Hub for London

Climate Change: Operational Carbon Emissions and Mitigation and Adaptation Issues for a Hub Airport: Technical Note

Transport for London

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Plan Design Enable

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Table of contents

1. Executive Summary

The Airport Commission has defined a narrow scope for the issues relating to Climate Change to be covered within the July submissions on long term capacity options, focusing on:

- the extent to which the options proposed could reduce emissions levels relative to other options to provide the same capacity and could then provide ongoing improvement in performance; and
- the extent to which climate change might influence the resilience of the sites.

While there is some variation in the risks posed by climate change, with flooding more significant at the estuary sites and fog more of a risk at Stansted, there is relatively little difference between the three potential hub sites in terms of likely climate change impacts. Indicative modelling and analysis has estimated the hub airports would generate:

- 130-140 kg of ATM CO_2 emissions per passenger;
- 60 kT CO_2 per annum from airside support operations;
- 330-360 kT CO_2 per annum from surface access

The key points are that the proposed options will be:

- Designed with carbon and climate change in mind from the start and so will:
    - implement measures at the start to reduce emissions at their full potential, without the constraints imposed by retro fitting them in the context of existing operations;
    - build-in resilience to predicted climate change from the outset;
- Large scale:
    - allowing flexible movement planning on the ground and in the air, allowing more efficient movement and use of appropriate aircraft;
    - drawing together large volumes of demand on common routes allowing them to be served by larger, better loaded planes;
    - generating sufficient passenger population and demand to support surface access measures to promote high public transport mode share;
    - able to enforce restrictions requiring planes to meet efficiency/age criteria.

The characteristics of the hub airports and their location will mean that they can be designed to generate below average emissions per passenger relative to other approaches for providing the same capacity (such as through the expansion of existing airports). It is however important to note that the differences in emissions associated with a given capacity of airport that can be achieved through variations in design and operation are small compared to the overall (largely cruise based) emissions associated with the airport, which, as the Commission identified, are likely to be largely consistent regardless of the location of the capacity.

2. Introduction

This Technical Note provides a summary of issues relating to Climate Change that are of relevance for TfL's submissions to the Airport Commission for each of their hub options for long term airport capacity expansion (the Inner Estuary, Outer Estuary and Stansted sites).

The focus of the information presented below reflects the emphasis of the Airport Commission's initial guidance document on making submissions[1] and more recent summary of the criteria that will be applied to submissions to identify which options for long term capacity provision will be considered in more detail[2].

The Climate Change criteria relates to the context of the UK's overriding Climate Change commitment, set in the Climate Change Act 2008, to meet a legally binding target to reduce the UK's emissions of greenhouse gases by at least 80% relative to 1990 levels by 2050. To help progress towards the 2050 target, the Act also established a system of five yearly 'carbon budgets', set by the Committee on Climate Change (CCC). Each budget identifies a permitted volume of greenhouse gas emissions during the five year budget period (net of credits purchased from schemes such as the European Emissions Trading Scheme (EU ETS) and Clean Development Mechanism). In April 2012[3] the CCC recommended that international aviation should be formally included in future carbon budgets and targets, at the emissions cap level set in the EU ETS[4]. Aviation currently accounts for 6% of UK emissions, with the absolute and relative contribution forecast to continue to grow significantly in future years. The ETS cap level has been set at 95% of the average of 2004-2006 levels for years between 2013 and 2020, with the sector obliged to offset any emissions above that level through the purchase of credits from other sectors in the trading scheme.

Work by the CCC in 2009[5] considered the scope for the aviation sector to meet the planning guideline set by the government in 2009, which stated that CO_2 emissions from aviation should return to 2005 levels by 2050. Three scenarios were developed (likely, optimistic and speculative) and the report concluded that in the 'likely' scenario (with currently prudent assumptions on technological and demand developments), it would be possible to meet the planning target and still accommodate growth of 60% in passenger movements or 55% in Air Traffic Movements relative to 2005.

The Airport Commission documents identify and recognise these overriding issues but specify a clear, restricted scope for the coverage of climate change related issues in the July submissions on capacity options. The largest questions relating to aviation and climate change are considered to be out of scope, including the extent to which the general growth in aviation is consistent with wider climate change objectives and the international emissions implications of changes in UK airport capacity (including issues of international emissions leakage).

They are scoped out through the Commission's recognition that average greenhouse gas emissions generated by the cruise elements of flights (associated with a given number and mix of Air Traffic Movements (ATM)) are likely to be largely consistent wherever the airport capacity is located. The Commission therefore suggests that submissions on different options for capacity provision should focus on identifying any 'distinguishing characteristics' in relation to the airport and its operations which might mean that the emissions it would generate would vary from other proposals providing the same level of capacity.

The Commission suggests that considerations could include:

- aircraft take off and landing emissions;
- ground support operations;
- buildings;

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[1] Guidance Document 1: Submitting evidence and proposals to the Airports' Commission, February 2013 https://www.gov.uk/government/publications/submitting-evidence-and-proposals-to-the-airports-commission
[2] Guidance Document 2: Long term capacity options sift criteria, May 2013 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/193867/sift-criteria.pdf
[3] Scope of carbon budgets. Statutory advice on inclusion of international aviation and shipping. Committee on Climate Change, April 2012
[4] When operating fully, it is noted that at the moment a temporary 'stop the clock' exemption applies meaning that international (to or from areas outside the EU) are excluded from the ETS whilst negotiators try to agree on a global, market based system to reduce emissions through the ICAO this autumn
[5] Meeting the UK Aviation target – options for reducing emissions to 2050, Committee on Climate Change, December 2009

- construction; and
- surface access.

It is noted that, whilst all aircraft take off emissions would be included within the scope of 'UK aviation emissions' as defined by the DfT[6] (i.e. emissions associated with all flights leaving UK airports), only the landing emissions of domestic flights would be relevant. Building, ground operations and surface emissions would be associated with other UK sectors and would therefore only contribute to overall national greenhouse gas emissions totals and targets. Landing emissions for incoming international flights are treated as being associated with wider global emissions[7].

Box 1 below sets out the specific climate change related questions raised in the Commission's criteria document in May, showing that it is also interested in the extent to which each capacity option might be subject to impacts from forecast climate change ('adaptation') and the implications of the impacts for the resilience of operations.

The remainder of this note focuses on the issues raised in the Commission's criteria document and consists of three sections. Section 3 considers the emissions of greenhouse gases associated with aviation and the scope for a newly designed hub airport to reduce the rate of emissions per passenger kilometre by applying best practice to maximise efficiency. The limited focus of the Commission's questions, limits the points that can be raised in relation to the hub options. The key focus of the section is therefore on emissions improvements that could be implemented more efficiently at newly built hub airports than at other sites due to the opportunities afforded by designing and building a new site from the outset and/or by the scale of the site and its operations.

Section 4 then considers the implications of forecast climate change for each of the three proposed hub sites and associated constraints and opportunities to be considered in their design.

Section 5 provides a brief concluding summary and supporting Appendices provide information on calculation methodologies, current emissions at London Heathrow (for context), climate change projections and potential impacts of climate change on environmental impacts.

Box 1: Airport Commission: Guidance Document 02:Long Term Capacity Options: Sift Criteria - Questions relating to Climate Change

Climate Change
How might the proposal compare, in terms of its impact on greenhouse gas emissions, with alternative options for providing a similar amount of additional capacity?

What are the proposals plans for continuous improvement and reduction of carbon emissions over time?

Operational viability
Is the proposal consistent with relevant safety requirements?

What operational, safety and/or resilience risks are associated with the proposal?

What measures are proposed to manage these?

In considering this criteria, scheme developers may also consider the need to understand and accommodate the potential impacts of climate change, for instance in relation to severe weather or flood risks.

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[6] UK Aviation Forecasts 2013, DfT. https://www.gov.uk/government/publications/uk-aviation-forecasts-2013
[7] This has the important implication that the majority of stacking emissions associated with UK airports are not included in the estimates of UK 'aviation sector emissions' as they are associated with international flights landing at rather than departing from UK airports

3. Climate Change Mitigation

3.1. Emissions and Potential Mitigation

In line with the emphasis identified in the Airport Commission's guidance documents, the discussion below focuses on the extent to which the characteristics of the proposed hub airport options could reduce emissions across all airport related operations, relative to other options for delivering the same level of capacity in terms of million passengers per annum (mppa).

A number of recent documents (including the Sustainable Aviation CO_2 Road map[8] and DfT's Aviation Policy Framework[9] and preceding DfT and Committee on Climate Change documents[10], as well as the Airport Commission's Discussion Paper on Climate Change[11]) have highlighted the range of ongoing activity in the aviation sector intended to reduce greenhouse gas emissions. Identified approaches include a combination of technology developments, system improvements, operating procedure improvements and behaviour changes.

Although these changes are proposed and, in some cases, already being implemented across the sector, the construction of a new hub airport would provide the opportunity to increase the scale of impact by building best practice into the airport and its operations from the outset. This would help to achieve greater impacts from the measures than in scenarios where retrofitting into existing operations is required (as the scope and impacts are typically limited by accounting for existing constraints).

The discussion below considers the ways in which the design of a new hub airport would provide the opportunity to reduce emissions per passenger kilometre, relative to other means of providing the same capacity (such as a virtual or dispersed hub).

Relevant measures exist in each of the four categories of airport related emissions identified by the Commission:

- Operational emissions – associated with take off, cruising and landing of all flights starting at the airport (following the convention for allocating emissions to countries applied in the DfT Aviation modelling[12]);
- Airside support operations – associated with all vehicle movements within the airport (other than planes) to support flight activity;
- Surface access – associated with the transport used for the arrival and departure of all passengers and staff; and
- Construction and buildings – emissions associated with the construction of new airport infrastructure and supporting surface access infrastructure, and ongoing operations of the buildings.

3.2. Operational Emissions

Aircraft operations account for the large majority of emissions associated with any airport (for instance accounting for nearly 90% of emissions associated with Heathrow, as documented in the 2009 carbon footprint[13].

