use / emissions and changes in passenger numbers or building floor area of the airport's principal buildings.

9.8.4 Construction emissions were estimated by the AC based on indicative costs for master plan developments, using benchmarks from the WRAP AggRegain CO_2 Carbon Emissions Calculator Tool[29] for embodied carbon emissions.

9.8.5 In addition to assessment under a central scenario below, sensitivity testing was undertaken for the highest demand economic growth scenario in order to test the impact of greater carbon emissions at Section 9.13 below.

9.9 ASSESSMENT OF SHORTLISTED SCHEMES

9.9.1 The carbon impacts of the schemes are assessed at the airport level. This analysis therefore shows a "gross" picture of the increase in carbon emissions relative to the baseline but does not take account of the potential reductions at other airports, again relative to the baseline of no expansion.

9.9.2 At the airport level, ATMs and aircraft ground movements are by far the largest sources of total emissions from aviation, predicted for 'do minimum' to be at around 92% of total airport emissions in 2030 in the case of Gatwick, and around 98% in the case of Heathrow[30]. The emission levels at local airport level from this source in both the carbon-capped and carbon-traded cases are higher from the Heathrow schemes than from LGW-2R, as Heathrow sees a larger proportion of long-haul flights, which have higher carbon impacts.

9.9.3 To assess the consistency with carbon obligations, which are based on UK-wide targets, it is necessary to consider the impact of expansion on total UK carbon emissions. The AC's forecasts show that CO_2 emitted by UK-departing aircraft does not lead to increased emissions overall either at the international level (in the carbon-traded forecast) or within the UK economy (in the carbon-capped forecast).

9.9.4 In the case of the carbon-capped forecast, the AC assumed the introduction of measures to ensure that the CCC's planning assumption is met. These include the introduction of biofuels into aviation fuel, improvements to aircraft design, operational efficiency improvements and limitation of demand growth, for example through carbon pricing. The degree to which such measures need to be implemented to meet the planning assumption varies across the schemes.

9.9.5 Under the carbon-capped scenario, the planning assumption was met by raising the carbon price to reduce demand to a level that was considered consistent with meeting the target. The AC modelling showed this was technically possible although under the high demand scenarios it would require a very high carbon price[31].

9.9.6 The AC also published analysis[32] based on a hybrid approach that combines a higher carbon price than the carbon traded scenario[33], with two specific abatement measures: higher uptake of biofuels, and operational improvements including electric-powered taxiing and fuel efficient cruising speeds.

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[29] WRAP, 2010. *AggRegain CO_2 Carbon Emissions Calculator Tool*. WRAP: Oxon.
[30] Jacobs, 2014. *8. Carbon: Baseline*. Table A2 and A3. [online] Accessed 04/01/2016.
[31] Airports Commission, 2015. *Strategic Fit: Forecasts*, Appendix 5, pp. 258-260. [online] Accessed 13/01/2017.
[32] Airports Commission, 2015. *Economy: Carbon Policy Sensitivity Test*. [online] Accessed 13/01/2017.
[33] £334/tCO2 in 2050 as opposed to £196/tCO2 in 2050. The AC used five possible future scenarios for global aviation demand in its analysis. The 'assessment of need' scenario is used as the core scenario, supplemented by sensitivity analysis where appropriate.

9.9.7 In all schemes, the AC concluded that implementing such measures would be technically feasible.

9.9.8 In the carbon-traded case, the AC considered that UK aviation emissions could continue to grow unconstrained, with compensatory reductions being made elsewhere via a carbon trading mechanism in which aviation emissions could be traded with other sectors of the global economy.

9.9.9 The AC concluded that, therefore, the increases in emissions from flights should not be considered to be additional and therefore did not monetise these in its economic analysis of carbon impacts. All schemes could therefore be delivered consistent with future carbon obligations. The economic analysis of carbon impacts therefore focused on the AC's objective to reduce carbon emissions from the construction and operation of the airport itself.

9.9.10 Airport operations are dependent to a large extent on the nature and scale of the passenger and support facilities at the airport, and the larger scale of both of the Heathrow schemes explains the greater emissions from these relative to Gatwick. However, because grid electricity use is such a large part of the operational energy used (about two thirds of the 2026 carbon emissions for the LHR-NWR scheme, for example) and the CO_2 emissions from this source are expected to decrease per kW of power with technology improvements (a reference to the planned decarbonisation of the electricity grid), both the do minimum and expansion scheme forecasts show lower levels of carbon produced in 2050 than in 2025[34].

9.9.11 All schemes result in additional emissions from surface access compared to the do minimum, with the highest level of additional CO_2 due to passenger surface access produced by the LGW-2R scheme. There are two factors driving this result. First, the LGW-2R scheme provides the greatest number of additional passengers, relative to today, whose journeys to and from the airport lead to increased CO_2 emissions. Second, at the national level, both schemes at the Heathrow site produce a decrease in total surface access emissions as passengers who move into an expanded Heathrow do so from airports where the mode share is more heavily weighted towards road than rail. The same trend is also seen in the LGW-2R scheme but to a lesser extent.

9.9.12 In addition to the on-going impacts described above, the construction of new facilities and infrastructure will have a one-off carbon emissions impact. For the LGW-2R scheme this is expected to be approximately 3.9 $MtCO_2e$, much of this occurring in 2025. For the Heathrow schemes the impact is mainly in 2026, and substantially higher, with the LHR-NWR scheme emitting 11.3 $MtCO_2e$ and the LHR-ENR scheme emitting 10.1 $MtCO_2e$.

9.9.13 The results of the AC's assessment are summarised in the Table 9.3 below:

[34] Airports Commission, 2015. *Final Report*, paragraph 9.113, p. 204. [online] Accessed 04/01/2016.

Table 9.3. Summary of results of AC's assessment of emissions (expressed as change in $MtCO_2$ over the appraisal period) for each scheme under assessment of need demand forecast for both carbon-capped (CC) and carbon-traded (CT) policy scenarios[35].

AREA OF EMISSIONS	LGW-2R		LHR-ENR		LHR-NWR	
Impacts on	**CT**	**CC**	**CT**	**CC**	**CT**	**CC**
Passenger surface access	10.1	6.6	6.3	4.9	7.4	5.7
Airport operations (energy and fuel use)	1.1	0.8	2.1	1.8	2.6	2.2
Construction of airport facilities and surface access infrastructure *	3.9	3.9	10.1	10.1	11.3	11.3
Total	**15.1**	**11.3**	**18.5**	**16.8**	**21.3**	**19.2**
Air travel at the expanded airport (not included in the monetised assessment)	110.2	68.9	251.3	210.4	298.9	236.7

** Figures for construction emissions are expressed as carbon dioxide equivalent, or $MtCO_2e$. All other figures are in terms of carbon, $MtCO_2$.*

9.9.14 From Table 9.3, it is clear that the LGW-2R scheme has the lowest additional emissions under both the carbon-capped and carbon-traded scenarios. Both Heathrow schemes produce higher emissions than Gatwick, with LHR-NWR producing the greatest emissions due to an overall larger number of passengers and a bigger construction programme. The scheme would also have a higher number of ATMs, of which a greater proportion are likely to be long-haul.

9.9.15 At the UK level, LHR-NWR leads to the highest emissions from aviation in 2050 of 43.3 $MtCO_2$. LGW-2R produces the least with emissions of 40.8 $MtCO_2$ in 2050.

9.9.16 The above analysis is based on the AC's central aviation demand forecast, assessment of need (AoN). There are a range of growth forecasts which may produce higher or lower forecasts than those presented here. The worst-case growth forecasts are discussed in the Annex presented at Section 9.13.

9.9.17 The AC Final Report concluded that, overall the LGW-2R scheme is judged to perform best on the objective of minimising carbon emissions in airport runway construction and operation, even allowing for its higher impact in terms of increased passenger surface access emissions. Of the two Heathrow schemes, the LHR-ENR performs marginally more strongly than the LHR-NWR scheme.

Objective 14: To minimise carbon emissions in airport construction and operation

LGW-2R

9.9.18 Carbon emissions have been assessed over a 60-year appraisal period under two climate change policy scenarios: carbon-capped, and carbon-traded, using the AC's central passenger demand scenario, AoN. Carbon emissions from the airport are associated with ATMs, ground movement of planes, passenger surface access journeys, and airport operations (energy and fuel use). Direct aviation-related emissions make up over 90% of the total carbon emissions associated with Gatwick over the 60-year appraisal period.[36]

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[35] Based on: Airports Commission, 2015. Final Report, p. 205, Table 9.6. [online] Accessed 04/01/2016; with amendments using figures taken from Jacobs, 2014. 8. Carbon: Baseline. [online] Accessed 04/01/2016, Jacobs, 2014. *8. Carbon: Assessment.* [online] Accessed 04/01/2016 and Jacobs, 2015. Module 8: Carbon, Carbon Further Assessment. [online] Accessed 04/01/2016.

[36] Jacobs, 2015. *Module 8: Carbon, Carbon Further Assessment*, Table 1.12. [online] Accessed 04/01/2016.

