Feasibility of Zero Emissions Airport Operations in England by 2040

April 2022

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1 Executive summary

The UK Government has set a target for the UK aviation sector to reach net zero by 2050, as part of the government's wider commitment to reducing UK emissions, in line with the Paris Agreement[1]. To support this target, a consultation was launched in summer 2021[2] on plans to develop a 'Jet-Zero' strategy, which will ensure the UK is at the vanguard of progress on reducing aviation emissions and continues to drive international progress. This consultation included a proposal for a zero-emission target for airports operations in England by 2040. A short, further technical consultation is to be published in the second quarter of 2022. Responses to both consultations will inform the Jet Zero Strategy which will be published later this year.

Following this consultation, and in support of the development of the strategy to formalise this target, the Department for Transport is seeking to strengthen the evidence base of emissions from airport operations. Whilst airport operations are responsible for only 5% of air transport sector emissions, there are still significant ways in which airports and their users can reduce emissions and contribute their part to addressing climate issues within the sector. The objective of this study is to provide analysis showing the emissions sources at English airports and whether the innovations available will make zero carbon emission airport operations feasible by 2040. Emissions referenced in the report will refer to emissions of Greenhouse gases. Greenhouse gases, or GHGs, are compound gases that trap heat or longwave radiation in the atmosphere. The principal GHGs, also known as heat trapping gases, are carbon dioxide, methane, nitrous oxide, and the fluorinated gases. Zero carbon airports are defined as having operations that do not produce GHG emissions, instead of net zero airports, which have operations that produce residual GHG emissions which are offset to negate their impact.

The emission sources under consideration are Scope 1 emissions (Direct Airport GHG emissions) and Scope 2 emissions (Indirect GHG emissions through the purchase of electricity, heating or cooling), which the Department of Transport specially refer to in their 2040 zero emissions airport operations target. In addition, Scope 3 emissions for the airport's users related to the airside operation of the airport are also included to explore the feasibility of actions to further decarbonise activities within the airport boundary. The focus of the study is to look at on-airport emission sources, as such Scope 3 emissions are limited to operations at the airport rather than journeys to and from the airport e.g. aircraft flight segments or surface access journeys. To assess the feasibility for airports to become zero carbon emissions by 2040, this study considers the following three scope elements:

- Map emissions across English airports for all emissions scopes (Scope 1, 2 and 3 Airport Operations - excludes flights and surface access journeys to/from the airport) and to review their future decarbonisation strategies;
- Identify zero emissions technologies and innovations which are available now or likely to be available before 2040; and
- Review the technical and commercial viability of airport operations at English airports to become zero emissions by 2040.

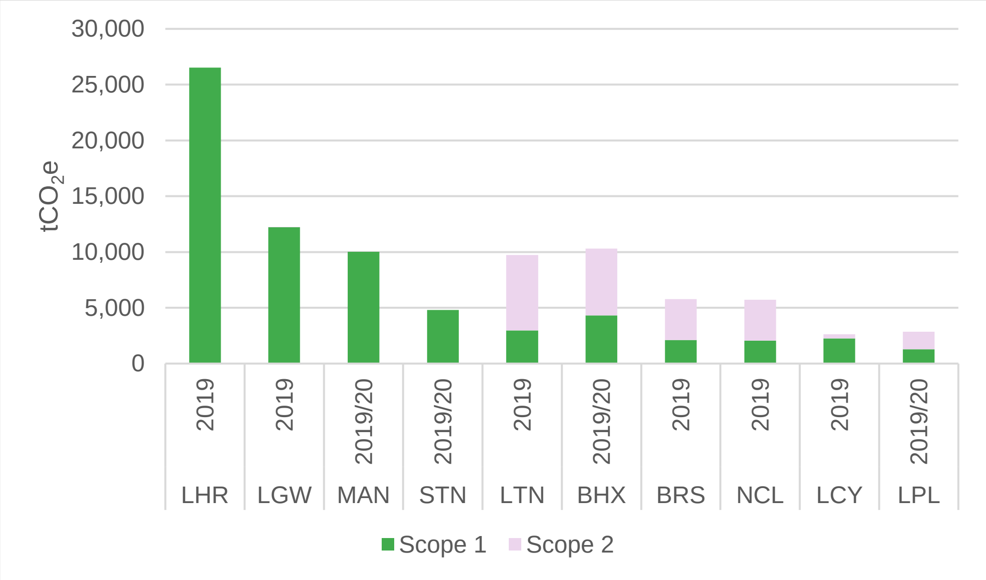
The top 10 English airports by passenger volume have been reviewed from a current carbon emission and future decarbonisation planning perspective. The Scope 1 and 2 emissions (based

[1] United Nations, 'United Nations Paris Agreement Overview Page' (2015) available at: *https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement* (last accessed March 2022)

[2] UK Government (2020) *achieving net zero aviation by 2050* available at https://www.gov.uk/government/consultations/achieving-net-zero-aviation-by-2050 (last accessed March 2022)

upon 2019 data) are shown in Table 1.1. The reported emissions relate to market-based accounting methods, with Scope 3 omitted because the reported emissions are non-comparable between airports.

Table 1.1: Comparison of studied airport Scope 1 and 2 emissions (based on 2019 or 2019 financial year data- market based emissions) [3]



The English airports researched have published plans to become net zero by the following timeframes. Net zero is determined to be a state where emissions have been reduced as far as possible (~85-95%) through using mitigation measures, with the remaining emissions offset through verified carbon offsets.

- 2033 BHX
- 2035 NCL
- 2038 MAN, STN
- 2040 LTN
- 2050 LHR, BRS, LCY

LGW and LPL have pledged to reduce their carbon emissions over this timeframe but have not explicitly stated that they would become net zero by a given year. It is important to note that these are net zero plans rather than achieving zero carbon emissions. The plans may also be taking into account other Scope 3 emissions.

Zero carbon emission technology is advancing at pace across the different Scope 1, 2 and 3 on-airport related operations sectors. Zero carbon technology exists for a large proportion of airport infrastructure and airport operations vehicles, as can be seen in Table 1.2. Many airports are also now purchasing Scope 2 power from renewable energy tariffs.

[3] Mott Macdonald analysis of publicly available emission data for England's 10 largest airports by passenger volume (2019). Emission data has been selected for 2019, where the company reports in financial years the 2019-20 financial year has been selected.

Table 1.2: Technology Status Summary

Emission Scope	Primary Source	Secondary Source	Currently Available	Available by 2040
Scope 1				
	Buildings & Infrastructure Fuel Consumption	HVAC System	Commercially available	New generation compressors / Refrigerant cycles
		Thermal Storage	Commercially available	Electro-chemical storage
		Lighting	Commercially available	Improved efficiency
		Comms	Commercially available	Advanced internet technology for instantaneous instrument control and energy monitoring
		Power	Commercially aailable	Higher spec equipment
		De-icing	Commercially available	Low to zero de-icing fluid required
		Refrigerants	Commercially available	Commercially available
	Airport Owned Vehicles	Fire tenders		Currently Testing Vehicles
		Airport de-icing/snow		None identified but should be feasible
		TTS/APM	Already in use	Already in use
		Cars (Ops/Company)	Already in use	Already in use
Scope 2				
	Power from grid		Already in use	Already in use
	Site renewable energy generation		Already in use	Already in use
Scope 3 (Airport Operations)				
	Aircraft Taxi (and Hold)		Taxibot trials at airports in India and The Netherlands	Methods are in place which can reduce carbon emissions, but not eliminate. Full elimination requires electric or hydrogen-based aircraft
	Aircraft Engine Testing			Not yet feasible. Requires electric or hydrogen-based aircraft
	On stand power and air		FEGP/PCA already in Use	Electric Mobile GPU/PCA Units available but under test
	Aircraft Line Maintenance		AI and predictive maintenance in operation today	Some specialist vehicles not yet identified but could be feasible
	Waste		Waste efficiency plans in place	Wastewater could be turned into biofuel
	3rd Party Airside Vehicles	Baggage tugs	Already in Use	Already in use
		Baggage loaders	Already in Use	Electric ULD Loaders/Hi-lift are available but not as common

		Cargo handling	Already in Use	Electric ULD Loaders/Hi-lift are available but not as common
		Catering trucks		None identified but should be feasible
		Re-fuelling trucks		Only one test vehicle identified, but should be feasible
		Aircraft tugs	Already in Use	Already in use
		Aircraft service (bowser, water, cleaning staff, materials/waste)		No specialist vehicles identified but should be feasible
		Aircraft De-icing		Electric de-icers are available but not common, and some only use electric power when close to aircraft
		Mobile stairs	Already in Use	Already in use
		Buses	Already in Use	Already in use
		Crew transport	Already in Use	Already in use
		Operations cars	Already in Use	Already in use
		Other 3rd party vehicles (Logistics, maintenance, construction)	Already in Use	Some specialist vehicles (e.g. Construction) not yet available, but research/development reported to be underway

It is expected by 2040 that technology sufficient to achieve zero carbon airports will exist. However, some of this technology will exist at a price point beyond that which is affordable, and the time required to implement technology change may also prevent zero carbon airport operations by 2040. If the right commercial model and incentives can be put in place in time, then it is feasible to reach zero carbon by 2040, but it will require a concerted effort by all stakeholders, including Government, Regulator, Airports, Airlines, Ground Handlers and Energy suppliers, to create an integrated and achievable strategy which works for all.

There are four key commercial factors which will need to be addressed and supported in a future commercial strategy:

- Balance Sheet – airports have a variety of assets with different lifespans and book values. Whilst new vehicles, with a lifespan of 5-10 years, could be readily replaced by 2040; boiler plants with a 15-20 year typical lifespan may not align with a 2040 trajectory; and large, fixed building structures can have up to 50 year lifespans. Airports will need support if they are to replace some of these longer life assets by 2040.
- Regulatory Model – the regulatory model (if airports are formally regulated) or airport charging model (if not regulated), needs to support investment in green technology. Given the regulatory cycle programme, as well as planning, design and construction lead-in times, getting an agreed strategy to deliver carbon zero infrastructure by 2040 is likely to be needed to be agreed in the next 5 years. If the solution has not been agreed by then, then having a change control mechanism in the regulatory or airport charging model is important for being able to respond in an agile manner.
- Access to Finance – the aviation industry has been one of the worst hit industries by Covid. Airport and airlines have suffered major losses over the past two years and they are not as safe an investment as they once were. Access to bridging finance or green investment funds

may offer support to help incentivise investment and early adoption of carbon zero technologies. Policy support which can be incorporated into commercial agreements e.g. CORSIA targets, could also help airports gain better access to finance.

- Affordability – ultimately, is the large-scale investment required affordable for airports, airlines, ground handlers and the passenger? How will the carbon credit and offset pricing strategy fit with other airport charges and duties? For it to be a success, it will require airlines and ground handlers to invest, as well as airports. The success of whether airports can achieve carbon zero emissions for Scope 1, 2 and 3 airport operations by 2040 will also be influenced by other Scope 3 emission sources outside of this study such as future aircraft fuels. Understanding future hydrogen and electricity demand, cost and availability, at both an airport as well as wider network level, will play a significant part in determining the overall affordability.

Setting out a programme with realistic timescales will be critical to fulfilling the 2040 carbon zero plan, as well as identifying differences in approach according to whether the airport size is large, medium or small, as the different business models of airport scale will have different drivers and financial pressures.

Several other initiatives would also help to achieve a carbon zero pathway by 2040, including:

- Standardising emission reporting, to track progress and compare
- Incentivisation for early adoption
- Establishing a knowledge base of best practice for airport infrastructure requirements

To conclude, it is feasible from a technology and commercial perspective for airports to achieve zero carbon emissions for Scope 1, 2 and 3 airport operations by 2040. Whilst this is still 18 years away at time of writing, the next few years are critical. The Government and the aviation industry must work together to create and agree a plan which addresses the challenges identified in this report and ensure the plan is adopted by all stakeholders and delivered.

2 Introduction

The UK Government has committed to reducing UK emissions in line with the 2015 Paris Agreement[4]. It has legislated for net zero emissions by 2050 across the economy, and recently agreed with the Climate Change Committee to a 78% reduction in emissions in Carbon Budget Six by 2035 on 1990 levels[5]. While aviation contributes only 2-3% of global greenhouse gas emissions today, it is forecast to become the second highest residual emitter in 2050 as other sectors reduce their emissions. At a UK level, international aviation (and shipping) will come into scope from a target perspective, and this will then cause aviation to reflect a bigger share of UK emissions than for domestic aviation only.

Despite aviation being one of the most challenging sectors to decarbonise, the Government is clear that it will play its part in ensuring the UK reaches net zero. The Department for Transport has set a target for net zero aviation by 2050, as part of the government's wider commitment to reducing UK emissions, and in line with the Paris Agreement. To support this target, a consultation was launched in summer 2021[6] on plans to develop a 'Jet-Zero' strategy, which will ensure the UK is at the vanguard of progress on reducing aviation emissions and continues to drive international progress. This consultation included a proposal for a zero-emission target for airports in England by 2040.

Following this consultation, and in support of policy development relating to zero emissions airport operations in England by 2040, the Department for Transport is seeking to strengthen the evidence base of emissions from airport operations. Whilst airport operations are responsible for only 5% of air transport sector emissions, there are still significant ways in which airports and their users can reduce emissions and contribute their part to addressing climate issues within the sector. The Department for Transport has commissioned and funded this study, however the findings and opinions contained in this report are those of Mott MacDonald and Connected Places Catapult.

The objective of this study is to provide analysis showing the emissions sources at English airports and whether the innovations available will make zero carbon emission airport operations feasible by 2040. The study, conducted in March 2022, is primarily based on public domain sources which are referenced and draws on experience of the Mott MacDonald team in aviation and the wider transport and energy sector in the UK and internationally, subject to limits of non-disclosure agreements.

The emissions referenced in the report will refer to emissions of Greenhouse gases. Greenhouse gases, or GHGs, are compound gases that trap heat or longwave radiation in the atmosphere. The principal GHGs, also known as heat trapping gases, are carbon dioxide, methane, nitrous oxide, and the fluorinated gases. Zero carbon is defined as having operations that do not produce GHG emissions and not net zero, which have operations that produce GHG emissions which are offset to negate the impact.

The emission sources under consideration are Scope 1 emissions (Direct Airport GHG emissions), Scope 2 emissions (Indirect GHG emissions through the purchase of electricity,

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[4] United Nations, 'United Nations Paris Agreement Overview Page' (2015) available at: *https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement* (last accessed March 2022)

[5] Climate Change Committee (2020) *Sixth Carbon Budget* available at https://www.theccc.org.uk/publication/sixth-carbon-budget/?msclkid=18163491af6211eca8e429c92766aa68 (last accessed March 2022)

[6] United Kingdom Government (2021) *Jet zero: our strategy for net zero aviation* available at https://www.gov.uk/government/consultations/achieving-net-zero-aviation-by-2050 (last accessed March 2022)

heating or cooling) and Scope 3 emissions for the airport's users related to the airside operation of the airport. The focus of the study is to look at on-airport emission sources, and so Scope 3 emissions is limited to operations at the airport rather than journeys to and from the airport, such as aircraft flight segments or surface access journeys.

To assess the feasibility for airports to become zero carbon emissions by 2040, this study considers the following three scope elements:

1. Map emissions across English airports for all emissions scopes (Scope 1, 2 and 3 Airport Operations (excluding flights and surface access journeys to/from the airport) and to review their future decarbonisation strategies (Section 3 of this report);
2. Identify zero emissions technologies and innovations which are available now or likely to be available before 2040 to address:
   - Scope 1 Direct Airport GHG emissions (Section 4 of this report);
   - Scope 2 Indirect GHG emissions through the purchase of electricity, heating or cooling (Section 5 of this report);
   - Scope 3 Airport Operations emissions from airport users (Section 6 of this report)
3. Review the technical and commercial viability of airport operations at English airports to become zero emissions by 2040 (Section 7 of this report).

By addressing these areas, the report will assess the feasibility for English airports to achieve zero carbon emissions by 2040.

3 Current Airport Emissions

3.1 Introduction

This section addresses the scale of the decarbonisation challenge facing England's airports. It will outline the 2019 emissions associated with the ten largest airports in England, broken down by emission scope (1,2,3) as well as key commitments to deliver this decarbonisation already outlined by airports. The report will then consider pathways to address these emissions and the blockers/avenues for success in subsequent sections. The year 2019 has been chosen as it removes the impact of the 2020-22 COVID-19 Pandemic and allows for more realistic emissions values for the airports selected.

Map 3.1: Airports included in the study*

3.2 Data capture exercise

Data has been taken from company reports[7] and sustainability strategies, with references provided for each as part of a desk-top research exercise for this report. Data collected reflects both the 'location based' method which views emissions based on national averages and the 'market' based emission method which considers individual 'market' conditions. For emissions recorded under a 'market' methodology, an airport which purchases a renewable energy (REGO) tariff would report electricity emissions as zero; for a location-based method, the UK average grid

*Contains OS data © Crown copyright and database right 2022, made with QGIS.

[7] The majority of Airports included in the study are required to report emissions under The Companies (Directors' Report) and Limited Liability Partnerships (Energy and Carbon Report) Regulations 2018 ("the 2018 Regulations") implement the government's policy on Streamlined Energy and Carbon Reporting (SECR).

electricity factor would be used. Both methods have been included for reference. 2019 has been selected for the data capture period as it represents a reasonable emissions assessment for a year of full operation.

The data tables include all emissions reported by airports during the reference year, whilst some of these emissions are beyond the scope of the study, as outlined in Section 3.2.1, they are referenced to demonstrate the maturity of emission reporting for different airports. Emissions which are not included in the assessment are included for information only and will not form part of the analysis in Section 4, 5 and 6.

Table 3.1: Study Airport Passenger (pax) and reported emissions[8]

Airport	2019 Pax	Percentage of UK airport PAX	2019 Emissions – all scopes (tCO_2e, market based)	Source
Heathrow	80,900,000	27%	20,804,708	Heathrow 2.0 2019 Sustainability Progress
Gatwick	46,600,000	16%	734,294	2020 Performance Summary
Manchester	29,400,000	10%	3,430,568	MAG GHG Emission report 2020/21
Stansted	28,100,000	9%	2,206,931	MAG GHG Emission report 2020/21
Luton	18,000,000	6%	286,215	2020 Sustainability Report
Birmingham	12,600,000	4%	10,408	GHG Emissions 2020-21
Bristol	8,960,000	3%	5,773	Annual Monitoring report 2020
Newcastle	5,200,000	2%	80,893	Net zero Carbon 2035
London City	5,120,000	2%	2,657	Full Accounts 2020
Liverpool (John Lennon)	5,040,000	2%	2,860	Full Accounts 2020

3.2.1 The emissions assessment

The assessment considers GHG emissions that are "on-airport" i.e. under direct control of the airport and its users, these are shown in Table 3.3. Actions to target emissions to and from the airport, such as aircraft take-off and landing (whilst still Scope 3) or surface access road or rail journeys to and from the airport will not be addressed in the feasibility section of the report and are beyond the limit of the study boundary. Whilst the table below (Table 3.2) includes potential Scope 3 on-airport emission sources, airports included in the study do not universally report on all of them. Some airports also aggregate on-airport and off-airport emissions together, such as ground taxiing in the Landing and Take Off (LTO) cycle. The table does represent emissions which will be included in the study if they are reported on; other emission sources e.g. emissions associated with aircraft movements are also captured for information only.

Table 3.2: Emission scope definitions

Scope 1 emissions	Direct GHG emissions that occur from sources that are owned or controlled by an organisation e.g. emissions associated with fuel combustion in boilers, furnaces and vehicles.
Scope 2 emissions	Indirect GHG emissions associated with the purchase of electricity, steam, heat or cooling. Whilst they physically occur at the facility where they are generated, they are accounted for

[8] UK Civil Aviation Authority (2019) available at https://www.caa.co.uk/data-and-analysis/uk-aviation-market/airports/uk-airport-data/uk-airport-data-2019/ (Last accessed Mar 2022)

	in an organisation's GHG inventory because they are a result of that organisation's energy use.
Scope 3 emissions	Result of activities from assets not owned or controlled by the reporting organisation, but that the organisation indirectly impacts in its value chain. These are often referred to as the 'value chain' emissions.

Table 3.3: Emission sources included in the study

Emission Scope	Primary Source	Secondary Source
Scope 1		
	Buildings & Infrastructure Fuel Consumption	HVAC System
		Thermal Storage
		Lighting
		Comms
		Baggage
		Cooking
		Power
		De-icing
		Refrigerants
	Airport Owned Vehicles	Fire tenders
		Airport de-icing/snow
		Tracked Transit System (TTS) / Automated People Mover (APM)
		Cars (Ops/Company)
Scope 2		
	Power from grid	
	Site renewable energy generation	
Scope 3 (Airside Operations)		
	Aircraft Taxi (and Hold)	
	Aircraft Engine Testing	
	On stand power and air	
	Aircraft Line Maintenance	
	Waste	
	3rd Party Airside Vehicles	Baggage tugs
		Baggage loaders
		Cargo handling
		Catering trucks
		Re-fuelling trucks
		Aircraft tugs
		Aircraft service (bowser, water, cleaning staff, materials/waste)
		Aircraft De-icing
		Mobile stairs
		Buses
		Crew transport
		Ops cars

		Other 3rd party vehicles (Logistics, maintenance, construction)
	3rd Party Electricity Generation	

For each airport included in the study (Table 3.1), the report will provide a description of the airport, followed by a reference to their current decarbonisation initiatives. The report will then state their 2019 emissions, in both the market and location methodologies (differences in emissions will be highlighted in the table in **bold**), before introducing their future plans to zero carbon emissions/net-zero. The purpose of this exercise is to establish the current state of play in the English aviation sector, providing context to the upcoming sections in the report.

A short series of conclusions, summarising this data capture exercise have also been included to highlight particular trends in the current data (Section 3.13), with the website link to each report available in the Appendix A.1.

3.3 Heathrow Airport

Heathrow airport, located in the west of London, is the UK's busiest and largest airport serving over 80.9 million passengers in 2019[9]. The airport is the primary hub of British Airways and serves as a base for Virgin Atlantic. As the UK's main air travel hub, carbon emissions are considerably greater than other airports in the country.

3.3.1 Current decarbonisation initiatives

Within their Heathrow 2.0: Connecting People and Planet document, the airport states their aim to "get our own house in order" with a target to get to net zero on the ground. Heathrow anticipate that the UK Government's aim for a shift to electric vehicles will catalyse decarbonisation 'on the ground'. Heathrow Airport Limited state that all conventional fossil fuel vehicles they own will be zero emissions by 2030, and that they will support Heathrow's stakeholders to make the same transition. They also aim to support ground handlers to use electric pushback tugs and move aircraft away from the use of their APUs by the provision of Fixed Ground power and air start equipment on the stands.