Emissions estimates for each option have been calculated on the basis of the profile of ATM departures and the future Heathrow fleet composition and emissions factors applied for the DfT's aviation model[14] (the

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[8] Sustainable Aviation CO_2 Road-Map, Sustainable Aviation, March 2012
[9] Aviation Policy Framework, DfT, March 2013 https://www.gov.uk/government/publications/aviation-policy-framework
[10] Meeting the UK aviation target – options for reducing emissions to 2050, Committee on Climate Change, December 2009, Government Response to the Committee on Climate Change Report on Reducing CO2 Emissions from UK Aviation to 2050, DfT, August 2011, A Marginal Abatement Cost Curve Model for the UK Aviation Sector: Technical Report Final, EMRC & AEA for DfT, 2011
[11] Discussion Paper 03: Aviation and Climate Change, Airport Commission, April 2013 https://www.gov.uk/government/publications/discussion-paper-on-aviation-and-climate-change
[12] i.e. considering all emissions associated with flights departing from the country only
[13] Towards a sustainable Heathrow, Heathrow Airport, www.heathrowairport.com/static/Heathrow/.../LHR_Climate_brochure.pdf, more detail is provided in Appendix B

methodology is shown in more detail in Figure 1 of Appendix A). The figures suggest that flights departing from the proposed hub airport options would generate nearly 25 Mt CO_2 p.a. in 2050, equating to approximately 140kg per passenger for the Estuary options (operating at 180 mppa)[15] . The equivalent figure for Stansted (operating at 208mppa) is approximately 120kg per passenger, reflecting the greater role at Stansted of low cost flights, which typically have higher load factors and involve shorter travel distances than typical hub flights. The variation between the CO_2 per passenger figures for the different hub options reflects the slight variations in the number/type of ATMs assumed to operate at each airport to serve the 180 mppa forecast demand. This implies slightly different loading levels per flight, leading to the variation in values[16].

Table 1. Estimated Annual Aviation Emissions Hub Airport Options in 2050 *

	.Hub ATM kT CO_2 p.a.	Low Cost ATM kT CO_2 p.a.	Total kTCO_2 p.a.	mppa	Kg CO_2/ passenger
Inner Estuary	25,000	n/a	25,000	180	140
Outer Estuary	24,600	n/a	24,600	180	140
Stansted	23,300	1,500	24,800	208 *(180 hub only)*	120 *(130 hub only)*

* *includes taxiing, ATM emissions rounded to nearest 100 kT, per passenger figures rounded to nearest 10kg*

These estimates are consistent with those used in the Airport Commission's analysis on climate change, which also draws on the DfT 2013 Aviation 'central' forecasts. They therefore include the assumptions on future fleet consumption and aircraft fuel efficiency and fuel use incorporated in the DfT forecasts[17]. Appendix B shows the equivalent information for Heathrow under the constrained and unconstrained DfT scenarios, as well as showing the emissions in 2009 (based on different data). The hub forecasts presented above use the fleet and flight mix and fleet efficiency underpinning the unconstrained scenario for Heathrow. The differences in absolute emissions between the Hub options and the unconstrained Heathrow option therefore reflect the differences in the number of ATMs assumed and the differences in emissions per passenger largely reflect the differences in the average loading assumed per plane.

The design of a new, unconstrained hub airport is likely to provide the potential to improve on these central DfT assumptions, which are acknowledged to be conservative. Such improvements would be expected to reduce the absolute and per passenger emissions from the values quoted above. This could be achieved by attaining greater than average emissions savings from the measures being developed and applied in the sector generally as a result of a number of factors, including the following:

- It will be possible to 'design the measures in' to operations from the outset, rather than attempting to retrofit them. This is likely to facilitate performance that is closer to optimal.
- The characteristics of the hub may also mean that there is less need to compromise; for instance, balancing changes to maximise operational efficiency against the requirements of space and capacity constraints. There may also be less need to trade off emissions savings against other objectives (such as noise and NOx emissions) at airports in less densely populated locations.
- It may be possible (dependent on the wider context) to use the opening of the new airport as an opportunity to enforce restrictions/apply incentives to promote emissions reductions through standing

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[14] Fleet and emissions factor information provided by DfT Aviation in May 2013 for the constrained and unconstrained forecasts published in January 2013 for the forecast years 2010, 2020, 2030, 2040 and 2050. Fleet information for Heathrow airport in the unconstrained scenario used.

[15] Calculated by applying fleet composition proportions and emissions factors for Heathrow for the 2050 DfT 2013 aviation forecast to the forecast ATMs for the hub airport.

[16] The differences are also accentuated by very minor differences in the assumptions for each hub on the balance of fleet between different aircraft size categories and the fact that the values are rounded to the nearest 10kg

[17] Assumptions include steady changes in efficiency of new fleet, reaching a 30% to 32% saving relative to 2000 by 2040 and the use of sustainable biofuel for 2.5% of fuel by volume in 2050. Further details are provided in pages 58 to 69 of the main DfT forecast document:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/183931/aviation-forecasts.pdf

instructions – for instance charging lower fees to use the airport for planes meeting certain efficiency or age criteria.

These factors could lead to greater than average emissions savings at newly designed hub airports from a number of measures, including:

A) Plane loading and matching to mission requirements

The characteristic functioning of the large capacity hub should improve the net efficiency of travel associated with the airport, by focussing a significant proportion of demand on common departure routes from the single hub, allowing it to be served by fewer, larger and better loaded planes than if the same routes and capacity were distributed between two or three airports.

The scale of operations at the new hub and its physical design should allow sufficient space and capacity to provide flexibility in plane usage, meaning that planes can be better matched to the requirements of specific missions (in terms of size, weight and fuel usage).

Aircraft are therefore more likely to be used at high load factors on average (assuming the new airport can also devise a slot allocation system that overcomes airlines' current incentive to fly planes that are not full to retain their allocated slots), reducing emissions per passenger kilometre.

Indicative analysis undertaken by the Oxford University Environmental Change Institute[18] in 2009 for others, illustrates the potential significance of these points. It compares the average kg CO_2 emitted per seat per kilometre of flight for a Boeing 737 (up to 4000 km) and a Boeing 747 (from 4000 km) for high, median and low density seating configurations in each case. At the 4000 km switchover point (approximately equivalent to a flight to East Africa), the emissions associated with each seat kilometre for the smaller 737 planes (typically seating up to approximately 200) are 10% to 15% greater than those associated with each seat kilometre for the equivalent seat density configuration on the larger 747 planes (typically seating 450 to 600).

If the hub airport drew sufficient demand onto a common route to support the use of the larger 747 it would achieve significant savings in emissions per passenger, if plane loading levels were similar. However, a potential further benefit of the hub is that the volume of demand would allow improved loading of the larger plane, relative to smaller planes operated from individual airports. If, for instance, the larger plane achieved an 85% load factor compared to 75% on the smaller planes, the difference in emissions per passenger on a common route would increase to the point that the emissions per passenger on the smaller plane would be 25% to 30% greater than those on the larger plane.

Higher loading could also potentially result in airlines using higher density seating configurations on their aircraft, further reducing fuel consumption per passenger (or seat) km. For example, data provided by Japan Airlines[19] for a Boeing 747-400 shows energy use of 1.7 MJ per seat km for a 4,000 km flight using the "long range configuration" (262 seats); compared to 0.8 MJ per seat km for the same flight using the "high density configuration" (568 seats). The ECI analysis also shows the significance of seating configuration with, in its case, emissions per seat kilometre in the low density configuration approximately 50% greater than the emissions associated with the high density arrangement.

B) Aircraft ground activity

A new site is more likely to include sufficient land to provide larger airside areas, with the ability to support more efficient ground movements for aircraft (aprons and taxiways). For instance, it would potentially enable sufficient capacity for planes to taxi using a single engine[20]. This measure was advocated in the recent industry code of practice on reducing the environmental impacts of ground operations and departing aircraft[21] identified in the Sustainable Aviation CO_2 Road Map as having the potential to achieve a worthwhile saving in emissions, (but was excluded from the Road Map because single engine operation results in planes moving more slowly, with potentially negative impacts on taxiway capacity[22], making it a less suitable measure for existing airports, such as Heathrow, which have more limited capacity).

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[18] Calculating the Carbon Dioxide Emissions of Flights, Jardine, C.N., ECI, Oxford University, February 2009

[19] *Source: IPCC Special Reports on Climate Change, Aviation and the Global Atmosphere (www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/aviation/index.htm)*

[20] As recommended by Reducing the Environmental Impacts of Ground Operations and Departing Aircraft, An Industry Code of Practice (www.gov.uk/government/publications/reducing-the-environmental-impacts-of-ground-operations-and-departing-aircraft)

[21] Reducing the Environmental Impacts of Ground Operations and Departing Aircraft: An Industry Code of Practice, 2012

[22] Sustainable Aviation: CO_2 Road Map 2050, Sustainable Aviation, March 2012

The efficient design of the new hub, using a taxiing network and End Around taxiways would also provide the scope to reduce the amount of taxing within landing and take-off cycles, for instance through the elimination of runway crossings. Taxi and idling periods are identified as a "key factor in the variability of emissions from aircraft during airport operations"[23]. The 2009 Heathrow Carbon Footprint[24] identifies that ground movement of aircraft contributes over 25% to emissions considered to be within the airport's footprint (i.e. including surface access, landing and take-off but excluding cruise emissions of aircraft) or 3% of total emissions. Consequently design changes that allow more efficient movement could achieve valuable emissions savings.

The new Hub airport could be designed to provide ground based equipment to deliver fixed electrical ground power (FGEP) and preconditioned air to aircraft (PCA), reducing the use of less efficient on-plane auxiliary power units (APU)[25], a measure also included in the industry code of practice on ground operations. The hub could be designed to guarantee access to terminal based power for the majority of aircraft, with the power also potentially derived from renewable sources, further reducing the emissions impacts of the power used. The DfT 2013 CO_2 forecasts[26] suggest that energy associated with APU accounts for over 1% of total flight related emissions suggesting a contribution of 5% to 10% to the airports' defined 'footprint' (i.e. including surface access, landing and take-off but excluding flights) [27]. A new airport designed to promote energy efficiency and the use of ground based, renewably powered units could potentially remove the majority of these direct emissions.

C) Air traffic management

A new hub airport with increased capacity could also enable more energy efficient management of aircraft movements including continuous climb operations (CCO), air traffic management, dynamic plane sequencing to improve energy efficiency for flights using the new hub (also using new bespoke air traffic management systems)[28].