9.9.19 The key figures relating to aviation emissions in 2025 and 2050 and their relationship to UK National aviation emissions are summarised in Table 9.4 below, along with a summary of passenger surface access emissions for the same periods:

Table 9.4. LGW-2R Summary of annual emissions over appraisal period under carbon-capped (CC) and carbon-traded (CT) scenarios (assessment of need demand scenario)

YEAR	2025	2050	2025	2050	2025	2050	2025	2050
Emissions Source / Scenario	**Do Minimum, CC**		**Do Minimum, CT**		**Do Something, CC**		**Do Something, CT**	
Aviation Emissions ($MtCO_2$)	4.4	3.9	4.5	4.0	4.4	5.3	4.7	6.3
Contribution to UK Aviation Emissions (%)	11.3%	10.3%	11.4%	10.1%	11.4%	14.2%	11.8%	15.4%
Passenger Surface Access Emissions ($MtCO_2$)	0.304	0.309	0.306	0.308	0.312	0.448	0.323	0.523

9.9.20 The impacts on carbon emissions will arise directly from the development of the airport, and also cumulatively with other development elsewhere including major road and rail infrastructure developments planned under plans, policies and programmes such as the National Networks National Policy Statement (NPS), or from major residential and commercial development. Major infrastructure schemes which are located nearby include the Lower Thames Crossing and also improvements to the A27 in West Sussex, and the M25. The nearby local authorities also have plans for housing and employment growth, and these will contribute to increasing carbon emissions.

LHR-ENR

9.9.21 Carbon emissions have been assessed over a 60-year appraisal period under two climate change policy scenarios: carbon-traded, and carbon-capped, using the AC's central growth forecast, AoN. Carbon emissions from the airport are associated with air travel, ground movement of planes, passenger surface access journeys, and airport operations energy and fuel use. Aviation makes up over 97% of the total carbon emission associated with LHR-ENR scheme over the 60-year appraisal period.[37]

9.9.22 The key figures relating to aviation emissions in 2025 and 2050 and their relationship to UK National aviation emissions are summarised in Table 9.5 below, along with a summary of passenger surface access emissions for the same periods:

Table 9.5. LHR-ENR Summary of annual emissions over appraisal period under carbon-capped (CC) and carbon-traded (CT) policy scenarios (assessment of need demand scenario)

YEAR	2026	2050	2026	2050	2026	2050	2026	2050
Emissions Source / Scenario	**Do Minimum, CC**		**Do Minimum, CT**		**Do Something, CC**		**Do Something, CT**	

[37] Jacobs, 2015. *Module 8: Carbon, Carbon Further Assessment,* Table 3.12. [online] Accessed 04/01/2016.

Aviation Emissions ($MtCO_2$)	20.3	16.6	20.6	17.1	21.6	19.9	22.2	21.1
Contribution to UK Aviation Emissions (%)	52.2%	44.2%	51.7%	42.9%	55.8%	53.1%	53.8%	49.3%
Passenger Surface Access Emissions ($MtCO_2$)	0.373	0.469	0.375	0.478	0.383	0.556	0.391	0.591

9.9.23 The impacts on carbon emissions will arise directly from the development of the airport, and also cumulatively with development elsewhere including major road and rail infrastructure developments planned under plans, policies and programmes such as the National Networks NPS, or from major residential and commercial development. Major rail infrastructure schemes which are located nearby include HS2, and Crossrail and also improvements to the road network including the M25. The nearby local authorities all have plans for housing and employment growth, and these will also contribute to increasing carbon emissions.

LHR-NWR

9.9.24 Carbon emissions have been assessed over a 60-year appraisal period under two climate change policy scenarios: carbon-traded, and carbon-capped, using the AC's central growth forecast, AoN. Carbon emissions from the airport are associated with air travel, ground movement of planes, passenger surface access journeys, and airport operations energy and fuel use. Aviation makes up over 97% of the total carbon emission associated with LHR-NWR over the 60-year appraisal period.[38]

9.9.25 The key figures relating to aviation emissions in 2025 and 2050 and their relationship to UK National aviation emissions are summarised in Table 9.6 below, along with a summary of passenger surface access emissions for the same periods:

[38] Jacobs, 2015. *Module 8: Carbon, Carbon Further Assessment*, Table 2.12. [online] Accessed 04/01/2016.

Table 9.6. LHR-NWR Summary of annual emissions over appraisal period under carbon-capped (CC) and carbon-traded (CT) policy scenarios (assessment of need demand scenario)

YEAR	2026	2050	2026	2050	2026	2050	2026	2050
Emissions Source / Scenario	**Do Minimum, CC**		**Do Minimum, CT**		**Do Something, CC**		**Do Something, CT**	
Aviation Emissions ($MtCO_2$)	20.3	16.6	20.6	17.1	21.6	20.5	22.2	22.0
Contribution to UK Aviation Emissions (%)	52.2%	44.2%	51.7%	42.9%	56.1%	54.6%	53.8%	50.7%
Passenger Surface Access Emissions ($MtCO_2$)	0.373	0.469	0.375	0.478	0.385	0.573	0.391	0.614

9.9.26 The impacts on carbon emissions will arise directly from the development of the airport and also cumulatively with development elsewhere, including major road and rail infrastructure developments planned under plans, policies and programmes such as the National Networks NPS, or from major residential and commercial development. Major rail infrastructure schemes which are located nearby include HS2, and Crossrail and also improvements to the road network including the M25. The nearby local authorities all have plans for housing and employment growth, and these will also contribute to increasing carbon emissions.

9.9.27 It should be noted that for all three schemes the emissions due to staff surface access and freight transport movements were not included in the assessment undertaken for the AC and published in the AC Final Report. Emissions from staff and freight surface access are likely to be significant, and, furthermore, can also be expected to rise with any future development of the airport. This is discussed further under Section 9.11, Assumptions and Limitations.

OBJECTIVE 14: TO MINIMISE CARBON EMISSIONS IN AIRPORT CONSTRUCTION AND OPERATION.

Question 27: Will the approach to the development be consistent with overall carbon requirements?

	LGW-2R	LHR-ENR	LHR-NWR
Description of Impact (including receptor)[39]	Over the 60-year Appraisal Period (2025 to 2085), under the carbon-capped scenario, it is forecast that the development of LGW-2R will result in the emission of a further 76.2 $MtCO_2$ from the expanded airport over the baseline case[40]. Over the same Appraisal Period under the carbon-traded scenario, it is forecast that the development of LGW-2R will result in the emission of a further 121.5 $MtCO_2$ from the expanded airport over the baseline case[41]. In both cases, construction emissions will contribute a further 3.9 $MtCO_2e$ to UK emissions, however, this is a one-off impact at the beginning of the appraisal period[42].	Over the 60-year Appraisal Period (2026 to 2086), under the carbon-capped scenario, it is forecast that the development of LHR-ENR will result in the emission of a further 217.1 $MtCO_2$ from the expanded airport over the baseline case[43]. Over the same Appraisal Period under the carbon-traded scenario, it is forecast that the development of LHR-ENR will result in the emission of a further 259.6 $MtCO_2$ from the expanded airport over the baseline case[44]. In both cases, construction emissions will contribute a further 10.1 $MtCO_2e$ to UK emissions, however this is a one-off impact at the beginning of the appraisal period[45].	Over the 60-year Appraisal Period (2026 to 2086), under the carbon-capped scenario, it is forecast that the development of LHR-NWR will result in the emission of a further 244.6 $MtCO_2$ from the expanded airport over the baseline case[46]. Over the same Appraisal Period under the carbon-traded scenario, it is forecast that the development of LHR-NWR will result in the emission of a further 308.9 $MtCO_2$ from the expanded airport over the baseline case[47]. In both cases, construction emissions will contribute a further 11.3 $MtCO_2e$ to UK emissions, however this is a one-off impact at the beginning of the appraisal period[48].
Direct/ Indirect/ Cumulative	**Direct/ Cumulative** The impacts on carbon emissions will arise directly from the development of the airport, and also through other development, including from major road and rail infrastructure developments planned associated with this development but located elsewhere under plans, policies and programmes such as the National Networks NPS, and from major residential and commercial	**Direct/ Cumulative** The impacts on carbon emissions will arise directly from the development of the airport, and also through other development including from major road and rail infrastructure developments planned associated with this development but located elsewhere under plans, policies and programmes such as the National Networks NPS, and from major residential and commercial	**Direct/ Cumulative** The impacts on carbon emissions will arise directly from the development of the airport, and also through other development including from major road and rail infrastructure developments planned associated with this development but located elsewhere under plans, policies and programmes such as the National Networks NPS, and from major residential and commercial

[39] For source of figures presented, please refer to Table 9.3.
[40] Jacobs, 2014. *Module 8. Carbon: Assessment*, Table 3.17. [online] Accessed 04/01/2016.
[41] Jacobs, 2015. *Module 8. Carbon: Further Assessment*, Table 1.12 [online] Accessed 04/01/2016.
[42] Jacobs, 2014. *Module 8. Carbon: Assessment*, Table 3.17. [online] Accessed 04/01/2016.
[43] Jacobs, 2014. *Module 8. Carbon: Assessment*, Table 5.16. [online] Accessed 04/01/2016.
[44] Jacobs, 2015. *Module 8. Carbon: Further Assessment*, Table 3.12 [online] Accessed 04/01/2016.
[45] Jacobs, 2014. *Module 8. Carbon: Assessment*, Table 5.16. [online] Accessed 04/01/2016.
[46] Jacobs, 2014. *Module 8. Carbon: Assessment*, Table 4.18. [online] Accessed 04/01/2016.
[47] Jacobs, 2015. *Module 8. Carbon*: Further Assessment, Table 2.12 [online] Accessed 04/01/2016.
[48] Jacobs, 2014. *Module 8. Carbon*: Assessment, Table 4.18. [online] Accessed 04/01/2016.