3.3.2 Greenhouse gas emissions

Heathrow Airport Limited (HAL) report their Greenhouse Gas (GHG) emissions annually, the following data has been obtained from their 2019 Heathrow 2.0 Sustainability Guide. The emission reporting follows the Greenhouse Gas Protocol and Airport Carbon Accreditation (ACA) guidelines. HAL has recently revised their refrigerant emissions for 2019, which are captured in the below table. Heathrow currently procure 100% of their grid power via a renewable REGO tariff, as such under the market-based reporting mechanism they are able to record zero emissions for grid electricity.

Table 3.4: HAL 2019 Emissions (tCO_2e)

	Market Based	Location based
Emission Source		
Scope 1		
Fuel Consumption	21,942	24,335
Airport Operation Vehicles	1,668	1,668
LPG for fire training	35	35
Refrigerants	2,871	2,871
Scope 2		

9 Heathrow (2020) *Heathrow reports superb end to 2019.* Available at: Heathrow reports outstanding end to 2019 | Heathrow (last accessed March 2022)

	Market Based	Location based
Grid Electricity	0	71,163
Scope 3 Airside Operations		
Waste	588	588
Water	2,068	2,068
Operational vehicles & equipment	33,015	33,015
Fuel consumption – utilities	272	272
3rd Party Electricity	146	43,706
Aircraft in the Landing and Take-off cycle (LTO)	1,250,648	1,250,648
Cruise emissions from all departure flights	18,742,505	18,742,505
Business Travel	1,070	1,070
Passenger Surface Access	632,348	632,348
Staff Surface Access	115,531	115,531

3.3.3 Future plans to zero carbon emissions / Net Zero

Heathrow's plan to deliver net-zero is outlined in their 2022 Heathrow Net Zero Plan[10]. They target at least a 45% reduction in emissions from surface access, supply chain, vehicles, buildings and infrastructure, (or carbon 'on the ground').

- On the Ground
  - Goal 5: Net Zero Surface Access – Achieve an emissions reduction of 49% by 2030 by electrifying surface access for passengers and staff.
  - Goal 6: Supply Chain – Achieve an emissions reduction of 35% by delivering a net zero supply chain.
  - Goal 7: Airport Vehicles – Achieve an emissions reduction of 87% by 2030 by replacing airport vehicle fleet with zero emission or low emission vehicles.
  - Goal 8: Buildings and Infrastructure – Achieve an emissions reduction of 39% by 2030 by improving the efficiency of airport buildings and infrastructure.

3.4 Gatwick Airport

Gatwick airport, also known as London Gatwick, serves as London's second major airport. Located only 30 minutes by train from London, it is also the UK's second busiest airport and the 10th busiest airport in Europe. The airport operates two terminals which served 46.6 million passengers in 2019[11] and could serve 75 million passengers a year by 2038.

3.4.1 Greenhouse gas emissions

Gatwick Airport Limited (GAL) report their emissions annually, their data is externally verified and captured in their annual performance summary. Gatwick currently procure the vast majority of their grid power via a renewable REGO tariff, as such under the market-based reporting mechanism they are able to record near-zero emissions for grid electricity (0.0001% of their location-based emissions).

[10] Heathrow (2022) *TARGET NET ZERO.* Available at: Target Net Zero (heathrow.com) (Last accessed March 2022)

[11] Gatwick Airport (2020) *Gatwick Key Facts*. Available at: Gatwick key facts | Gatwick Airport (last accessed March 2022)

Table 3.5: GAL 2019 Emissions (tCO_2e)

2019	Market based	Location based
Emission Source		
Scope 1		
Fuel Consumption	12,233	12,233
Scope 2		
Grid Electricity	5	25,443
Scope 3 Airside Operations		
Aircraft Engine Testing	1,629	1,629
Operational vehicles & equipment, third party electricity T&D losses, airport water, wastewater and waste systems.	26,484	26,484
Aircraft take-off and landing cycle	426,923	426,923
GAL Business Travel	418	418
Airport Staff Commuting	45,482	45,482
Passenger surface access	195,692	195,692

3.4.2 Future plans to zero carbon emissions / Net Zero

Gatwick airport outline their current decarbonisation plans to 2030 in their (2021) *Second Decade of Change To 2030 publication*.[12]

- Airport emissions
  - Reducing Scope 1 and 2 emissions by a further 25% by 2030
  - Source 50% of on-site electricity and 50% of heat network from UK renewable sources by 2030.
  - Replace all airport vehicles with zero emissions or ultra-low emission vehicles, this includes ground support equipment and mobile construction equipment.
- Aircraft and ground transport emissions
  - Collaborating with fuel providers and airlines to implement the Sustainable Aviation decarbonisation roadmap and interim goals; and setting a science-based target for Gatwick.
  - Collaborating with local transport partners improve modal shift towards public transport and zero and ultra-low emission journey modes to 60% by 2030

3.5 Manchester Airport

Manchester Airport, just 13.9 km south-west of Manchester city centre, is the third busiest airport in the UK in terms of passenger numbers and the busiest of those not serving London. The airport is owned and managed by the Manchester Airport Holdings (trading as *Manchester Airport Group*), which also owns East Midlands Airport and London Stansted. The airport serves as an important travel hub for the north of England, flying to over 200 international destinations with average annual passenger numbers of 27 million. Current decarbonisation initiatives

3.5.1 Greenhouse gas emissions

Manchester Airport emissions are recorded yearly as part of their verification process through the carbon trust utilising the World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI) GHG Protocol methodology[13]. Manchester Airport currently

[12] Gatwick Airport (2021) *SECOND DECADE OF CHANGE TO 2030.* Available at: decade-of-change-policy-to-2030.pdf (gatwickairport.com) (Last accessed March 2022)

[13] GHG Protocol (2015) available at https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf (last accessed March 2022)

procure 100% of their grid power via a renewable REGO tariff, as such under the market-based reporting mechanism they are able to record zero emissions for grid electricity.

Table 3.6: Manchester Airport 2019/20 Emissions (tCO_2e)

2019/20	Market Based	Location Based
Emission Source		
Scope 1		
Fuel Consumption	6,109	6,109
Airport Operation Vehicles	2,899	2,899
F – Gas	505	505
Scope 2		
Grid Electricity	0	18,399
Scope 3 Airside Operations		
On Stand Power and Air	11,102	11,236
Fuel combustion	4,762	4,762
3rd Party Airside Vehicles	64,101	64,101
3rd Party Electricity	0	11,039
Landing and take-off cycle	255,307	255,307
Aircraft en-route	2,680,711	2,680,711
Commuting	4,611	4,611
Non-MAG staff commuting	45,089	45,089
Business travel - public transport	394	394
Business travel – grey fleet	6	6
Passenger surface access	345,259	345,259

3.5.2 Future plans to zero carbon emissions / Net Zero

Manchester Airport Group (Manchester Airport) outline their decarbonisation plans in the Manchester Airport Group 2020 CSR Strategy[14].

All of Manchester Airport Group (MAG)'s airport operations will be net zero carbon by 2038.

- Airport infrastructure will operate on renewable energy by 2030, with new and replacement infrastructure running on renewable energy from 2025
- Airport vehicle fleet to comprise of 100% ultra-low emission vehicles by 2030.
- Maintain carbon neutral operations whilst transitioning to net zero carbon by no later than 2038.

3.6 London Stansted Airport

London Stansted airport, owned and managed by the MAG group, was the first UK airport to hold both the ISO14001 and OHSAS18001 standard. It is the fourth busiest airport in the UK and third busiest in freight. The airport serves as the base for Ryanair and flies to over 100 destinations internationally. In 2019, the airport served 28.12 million passengers[15].

[14] MAG (2020) *WORKING TOGETHER FOR A BRIGHTER FUTURE, MAG Corporate Social Responsibility Report 2020/21.* Available at: mag-csr-report-2020-2021.pdf. (Last accessed March 2022)

[15] statista (2021) *Number of terminal passenger arrivals and departures at London Stansted Airport in the United Kingdom (UK) from 2000 to 2020.* Available at: • Arrivals and departures at London Stansted Airport 2000-2020 | Statista (last accessed: March 2022)

3.6.1 Greenhouse gas emissions

Stansted emissions are recorded yearly as part of their verification process through the carbon trust utilising the WRI/WBCSD GHG Protocol methodology. Stansted Airport currently procure 100% of their grid power via a renewable REGO tariff, as such under the market-based reporting mechanism they are able to record zero emissions for grid electricity.

Table 3.7: Stansted Airport 2019/20 Emissions (tCO_2e)

2019/20	Market Based	Location Based
Emission Source		
Scope 1		
Fuel Consumption	2,609	2,609
Airport Operation Vehicles	900	900
F – Gas	641	641
Scope 2		
Grid Electricity	0	11,189
Scope 3 Airside Operations		
On Stand Power and Air	4,924	4,924
Fuel combustion	153	153
3rd Party Airside Vehicles	19,847	19,847
3rd Party Electricity	0	8,606
Landing and take-off cycle	251,303	251,303
Aircraft en-route	1,569,974	1,569,974
Commuting	4,812	4,812
Non-MAG staff commuting	36,707	36,707
Business travel - public transport	516	516
Business travel – grey fleet	16	16
Passenger surface access	305,691	305,691

3.6.2 Future plans to zero carbon emissions / Net Zero

Manchester Airport Group (Stansted Airport) outline their decarbonisation plans in the Manchester Airport Group 2020 CSR Strategy [16].

All of MAG's airport operations will be net zero carbon by 2038.

- Airport infrastructure will operate on renewable energy by 2030, with new and replacement infrastructure running on renewable energy from 2025
- Airport vehicle fleet to comprise of 100% ultra-low emission vehicles by 2030.
- Maintain carbon neutral operations whilst transitioning to net zero carbon by no later than 2038.

3.7 London Luton Airport

London Luton (LTN) is the UK's fifth busiest airport, serving over 16.5 million passengers in 2018. The airport mainly serves the London region and is the fourth largest airport serving the city. A three-year development of the airport was completed in 2018, the scheme cost a total of £160 million and upgraded overall infrastructure at the airport.

[16] See Footnote 14

3.7.1 Greenhouse gas emissions

LTN records emissions annually as part of its reporting, in line with the ACI carbon reporting guidance for scope 1 and 2 emissions since 2015 and included scope 3 emissions. Luton's market based emissions for electricity are higher than their location-based reporting, this implies that their local energy supply is more carbon-intensive than the UK grid average for electricity.

Table 3.8: LTN 2019 Emissions (tCO_2e)

2019	Market Based	Location Based
Emission Source		
Scope 1		
Fuel Consumption	1,765	1,765
Airport Operation Vehicles	203	1,137
Refrigerants and fire training	55	63
Scope 2		
Grid Electricity	6,772	4,981
Scope 3 Airside Operations		
3rd Party Airside Vehicles	3,179	3,179
3rd Party Electricity	6,670	5,115
Electricity T&D Losses	790	790
Water	136	136
Waste	50	50
Engine Tests	608	608
Aircraft movements	136,145	136,145
Business travel	103	103
Staff Commuting	1,010	1,010
Passenger surface access	131,923	131,923

3.7.2 Future plans to zero carbon emissions / Net Zero

The airport has committed to achieving carbon neutrality by 2026 or sooner and net zero by 2040, this is outlined in their Net Zero 2040 plan[17] published in 2020.

- By 2022
  - Publish a Net zero roadmap
  - Launch the Sustainable Supply Chain Charter
  - DART (Direct Air-Rail Transit) in operation
  - Publish an Air Quality Strategy
- By 2026:
  - 25% on-site renewables
  - Achieve carbon neutrality for airport emissions
  - Support airlines in decarbonisation of flights
- By 2030:
  - 50% on-site renewables working with airport owners
  - Increase the number of electric charging points in car parks
- By 2040:
  - Achieve Net Zero for airport emissions

[17] London Luton (2020) *NET ZERO 2040 Reducing our carbon emissions.* Available at: LTN Net Zero 2040 Report.pdf (Last accessed March 2022)

3.8 Birmingham Airport

Birmingham Airport, located approx.17km from Birmingham City Centre, is the 7th largest UK Airport, with around 50 airlines flying 12.5 million passengers a year to more than 150 destinations.

3.8.1 Current decarbonisation initiatives

Birmingham Airport is looking to implement a new environmental strategy focussed on the United Nations Sustainable Development Goals as well as other industry and governmental plans and policies. The aim of the airport is to be Net Zero by 2033 prioritising a Zero Carbon airport operation (BHX Sustainability Strategy 2020-2025, P10).

To meet this aim of a Zero Carbon airport operation, the airport has already made steps in replacing their owned vehicles with electric versions. This includes their car park buses as well as their diesel pool cars. (BHX Sustainability Strategy 2020-2025, P19). With respect to emissions from aircraft, they wish to minimise emissions from APUs by encouraging the use of Fixed ground power when on stand, as well as encouraging aircraft operators to taxi with a limited number of engines operating.

Recognising the impact of airside vehicles, the airport is looking to review all airport owned and third party owned fleet vehicles with the aim of moving to electric and hybrids, where possible, and develop infrastructure to serve the electric vehicles. It should be noted that, due to the power supply for these vehicles being generated off site, these are included under Scope 2 within the BHX analysis.

3.8.2 Greenhouse gas emissions

BHX reports emissions as required by the SECR (2018) requirements, as such scope 3 emissions are not included for the majority of factors as these are not currently required by law to report.

Table 3.9: BHX 2019/20 Emissions (tCO_2e)

2019/20	Market Based	Location Based
Emission Source		
Scope 1		
Fuel Consumption	3,469	3,469
Airport Operation Vehicles	673	673
Refrigerants	176	176
Scope 2		
Grid Electricity	5,996	5,996
Scope 3 Airside Operations		
Business travel	91	91

3.8.3 Future plans to zero carbon emissions / Net Zero

Birmingham outline their strategy to achieve a net-zero carbon airport in their Sustainability Strategy 2020-2025[18], published 2020.

- Aim to be a net zero carbon Airport by 2033
- Scope 1 & 2 emissions reductions actions
  - Implement a Carbon Management Plan to deliver a roadmap to become a net zero carbon Airport by 2033, 'prioritising zero carbon Airport operations and minimising carbon offsets.

[18] Birmingham Airport (2020) *Sustainability Strategy 2020-2025I.* Available at: BHX - mb22164_airport-sustainability-strategy-booklet_v8-3.pdf. (Last accessed March 2022)

- Annual carbon emissions reporting
- Review of energy efficiency investment
- Replace all lighting with LED where possible
- Install solar controlled window film on Airport buildings
- Develop a Heating and Cooling and Ventilation Strategy to improve energy efficiency
- On-site generation of renewable energy
- Develop Energy and Sustainable Building Standards and monitor implementation

- Scope 3 emissions reductions actions
  - Encourage transition to electric vehicles for airport vehicle fleet.
  - Provide additional EV infrastructure for use by passengers and staff.
  - Encourage modal shift of transport to and from the airport, target 35% Public Transport Modal Share by 2030 by improving cycling routes and bicycle parking provision.
  - Collaborate with NATS and the Civil Aviation Authority to identify and deliver changes to Airspace to reduce aircraft operation emissions.

3.9 Bristol Airport

In 2018, Bristol Airport became the eighth busiest airport in the UK (overtaking Glasgow International Airport) and served 8.9 million passengers for that year[19]. The airport has undergone significant development in the last 10 years; a £6.5m central walkway completed in 2013 and a £24m West Terminal Extension in 2016.

3.9.1 Current decarbonisation initiatives

Bristol Airport is aiming to play their part in the UK's target of "Net Zero" by 2050. In their 2020 Annual Monitoring Report they stated their expectation that they would have reduced or offset all of the carbon emissions under their control by the end of 2021, 4 years ahead of their 2025 target.

As part of their carbon reductio strategy BRS has installed 14 Electric Vehicle charging points around the site, including those which are accessible to both customers and staff. In 2020 these used 5,166 kilowatt hours (kWh) of electricity, equivalent to 2,293kg of CO_2e saved.

Fixed Ground power and mobile ground power units are supplied, and the airport have made it mandatory to use these where they are provided to avoid the use of aircraft APUs.

3.9.2 Greenhouse gas emissions

Bristol Airport's carbon footprint includes all Scope 1 and Scope 2 emissions. There was no scope 3 value reported for 2019.

Table 3.10: BRS 2019 Emissions (tCO_2e)

2019	Market based	Location based
Emission Source		
Scope 1		
Fuel Consumption	2,113	2,113
Scope 2		
Grid Electricity	3,660	3,660
Scope 3 Airside Operations	n/a	

[19] UK Civil Aviation Authority (2022) *Data and analysis.* Available at: Data and analysis | Civil Aviation Authority (caa.co.uk).(Last accessed March 2022)

3.9.3 Future plans to zero carbon emissions / Net Zero

Bristol Airport outlines its net zero target in their 2019 Carbon Roadmaps document[20].

- Scope 1 & 2 targets
  - Be carbon neutral by 2025
  - Be net zero by 2050
- Scope 3 targets
  - Be carbon neutral by 2020 for journeys to and from the airport
  - "Stabilise net carbon emissions from flights at 2020 levels through implementation of CORSIA"

3.10 Newcastle International Airport

Newcastle airport's (NCL) main catchment area is the region of Northeast England, a population of approximately 2.4 million people, and is located around 9.6km northwest of Newcastle City Centre. The airport handles approximately 5.2 million passengers annually and passenger numbers have grown by 102% in the last 20 years[21].

3.10.1 Greenhouse gas emissions

Emission data is available in NCL's Net Zero Carbon 2035, report[22].

Table 3.11: NCL 2019 Emissions (tCO_2e)

2019	Market based	Location based
Emission Source		
Scope 1		
Fuel Consumption	2,049	2,049
Scope 2		
Grid Electricity	3,662	3,662
Scope 3 Airside Operations	n/a	
Solid Fuel	1,279	1,279
Waste	31	31
Aircraft landing and take-off	51,685	51,685
Staff commuting	464	464
Passenger surface access	21,723	21,723

3.10.2 Future plans to zero carbon emissions / Net Zero

Newcastle Airport outlines its net zero target in Net Zero Carbon 2035[23], published 2020.

- Scope 1 & 2 emissions
  - Be a Net Zero carbon airport by 2035.
  - Improve energy efficiency in buildings and infrastructure, use more electric vehicles, to generate and procure zero carbon energy for buildings and vehicles.

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[20] Bristol Airport (2019) *Becoming a net zero airport*. Available at: https://www.bristolairport.co.uk/about-us/environment/carbon-roadmap?msclkid=cb9a96ceb0d311ec83d185789f048092 (Last accessed March 2022)

[21] See Table 3.1

[22] Newcastle Airport (2020) *Net Zero Carbon 2035.* Available at: Net Zero Carbon 2035 (newcastleairport.com). (Last accessed March 2022)

[23] Newcastle Airport (2020) *Net Zero Carbon 2035.* Available at: Net Zero Carbon 2035 (newcastleairport.com). (Last accessed March 2022)

- Scope 3 emissions
  - Be carbon neutral for passengers' journeys to and from the Airport by 2035.
  - Implement the Airport Surface Access Strategy to improve the efficiency of travel on existing and future infrastructure. Continue to collaborate local partners, including metro and bus operators to improve transport provision to suit customer needs.
  - To increase the number of Fixed Electrical Ground Power (FEGP) units and allow aircraft to reduce their emissions by drawing electricity from a 100% renewable supply.

3.11 London City Airport

The airport served 5.1m passengers in 2019[24]. It is the fifth-busiest airport by passengers and aircraft movements serving the London area, after Heathrow, Gatwick, Stansted and Luton, and is the 14th-busiest in the UK. In 2019, the airport achieved carbon neutral status.

3.11.1 Current decarbonisation initiatives

In their Net Zero Announcement of June 2019, London City Airport (LCY) pledged to achieve net zero carbon emissions by 2050. As part of their strategy to meet this target they looked to install 900sqm of solar panels which would produce 140,000 kWh of energy per year, reducing carbon by 307T CO_2 per year. The wider energy strategy includes the operation of greener and cleaner vehicles at the airport, ensuring that all vehicles and equipment used by staff at the airport will be electric by 2030.

3.11.2 Greenhouse gas emissions

LCY reports emissions annual as part of their requirements under the streamlined energy and carbon reporting (2018).

Table 3.12: LCY 2019 Emissions (tCO_2e)

2019	Market based	Location based
Emission Source		
Scope 1		
Fuel Consumption	325.97	325.97
Scope 2		
Grid Electricity	2,261.62	2,261.62
Scope 3 Airside Operations	n/a	
Fuel from transport	68.99	68.99

3.11.3 Future plans to zero carbon emissions / Net Zero

The airport is committed to achieving net zero emissions in scope 1 and 2 emissions by 2050. To achieve this, it will encourage innovation and deploy several practices to reduce emissions even further and meet international industry standards to advocate net zero emissions in the wider industry.

The airport has invested in aircraft innovation through its City Airport Development Programme (CADP). It will increase opportunities to further improve emissions by accommodating quieter, cleaner, more fuel-efficient new generation aircraft (such as the Airbus 220-100 and Embraer E190-E2).

[24] London City Airport (2022) *CORPORATE INFORMATION & REPORTS.* Available at: London City Airport Passenger Statistics | LCY (last accessed March 2022)

As part of their masterplan application in 2020, LCY submitted a technical note on carbon and greenhouse gas emissions, this outlines their future projected emissions in 2025[25]. The masterplan would result in an emissions increase up to 2025 of 21,176 tCO_2e.

Table 3.13: LCY Projected emissions up to 2025

Table 17.2: Future year (2025) GHG emissions without development

Emissions Source	Scope 1 emissions	Scope 2 emissions	Scope 3 emissions	Total emissions
Terminal energy, fuel consumption and waste (tCO_2e)	1,013	1,127	312	2,452
Aircraft LTO emissions (tCO_2e)	74,794	-	15,419	90,213
TOTAL (tCO_2e)	75,807	1,127	15,731	92,665

Table 17.3: Future year (2025) GHG emissions with development

Emissions Source	Scope 1 emissions	Scope 2 emissions	Scope 3 emissions	Total emissions
Terminal energy, fuel consumption and waste (tCO_2e)	1,314	4,598	616	6,528
Aircraft LTO emissions (tCO_2e)	88,971	-	18,341	107,313
TOTAL (tCO_2e)	90,285	4,598	18,957	113,841

3.12 Liverpool (John Lennon) Airport

Liverpool John Lennon Airport (LJLA) is located within the City of Liverpool in the Northwest of England. The airport is the 11th busiest in the UK serving 5m passengers in 2019. LJLA is presently served by six airlines, the largest of which in passengers carried is EasyJet, followed by Ryanair.