Similarly the increased capacity will provide increased landing slot flexibility and reduce the need for stacking and queuing of aircraft waiting for a slot to land[29]. The 2009 Committee on Climate Change report[30] highlighted the scale of the impact of limited capacity on stacking times quoting average 2008 holding times of 10 minutes for Heathrow (at 99% of capacity) compared to just 5 minutes and 2 minutes for Frankfurt and

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[23] Source: IPCC Special Reports on Climate Change, Aviation and the Global Atmosphere quoting USFAA, 1982, 1988 (http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/aviation/index.htm)
[24] 2009 Heathrow Carbon Footprint reported in Towards a sustainable Heathrow, Heathrow Airport, www.heathrowairport.com/static/Heathrow/.../LHR_Climate_brochure.pdf
[25] *"*Auxiliary power units (APUs) are engine-driven generators contained in the aircraft (usually in the tail) that provide the aircraft with necessary energy during the time the aircraft is at the gate. Part of the generated energy is used for air conditioning. As an alternative, the required energy can be supplied by ground-based equipment that delivers electrical power at 400 Hz and preconditioned air to the aircraft. Herau (1992) investigated the financial and energy savings of such ground-based installations at Brussels Zaventum Airport's 2000 terminal and concluded that a significant net saving of carbon emissions could be achieved. At Zurich Airport in 1997, about 68,000 aircraft used terminal A and B, which has the facility to provide preconditioned air and 400 Hz power. Provision of these services achieved estimated savings of about 95% in APU fuel consumption and emissions. However, fuel used by APUs is only a relatively small part of the total fuel use of an aircraft. For example, for B737, B747, A310, MD81, and F100 aircraft, average APU fuel use is only 2.6, 0.8, 1.4, 2.5, and 3.5% of the fuel use at cruise per hour of operation, respectively (USFAA, 1982, 1995). British Airways estimates that the amount of fuel used by an APU is less than 1% of the total fuel used by an aircraft*".* Source: IPCC Special Reports on Climate Change, Aviation and the Global Atmosphere (www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/aviation/index.htm)
[26] UK Aviation Forecasts 2013, DfT. https://www.gov.uk/government/publications/uk-aviation-forecasts-2013
[27] Estimated on the basis of the levels of emissions from different sources identified in the 2009 Heathrow Carbon Footprint reported in Towards a sustainable Heathrow, Heathrow Airport, www.heathrowairport.com/static/Heathrow/.../LHR_Climate_brochure.pdf and the 2012 Stansted Carbon Footprint reported in 2012 Sustainability Report, Stansted Airport, www.stanstedairport.com
[28] "*UK air traffic services provider, NATS recently announced plans to cut the amount of CO_2 emitted by aircraft waiting to arrive at London's airports by half. According to NATS, as much as 300,000t of CO_2 could be saved by aircraft joining the arrival sequence earlier and slowing down their approach".* Source: http://www.airport-technology.com/news/news44639.html Also on lower approach speeds: (http://www.airport-technology.com/contractors/traffic/lfv-air/presslowered-approach-speeds-reduce-emissions.html
[29] NB for the consideration of UK emissions this measure is only relevant for internal flights landing at the airport.
[30] Meeting the UK aviation target – options for reducing emissions to 2050, Committee on Climate Change, December 2009

Amsterdam with utilisation of 74% and 73% respectively, suggesting the additional capacity associated with a new hub airport could achieve significant savings in holding times and associated fuel use and emissions.

The Sustainable Aviation 2050 CO_2 Road Map[31] assumes an average saving of 2.5% in aviation sector emissions could realistically be achieved due to ATM measures introduced between 2020 and 2050, out of a potential of over 5%, although the road map does not assume a wholesale redesign of UK airspace, which a new Hub airport would necessitate.

D) Aircraft Efficiency

The new hub airport could be used to encourage the replacement of existing fleet through the introduction of standing instructions potentially identifying minimum standards eligible for a landing slot[32]. This could encourage earlier retirement of older, less efficient aircraft. A similar approach could be used to encourage retrofit of any developments in technology to older aircraft.

Summary

A hub designed to maximise its potential to achieve greater than average emissions savings on the measures described above could achieve valuable reductions in emissions, compared to emissions generated by equivalent aviation capacity provided at an airport or airports with less efficient design. These benefits would apply fully to the Inner and Outer Estuary options as they will be designed and constructed wholly from new. For Stansted, the benefits will be more limited, reflecting the fact that the proposed airport will need to work around the constraints of continuing to operate the existing airport.

3.3. Airside Support Operations

Airside support operations are all vehicle movements within the airport (other than planes) to support flight activity. Airside support operations associated with each of the hub options would be of the order of approximately 60 kT CO_2 p.a. in 2050.

Table 2. Estimated Annual Airside Support Emissions 2050 (kT CO_2 p.a.)

	2050
Support Operations	60

; These figures have been estimated from the ratio between current reported relative levels of airside support emissions and current reported take off emissions and therefore represent an indicative average forecast emissions level[33]. The construction of the new hub would provide the opportunity to build best practice measures into the operations of the airport, helping to reduce emissions rates from this level. Key relevant measures would include ensuring efficient patterns of operations and logistics (to avoid unnecessary travel), promoting efficient driving, and ensuring fuel efficient fleets are used by the airport and its contractors (including hybrid and electric vehicles where possible)[34]. These measures could achieve a noticeable reduction in emissions relatively quickly. For instance Heathrow's Clean Vehicle Programme has reported a 6% reduction in fuel consumption amongst participating fleets between 2010 and 2011[35].

Emissions reduction would be facilitated by the fact that the commissioning of the new hub would provide the opportunity to establish new fuelling or energy infrastructure and to procure an entirely new fleet as well as including energy efficiency within procurement criteria for contractors. The impact on emissions reductions could be increased if electric vehicles could be powered through renewable electricity, ideally produced on site, potentially reducing emissions from this category to virtually zero (from current levels which, for

[31] Sustainable Aviation CO_2 Road-Map, Sustainable Aviation, March 2012

[32] The knock on effects of this measure would depend on the way in which older aircraft were redistributed between routes and countries. However, the net global effect should be to increase the average efficiency of the global fleet, with older, less efficient aircraft phased out.

[33] Derived from the 2009 Heathrow Carbon Footprint reported in Towards a sustainable Heathrow, Heathrow Airport, www.heathrowairport.com/static/Heathrow/.../LHR_Climate_brochure.pdf and the 2012 Stansted Carbon Footprint reported in 2012 Sustainability Report, Stansted Airport,

[34] Fuel cell-powered baggage vehicles are already being used in some US airports. Source: www.weather.com/travel/six-energy-efficient-airports-20121109

[35] http://www.heathrowairport.com/about-us/community-and-environment/sustainability/case-studies/clean-vehicle-programme

Heathrow, account for about 2% of the airport's 'footprint' emissions i.e. including landing and take-off and surface emissions but excluding flight cruising)[36].

3.4. Surface Access

3.4.1. Overview

The design and delivery of a new hub airport would also provide the opportunity to strongly promote the use of alternatives to car to reach the airport, with the intention of reducing the emissions associated with surface access to the airport by passengers and staff.

Levels of surface access emissions depend on the average distance of travel and mode of travel. The location of the new hubs to the East of London ensures close proximity to a significant proportion of the national population, acting to reduce average travel distance associated with access.

In addition, the airports and the surface access measures for each site have been designed with the intention of achieving a target of 65% of trips (passengers and staff) accessing the airport by non-car modes, a considerable increase on current best practice mode shares of less than 50%[37] . Public transport journeys typically generate less carbon per kilometre than trips made by car. Relative figures vary significantly according to vehicle type and size, fuel type and occupancy; however DEFRA suggests a current average comparison, over all trips of 0.12kg /passenger km for car trips and 0.06kg/passenger km for rail trips[38]. On this basis, the intended high public transport mode share for the proposed hubs should significantly reduce the carbon impact of surface access.

However, it is important to note that the balance will be more complicated when considering the net impact of the relative mode share for the airport. In order to achieve this mode share, a significant expansion of rail services will be needed with frequent additional services and long operating hours required to provide the appropriate level of service to attract people to use public transport. Operating these services would require significant energy input in its own right, particularly as a number of the intended services would be operated at high speed.

The comparison in future years is further complicated by changes in vehicle type and energy used. Forecasts of future transport supply (such as those set out in the Committee on Climate Change reports[39]) predict increasingly efficient vehicles (road and rail), increasingly powered by low carbon electricity.

3.4.2. Estimated Emissions

Table 3 below summarises the estimated emissions associated with access by road vehicles and the additional rail services provided in 2050, calculated on the basis of the forecast change in vehicle kilometres (road and rail) and appropriate emissions factors derived from DfT guidance[40] (the methodology used is set out in more detail in Figure 2 of Appendix A). Estimates for the 2034 opening year are also included, on the basis that the level of traffic generated by the airport grows in proportion to passenger usage and additional rail infrastructure and services would be in place from the opening year.

Appendix B contains Heathrow Airport's estimate of the emissions associated with surface access in 2009[41] to provide an indicative sense of scale, subject to the important caveat that the figures are not directly

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[36] 'Ground based emissions on site' exclude any emissions associated with aircraft movement

[37] 2012 Sustainability Report, Stansted Airport, www.stanstedairport.com

[38] 2012 Greenhouse Gas Conversion Factors for Company Reportin, DEFRA & DECC https://www.gov.uk/government/publications/2012-greenhouse-gas-conversion-factors-for-company-reporting

[39]For instance: The Fourth Carbon Budget – reducing emissions through the 2020s December 2010, http://www.theccc.org.uk/publication/the-fourth-carbon-budget-reducing-emissions-through-the-2020s-2/

[40] WebTAG Unit 3.5.6 and 3.5.3 (for highway, with additional assumption that electric cars increase to approximately 50% of the fleet by 2050, a conservative assumption relative to those made by the Committee on Climate Change in their fourth Carbon Budget) and *Traction Electricity and Electrification Asset Usage Charges in CP5 – Conclusions of Network Rail's Consultation – February 2013*" (conventional rail consumption rates, regenerative braking and electrical losses factors), "*Factors affecting the carbon emissions of HS2",* Systra, February 2011 (high speed rail consumption rates) and WebTAG 3.5.3 for gCO_2/kWh .Emissions relate to trips to and from the airport only, not impacts on other road users through impacts on travel speed

[41] As cited in the 2009 Heathrow Carbon Footprint reported in Towards a sustainable Heathrow, Heathrow Airport, www.heathrowairport.com/static/Heathrow/.../LHR_Climate_brochure.pdf

comparable as they have been calculated in different ways. As summarised in Appendix A, the figures presented below are based on modelled estimates of traffic flows and speed related emissions factors for road traffic and additional emissions for new and extended public transport services. In contrast, although the methodology for the Heathrow estimate is unstated, the likelihood is that it was based on surveys of modes of travel and typical emissions values in grammes/passenger by mode

Table 3. Estimated Annual Surface Access Emissions 2034 and 2050 (kT CO_2 p.a.*)

	2034			2050		
	Inner Estuary	**Outer Estuary**	**Stansted**	**Inner Estuary**	**Outer Estuary**	**Stansted**
Road	280	310	320	310	340	350
Rail	190	230	170	20	20	10
Total	**470**	**540**	**490**	**330**	**360**	**360**

*Represents emissions associated with trips to and from the airport only, not impacts on the wider network (through impacts on speed). Figures rounded to nearest 10kt CO_2.