	LGW-2R	LHR-ENR	LHR-NWR
	development planned by local planning authorities.	development planned by local planning authorities.	development planned by local planning authorities.
Probability (High, Medium, Low, Very Low)	**High** There is a high probability that development of the airport will increase carbon emissions.	**High** There is a high probability that development of the airport will increase carbon emissions.	**High** There is a high probability that development of the airport will increase carbon emissions.
Phase, Duration (Long-term, Medium-term Short-term), Frequency	**Construction, S and Operation, Long-term / Continuous** Carbon emissions are likely to be generated through both construction and operational activities associated with the airport. Increases in aircraft emissions from expansion will not be additional in either the carbon-capped or carbon-traded scenarios for the reasons given at 9.9.9. Emissions from construction and airport operation (such as energy use in terminal buildings) are assumed to be additional and to contribute to total UK emissions.	**Construction, S and Operation, Long-term / Continuous** Carbon emissions are likely to be generated through both construction and operational activities associated with the airport. Increases in aircraft emissions from expansion will not be additional in either the carbon-capped or carbon-traded scenarios for the reasons given at 9.9.9. Emissions from construction and airport operation (such as energy use in terminal buildings) are assumed to be additional and to contribute to total UK emissions.	**Construction, S and Operation, Long-term / Continuous** Carbon emissions are likely to be generated through both construction and operational activities associated with the airport. Increases in aircraft emissions from expansion will not be additional in either the carbon-capped or carbon-traded scenarios for the reasons given at 9.9.9. Emissions from construction and airport operation (such as energy use in terminal buildings) are assumed to be additional and to contribute to total UK emissions.
Permanent/ Temporary **Irreversible/ Reversible**	**Permanent / Irreversible** The proposed scheme will be a permanent development and is not expected to be removed. The impacts from the operation of this scheme are therefore also considered permanent. Impacts from construction will be temporary, but irreversible. These impacts could be reversed, e.g. by cessation of operations and removal of infrastructure, however this is not expected. At a global level, the adverse effects associated with climate change can be mitigated through trading with other sectors of the global economy in the carbon-traded case.	**Permanent / Irreversible** The proposed scheme will be a permanent development and is not expected to be removed. The impacts from the operation of this scheme are therefore also considered permanent. Impacts from construction will be temporary, but irreversible. These impacts could be reversed, e.g. by cessation of operations and removal of infrastructure, however this is not expected. At a global level, the adverse effects associated with climate change can be mitigated through trading with other sectors of the global economy in the carbon-traded case.	**Permanent / Irreversible** The proposed scheme will be a permanent development and is not expected to be removed. The impacts from the operation of this scheme are therefore also considered permanent. Impacts from construction will be temporary, but irreversible. These impacts could be reversed, e.g. by cessation of operations and removal of infrastructure, however this is not expected. At a global level, the adverse effects associated with climate change can be mitigated through trading with other sectors of the global economy in the carbon-traded case.
Magnitude and Spatial Extent, incl. Transboundary	**High, International** Carbon emissions from international flights arriving in or departing from the UK constitute the largest source of emissions as a result of the scheme. These are currently excluded from carbon budgets, although carbon budgets to	**High, International** Carbon emissions from international flights arriving in or departing from the UK constitute the largest source of emissions as a result of the scheme. These are currently excluded from carbon budgets, although carbon budgets to	**High, International** Carbon emissions from international flights arriving in or departing from the UK constitute the largest source of emissions as a result of the scheme. These are currently excluded from carbon budgets, although carbon budgets to

	LGW-2R	LHR-ENR	LHR-NWR
	date have been set at a level which is intended to put the UK on track to meet its 2050 target when international aviation is included. Carbon emissions from UK domestic aviation and associated airport operational emissions contribute to carbon budgets. In the carbon-capped scenario, emissions from flights would be capped by policy to a level commensurate with the CCC's planning assumption for 2050. In the carbon-traded case these reductions would need to be made elsewhere in the global economy.	date have been set at a level which is intended to put the UK on track to meet its 2050 target when international aviation is included. Carbon emissions from UK domestic aviation and associated airport operational emissions contribute to carbon budgets. In the carbon-capped scenario, emissions from flights would be capped by policy to a level commensurate with the CCC's planning assumption for 2050. In the carbon-traded case these reductions would need to be made elsewhere in the global economy.	date have been set at a level which is intended to put the UK on track to meet its 2050 target when international aviation is included. Carbon emissions from UK domestic aviation and associated airport operational emissions contribute to carbon budgets. In the carbon-capped scenario, emissions from flights would be capped by policy to a level commensurate with the CCC's planning assumption for 2050. In the carbon-traded case these reductions would need to be made elsewhere in the global economy.
Assumptions and Limitations	The carbon forecasts are based on a number of assumptions about passenger growth and expected mitigation measures. Some of the mitigation measures will be brought about by legislation or through market forces. It is a limitation of the assessment that, as with any forecast, if these assumptions prove incorrect, emissions may rise higher than is forecast. A range of policy measures are available at national and local levels to constrain carbon emissions.	The carbon forecasts are based on a number of assumptions about passenger growth and expected mitigation measures. Some of the mitigation measures will be brought about by legislation or through market forces. It is a limitation of the assessment that, as with any forecast, if these assumptions prove incorrect, emissions may rise higher than is forecast. A range of policy measures are available at national and local levels to constrain carbon emissions.	The carbon forecasts are based on a number of assumptions about passenger growth and expected mitigation measures. Some of the mitigation measures will be brought about by legislation or through market forces. It is a limitation of the assessment that, as with any forecast, if these assumptions prove incorrect, emissions may rise higher than is forecast. A range of policy measures are available at national and local levels to constrain carbon emissions.
Significance	Significant Negative effect (--)	Significant Negative effect (--)	Significant Negative effect (--)
	The effects are characterised as direct and cumulative, with high probability; long/continuous duration (for operation only), permanent but potentially reversible and international in extent, with high magnitude. The combined nature of these effects has led to the conclusion that the unmitigated impact can be considered to be a "Significant Negative" effect.	The effects are characterised as direct and cumulative, with high probability; long/continuous duration (for operation only), permanent but potentially reversible and international in extent, with high magnitude. The combined nature of these effects has led to the conclusion that the unmitigated impact can be considered to be a "Significant Negative" effect.	The effects are characterised as direct and cumulative, with high probability; long/continuous duration (for operation only), permanent but potentially reversible and international in extent, with high magnitude. The combined nature of these effects has led to the conclusion that the unmitigated impact can be considered to be a "Significant Negative" effect.

QUESTION 28: WILL THE APPROACH MINIMISE CARBON EMISSIONS ASSOCIATED WITH SURFACE TRANSPORTATION?

SEA Topic	LGW-2R	LHR-ENR	LHR-NWR
Description of Impact (including receptor)	Over the 60-year Appraisal Period (2025 to 2085), under the carbon-capped scenario, it is forecast that the development of LGW-2R will result in the emission of an additional 6.6 $MtCO_2$ at the expanded airport due to Passenger Surface Access over the baseline case[49]. Over the same Appraisal Period under the carbon-traded scenario, it is forecast that the development of LGW-2R will result in the emission of an additional 10.1 $MtCO_2$ at the expanded airport due to Passenger Surface Access over the baseline case[50]. Emissions from staff surface access and freight transport movements are also likely to rise, but these were not quantified in the AC's assessment. It is recommended that they be assessed by an applicant at the time of detailed design.	Over the 60-year Appraisal Period (2026 to 2086), under the carbon-capped scenario, it is forecast that the development of LHR-ENR will result in the emission of an additional 4.9 $MtCO_2$ at the expanded airport due to Passenger Surface Access over the baseline case[51]. Over the same Appraisal Period under the carbon-traded scenario, it is forecast that the development of LHR-ENR will result in the emission of an additional 6.3 $MtCO_2$ at the expanded airport due to Passenger Surface Access over the baseline case[52]. Emissions from staff surface access and freight transport movements are also likely to rise, but these were not quantified in the AC's assessment. It is recommended that they be assessed by an applicant at the time of detailed design.	Over the 60-year Appraisal Period (2026 to 2086), under the carbon-capped scenario, it is forecast that the development of LHR-NWR will result in the emission of an additional 5.7 $MtCO_2$ at the expanded airport due to Passenger Surface Access over the baseline case[53]. Over the same Appraisal Period under the carbon-traded scenario, it is forecast that the development of LHR-NWR will result in the emission of an additional 7.4 $MtCO_2$ at the expanded airport due to Passenger Surface Access over the baseline case[54]. Emissions from staff surface access and freight transport movements are also likely to rise, but these were not quantified in the AC's assessment. It is recommended that they be assessed by an applicant at the time of detailed design.
Direct/ Indirect/ Cumulative	**Direct/ Cumulative** The impacts on carbon emissions will arise directly from the surface transportation associated with the development at Gatwick Airport. It is expected that there will be further, indirect and cumulative effects due to traffic associated with other development which is proposed elsewhere near to the airport, for example from traffic associated with new residential or commercial development (secondary development) planned by local authorities as part of their future plans for growth.	**Direct/ Cumulative** The impacts on carbon emissions will arise directly from the surface transportation associated with the development at Heathrow Airport. It is expected that there will be further, indirect and cumulative effects due to traffic associated with other development which is proposed elsewhere near to the airport, for example from traffic associated with new residential or commercial development (secondary development) planned by local authorities as part of their future plans for growth.	**Direct/ Cumulative** The impacts on carbon emissions will arise directly from the surface transportation associated with the development at Heathrow Airport. It is expected that there will be further, indirect and cumulative effects due to traffic associated with other development which is proposed elsewhere near to the airport, for example from traffic associated with new residential or commercial development (secondary development) planned by local authorities as part of their future plans for growth.

