Heathrow's North-West Runway – Resource Use Assessment

10

Appendix to 5.8 – A resource efficient Heathrow
Taking Britain Further, Volume 1 Technical Submission

This report has been produced by a global strategy consultancy for Heathrow Airport Limited

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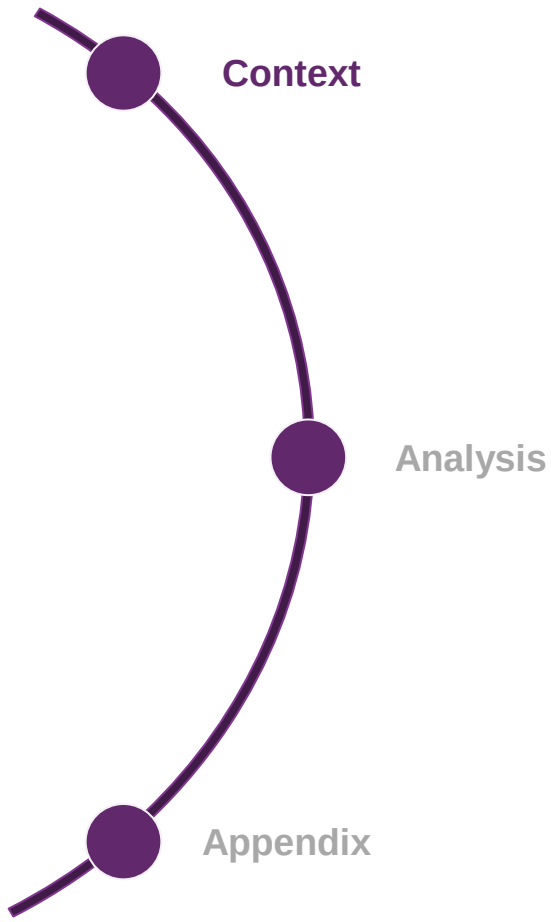

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Context and Objectives

Context

The Airports Commission has confirmed the need for at least one new runway in the South East of England before 2030. Heathrow, Heathrow Hub and Gatwick have been shortlisted and invited to submit additional evidence.

The Airports Commission will assess these options according to their ability to meet the UK's international connectivity needs, including their economic, social and environmental impact.

To this end, this document provides additional detail to support Heathrow's resource efficiency goals whilst considering the impact of expanding capacity.

Purpose of this document

This document serves as a technical appendix to chapter 5.8 – 'A resource efficient Heathrow' in 'Taking Britain further, Volume 1 Technical Submission'. It is intended to provide additional detail to substantiate Heathrow's submission to the Airports Commission.

This technical appendix provides details regarding the forecast energy and water consumption, and waste arisings and treatment across the airport in the two-runway scenario at 2020 and in the three-runway scenario at full capacity.

Improved sustainability performance can be realised from new 3R infrastructure. Retrofits of older buildings can also be funded from revenues generated by a three-runway Heathrow

Reductions in resource intensity per passenger against a 2010 baseline

	2R at 2020	3R at 130 Million Passengers Per Annum
Energy	CO_2 from energy from fixed assets per passenger reduced by **38%*** An absolute reduction of **1.8 kg CO_2e** per passenger	CO_2 from energy from fixed assets per passenger reduced by **86%** An absolute reduction of **4.1 kg CO_2e** per passenger Requires implementation of **10** solutions
Waste	Waste arisings per passenger reduced by **7%** An absolute reduction of **27 grams of waste arisings** per passenger	Waste arisings per passenger reduced by **14%** An absolute reduction of **57 grams of waste arisings** per passenger Requires implementation of **8** solutions
Water	Water extraction per passenger increased by **6%** An absolute increase of **2.0 litres water extracted** per passenger (2020 targets are under development)	Water extraction per passenger reduced by **70%** An absolute decrease of **25.3 litres water extracted** per passenger Requires implementation of **14** solutions

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*This is consistent with the airport's absolute corporate target to reduce carbon emissions from energy used by fixed assets by 34% compared to a 1990 baseline

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Analyses have been conducted based on two scenarios, with forecasts largely driven by passenger and Air Traffic Movement projections

Two-Runway (2R) at 2020 – Masterplan Scenario Specifics

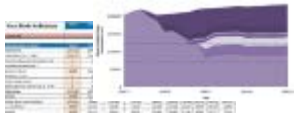
- **Passenger capacity:** 75.5 million passengers per annum ('mppa')
- **Air Traffic Movements:** 478 thousand per annum
- **Key forecast elements:** The airport's 2020 energy strategy (published 2011), 2020 waste management strategy (published 2010) and 2020 water management strategy (published 2010) will be implemented. These strategies include the following corporate targets to be met by 2020:
    - Carbon emissions from energy used by fixed assets will be reduced by 34% compared to a 1990 baseline
    - 70% of general waste managed through the airport contract will be recycled
    - Waste arisings per passenger will be reduced against 2008 levels

Three-Runway (3R) at full capacity – Masterplan Scenario Specifics

- **Passenger capacity:** 130 mppa at end year
- **Air Traffic Movements:** 740 thousand at end year

To identify appropriate ambitions for a three-runway airport including sufficient energy, water and waste solutions, 2030 was used as the end year of the 3R forecasts. This is a notional 'worse case' scenario and assumes that the airport will operate at maximum capacity, and have all infrastructure fully operational, by 2030.

Demanding resource efficiency targets were developed through detailed analysis of priority sustainability issues, followed by granular modelling of the solutions required to meet the targets

Methodology	Output	Process specifics
Framework		A materiality analysis identified and prioritised the sustainability issues on which to focus in a revised Sustainability framework
Top-Down Targets		Desk-based research of the aviation and other industries' published sustainability targets allowed development of objectives and selection of targets
Baseline / Basecase		2010 Baselines were established using energy and water demand and supply, and waste arisings and treatment figures from across HAL's operations. Basecases were formed by forecasting Baselines forward using HAL's 2020 energy, waste management and water management strategies, along with passenger, air traffic, infrastructure and other projections
Longlist		Lists were developed of approximately 240 energy, water and waste solutions that could be implemented to assist HAL in reaching top-down targets
Shortlist		Longlists were qualitatively assessed to identify the solutions that were expected to offer both the greatest potential sustainability benefit and the greatest potential 'overall' benefits, such as low cost or ease of implementation
MACC		Impacts and the associated costs and benefits of the shortlisted solutions were quantified using benchmarks, case studies and other sources. Marginal Abatement Cost Curves ('MACCs') were created to further prioritise solutions, ensuring they would be financially credible and deliver investment returns
Final suite of solutions		Solutions from the MACCs were applied in logical order to the Basecase forecasts to evaluate the combination of solutions required to achieve the selected top-down targets, which were then revised if necessary. Allowances were included in Heathrow's Capital Plans for the investment required to implement the suggested solutions

To agree on targets from a bottom-up approach

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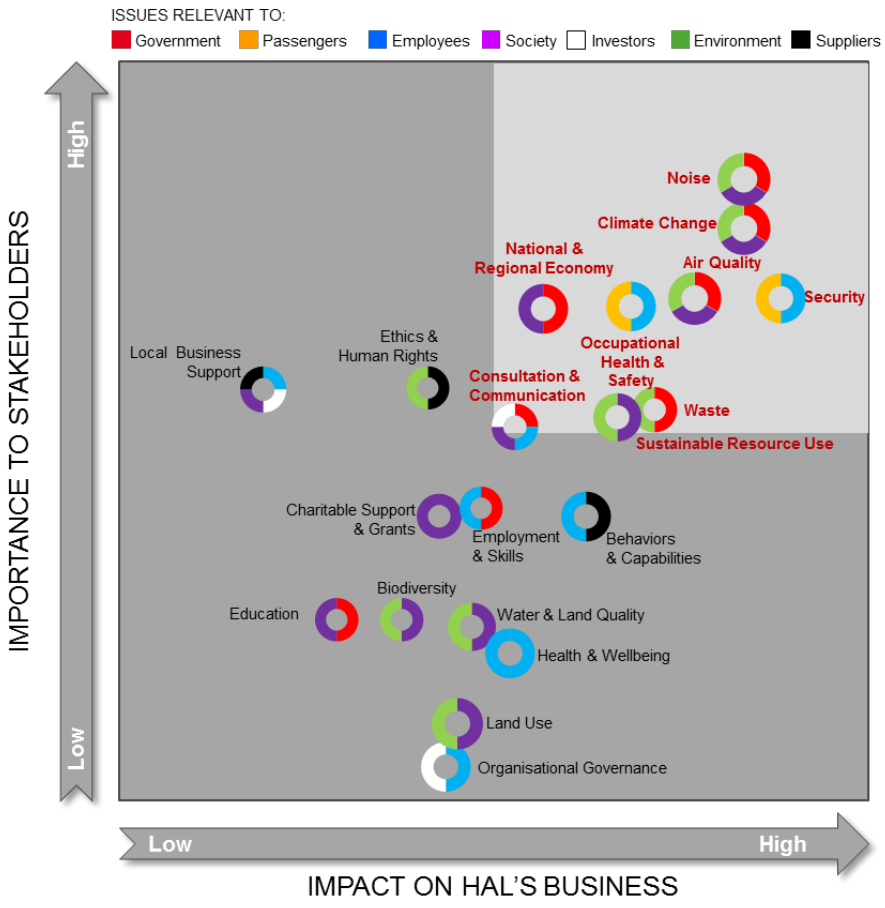
This technical appendix focusses energy, water and waste but a broader range of sustainability issues have been analysed