The table shows the importance of assumptions made in relation to technology change through time. WebTAG 3.5.3 suggests that the average carbon intensity of electricity (in g/kWh) in 2050 will be less than 15% of the intensity of electricity in 2034, leading to the significant reduction in the carbon impact of the same rail services shown between 2034 and 2050 in the table above. Although WebTAG does not forecast car fleet composition beyond 2035, the 2050 figures above are based on the assumption that electric vehicles account for 50% of the fleet by 2050 (a conservative proportion relative to the assumptions made in the Committee on Climate Change Fourth Carbon Budget Report[42]). This fleet change combined with the reducing carbon intensity of electricity leads to the situation shown, where despite a 50% forecast increase in traffic between 2034 and 2050, the forecast growth in emissions is closer to 10%.

The varying levels of emissions at the different sites primarily reflects the different locations of the sites and the implications for average distance travelled by road and additional rail services required to provide public transport access. For instance, the additional distance to the Outer Estuary site adds about 15% to total emissions relative to the Inner Estuary site in 2034.

As discussed, the achievement of a high public transport mode share has a significant impact on the scale of surface access emissions shown. Under the modelled assumptions on future fleet composition, reducing the share from 65% to 50% by public transport (in line with highest levels at existing airports), would increase road emissions by about 25%.

The achievement of a high proportion of surface access by public transport could be encouraged through a number of measures including:

- the provision of fast and reliable public transport between key areas of population and the new hub, focussing particularly on rail links including high speed connections to London (and the wider high speed rail network for the Estuary sites) and direct stopping services linking to London and surrounding areas, including an extension to Crossrail for the Estuary sites and Crossrail 2 for Stansted. These high quality connections would also potentially lead to short haul connections to and from the new hub being replaced by rail journeys. As outlined above however, the provision of these services also implies significant energy demand, with associated emissions impacts;
- developing “air-rail alliances” where possible to encourage the use of public transport to/from the airport and for onwards journeys replacing short haul flight connections (for example developing agreements for plane tickets to be valid on rail services and for air and rail travel to be purchased together);
- focusing particularly on discouraging travel by car for ‘kiss-and-fly’[43] which leads to additional car trips. In addition to the service provision and “rail air alliances” described above, this might involve low price public transport tickets for escort/accompanying trips to the airport; and

[42] The Fourth Carbon Budget – reducing emissions through the 2020s December 2010, http://www.theccc.org.uk/publication/the-fourth-carbon-budget-reducing-emissions-through-the-2020s-2
[43] “*A significant proportion of airport carbon emissions can be attributed to excessive car trips that passengers take to and from airports. The emissions have been blamed on so-called 'kiss-and-fly' passengers, who are dropped off at the airport and then picked up again resulting in four car trips for every return flight. Evidence for this statement was based on statistics released by the Manchester Airport in the UK, which revealed that 25,800t of CO_2, 58% of the airport’s total carbon emissions, can be attributed to the vehicles that carry passengers and staff to and from the airport. The excessive carbon emissions emitted by*

- parking charging regime to favour public transport use (and potentially lower carbon vehicle use).

At a broader level, the scale of activity generated by the presence of a new, high capacity hub is likely to encourage development in the vicinity of the airport, acting to reduce average distance of travel to the airport for freight and business travel associated with the nearby developments. .

A development of the scale of the proposed airport and the potential associated surrounding development would also be likely to provide the scope to develop a freight consolidation centre, to be used for the construction stage as well as once the airport is operational. This would lead to reduced emissions from on-site deliveries and waste disposal as illustrated by existing centres at London Heathrow, Manchester Airport and East Midlands Airport[44.]

3.5. Construction and Buildings Operation

The opening of a new hub airport and associated infrastructure would involve significant construction, with inevitable emissions implications associated with the works and the materials used. However, it would also provide the opportunity for the design to apply best practice to minimise the emissions associated with construction (for instance through use of low embodied carbon materials, recycled materials and locally sourced materials and co-ordination and consolidation of freight activity).

The airport could also be designed to ensure that ongoing operation and maintenance of the infrastructure and buildings involves low levels of ongoing emissions through measures such as:

- designing energy and water efficient buildings (e.g. meeting the highest standards of assessment codes such as BREEAM) and applying similar principles to systems such as baggage handling;
- maximising the use of renewable and low carbon energy resources, particularly from the site; including solar energy, ground source heat, small scale wind, combined heat and power systems and potentially tidal flow. The viability of low carbon energy would be increased by factors including the scale of the site, the fact that the scale of the power requirements at a hub airport would facilitate the use of a range of power sources (potentially offsetting some of the variability of supply issues associated with renewable energy) and that the location of the proposed sites in the South of England would enhance their potential for gathering solar energy; and
- providing flexible buildings and infrastructure that are easy to upgrade to reflect changing requirements, without the need for large scale construction works.

Such measures have the potential to achieve significant savings in emissions, relative to average and existing operations. For instance, installation of energy efficient baggage handling systems could achieve efficiency savings of up to 50% relative to standard systems, potentially saving 5% to 10% of airport site operations emissions[45]. Heathrow Airport Holdings Limited (formerly BAA) estimated that "*Heathrow's redeveloped Terminal 2 will save over 40% CO_2 emissions compared to the minimum specified for a new building*", savings of 20% are to be achieved through energy efficiency measures and renewable energy sources will contribute another 20%. Energy efficient design elements include the use of high levels of insulation and passive lighting. "*The renewable energy for the building will come from photovoltaic solar panels on the roof and through a combined heat and power (CHP) plant that will be fuelled with wood chips, sourced locally to Heathrow*"[46].

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the airports transport network were identified as a point of concern in Manchester airport's bid to be carbon neutral by 2015. The airport currently emits a total of 436,000t of CO_2 a year and has put in plans to reduce this figure, including reducing the amount of fuel used by the airport's fleet by 25% compared to the 2006 level". Source: http://www.airport-technology.com/news/news44774.html

[44] *"The detailed evaluations of the Heathrow and Bristol retail consolidation centre implementations revealed delivery vehicle mileage reductions of 50-75%, depending on the stage of development of the scheme, time of year etc"*. Source: Freight Consolidation Centre Study, Main report, prepared for the DfT by TTR and TRL, July 2010 (www.worcestershire.gov.uk/cms/pdf/Freight-Consolidation-Centre-Study-Main-Report.pdf)

[45] New handling techniques potentially capable of reducing energy consumption by up to 50%, equating to 10% of the airports energy consumption. Survey of Regional Airport undertaken and quoted by Vanderlande Industries UK Ltd in their submission on the Aviation Strategy to the 2012/13 Session of the Parliamentary Transport Select Committee on Transport
http://www.publications.parliament.uk/pa/cm201213/cmselect/cmtran/writev/aviation/m34.htm

[46] Source: www.heathrowairport.com/about-us/community-and-environment/sustainability/case-studies/energy-efficiency-at-the-new-terminal-2

4. Climate Change Forecasts and Impacts

4.1. Adaptation

All UK airports and associated infrastructure will need to take account of the implications of forecast future climate change on resilience and operations.

The construction of a new hub airport will provide the opportunity for the design to take account of forecast climate change from the start, avoiding the need to attempt to retrofit changes to existing infrastructure to ensure operational resilience is maintained against the context of changing climate (such as increased storminess) and that any opportunities (such as reduced heating requirements) are maximised.

Appendix C shows projections from UKCP09 (UK Climate Projections 2009) for standard variables such as temperature, precipitation, cloud cover and sea level rise) for each of the three locations. The figures show that design for the three sites will need to account for impacts of climate change that would be common across the majority of the South East of the UK as follows (described in more detail in Appendix D):

- Delays and cancellations due to more intense rainfall events, an increase in lightning frequency, an increase in winter fog and possibly stormier conditions;
- Risk of passenger injuries and illness due to more intense rainfall events and extreme high temperatures;
- Damage to airport and access transport infrastructure through flooding (fluvial, coastal and surface), extreme high temperatures and possibly windier conditions;
- Increase in the risk of fire due to high temperatures;
- Reduced delays, cancellations, operational issues and passenger injuries relating to snowfall and ice;
- Reduced need for space heating but increased need for air conditioning;
- Increased likelihood of needing to respond to impacts at other or/and multiple airports e.g. knock-on impacts, or widespread impacts; and
- Changes in demand in response to international changes in climate.

The particular geographical locations and characteristics of the sites lead to above average probability of certain impacts as summarised below:

a) Stansted: increase in winter fog accentuated by the site's high elevation, potentially leading to delays, diversions and cancellations; and

b) Inner and Outer Estuary: increase in coastal water flooding, potentially causing damage to infrastructure and delays and cancellations, reflecting the impacts of storm surges and sea level rise;

The new hub airports could be designed with an understanding of these potential future issues from the outset, it would therefore be possible for appropriate mitigation measures to be built in cost effectively.