49 Jacobs, 2014. *Module 8. Carbon*: Assessment, Table 3.17. [online] Accessed 04/01/2016.
50 Jacobs, 2015. *Module 8. Carbon*: Further Assessment, Table 1.12 [online] Accessed 04/01/2016.
51 Jacobs, 2014. *Module 8. Carbon*: Assessment, Table 5.16. [online] Accessed 04/01/2016.
52 Jacobs, 2015. *Module 8. Carbon*: Further Assessment, Table 3.12 [online] Accessed 04/01/2016.
53 Jacobs, 2014. *Module 8. Carbon*: Assessment, Table 4.18. [online] Accessed 04/01/2016.
54 Jacobs, 2015. *Module 8. Carbon*: Further Assessment, Table 2.12 [online] Accessed 04/01/2016.

SEA Topic	LGW-2R	LHR-ENR	LHR-NWR
Probability (High, Medium, Low, Very Low)	**High** There is a high probability that surface transport emissions will increase carbon emissions at a local level compared to the "do minimum" scenario.	**High** There is a high probability that surface transport emissions will increase carbon emissions at a local level compared to the "do minimum" scenario.	**High** There is a high probability that surface transport emissions will increase carbon emissions at a local level compared to the "do minimum" scenario.
Phase, Duration (Long-term, Medium-term Short-term), Frequency	**Operation, Long-term** The emissions associated with the surface access proposals will be experienced during the operational phase. These will be long term effects, and will be continuous in nature.	**Operation, Long-term** The emissions associated with the surface access proposals will be experienced during the operational phase. These will be long term effects, and will be continuous in nature.	**Operation, Long-term** The emissions associated with the surface access proposals will be experienced during the operational phase. These will be long term effects, and will be continuous in nature.
Permanent/ Temporary **Irreversible/ Reversible**	**Permanent and Irreversible** The surface access transportation systems which will be put in place as part of the development at Gatwick Airport are considered to be a permanent and irreversible development. The carbon emissions which will be associated with transportation using these systems may reduce over time due to improvements in technology. Emissions from surface access are not currently tradeable in any market, so cannot be mitigated through carbon trading, however, there are other measures available to reduce transport emissions e.g. electrification, hydrogen-fuelled vehicles, etc.	**Permanent and Irreversible** The surface access transportation systems which will be put in place as part of the development at Heathrow Airport are considered to be a permanent and irreversible development. The carbon emissions which will be associated with transportation using these systems may reduce over time due to improvements in technology. Emissions from surface access are not currently tradeable in any market, so cannot be mitigated through carbon trading, however, there are other measures available to reduce transport emissions e.g. electrification, hydrogen-fuelled vehicles, etc.	**Permanent and Irreversible** The surface access transportation systems which will be put in place as part of the development at Heathrow Airport are considered to be a permanent and irreversible development. The carbon emissions which will be associated with transportation using these systems may reduce over time due to improvements in technology. Emissions from surface access are not currently tradeable in any market, so cannot be mitigated through carbon trading, however, there are other measures available to reduce transport emissions e.g. electrification, hydrogen-fuelled vehicles, etc.
Magnitude and Spatial Extent, incl. Transboundary	**High, International** Carbon emissions from surface transportation will contribute to the UK's overall carbon emissions and carbon budgets. The government is working to reduce overall carbon emissions. In both the carbon-traded and carbon-capped scenarios, the contribution of Gatwick to UK emissions from surface access would increase, however, at a UK-level; there would be an overall slight reduction in these carbon emissions by 2050 in both the	**High, International** Carbon emissions from surface transportation will contribute to the UK's overall carbon emissions and will impact on the UK's carbon budget. The government is working to reduce overall carbon emissions. In both the carbon-traded and carbon-capped scenarios, the contribution of Heathrow to carbon emissions would increase, however, at a UK-level; there would be an overall reduction in carbon emissions by 2050 in both the carbon-	**High, International** Carbon emissions from surface transportation will contribute to the UK's overall carbon emissions and will impact on the UK's carbon budget. The government is working to reduce overall carbon emissions. In both the carbon-traded and carbon-capped scenarios, the contribution of Heathrow to carbon emissions would increase, however, at a UK-level; there would be an overall slight reduction in carbon emissions by 2050 in both the carbon-

SEA TOPIC	LGW-2R	LHR-ENR	LHR-NWR
	carbon-capped[55] and carbon-traded[56] scenarios, when compared to the “do minimum” case.	capped[57] and carbon-traded[58] scenarios, when compared to the “do minimum” case.	capped[59] and carbon-traded[60] scenarios, when compared to the “do minimum” case.
Assumptions and Limitations	The transport emissions carbon forecasts are based on a number of assumptions about passenger growth, transport mode and expected mitigation measures, such as an increase in low emission vehicles, modal shift to public transport and increasing electrification of rail alongside decarbonisation of the electricity grid. It is a limitation of the assessment that, as with any forecast, if these assumptions prove incorrect, emissions may rise higher than is forecast. A range of policy measures are available at national and local levels to constrain carbon emissions.	The transport emissions forecasts are based on a number of assumptions about passenger growth, transport mode and expected mitigation measures, such as an increase in low emission vehicles, modal shift to public transport and increasing electrification of rail alongside decarbonisation of the electricity grid. It is a limitation of the assessment that, as with any forecast, if these assumptions prove incorrect, emissions may rise higher than is forecast. A range of policy measures are available at national and local levels to constrain carbon emissions.	The transport emissions forecasts are based on a number of assumptions about passenger growth, transport mode and expected mitigation measures, such as an increase in low emission vehicles, modal shift to public transport and increasing electrification of rail alongside decarbonisation of the electricity grid. It is a limitation of the assessment that, as with any forecast, if these assumptions prove incorrect, emissions may rise higher than is forecast. A range of policy measures are available at national and local levels to constrain carbon emissions.
Significance	Significant Negative effect (--)	Significant Negative effect (--)	Significant Negative effect (--)
	The effects are characterised as direct and cumulative, with high probability; long/continuous duration, permanent and irreversible and international in extent, with high magnitude. The combined nature of these effects has led to the conclusion that the unmitigated impact can be considered to be a “Significant Negative” effect at a local level. It should be noted that there is forecast to be a small positive impact on emissions from surface transportation across the whole UK airport network as a result of the LGW-2R scheme.	The effects are characterised as direct and cumulative, with high probability; long/continuous duration, permanent and irreversible and international in extent, with high magnitude. The combined nature of these effects has led to the conclusion that the unmitigated impact can be considered to be a “Significant Negative” effect at a local level. It should be noted that there is forecast to be a small positive impact on emissions from surface transportation across the whole UK airport network as a result of the LHR-ENR scheme.	The effects are characterised as direct and cumulative, with high probability; long/continuous duration, permanent and irreversible and international in extent, with high magnitude. The combined nature of these effects has led to the conclusion that the unmitigated impact can be considered to be a “Significant Negative” effect at a local level. It should be noted that there is forecast to be a small positive impact on emissions from surface transportation across the whole UK airport network as a result of the LHR-NWR scheme.

55 Jacobs, 2014. *Module 8. Carbon*: Assessment, Table 3.5. [online] Accessed 04/01/2016.
56 Jacobs, 2015. *Module 8. Carbon*: Further Assessment, Table 1.7. [online] Accessed 04/01/2016.
57 Jacobs, 2014. *Module 8. Carbon*: Assessment, Table 5.5. [online] Accessed 04/01/2016.
58 Jacobs, 2015. *Module 8. Carbon*: Further Assessment, Table 3.7. [online] Accessed 04/01/2016.
59 Jacobs, 2014. *Module 8. Carbon*: Assessment, Table 4.5. [online] Accessed 04/01/2016.
60 Jacobs, 2015. *Module 8. Carbon*: Further Assessment, Table 2.7. [online] Accessed 04/01/2016.

9.10 MITIGATION

9.10.1 There are various mitigation techniques that could be applied to reduce the carbon emissions of all three schemes. At the next stage of project development (detailed scheme design), the scheme promoter or applicant would need to consider measures to minimise emissions of carbon during construction and operation.

9.10.2 As part of their submissions, the scheme promoters prepared materials on the potential range of mitigation measures that could be applied to their own schemes. These measures are detailed below.

SCHEME PROMOTER MITIGATION PLANS – LGW-2R

9.10.3 The scheme promoter identified and documented a number of enhanced carbon mitigation measures which might be implemented as part of the Second Runway[61]. Since these were not included in the AC's assessment these are not covered in detail here, but may be referred to in the promoter's own materials referenced in the footnote below.