3.12.1 Greenhouse gas emissions

LJLA reports emissions annual as part of their requirements under the streamlined energy and carbon reporting (2018).

Table 3.14: LJLA 2019/20 Emissions (tCO_2e)

2019/20	Market based	Location based
Emission Source		
Scope 1		
Fuel Consumption	1272.53	1272.53
Scope 2		
Grid Electricity	1587.86	1587.86
Scope 3 Airside Operations	n/a	

[25] RPS Group (2019) *Technical Note On Carbon And Greenhouse Gas Emissions* available at https://assets.ctfassets.net/ggj4kbqgcch2/5LiWPF3RQw6XB5AayLKIrR/502fcde7dc9d4fba194a6789ded91d32/LCY_Draft_Master_Plan_Technical_Note_on_Carbon_and_Greenhouse_Gas_Emissions.pdf (last accessed March 2022)

3.12.2 Future plans to zero carbon emissions / Net Zero

The airport has set an annual carbon reduction target of 3% in their Masterplan to 2050 document, published 2018[26].

LJLA will develop a carbon management plan to mitigate and reduce the construction and operation emissions of its expansion, with additional scope to significantly further reduce emissions.

The carbon management plan identifies a range of measures across the airport in order of priority:

- Energy Conservation
- Energy Control
- Energy Efficiency
- Renewables Investment which includes deployment of solar panels at the airport

In addition, the Airport will collaborate with airlines and operators to reduce fuel and carbon emissions from the vehicles and aircraft that use LJLA which include:

- Use of zero or low-emission hybrid or electric vehicles.
- Reduced engine taxiing; and
- Measures to encourage passengers to use public transportation to and from the Airport.

3.13 Conclusion

Differences in emission reporting and data quality

As expected, there was a large discrepancy in the quality of reported data between airport operators. Reporting varied from the minimum required in the Streamlined Energy and Carbon Reporting (2018), as part of their yearly 'Director's Report'[27] and more detailed reporting captured in some bespoke sustainability reports.

Due to this variation, it is difficult to directly compare airports as the reporting boundaries varied between operators. Nevertheless, certain emission areas represented the majority of emissions in most case studies and represent areas to target emission reduction efforts.

The study captured all reported emissions to demonstrate this disparity in recording, of particular note is Gatwick Airport which reported the fourth largest emissions value despite carrying the second largest quantity of passengers in 2019.

Zero carbon vs net zero

Whilst the majority of airports adopt a net-zero terminology in their documentation, some reference zero carbon. For example, Heathrow targets zero carbon emissions vehicles by 2030 and Birmingham airport provides a separate narrative to net-zero and zero carbon in their decarbonisation trajectories. The main driver for the focus on net-zero is most likely the inclusion of aircraft emissions in reporting, which follows a longer decarbonisation trajectory than airportcontrolled infrastructure.

Observed trends

In 2019, there was a clear trend with the largest UK airports purchasing renewable electricity to offset their Scope 2 emissions (Figure 3.1). This trend is reflected in a lower emission intensity

[26] Liverpool John Lennon Airport (2018) *Master Plan to 2050.* Available at: LPL liverpool-john-lennon-airport-master-plan-to-2050.pdf (Last accessed March 2022)

[27] A legal requirement as part of the 2006 Companies Act, in April 2022 this reporting requirement is set to change again to incorporate elements of Task force for climate finance disclosure (TCFD) reporting to greater consider climate risk.

per passenger for larger English airports compared to their lower pax equivalents (Figure 3.2). Larger purchasing power afforded to larger airports could enable faster emission reductions with elements such as 'REGO' tariffs.

Figure 3.1: Comparison of studied airport Scope 1 and 2 emissions (based on 2019 or 2019 financial year data – market based)

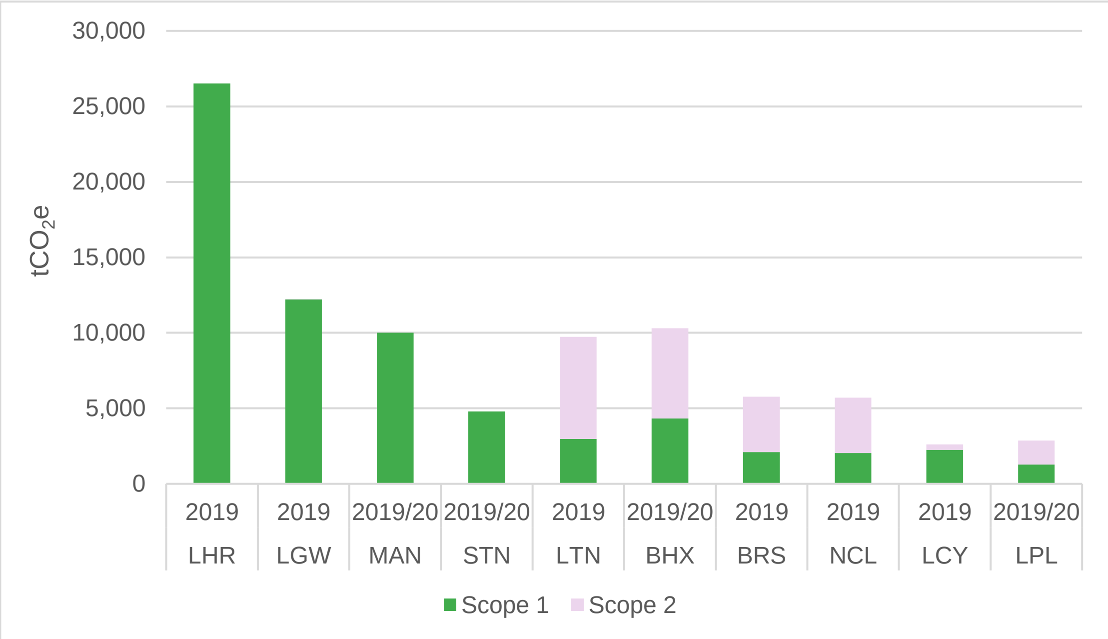
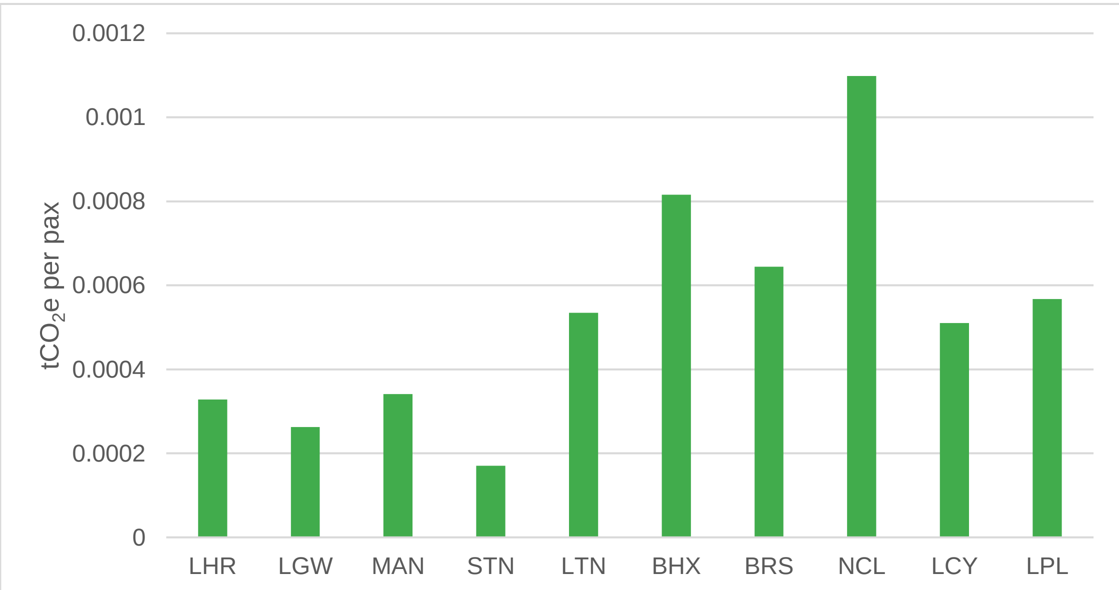


Figure 3.2: Intensity ratio for study airports (2019 passenger figures divided by 2019 or 2019 financial year emissions – Scope 1 and 2 – market based)



Further analysis on the emissions data was carried out to establish the quantity of airports which rely on natural gas as part of their energy mix, the following data is captured below.

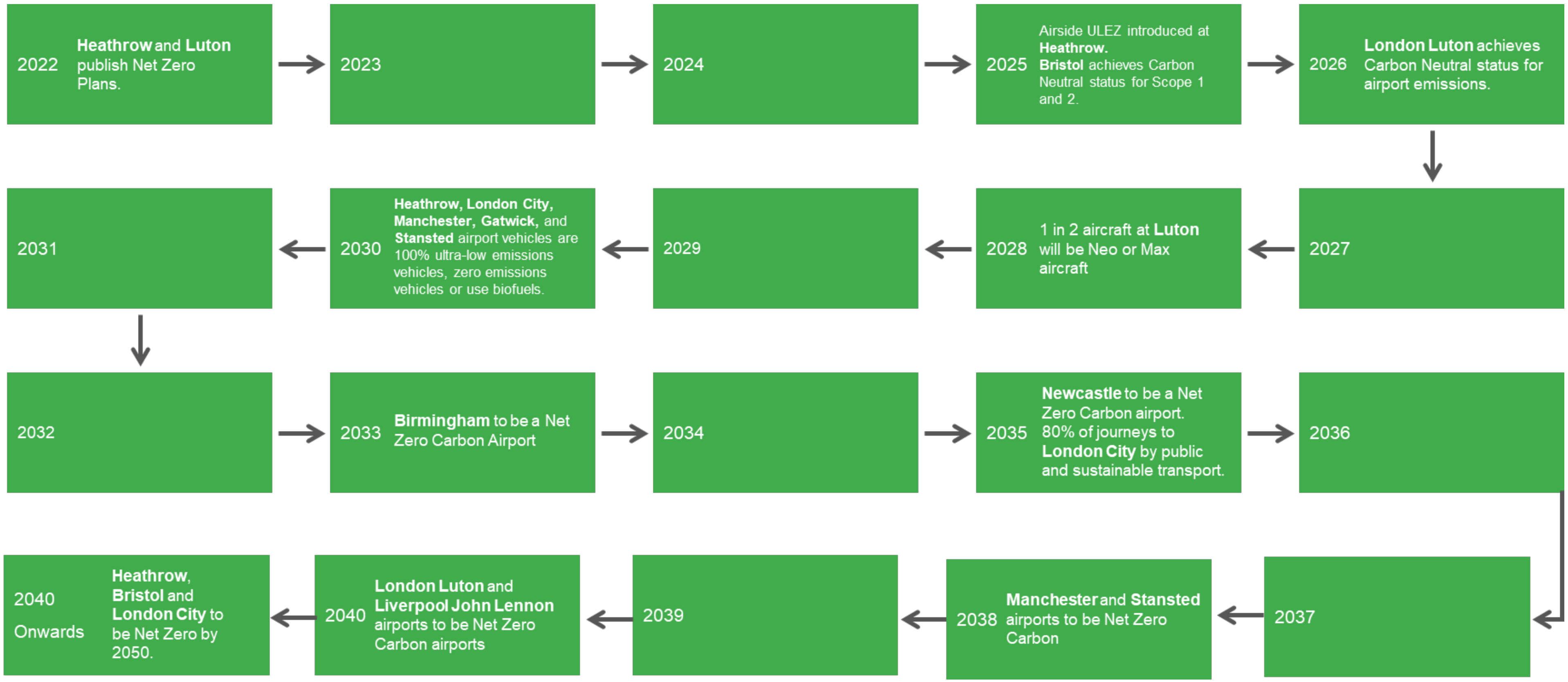
Table 3.15: Natural Gas Associated Emissions for Airports Reported emissions (tCO_2e)

Market based	LHR	LGW	MAN	STN	LTN	BHX	BRS	NCL	LCY	LPL
	2019	2019	2019/20	2019/20	2019	2019/20	2019	2019	2019	2019
Gas emissions	21,942	n/a	6,032	2,609	1,562	3,358	660	n/a	326	n/a
Percentage of total emissions	0.11%	n/a	0.18%	0.12%	0.55%	32.26%	11.43%	n/a	12.27%	n/a
Total	20,804,708	734,294	3,430,568	2,206,931	286,215	10,408	5,773	80,893	2,657	2,860

Decarbonisation forward outlook

The below Figure 3.3 provides a summary of the commitments made to date, in the form of a timeline. It demonstrates the commitments made by the airports included in this study and identifies where the current net-zero trajectories sit temporally. There is a large disparity in net-zero commitment dates, with the earliest occurring in 2033 (BHX) and the latest in 2050 (LHR, BRS, LCY).

Figure 3.3: Current Decarbonisation Forward Outlook

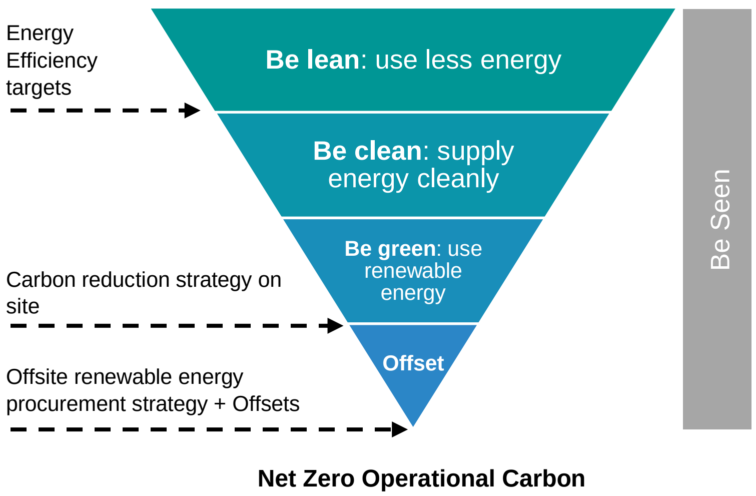


4 Scope 1 Emission Technology and Innovation

4.1 Introduction

Scope 1 emissions are direct greenhouse (GHG) that occur from sources that are controlled by the organisation. The on-site energy consumption is related to demand and the efficiency of the equipment. Achieving an efficient building design can act as the first step to help reduce the demand. Reducing the need for energy in equipment design and processes, including specialist airport equipment powered by electricity such as baggage systems, is also best practice to reduce the demands on the system. Every design should start by following the principles of good passive design. Reducing the total demand of carbon and energy intense activities will allow for reduced requirements in the following steps of energy hierarchy.

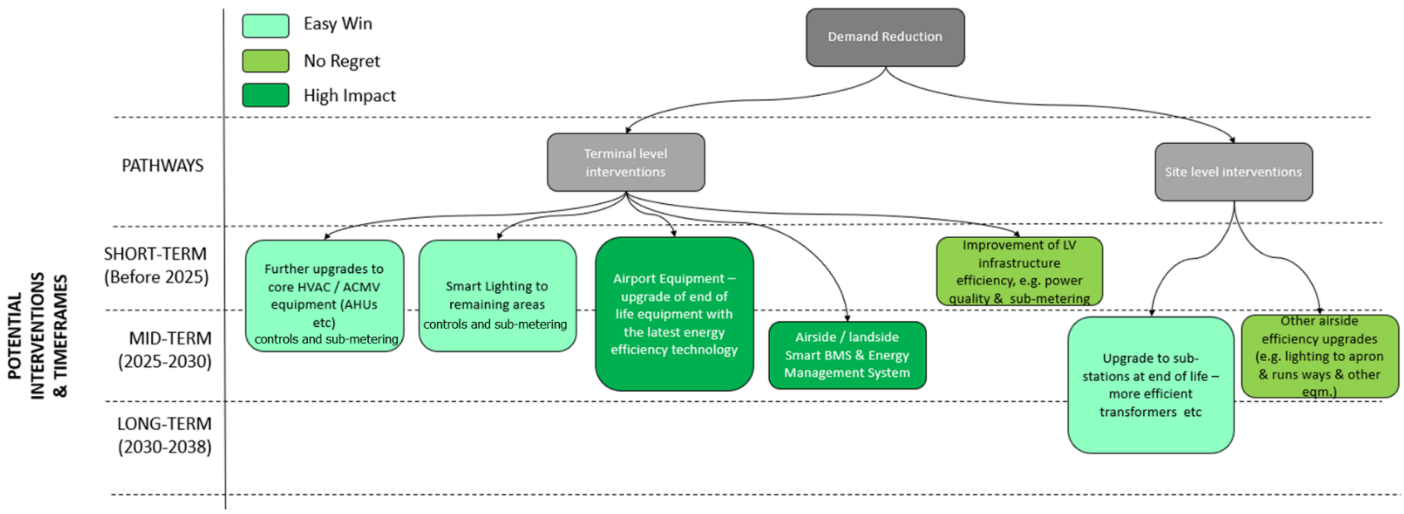
Figure 4-1: Energy Hierarchy[28]



As a second step, supplying low carbon heat to each building will further reduce Scope 1 emissions. Renewable energy systems will be maximised where spatially and financially possible, and lastly, energy in use will be addressed though the proactive use of smart meters and controls together with provision of support and training on decision making for the facility managers.

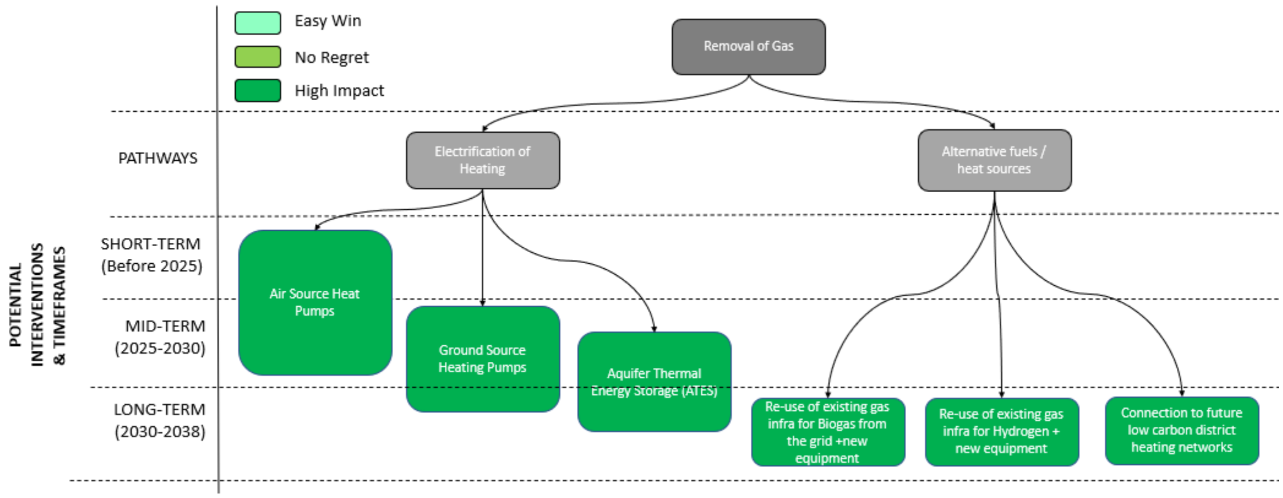
[28] Adapted from: Mayor of London, Energy Assessment Guidance, Greater London Authority guidance on preparing energy assessments as part of planning applications (October 2018)

Figure 4-2: Potential interventions after demand reduction [29]



Removal of the gas is considered as the solution for the electrification of heating and as a part of net zero operational carbon pathway. As a part of the regulated energy section, HVAC systems are focused on the technologies which enables the electrification of heating in line with cooling and in the cooking section all-electric catering technologies considered.

Figure 4-3: Removal of gas pathway[30]



This section provides a high-level technical description of various technologies for the systems using the on-site energy to achieve net zero. In particular, the technologies included are selected because of their current and future potential availability for energy efficiency. The pathway to decarbonisation is being proposed to eliminate the use of GHG emitting fuel on site, mainly by electrification of the heating and transportation, energy storage as well as potentially employing some extent of zero carbon hydrogen. Therefore, this eliminates all Scope 1 emissions, except

[29] Mott MacDonald reference study

[30] Mott MacDonald reference study

for potential refrigerant leaks from refrigeration systems and all the energy used on site can be considered under Scope 2 emissions.

4.2 Fuel consumption – Regulated energy

Total operational energy is made up of regulated components – including heating and cooling, hot water, ventilation, and lighting – and unregulated ones, such as IT equipment, catering facilities, and so on.

Building owners will be concerned with minimising the running costs associated with their assets. Regulated energy uses are inherent in the design of a building; they are related to the 'quality' of the building itself. While designers cannot predict how these systems will ultimately be used, they can ensure they are installed to be as energy efficient as possible.

4.2.1 HVAC Systems

Like any other buildings, airport buildings use some form of heating, ventilation, and air conditioning (HVAC) system for space heating, cooling, ventilation, and domestic hot water generation. Until more recently, the majority of space heating and domestic hot water energy consumption has been associated with natural gas and other fossil fuels. A considerable amount of space cooling equipment runs on electricity. Ventilation systems use electric-driven fans to provide the required air for the building.

Solutions

Removal of on-site natural gas, and electrification of heating is one of the key aspects to achieve the net-zero energy aspiration in existing and new-built airport buildings. For this purpose, devices converting electricity as a fuel to heating and cooling energy in an efficient way become essential.

A heat pump (HP) is a device that transfers thermal energy in the opposing direction of naturally occurring heat diffusion, through the application of electrical input. An evaporator and condenser coil form the heat transfer surfaces, whereby a refrigerant transfers the thermal energy from a variety of sources to internal spaces, as required. The electrical energy is used in compression and allows for a vapour-compression refrigeration cycle to be achieved within the unit; this being the driving force of the heat pump.

HP is a very efficient way to generate heating and cooling energy using electricity as fuel. HPs are classified depending on the source they use as Air Source Heat Pumps (ASHP), Water Source Heat Pumps (WSHP) and Ground Source Heat Pumps (GSHP). Plant performance and efficiency vary based on the source temperatures. Ground temperatures are likely to be more stable and by no means extreme throughout the year. This boosts the performance and efficiency and makes the GSHP a reliable and efficient system solution.

Another solution is to use Aquifer Thermal Energy Storge (ATES), in which heat and cold from the building are stored on a seasonal basis in the ground by which in the end little energy is needed for both. This solution only works well when there is a heating season and a cooling season. The quantities of heat and cold stored in the ground must be balanced. It is also mandatory to make sure and demonstrate that there is a thermal balance in the ground, meaning that the quantity of heat extracted is the same as the quantity of heat supplied to the ground.