At Stansted, it would be possible to maximise the use of ever improving technology to reduce the impact of fog on operations. For instance, the precision of aircraft location systems has improved consistently over time and will continue to do so (as illustrated by the Galileo system and Local Area Augmentation System, LAASS) and the technology in large modern aircraft allows them to take off and land in fog. Although additional separation between aircraft is still required for manoeuvres in foggy conditions, this would have less impact at a newly designed hub than at an existing airport operating close to capacity, as the spare hub capacity available would allow the separation to be accommodated with relatively little impact on schedules. In terms of physical airport design and construction, the physical infilling required to enable the construction of the runways to the north east of the current airport would reduce the natural dip in the landscape, reducing the associated risk of fog.

For the Estuary options, the majority of off-airport required defences would already be in place due to the planned Thames Estuary 2100 flood defence programme[47] with any off-airport additions required to cater for the airports likely to be relatively minor in scale. On-airport defences are already within the masterplan. Carefully designed adaptation measures implemented for the airport could also potentially bring benefits to the wider area.

4.2. Climate Change Implications for Other Impacts

Future climate change could potentially exacerbate or improve some of the forecast impacts of the proposed hub airports on other aspects of the environment, as considered under other work streams.

Appendix E provides tables summarising a high level overview of the likely impact of climate change on the flood risk, water quality and ecological impacts of the proposed hub airport at each of the three sites in the 2050s.

In summary, the review suggests that forecast climate change is likely to exacerbate the impacts of each of the three sites on water quality and ecology and of the estuary sites on coastal flood risk, unless suitable mitigation is built into the original design. The implications for coastal processes require further consideration.

4.3. Summary

Future climate change will inevitably need to be accounted for in locating and designing future airports and planning for their operations.

The review of climate change forecasts and issues summarised above (and presented in more detail in Appendices C, D and E) suggests that the implications of future climate change do not weaken the case for the three sites under consideration. The majority of manifestations of climate change faced at the sites would be common across the South East. Where location specific issues do arise (specifically winter fog at Stansted and coastal flooding at the Estuary sites), mitigation using available technology is easier if the issues are understood and addressed through design from the outset.

Similarly, although climate change is forecast to be likely to accentuate the possibility of the sites impacting on water quality, ecology and coastal flood risk (the latter for the Estuary sites only), it should be possible to mitigate the issues if understood and catered for in the design of the site from the outset.

By understanding relevant climate projections and the likely impacts on airport construction and operation in advance, the airport can be sited and designed (physically and operationally) for resilience to anticipated change. This is likely to be more effective and cost-effective than retrofitting partial solutions in the context of existing constraints at existing airports.

[47] The Environment Agency’s TE2100 Plan sets out the strategic direction for managing flood risk in the Thames Estuary to the end of the century and beyond. It sets out what actions the Environment Agency and others will need to take in the context of increasing flood risk – in the short term (next 25 years), medium term (the following 15 years) and long term (to the end of the century). The plan is based on current guidance on climate change, but is adaptable to changes in predictions for sea-level rise and climate change over the century.

5. Summary

The Airport Commission has defined a narrow scope for the issues relating to Climate Change to be covered within the July submissions on long term capacity options, focusing on:

- the extent to which the options proposed could reduce emissions levels relative to other options to provide the same capacity and could then provide ongoing improvement in performance; and
- the extent to which climate change might influence the resilience of the sites.

While there is some variation in the risks posed by climate change, with flooding more significant at the estuary sites and fog more of a risk at Stansted, there is relatively little difference between the three potential hub sites in terms of likely climate change impacts. Indicative modelling and analysis has estimated the hub airports would generate:

- 130-140 kg of ATM CO_2 emissions per passenger;
- 60 kT CO_2 per annum from airside support operations;
- 330-360 kT CO_2 per annum from surface access

The key points are that the proposed options will be:

- Designed with carbon and climate change in mind from the start and so will:
    - implement measures at the start to reduce emissions at their full potential, without the constraints imposed by retro fitting them in the context of existing operations;
    - build-in resilience to predicted climate change from the outset;
- Large scale:
    - allowing flexible movement planning on the ground and in the air, allowing more efficient movement and use of appropriate aircraft;
    - drawing together large volumes of demand on common routes allowing them to be served by larger, better loaded planes;
    - generating sufficient passenger population and demand to support surface access measures to promote high public transport mode share;
    - able to enforce restrictions requiring planes to meet efficiency/age criteria.

The characteristics of the hub airports and their location will mean that they can be designed to generate below average emissions per passenger relative to other approaches for providing the same capacity (such as through the expansion of existing airports). It is however important to note that the differences in emissions associated with a given capacity of airport that can be achieved through variations in design and operation are small compared to the overall (largely cruise based) emissions associated with the airport, which, as the Commission identified, are likely to be largely consistent regardless of the location of the capacity.

Appendices

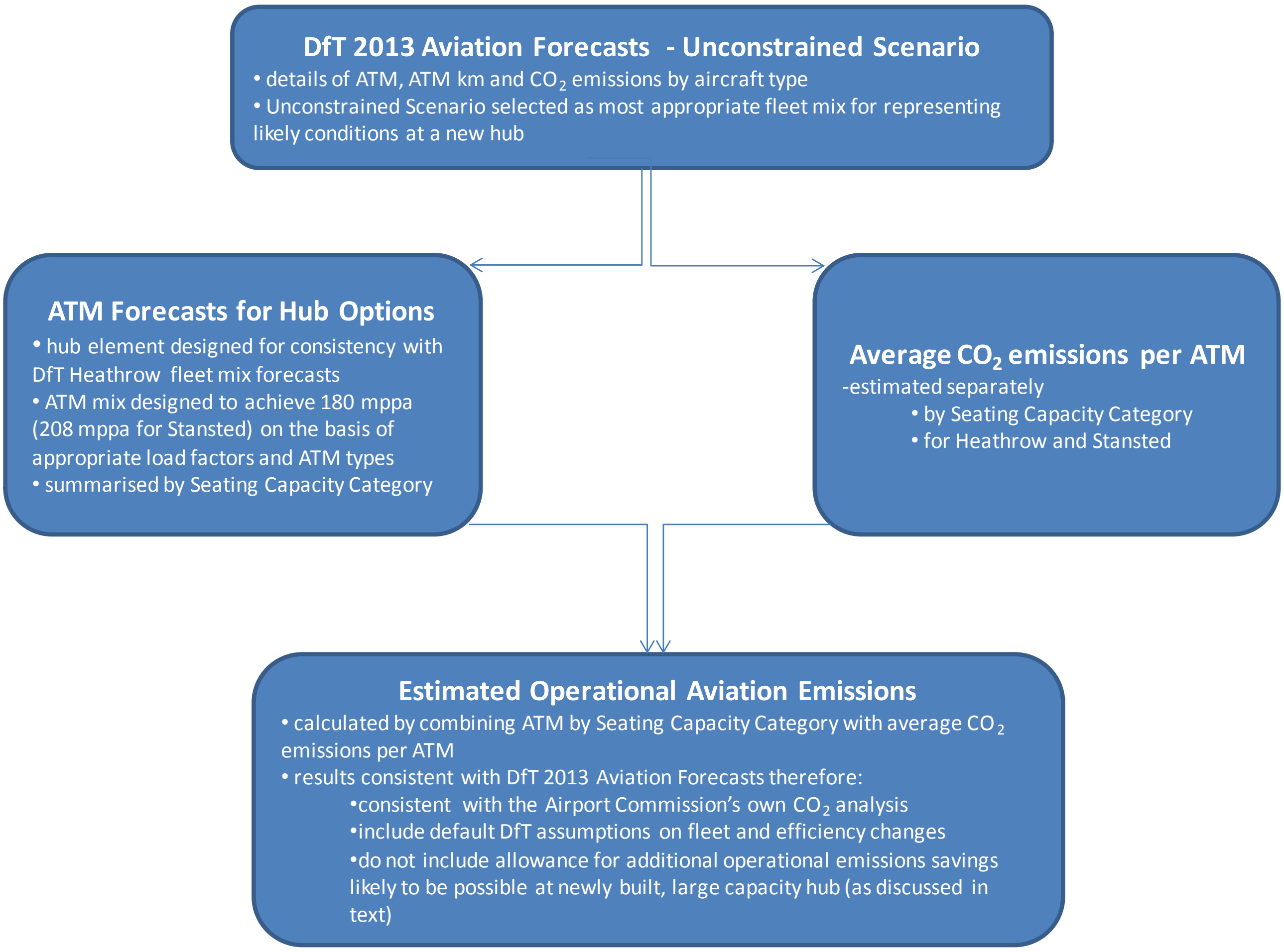
Appendix A. Calculation Methodologies

A.1. Introduction

The following flow charts summarise the approaches and data sources used for the calculation of estimated operational and surface access emissions for each hub option.