SCHEME PROMOTER MITIGATION PLANS – LHR-ENR

9.10.4 The scheme promoter identified and documented a number of enhanced carbon mitigation measures which might be implemented as part of the Extended Northern Runway[62]. Again, since these were not included in the AC's assessment these are not covered in detail here, but may be referred to in the promoter's own materials referenced in the footnote below.

SCHEME PROMOTER MITIGATION PLANS – LHR-NWR

9.10.5 The scheme promoter identified and documented a number of enhanced carbon mitigation measures which might be implemented as part of the LHR-NWR[63,64]. Again, since these were not included in the AC's assessment these are not covered in detail here, but may be referred to in the promoter's own materials referenced in the footnote below.

MITIGATION CONSIDERED BY THE AC

9.10.6 During its work, the AC separately identified a range of mitigation options. These were not necessarily linked to the mitigation measures identified and outlined by the scheme promoters in their submissions. The mitigation measures considered by the AC are as follows:

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[61] RSK Environment, 2014. *A Second Runway for Gatwick*, Appendix A11, Carbon. Section 7: Further Reduction of Carbon Impacts. [online] Accessed 02/08/2016.

[62] URS, 2014, *Heathrow Expansion*, Stage 2 Submission, Attachment 5-1, Section 5, Carbon and Section 10, Sustainability.

[63] AMEC Environment & Infrastructure UK Limited, 2014, *Heathrow's North-West Runway-Carbon Footprint Assessment*. [online] Accessed 02/08/2016.

[64] Heathrow Airport Limited, 2014. *A resource efficient Heathrow in Volume 1 of Taking Britain further, Heathrow's plan for connecting the UK to growth*, Chapter 5.8. Heathrow Airport Limited.

AIR TRAVEL

9.10.7 As set out above, carbon emissions from ATMs could be consistent with UK carbon obligations. In the carbon-capped scenario, mitigation measures to reduce emissions from aviation could include the introduction of biofuels into aviation fuel, improvements to aircraft design, operational efficiency improvements and limitation of demand growth, for example through carbon pricing. These are all measures which are largely or entirely outside the airport's control. At the airport level, this could include the introduction of mechanisms that would encourage the new demand to be utilised by the cleanest aircraft. Potential options identified by the AC for this include increased airport charges for older aircraft, or mandated "green slots" which require planes of a certain standard to take up the new capacity.[65]

9.10.8 Emissions from ATMs within the EEA are already covered under the EU ETS. At the 2016 ICAO Assembly, ICAO agreed to implement a GMBM which aims to offset the growth in international aviation CO_2 emissions above 2020 levels with emissions reductions in other sectors of the global economy. Negotiations are ongoing to develop the technical elements of the scheme. Emissions trading and emissions offsetting schemes aim to allow growth in air travel, with emissions credits being purchased from other sectors of the economy that may be making reductions in emissions. The cost of such allowances could also be expected to be passed through to passengers which in turn would increase the cost of air travel. This would have the additional effect of limiting demand.

AIRSIDE GROUND IMPACTS

9.10.9 The primary way in which to reduce the emissions associated with airside ground movements is through efficient runway and taxiway design and use. Airports have made advances in these areas, and could apply best practice to any new designs. This could include:

- → Use of airport fixed electrical ground power and pre-conditioned air sources. This would reduce the burden on aircraft Auxiliary Power Units (APUs)[66] and airport Ground Power Units (GPUs)[67].
- → Reduce engine operation during taxiing. By shutting down one or more engines during taxiing, both fuel use and emissions can be reduced. This is increasingly becoming standard operating procedure with a number of airlines.

SURFACE ACCESS

9.10.10 There are opportunities to reduce emissions from surface access, for example by incentivising modal shift from private car or taxi, to public transport options such as rail or bus/coach. It may be necessary to build appropriate infrastructure to facilitate and encourage the use of public transport, for example, additional rail or other rapid transit systems, bus/coach terminals, etc, particularly where existing provision is poor.

[65] Jacobs, 2014. *8. Carbon: Assessment.* [online] Accessed 04/01/2016.

[66] An Auxiliary Power Unit (APU) is an aircraft's on-board power supply. This is typically a small gas turbine fuelled by the aircraft's aviation fuel. An APU typically has very low efficiency and is therefore costly to operate both in fuel burn and emissions terms, as well as contributing to noise and impacting on local air quality.

[67] A Ground Power Unit (GPU) is typically a mobile, diesel-fuelled generator which can be brought to the gate to supply electrical power to the aircraft while on stand. They have low efficiency and also impact on local air quality.

9.10.11 The improvement of electric and alternatively-fuelled vehicle infrastructure, through provision of charging points, and similar, may help in encouraging a general shift towards these lower carbon vehicle types. In addition, this kind of provision may encourage vehicles that would otherwise have range concerns.

9.10.12 It may be desirable to allow for more preferential parking for zero- and low-emission vehicles, for similar reasons as above.

9.10.13 An avenue for improving emissions from surface access could be through agreements with suppliers and transport partners. By requiring a certain level of low emission vehicle provision from coach and freight operators that utilise the airport, the resultant emissions can be reduced.

ENERGY AND FUEL USE

9.10.14 There are several avenues for development in terms of reducing the carbon emissions associated with operation, both of the existing facilities and any new construction.

9.10.15 Any new construction could make use of the latest developments in energy efficiency, allowing for a reduction in electricity use and required heating. As an example of these principles, Stockholm-Arlanda airport, having set a zero-carbon target for 2020, is involved in the following carbon mitigation strategies:

- Utilisation of renewable fuels, such as biogas, to power the ground vehicle fleet;
- New buildings that are constructed to a recognised environmental standard;
- A carbon emission inventory is regularly produced, and augmented, in order to target outstanding emissions sources;
- The use of biomass boilers, to replace fuel burning heat sources; and
- LED light sources, both in terminals and facilities, but also for aircraft parking stands and other areas with lighting requirements.

9.10.16 Other potential mitigating methods include the use of electric vehicles in addition to alternative fuel vehicles, the utilisation of local renewable generation where safe and feasible, the use of low or zero carbon heating technology, and the utilisation of “loop-closing” technology, such as energy-from-waste.

CONSTRUCTION OF FACILITIES AND INFRASTRUCTURE

9.10.17 Mitigation for the emissions associated with construction is wide-ranging, and variously applicable. These include:

- Use of energy efficient site accommodation;
- Increased efficiency in use of construction plant, for example through no-idle policies;
- Construction site connection to grid electricity to avoid use of mobile generation, and smart energy management practices;
- Reduction of waste, and the transport of waste, for example through increasing on-site recycling;
- Selection of construction material to utilise low carbon options, such as carbon-negative cement;
- Selection of construction material to minimise distance of transport, and increasing recycling percentages of the material where appropriate; and

- Consideration of modal shift for transport of construction materials and removal of wastes, so reduce transport emissions, i.e. by rail or water, where possible.

It should be noted that the assessment in this appendix primarily deals with mitigation for climate change through reduction of carbon emissions. However, it should be noted that, during detailed design, climate change adaptation should also be considered. This would include design of infrastructure for climate change impacts such as extreme weather (e.g. high winds and heatwaves) in line with the Government's Climate Change Risk Assessment (2012)[68] and forthcoming updates.

It is recommended that an applicant should seek to adopt best practice approaches from other recent, similar major infrastructure projects.

OTHER MEASURES TO BE CONSIDERED

9.10.18 The DfT has developed an Ultra-Low Emission Vehicles Strategy[69] which sets out the Government's ambition and strategy for the decarbonisation of road transport. Implementation of this strategy would have the effect of decreasing carbon emissions arising from passenger surface access.

9.11 ASSUMPTIONS AND LIMITATIONS

9.11.1 The AC Final Report's assessment of the three shortlisted schemes study area considered the main impact areas giving rise to carbon emissions, namely: ATMs, both in the air and on the ground, passenger surface access (the second largest contributor after ATMs), emissions from the operation of the airports (gas, electricity and fuel use), and construction related emissions, as well as embodied carbon in construction materials.

9.11.2 The baseline and future projection figures referred to in this report are consistent with those used by the AC in their analysis. As these are projections, they may be subject to future changes. The carbon forecasts are based on a number of assumptions about passenger growth and any mitigation measures considered by the AC in their work. Some of the mitigation measures will be brought about by legislation or through market forces. It is a limitation of the assessment that, as with any forecast, if these assumptions prove incorrect, emissions may rise higher than is forecast. A range of policy measures are available at national and local levels to constrain carbon emissions.

9.11.3 BEIS has produced updated carbon appraisal values since the AC completed its assessment, as part of its annual review of energy data projections. However, for consistency with the AC's work and the rest of the AoS, the appraisal has not been re-run with the updated figures as the updated values were only marginally different from those used in the AC assessment and did not materially affect the overall assessment.

[68] Defra, 2012. *UK Climate Change Risk Assessment: Government Report* [online]. Accessed 13/01/2017.
[69] Department for Transport , 2013. *Driving the future today: A strategy for ultra low emission vehicles in the UK*. [online]. Accessed 06/12/2016.