A materiality analysis identified and prioritised the issues that affect HAL and its stakeholders



Indicative levels of ambition were set across a framework of nearly 150 objectives

Whilst a 'compliance' or 'best practice' level of ambition was available for each objective, on issues that are most critical for Heathrow, a 'leading edge' position was often adopted through which Heathrow would set the example in the industry and be recognised as a leader among other airports.

Energy, waste and water have been identified as issues where HAL can improve resource efficiency (not exhaustive)

Energy

- **Reducing energy intensity** from assets and processes
- **Sourcing sustainable energy** from renewables
- **Increasing energy recovery** from assets and waste

Waste

- **Reducing waste generation** from passengers
- **Reducing waste generation** from processes
- **Increasing waste recycling** in terminal and in transit

Water

- **Reducing water intensity** from assets and processes
- **Increasing water recovery** from assets and processes
- **Reducing water extraction** from local aquifers

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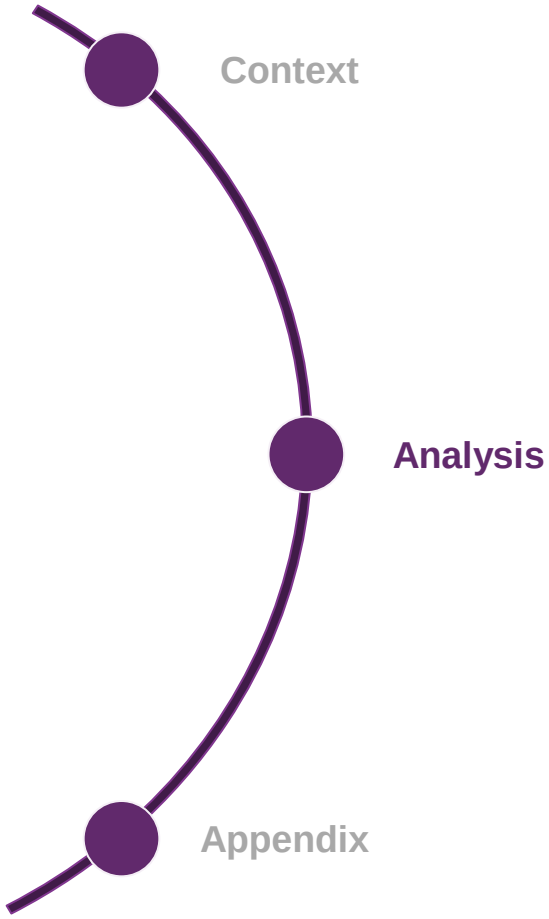
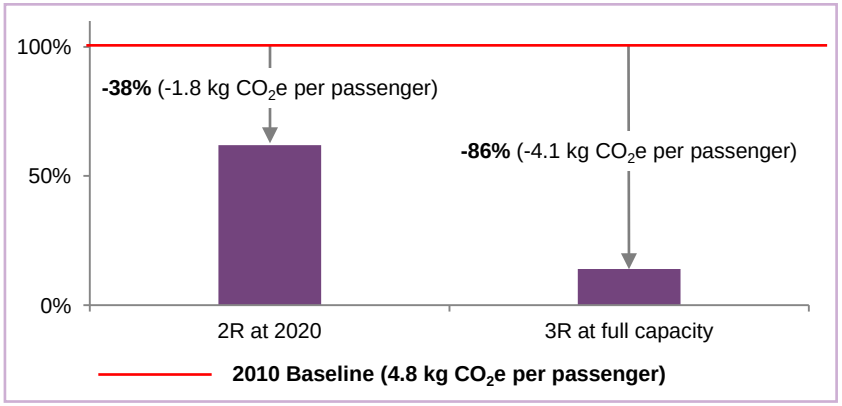
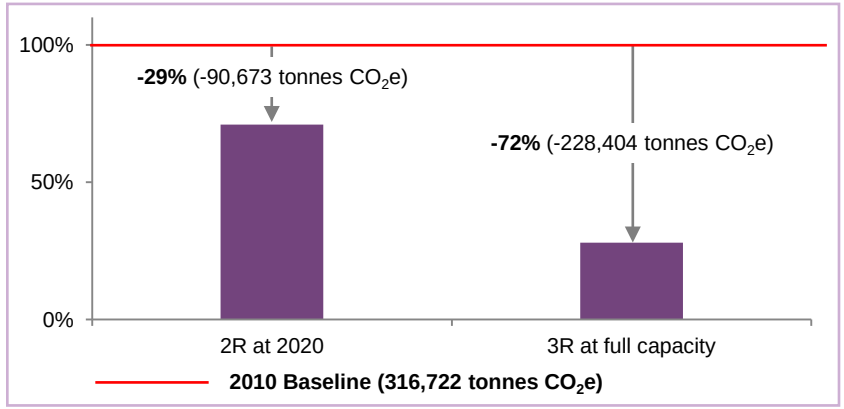


Heathrow can reduce carbon emissions from fixed assets per passenger by 86% in a three-runway scenario

Carbon emissions from fixed assets per passenger
(Reduced by 86% in 3R at full capacity but by only 38% in 2R at 2020, based on a 2010 baseline)



Carbon emissions from fixed assets
(Reduced by 72% in 3R at full capacity but by only 29%* in 2R at 2020, based on a 2010 baseline)



Delivering carbon reductions requires Heathrow to implement ten solutions in the 3R scenario

Solution	3R
Smart Buildings and AM&T	✓
Heathrow Smart Grid	✓
Thin Film Photovoltaics	✓
Energy Efficient Baggage Handling	✓
Retrofit of Older Terminals	✓
Night Time Purging (via High Level Louvres)	✓
Liquid Desiccant Cooling	✓
New EfW Plant Waste Heat Utilization and District Heating	✓
Ground Source Heat Pumps	✓
1:1 Combined Heat and Power	✓

Maximising use of waste heat from the new Energy from Waste ('EfW') plant can provide significant reductions in CO_2 emissions

- Installing a district heating network supplied with waste heat from **the new EfW plant could provide Heathrow a large volume of CO_2 emissions reductions**. Such a network would offset fuel consumption otherwise used in mains gas and biomass boilers
- Additionally, **new infrastructure** in 3R **provides opportunity** to install ground source heat pumps and a combined heat and power plant, as well as expanding the roll-out of rooftop thin film photovoltaics

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*This is consistent with the airport's absolute corporate target to reduce carbon emissions from energy used by fixed assets by 34% compared to a 1990 baseline