Multispeed or variable speed fan motors increase the overall efficiency and can be integrated to smart grid services with a fast response availability. Electrically commutated motors (ECM) have higher overall efficiencies.

Multispeed or variable speed circulation pump increase the overall efficiency and enable the non-critical plants to run low speeds by modulation.

Maturity

Heat Pumps and ATES solutions are commercialized with the current technology and widely available in different sizes and combination potentials. Additional short-term opportunities which are still available in the current market include replacement of existing boilers and R-134a heat pump water heaters with highly efficient low-GWP (global warming potential) alternatives such as CO_2 heat pump water heaters.

Electronic motor controls have enabled substantial energy efficiency improvements in compressor and fan motors through variable-speed operation. By modulating motor speed on compressors, the A/C (air conditioning) system can more closely match the part-load cooling demand and improve seasonal efficiency by reduce cycling losses that are common during the majority of the cooling season when the system's full capacity is not required.

The mid-term opportunities (2025s) will be to integrate systems that can handle next generation refrigerants. Absorption and adsorption heat pump water heaters using non-toxic fluids will significantly boost water heater efficiency by transferring heat to the water from water or ambient air[31].

The long-term opportunities (2035s) will be to use non-vapor compression systems that use zero-GWP refrigerants, magnetocaloric, electrocaloric systems, electrochemical compression which requires no moving parts and membrane-based systems which will allow momentous energy saving in the next era.

Examples

One of the good case studies for HP applications in airports is New Zealand's Christchurch International Airport (CHC). It features a water source heat pump system with a payback period of only two years. After the significant reduction in operational energy and cost, the airport operation group decided to implement a similar water-based set-up to the existing terminals[32].

Another case study is a cascaded heat pump-gas fired boiler solution in an existing terminal in Copenhagen Airport (CPH). In 2018, existing boilers were replaced with natural gas fired highly efficient condensing boilers and industrial type heat pumps. According to the facility management team, estimated saving with the heat pump is about 1000 MWh per year[33].

Beijing Daxing International Airport (PKX) in China has the largest ground source heat pump project in the country. The estimated annual natural gas saving from the GSHP is 1,735,900 Nm^3, equivalent to 21,078 tons of standard coal, cutting carbon emissions by more than 15,800 tons[34].

The worlds larges ATES system is serving Arlanda Airport (ARN) in Stockholm in which estimated reduction of electricity use by 4-5 GWh per year and the district heating use by 10-15 GWh per year with a heating and cooling capacity of 8 MW[35].

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[31] US Department of Energy (2017) Energy Savings Potential and RD&D Opportunities for Commercial HVAC Systems

[32] CIBSE (2021) CIBSE Case Study: Christchurch International Airport. Available at: https://www.designingbuildings.co.uk/wiki/CIBSE_Case_Study:_Christchurch_International_Airport (last accessed March 2022)

[33] Oilon (n.d.) Copenhagen airport, Denmark. Available at: https://oilon.com/en-gb/references/copenhagen-airport-denmark/ (last accessed March 2022)

[34] China Daily (2019) China's largest GSH{ project near completion. Available at: https://www.chinadaily.com.cn/a/201904/24/WS5cbfff66a3104842260b80f4.html (last accessed March 2022)

[35] Power Technology (2021) Arlanda airport aquifer – Thermal energy storage system, Sweden. Available at: https://www.power-technology.com/marketdata/arlanda-airport-aquifer-thermal-energy-storage-system-sweden/ (last accessed March 2022)

Barriers

Air source heat pumps system performance and efficiency vary based on outdoor temperatures, often decreasing for off-design conditions. Bespoke design based on specific climates instead of one-size-fits-all-region approaches can reduce this barrier.

Sizing for the hottest day condition in a given year can often reduce the operational performance conditions which is more moderate. Incorporating variable-speed components such as pumps, fans and compressors can improve part-load performance of the system.

System complexity increases in order to achieve greater performance, degradation can have an outsized impact.

In the ATES system the quantities of heat and cold stored in the ground must be balanced.

Assessment of age and state of current HVAC in use is critical, which necessitates a plan for rollout of new equipment. Heating systems may otherwise be in use for prolonged periods unnecessarily; re-commissioning of HVAC systems may therefore be a solution.

4.2.2 Thermal energy storage

Energy Storage Thermal end-uses can dominate the energy consumption in airport terminals. The main drivers in HVAC and refrigeration are the peak demands which shift electrical load in line with the demand. Energy storage can play a key role in helping to balance supply and demand of electricity. Thermal energy storage (TES) helps stabilize these peaks with higher roundtrip efficiency, lower capital cost and longer operational lifetime than the batteries for HVAC systems. Nevertheless, batteries and TES technologies should not be looked at as competitors.

On the other hand, the electrification of air-side vehicles provides an opportunity to use the batteries in these as part of the energy storage solutions. In simple terms, these would include charging the vehicles more frequently when there is an excess electricity generation from PV's, using potentially redundant night-time vehicles to power parts of the building etc.

Solutions

The traditional solutions for building energy storage are thermal mass (e.g., adobe) or phase change (ice storage) and as a more recent one electrochemical (e.g., batteries). As 50% or more of the energy consumed in buildings can be for thermal end uses, thermal energy storage (TES) can also play an important role in facilitating a balanced energy system that is efficient, resilient, and affordable[36]. TES can increase the HP performance which can vary with ambient conditions. With proper controls, TES can provide efficiency improvements if heat pump lifts are high during peak demand periods.

In order to employ the electric air-side vehicles as part of the energy storage solution, careful vehicle use planning should be carried out, with a full synergy between these and the on-site renewable electricity generation. For instance, shorter charge-discharge cycles could be implemented when on-site electricity is likely to be available to be stored, which would require consideration of the functional operations of these vehicles. Similarly, in the likely event that night-time traffic would be less than peak time traffic, redundant electric vehicles may be used to power parts of the terminal building operations; this would require careful planning and collaboration between the airside and building side operations.

Maturity

All of the proposed solutions are commercially available in the current market. These can both be integrated with existing and new terminal buildings. However, material improvements and heat

[36] US Dept. of Energy (2021) Thermal Energy Storage Systems for Buildings Workshop

transfer enhancements may be required to provide high power delivery. Heat transfer into and out of the TES material is critical, which is typically a more expensive part of the TES system than the material alone.

Examples

In Amsterdam, Schiphol (AMS) airport has 13 TES units storing the energy underground. Main terminal building, piers and BOH areas run on TES system. Terminal 3 that uses a large TES system since 2019 approximately saves 1.5 million m^3 of natural gas per annum[37].

Barriers

Envelope-based systems have seen limited adoption, largely because they charge and discharge passively in response to ambient temperatures and can only shift to off-peak hours either in heating or cooling modes, not both. More generally, adoption is limited due to most phase change materials (PCMs) suffering from issues such as supercooling, broad transition temperatures, low energy density, poor heat transfer, degradation with cycling, and high prices. These problems collectively limit increased deployment of TES technologies.

4.2.3 Lighting

Solutions

There are two main areas of innovation in lighting design. The first one is the product efficiency which is about the optical delivery to satisfy lighting requirements while using less energy from the luminaire. The second one is the communication with other building systems in an interoperability manner, sensors and connected controls in other building systems such as HVAC etc.

Light emitting diodes (LED) are one of the predominant technologies in the solid-state lighting (SSL) area. It offers both an improved functionality along with a significant energy saving opportunity when compared with conventional lighting technologies. The technology is also an ongoing research field compelling new features for visual comfort and further energy saving.

LED lighting design in new builds and retrofit of existing buildings will reduce the amount of energy consumed by lighting. This directly supports the development of zero operational energy and carbon aspects. LED lighting is inherently dimmable and instant on/off. Intelligent lighting systems can be configured with controls systems to respond to transactive control signals to instantaneously reduce grid load.

LED lighting has a longer operational lifetime when compared to traditional lighting and it requires less maintenance and replacement. Embodied carbon impact of LED lighting lamps is relatively low when compared against the conventional lighting technologies such as florescence lamps.

Maturity

LED lighting technology has a growing interest each year due to its effectiveness in achieving high energy savings and operational benefits. US Department of Energy (DOE) SSL path scenario estimates that the 35% projected instalment of LED in 2020 will increase to 84% by 2035. Along with the increase in demand, the efficiency of LED lighting has continuously improved accordingly[38].

[37] Royal Schiphol Group (2022) *Thermal energy storage at the airport*. Available at: https://www.schiphol.nl/en/schiphol-group/page/sustainable-climate-control-at-the-airport/ (last accessed March 2022)

[38] US Dept. of Energy (2022) Solid-State Lighting R&D Opportunities

Examples

LED lighting technology gained popularity in the aviation industry due to its benefits of low maintenance, longer operation lifetime and energy consumption. Listing the examples can be complex due to the number of applications involved. Some of the recent applications are Bournemouth (BOH), Heathrow (LHR), Jersey (JER), Manchester (MAN) and Trondheim (TRD) airports.

Barriers

There are no significant technological barriers which should hinder the design and integration of LED technology into new built and existing airport buildings. It's only important that to maximize the benefit, smart lighting systems overlay/controls should be included. The main "barrier" may simply be the attributes move beyond just luminous efficacy and cost to provide the right light at the right time for the application. Improving performance in one of these attributes can often lead to performance trade-offs within other metrics.

4.2.4 Communications

The services provided under communication systems in airports can be listed as phone and data systems, local area networks (LANs), building management systems (BMS), energy monitoring systems (EMS) and sound systems. The following section proposes the solutions that provide carbon emission reduction and energy saving opportunities through the design and the operation which are BMS and EMS.

Solutions

1. **BMS**

An effective BMS will help to automate the HVAC and lighting systems within the airport buildings, helping facility managers understand how the building is operating and allow them to control and adjust systems to optimise performance, in a simple, efficient manner. BMS control of HVAC and lighting systems will be designed with energy efficiency as the key driver. Some examples of the energy efficient controls include;

- **Demand led control strategies**: the BMS shall use demand led strategies where appropriate, demands for heating and cooling shall be monitored by the BMS, evaluated and processed, prior to commanding systems operational.
- **Time program control**: the BMS shall provide time schedules that can be programmed to define when an operation signal is to be sent to the controlled plant. The time schedules shall allow different on/off times for building/plant control strategies to be defined throughout the year.
- **Optimisation Control**: the BMS shall provide individual optimisation programmes for the time schedules associated with temperature control of a space/zone, to enable the operation of the related heating and/or cooling systems prior to normal operating periods, in order to bring the zones within comfortable temperatures at the start of normal occupancy times. The optimisation programme shall be self-adaptive using an iterative process after each period of operation to improve its performance.
- **Seasonal Operation**: plant controls shall be pre-programmed for seasonal operation, allowing plant start-up routines and temperature control set points to be determined and automatically adjusted based on the season of operation
- **Lighting Control:** Lighting shall be controlled with addressable dimmable control gear by building management system.

Upgrading of all BMS across existing sites to be a fully integrated smart system utilizing artificial intelligence (AI) or machine learning (ML), connected to all key equipment & systems across the terminals will allow significant energy savings and will also likely prolong the lifetime of systems and equipment.

2. EMS

Energy monitoring enhancement can be achieved by installation of IoT sensor, meters and advanced data loggers to set up measurement of parameters such as temperature, pressure, flow rates, electrical consumption etc. This shall identify scheduling problems, incorrect heating and cooling settings, lack of calibration or maintenance; it shall also monitor and identify overloads / loading requirements in the system. Significant operational energy savings expected. Will also likely prolong the lifetime of systems and equipment.

Maturity

BMS and EMS systems are widely recognized in the industry. Advanced internet technology for instantaneous instrument control and energy monitoring would offer a stable and secure connection and help to optimize the efficiency further.

Digital twins are in their infant stage at the moment, slowly being deployed on increasing scales. In the UK the proposed National Digital Twin has been cited by the National Infrastructure Commission as having the potential to unlock an additional £7 billion per year of benefits across the UK infrastructure sector[39].

Barriers

Full BMS installation cost due to sensors and other instruments are high and justifying the added value can sometimes be difficult. These systems are open to large blind spots if they are not fully integrated in the building design. Scalability is another barrier, due to different data protocols of each individual manufacturer which requires different processes and integrations to maintain the data.

4.3 Fuel consumption – Unregulated energy

Unregulated energy uses are often undetermined until very late on in the design process. Designers have very little influence over which unregulated energy uses are included and how they are used, however, can work with their clients to attempt to help minimise it through the inherent building design and the way occupants use it.

4.3.1 Refrigerants

The majority of the end-use application of refrigerants are HVAC system and refrigeration systems in airports. It's a rapidly changing industry since the passage of Montreal Protocol in 1987, which has helped to accelerate the phase-out of substances (including refrigerants) that deplete the ozone layer and contribute to global warming. The progress towards widespread applications is to use high performing low-GWP refrigerants and smart solutions for leakage detection.

Solutions

The choice of low GWP refrigerants is growing and it is therefore the case of selecting the most appropriate for a given application. Prompt action is to phase down the use of high-GWP

[39] Walters, A. (2019) *Media release: national digital twin day launches week of activity to help modernise national infrastructure.* Available at: https://www.cdbb.cam.ac.uk/news/media-release-national-digital-twin-day-launches-week-activity-help-modernise-national (last accessed March 2022)

refrigerants and replace them with alternative very low GWP solution replacements including toxicity, flammability, cycle coefficient of performance (COP)[40].

Maturity

Low-GWP refrigerants are readily available from a range of manufacturers and the market is only projected to grow. This market growth can be attributed to the increasing demand for industrial application.

Examples

To help meet LGW airport's strict environmental policy, chillers making use of refrigerant with a GWP rating of less than 1 were recently installed[41]. The chiller's efficiency also results in a significantly lower carbon footprint and running costs.

Barriers

Barriers to the uptake of low-GWP refrigerants are typically relevant to regulations, market and cost. These could be affected by certain aspects such as equipment sizes, sector and the equipment types. It's also important to have the characteristic information readily available which can be hard-to-reach information for the alternative refrigerants.

4.3.2 Cooking

Switching to certified, high-performance equipment can help boost energy savings as well as minimise energy costs. Investing in high energy-efficient equipment can therefore have a huge impact, offering enhanced performance and ensuring that systems in place are future-proof.

Regular maintenance and cleaning of equipment helps to extend the life of appliances and ensures they are at peak performance. Equipment that hasn't been properly cleaned or has damaged parts will need to work harder and use more energy[42].

Having simple procedures or controls in place to shut down idle equipment can also help to conserve energy.

All-electric catering solutions are a possibility, however sometimes a combination of both electric and gas is the most practical solution. From a net zero perspective, gas ranges are less energy efficient. In addition, gas equipment tends to result in a higher upfront cost. However, despite having a cheaper initial cost, electrical appliances are more expensive to run. From a culinary perspective, commercial gas solutions are traditionally preferred due to the ability to manually adjust the size of the flame.

4.3.3 Power

The main energy consumers in airports can be divided between the airside and landside of the airport. Airside energy consumers are fundamentally the airfield lighting and radio navigation systems. Landside energy consumers are fundamentally the terminal building of the airport due the large processing requirements of passengers and cargo and the number of facilities required for its operation. HVAC, lighting and ICT systems are usually the most important energy

[40] Danfoss (n.d.) *Refrigerants with low GWP*. Available at: https://www.danfoss.com/en/about-danfoss/our-businesses/cooling/refrigerants-and-energy-efficiency/refrigerants-for-lowering-the-gwp/ (last accessed March 2022)

[41] ACR (2019) *Ultra-low GWP HFO chiller from carrier lands at Gatwick*. Available at: https://www.acr-news.com/ultra-low-gwp-hfo-chiller-from-carrier-lands-at-gatwick (last accessed March 2022)

[42] Die Pat (n.d.) *Tips for commercial kitchen maintenance*. Available at: https://www.die-pat.co.uk/tips-for-commercial-kitchen-maintenance (last accessed March 2022)

consumers at airports, so it is essential to investigate new methods to achieve a reduction in energy consumption.

Electricity is the dominant energy source because it is necessary for the supply of the main airport energy consumers and to ensure the safety of air traffic operations[43]. This electricity usually comes from the commercial grid and is supplied by a power company. However, during the last several years it is possible to find other kinds of energy sources such as CHP plants or renewable energy technologies which contribute to reduced emissions.

Plug load related electricity consumption at an airport may account for up to 25% of the total consumption, moving closer to 50% for high efficiency buildings[44]. Servers typically contribute most significantly to overall consumption; therefore, 'Sustainable IT' programmes can offer rebates for server virtualisation and relocation from distributed server closets[45]. Similarly with cooking appliances, an energy retrofit programme for equipment such as computers and printers can also help to reduce consumption through upgrades and utilising timers or smart power strips to conserve energy.

Modern airports now seek the use of digitised hardware and software solutions to manage complex electrical distribution infrastructure and the power monitoring and control systems that run it. Such solutions can help to maintain uptime and drive down energy costs in a number of ways: power event notification, integrated tenant sub-billing and advisory services[46] to help review the quality of the power and data being collected.

As above, one of the most important measures relating to conservation and energy efficiency at airports is associated with conducting an energy audit. In doing so, the way an airport consumes energy is analysed and it becomes easier to propose measures to improve performance. Likewise, modelling and simulation of energy consumption at airports can be an important factor in lowering consumption.

4.3.4 De-icing

Ice accumulation is a serious safety hazard at airports. Not only for aircraft, but also on runways, taxiways and on aircraft parking stands. De-icing fluid (typically glycol-based fluid) is generally heated and sprayed under pressure to remove ice and snow. There is a large carbon footprint associated with buying and operating the new equipment and the risk of environmental damage from chemical run-off, albeit that the liquid itself, although typically a hydro-carbon, is not a primary GHG source.

Solutions

- **Interseason heat transfer (IHT):** ice can be prevented from forming on the aprons and parking stands by feeding gentle heat into the road surfaces through an array of pipes embedded in the surface. High temperatures can be "harvested" from the road in the summer, reaching nearly 50°C, using the same array of pipes until needed to maintain the surface above freezing in Winter[47]. This technique is called Interseason Heat Transfer (IHT).

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[43] Ortega Alba, S. & Manana, M. (2016) *Energy research in airports: A review.* Energies

[44] NRDC (2015) *Home idle load: Devices wasting huge amounts of electricity when not in active use*. Available at: https://www.nrdc.org/sites/default/files/home-idle-load-IP.pdf (last accessed March 2022)

[45] Green Business Journal (n.d.) *Addressing the data centre energy drain.* Available at: https://greenbusinessjournal.co.uk/addressing-the-data-centre-energy-drain/ (last accessed March 2022)

[46] Hunt, T. (2019) *Across airports, power monitoring and control systems*. Available at: https://blog.se.com/power-management-metering-monitoring-power-quality/2019/10/10/across-airports-power-monitoring-and-control-systems-often-determine-passenger-experience/ (last accessed March 2022)

[47] ICAX (n.d.) *Interseasonal heat transfer*. Available at: https://www.icax.co.uk/interseasonal_heat_transfer.html#:~:text=Interseasonal%20Heat%20Transfer%20provides%20sustainable,buildings%20without%20burning%20fossil%20fuels. (last accessed March 2022)

- **Infrared ray (IR):** IR de-icing technology is proved to be a promising alternative to chemical de-icing due to its high efficiency, safety performance and environmental protection. However, the energy efficiency has not yet been fully researched and understood[48].
- **Closed-loop system:** after the de-icing fluid is sprayed, the waste liquid is channelled from the pads into large subterranean tanks. The fluid-water mixture is then taken to the airport's recycling facility and treated to produce newly useable de-icing fluid. This circular economy approach allows airports to meet up to 70% of its requirements through recycling[49].

Maturity

IHT is process by which thermal energy is collected and balanced between periods of demand and excess supply. This process is proven elsewhere, with a range of applications using aquifers, boreholes or even shallow pits to store and keep thermal energy available whenever needed.

IR de-icing technology is proved to be a promising alternative to chemical de-icing due to its high efficiency, safety performance and environmental protection. However, the energy efficiency has not yet been fully researched and understood.

Airports generally do their de-icing on the apron, where recycling is impractical. Modern airports are often able to recycle de-icing fluid more efficiently than older ones as they are more flexible with space.

Examples

Michigan (MBS) has a sophisticated roof de-icing system of temperature moisture sensors which activate when the temperature falls below the set point while moisture is present.

New York City's (JFK) airport sites an open-ended hangar with IR technology which removes frost, snow and ice with a minimum amount of glycol usage, increasing aircraft throughput and decreasing de-icing time and cost[50].

Munich (MUC) recycles de-icing fluid on site and its operator estimates that its recycling saves 2 million euros per year and reduces carbon emissions by about 15,000 tonnes over the same period[51].

Barriers

As most airport's runways are used intensively every day, it would be difficult to install IHT on main runways without causing disruption. If the intended use was for parking stands, which LHR suffered an issue with during December 2020, it would be practical to install IHT on groups of the parking stands in batches.

Even though IR technology can remove ice, certain regulations still require the use of some glycol anti-icing fluid to be applied.

Recycling of de-icing fluids requires the construction of remote de-icing pads, as well as a recycling plant which collects and recycles the spent fluid. For most older airports, there is rarely the available space to site these special pads and tanks. This would mean huge investment in infrastructure and subsequently the recycling costs would be very high.

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[48] Rosenlof, K. (2013) *Infrared de-icing speeds process and reduces cost.* Available at: https://www.ainonline.com/aviation-news/aviation-international-news/2013-10-02/infrared-de-icing-speeds-process-and-reduces-cost (last accessed March 2022)

[49] Airside (2018) *Developments in de-icing*. Available at: https://www.airsideint.com/issue-article/developments-in-de-icing (last accessed March 2022).

[50] See Footnote 48

[51] See Footnote 49

4.4 Airport Operation Vehicles

Specific airport owned operational vehicles are considered below with respect to progress in development, and potential barriers to, achieving a Zero Carbon version of these vehicles. However, it should first be commented that the overarching "barrier" with respect to Zero Carbon airside vehicles is likely to be the ability for enough Green Energy (electricity or hydrogen) to be provided to serve the growing fleet of EVs operating at the airports.

4.4.1 Fire tenders

Solutions

Provision of a fully electric fire fighting vehicle, although feasible, does have issues which may mean that this particular airport vehicle may be required to operate as a "hybrid" (see **Barriers**). The vehicle itself would be expected to be electrically driven with an on-board internal combustion engine range-extender. The use of a hydrogen fuel cell may allow for the electrical capacity of the vehicle to be increased, although this would only be possible if it could be demonstrated the cell was safe under fire conditions.