9.11.4 Emissions arising from freight movements and staff surface access were not addressed in the AC's work. This was due to limited availability of baseline data, uncertainty regarding freight tonnages, workforce and distances travelled from and to airport meaning that no robust pro-rata method was available to quantify these emissions.[70] This remains the case. However, for Gatwick these two sources of emissions combined are likely to be of a similar magnitude to the emissions from airport electricity and fuel use. For Heathrow they are likely to be of a similar magnitude to the passenger surface access emissions. If these emissions are of the scale indicated, they would not be expected to change the ranking of the schemes in terms of overall carbon emissions, nor the assessment that any of the three schemes can be delivered within the UK's carbon obligations. These emissions would, however, be expected to grow with any future expansion and so should be assessed as far as possible by the developer during the detailed design stage and possible mitigation measures proposed.

9.11.5 The assessment to date has focussed on the emissions of carbon (as carbon dioxide, CO_2) associated with the combustion of fuels, either directly in aircraft, surface vehicles or boilers or other plant at the airport, or indirectly, such as in large scale boiler plant used in the generation of electricity. In addition, there are other emissions of greenhouse gases associated with the operation of an airport, and with aviation. Of these, the most common are emissions due to leaks of refrigerant gases used in refrigeration and air conditioning systems, and emissions of methane and other gases as a result of the organic waste arisings from the airport. These were judged to be insignificant by the AC[71] and were therefore not included in the AC's work. An assessment has been made of airport carbon footprints available in the public domain. This assessment found that refrigerant gases are typically between 0.01% and 0.043% of an airport's total operational carbon footprint, and that emissions from organic waste are typically between 0.05% and 0.46% of an airport's total operational carbon footprint. Both have therefore been judged to be relatively insignificant and not considered further in this assessment.

9.11.6 In addition, there are non-carbon emissions associated with the combustion of fuels in aircraft engines while in flight, which are also thought to have an impact on climate change[72]. As well as CO_2, combustion of aviation fuel results in emission of water vapour, nitrogen oxides (NO_x) and aerosols. NO_x are indirect greenhouse gases, in that they do not give rise to a radiative effect themselves, but influence the concentration of other direct greenhouse gases by enhancing ozone (which leads to warming) and suppressing methane (leading to cooling). With the exception of sulphate aerosols, all other emissions cause warming. In addition, the flight of aircraft can also cause formation of linear ice clouds (contrails) and can lead to further subsequent aviation-induced cloudiness. These cloud effects cause additional warming. Evidence suggests that the global warming impact of aviation, with these sources included, could be up to two times that of the CO_2 impact by itself, but that the level of scientific uncertainty involved means that no multiplier should be applied to the assessment.[73] For these reasons the AC did not assess the impact of the non-CO_2 effects of aviation and these emissions have not been included in this AoS assessment.[74] This position is kept under review by DfT but it is worth noting that non-CO_2 emissions of this type are not currently included in any domestic or international legislation or emissions targets and so their inclusion in the assessment would not affect its conclusion regarding legal compliance. It is recommended that further work be done on these impacts by an applicant during the detailed scheme design, according to the latest appraisal guidance.

[70] Jacobs, 2014. *Module 8. Carbon: Assessment*, paragraph. 2.2.4, p.10. [online] Accessed 04/01/2016.
[71] Jacobs, 2014. *8. Carbon: Baseline*, p. 44. [online] Accessed 04/01/2016.
[72] Committee on Climate Change, 2009. Meeting the UK aviation target – options for reducing emissions to 2050. Chapter 6, Non-CO_2 Effects of Aviation. [online] Accessed 02/08/2016.
[73] Department for Transport, 2013. 2013. *UK Aviation Forecasts*, paragraph. 6.15, p.88. [online] Accessed 13/01/2017
[74] Jacobs, 2014. *Module 8: Carbon Assessment*, paragraph. 2.2.8, pp.11-12. [online] Accessed 13/01/2017.

9.11.7 The modelling work undertaken by the AC focusses on the emissions associated with the construction and operation of the airport facilities themselves. There is potential that the developments could trigger secondary developments in the chosen location, such as business parks or freight hubs, which in turn would result in increased emissions, particularly around surface access. Although these would not be emissions directly linked to the airport, they would be indirectly caused by the development. At present there is little to indicate the extent of any secondary development, and any resultant emissions are not captured in the AC's assessment. It is assumed that more information on any likely secondary development will become available during detailed scheme design stage.

9.11.8 In both the 'carbon-capped' and 'carbon-traded' policy scenarios there are measures in place to ensure that emissions from ATMs are not additional. Under the AC's carbon-capped scenario, aviation emissions would be constrained to around 2005 levels, which means an effective cap of 37.5 $MtCO_2$/year[75]. There are a number of different ways in which this cap could be met in practice. One approach looked at by the AC used a mix of measures, such as the introduction of biofuels into aviation fuel (0.5% biofuel use in 2030, rising to 2.5% in 2050), improvements to aircraft design, operational efficiency improvements and some limitation of demand growth. Another approach looked solely at limiting demand growth through carbon pricing. This would have the effect of driving up the cost of flying, thereby reducing demand. The work of the AC used a range of future carbon prices to determine the price at which demand would be curtailed sufficiently to meet the cap.[76]

9.11.9 In the AC's carbon-traded policy scenario, the AC considered a case in which aviation carbon emissions were allowed to continue to grow unconstrained, with compensatory reductions being made elsewhere via a carbon trading mechanism.

9.11.10 The AC's objective in using these two approaches was to understand the varying effects on aviation demand of differing constraining and carbon emissions pricing scenarios, the 'carbon-capped' and carbon-traded' policy scenarios, with the future reality most likely to lie somewhere between the two extremes of this scale[77]. The agreement by the ICAO at its 2016 Assembly to implement a GMBM which aims to offset the growth in international aviation CO_2 emissions above 2020 levels with emissions reductions in other sectors of the global economy shows that carbon trading is likely to be a reality in future, which itself offers a further incentive for operators to implement measures to reduce aviation emissions.

[75] Committee on Climate Change, 2013. *Factsheet: Aviation*. [online] Accessed 04/01/2016.
[76] Jacobs, 2014. *8. Carbon: Assessment*, Appendix B, Methodology, Table B1. [online] Accessed 04/01/2016.
[77] Airports Commission, 2015. *Final Report*, paragraph 3.51, p. 82. [online] Accessed 13/12/2016.

9.12 CONCLUSIONS

Objective 14: To minimise carbon emissions in airport construction and operation

9.12.1 The AC modelled future carbon emissions relating to air travel, passenger surface access, the operation of airport buildings and infrastructure, fuel use and construction-related carbon emissions for all three schemes under two climate change policy scenarios, compared to futures without expansion.

9.12.2 The AC modelled emissions for both Gatwick and Heathrow Airports without expansion over a 60-year period from 2025/2026 to 2085/2086 for both carbon-capped and carbon-traded policy scenarios.

9.12.3 The AC then modelled the likely future emissions of the two airports over the same period, under the three shortlisted schemes: LGW-2R, LHR-ENR and LHR–NWR.

9.12.4 Two carbon policy scenarios were studied, each of which represents a different approach to managing CO_2 emissions from aviation in the future.

9.12.5 Under the AC's 'carbon-capped' scenario, the 'gross' CO_2 emissions from flights departing UK airports are limited to the CCC's planning assumption of 37.5 $MtCO_2$ in 2050, and there is no trading of aviation emissions either within the UK economy or internationally.

9.12.6 In contrast, under the AC's 'carbon-traded' scenario, there are measures in place which ensure that any increase in CO_2 emissions from flights departing UK airports as a result of airport expansion would not lead to an increase in CO_2 emissions at the international level. In particular, both with and without expansion, it was assumed that the CO_2 emissions from flights departing UK airports are traded at the European level until 2030 and then as part of a global carbon market.

9.12.7 The assessment shows that ATMs are by far the biggest source of emissions. Although domestic (intra-UK) ATM emissions are included within the UK's carbon budgets, international ATMs are not. However, the AC's forecasts incorporate measures to ensure that CO_2 emitted by UK flights and ground movements does not lead to increased emissions overall either at international level (in the carbon-traded forecast) or within the UK economy (in the carbon-capped forecast). The AC concluded, therefore, that the increases in emissions from flights would not be additional and were not monetised in the AC's economic analysis of carbon impacts.

9.12.8 The AC Final Report makes use of a number of assumptions about measures which may result in reduced carbon emissions, and these are built into both the do minimum and do something forecasts.[78] These include future changes to aircraft fleets to include a shift to larger aircraft, resulting in fewer ATMs, the introduction of more efficient aircraft, as well as reductions in emissions from airport operations and passenger surface access by rail due to on-going decarbonisation of the grid, and reduced emissions from passenger surface access due to increasing vehicle efficiency.

9.12.9 Some of these changes will be brought about through international agreements such as the ICAO GMBM or national legislation. Others will happen as a result of market forces, for example increasing fuel energy costs favouring more efficient aircraft, vehicles and buildings.

[78] Airports Commission, 2015. *Final Report*, pp. 203 - 204. [online] Accessed 04/01/2016.

9.12.10 The emissions assessment carried out by the AC is considered to be broadly robust with the majority of the major emissions sources considered. Emissions related to staff surface access and freight operations at the airport, either directly related to airport operations, or as a result of secondary development, are considered likely to be significant, and further work is required by an applicant during the detailed scheme design to quantify and model these under the demand forecasts in a similar manner.