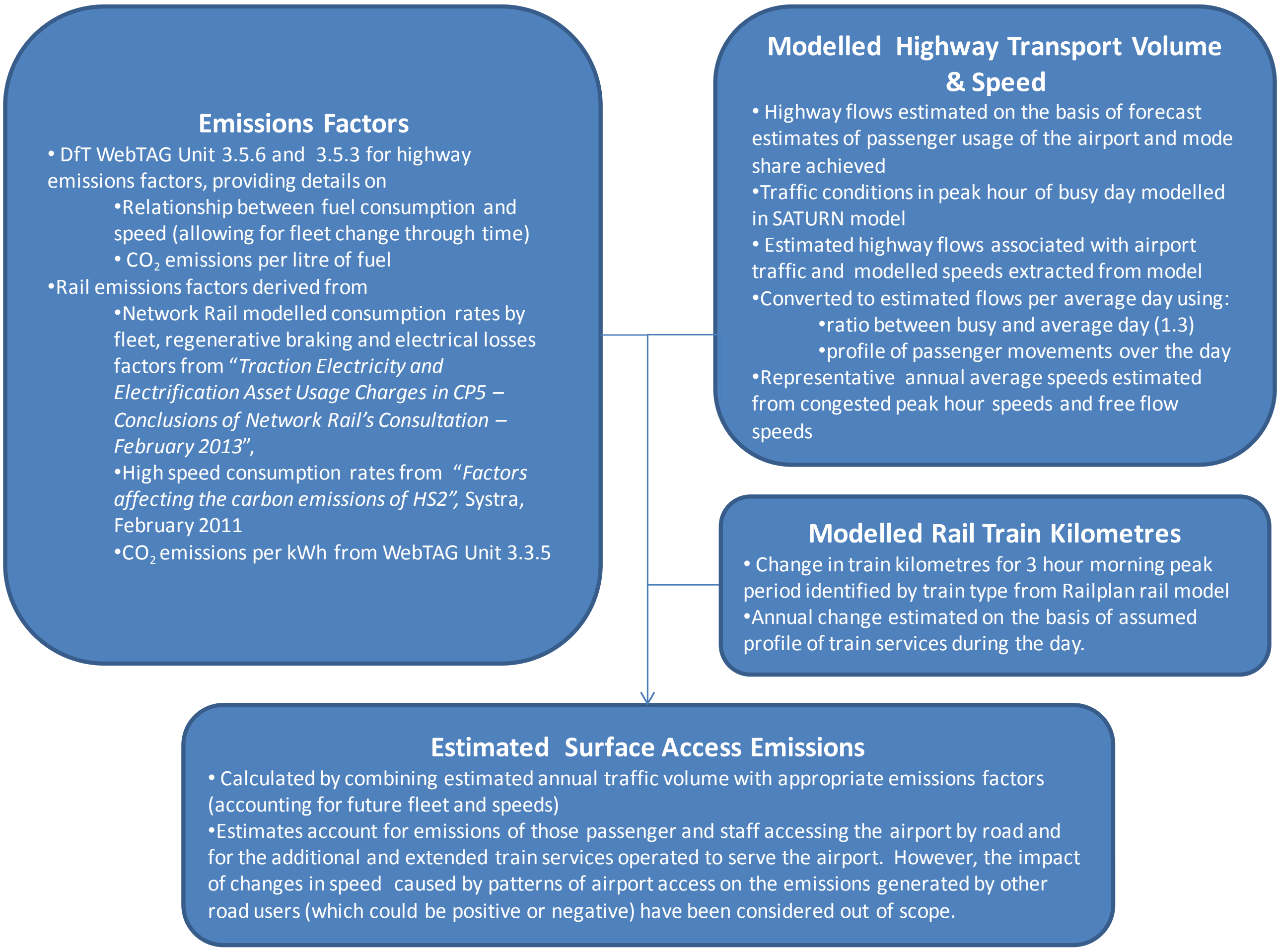
A.2. Operational Emissions Calculation Methodology

Figure 1. Flow Chart Summarising Calculation of Operational Emissions



A.3. Surface Emissions Calculation Methodology

Figure 2. Flow Chart Summarising Calculation of Surface Access Emissions



Appendix B. Heathrow Airport Emissions Estimates

B.1. Introduction

This Appendix provides a summary of estimates of emissions generated by Heathrow which have been drawn from two main sources:

- Heathrow Airport's 2009 carbon footprint[48]
- DfT's UK Aviation Forecasts 2013[49]

It is important to note that the 2009 figures are presented to give an indicative sense of scale and to provide a cross check for the 2034 to 2050 figures only. They are not directly comparable with the figures presented for 2050 (and 2034) here and in the main report as they have not been calculated in the same way. In particular, the surface access figures presented in the main report for the Hub options for 2034 and 2050 have been calculated on the basis of traffic model estimates of traffic flows and speed related emissions factors for road traffic. Additional emissions for new and extended public transport services have also been calculated.

In contrast, although the methodology for the Heathrow estimate is unstated in the source document, the likelihood is that it was based on surveys of modes of travel for those arriving at and leaving the airport. Numbers using each mode are likely to have been multiplied by typical emissions values in grammes/passenger by mode. The figures are therefore useful to provide an indication of the relative scale of emissions from different sources in 2009 and a broad sense of scale for comparison with the 2034 and 2050 forecasts. However, they should not be used for detailed investigations of similarities and difference between years.

B.2. Heathrow 2009 carbon footprint

The following table summarises the emissions figures quoted in Heathrow Airport's 2009 carbon footprint[46].

Table 4. Estimated Emissions at Heathrow 2009 (Kt CO_2 p.a.)

Item	Source	Kt CO2 p.a.
1	Heathrow flights (2005)	17,100*
2	Aircraft landing	260
3	Aircraft taking off	420
4	Aircraft movements on the ground	630
5	Passenger travel	380
6	Staff travel	240
7	BAA vehicles	<10
8	3rd party vehicles and equipment	30
9	Electricity	250
10	Other energy	80
11	Refrigerants	<10
Sub totals		
(1+2+3+4)	ATM related emissions	18,410
(5+6)	Surface access	620
(7+8)	Airside Support	<40

[48] As cited in the 2009 Heathrow Carbon Footprint reported in Towards a sustainable Heathrow, Heathrow Airport, www.heathrowairport.com/static/Heathrow/.../LHR_Climate_brochure.pdf
[49] UK Aviation Forecasts 2013, DfT. https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

** The Heathrow carbon footprint document refers to flight emissions being related to flights to and from Heathrow but source the figure quoted (17.1Mt) to the DfT's, "UK air passenger demand and CO2 forecast" 2009. Table 3.7, p84 which refers to emissions associated with flight departures only, consistent with the approach taken in the DfT's 2013 forecasts and underpinning the figures presented in this report.*

NB there appears to be some potential double counting in the ATM related emissions as the 17,100 kT flight related figure sourced from the DfT aviation forecasts also includes an allowance for landing, take-off and taxiing. However, these figures only account for 7% of total ATM emissions and may have been included to compensate for the fact that the ATM figure is for an earlier year (2005). The figures have therefore been left as quoted in the footprint report to ensure consistency and traceability.

The table below combines the estimated ATM related emissions shown above with Heathrow's estimate of the number of passengers in 2009 to provide an estimate of emissions per passenger.

Table 5. Estimated Emissions per Passenger, Heathrow, 2009

	ATM kT CO_2 p.a.	mppa	kg CO_2 passenger
Heathrow 2009	18,400	66[50]	280

* includes taxiing, total emissions rounded to nearest 100 kT, per passenger emissions rounded to nearest 10kg

B.3. Heathrow DfT 2013 Forecasts

The following table summarises the ATM related emissions and mppa forecast for Heathrow in the constrained and unconstrained scenarios in the DfT's 2013 aviation forecasts

Table 6. Estimated Annual Aviation Emissions Heathrow Scenarios in 2050 (kT CO_2 p.a. *)

	ATM kT CO_2 p.a.	mppa	kg CO_2/ passenger
Heathrow (constrained scenario)	18,300	93	200
Heathrow (unconstrained scenario)	25,500	170	150

- * includes taxiing, total emissions rounded to nearest 100 kT, per passenger emissions rounded to nearest 10kg

The figures presented are drawn directly from the DfT's 2013 aviation forecasts and associated unpublished analysis[51]. The hub forecasts presented in the main report use the same fleet and flight mix and fleet efficiency as those underpinning the DfT's unconstrained scenario for Heathrow. The differences in absolute emissions between the Hub options and the unconstrained Heathrow option therefore reflect the differences in the number of ATMs assumed and the differences in emissions per passenger largely reflect the differences in the average loading assumed per plane, as the ratio between ATMs and passengers assumed in the DfT forecasts for Heathrow implies slightly fewer passengers per flight than the ratio adopted for the hub options.

The same factors influence the differences in emissions associated with the constrained Heathrow scenario, along with the additional factor that in a scenario of constrained capacity (nationally) the mix of aircraft and routes assumed to be using Heathrow varies, with an increase in the proportion of larger planes on longer distance journeys.

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[50] Source: Our Performance: Detailed Statistics, Heathrow Airport, 2009
http://www.heathrowairport.com/static/HeathrowAboutUs/Downloads/PDF/LHR_stats_2009.pdf

[51] DfT provided unpublished information on the CO_2 emissions associated with the unconstrained scenario for the purposes of this study.

Appendix C. Climate Projections

C.1. Background

This Appendix summarises the projected impacts of climate change on three locations in the UK identified as potential sites for a new or expanded airport. Full references are included in Appendix F.

The projections are taken from UKCP09 (UK Climate Projections 2009). For standard variables (temperature, precipitation, cloud cover, sea level rise, etc), the projections have probabilities associated with them, and these are presented with the median projection of the Medium emissions scenario as the principal quoted value and a range presented in brackets (10^{th} percentile of the Low emissions scenario to the 90^{th} percentile of the High emissions scenario) to give an indication of the range[52]. More information on the projections can be found in Murphy *et al*. (2009).

For some of the less standard variables (fog, snow, wind, and lightning) probabilistic projections were not produced as a result of large uncertainties in modelling accuracy and lack of appropriate baseline data. Instead, projections are available for an ensemble of 11 model runs for the Medium emissions scenario and 2080s time slice only. Results are predominantly presented as a mean of the ensemble. These less-standard projections are referenced separately.

Projections are presented below for two 30-year time slices: the 2050s (2040 to 2069) and the 2080s (2070 to 2099), covering both the period by which an airport would be fully constructed and running at full capacity, and also the furthest into the future the UKC09 projections were made, to reflect the long expected lifetime of an airport. All projections are presented as changes compared to a 1961-90 baseline period.

Projections are taken from the most appropriate $25km^2$ grid cell for each site. For the two estuary sites, an appropriate grid cell was also selected for the sea level rise and storm surge projections (as these differ from the land grid cells).

C.2. London Stansted

The probabilistic projections for London Stansted show an increase in both temperature and rainfall (see below). Summer mean daily maximum temperature is projected to rise by 3.3°C (1.1 to 6.6°C)[53] and 4.7°C (1.2 to 10.3°C) in the 2050s and 2080s[54] respectively. Mean and wettest-day winter precipitation is likely to increase, with 15% (1 to 37%) and 13% (-5 to 37%) rises projected for the 2050s respectively, with correspondingly larger increases by the 2080s. The winter cloud cover is also projected to increase, though the increases are relatively small at 1% (-2 to 3 or 4%) for the 2050s and 2080s.