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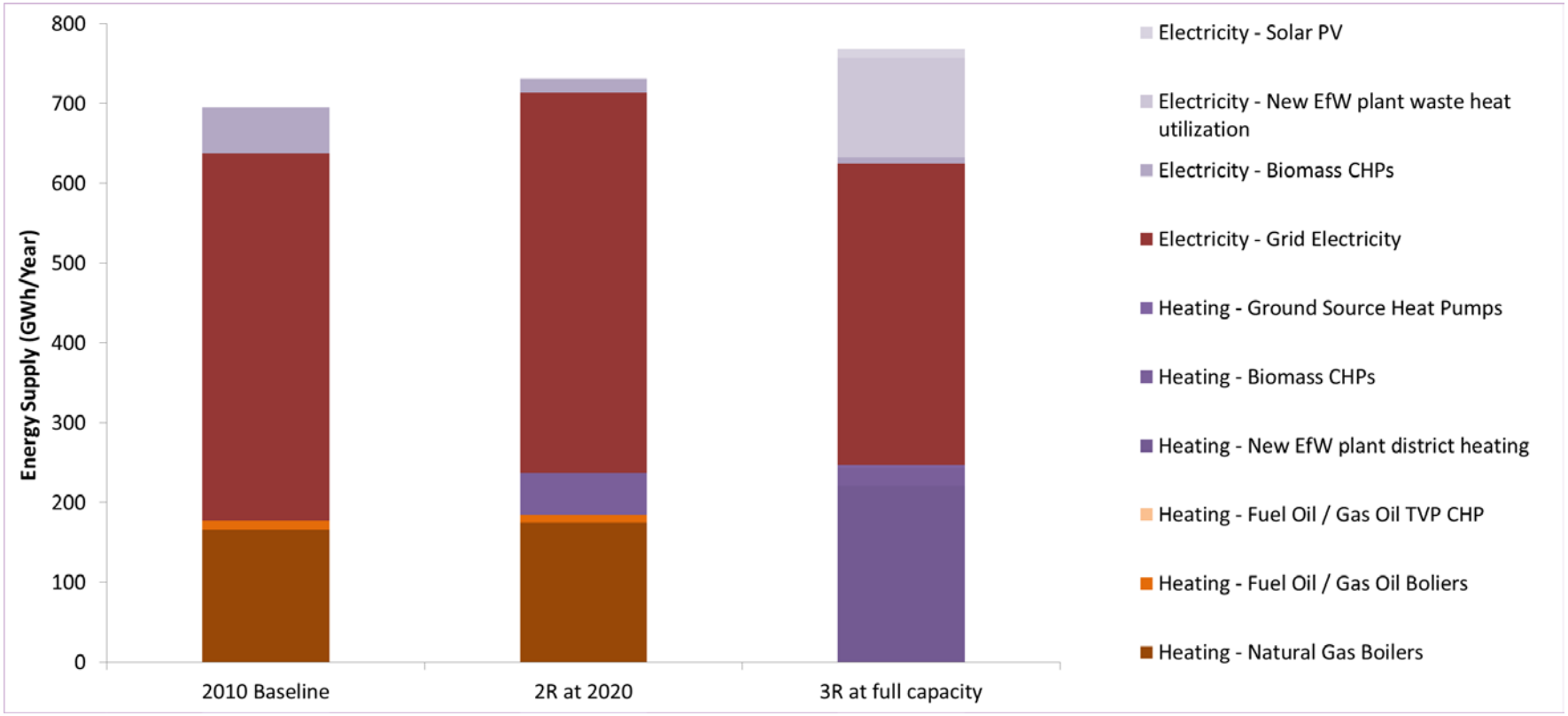
The 2R scenario focusses largely on demand-side energy reduction whilst the 3R scenario facilitates a low- / zero-carbon growth in energy demand

Significant reductions in CO_2 emissions from fixed assets will be delivered through the new biomass-fuelled Heathrow Energy Centre, plus other biomass Combined Heat and Power Plants ('CHPs') and low- / zero-carbon sources



- **In addition to the measures taken by Heathrow, the Government's overall policy to de-carbonise grid electricity supply will also be important in meeting targets**
- **Values for 2R at 2020 and 3R at full capacity shown represent end year, not an average over the modelled period**

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Fixed Electrical Ground Power and Pre Conditioned Air are key drivers of carbon savings for Heathrow

Fixed Electrical Ground Power: Overview

- Fixed Electrical Ground Power (FEGP) replaces much of the use of Auxiliary Power Units (APUs) whilst planes are on the ground but still in need of electricity

Auxiliary power units (APUs) are small jet engines in the tail of an aircraft that are used to deliver electrical power and cabin air conditioning while on the ground

Source: HAL Air Quality Strategy

Pre Conditioned Air: Overview

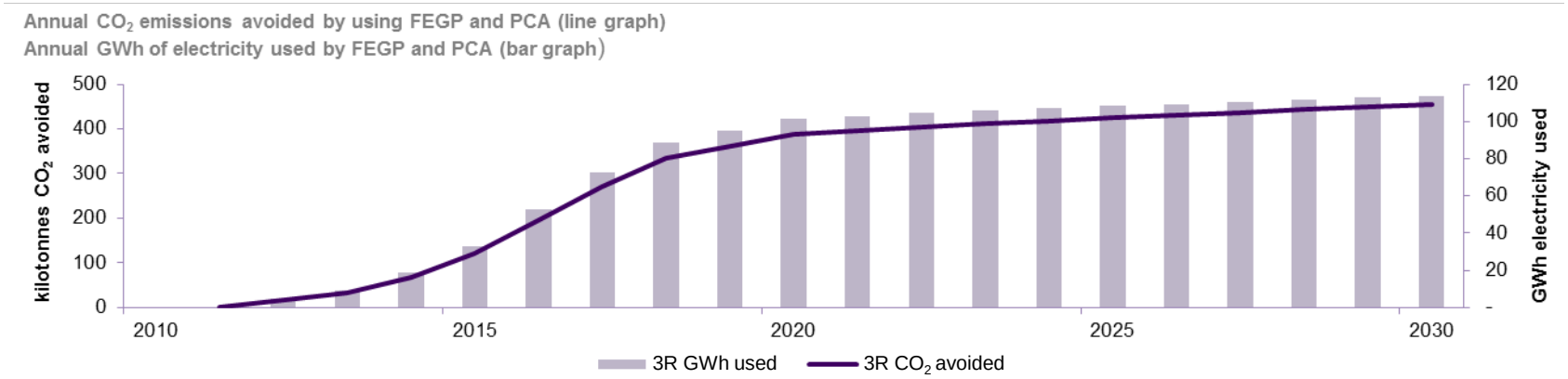
- Pre Conditioned Air (PCA) replaces much of the use of Auxiliary Power Units (APUs) whilst planes are on the ground and requiring in-cabin air conditioning

The PCA units are often located on the aprons and connected to the fuselage by hoses that run along passenger loading bridges

Source: HAL Air Quality Strategy

- FEGP and PCA units deliver a number of benefits over APUs including reduced CO_2 emissions per unit of energy used and reduced noise levels
- Roll-out of FEGPs and PCAs will save airlines many millions of pounds in avoided jet fuel purchase costs, that would have otherwise been consumed by running APUs

In the three-runway scenario at full capacity **over 455,000 tonnes of CO_2 emissions can be avoided** through aircraft using FEGP and PCA for much of the time that they are on the ground, instead of consuming jet fuel to supply their APUs.



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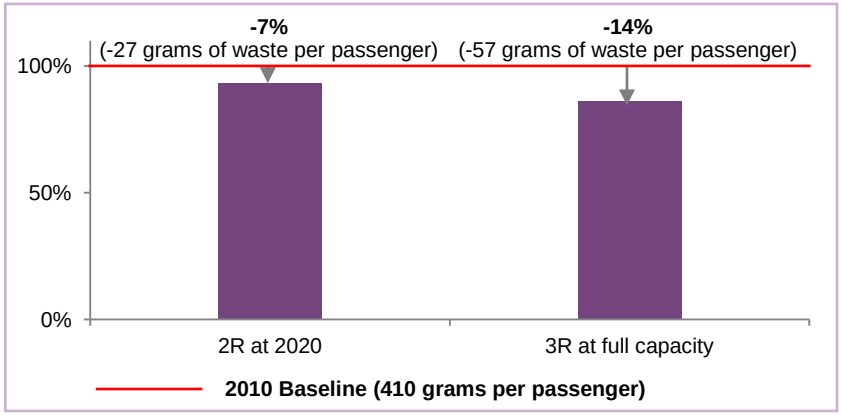
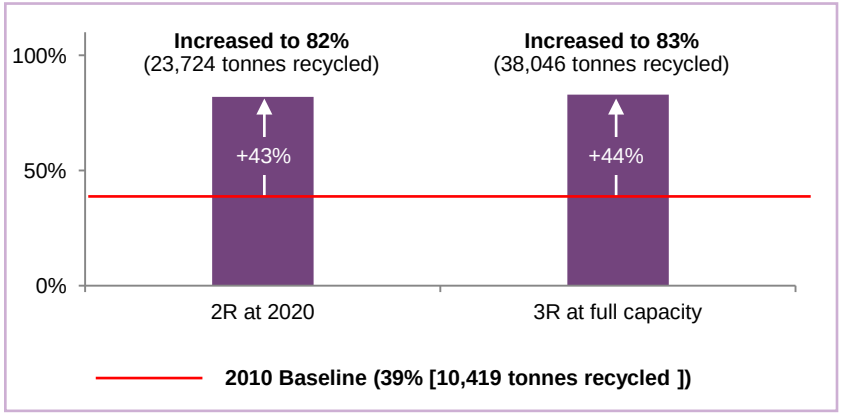
Heathrow can reduce waste arisings per passenger by 14% in a three-runway scenario