9.12.11 There are a wide range of mitigation options available to all three scheme promoters, and each has addressed the potential measures that could be undertaken in reports included in support of their submissions[79,80,81]. Jacobs have also addressed potential mitigation methods in the Carbon: Assessment Report[82], although these are generic, rather than the specific measures identified by the scheme promoters.

9.12.12 The emissions calculated by the AC are summarised in the Table 9.7.

Table 9.7. Summary of results of AC's assessment of emissions (expressed as change in $MtCO_2$ over the appraisal period) for each scheme under both carbon-capped (CC) and carbon-traded (CT) scenarios[83].

AREA OF EMISSIONS	LGW-2R		LHR-ENR		LHR-NWR	
Impacts on	**CT**	**CC**	**CT**	**CC**	**CT**	**CC**
Passenger surface access	10.1	6.6	6.3	4.9	7.4	5.7
Airport operations (energy and fuel use)	1.1	0.8	2.1	1.8	2.6	2.2
Construction of airport facilities and surface access infrastructure *	3.9	3.9	10.1	10.1	11.3	11.3
Total	**15.1**	**11.3**	**18.5**	**16.8**	**21.3**	**19.2**
Air travel at the expanded airport (not included in the monetised assessment)	110.2	68.9	251.3	210.4	298.9	236.7

** Figures for construction emissions are expressed as carbon dioxide equivalent, or MtCO2e. All other figures are in terms of carbon, MtCO2.*

9.12.13 All three schemes will result in an absolute increase in carbon emissions over the appraisal period at the airport level, and are therefore judged to have Significantly Negative effects. From Table 9.7, it is clear that the LGW-2R scheme results in the lowest emissions in absolute terms over the appraisal period under both the carbon-capped and carbon-traded scenarios. Both Heathrow schemes produce higher emissions than Gatwick, with LHR-NWR producing the greatest emissions due to an overall larger number of passengers and a bigger construction programme. The scheme would also have a higher number of ATMs, of which a greater proportion are likely to be long-haul.

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79 RSK Environment, 2014. *A Second Runway for Gatwick*, Appendix A11, Carbon. [online[online] Accessed 04/01/2016.
80 AMEC Environment & Infrastructure UK Limited, 2014. *Heathrow's North-West Runway-Carbon Footprint Assessment*. [online] Accessed 02/08/2016.
81 URS, 2014. *Heathrow Expansion*, Stage 2 Submission, Attachment 5-1.
82 Jacobs, 2014. *Module 8. Carbon: Assessment.* [online] Accessed 04/01/2016.
83 Based on: Airports Commission, 2015. *Final Report*, p. 205, Table 9.6. [online] Accessed 04/01/2016; with amendments from Jacobs, 2014. *8. Carbon: Baseline*. [online] Accessed 04/01/2016, Jacobs, 2014. *8. Carbon: Assessment*. [online] Accessed 04/01/2016 and Jacobs, 2015. *Module 8: Carbon, Carbon Further Assessment*. [online] Accessed 04/01/2016.

9.12.14 The AC's Final Report concluded that, overall the LGW-2R scheme is judged to perform best on the objective of minimising carbon emissions in airport runway construction and operation, even allowing for its higher impact in terms of increased passenger surface access emissions. Of the two Heathrow schemes, the LHR-ENR performs marginally more strongly than the LHR-NWR scheme.

9.12.15 However, for the reasons given above, emissions from aircraft are not considered additional either at international level (in the carbon-traded forecast) or within the UK economy (in the carbon-capped forecast). Other emissions may contribute to the stationary sources EU ETS or UK carbon budgets, dependant on source, but any of the three schemes could still be delivered consistent with the UK's carbon commitments.

9.12.16 It is important that, to accompany the Government's preferred LHR-NWR scheme, an appropriate mitigation strategy is developed during the detailed design stage and finalised through the planning process, together with an emissions monitoring programme to ensure that both the measures identified are implemented, and also that the operation is continually optimised to minimise future emissions throughout its life.

9.13 ANNEX: SENSITIVITY ANALYSIS

9.13.1 This sensitivity test discusses the carbon emission impacts under the demand scenario where their magnitude is expected to be at its highest of all five economic growth scenarios analysed by the AC[84]. This is the global growth (GG) scenario for Heathrow and low cost if king (LCIK) scenario for Gatwick. This is to demonstrate what the impacts of expansion might be under a 'worst case scenario' in terms of the possible global economic scenarios considered by the AC and to test whether they are compatible with the UK's climate change obligations. The scenario with the biggest impact varies by carbon emission source and expansion scheme. The chosen scenario is explained in each emission source section below.

9.13.2 As previously explained, the AC assessed carbon emissions from four sources:

- Increased airport capacity leading to a net change in air travel;
- Airside ground movements and airport operations;
- Changes in non-aviation transport patterns brought about by the scheme's surface access strategy; and
- Construction of new facilities and surface access infrastructure.

9.13.3 The impacts of these are assessed below with the exception of construction of new facilities and surface access infrastructure. New facilities are not expected to change in response to higher demand, and surface access infrastructure requirements where identified are already using the higher demand "worst case" scenarios[85,86,87].

9.13.4 Only the impact on emissions from flights is assessed quantitatively as the data for other sources are not available. In any case the impact from surface access and airport operations is relatively small. The ordering of schemes in terms of total carbon impacts remains the same in this high demand scenario, only the magnitude of the impacts is larger.

NET CHANGE IN AIR TRAVEL

9.13.5 To reflect the uncertainty over the treatment of international aviation emissions, the carbon emissions from flights, along with potential mitigation strategies, are presented below separately for both the carbon-capped and carbon-traded scenarios. Figures are presented at the national rather than airport level due to availability of data.

[84] For a full description of the scenarios see: Airports Commission, 2015. *Strategic Fit: Forecast*, p. 44. [online] Accessed 13/01/2017.
[85] Airports Commission, 2015. *Appraisal Framework Module 4*. Surface Access: Dynamic Modelling Report Gatwick Airport Second Runway [online] Accessed 13/01/2017.
[86] Airports Commission, 2015. *Appraisal Framework Module 4*. Surface Access: Dynamic Modelling Report Heathrow Airport Northern Runway Extension [online] Accessed 13/01/2017.
[87] Airports Commission, 2015. *Appraisal Framework Module 4*. Surface Access: Dynamic Modelling Report Heathrow Airport North West Runway [online] Accessed 13/01/2017.

CARBON-CAPPED

9.13.6 The carbon-capped scenario was developed to explore the case for expansion under each of the schemes presented even in a future where aviation emissions were limited to the CCC's planning assumption. The UK's emissions from flights are therefore not presented as, by design, they meet the CCC's planning assumption of 37.5 $MtCO_2$ in 2050 in both the no expansion baseline and the expansion scenario.

9.13.7 There are a number of different ways in which the planning assumption could be met. Under the main carbon-capped scenario used by the AC, it was met by raising the carbon price to reduce demand to a level that is consistent with meeting the target. The AC modelling showed this was technically possible, even under the high demand "worst case" scenarios, although it would require a very high carbon price[88].

9.13.8 The AC also published analysis in its Carbon Policy Sensitivity Test[89] based on a hybrid approach that combines a higher carbon price than the carbon traded scenario[90], with two specific abatement measures: higher uptake of biofuels; and operational improvements including electric-powered taxiing and fuel efficient cruising speeds.

9.13.9 The AC's analysis in this 'Carbon Policy Sensitivity Test' is based on the AoN demand scenario. DfT re-ran the analysis[91] using the same method but basing it on the GG demand scenario to understand the levels of biofuel uptake and operational efficiency improvement required to meet a cap at 37.5 $MtCO_2$ in 2050 in a 'worst-case scenario'. The levels of abatement required by the policy measures are presented in Table 9.8 below. The figures for LGW-2R are an underestimate of the worst-case scenario as the increase in carbon emissions is greatest under the "low cost is king" (LCIK) scenario. However, even under the LCIK scenario the increase in emissions is lower for LGW-2R than under the LHR-NWR 'worst-case' scenario[92]. The increase in emissions under the LGW-2R worst case scenario would be less than the corresponding increase in emissions under the LHR-NWR worst case scenario.

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[88] Airports Commission, 2015. *Strategic Fit: Forecasts*. Appendix 5, pp. 258-260. [online] Accessed 13/01/2017.
[89] Airports Commission, 2015. *Economy: Carbon Policy Sensitivity Test*. [online] Accessed 13/01/2017.
[90] £334/tCO2 in 2050 as opposed to £196/tCO2 in 2050
[91] Department for Transport, 2017*, Carbon Policy Sensitivity Test Supplementary Analysis,* published as part of the draft Airports NPS Consultation documentation.
[92] The worst-case scenario for both Heathrow expansion options occurs under the GG demand scenario.