Table 7. Probabilistic Change Projections for Stansted

Variable	Units	2050s			2080s		
		Low 10th	Med 50th	High 90th	Low 10th	Med 50th	High 90th
Summer mean daily max temp.	°C	1.1	3.3	6.6	1.2	4.7	10.3
Winter mean precipitation	%	0.9	15.4	37.2	3.7	20.7	61.3
Winter wettest-day precipitation	%	-5.0	12.6	37.3	-1.2	17.0	64.0
Winter cloud cover	%	-2.3	-0.4	3.5	-1.9	0.9	4.3

The projected changes in non-probabilistic variables are summarised below (all figures refer to the Medium emission scenario and the 2080s time slice):

[52] For sea level rise projections, those presented are taken from the same emissions scenarios, but use the 5^{th} and 95^{th} percentiles for the range, rather than the 10^{th} and 90^{th}.
[53] Results for terrestrial probabilistic projections are presented for the median probability level of the Medium emissions scenario (with a range in brackets from the 10^{th} percentile of the Low emissions scenario to the 90^{th} percentile of the High emissions scenario).
[54] The 2050s is the average of the period 2040 to 2069; the 2080s relates to the period 2070 to 2099.

- Projections for changes in lightning show an increased frequency of days across southeast England where lightning occurs. Projected increases are highest in autumn (1-3 additional days) followed by summer (1-2 days) over baseline values of 1-2 and 4-5 days respectively (Boorman *et al*., 2010a).
- Projections suggest a future decrease in snow days (defined as a day with greater than 0.02 mm of snowfall) in southeast England. Mean projections show a likely decrease in winter and spring snowfall of 70-90% and 80-90% respectively. Projections for heavy snow events (90th percentile of snowfall rate) also show large reductions, but with greater uncertainty within the ensemble (Brown *et al*., 2010)
- Projections of days with fog for the London area show mean increases of 20% in winter, and decreases of 38%, 67% and 28% for spring, summer and autumn respectively. The winter increase is the largest of all areas in the UK (Boorman *et al*., 2010b).
- Projected future changes in 30-year averages of surface wind speed are small within the RCM ensemble, with seasonal changes across the mainland UK lying within the range -15% to +10% (Brown *et al*., 2009).

C.3. Inner Estuary

Probabilistic projections for the Inner Estuary site are shown below. Summer daily maximum temperature is projected to increase by 3.2°C (1.1 to 6.5°C) [55] and 4.6°C (1.2 to 10.1°C) by the 2050s and 2080s[56] respectively. Winter precipitation is also likely to increase, for both the average and the wettest day of the season, with projected increases of 12% (-2 to 30%) and 14% (-4 to 31%), and 16% (-1 to 47%) and 18% (-2 to 53%) for the 2050s and 2080s respectively. Small changes are expected for cloud cover (<5%) for both the 2050s and 2080s.

Table 8. Probabilistic Change Projections for the Inner Estuary

Variable	Units	2050s			2080s		
		Low 10th	Med 50th	High 90th	Low 10th	Med 50th	High 90th
Summer mean daily max temp.	°C	1.1	3.2	6.5	1.2	4.6	10.1
Winter mean precipitation	%	-2.4	12.1	30.2	-1.0	15.7	46.8
Winter wettest-day precipitation	%	-3.8	14.2	30.8	-2.1	17.5	52.7
Winter cloud cover	%	-2.5	0.5	3.8	-2.1	1.0	4.8

Projections of relative sea level rise show an increase of 0.47m (0.21 to 0.89m)[57] by the end of the century; these projections do not include any allowance for major ice sheet loss. Storm surge projections show small decreases in height (<0.05m by 2099 for 1 in 20-year storm surges under Medium emissions), though the projections are not statistically significant.

The projected changes in non-probabilistic variables are summarised below (all figures refer to the Medium emission scenario and the 2080s time slice):

- Projections for changes in lightning show an increased frequency of days across southeast England where lightning occurs. Projected increases are highest in autumn (1-3 additional days) followed by summer (1-2 days) over baseline values of 1-2 and 4-5 days respectively (Boorman *et al*., 2010a).
- Projections suggest a future decrease in snow days (defined as a day with greater than 0.02 mm of snowfall) in southeast England. Mean projections show a likely decrease in winter and spring snowfall of 70-90% and 80-90% respectively. Projections for heavy snow events (90th percentile of snowfall rate) also show large reductions, but with greater uncertainty within the ensemble (Brown *et al*., 2010)
- Projections of days with fog for the London area show mean increases of 20% in winter, and decreases of 38%, 67% and 28% for spring, summer and autumn respectively. The winter increase is the largest of all areas in the UK (Boorman *et al*., 2010b).
- Projected future changes in 30-year averages of surface wind speed are small within the RCM ensemble, with seasonal changes across the mainland UK lying within the range -15% to +10% (Brown *et al*., 2009).

[55] Results for terrestrial probabilistic projections are presented for the median probability level of the Medium emissions scenario (with a range in brackets from the 10th percentile of the Low emissions scenario to the 90th percentile of the High emissions scenario).
[56] The 2050s is the average of the period 2040 to 2069; the 2080s relates to the period 2070 to 2099.
[57] The range for the marine probabilistic projections is the 5th percentile of the Low emissions scenario to the 95th percentile of the High emissions scenario.

C.4. Outer Estuary

Probabilistic projections for the Outer Estuary site are shown below. Summer daily maximum temperature is projected to increase by 3.2°C (1.1 to 6.5°C)[58] and 4.6°C (1.2 to 10.1°C) by the 2050s and 2080s[59] respectively. Winter precipitation is also likely to increase, for both the average and the wettest day of the season, with projected increases of 12% (-2 to 30%) and 14% (-4 to 31%), and 16% (-1 to 47%) and 18% (-2 to 53%) for the 2050s and 2080s respectively. Small changes are expected for cloud cover (<5%) for both the 2050s and 2080s.

Table 9. Probabilistic Change Projections for the Outer Estuary

Variable	Units	2050s			2080s		
		Low 10th	Med 50th	High 90th	Low 10th	Med 50th	High 90th
Summer mean daily max temp.	°C	1.1	3.2	6.5	1.2	4.6	10.1
Winter mean precipitation	%	-2.4	12.1	30.2	-1.0	15.7	46.8
Winter wettest-day precipitation	%	-3.8	14.2	30.8	-2.1	17.5	52.7
Winter cloud cover	%	-2.5	0.5	3.8	-2.1	1.0	4.8

Projections of relative sea level rise show an increase of 0.48m (0.21 to 0.89m) [60] by the end of the century, though these projections do not include any allowance for major ice sheet loss. Storm surge projections show small decreases in height (<0.05m by 2099 for 1 in 20-year storm surges under Medium emissions), though the projections are not statistically significant.

The projected changes in non-probabilistic variables are summarised below (all figures refer to the Medium emission scenario and the 2080s time slice):

- Projections for changes in lightning show an increased frequency of days across southeast England where lightning occurs. Projected increases are highest in autumn (1-3 additional days) followed by summer (1-2 days) over baseline values of 1-2 and 4-5 days respectively (Boorman *et al*., 2010a).
- Projections suggest a future decrease in snow days (defined as a day with greater than 0.02 mm of snowfall) in southeast England. Mean projections show a likely decrease in winter and spring snowfall of 70-90% and 80-90% respectively. Projections for heavy snow events (90th percentile of snowfall rate) also show large reductions, but with greater uncertainty within the ensemble (Brown *et al*., 2010)
- Projections of days with fog for the London area show mean increases of 20% in winter, and decreases of 38%, 67% and 28% for spring, summer and autumn respectively. The winter increase is the largest of all areas in the UK (Boorman *et al*., 2010b).
- Projected future changes in 30-year averages of surface wind speed are small within the RCM ensemble, with seasonal changes across the mainland UK lying within the range -15% to +10% (Brown *et al*., 2009).

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[58] Results for terrestrial probabilistic projections are presented for the median probability level of the Medium emissions scenario (with a range in brackets from the 10th percentile of the Low emissions scenario to the 90th percentile of the High emissions scenario).
[59] The 2050s is the average of the period 2040 to 2069; the 2080s relates to the period 2070 to 2099.
[60] The range for the marine probabilistic projections is the 5th percentile of the Low emissions scenario to the 95th percentile of the High emissions scenario.

Appendix D. Climate Change Impacts on Airports

This section discusses the likely impacts on a potential airport at the three proposed locations from the climatic changes described above.

Wet and stormy weather can have a number of impacts on airport operations. Very wet and/or windy conditions can cause delays and cancellations as landing, taxiing and taking off are disrupted. Uncertainty around likely changes to low pressure storm events is high, particularly with regard to change in wind speeds; however, greater rainfall totals are projected when heavy rainfall events occur. Mean precipitation is likely to increase for spring, autumn and winter, which would cause an increase in the risk of passenger injuries from slips, trips and falls. Lightning frequency is also projected to increase for all three sites, which would result in greater number of delays as aircraft take-offs and landings are disrupted, and ground operations are suspended to ensure the safety of staff.

Extreme weather events also have the risk of causing damage to infrastructure through wind damage and flooding. The existing London Stansted site sits on a plateau with a relatively high elevation, and as a result has a low flood risk, predominantly associated with heavy rainfall events causing high levels of runoff from the considerable expanse on impermeable surfaces on the site (Jefferson, 2011), possibly exacerbated by changes associated with airport construction, particularly the increased run-off risk associated with the infilling of landscape depressions in the expansion area. The Inner and Outer Estuary sites have considerably higher flood risks, particularly as a result of being on the coast and thus being at risk from sea level rise and storm surges. These risks will increase as sea levels continue to rise. The flood risks also apply to the road and rail networks that connect the airports.

While projections for snowfall are uncertain, they suggest that days where snowfall will occur will decrease under a warmer future climate. It is likely, therefore, that disruptions caused by heavy snowfall will decrease in frequency and severity. Disruption from fog is likely to increase during winter months, though it is projected to decrease in spring, summer and autumn. Fog caused by low cloud in autumn and winter is particularly a problem for the existing London Stansted airport as a result of its high elevation; this can result in flights having to be diverted (Jefferson, 2011).

High summer temperatures will also have an impact on the airports; very high temperatures can cause softening of asphalt road and apron surfaces and increase the risk of rail buckling for travel connections. There is also a greater risk to vulnerable passengers of feeling unwell in very warm conditions. In very rare circumstances, flights may be cancelled as aircraft are unable to function in very hot conditions as a result of reduced lift in warm air. Risk of fires will also increase in hot conditions, particularly where the flashpoint of fuel (38°C) is exceeded (HAL, 2011).

The projected increase in year-round temperatures will result in a reducing energy demand for space heating, however this may be outweighed by a corresponding increase in the need for cooling in airport terminals. Additionally, warmer temperatures will reduce the need for aircraft de-icing after flights in cold conditions (USGCRP. 2009).