However, with improvement in battery technology (or provision of a hydrogen fuel cell), it may still be possible to provide a fully electric fire fighting vehicle within the middle term, and well before the 2040 timeline required for Zero Carbon.

Maturity

From the review of available information, there would appear to be a move for manufacturers to develop electric fire-fighting vehicles, with both Rosenbauer and Oshkosh having developed an "electric" fire engine. The Rosenbauer concept was unveiled in 2019 and in late 2020 it was reported that these fire engines were about to begin real-world customer testing in Berlin, Amsterdam and Dubai. An Oshkosh vehicle was reported to have gone into service in Wisconsin in 2021. However, this report has found no record of how these may have performed.

Figure 4-4: Electric fire-fighting vehicle

Examples

This report has found no examples of the Rosenbauer electric fire engine operating at an airport. The above stated real-world customer testing would appear to relate to service within the cities' municipal fire departments and so would not appear applicable to this study. There is a similar story with the Oshkosh vehicle, although in 2021 there was mention of them developing a Striker Volterra ARRF hybrid vehicle, and this is understood to have undertaken a "tour" of airports in North America.

Barriers

Airport fire tenders are potentially the most "difficult" to replace or upgrade to enable a Zero Carbon approach for airside vehicles. Although, as outlined above, these can be electrically driven, the equipment is safety critical for an airport and so requires reliability of power to not only reach the site of an incident within the requisite response time, but to then be able to fight the fire before returning to base.

To meet their Airport Rescue and Fire Fighting (ARRF) fire category, an airport must have a certain number of vehicles which must be of a defined size depending on the level of fire fighting material required to be carried. Given the cost of ARRF vehicles, and the requirement to always have a certain number in service, these are normally replaced over a period of time rather than all at once, and so there is a potential limit as to how many can be replaced in a specified time frame.

The weight of vehicles and battery weight/power ratios may possibly hinder the larger ARRF vehicles being reliably replaced by a fully electric vehicle.

It should be considered that, unlike other large vehicles which serve the airport (busses, pushback tugs, etc.), these fire tenders cannot be "swapped out" should the electric power not be sufficient to both attend an incident and provide the pump power to deal with the incident. It is therefore possible that, in the case of an airport fire tender, provision of a back-up generator may be required on the vehicle to ensure "continuity of safety margins".

4.4.2 Airport de-icing/snow clearance

Solutions

Airport de-icing/snow clearance is usually undertaken by "specialist" vehicles although these are often based around a modified truck chassis. As such, the ability to provide a Zero Carbon solution for this airport role revolves around the capabilities of developing large electric vehicles in general.

In some instances, snow clearance/de-icing will be undertaken using attachments to tractor type vehicles, with the attached equipment taking its power from the tractor itself. As such, the capability for a Zero Carbon solution for snow clearance using attachments could be linked to the provision of an electric tractor for use within the airport environment.

This report advises it should be possible to develop a Zero Carbon snow clearance vehicle and so cannot see why a target of 2040 for these to be in place would not be achievable. However, to date, these vehicle types do not appear to have been a priority (see **Barriers**).

Maturity

This report has reviewed the available information with regards to current snow-clearance vehicles and are unable to find any examples of manufacturers developing dedicated zero carbon vehicles to fulfil this role on a large scale. There would appear to be smaller vehicles on the market which can be used on roads and potentially apron areas, similar to ramp cleaning vehicles, but none which could be capable of runway clearance.

As stated above, some snow clearance/de-icing can be undertaken with tractors utilising specialist attachments. In such cases there would not be a need for specialist zero carbon vehicles, although it should be noted that the development of large electric tractors would still appear to be in the early stages. Currently there are small electric tractors on the market, but these would require scaling up for use in the airport environment.

Examples

As mentioned above, this report has found no examples of zero carbon large scale snow clearance vehicles.

Barriers

There do not appear to be any significant technological barriers which should hinder the development of a Zero Carbon snow clearance/de-icing vehicle, although battery performance under cold temperature conditions could be an element to consider. It is understood that lithium-ion batteries (as used in electric vehicles) do work under such conditions, but even these can be subject to a reduction in capacity at the lower temperatures.

What could be the main "barrier" may simply be the willingness of manufacturers to invest time and money in the development of specialised vehicles which are utilised for potentially only a short time each year. The development of a new vehicle, or conversion of an existing vehicle, could potentially be expensive and this might therefore put the manufacturers off until such time as technology or the cost of batteries makes this more financially viable.

4.4.3 TTS/APM

Solutions

The Track Transit System (TTS) or Automated People Mover (APM) is usually used to provide a link over longer distances such as between terminals or a terminal and satellite pairing. Their main use is to allow for a mass transit of people which would otherwise need to be transported by bus.

It should be possible that these systems are able to be operated using grid electricity, if they aren't already.

Maturity

TTS/APMs are in evidence at airports around the world and so could be regarded as "mature". In some places, however, they are being replaced by simple fixed links with moving walkways to, it is assumed, reduce the cost of maintenance and power.

Examples

In the UK these systems can be observed at LHR, LGW, STN and BHX (landside) and will soon be operational at LTN (landside).

Barriers

Some of the above examples are cable-pulled TTS and so would require the motors at the stations to have the capacity to be able to move the weight of the vehicles and passengers along the track. On the basis that these would be electric motors served by the grid, this should be possible.

The main "barrier" to achieving Zero Carbon with the use of TTS/APM would therefore be the ability to provide enough Green Electricity to power these "vehicles".

4.4.4 Cars (Operations / Company)

Solutions

This is technically the simplest area to provide Zero Carbon capability. Airports are expected to have a significant number of cars, and these are, in the main, standard vehicles although often with modifications in line with their operational role. In the UK the airside cars are often diesel powered to take advantage of the tax subsidy for Red Diesel.

As these are usually standard vehicles which often will carry a single person, the replacement of medium sized, internal combustion engine vehicles with small electric "SMART" cars could help to reduce CO_2 emissions considerably.

One additional concept to consider would be the use of any electric vehicles not required within the quieter periods, such as overnight, as potential power sources for parts of the terminal. The feasibility of this would depend upon the charging cycles of the vehicles, and when that vehicle may be required to be fully charged for operational purposes, but it may be possible careful planning and collaboration.

Maturity

Electric cars have been in evidence around the world for many years and are coming down in price. With respect to their use within an airport environment, many airports have already moved to these vehicles.

Examples

LHR state in their Heathrow 2.0: Connecting People and Planet document[52] that they plan to have all Zero Carbon vehicles by 2030 as well as support "Team Heathrow" with their transition.

In BHX they report that they have replaced car park buses with electric, as well as all their diesel pool cars with electric versions. As part of this exercise, they have also put in electric vehicle infrastructure.

LCY also have a pledge to have Zero Carbon airside vehicles by 2030, whilst BRS has installed EV charging points both airside and landside and these are currently in use.

Barriers

The main barrier with respect to the replacement of airside cars with Zero Carbon versions is likely to be the cost. Electric vehicles are likely to be more expensive than their internal combustion engine equivalents and so replacement of a whole fleet at one time would probably be too expensive.

Additionally, it is possible that some specialist airside cars, such as the airport operations vehicles complete with radios, lights, signage, etc., may not be available at this time in a Zero Carbon version on the assumption that these are custom built and not purchased and customised afterwards.

And, as mentioned at the start of this section, the key barrier is likely to be the provision of sufficient green energy to service these vehicles.

4.5 Summary

Potential technologies for heating, cooling, ventilation (HVAC), domestic hot water (DHW) generation, lighting and control systems are categorized under the regulated energy section. Proposed solutions as existing and emerging technologies have been recommended to help minimise the energy consumption due to regulated energy systems.

HVAC system source energy should be replaced from natural gas or other fossil fuels to electricity. Heat Pump solutions which use electricity as fuel are the effective way to generate heating and cooling energy. An alternative solution is an Aquifer thermal energy storage (ATES) system which has a similar operation principle. The way they store energy can vary in between ATES and other HP solutions. These readily available technologies have further energy saving

[52] Heathrow Airport Ltd (2022) *Heathrow 2.0* available at https://www.heathrow.com/company/about-heathrow/heathrow-2-0-sustainability-strategy?msclkid=08155a8cb0fc11ec85b444e1ebf91abb (Last accessed March 2022)

potentials with developing compressor technology and refrigerants used in their cycles. Also, the developments in the energy storage have positive impact on HVAC system load/energy reductions and equipment sizes.

Lighting is a rapidly developing technology and LED is the predominant one in this area. Both in new and existing airports LED technology has lower energy consumption, longer operational lifetime and wider range of control options over traditional lighting technologies such as florescence lamps.

Control Systems can save energy through effective operation of building, demand led strategies, time program control, optimization control, seasonal operation and lighting control. Further saving can be enabled integrating smart system utilizing artificial intelligence (AI) or machine learning (ML), connected to all key equipment & systems across the terminals.

Certain strategies and technologies have been identified to minimise the unregulated energy consumption of an airport. These are areas in which the effect is often not realised until a building is occupied and can vary throughout the building life cycle.

- Refrigerants used within HVAC and refrigeration systems should be specified with a low-GWP. Not only to reduce their environmental impact, but as these are readily available and the market is only project to grow. In some equipment cases these options may be less feasible, however with protocols only becoming stricter (phasing out high-GWP alternatives) there is an economical incentive to introduce them sooner (demand will increase over time).
- Making easy-win decisions with cooking equipment includes switching to high-performance alternatives, ensuring regular maintenance, as well as having controls in place to conserve energy from idle equipment.
- Plug load related energy consumption can be reduced by means of server virtualisation or relocation, in addition to considering an energy retrofit programme for equipment such as computers and printers.
- Power monitoring and control systems, as with modelling and simulation of energy consumption, can help to maintain uptime and drive down energy costs by means of identifying inefficiencies and improving building performance.
- Alternatives to traditional de-icing techniques can help minimise emissions from the use of equipment and environmental damage from chemical run-off. Solutions described include IHT to prevent ice forming on the aprons and parking stands, IR technology as a direct alternative to the prevention of ice build-up on aircraft, and a closed-loop system for the recycling of glycol. Recycling of glycol is desirable where feasible, but it is important consider wider implications such as fuel burn in holding on engine power.

A number of airport operational vehicles have been discussed in this section, including fire tenders, de-icing and cars. A number of use cases have been identified, however the main barrier to zero carbon versions of these vehicles is an airport's ability to provide sufficient electricity or hydrogen to serve an EV fleet in operation. Currently, TTS or APM and cars offer the simplest areas in which to provide zero carbon vehicle capability.

5 Scope 2 Emission Technology and Innovation

5.1 Introduction

The GHG Protocol[53] requires organisations to quantify emissions from the generation of acquired and consumed electricity, steam, heat, or cooling. These emissions are termed Scope 2 and are considered an indirect emissions source (along with Scope 3), as the emissions are a consequence of activities of the reporting organisation, but actually occur at sources owned or controlled by another, i.e. owned or controlled by an electricity generator or utility.

This section will cover the technologies available to airports to help them achieve zero Scope 2 emissions. Firstly, the feasibility of removing an airport's reliance on grid electricity through the use of smart or microgrid technology. In addition, an assessment of on-site renewable energy alternatives for their application in an airport environment.

5.2 Grid Electricity

5.2.1 Smart grid & Microgrid technology

Solutions

Smart grids are electricity supply networks that use digital monitoring, communication and automation devices to detect and react to changes in usage. Smart grids are able to re-route power where there is a fault to enable faster restoration of energy supplies.

All microgrids are a type of smart gird; however, not all smart grids are microgrids. A microgrid means distributed generation on small scale rather than centralized generation, such as in the case of an airport. Smart grids and microgrids provide multiple benefits including increased energy efficiency, more reliable and lower cost power[54].

Microgrids are a purpose-built local electrical system that can operate either in parallel with or separate from the utility grid. They can integrate several different local generation resources, including fuel cells and solar photovoltaics, as well as some type of energy storage to allow for flexibility in peak conditions. Microgrids can connect to the grid during normal conditions, while also providing the capability to disconnect and operate independently if needed; at certain times, utility energy costs may be high enough that it becomes cheaper for an airport to generate power itself.

Maturity

Microgrid technology as a whole is very mature and has long been central to meeting sustainability and power reliability challenges. However, airports have only recently begun adopting them.

Examples

[53] GHG Protocol Corporate Accounting and Reporting Standard (Corporate Standard)

[54] Vattenfall (n.d.) *Smart grids and microgrids*. Available at: https://network-solutions.vattenfall.co.uk/services/smart-grids-and-micro-grids (last accessed March 2022)

The John Wayne Airport (JWA) in California was possibly the first of its kind, utilising microgrid technology to help the airport mitigate some of its frequent power quality issues with on-site battery storage and the use of a parking structure already designed for solar panel capacity[55].

More recently, the Pittsburgh International Airport (PIT) took itself completely off the local power grid, establishing its own microgrid based on on-site natural gas wells, as well as solar power[56]. Having its own dedicated power through the microgrid means greater energy reliability at a cheaper cost, as well as minimised risk of an unplanned power outage.

JFK airport is redeveloping its Terminal One using a microgrid and connected microgrid tools which are expected to reduce the total amount of fuel required to operate the terminal by as much as 30%[57].

Barriers

High energy demands can pose a risk, as both airports and public transit operations have potentially large critical electrical loads. This is not an absolute barrier to implementing a microgrid, but it does necessitate very large systems. Both generation and energy storage assets must be of considerable capacity to support a reasonable portion of peak and daily demands.

Microgrids that are able to maximise on solar generation self-consumption are generally more successful models. Airports and public transit operations are essentially 24-hour-a-day operations, meaning larger than average night-time loads, an earlier ramp up at the start of the day, and a later ramp down when compared to commercial buildings. Although they have a large load during solar PV generating times, their load continues to be high for several hours outside this period, necessitating high volumes of stored energy or other significant generation assets.

Most existing facilities installing a microgrid would have a need to continue their operations through construction – at least in part – meaning energy supply during the construction phase presents a challenge.

5.3 On-site Electricity Generation

Airport systems have a high electrical demand due to unique requirements of airport buildings and facilities – such as terminal air conditioning, pre-conditioned air and power at gates, and other systems specific to airports. The reliable provision of electricity at airports is essential for their operation, and renewable energy increases the options available to airports for their energy needs. Not all energy sources have the same technical and operational characteristics and depending on the end usage, the source of renewable energy or the energy mix will differ. This report has therefore considered a number of options for on-site generation.

5.3.1 PV

Solutions

Airports make an ideal location for solar photovoltaics (PV), with wide open spaces on the ground and large terminal buildings on which to build them. Solar arrays can be mounted on buildings and structures (e.g. parking garages) or ground-mounted on supporting poles or racks. The

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[55] Howell, M. (n.d.) *Harnessing the power of microgrids for resilient airports*. (last accessed March 2022)

[56] Markind, D. (2021) New 'Microgrid' at Pittsburgh International Airport. Available at: https://www.forbes.com/sites/danielmarkind/2021/08/04/will-pittsburgh-international-airports-microgrid-show-how-america-can-build-infrastructure/?sh=7e1558b77a48 (last accessed March 2022)

[57] Layan, V. (2021) Why airports turn to microgrids for sustainability. Available at: https://blog.se.com/transportation/2021/03/16/why-airports-turn-to-microgrids-for-sustainability/ (last accessed March 2022)

systems require very little maintenance, make no noise, and operate without moving parts and without producing air pollution or greenhouse gases.

Maturity

Application in the aviation sector is proven, with over 100 airports worldwide making use of solar panels to produce ‘clean’ energy for powering the terminal(s)[58].

The high upfront cost of PV is often a barrier to implementation, however mid- to long-term benefits outweigh commercial PV panel cost. The average cost of producing PV energy is far lower at 5p/kWh vs. 11-15p/kWh for grid electricity[59]. Feed-in-tariffs (FIT) also provide businesses the opportunity to sell excess amounts of renewable energy back to the national grid, although it is expected that all power will be used.

Examples

Cochin International Airport (CIA) in the state of Kerala – a medium-sized airport handling 7.7 million PAX – was the first in the world to be completely powered by solar energy. The airport generates 52,000 kWh/day whilst only consuming 48,000[60], with the excess being sold to the general grid.

Melbourne (MEL) sites a PV array across a proposed 150,000 m^2, having capitalised on flight cancellations caused by COVID-19 to install the 30,000 solar panels. The solar farm does not require major airport operational interface as the system has been designed to have minimal impact on aviation operations. The energy generated is expected to supply between 15-20% of the airport’s annual electricity consumption, providing enough power for the site’s four passenger terminals[61].

Austria’s largest solar PV plant is planned at the airport of its capital, Vienna (VIA). The project will cover a surface area of 24 hectares and is predicted to cover a third of the airport’s electricity consumption.

A strategy for PV is generally already in place for MAN and being considered for STN and East Midlands (EMA)[62]. The preference is for leasing land offsite and procuring power under a power purchase agreement (PPA), i.e. not investing in PV as a business.

Barriers

Airports need to control airside access to keep contractors clear of aircraft and vehicles to enable maintenance. Airports tends to cease or reduce operations at night, meaning night-time maintenance is often a suitable solution.

Glint and glare from solar panels pose risks to airport’s air traffic control and pilots. However, modern PV typically contains anti-reflective surfaces, but this does not eliminate the issue entirely.

Cost is seen as a barrier in some cases, however a bigger factor for airports to consider is land use. Siting a PV farm requires a complex assessment of potential locations, taking into

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[58] AIR (2020) *Solar power: the future of airport infrastructure*. Available at: https://airport.nridigital.com/air_nov20/solar_power_airports (last accessed March 2022)

[59] CAT (n.d.) *Photovoltaic (PV) Solar Panels*. Available at: https://cat.org.uk/info-resources/free-information-service/energy/solar-photovoltaic/ (last accessed March 2022)

[60] CIAL (2018) *Kochi airport becomes world’s first to completely operate on solar power*. Available at: https://cial.aero/pressroom/newsdetails.aspx?news_id=360 (last accessed March 2022)

[61] Airport review (2021) *The sun shines on Melbourne’s Airport’s new solar farm.* Available at: https://www.internationalairportreview.com/article/146676/melbourne-airport-solar-farm/ (last accessed March 2022)

[62] See Footnote 14

consideration: size, proximity to substations, planning and ownership (often an issue with site boundaries), operational impact, environment and ecology, aerodrome safeguarding and master planning. This can significantly limit available and/or viable options. Expansion can also pose an issue as land that is unused today may well be earmarked for other uses in future.

5.3.2 Wind

Solutions

Wind energy is potentially a very useful source of renewable energy for airports, due to the fact airports typically contain large unoccupied areas. Traditional wind turbines are oriented on a horizontal axis (HAWT), with a vertical propeller facing the wind horizontally. HAWTs provide maximum efficiency of energy generation when placed in the wind direction and with consistent wind flow.

Less common is the vertical axis wind turbine (VAWT) which spins around a vertical axis and faces the wind vertically. VAWTs can receive and process wind from any direction, therefore suiting areas with inconsistent wind patterns.

VAWTs appear less productive than HAWTs due to lower operational speed and subsequent productivity, but they are more easily installed, equipped with lower-speed blades and are permissible where taller structures are prohibited[63]. As VAWTs are smaller and lower to the ground, they are more practical to install on a level base, such as the ground or the top of a building.

Maturity

The coexistence of the aviation and the wind sectors has been challenging. In the UK, both are critical to economic growth. However, the positioning of aviation infrastructure and wind infrastructure will continue to be a challenge. Further research about safe distances to wind turbines is still required, although some guidance is available and needs to be considered[64].

Examples

La Palma Airport (SPC) in Spain sites two 46m turbines 420 metres east of the main runway. These were constructed in 2002 and are stated as representing the main energy source for the airport.

Similarly, EMA installed two 45m turbines in 2012 approximately 1.3km south of the main runway.

Other airports with wind turbines in the immediate vicinity include Galapagos, Liverpool, Amsterdam, Copenhagen, Lubeck, Bristol, Lydd, Newcastle, Honolulu and Boston.

Barriers

Airports generally have severe limitations on the placement of obstacles that may restrict the practical location of wind turbines near the airport as the turbine is regarded as a physical barrier and possible interference to radio navigation systems. Aircraft departure and arrival routes also have protected zones around them that may be compromised.

In addition, rotating blades of wind turbines create turbulence downwind which can be dangerous for small and light aircraft[65].

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[63] Arcadia (2017) *VAWT advantages & disadvantages*. Available at: https://blog.arcadia.com/vertical-axis-wind-turbines-advantages-disadvantages/ (last accessed March 2022)

[64] AIR (2020) *Aviation and wind farms: working together for a safer future*. Available at: https://airport.nridigital.com/air_jul20/aviation_wind_turbines (last accessed March 2022)

[65] See Footnote 64

Aviation stakeholders expect wind turbines to be marked with lights as per international requirements, but the wind sector is very conscious that local communities find the lights a nuisance[66]. Automatic detection systems that activate obstacle lights are probably the best technological solution to this issue today.

5.3.3 Hydrogen

Solutions

Hydrogen is a clean source of energy with extensive applications in the aerospace industry. Used in a fuel cell, hydrogen combines with oxygen from the air to produce electricity, with water as the only by-product. Alternatively, fuel cells can also be configured for combined heat and power (CHP) systems. New CHP systems can operate off natural gas to begin with and hydrogen can be gradually blended-in up to 40% or switched to 100% when available[67].

Fuel cell technologies are scalable and flexible, allowing for application throughout an airport, for any size power need[68]. Hydrogen can power a variety of service and logistics at an airport including ground support needs, communications networks, computer systems and other applications (e.g. runway lighting, automatic walkways, retail etc.).

Fuel cells can offer significantly lower, or zero emissions compared to traditional combustion engines, with the ability to offer climate-neutral fuel with 100% green hydrogen for CHP.

Maturity

Hydrogen production is currently a low-efficiency proposition. The energy value of hydrogen is approximately 60-70% of the total electricity used to produce it, meaning that the renewable power required to produce liquid hydrogen is immense.

Hydrogen can only remain a niche aviation fuel in the mid-term due to this limitation, with alternative technologies such as hybridized engines and sustainable biofuels perhaps representing more viable pathways to low-carbon aviation in the short-term.

The current maturity of hydrogen has prevented its consideration for anything other than commuter or regional air travel.

Examples

Leeds Bradford (LBA) is set to become the UK's first regional airport to produce its own hydrogen which will power the airport's fleet of vehicles, as well as the next generation of hydrogen-powered ground-handling vehicles.