Table 9.8[93]: Carbon policy sensitivity test, carbon abated by measure, UK level ($MtCO_2$)

Expansion Scheme	Demand Scenario (AoN and 'worst case' scenario)	2050 carbon-traded base, national level ($£/tCO_2$ = 196)	2050 carbon abated from higher carbon price ($£/tCO_2$ = 334)	2050 carbon abated from higher operational efficiency	2050 carbon abated from higher uptake of biofuels
LGW-2R	AoN	40.8	2.6	0.0	0.7
LGW-2R	GG*	49.4	3.6	2.8	5.5
LHR-NWR	AoN	43.3	2.3	1.2	2.3
LHR-NWR	GG	51.5	3.3	3.0	7.8
LHR-ENR	AoN	42.6	2.2	1.2	1.8
LHR-ENR	GG	50.9	3.2	2.9	7.2

**Figures in DfT supplementary analysis relate to GG scenario only*

9.13.10 The levels of operational efficiency and biofuel uptake required under GG are obviously higher than those required for the AoN scenario. For LHR-NWR – the scheme with the biggest impact on carbon - operational efficiency improvements of around 7% and biofuel uptake of 19% are required to meet the cap. However, these levels still fall within the 'mid-range' policy level scenario as defined by an aviation carbon reduction study commissioned by DfT in 2011[94], and therefore fall within the bounds of what the researchers believed to represent a reasonable assumption of the impact that could be achieved.

9.13.11 Alternative measures could be applied in practice to reduce the reliance on biofuels and operational measures, including those mitigation measures identified in the main appendix. However, in order to maintain consistency with the AC's analysis, consideration of these measures was not included.

9.13.12 DfT's work applying the Carbon Policy Sensitivity Test to the GG Scenario[95] suggests that employing such measures to such a degree would be technically feasible. As such, it demonstrates that it is possible for the UK to meet its carbon obligations with expansion even under the highest demand scenarios. It is to be expected that significant policy intervention might be required in this worst-case demand scenario.

CARBON-TRADED

9.13.13 The increase in CO_2 emissions from flights, above the "do minimum" baseline are presented in Table 9.9 below at national level for 2030, 2040, and 2050, as well as for the whole 60-year appraisal period. For the Gatwick scheme, the biggest increase in carbon emissions compared to the baseline is under the LCIK scenario. This is to be expected as this scenario includes a number of assumptions that boost traffic at this airport, including a strengthening of the position of low cost carriers who dominate at Gatwick in both the short- and long-haul markets, and increased attractiveness for transfer passengers. GG is the scenario that leads to the largest increase in emissions under the two Heathrow

[93] Source: Airports Commission, 2015. Economy: Carbon Policy Sensitivity Test. [online] Assessed 17/01/2017. & Department for Transport (2017) Carbon Policy Sensitivity Test Supplementary Analysis
[94] EMRC and AEA, 2011. *A Marginal Abatement Cost Curve Model for the UK Aviation Sector*. [online] Accessed 13/01/2017.
[95] Department for Transport (2017) Carbon Policy Sensitivity Test Supplementary Analysis

expansion schemes. It has many of the same underlying assumptions as LCIK, including gross domestic product (GDP) and trade growth, but without the specific measures to increase traffic in the low-cost sector.

Table 9.9[96]. Additional emissions at the UK level under each expansion scheme for highest demand scenario and assessment of need (for comparison), carbon traded ($MtCO_2$) compared to 'do minimum'

SCHEME	SCENARIO	2030	2040	2050	WHOLE APPRAISAL PERIOD (60 YEARS)
LGW-2R	AoN	0.4	1.0	0.9	54.6
LGW-2R	LCIK	2.7	3.5	3.9	230.5
LHR-NWR	AoN	3.0	4.1	3.4	212.1
LHR-NWR	GG	3.9	4.0	4.9	290.8
LHR-ENR	AoN	3.0	3.6	2.7	179.6
LHR-ENR	GG	3.7	3.2	4.3	243.5

9.13.14 Over the 60-year appraisal period, additional emissions over the baseline "do minimum" scenario are around 40% higher under the high demand scenario than they are under AoN for the two Heathrow schemes, and around 325% higher for the Gatwick scheme. The large difference for Gatwick is explained by the demand features of the LCIK scenario as described above.

9.13.15 Under the carbon-traded scenario, UK aviation emissions could continue to grow unconstrained, provided that compensatory reductions are made elsewhere in the global economy. This could be facilitated by a carbon trading mechanism in which aviation emissions could be traded with other sectors of the global economy. This remains the case under the higher demand scenarios, although higher global economic growth and emissions could lead to higher demand for carbon permits in all sectors, including aviation, so increasing their price. This higher price could in turn lead to lower aviation demand, and carbon emissions, but this effect has not been captured in this analysis. It is not the purpose of this work, nor that of the AC, to speculate on the effectiveness and therefore abatement potential of a theoretical future carbon trading scheme as far ahead as 2050. It is therefore assumed that, for the purposes of this analysis, provided a global trading scheme is place, higher UK aviation demand would have no impact on global emissions as these would be capped and therefore there is nothing to indicate that the UK would not be able to meet its carbon obligations even if the increase in emissions was as high as that seen under the LHR-NWR scheme.

[96] Source: Jacobs, 2015. *Module 8: Carbon, Carbon: Further Assessment*. [online] Accessed 13/01/2017 and Airports Commissions Carbon Forecasts

SURFACE ACCESS

9.13.16 For consistency with the approach in the rest of this appendix and because of its local nature, the impact of passenger surface access emissions have been assessed at the airport level in the worst-case demand scenarios. Due to the limitations of data availability only a qualitative assessment has been presented.

9.13.17 As discussed, the emissions from surface access to the expanded airport depend on the number of passengers using the airport; the share of passengers using different modes and the carbon intensity of those modes. It can be expected that the first would change depending on the demand scenario, but not the other two to any significant degree. It is worth noting that the surface access studies carried out by the AC[97], which included analysis of likely mode shares, was based on the GG scenario for the two Heathrow schemes and on the LCIK scenario for Gatwick, and can be considered robust to this 'worst case' sensitivity.

9.13.18 In contrast to the UK level carbon impacts, LCIK is the demand scenario that typically generates the highest number of additional passengers, at airport level, under both the carbon-traded and carbon-capped scenarios for all three expansion schemes. The difference between this demand scenario and AoN is relatively large in some years, being most pronounced in the years immediately after expansion as higher demand causes the additional capacity to fill up faster, especially at Gatwick.

9.13.19 However, given how small the additional emissions from surface access are in relation to UK carbon budgets[98] under the AoN scenario[99], the additional emissions that would be anticipated under the high demand scenarios are still unlikely to have any significant impact on the UK's ability to meet its climate change obligations, especially given that the surface access impacts in this AoS focus on the airport itself and do not take into account reductions in passengers at other airports, compared to the "do minimum" scenario.

9.13.20 The mitigation measures discussed in Section 9.10 above would apply under this high demand scenario also. These include incentives for passengers to shift from car or taxi to public transport, improvement of electric vehicle infrastructure and preferential parking for low emission vehicles.

[97] Airports Commission, 2015. *Appraisal Framework Module 4*. Surface Accessed: Dynamic Modelling Report Gatwick Airport Second Runway. [online] Accessed 13/01/2017.; Airports Commission, 2015. *Appraisal Framework Module 4*. Surface Access: Dynamic Modelling Report Heathrow Airport Northern Runway Extension. [online] Accessed 13/01/2017. Airports Commission, 2015. *Appraisal Framework Module 4*. Surface Access: Dynamic Modelling Report Heathrow Airport North West Runway. [online] Accessed 13/01/2017.

[98] E.g. Carbon Budget 5 (2028 – 2032) is 1,765 $MtCO_2e$. See: Committee on Climate Change, date unknown. Carbon Budgets and targets. [online] Accessed 13/01/2017.

[99] See table 9.3 above

AIRPORT OPERATIONS (ENERGY AND FUEL USE)

9.13.21 For consistency with the approach above and because of its local nature, the impact of the worst-case demand scenarios on emissions from airport operations has been assessed at the airport level. Due to the limitations of data availability only a qualitative assessment has been presented.

9.13.22 Emissions from airport operations arise mainly from electricity and gas used in terminal buildings and fuel used for transportation around the airport site. There may be some variation in the amount of gas used to heat terminal buildings and domestic hot water, in line with variations in passengers, however, there might be greater variations in the amount of electricity used for cooling and operation of passenger-sensitive equipment and on-site transport. The extent of the overall increase is uncertain as it is likely that, given economies of scale and other efficiency savings, the increase may be less than proportional to the increase in passengers using the airport.

9.13.23 As mentioned above, the number of additional passengers under the high demand scenarios does increase significantly at the airport in question. However, as with emissions from surface access, given how small the additional emissions from airport operations are in relation to UK carbon budgets[100] under the AoN scenario[101], the additional emissions that would be anticipated under the high demand scenarios are still unlikely to have any significant impact on the UKs ability to meet its climate change obligations, especially given that the airport operation impacts presented in this AoS focus on the airport itself and do not take into account reductions in passengers at other airports, compared to the "do minimum" scenario.

9.13.24 Again, the mitigations proposed in Section 9.10 above apply to this high demand scenario. These include constructing energy efficient terminal buildings to reduce energy consumption, the use of renewable fuels in airport operation and zero or low-emission vehicles for transport around the airport site.

[100] E.g. Carbon Budget 5 (2028 – 2032) is 1,765 MtCO2e. See: Committee on Climate Change, date unknown. Carbon Budgets and targets. [online] Accessed 13/01/2017.

[101] See table 9.3 above