Waste arisings per passenger
(Reduced by 14% in 3R at full capacity but by only 7% in 2R at 2020, based on a 2010 baseline)



Airport waste recycling
(Increased to 83% in 3R at full capacity and to 82% in 2R at 2020, based on a 2010 baseline)



Delivering waste arisings reductions and increased recycling requires Heathrow to implement eight solutions in the 3R scenario

Solution	3R
Decrease Newspapers and Magazines at Gates	✓
Collaboration with Retailers	✓
Sustainable Procurement	✓
Paperless Offices and Passenger Manifests	✓
Reducing Waste in Airport Lounges	✓
Improved Inventory Management	✓
Improved Office Communications for Staff	✓
Improved In-terminal Communications for Staff	✓

Continued use of waste management contactors is forecast to be more viable than constructing on-site treatment facilities

- **On-site treatment facilities have been forecast to not contribute to increased recycling rates.** On-site waste treatment facilities, such as Anaerobic Digestion, require feedstock volumes greater than Heathrow's to be economically viable. Sourcing additional feedstock from external sources presents many supply chain risks
- Higher net waste arisings in a three-runway scenario also presents an opportunity for Heathrow to **demand greater performance and transparency from their waste management contractors**
- Over the modelling time period, the increasing prevalence of **circular economy business models** and **design for end-of-life packaging** are likely to further improve waste arisings reduction and recycling performance at Heathrow. Forecasts shown here are conservative as they exclude such impacts

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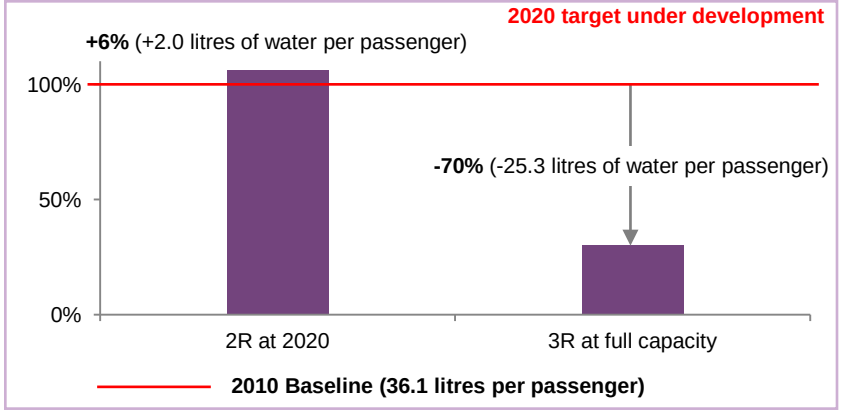
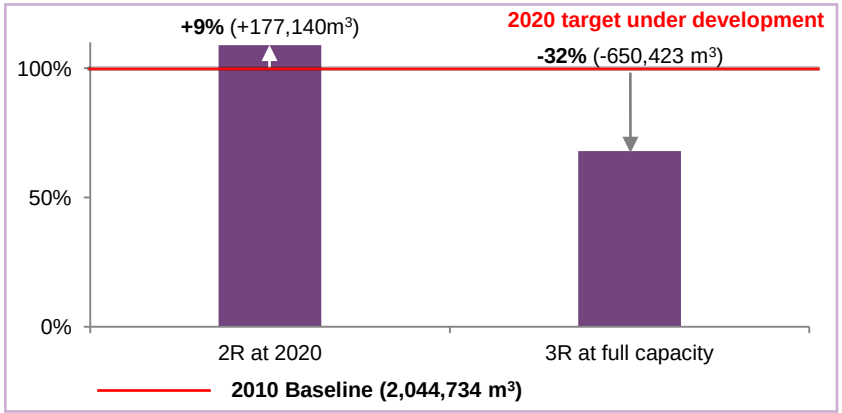
Heathrow can reduce water extraction per passenger by 70% in a three-runway scenario

Total water extraction per passenger
(Decreases by 70% in 3R at full capacity but increases by 6% in 2R at 2020, based on a 2010 baseline)



Absolute mains potable water extraction
(Decreases by 32% in 3R at full capacity but increases by 9% in 2R at 2020, based on a 2010 baseline)



Delivering water reductions requires Heathrow to implement 14 solutions in the 3R scenario

Solution	3R
Water Efficient Fittings	✓
Rainwater and Greywater Harvesting	✓
Airport-wide Guide on Water Management	✓
Metering Water Used During Construction	✓
Smart Buildings, Water Management and Analytics	✓
Use of Non-potable Water For Washing Planes, Vehicles, and For Runway Cleaning	✓
Vehicle Wash Systems Retrofitted / New Systems Installed With A Full or Partial Water-reclaim Unit	✓
Classroom-based Staff Training	✓
Proactive Management of Airport-wide Water Consumption	✓
De-icer Recovery	✓
Improved Leakage Detection and Prevention	✓
Sewage Treatment Plant	✓
Water Management Equipment for Mechanical Seals	✓
Reverse Osmosis	✓

Water extraction per passenger represents a holistic approach to water use at Heathrow which incorporates closed loop treatment. Taking this approach allows the airport to increase their water security, an important consideration given Heathrow's location in the South East of England – a region with forecast water scarcity.

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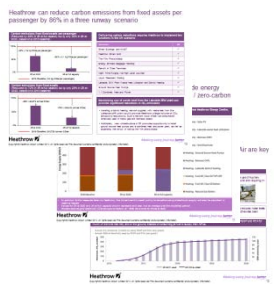
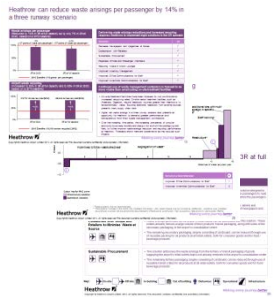
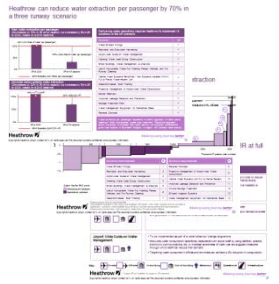
Expanding Heathrow to a three-runway airport presents multiple opportunities to operate in the most efficient way possible

	Current plans for 2R at 2020	Future plans for 3R at 130 mppa	
Less carbon from energy even with more passengers	• By 2020, the planned strategy will reduce CO_2 per passenger by 38% on a 2010 baseline • The new Heathrow Energy Centre will support the airport to meet its 2020 target by saving around 13,000 tonnes of CO_2 per year when operating at its full potential	• In a 3R at full capacity scenario, Heathrow can reduce CO_2 per passenger by at least 60% (86% with the full adoption of ten solutions) on a 2010 baseline. Solutions focus on reducing energy demand and shifting to a low- / zero-carbon energy supply • Projections account for legislative and regulatory commitments, as well as the Government's overall policy to de-carbonise grid electricity supply	
Less waste per passenger	• By 2020, existing waste management plans will reduce waste arising per passenger by 7% and increase recycling to at least 70% on a 2010 baseline • Current initiatives are well on the way to meeting targets with recycling in terminals increased by 10% during 2013 alone	• In a 3R at full capacity scenario, Heathrow can reduce waste arisings per passenger by 14% and increase recycling to at least 80% (83% with the full adoption of eight solutions) on a 2010 baseline • Even with the full adoption of the solutions, the near doubling of passenger numbers will lead to an increase in overall airport waste arisings	
More efficient water use	• By 2020, water extraction per passenger will increase by 6% based on a 2010 baseline but targets to reduce this are under development • The production of a Surface Water Management Plan for the entire airport will focus on reducing detrimental impacts on the environment, identifying risks and implementing measures to achieve the defined environmental outcomes agreed with the Environment Agency	• In a 3R at full capacity scenario, Heathrow can more than halve the water use per passenger (and reduce water extraction per passenger by 70% with the full adoption of 14 solutions) on a 2010 baseline • Solutions focus on reducing overall water demand along with maximising the collection and use of non-potable water wherever possible	