Similarly, Teesside Airport (MME) was announced as one of the UK's first pilot areas to test hydrogen vehicles, which will see commercial and support vehicles fitted with 100% hydrogen zero emission engines.

Despite not currently being considered for generation onsite, there are potential plans post-2030 for MAN to become an industrial cluster hydrogen from 2030 onwards.

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[66] Young, A. (2018) *The dangerous relationship between wind turbines and aviation*. Available at: https://to70.com/dangerous-relationship-wind-turbines-aviation/ (last accessed March 2022)

[67] IRENA (2018) *Hydrogen from renewable power: technology outlook for the energy transition*. Available at: https://www.irena.org/-/media/files/irena/agency/publication/2018/sep/irena_hydrogen_from_renewable_power_2018.pdf (last accessed March 2022)

[68] FCHEA (n.d.) *Fuel cells and airport applications*. Available at: https://www.californiahydrogen.org/wp-content/uploads/files/Airports.pdf (last accessed March 2022)

Barriers

There is current lack of clear regulatory frameworks to allow projects to understand their cost and revenue basis, making it difficult for commercial projects to reach a financial investment decision[69]. However, the current cost for a unit of power from hydrogen fuel cells is still shown to be greater than other energy sources[70], whilst hydrogen engine CHP systems are generally shown to be more robust and cheaper than fuel cells.

Airports currently lack the necessary infrastructure to support hydrogen, as well as awaiting further technological advances to help lower the associated costs, storage and transportation requirements. There is however a huge future energy requirement consideration as the reliance on fossil fuels must inevitably decrease. The production of hydrogen at scale will remain the main challenge to be addressed.

5.3.4 Biogas

Solutions

Anaerobic digestion (AD) is the natural breakdown of organic matter, in the absence of oxygen, which place in a plant called a digester. This process generates biogas and a bio-fertiliser called digestate. The ‘green gas’ biogas generated by the AD process can be used for electricity and power or upgraded into biomethane, sometimes called renewable natural gas.

By treating food and other organic waste and transforming it into biogas, AD can help establish a low carbon circular economy within an airport, saving both money and carbon emissions.

Maturity

AD is a mature, readily available technology that stands first in the waste management hierarchy to treat waste that cannot be reduced or reused – ahead of composting and energy recovery.

Examples

LHR has set itself a net zero waste policy and sends some of its food waste to AD, having just entered a partnership with Engie to use biomethane across all its terminal until 2022[71].

LGW became the first airport in the world to convert waste into energy, in turn saving £1k per day in energy costs[72]. The waste management plant turns airport waste such as food and packaging into energy onsite.

Airport authority Hong Kong has been collecting food waste for recycling since 2003, with most of it being sent for conversion into biogas. Its collection network now spans 17 airport business partners including restaurants and lounges operating in terminal buildings, as well as airline catering companies, hotels and cargo terminals[73].

Barriers

A barrier to the generation of biogas on-site is the low commercial value which it offers. The return on investment can however be improved by making a product of higher value; one method of improving the return may be to arrest AD midway, produce what are known as volatile fatty acids,

[69] See Footnote 67

[70] BEIS (2021) *Hydrogen production cost 2021*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011506/Hydrogen_Production_Costs_2021.pdf (last accessed March 2022)

[71] Bia, J. (2020) *Green energy*. Available at: https://airport-world.com/green-energy (last accessed March 2022)

[72] See Footnote 71

[73] See Footnote 71

and then catalytically upgrade them to hydrocarbon fuels[74]. Investments into processing low-value waste to produce low-value biogas could therefore be repurposed to result in additional value from sustainable aviation fuels (SAF).

5.4 Summary

Microgrids can offer energy with greater efficiency and with more reliable provision. However, in the context of airports, there are only very recent examples of their implementation and only one which operates completely independently. The high and essentially 24-hour-a-day energy demand of airports also pose a risk as very large systems are required, requiring generation and energy storage assets of significant capacity. In each case, energy at a reduced cost was demonstrated, but the use of microgrid technology necessitates significant on-site electricity generation. Electricity consumption and reliance on grid electricity is continuing to grow for most airports[75], therefore microgrids should in most cases be viewed as a long-term ambition.

Similarly, renewable energy sources can increase the reliability of energy provision to airports. On-site generation options have a range of barriers to their use and there is therefore no one-size-fits-all approach given the complexities of different airports. The key considerations for each have been summarised below:

- PV
  - Proven application worldwide; strong mid- to long-term commercial benefits;
  - Requires robust maintenance strategy; complex land use assessment required (may limit available and/or viable options drastically); future expansion limitations;
  - *Assessments should be carried out and PV considered now*
- Wind
  - Availability of horizontal or vertical turbines based on site limitations;
  - Limitations of placement due to protected zones; creation of turbulence can be dangerous for small aircraft; typically only small-scale application proven;
  - *Should be considered for viability, however likely a mid-term ambition*
- Hydrogen
  - Fuel cells are scalable and flexible, offering application for any size power need; production at scale will become a future necessity;
  - Currently low-efficiency proposition and will remain a niche aviation fuel in the mid-term due to this; lack of regulatory frameworks for commercial awareness; airports lack the necessary infrastructure to support hydrogen
  - *Infrastructure should be addressed in short- to medium term to enable future use*
- Biogas
  - Mature and readily available technology to treat waste; potential for the production of hydrocarbon fuels (type of SAF) from biogas
  - *Should be reviewed against other waste strategies, however future SAF use is promising*

[74] US Dept. of Energy (2021) *Sustainable aviation fuel: review of technical pathways*. Available at: https://www.energy.gov/sites/prod/files/2020/09/f78/beto-sust-aviation-fuel-sep-2020.pdf (last accessed March 2022)

[75] Energie (n.d.) *Optimize electricity usage in airports.* Available at: https://energie-industrie.com/media/Presentation/airport_blog_510345.pdf (Last accessed March 2022)

6 Scope 3 Emission Technology and Innovation

6.1 Introduction

Scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organisation (airports in this case), but that the organisation indirectly impacts in its value chain. Within the context of this study which focusses on the feasibility of airports to have zero carbon operations, Scope 3 emissions is limited to operations occurring at the airport, rather than journeys to and from the airport, such as aircraft flight segments or surface access journeys. Whilst aircraft flight operations are excluded from this study, aircraft operations on the ground at the airport are impacted by the technological choices made for flight and so there is some element of crossover and commonality.

This section therefore covers aircraft ground operations, on-airport vehicle operations by users such as airlines, ground handlers and control authorities (predominantly airside) and then 3rd party energy usage and generation (which will be similar in technological terms to Scope 2 emission technology and innovations covered in the previous section).

6.2 Aircraft Related Ground Emissions

6.2.1 Aircraft Taxi (and hold)

Solutions

The introduction of Sustainable Aviation Fuels (SAF) to aircraft fleets will help reduce carbon emissions during taxiing to and from the runway, as well as holding prior to departure. Improvements in emissions can also be provided by “single” or “limited” engine taxiing, by which only one engine (or a reduced number for larger aircraft) is used to power the aircraft in this phase. These will not however provide a zero emissions solution and so alternative methods would be required to meet this aim.

Aircraft taxiing is probably the most “straightforward” to address with respect to a Zero Carbon solution. An aircraft on departure can be pushed back by a “zero carbon method” (electric tug, “TaxiBot”, aircraft wheel electric motor, dolly system, etc.) and then be towed/driven to the hold/detach point adjacent to the runway without having to utilise its engines. The same could be applied on arrival with the aircraft met by the applicable towing method and then towed to stand without requirement for engines. Although relatively simple in concept the impacts on the overall airport may make this unfeasible (see **Barriers**). It should also be noted that aircraft engines will require both warm up and cool down periods – a process which would normally occur during taxiing under power.

With respect to an aircraft at a holding point, this is more difficult to address. At this point the aircraft is preparing for departure and so requires the engines to be spooled up and running at operational levels ready for taxi to the runway and application of take-off power. As such reduction or elimination of carbon emissions at this point would probably revolve around minimising the duration of time that the aircraft is in this phase of ground operation. If considered in conjunction with potential towing of aircraft to this point, this minimisation may include not starting aircraft engines until such time as they are about to move to the runway, although the “warm up” requirements may make this unfeasible (see **Barriers**).

For both taxiing and holding of aircraft effective ground traffic management could be used to minimise both segments of the aircraft movement on the ground. If an aircraft is able to taxi at a constant speed, and avoid having to hold prior to accessing the runway, then emissions could be greatly reduced for both phases. However, such management would be very difficult to achieve at a major airport with requirements for sequencing and wake vortex considerations.

The use of “zero carbon methods” to provide aircraft taxiing assistance is perfectly feasible and is understood to being currently tested for departing Lufthansa operation at Frankfurt. However, the use of these methods is unlikely to eliminate all carbon emissions from the aircraft taxiing phase of movement as operational requirements at major airports will require some taxing after arrival before a tug could be attached, and some “warm up” time of the engines prior to departure which may well be undertaken in the latter stages of “towing” to the runway hold.

Maturity

SAF is mature with respect to development and production but is still under test with respect to use in aircraft blended with conventional aviation fuel. To date tests appear to have been successful.

The supply of Zero carbon aircraft tugs is a relatively mature market, with several manufacturers having developed and sold electric versions of their tugs. Having said that, roll out of electric aircraft tugs would appear to have been focussed in the last two years.

At least one manufacturer, Wheeltug, has developed an electric motor attached to the aircraft front wheel which many airlines are understood to have shown an interest in. This is predominantly for use in the vicinity of the terminal – for pushback and associated manoeuvres – due to the low taxi speed, but could possibly be used for a larger proportion of the taxi, should conditions permit.

The “dolly” tow system is understood to still only be a concept and may potentially only be relevant for smaller airports if implemented due to the requirement for capital works in installing the required equipment at the airports.

Examples

Zero Carbon electric aircraft tugs are evident at airports around the world. In Munich they were introduced in January 2021 and in Frankfurt Lufthansa LEOS has just announced that they will be the launch customer for the Goldhofer Phoenix E tug

With respect to the Wheeltug, reports indicate that these were due to go into service at the end of 2021. However, the pandemic may have affected this roll out as operators look to save costs.

With respect to the “tow dolly” system, a company in Oklahoma (ATS World Wide) has invented an automated taxi system using a dolly system which utilises an underground channel system.

It is understood that the TaxiBot electric tug is being tested by Lufthansa for departing aircraft taxi movements at Frankfurt Airport. It is not clear whether this technology is also be used for arriving aircraft. This report has not found examples of the other technologies being used to reduce carbon emissions from taxiing to the runway, or for aircraft holding positions.

EasyJet have done analysis on towing for the A320 aircraft family, however, they have not been able to make a justifiable business case for their introduction, even at a weight of 200Kg. Furthermore, the system weight would have to increase and decrease for different sized aircraft, a additional negative. EasyJet also struggled to make the economics case with their high utilisation operating model. These systems may be better suited to aircraft that operate sub 1-hour sectors.

Barriers

Although the development and tests with respect to the use of SAF appear to be going well, one of the biggest barriers will be the availability of SAF in the future. Currently the SAF is blended with conventional aviation fuel, but the aim is to be able to operate with 100% SAF to get maximum CO_2 emission reduction. However, should this goal be reached, there will then be a question as to whether enough SAF can be produced to meet the needs of the aviation industry.

Although utilising electric tugs; “taxibots”; electrically powered wheels; or a dolly system would facilitate a “zero carbon” aircraft taxi, these would all have impacts upon the operation and capacity of the airport at which they are implemented.

Although the departure process may be relatively straightforward (pushback the aircraft and tow it to a hold/detach point), the process on arrival of the aircraft would not be so simple and would likely impact capacity. As an illustration, an arriving aircraft would have to stop on leaving the runway to allow the “towing method” to be attached. As sufficient distance would be required between arrivals to allow for such attachment, this may reduce the runway and taxiway capacities. The taxiing speed may also be slower with a “towed method”, again reducing airport capacity, although it is understood that the TaxiBot under test at Frankfurt Airport can operate at “aircraft taxi speed”.

The use of an electric motor to power the aircraft wheels could address the “attachment time” issue but airlines may see this as extraneous weight that they’d prefer not to be carrying in order to simply address one small part of an aircraft’s journey. To meet the zero-carbon aim, these motors would also require battery power – further weight – and may not provide the taxiing speed required to maintain capacity of the taxiway system. Having said that, it is reported that the Wheeltug system is around 200kg and it is anticipated that the savings made in fuel required for taxiing, etc. should compensate for the additional weight.

The provision of a “dolly system” would be possible but would require significant retrofit of an airport’s taxiway system and aprons, a capital expense which is unlikely to be accepted by the airport operator.

One other point with respect to taxing is that aircraft engines will still require warm up and cool down periods and so, even with a “tug” in place, some level of engine operation would be required.

With respect to zero carbon emissions at the hold point, as with the taxiing, this is only possible if engines are not operational in this phase of the aircraft ground movement. However, the operation of the aircraft engines needs to be checked prior to the point at which the aircraft enters the runway. This forms part of the check list performed by the pilots, usually whilst taxiing and so, if aircraft were towed to the runway hold, all the engine start up and testing would have to be performed at this point

Looking to the future, the implementation of electric or hydrogen powered aircraft would hopefully allow for an airport to achieve zero carbon emissions from the ground movement of aircraft. However, this is expected to be a relatively slow process as electric aircraft currently do not have the payload range that would be required to serve existing markets; and hydrogen aircraft is a relatively untested technology which, although expected to be able to serve the markets currently operated, will require the development of new airframes and other new technologies. And, even when these new aircraft achieve certification, it will take decades to be able to replace the legacy aircraft fleets.

6.2.2 Aircraft Engine Testing

Solutions

Aircraft engine testing is usually performed in a dedicated area/facility and is undertaken when maintenance has been performed on the aircraft or engine. The location and design of the testing facility is normally based upon minimising the noise impact of the testing on the surrounding area as opposed to other environmental impacts.

Achievement of Zero Carbon for this particular aspect of airport operation is potentially the most difficult. Conventional aircraft engines will require a fuel source to power the engine during testing and so, unless the aircraft engine is electric or operates using hydrogen or another “non-carbon fuel”, there will be a CO_2 emission. Even an aircraft using 100% Sustainable Aviation Fuel (SAF) will have a CO_2 output, although greatly reduced from Jet A1

Maturity

The development of SAF fuels is in its early days with tests, including in-flight, still ongoing. Although this will not provide a zero carbon solution, it should at least reduce CO_2 emissions.

The Fly Zero Project, funded by the UK Government, has proposed that a liquid hydrogen aircraft could be the future of zero carbon aviation. However, this is currently a “concept aircraft fleet” and so is unlikely to be available in the medium term.

Examples

Any airports in the world which undertake some form of aircraft maintenance work would be expected to require aircraft engine testing to be performed, whether this be undertaken in a specialist facility or on stand.

This report has found no specific examples of “zero carbon” engine test facilities.

Barriers

To date no flights have been undertaken powered purely with SAF, although the proportion of SAF allowed within the blended aviation fuel has been increased (currently around 50%). Should aircraft be cleared to operate on 100% SAF, it is estimated that this could reduce CO_2 emissions by around 75%. However, there will then be a question as to whether there is the capability or capacity to produce enough SAF to serve all aircraft currently flying.

As mentioned above, the Fly Zero Project proposed that a zero-carbon solution could be provided by the introduction aircraft powered by liquid hydrogen. Although positive, this is expected to require the development of new airframes and engines to accommodate the hydrogen, and so these would not be available within the next 10 years. It is estimated that hydrogen aircraft would not enter service until the mid-2030s and, even as they come on stream, this will not be in numbers to replace conventional fuel burning aircraft for possibly 10-20 years after that.

The most significant barrier, as alluded to above, is that engine testing requires running of the engine in question and thus requires fuel. Although the industry is looking at the development of hydrogen burning engines, these are unlikely to come on stream in any great numbers before 2040. In the meantime the industry is also putting energy into the development of SAFs which will, hopefully, in time replace fossil fuels and allow a reduction in CO_2 emissions. But it must be recognised that this will not be a “zero emissions” solution.

6.2.3 On-Stand Power and Air (Contact and remote)

Solutions

Most airports look to provide power to aircraft when on stand to help minimise the requirement for the aircraft to use their Auxiliary Power Unit (APU). This is usually provided by Fixed Electric Ground Power (FEGP) which can be either ground mounted (usually with some form of concertina type framework to protect the cabling); or mounted on the Passenger Boarding Bridge (PBB).

Figure 6-1: FEGP system

Where it is not possible to provide an FEGP, usually due to difficulties in getting power to the stand, a mobile GPU unit is often used. These are often diesel generators providing the electricity, with the view that this is still an improvement on the use of the aircraft APU. However, an electric GPU unit for use with wide body aircraft is now in testing at Schiphol Airport which, if successful, will allow a reduction in the requirement for the diesel GPU. There are currently electric GPU units in service which can be used on narrow body aircraft.

As with Ground Power, Pre-conditioned air (PCA) can also be supplied to the aircraft to avoid the use of the aircraft APU. Again, this can be fixed on the ground or PBB, and mobile units are also available, although this report has not identified an electric version.

Maturity

Fixed Ground power is very mature and most major airports will provided this service on their aircraft stands, where possible. Due to cost and complexity some airports are only able to provide FEGP to the contact stands, with remote stands having to rely on mobile units.

The provision of electric mobile GPU units is less advanced but, as mentioned above, there are models on the market which have been proven to serve narrowbody aircraft, and models being tested which will hopefully be able to serve the wide body aircraft power requirements.

Figure 6-2: Electric mobile GPU unit

With respect to PCA, fixed units are also very mature, with most airports (particularly those with PBBs) being able to provide this service on contact stands. As yet this report has not identified an electric version of the mobile PCA equipment but believe these should be possible to develop.

It should be noted that many airports include in their Conditions of Use that aircraft must not use their APU on stand and so, if power or PCA is required, must use the GPU/PCA provided by the airport or Ground handler.

Examples

FEGP and PCA units are very common at all major airports and so no specific examples are provided here. With respect to the mobile electric GPU units, Schiphol would appear to use these for narrow body aircraft and are testing them on wide body aircraft (initially cargo). This report has not found any examples being used in the UK, but there is no reason why they may not already be in use.

Barriers

The most significant barrier for the installation of FEGP is the logistics of getting the electrical supply to the relevant stand, and then to the aircraft itself. As electricity is already provided to the terminal area, provision of FEGP at contact stands is more straightforward, with remote aprons mor commonly served by mobile units. A potential barrier for zero carbon is therefore the replacement of the mobile diesel generators providing power and PCA with electric versions.

Even with the provision of FEGP/PCA and electric mobile units, the other main barrier with respect to providing zero carbon could be the electricity generation source. Without provision of a green energy source the issue is simply shifted from the airside area to the power generation station.

6.2.4 Aircraft line maintenance

Line maintenance consists of inspection of aircraft and the carrying out of running repairs for regular replacement items. The current maintenance model is broken, with reactive maintenance being incredibly inefficient and creating costly service disruptions.

Solutions

The predictive power of AI could contribute to a step change in airline efficiency and profitability by removing maintenance-caused disruption from day-to-day operations. Additionally, could help to achieve a leaner operational strategy by maximising the benefit of all maintenance carried out.

Maturity

Many airlines have in recent years benefited from the use of AI in engine health monitoring (EHM) and have embarked on program optimisation campaigns designed to contain costs and increase aircraft reliability. However, relatively few have succeeded in early attempts to apply AI to the more complex component and line maintenance environments.

Examples

Leading European low-cost carrier easyJet successfully deployed a fleet maintenance planning platform. Since introducing the system, easyJet has not only been able to improve aircraft utilisation, but also increase the cost efficiency of the carrier’s maintenance activities.

Barriers

COVID-19 has pushed airlines towards severe and pro-longed cash-conserving measures; therefore, it is reasonable to assume that investments into predictive maintenance may be pushed back.

The airlines already exploring the potential of predictive maintenance have found their attempts plagued by inadequate sponsorship at the executive level, data fragmentation and usability issues, and a range of downstream implementation challenges.

6.2.5 Waste

Aircraft waste can be categorised by cabin waste (including catering and cleaning waste) and wastewater.

Solutions

Developing an airline waste resource efficiency strategy is one of the best means of establishing an airline's aims, approach and reducing the impact and cost of cabin waste. An agreed strategy provides a top-down approach to ensure all business units are working to an agreed plan and a framework is provided to ensure that the waste hierarchy is applied correctly by those treating or disposing of waste.

Recent research has shown that by converting "wet waste" or wastewater materials into biofuel, the aviation industry could massively reduce its carbon footprint. Unlike production methods for other biofuels like ethanol or biodiesel, the new approach uses a chemical process to remove excess water from the wastewater.

Maturity

A clear, defined strategy that is owned by all parts of the business will enable an airline to deliver zero cabin waste.

Current research into wastewater biofuels is at very early stages, having only tested a few hundred millilitres of their sustainable fuel.

Examples

Air New Zealand (NZ) reports annually on recycling performance at Auckland (AKL) ground sites and has set a target of 85% recycling by 2018 and zero waste to landfill by 2020.

British Airways (BA) has committed to improving resource efficiency through waste minimisation, increased re-use and recycling and reduced reliance on landfill for disposal. The airline has published a target to recycle 50% of waste generated through its ground operations at LHR and LGW.

Barriers

Buy in across a company is critical and a strategy must ensure that all departments can see and measure the benefits of dealing with waste properly. Waste strategies are typically only short to medium term solutions and will require reviewing over time, in addition to having a high cost associated with them.

6.3 3rd Party Airside Vehicles

Specific airport operational vehicles operated by 3rd Parties are considered below, with respect to progress towards Zero Carbon. However, as commented in Section 4.4, the overarching "barrier" with respect to Zero Carbon airside vehicles is likely to be the ability for enough Green Energy (electricity or hydrogen) to be provided to serve the growing fleet of EVs operating at the airports.

As mentioned in Section 4.4.4, consideration could be given to the use of any electric vehicles not required within the quieter periods, such as overnight, as potential power sources for parts of the terminal or, in this case, potentially the 3rd Party Operators' facilities. The feasibility of this would depend upon the charging cycles of the vehicles, and when that vehicle may be required to be fully charged for operational purposes, but it may be possible careful planning and collaboration.

6.3.1 Baggage tugs

Solutions

Baggage Tugs are small, relatively simple, vehicles which have the sole purpose of towing baggage carts and dollies, and even other small pieces of equipment (Ground Power, air-start units, towable steps, etc.)

The size of these can vary depending upon what they are expected to tow, but they are often single person vehicles. These used to be run on fossil fuels but, as stated below, the replacement of these vehicles is quite advanced.