With the projected increase in year-round temperatures, there is the potential for an increase in tourists in the UK. A contributing factor may be that traditional summer locations, such as the Mediterranean, could become less popular due to very high temperatures during the summer holiday season (Bujosa & Rosselló, 2013). However, while there may be an increase in British holidaymakers remaining in the UK in a good summer, there may be an increase in tourists flying to the UK for their holidays.

It should also be noted that individual airports are also affected by the weather conditions at other airports across the country. This can be caused by increased traffic if flights are diverted to that airport, and scheduling problems caused by aircraft and personnel being in the wrong location. As a result, where adverse weather conditions affect a number of airports, the impact can extend beyond the point at which weather conditions settle down, as airports attempt to return their services to the normal timetable.

Appendix E. Future Environmental Impacts of the Airports

This Appendix provides an assessment of how selected impacts of the airport might be exacerbated or improved under future climate change at each site. The assessment indicates, at a high level, the significance of the impact of the airport that could be experienced at the time when it is constructed and operated. The assessment is restricted to themes most likely to be affected by climate change: flood risk, water quality and ecology. Other themes such as agriculture and the landscape may also be affected and would be assessed in an Environmental Statement as the proposal developed.

The assessment is preliminary and based on expert judgement. The projections of climate change (see above) have a high level of uncertainty and this also applies to the future impacts of climate change on receptors.

E.1. Stansted

Climate change is likely to exacerbate impacts associated with flood risk (see below).

Table 10. Implications of Climate Change for Flood Risk Impacts at the Stansted Site

Flood risk category	Impact	Climate change projection	Effect of climate change	Mitigation
Fluvial	Increase flood risk downstream	Wetter winters, more intense rainfall events	Exacerbate flood risk downstream	Factor climate change into mitigation design
Surface water	Higher runoff rate	More intense rainfall events	Exacerbate runoff rates	Factor climate change into mitigation design
Groundwater	Unknown	Wetter winters	Exacerbate any impact	TBC
Sewer and drainage	Would be mitigated	More intense rainfall events	Exacerbate impacts	Factor climate change into mitigation design
Artificial sources	Unknown	Wetter winters, more intense rainfall events	Exacerbate any impact	TBC

Climate change is likely to exacerbate impacts associated with water quality (see below).

Table 11. Implications of Climate Change for Water Quality Impacts at the Stansted Site

WFD Quality Elements	Impact	Climate change projection	Effect of climate change	Mitigation
Hydromorphological elements	Loss of headwaters; change to downstream flow regime; recharge impacts	Wetter winters; more intense rainfall events; drier summers; increase in dry spells.	Exacerbate impacts e.g. dependency on recharge	Factor climate change into mitigation design
Biological elements	Loss of habitat and associated ecology	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. by reducing adaptive capacity	Factor climate change into mitigation design
Critical Sensitive Habitats/species	3 SSSI sites with potential water level changes	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. through fragmentation	Factor climate change into mitigation design (existing and replacement habitat)
Physico-chemical elements	Loss of natural water quality; potential pollution risk	Wetter winters; more intense rainfall events; drier summers; increase in dry spells.	Exacerbate impacts e.g. lower receiving flows in summer, flood risk in winter	Factor climate change into mitigation design

Climate change is likely to exacerbate impacts associated with ecology (see Table 9; note some water-related ecological impacts are covered in Table 8).

Table 12. Implications of Climate Change for Ecological Impacts at the Stansted Site

Impact pathway	Impact	Climate change projection	Effect of climate change	Additional mitigation
Habitat loss and fragmentation	Loss of habitat and associated ecology; effect on distribution of species	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. by reducing adaptive capacity	Factor climate change into mitigation design
Habitat quality	Changing water levels, dust and vehicle pollution, noise pollution, competition from non-native species	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. by reducing adaptive capacity	Factor climate change into mitigation design
Air quality	Air pollutants and dust from aircrafts, passenger traffic and construction vehicles; affect species diversity of local habitats; smother vegetation and associated fauna	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts particularly in hot dry periods	Factor climate change into mitigation design
Species invasion	Non-native species invasion from vehicle movements and import of materials; competition for space and resources	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. by reducing adaptive capacity	Factor climate change into mitigation design

E.2. Inner Estuary Site

Climate change is likely to exacerbate impacts associated with flood risk, although the implications for coastal processes require further consideration (see below).

Table 13. Implications of Climate Change for Flood Risk Impacts at the Inner Estuary Site

Flood risk category	Impact	Climate change projection	Effect of climate change	Mitigation
Fluvial	Alteration of flood risk to neighbouring land	Wetter winters, more intense rainfall events	Exacerbate flood risk	Factor climate change into mitigation design
Coastal	Increase in flood risk, although some wave sheltering effects	Sea level rise	Exacerbate flood risk	Factor climate change into mitigation design; ensuring best use is made of TE2100 provision.
Coastal processes	Substantial changes to sediment budgets and morphology	Sea level rise	Uncertain	Climate change to be considered further
Surface water	Higher runoff rate	More intense rainfall events	Exacerbate runoff rates	Factor climate change into mitigation design
Sewer and drainage	Unknown	More intense rainfall events	Exacerbate impacts	Factor climate change into mitigation design

Climate change is likely to exacerbate impacts associated with water quality, although the implications for coastal morphology require further consideration (see Table 11).

Table 14. Implications of Climate Change for Water Quality Impacts at the Inner Estuary Site

WFD Quality Elements	Impact	Climate change projection	Effect of climate change	Mitigation
Hydromorphological Elements	Loss of water bodies; morphological changes	Sea level rise	Unknown	Climate change to be considered further
Biological Elements	Loss of habitat and associated ecology	Sea level rise	Exacerbate impacts on transitional bodies	Factor climate change into mitigation design (existing and replacement habitat)
Critical Sensitive Habitats/species	Impact on Medway transitional water body rMCZ; SAC; SPA	Warmer, wetter winters; hotter, drier summers; sea level rise	Exacerbate impacts e.g. through fragmentation	Factor climate change into mitigation design (existing and replacement habitat)
Physico-chemical elements	Loss of natural water quality; potential pollution risk	Wetter winters; more intense rainfall events; drier summers; increase in dry spells; sea level rise	Exacerbate impacts e.g. lower receiving flows in summer, flood risk in winter	Factor climate change into mitigation design

Climate change is likely to exacerbate impacts associated with ecology (see Table 12; note some water-related ecological impacts are covered in Table 11).

Table 15. Implications of Climate Change for Ecological Impacts at the Inner Estuary Site

Impact pathway	Impact	Climate change projection	Effect of climate change	Additional mitigation
Habitat loss and fragmentation	Loss of habitat and associated ecology; fragmentation (e.g. barrier to movement); effect on distribution of species	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. by reducing adaptive capacity	Factor climate change into mitigation design
Habitat quality	Changing water levels, dust and vehicle pollution, noise pollution (close proximity to internationally important bird assemblage designated areas), competition from non-native species	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. by reducing adaptive capacity	Factor climate change into mitigation design
Air quality	Air pollutants and dust from aircrafts, passenger traffic and construction vehicles; affect species diversity of local habitats; smother vegetation and associated fauna	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts particularly in hot dry periods	Factor climate change into mitigation design
Species invasion	Non-native species invasion from vehicle movements and import of materials; competition for space and resources	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. by reducing adaptive capacity	Factor climate change into mitigation design
Critical Sensitive Habitats/ species	Risk of bird strikes, close proximity to areas designated for their internationally important bird assemblages	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. through fragmentation	Factor climate change into mitigation design; may be opportunities implement bird control measures that are sensitive to birds of future conservation importance

E.3. Outer Estuary Site

Climate change is likely to exacerbate impacts associated with coastal flood risk, although the implications for coastal processes require further consideration (see below).

Table 16. Implications of Climate Change for Flood Risk Impacts at the Outer Estuary Site

Flood risk category	Impact	Climate change projection	Effect of climate change	Mitigation
Coastal	Increase in flood risk, although some wave sheltering effects	Sea level rise	Exacerbate flood risk	Factor climate change into mitigation design; ensuring best use is made of TE2100 provision.
Coastal processes	Substantial changes to sediment budgets and morphology (shoreline and seabed)	Sea level rise	Uncertain	Climate change to be considered further

Climate change is likely to exacerbate pollution impacts but the implications of sea level rise for morphological changes and the net effect on ecology require further consideration (see below).

Table 17. Implications of Climate Change for Water Quality Impacts at the Outer Estuary Site

WFD Quality Elements	Impact	Climate change projection	Effect of climate change	Mitigation
Hydromorphological Elements	Partial loss of water body; potential flow changes	Sea level rise	Unknown	Climate change to be considered further
Biological Elements	Partial loss of habitat and associated ecology within the benthic sublittoral zone. Potential to gain biological elements if fringe habitat is created by the scheme	Sea level rise; warmer sea water	Unknown	Climate change to be considered further
Physico-chemical elements	Potential pollution risk	More intense rainfall events; sea level rise	Exacerbate impacts e.g. storage requirements	Factor climate change into mitigation design

Climate change is likely to exacerbate impacts associated with ecology (see Table 15; note some water-related ecological impacts are covered in Table 14).

Table 18. Implications of Climate Change for Ecological Impacts at the Outer Estuary Site

Impact pathway	Impact	Climate change projection	Effect of climate change	Additional mitigation
Habitat loss and fragmentation	Loss of habitat and associated ecology; fragmentation (e.g. barrier to movement); effect on distribution of species	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. by reducing adaptive capacity	Factor climate change into mitigation design
Air quality	Air pollutants and dust from aircrafts, passenger traffic and construction vehicles; affect species diversity of local habitats	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts particularly in hot dry periods	Factor climate change into mitigation design
Species invasion	Non-native species invasion from vehicle movements and import of materials; competition for space and resources	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. by reducing adaptive capacity	Factor climate change into mitigation design
Critical Sensitive Habitats/ species	Risk of bird strikes, close proximity to areas designated for their internationally important bird assemblages	Warmer, wetter winters; hotter, drier summers	Exacerbate impacts e.g. through fragmentation	Factor climate change into mitigation design; may be opportunities implement bird control measures that are sensitive to birds of future conservation importance

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