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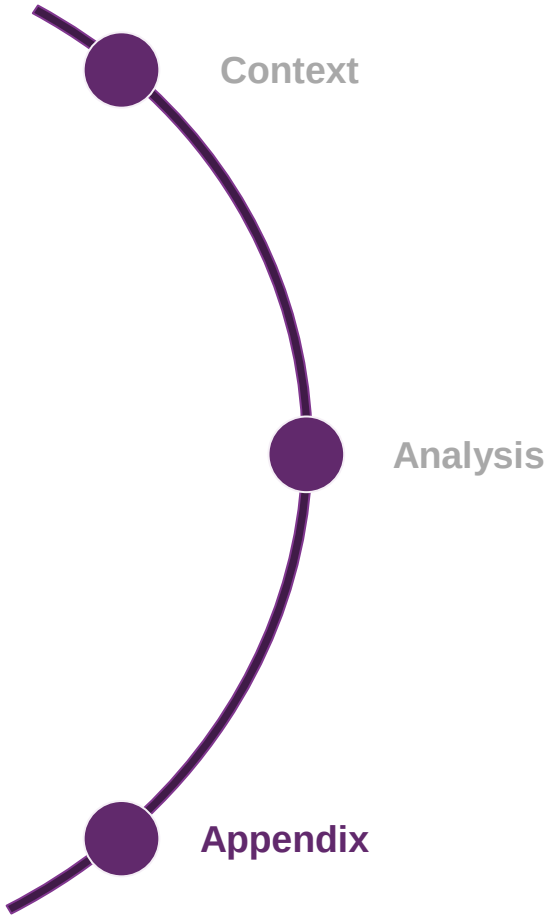

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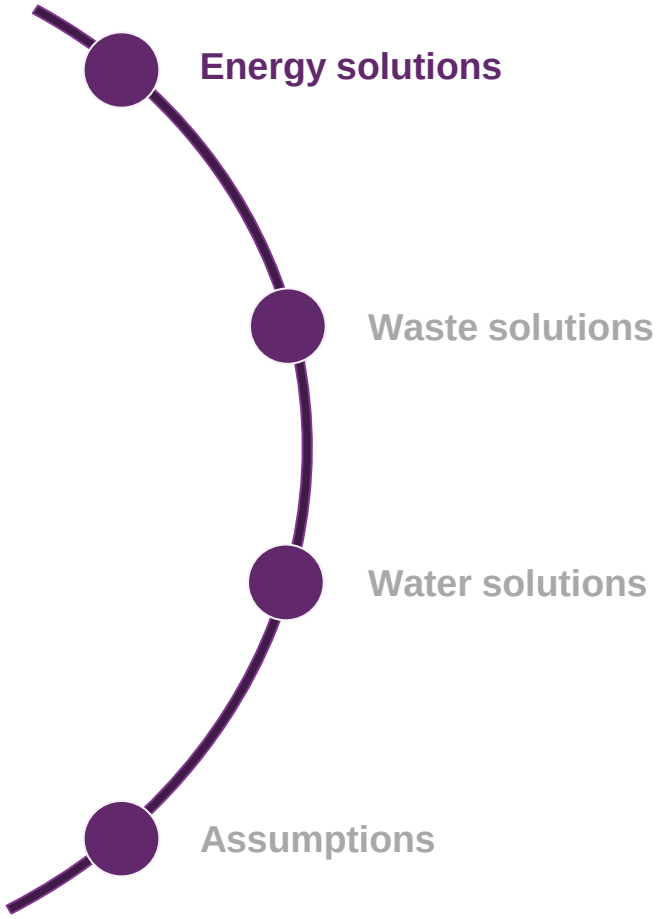

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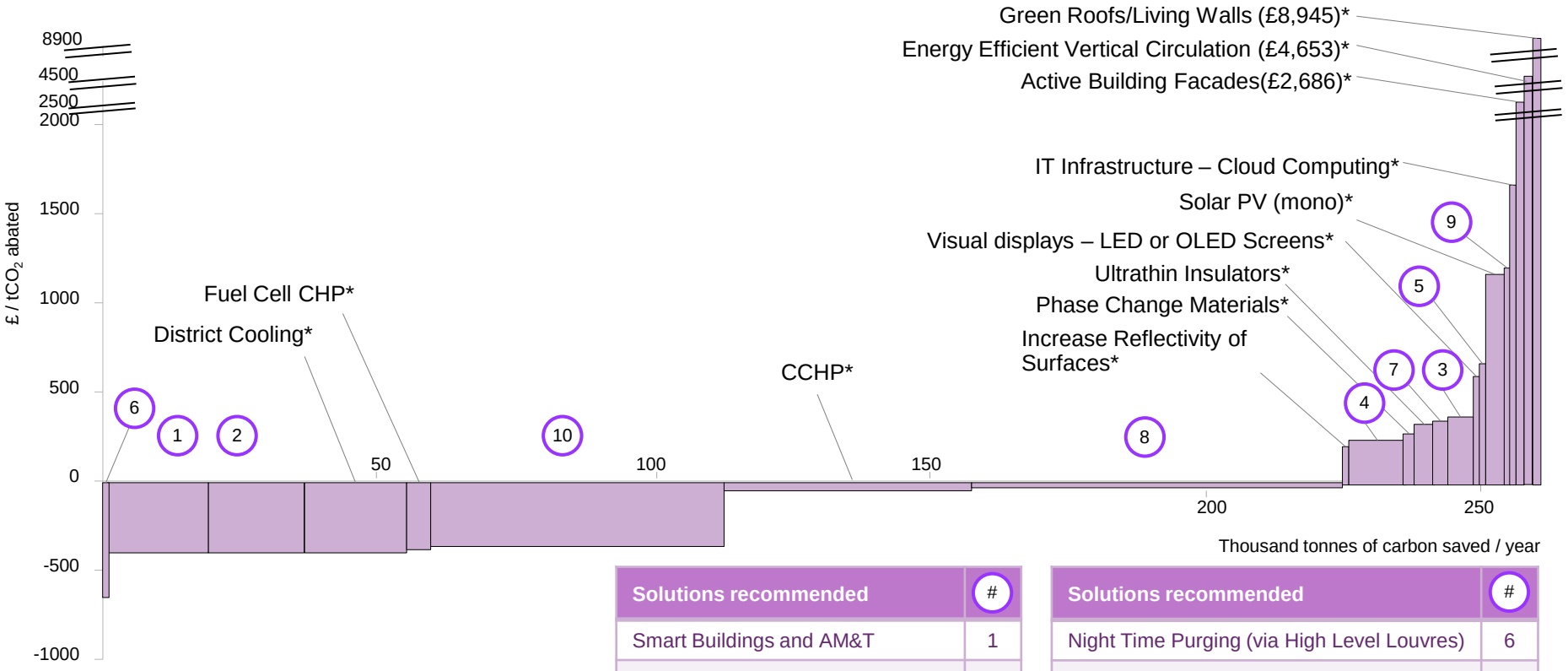
MAC curve: Solutions to reduce CO_2 emissions from fixed assets



Solutions recommended	#
Smart Buildings and AM&T	1
Heathrow Smart Grid	2
Thin Film Photovoltaics	3
Energy Efficient Baggage Handling	4
Retrofit of Older Terminals	5

Solutions recommended	#
Night Time Purging (via High Level Louvres)	6
Liquid Desiccant Cooling	7
New EfW Plant Waste Heat Utilization and District Heating	8
Ground Source Heat Pumps	9
1:1 Combined Heat and Power	10

Colour key for MAC curve

Infrastructure solutions

Operational solutions

* These solutions are not recommended

** The solutions included in the MACC are modelled individually – the carbon impacts are not cumulative. Additionally, solutions were modelled according to a conservative scenario that assumed early infrastructure construction, high occupancy rates and a 20 year solution lifetime

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The following **Energy** solutions were modelled for the 3R at full capacity scenario [1]