Figure 6-3: Baggage tug

Maturity

Electric "baggage" tugs have been in evidence around the world for many years and there are many versions on the market.

Examples

It is likely that electric baggage tugs will be in evidence at all of the 10 largest UK airports, as well as most of the other main airports around the world.

Barriers

The main barrier with respect to the replacement of baggage tugs is likely to cost, with regards to replacing a whole fleet of tug. However, this is unlikely to actually stop the changeover, just slow it down as diesel vehicles at the end of their life are replaced by electric vehicles.

On the assumption that suitable power can be provided to the airport, the provision of 100% electric baggage tugs by 2040 should be achievable.

6.3.2 Baggage loaders

Solutions

Baggage loading devices can come in two main forms: mobile belt loader used to load loose baggage or cargo; and Hi-loaders which are utilised to load ULD devices. The size and operational characteristics of these vehicles could mean that these have a different timeline for providing a Zero Carbon outlook.

Maturity

Electric belt loaders, whether self-propelled or towed, have been developed by a range of manufacturers and so are relatively mature within the market.

Figure 6-4: Electric belt loader

Electric ULD/Cargo Loaders are less prevalent, in so much as this report has only found one manufacturer (JBT), but they have a range of e-loaders which would indicate that this is also a relatively mature market.

Figure 6-5: Electric ULD/cargo loader

Examples

It is likely that electric baggage belt loaders will be in evidence at all of the 10 largest UK airports, as well as most of the other main airports around the world.

The electric hi-loaders may be observed at less airports, but it is expected that they will become more common as the ground handlers look to become more eco-friendly and as old equipment reaches end of life and is replaced.

Barriers

As with other vehicles, it would appear that there are electric versions available for baggage loading. The barriers to uptake would therefore likely be cost, and the life span of any existing vehicles, on the basis that an operator may wish to wait until that time to replace a fuel driven vehicle with an electric version.

6.3.3 Cargo handling

Solutions

Cargo Tugs are usually larger than baggage tugs, but still relatively simple, and have the sole purpose of towing cargo dollies, as well as other small pieces of equipment (Ground Power, air-start units, etc.)

The size of these can vary depending upon what they are expected to tow, but they are often single person vehicles. These used to be run on fossil fuels but, as stated below, the replacement of these vehicles is quite advanced.

As well as tugs, cargo handling can involve the use of ULD transporter vehicles - small self-propelled roller bed vehicles which are used to move a ULD or pallet from dollies to a hi-lift vehicle – and cargo hi loader vehicles.

Figure 6-6: ULD transporter vehicles

Maturity

Electric "cargo" tugs have been in evidence around the world for many years and there are many versions on the market.

With respect to the ULD transport vehicles and the Hi-loader these are less prevalent, but there are examples of fully electric versions on the market.

Examples

It is likely that electric cargo tugs are likely be in evidence at all of the 10 largest UK airports, as well as most of the other main airports around the world.

The electric hi-loaders may be observed at less airports, but it is expected that they will become more common as the ground handlers look to become more eco-friendly and as old equipment reaches end of life and is replaced.

Barriers

The main barrier with respect to the replacement of cargo tugs is likely to cost, although there are less of these required than baggage tugs. However, this is unlikely to actually stop the changeover, just slow it down as diesel vehicles at the end of their life are replaced by electric vehicles.

On the assumption that suitable power can be provided to the airport, the provision of 100% electric cargo tugs by 2040 should be achievable.

With respect to the ULD Transporters and Hi-Loaders, these are already on the market and it should therefore be possible to have a fully zero emission fleet by 2040.

6.3.4 Catering trucks

Solutions

Aircraft catering trucks are usually in the form of a medium size lorry with a scissor lift attached to the rear flatbed to allow the rear of the truck to be raised to aircraft door height.

Given these are of a similar form to standard HGVs, the move of these to Zero Carbon is likely to be in line with the progress of converting standard lorries, although possibly quicker given there are less specialised catering lorries.

Maturity

In 2019 it was reported that end-users preferred hybrid airport catering trucks as these provided a flexibility in fuel consumption and engine robustness. There was however recognition that this may well change given environmental concerns, and that manufacturers would put more effort into developing electric catering trucks. A review of available information would indicate that, as yet, there are not many manufacturers of electric only catering vehicles for use at airports.

Figure 6-7: Hybrid catering truck

Examples

This report has found no examples of the use of Zero Carbon catering trucks.

Barriers

As stated above, the current barrier to a wider roll out of Zero Carbon catering vehicles would appear to be the wishes of the end-user. The use of a hybrid would appear to provide them with comfort as to reliability and power for the vehicle, although they do appear to recognise that an electric vehicle would help to meet "Green" targets.

6.3.5 Re-fuelling trucks

Solutions

Aircraft refuelling trucks are usually in the form of a medium sized HGV, either with a fixed fuel tank or towing a tank trailer or trailers. Although a relatively simple vehicle, there would appear to be very little interest in developing a Zero Carbon version.

Maturity

From available information, it would appear that the development of a Zero Carbon refuelling truck is not a very mature market. This report has found only one mention of an electric aircraft refuelling vehicle which was developed by a specialist manufacturer, Gaussin, in 2020.

Figure 6-8: Electric aircraft refuelling vehicle

Examples

As stated above, this report has found only one example of an electric refuelling vehicle. This was developed by Gaussin and, in 2020, it was reported that the prototype would be tested at the Airbus site in Toulouse

Barriers

One potential barrier to the development of an electric aircraft refuelling vehicle may be electrical safety in the vicinity of large quantities of fuel. Under current operations, the refuelling vehicle and aircraft are required to be earthed to ensure no build-up of static electricity causes sparks. It is therefore possible that there is a reticence to develop an electric refuelling vehicle due to the potential risks.

However, in line with other specialist vehicles, there should not be a reason why a Zero Carbon vehicle should not be possible.

6.3.6 Aircraft tugs

Solutions

Aircraft tugs, or tow tractors, are designed to facilitate the pushback of the various aircraft sizes, or to tow an aircraft from point to point. These originally used a towbar attached to the front wheel of the aircraft and to the front or rear of the aircraft tug. However, there are now many operators moving towards towbar-less tugs, as these have the advantage of being more flexible due to removing the requirement for the Ground handler to have multiple, aircraft specific, tow bars. There are electric versions of both types of tug.

Figure 6-9: Towbar-less aircraft tug

Maturity

The supply of Zero carbon aircraft tugs is a relatively mature market, with several manufacturers having developed and sold electric versions of their tugs. Having said that, roll out of electric aircraft tugs would appear to have been focussed in the last two years.

Examples

Zero Carbon electric aircraft tugs are evident at airports around the world. In Munich they were introduced in January 2021 and in Frankfurt Lufthansa LEOS has just announced that they will be the launch customer for the Goldhofer Phoenix E tug.

Barriers

The main barrier is likely to be cost and supply of the Zero Carbon aircraft tugs. The Goldhofer tug mentioned above is understood to have a capability to move a range of aircraft up to an MTOW of 352T, and so has proved its technical abilities. As with other vehicles, it is unlikely that all aircraft tugs would be replaced at one time, but it should be feasible for all aircraft tugs to be Zero Carbon by 2040.

6.3.7 Aircraft service (bowser, water, cleaning staff, materials/waste)

Solutions

Aircraft servicing can require a variety of vehicles, depending on what element is being served. The main service elements are toilet service; potable water provision; and aircraft cleaning.

- Toilet Service: The "dropping" of the toilet waste requires a specialist vehicle which usually consists of a vacuum hose and large tank, although this can often be a customisation of a flat bed truck.

Figure 6-10: Aircraft toilet waste removal

- Potable Water: This again usually requires a modified vehicle with a tank and hose for supplying the water to the aircraft
- Aircraft Cleaning: This is usually undertaken by staff brought to the aircraft by minibus. This staff would pass through the aircraft with all waste bagged up and removed from the aircraft, and potentially loaded either into the minibus, or into a dedicated waste collection vehicle

All of the above services should be capable of being provided using Zero Carbon vehicles

Maturity

This report has found no examples of vehicle manufacturers specifically selling electric vehicles providing the above services and so are unable to provide a view on the maturity of such a market.

Examples

This report has found no examples of vehicle manufacturers specifically selling electric vehicles providing the above services.

Barriers

The main barrier for the development of Zero carbon versions of these vehicles would probably be interest from the users. Technologically there should be no reason why the Toilet and Potable water specialist vehicles could not be electric, and so take up of these will be reliant on the users wishing to replace their existing vehicles. It should be noted that, as a single vehicle can serve multiple aircraft, there would probably only be a requirement for the user to replace one or two vehicles depending on how busy the user may be.

6.3.8 Aircraft De-icing

Solutions

Aircraft de-icing rigs are expected to be required at all UK airports for use in de-icing aircraft prior to departure. These are usually based around a large truck chassis with the addition of a small lift arrangement for the nozzle dispersing the de-icing fluid.

Research indicates that there are "electric" versions of these vehicles, although some are more electric than others.

Figure 6-11: De-icing rig dispersing de-icing fluid on aircraft

Maturity

Although there are examples, it would appear that development of these vehicles is possibly in the early days, as the information provided on the vehicles mentions them being "under trial" (see Examples).

It is therefore clear that there is a move towards electric versions of these vehicles, but they are not yet common.

Examples

In February 2021 Oslo Airport was trialling an electric powered vehicle made by Vestergaard. Looking at the Vestergaard company information these vehicles are now available for purchase, but it should be noted that these are not fully electric. These have a diesel engine for driving to and from the aircraft but can use the electrical system to then move around the aircraft during the de-icing process. Overall, the manufacturer states they can reduce CO_2 by up to 87% per vehicle annually. This same vehicle was also on trial in Munich Airport

In December 2020 Montreal Airport announced that they were operating a fully electric de-icing rig and that it was the first in the world.

Barriers

The main barriers with respect to the utilisation of these vehicles at UK airports is likely to be cost and the age of existing vehicles at the airports. Given these vehicles are only required at specific times of the year, it is possible that an airport will only look to purchase an electric rig when the time has come to replace the existing rig, or when an additional rig may be required.

Although rigs may not be replaced until such time as the existing vehicle reaches the end of its serviceable life, this may well still be before the 2040 Zero Carbon target date.

6.3.9 Mobile stairs

doors when the aircraft is on a “non-airbridge” stand, or the rear door if on a stand with airbridge. The Zero Carbon aspect of the towable stairs would be reliant on the tug used and so the comments under “Baggage Tugs” would be applicable here.

With regards to drivable stairs, these are essentially of a similar form to the baggage tugs or baggage belt loaders and so can have the same characteristics.

Figure 6-12: Mobile aircraft stairs

Maturity

The market for Zero Carbon drivable stairs would appear to be relatively mature. There are a number of manufacturers who offer a fully electric version of their stairs, and these can be observed in multiple locations.

Examples

This report has not been able to provide specific examples of where these Zero Carbon vehicles are in use, but photos on the manufacturer’s websites would indicate that they are in multiple locations around the world.

Barriers

Given these would already appear to be in use in multiple locations, there should not be barriers to these vehicles meeting the 2040 target.

6.3.10 Buses

Solutions

Airside busses are utilised to transfer passengers to and from remote stands at the airport. These are usually large vehicles doing relatively short journeys and so replacement of these with zero carbon versions could be very important in reaching the zero-carbon target.

Maturity

Research would indicate that the provision of Zero carbon airside busses is relatively mature, although maybe in the early days in the UK. News reports covering the implementation of fully electric busses in the UK date from the end of 2020 and mid-2021, which would suggest these are relatively new to the market.

Figure 6-13: Electric bus on EV- charge point

However, it is noted that one of the largest suppliers of airside busses in the world, Cobus, introduced their first zero carbon vehicles in 2016, and have implemented their e.START programme which deals with conversion of existing fleets to electricity.

Examples

In the UK, Newcastle Airport introduced a Yutong electric bus in December 2020; whilst Bristol Airport were said to be working with COBUS in September 2021 with regards to a trial of an electric bus at the airport.

Barriers

The main barrier with regards to implementation of zero carbon busses at UK airports is likely to be cost. Technologically a zero-carbon airside bus is possible, but an airport is unlikely to want to replace its fleet until such time as they reach the end of their useful lives, although the ability for COBUS to undertake conversions of existing vehicles (where an airport operates these) may help.

6.3.11 Crew transport

Solutions

Crew Transport is often by mini-bus or by the use of the airside busses. The mini-bus can be a standard vehicle and so is relatively straightforward to implement a zero carbon solution.

Maturity

The provision of electric minibuses is a relatively mature market with several manufacturers providing these vehicles.

With regards to the use of airside busses for crew transport, these may not be as prevalent, but implementation of these at UK airports would be in line with the supply of such busses for passenger operations.

Examples

This report has not been able to provide specific examples of where these Zero Carbon vehicles are in use but would expect them to have been implemented where an airport is looking to reduce its carbon footprint.

Barriers

It is not envisaged that there will be any barriers for implementation of zero carbon vehicles for crew transport, based upon the assumption that readily available electric minibuses can be used.

6.3.12 Operations cars

Solutions

As mentioned previously, this is technically the simplest area to provide Zero Carbon capability. 3rd Party operators (Ground handlers, engineers, etc.) utilise cars in performing their role and these are, in the main, standard vehicles although often with modifications in line with their operational role. In the UK the airside cars are often diesel powered to take advantage of the tax subsidy for Red Diesel.

As these are usually standard vehicles which often will carry a single person, the replacement of medium sized, internal combustion engine vehicles with small electric "SMART" cars could help to reduce CO_2 emissions considerably.

Maturity

Electric cars have been in evidence around the world for many years and are coming down in price. With respect to their use within an airport environment, many airports have already moved to these vehicles.

Examples

LHR state in their Heathrow 2.0: Connecting People and Planet document that they plan to support "Team Heathrow" with their transition to electric vehicles.

In BHX they have put in electric vehicle infrastructure to facilitate the use of such vehicles across the airport site.

LCY also have a pledge to have Zero Carbon airside vehicles by 2030, whilst BRS has installed EV charging points both airside and landside and these are currently in use.

Barriers

The main barrier with respect to the replacement of airside cars with Zero Carbon versions is likely to be the cost. Electric vehicles are likely to be more expensive than their internal combustion engine equivalents and so replacement of a whole fleet at one time would probably be too expensive.

6.3.13 Other 3rd party vehicles (Logistics, maintenance, construction)

Solutions

The provision of Zero Carbon capabilities for Other 3rd party vehicles is likely to depend upon their role and should, in the main, follow the rationales provided under the other specific vehicle headings. Many service providers will simply be using cars and small vans to undertake their work, and these should be relatively easy to replace with electric vehicles.

With respect to more significant infrastructure works, such as construction, these vehicles are unlikely to be replaced by electric versions any time soon, but it is understood that there are moves to make such a transition over the next 20 years. Should this be successful, then these will also be able to meet the 2040 Zero Carbon target. In the meantime, these vehicles could move towards hybrid operations.

Maturity

As covered previously, the provision of electric cars and vans is a relatively mature market, and will look to develop as time progresses.

With regards to the likes of construction vehicles, this is a less developed area although it is noted that the likes of JCB are already providing small electric diggers to the market.

Examples

This report has found no specific examples as to the switch to zero carbon vehicles by 3rd parties, but it is expected that such a change will be included as part of an airport's Zero Carbon strategy.

Barriers

For the majority of small, relatively standard vehicles, there shouldn't be barriers to achieving zero carbon by 2040, as these are already available.

For specialist vehicles, such as used in construction, the barriers may well be scalability and the available technology. There would appear to be a will to develop electric versions of such vehicles, but whether it is possible waits to be seen.

6.4 3rd Party Electricity Generation

Third parties at the airport may have their own facilities for which they directly source their electricity. This may be from grid electricity or, if third parties own or lease land at the airport, they may generate some of their own electricity. Solutions, maturity, examples and barriers for this technology area are as per set out for the Scope 2 electricity generation in Section 5.

6.5 Summary

This section has looked at the Scope 3 emission reduction technology and innovations pertaining to on-airport operations by airport users including airlines, ground handlers and other stakeholders such as control authorities. Only on-airport operations have been considered and not journeys to and from the airport such as flight segments or surface access journeys. Achievement of zero carbon by 2040 in relation to aircraft ground movements will be challenging because of the complexities and scale involved. This will be influenced by future aircraft and fuel sources (e.g. hydrogen, electric), with possibly partial but not full carbon reduction within this timeframe. On-airport vehicles, however, are developing quickly, with a significant number of zero carbon emission vehicles available commercially today or are in prototype form. The key vehicles which still need development but should be feasible for zero carbon operations by 2040 include:

- Catering trucks
- Re-fuelling trucks
- Servicing trucks
- Aircraft de-icing rigs

3rd party zero carbon electricity generation is also feasible by 2040, details of which are set out in Section 5.

7 Pathway to 2040

7.1 Introduction

This section sets out the feasibility of achieving carbon zero airport emissions by 2040, using the current plans of airports, future technology and identifying the other drivers which will influence the future pathway. This section summarises the technological feasibility, sets out the main financial drivers and assesses the commercial feasibility, assesses the feasibility for airports according to size and identifies some initiatives which will help to develop the pathway to 2040.

7.2 Technology Feasibility

Sections 4, 5 and 6 have identified a range of different technologies which can or have the potential to achieve carbon zero emissions and can help all airports to reach the 2040 Zero Carbon target. Table 7.1 summarises the findings from those sections and outlines what is currently freely available; what is in development and should be available by 2040; and what is unlikely to be available within this timeframe.

On the assumption that the airport itself will not be generating electricity, all equipment and vehicles which may switch to that power source will technically become "Source 2". However, it should be noted that the below table relates to the current "Scope" into which the carbon sources fall.

Table 7.1: Feasibility of reaching net zero by 2040 based on available technologies

Scope	Technology	Currently Available	Available by 2040	Not Feasible
Scope 1	**HVAC**			
	Heat pumps	Commercially available	New generation compressors / Refrigerant cycles	
	ATES	Commercially available		
	ECM	Commercially available		
	Thermal energy storage	Commercially available	Electro-chemical storage	
	Lighting (LED)	Commercially available	Improved efficiency	
	Communications	Commercially available	Advanced internet technology for instantaneous instrument control and energy monitoring	
	Power			
	Server virtualisation/relocation	Commercially available		
	Energy retrofit (equipment)	Commercially available	Higher spec equipment	

	Power monitoring and control systems	Commercially available	Higher accuracy sensors, increased predictive capability	
	De-icing			
	IHT	Commercially available		
	IR	Commercially available	Low to zero de-icing fluid required	
	Closed-loop system	Commercially available		
	Refrigerants (Low-GWP)	Commercially available		
	Airport Operation Vehicles			
	Fire Tenders		Currently Testing Vehicles	
	Airport De-Icing		None identified but should be feasible	
	Track Transit/Automated People Mover	Already in Use		
	Cars (Operation/Company)	Already in Use		
Scope 2	**Microgrid electricity**	Commercially available	Generation and energy storage assets of higher capacity	
	On-site electricity generation			
	PV	Already in Use		
	Wind	Already in Use	Restrictions and/or viability may improve	
	Hydrogen		Will be industry leading	
	Biogas	Already in Use	Repurposed for SAF	
Scope 3 Airside Ops	**Aircraft Taxi (and hold)**	Taxibot trials have taken place in India and The Netherlands	Methods are in place which can reduce carbon emissions, but not eliminate	Zero emissions require hydrogen or electric powered aircraft
	Aircraft Engine Testing			Zero emissions require hydrogen or electric powered aircraft
	On-Stand Power and Air (Contact and remote)	FEGP/PCA already in Use	Electric Mobile GPU/PCA Units available but under test	
	Aircraft Line Maintenance	AI and predictive maintenance in operation today	Some specialist vehicles not yet identified but could be feasible	

	Waste	Waste efficiency plans in place	Wastewater could be turned into biofuel	
	3rd Party Airside Vehicles			
	Baggage Tugs	Already in Use		
	Baggage Loaders	Already in Use	Electric ULD Loaders/Hi-lift are available but not as common	
	Cargo handling	Already in Use	Electric ULD Loaders/Hi-lift are available but not as common	
	Catering Trucks		None identified but should be feasible	
	Re-Fuelling Trucks		Only one test vehicle identified, but should be feasible	
	Aircraft Tugs	Already in Use		
	Aircraft Service		No specialist vehicles identified but should be feasible	
	Aircraft De-Icing		Electric de-icers are available but not common, and some only use electric power when close to aircraft	
	Mobile Stairs	Already in Use		
	Buses	Already in Use		
	Crew Transport	Already in Use		
	Ground Handler Cars	Already in Use		
	Other 3rd Party Vehicles	Already in Use	Some specialist vehicles (e.g. Construction) not yet available, but research/development reported to be underway	

7.3 Commercial Feasibility

7.3.1 Context

English airports operate in a variety of contexts, which each pose their own particular set of challenges to the successful delivery of decarbonisation measures. The majority of UK airports are privately funded, operated by private companies, relying on airline fees and passenger charges for their main income streams. There is a combination of airports owned operation and third parties which varies between airports.

In some circumstances, larger English airports are subject to control from the Civil Aviation Authority (CAA), which can influence investment decisions and operating company policy. For the majority of English airports investment is subject to agreement from a variety of stakeholders (airport, airlines, ground handlers, and in some cases, the CAA), this can pose difficulties in agreeing policies as airports have limited control over airlines and ground handling companies.

This section will address the main commercial factors to consider on the path to decarbonisation considering the balance between investing whilst it makes commercial sense and acting before the aviation sector is forced to adapt by command-and-control governmental intervention.

7.3.2 **Four** key commercial factors

- Balance sheet
  - The path to decarbonisation will require changing assets before the end of their lifespan to incorporate new, lower carbon, technologies and adapt existing more carbon intensive infrastructure. This early than planned change will particularly be the case for fixed infrastructure such as boiler plant, but also for other assets such as cars and buses (to enable the transition to electric / hydrogen). Airports will have to navigate a potentially difficult balance sheet issue to bring about quicker than planned changes to infrastructure, particularly when lower carbon technologies may exist at a premium in the early stages of their development and an early change may require assets with a value to be written off.