Solution:	Description and assumptions:
Smart Buildings and AM&T 	• Estate-wide, real-time building and energy performance analytics, Automated Fault Detection and insights into maintenance issues • As a software-based solution, this only requires limited hardware but has high potential for on-going financial and carbon savings through reduced inefficiency and enhanced maintenance regimes. The solution complements the airport's commitment to undertake continuous commissioning as part of the 2020 sustainability strategy and will provide a greater level of data on equipment performance, optimal set-points and opportunities for energy demand reduction
Heathrow Smart Grid 	• Implementation of technologies to control and optimise energy production and delivery throughout the airport and improve energy security • Electricity savings are delivered via advanced voltage control, accurate measurement and verification that identifies opportunities for savings, and end-user behaviour change as a result of better feedback information. On-site low- and zero-carbon energy generation is integrated with the smart grid with local generation reducing transmission losses.
Thin Film Photovoltaics 	• A zero-carbon energy production technology that captures sunlight and converts it directly into electricity. This is easy to install due to the flexible material and can be installed on multiple surfaces around Heathrow e.g. rooftops of different buildings • This is a mature technology with high availability of manufacturers and suppliers. Photovoltaics are one of the preferred low- and zero-carbon energy sources for the airport and are already included as part of the energy strategy for Terminal 2

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The following **Energy** solutions were modelled for the 3R at full capacity scenario [2]

Solution:	Description and assumptions:
Energy Efficient Baggage Handling	• Measures to improve the energy efficiency of new and existing baggage systems whilst improving operational reliability. This solution will address inefficiencies resulting from, amongst other areas, conveyor belt friction, older drive motors, and system speed management • Forecasts indicate that baggage handling systems account for a large proportion of Heathrow's process-related energy demand, therefore this solution can result in significant energy savings. As baggage handling is also critical to airport operations, this solution will help to enhance operational efficiency
Retrofit of Older Terminals	• Improving the energy efficiency of terminals by implementing new technologies to reduce energy demand and help to extend the useable life of the buildings. By 2020, existing terminals such as T5A, T5B, T5C, T2A and T2B will be relatively inefficient compared to other terminals, which will be designed and built in the meantime to meet tighter building regulation standards • This solution is focussed on measures included in a Category B refurbishment, namely phase change materials to reduce cooling demands, improved lighting and heat recovery (e.g. from baggage systems). Technology improvements will make further options more viable over time
Night Time Purging	• Cool outdoor night-time air is introduced via low level inlets and drawn through the building up to high-level louvres. The louvres are connected to temperature sensors and the Building Management System to automatically open under pre-determined conditions (or at a specific time) in order to cool internal spaces, improve thermal comfort and reduce demand for electrical powered cooling • The solution is most effective during spring and autumn months when the diurnal temperature difference between internal and external areas is greatest

Key: On-site; Off-site; In-building; Out of building; Behaviour; Operational; Infrastructure

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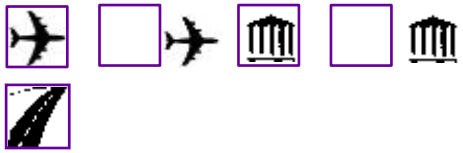
The following **Energy** solutions were modelled for the 3R at full capacity scenario [3]

Solution:	Description and assumptions:
Liquid Desiccant Cooling 	• Liquid desiccant cooling involves dehumidifying and cooling air temperature simultaneously, removing the need to overcool the air in order to reduce humidity (which consumes considerably more energy). Air is passed over a solution (e.g. sodium chloride) which removes heat, but also cleanses the air of particulates and micro-organisms, helping to improve air quality • The future impacts of climate change mean that cooling is likely to account for an increasingly large proportion of energy demand at the airport, therefore it is important to implement solutions that help to reduce this energy demand
New EfW Plant Waste Heat Utilization and District Heating 	• Heat that would otherwise be vented from the new EfW plant will be fed into an airport-wide district heating network to supply a large proportion of Heathrow's heating demand, mitigating requirements for gas oil and mains gas fuelled boilers • Heathrow would also procure low- / zero-carbon electricity from the new EfW plant through a private wire arrangement or via a green power purchase agreement
Ground Source Heat Pumps 	• The construction of new infrastructure and the resulting excavations in a three-runway Heathrow provides the opportunity to install several vertical borehole heat pumps which will feed into the airport's new district heating network • The solution assumes installation of ~0.36 MW of heating capacity which will commence operation in 2024 and reduce some of the demand for heating from the biomass fuelled boiler in the Heathrow Energy Centre that is due to open with Terminal 2 in 2014

Key:  **On-site**  **Off-site**  **In-building**  **Out of building**  **Behaviour**  **Operational**  **Infrastructure**

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The following **Energy** solutions were modelled for the 3R at full capacity scenario [4]

Solution:	Description and assumptions:
1:1 Combined Heat and Power 	• This solution will install an advanced 1:1 CHP that will be fuelled by biomass. The heat output will feed into the airport's new district heating network and reduce some of the demand for heating from the biomass fuelled boiler in the Heathrow Energy Centre that is due to open with Terminal 2 in 2014 • Assumes installation of ~1.5 MW of capacity

Key: On-site | Off-site | In-building | Out of building | Behaviour | Operational | Infrastructure

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The following **waste** solutions were modelled for the 3R at full capacity scenario [1]

Solution:	Description and assumptions:
Decrease Newspapers and Magazines at Gates 	• Targeting of newspapers and magazines provided at gates is an operational solution designed to reduce waste arisings. Periodicals and newspapers are often provided free for passengers to read whilst they wait to board their flight but are often discarded into airside bins before the passengers embark • As passengers are increasingly accessing these publications through laptops, tablets and smartphones, the demand for printed copies will decrease and the provision of newspapers and magazines can be phased-out at an escalated rate
Collaborate with Shops and Retailers to Minimise Waste at Source 	• Waste arisings generated by the airport's retail outlets can be addressed with this solution. These outlets already remove a large volume of their products' transit packaging, along with some of the secondary packaging, in the airport's consolidation centre • The remaining secondary packaging, largely consisting of cardboard, can be reduced through use of reusable packing for all products at all retail outlets, both for consumer goods and for food / beverage products
Sustainable Procurement 	• This solution addresses the waste arisings from the tertiary or transit packaging of goods supplying the airport's retail outlets that is not already removed in the airport's consolidation centre • This remaining tertiary packaging, largely consisting of cardboard, can be reduced through use of reusable transit crates for all products at all retail outlets, both for consumer goods and for food / beverage products

Key:  **On-site**  **Off-site**  **In-building**  **Out of building**  **Behaviour**  **Operational**  **Infrastructure**

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The following **waste** solutions were modelled for the 3R at full capacity scenario [2]

Solution:	Description and assumptions:
Paperless Offices and Passenger Manifests	• Across the airport, passenger manifests for flights are often printed as are paper documents in the offices of the many organisation's based at Heathrow • Through the use of tablets and other digital devices, the need for this printing for the verification of passengers as they pass a checkpoint, or for viewing and noting on documents in meetings, etc can be mitigated
Reducing Waste in Airport Lounges	• Passengers that use airline lounges generate approximately 50% more waste than non-lounge passengers due to the provision of food, newspapers and periodicals, and other amenities that lounges offer to their users • Rolling-out digital access to newspapers and periodicals will facilitate associated waste arisings from airport lounges to be largely avoided. Arisings of food waste from airport lounge can be reduced through implementing cook-on-demand processes and / or more accurate forecasting of peak passenger demand so that excess food is not cooked and then discarded
Improved Inventory Management	• This operational solution targets the waste arisings resulting from non-optimised inventory management systems and processes across the airport • By recruiting a dedicated member of staff who works with people across the airport, at the various different organisations based there, to improve their inventory management systems and processes, waste arisings can be reduced by decreasing the numbers of excess products that arrive at the airport and then have to be discarded at the end of their shelf life

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The following **waste** solutions were modelled for the 3R at full capacity scenario [3]

Solution:	Description and assumptions:
Improved In-Office Communication for Staff	• Targeting in-office paper, this solution is designed to increase recycling by staff working in offices across the airport • Through collecting and publishing data on the volume of paper being disposed of in general waste bins, improved pre-segregation of paper at source will be stimulated. Performance data could be disseminated via TV screens or other digital signage in and around offices, or via email bulletins
Improved In-Terminal Communications for Staff	• Targeting an increase of in-terminal non-office dry recycling, this solution is designed to increase the segregation at source of waste by staff such as those that man check-in desks, security and customs officers, and baggage handlers across the airport • Performance data of improved recycling rates for dry recyclables such as plastic, cans, paper and cardboard could be disseminated via TV screens or other digital signage in terminals, or via email bulletins

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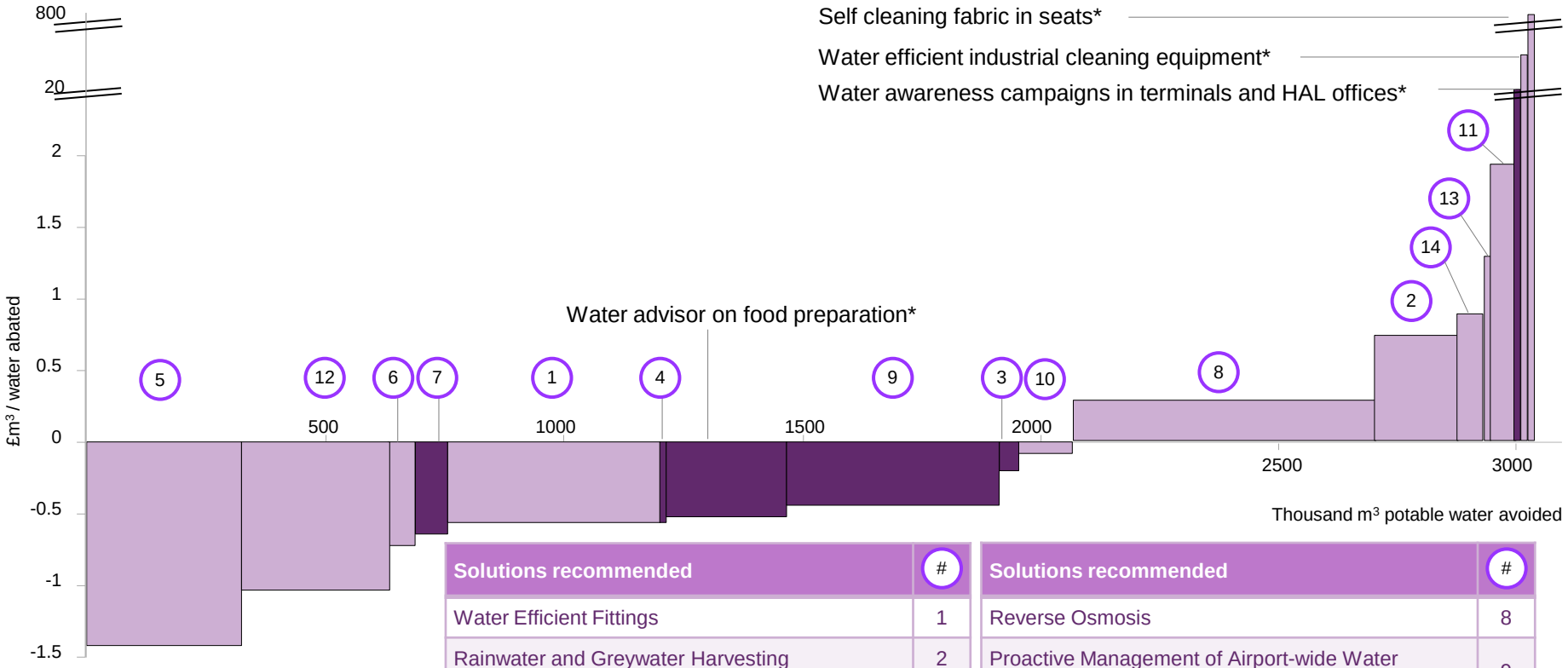
MAC curve: Solutions to reduce potable water extraction



Solutions recommended	#
Water Efficient Fittings	1
Rainwater and Greywater Harvesting	2
Airport-wide Guide on Water Management	3
Metering Water Used During Construction	4
Smart Buildings, Water Management & Analytics	5
Use of Non-potable Water For Washing Planes, Vehicles, and For Runway Cleaning	6
Classroom-based Staff Training	7

Solutions recommended	#
Reverse Osmosis	8
Proactive Management of Airport-wide Water Consumption	9
Vehicle Wash Systems with Full or Partial Reclaim	10
Improved Leakage Detection and Prevention	11
On-site Sewage Treatment	12
Efficient Irrigation Systems	13
Water Management Equipment for Mechanical Seals	14

Colour key for MAC curve

Infrastructure solutions

Operational solutions

* These solutions are not recommended

The solutions included in the MACC are modelled individually – the water impacts are not cumulative. Additionally, solutions were modelled according to a conservative scenario that assumed early infrastructure construction, high occupancy rates and a 20 year solution lifetime

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The following **water** solutions were modelled for the 3R at full capacity scenario [1]

Solution:	Description and assumptions:
Water Efficient Fittings	• With WCs alone consuming approximately 40% of Heathrow's water, this infrastructure solution involves installation of highly water efficient fittings in all new terminals and ancillary buildings constructed for a three-runway Heathrow. These fittings will meet demanding BREEAM performance levels and will reduce potable and non-potable water demand • There will also be an on-going phased retrofit of sanitary fittings in older buildings across the whole airport
Rainwater and Greywater Harvesting in New Terminals	• The construction of new infrastructure in a three-runway Heathrow provides the opportunity to install collection, processing, storage and distribution equipment for rainwater from terminal roofs and greywater from terminal bathrooms • The dedicated storage tanks and pipework will facilitate the collected water to be re-used for non-potable water demands such as WC flushing
Airport-wide Guide on Water Management	• This operational solution raises awareness of water use and suggests measures through which staff across the whole airport can reduce their demand. Electronic communications, leaflets and posters will distribute this information • This solution is designed to be implemented as part of a wider behaviour change programme

Key: On-site; Off-site; In-building; Out of building; Behaviour; Operational; Infrastructure

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The following **water** solutions were modelled for the 3R at full capacity scenario [2]

Solution:	Description and assumptions:
Meter Water Use in Construction 	• Construction projects are due to be on-going at the airport over the next 20 years. This infrastructure solution ensures water consumption during construction is accurately measured and charged through construction sites each being supplied with a metered standpipe / selection of outlets • Metering construction-related water use will result in contractors implementing measures and processes to reduce consumption
Smart Buildings, Water Management and Analytics 	• Water meters and sub-meters in terminals, offices and other ancillary buildings will be connected to advanced analytics software using this infrastructure solution • This software could provide real-time data on water consumption, including measurement and verification, identify trends and opportunities for savings – including detection of leaks – and facilitate automated fault detection of equipment, thus aiding maintenance regimes
Use Non-Potable Water for Washing Aircraft, Vehicles and Runways 	• Certain outdoor cleaning activities at the airport, such as washing of aircraft, ground vehicles and runways currently use potable water. This solution replaces the potable water supply to these washing activities with a non-potable supply by installing new pipework and thus reduces potable water consumption • The construction of new infrastructure in a three-runway Heathrow provides the opportunity to install, as standard practice, the pipework necessary to use non-potable water for the activities outlined above

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The following **water** solutions were modelled for the 3R at full capacity scenario [3]

Solution:	Description and assumptions:
Vehicle Wash Systems with Full or Partial Reclaim 	• The vehicle washes across the airport consume a great deal of water per day. This infrastructure solution rolls-out water reclamation systems which can recover 95% of this water, contributing to significant consumption savings. As all vehicle wash systems will be supplied with non-potable water via the 'use of non-potable water for washing planes, vehicles, and for runway cleaning' solution, this solution will ensure that non-potable water is conserved • In a three-runway Heathrow, this solution will be installed by default within all new vehicle wash systems constructed
Classroom-based Training 	• This programme will provide the face-to-face training, delivered by environmental behaviour change specialists, for all airport staff on how they can reduce their water consumption in the workplace • This will be an on-going training programme to ensure education of new staff when they begin working at the airport
Proactive Management of Airport-wide Water Consumption 	• This operational solution is designed to be implemented as part of a wider behaviour change programme, after all other operational and infrastructure solutions are implemented. This solution will pick up 'stragglers' to realise residual potential of all other previously implemented solutions • This programme targets the end consumers of water who are not conscientious about conserving water and are not impacted by either the 'classroom-based training' solution nor the 'airport-wide guide on water management' solution

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The following **water** solutions were modelled for the 3R at full capacity scenario [4]

Solution:	Description and assumptions:
Improved De-icer Recovery System 	• This infrastructure solution involves a two-stage system of removing pollutants from surface water run-off prior to it being processed in the existing or any new reed bed systems such as Heathrow's Mayfield Farm Treatment Facility. The recovered de-icer can be re-used by third parties in manufacturing and other processes • Stage one uses a vibrating ultrafiltration membrane at high temperature to remove suspended solids, oils and odour of spent de-icing fluid from surface water. Stage two involves dewatering the separated de-icing fluid to leave the final product at the required concentration for third parties
Sewage Treatment Plant 	• An advanced membrane bioreactor / similar plant will be constructed to treat all of the airport's blackwater. The system could provide both potable water as well as supplying all of the airport's non-potable water requirements, removing the need for extracting any non-potable water from the site's sensitive aquifers • Installation of the solution will involve extensive pipework adjustment across the campus. Any sludge produced could be used as feedstock for a third-party anaerobic digestion facility
Improved Leak Detection and Prevention 	• This solution uses the sensing and analytics provided by the 'Smart buildings, water management and analytics' solution, along with a member of staff dedicated to proactive targeting and reduction of leakage from in-ground pipework, as well as other non-BREEAM specific leak detection and mitigation

Key:  **On-site** **Off-site** **In-building** **Out of building** **Behaviour** **Operational** **Infrastructure**

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The following **water** solutions were modelled for the 3R at full capacity scenario [5]

Solution:	Description and assumptions:
Water Management Equipment for Mechanical Seals	• Mechanical seals are used in high pressure and high temperature heating systems across the airport to regulate flow. Freshwater is used in these devices to clean abrasive particulates from seal faces • This solution involves retrofitting all existing mechanical seals across the airport to reduce the water they consume. All seals installed in new infrastructure constructed for a three-runway will be efficient as standard
Reverse Osmosis	• The reverse osmosis process passes water through a membrane at high pressure to remove contaminants and particles • This solution will install a secondary water treatment facility that could be used to process the un-used non-potable water effluent from the 'sewage treatment plant' solution, which could be stored in a lagoon / balancing pond on-site, or near-site whilst it awaits processing

Key: On-site | Off-site | In-building | Out of building | Behaviour | Operational | Infrastructure

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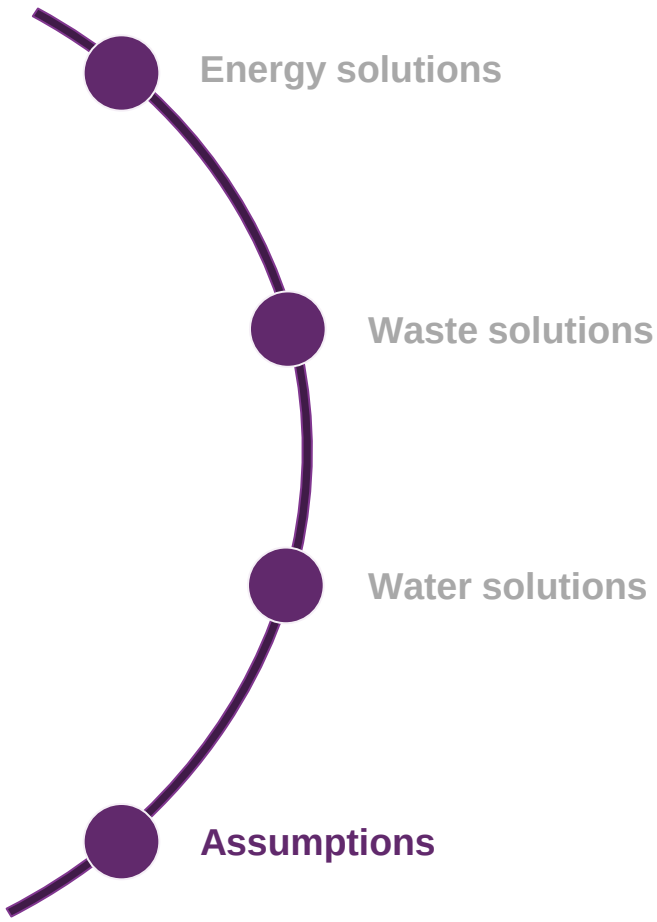
Appendix



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The following key assumptions were made during the modelling process [1]

#	Assumption	Source
1	Average PCA kW demand per socket is 43.1 kW	AXA Power FEGP and PCA unit manufacturers technical specifications
2	Average FEGP kW demand per socket is 68.8 kW	
3	The 2011 price paid for gas oil was 7.4p per kWh, and will escalate in line with oil prices	Nottingham Energy Partnership
4	The 2011 price paid for biomass was 1.7p per kWh, and will escalate in line with the Consumer Price Index	The Carbon Trust
5	The 2012 price paid for a unit of district heat was £13.74 per MWh, and will escalate in line with the price of EfW gate fees (which are driven by inflation)	Wien Energie
6	26.4km of piping would be required for district heating in the 3R scenario	Scale map based research
7	Sewage treatment plant capex based on a scaled-down figures from case studies showing US $18.5 M in 2006 for a 60,000 m^3 per day plant	Siemens, HAL consultant research
8	Sewage treatment plant opex based on case studies showing 0.0125 £/m^3/year for sludge treatment and disposal, 0.0017 £/m^3/year for chemicals and 0.853 kWh/m^3 energy consumption	Cranfield University, Black and Veatch water

The following key assumptions were made during the modelling process [2]

#	Assumption	Source
9	Ground source heat pump capex is £1 M per MW installed; opex is £1,000 per MW per year	Birmingham Eastside urban regeneration project, renewableheatincentive.co.uk
10	District heating network capex is £800,000 per km of piping installed	Energy Systems Research Unit, University of Strathclyde
11	Current 3:1 CHP capex is £1,500 per kW installed, price parity with 1:1 expected in c. 10 years	DECC / poyry study for the FIT consultation
12	The net potential energy export from the new EfW is 24.6 MWe and 43.5 MWth. Daily runtime has been modelled at 65% and yearly runtime at 89%	Energy from Waste CHP Scheme Feasibility Study - Fichtner
13	Heathrow has 150 mechanical seals requiring cooling for c. six hours per day	HAL / HAL consultant research
14	UK grid electricity CO_2e emissions factors flat-line from 2030 to 2040	HAL / HAL consultant research
15	Future carbon emission factors for electricity and heating fuels have been calculated based on forecast data available from DEFRA and DECC. These forecasts show emission factors decreasing over time as a result of an increase in the proportion of national grid energy being provided by LZC emission sources. A sensitivity of +25 percent has been applied to these published grid electrical carbon factors, to allow for national grid decarbonisation occurring at a slower than planned rate	Department for Environment, Food and Rural Affairs ('DEFRA') and the Department of Energy and Climate Change ('DECC')
16	All forecasts model out to the 'end year' of 2030	HAL / HAL consultant research

The following key assumptions were made during the modelling process [3]

#	Assumption	Source
17	All solutions have a 20 year operational lifetime	HAL / HAL consultant research
18	In 2010, a certain volume of the water supplied to the airport leaked out of pipework and fittings. The percentage figure used for this was set at 15 percent for potable and 15 percent for non-potable	HAL / HAL consultant research
19	Data on the volume consumed by many of the end uses of water was largely unavailable, thus assumptions were made on the numbers of sanitary fittings in the terminal buildings, and in approximately 270 other water using locations across the airport site such as portacabins, car rental company offices, and hotels	HAL / HAL consultant research
20	Water use in locations external to the terminals and other buildings, which includes consumption of water for runway cleaning, filling of planes with potable water, and irrigation, was calculated based on assumptions developed in collaboration with HAL	HAL / HAL consultant research

Treatment of Uncertainty

Throughout this document resource efficiency percentage changes are subject to uncertainty of +/-10% to account for forecasting uncertainties. This is due to the forecasting timescales involved (up to 18 years). The variances reflect the epistemic uncertainty in future costs of implementing and maintaining solutions, as well as in utility costs and in other parameters impacting financial returns. Additionally, throughout the forecasting process, data was sometimes limited or unavailable in amount, quality and consistency. Certain aspects of the baseline, basecase and solution affect forecasting were therefore impacted, further contributing to degrees of uncertainty.

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