Table 7.2: Average asset lifespan (Mott MacDonald Assessment)

Asset	Average lifespan
Car	5-10 years
Passenger Bus	8-12 years
Cargo Lorry	8-12 years
Boiler Plant	15-20 years
Building Structures	50 years

- Regulatory or passenger charge model (CAA for regulated airports, airlines direct for non-regulated airports).
  - The regulatory model for English airports needs to support the delivery of large-scale infrastructure to achieve low carbon airport operations. A key challenge for regulated airports is the 5-year regulatory period which has a fixed capital expenditure budget, and it being difficult to be able to respond quickly to change to fast evolving technology development. is a potential blocker to the large scale, and quick change needed to achieve low carbon airport operation. Airports may also be in a position where changes required to deliver carbon savings (e.g. a new electric bus fleet, or a new heating system) do not have a sound economic case, or lack support from airlines may be more focussed on keeping airport passenger charges low, especially in the current climate as they need to re-build their balance sheets post Covid. There needs to be a capacity in the regulatory system for change management to be agreed on the grounds of decarbonisation.
  - To help fund investment on the basis of decarbonisation it might be worth investigating the potential for the introduction of a special fee associated with airport decarbonisation similar to those introduced for other industry-level change issues. A good example of this type of charge would be the HBS charge that was introduced to enable the investment in airport security upgrades. To avoid market failure this type of fee might need to be leveraged

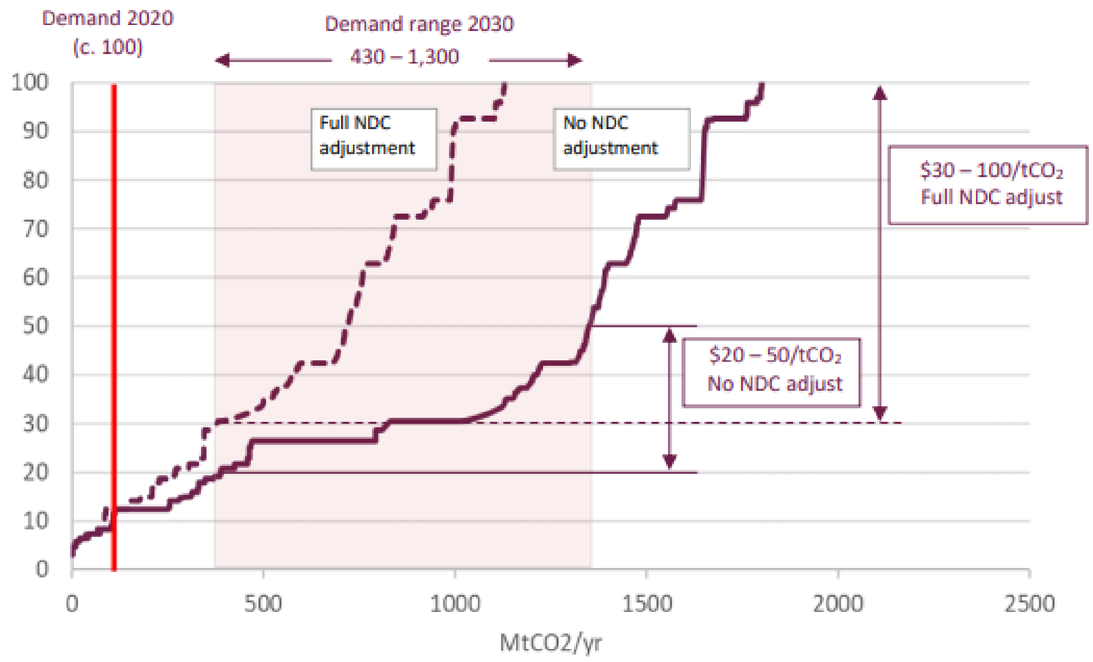
  across all UK airports to ensure that airlines don't attempt to circumvent this charge by routing to an airport outside of the charging facility or industry-level fund).
  - The current model looks to encourage the investing of an airport's own funds, the introduction of external finance through a facilitated channel would aid investment and bring about decarbonisation faster.
  - There is a strong temporal element to changes as planning for H8 will begin in a matter of only a couple years. The opportunity to influence investment decisions up to 2040 therefore rests in this current decade, with limited ability to alter investment decisions once the H8 period has been finalised.
  - It is envisaged that there is scope to introduce the Jet Zero initiatives as regulatory policy change management. This will aid faster decarbonisation of the sector and at the same time ensure consistency of adoption.
- Access to Finance
  - English airports are at a difficult crossroads, they need to invest in infrastructure to safeguard their business past 2040, aligning the aviation sector with the Paris Agreement. Delivering on decarbonisation commitments must occur before aviation demand fully recovers to deliver the revenues needed for investment.
  - At the same time investors are currently thinking through their portfolios. Many are starting to transition away from assets that have a perceived negative impact on the environment. This represents a significant transition risk to aviation assets under the current technology paradigm.
  - Support will be needed to aid airports who want to invest but don't have access to the capital to do so, this could occur in the form of bridging finance or special funding for 'green' infrastructure to help airports deliver low-carbon (e.g. renewable energy).
  - There is scope for a green infrastructure investment fund which could facilitate, airport growth, alongside aviation specific green finance which enables the delivery of the sustainable development goals through an aviation sector context.
- Affordability
  - There is an outstanding issue surrounding the ability for airports to afford the required decarbonisation measures whilst still remaining competitive. Environmentally conscious airports who invest early (and recover the costs through increases in landing charges) place their revenue at risk as airlines may move to cheaper airports. This may risk acting as a form of carbon leakage across the English aviation sector. The funding model should support airports who wish to invest but lack the capital to do so.
  - The price of carbon under carbon credit schemes will be a key driver to determine the business cases of investing in new technology versus offsetting.
  - Under CORSIA there is expected to be a large demand for carbon credits from which to claim carbon neutrality. Offsets raise further issues around additionality and availability past 2030. To claim neutrality under CORSIA the aviation sector is predicted to require between 60 and 150 $MTCO_2e$ a year in 2030, rising to 160-400 $MTCO_2e$ a year in 2040[76] (Figure 7-1). By 2030 offset prices could rise as high as $30-50 a tonne (Figure 7-2), resulting in a large cost to achieve carbon neutrality. It also acts as a direct opportunity cost for not investing in carbon reduction. Global offset markets will be influenced by national policy (driving availability of verified offsets on the voluntary market) and availability (land use changes technology readiness).

[76] UCL and Trove Research (2021) Future Demand, Supply and Prices for Voluntary Carbon Credits – Keeping the Balance available at https://trove-research.com/wp-content/uploads/2021/06/Trove-Research-Carbon-Credit-Demand-Supply-and-Prices-1-June-2021.pdf?msclkid=d98702fda93c11ec981ad82f45d3877b (last accessed Mar 2022)

Figure 7-1: Projected demand for carbon credits from CORSIA 2020 to 2050[77]

Scenario	Description	Cumulative demand for carbon credits 2020 to 2050 ($MtCO_2e$)
Low	Growth in international aviation suffers longer term decline. Pre-pandemic growth does not resume until 2025, and then follows ICAO Trend Report growth rates	4,000
High	Growth in international aviation resumes at the pre-pandemic rate in 2022 and ICAO Trends Report.[13]	9,600

Figure 7-2: Global voluntary carbon credit price projections – average over period 2020-2050 ($/$tCO_2$, 2020 prices) [78]



Source: Global Carbon Credit Supply model

7.3.3 Timescales

Notwithstanding commercial challenges, the practical implementation of measures is also a factor to consider. If funding is secured and available, there is a practicality element to the required changes, in terms of strategy development (implementing an EV strategy and a plan to deliver the strategy, procurement and implementation). To deliver decarbonisation airports will be required to move from strategy and into planning stages, even when a defined solution (e.g. electric vs hydrogen flight) is not apparent.

7.3.4 Smaller & Regional Airports,

For airports with fewer annual passengers, operating in a more regional market, the proposed challenges are likely to vary slightly. There will be balance sheet difference as confidence from investors falls in smaller airports and investors will be more cautious. The impact however will be dependent upon public policy around green finance. Smaller airports may also struggle with

[77] See footnote 76

[78] See footnote 76

altering infrastructure at the rate required to facilitate decarbonisation, but may benefit from the absolute number of changes required being smaller (e.g. fewer airside vehicles to decarbonise).

7.3.5 Social license to operate

This report also notes the requirements on airports to deliver positive social value to their local communities, the connectivity and associated economic benefits attributed to global aviation are substantial and contribute positively to a number of the UN SDGs. By delivering a robust decarbonisation plan, which provides clear targets and means to achieve those targets, airports will maintain their social license to operate allowing them to deliver continued positive social benefits to their local population.

To ensure infrastructure projects are able to continue, without prolonged public scrutiny and legal challenge, airports need to have sound carbon reporting, decarbonisation strategies and concrete plans to achieve carbon reductions which align airports with the 2016 Paris Agreement and deliver net zero operation as soon as is possible.

7.3.6 Summary

In summary the commercial feasibility for decarbonisation is viable for the majority of airports, however at time of writing there still exists barriers to success. These centre on certain assets (e.g. heating plant) which will require adaptation before their full lifecycle. For the conclusion of commercial feasibility to stand, airports should begin planning immediately and have appropriate policy and regulatory support.

Policy needs to recognise the drivers behind decarbonisation and not penalise early adopters in decarbonisation technologies. A common approach to decarbonisation which unifies airlines and airports would enable a faster transition to low carbon technologies and infrastructure.

7.4 What's the Feasibility of Reaching Carbon Zero?

7.4.1 General Factors to Consider

Whilst airport operations are responsible for only 5% of air transport sector emissions[79], there is building momentum in addressing climate issues in all areas of the sector. Many airports are adopting carbon management systems and more recently, committing to net zero carbon targets. ACI Europe and its members, which include major international airports and airport groups including Heathrow Airport and Manchester Airport Group, have committed to a net zero goal by 2050. ACI's 235 airports have committed to significantly reduce absolute emissions from their operations and to offset residual emissions, 91 airports are on track to achieve net zero earlier by 2030[80]. Despite the disruption from the

Aircraft Refuelling

Whilst aircraft re-fuelling is not considered directly in this report, analysis of in-scope areas, including infrastructure planning and operational fleet is directly linked to future aircraft fuelling strategies. This particularly centres on the requirement for hydrogen fuel to enter the airport site and the planning, and infrastructure requirements for this to take place. There is the potential for hydrogen powered airport operational fleet to help facilitate the transition to hydrogen fuelling by initially generating demand for hydrogen ahead of aircraft technology.

[79] ACI (2017) *Global airport industry hard at work to reduce and eliminate its CO2 emissions*. Available at: Global airport industry hard at work to reduce and eliminate its CO2 emissions - ACI World (Last accessed March 2022)

[80] See Footnote 79

pandemic, many airports are firmly on their path to net zero and remains a high strategic priority for long term growth[81]

Compared to aircraft operation emissions, the technological and commercial barriers to reducing airport emissions are not as insurmountable (see Section 7) and the goal of net zero by 2050 should be achievable with current and planned technology (see section 4,5 and 6). Current net zero targets address scope 1, 2 and 3 emissions of an airport's operation, as defined by the GHG (Greenhouse Gas) Protocol. Improvements to energy efficiency in airport buildings and a transition to low emissions/zero emissions vehicles will contribute to reductions in Scope 1 emissions. Scope 2 emissions can be targeted by decarbonising the airport's electricity use. Switching to a renewable energy supply or even producing electricity from on-site renewables will be an important tool for a zero carbon strategy. If these types of measures are implemented, the scope 1 and 2 emissions of airport operations can be drastically reduced, however, logistics and commercial risks are difficult to avoid.

Feasibility of zero emissions airport operations will be dependent on political, commercial, and third-party factors.

Green energy for flight

The next generation of aircraft will need to utilise a range of new and alternative fuels such as hydrogen, battery/hybrid aircraft and sustainable aviation fuel (SAF) in order to reach zero emissions aircraft operations. Airport infrastructure must evolve to enable the use of green energy for flight and contribute to a wider net zero goal for the aviation sector.

Sustainable aviation fuel, a petroleum derived from biomass or synthesised petroleum, may be an important short-term solution to reducing emissions. Chemically, SAF is similar to conventional jet fuel and can be blended at up to 50% with conventional jet fuel [82]. Due to their similarities, existing fuel infrastructure can be used for operation[83]. A current barrier to widespread adoption is high cost, about 5x the cost of conventional jet fuel, although it could be cost competitive by 2035 if supported by legislation[84].

Considerably harder infrastructure challenges impact the adoption of hydrogen and battery electric aircraft. Hydrogen's use as a jet fuel has many advantages; a high specific energy-per-unit mass 3x higher than conventional jet fuel and zero CO_2 emissions from combustion[85]. Hydrogen technology will need to mature before it is ready to be deployed and currently faces significant challenges for adoption. A key enabler for hydrogen operations at an airport will be dependent on the proximity to hydrogen producers or wider infrastructure clusters such as the Tees Valley Multi-Modal Hydrogen Transport Hub. Storage of hydrogen on-site will also require large areas of land to meet the scale of demand of any projected hydrogen use for airports[86].

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[81] Hemmings et al (2021) *Investigating the Impact of COVID-19 Disruption on the Decarbonisation Agenda at Airports: Grounded or Ready for Take-Off?.* Available at: Sustainability | Free Full-Text | Investigating the Impact of COVID-19 Disruption on the Decarbonisation Agenda at Airports: Grounded or Ready for Take-Off? (mdpi.com)(Last accessed March 2022)

[82] BP (2021) *What is sustainable aviation fuel (SAF)?.* Available at: What is sustainable aviation fuel (SAF) and why is it important? | News and views | Air bp (Last accessed March 2022)

[83] Catapult (2021) *Zero Emission Flight Infrastructure White Paper.* Available at: Zero Emission Flight Infrastructure White Paper (netdna-ssl.com) (Last accessed March 2022)

[84] McKinsey (2021) *How airlines can chart a path to zero-carbon flying | McKinsey*. Available at: How airlines can chart a path to zero-carbon flying | McKinsey (Last accessed March 2022)

[85] Aerospace Technology Institute (2021) *REALISING ZERO-CARBON EMISSION FLIGHT.* Available at: FZ_0_6.1-Primary-Energy-Source-Comparison-and-Selection-FINAL-230921.pdf (ati.org.uk) (Last accessed March 2022)

[86] Kearney (2021) *Aviation's hydrogen: the airport challenge* Available at: Aviation's hydrogen: the airport challenge - Kearney(Last accessed March 2022)

Battery-electric aircraft may not offer the same performance as SAF or hydrogen but produces absolute zero emissions during operation. Charging infrastructure will need to accommodate sufficient aircraft charging or battery swap operations. Existing infrastructure should be upgraded to use thick conductors or robust charging couplers with active cooling to support batteries which will need higher power ratings than current technology[87].

Policy

In the aviation sector, most net zero commitments have been made by non-governmental international bodies such as the ACI and IATA. However, to enable significant emissions reductions, commitments will need to be supported by national and local policy. In response to growing pressure from different shareholder groups, private sector, and public opinion, governments are beginning to introduce policies to decarbonise aviation.

As part of its wider climate plan to reduce emissions by 40% by 2030, the French government passed a bill in 2021 that will ban short haul internal flights if there is an alternative rail journey of under 2 and a half hours[88]. The regulation may also include a ban on construction of new airport or expansions and airlines would also be required to include carbon offset programmes for all domestic flights between 2022 and 2024[89]. Other countries have introduced similar policies. From 2020, Norway has mandated that 0.5% of aviation fuel must be sustainable, aiming for 30% by 2030 and its short haul network to be electrified by 2040[90]. National net zero goals will need all sectors to decarbonise rapidly. The aviation sector is often overlooked but will be a key sector if there is to be significant reductions in global emissions. The UK CCC sixth carbon budget set out policy recommendations for the UK governments for net zero aviation[91].

It recommends:

- The government to set a national net zero commitment for UK international aviation
- Introduce demand management policy to support SAF deployment and project developments in efficiency,
- Wider supporting policies for SAF deployment, innovation, continued R&D for aircraft efficiency measures, and enforce strict sustainability standards.
- Local and regional policies that support regional green energy ecosystem such as the Tees Valley multi-modal hydrogen transport hub will help to develop the infrastructure need for projected changes in green energy for flight.

Economics

Commercial factors and the bottom-line will be an important factor for the feasibility for achieving carbon zero. As seen in Section 7.3, there are five key commercial factors to consider. Airports face challenges in affordability and timeframe and will need appropriate policy and regulatory support to be viable.

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[87] NREL (2022) *Electrification of Aircraft: Challenges, Barriers, and Potential Impacts.* Available at: Electrification of Aircraft: Challenges, Barriers, and Potential Impacts (nrel.gov) (Last accessed March 2022)

[88] Reuters (2021) *French lawmakers approve a ban on short domestic flights*. Available at: French lawmakers approve a ban on short domestic flights | Reuters (Last accessed March 2022)

[89] EUROCONTROL (2021) *EUROCONTROL Data Snapshot #4 on CO_2 emissions by flight distance.* Available at: EUROCONTROL Data Snapshot on CO_2 emissions and flight distance | EUROCONTROL (Last accessed March 2022)

[90] AVINOR (2020) *Aviation in Norway. Sustainability and social benefit*. Available at: aviation-in-norway-sustainability-and-social-benefit-2020.pdf (avinor.no) (Last accessed March 2022)

[91] Climate Change Committee (2020) *The Sixth Carbon Budget*. Available at: Sector-summary-Aviation.pdf (theccc.org.uk) (Last accessed March 2022)

Third parties

Although most of the emissions of airport operations is directly under the airport's control, there needs to be a wider industry response from third parties including airlines and ground handlers to achieve carbon zero. As infrastructure providers and key stakeholders in the commercial value chain, airports can encourage other stakeholders to reduce emissions. This could be supporting public transport links to the airport, transitioning airside vehicle fleets to electric vehicles, or changing price structures to encourage airlines to use cleaner and quieter aircraft.

7.4.2 Airport Size

The following analysis has considered the factors which impact airport decarbonisation based on the size of an airport. A score has been assigned to each factor to quantify the relative impact and give an overall indication of the challenge facing individual airports.

Table 7.3: Large Airport (>25 mppa)

Factor	Impact	Feasibility to decarbonise	Impact score / 10
Strong financial base	Easier to invest and can purchase higher value items	Allows for easier decarbonisation as it is easier to invest in more costly technology	10
Large scale operation	Harder to decarbonise if infrastructure changes alter timetables, but it would be able to close part of the operation and still maintain high passenger numbers	Impact would be greater over a large scale, absolute carbon savings would be greater for a big operational fleet.	6
Large number of stakeholders	Harder to generate consensus and deliver change	Will make it difficult to decarbonise as a larger number of stakeholders to convince / bring about change through	5
Regulated	Regulation can make it difficult to implement decarbonisation measures	A flexible regulatory model which is responsive to change is required	4
Geography	A large airport footprint	May make it easier to acquire nearby land or land may exist to construct renewable energy	6

Table 7.4: Medium Airport (5-25mppa)

Factor	Impact	Feasibility to decarbonise	Impact score / 10
Medium financial base	Easier to invest and can purchase higher value items	Allows for easier decarbonisation as it is easier to invest in more costly technology	7
Medium scale operation	May be easier to decarbonise operational fleet due to smaller size, permanent infrastructure will be more difficult as it would be unable to close entire terminals/areas of terminals without capacity infringements	More challenging to decarbonise busy single pieces of infrastructure whilst keeping the operation running, some flexibility and simplification with a medium-sized operational fleet.	4

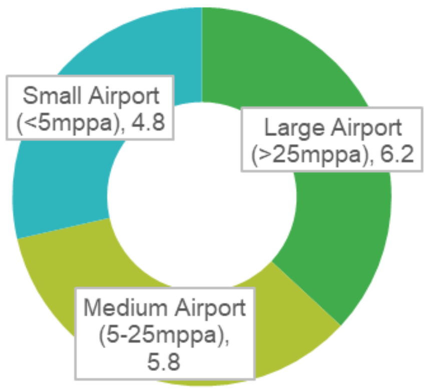
Factor	Impact	Feasibility to decarbonise	Impact score / 10
Medium number of stakeholders	Easier to generate consensus and deliver change than larger airports	Will make it easier to decarbonise as a larger number of stakeholders to convince / bring about change through	5
Unregulated	Regulation can make it difficult to implement decarbonisation measures, the absence of this can Fast track decision making	Decarbonisation becomes easier, particularly the introduction of external finance	7
Geography	A medium airport footprint	May be harder to acquire nearby land or land may exist to construct renewable energy	6

Table 7.5: Small Airport (Less than 5mppa)

Factor	Impact	Feasibility to decarbonise	Impact score / 10
Weaker financial base	Harder to invest and more difficult to secure external finance	Decarbonisation harder as it is more difficult to invest in more costly technology	2
Small scale operation	More flexibility but any loss in capacity could impact profit	Easier to change a smaller number of assets/vehicles	5
Fewer stakeholders	Harder to generate consensus and deliver change	Will make it difficult to decarbonise as a larger number of stakeholders to convince / bring about change through	6
Unregulated	More control over investment decisions and greater mandate to implement change	Makes it easier to decarbonise	7
Geography	Smaller airport size may make decarbonisation more difficult, renewable energy may require more land purchase	May make it easier to acquire nearby land or land may exist to construct renewable energy	4

The decarbonisation review has identified that large airports currently have the greatest feasibility to decarbonise (Figure 7-3), drive by the superior balance sheet, however the greater control bought about by fewer regulations could aid medium and small airports in their decarbonisation journey.

Figure 7-3: Average decarbonisation score for large, medium and small airports



7.5 Initiatives which will help to achieve 2040 Carbon Zero Pathway

7.5.1 Standard Emissions Reporting

- Consistent methodology with no gaps in data
- Better ability to compare
- Enable trends and projections to be seen
- Help to set future targets

Voluntary emissions reporting that is not standardised or aligned with an existing methodology can lead to data gaps in carbon accounting and poor-quality data collection. Standard emissions reporting can bring multiple benefits that can indirectly lead to emissions reductions[92]. Emissions reporting is not a direct driver of reductions but can help to identify and target emission hotspots. It can enable trends and projections to be identified, and future targets can be based on these findings. The framework developed by ACI for its Airport Carbon Accreditation provides guidance on how to identify the scope 1, 2, and 3 carbon footprint of a typical airport[93]. Airports that are accredited must follow the methodology set out by the ACI, which has been developed in line with GHG Protocol and ISO 14064 principles. Airports that have committed to net zero targets, including Heathrow and MAG Airports, are currently accredited with this scheme.

7.5.2 Incentives for early adoption

Early adoption of technology which is mature will help to make early carbon reductions, build momentum and reduce the amount of work needing to be done in later years when much more work will be ongoing. This can include not only Scope 1

Case study

Queen Alia International Airport (QAIA) is Jordan's largest airport and most important air travel hub. Since 2013, the airport has achieved the highest level of the Airport Carbon Accreditation (ACA) Programme and thus became the first carbon neutral airport in the Middle East Region.

It has actively utilised a carbon management system to reduce airport operation emissions across all stakeholders of its value chain. A comprehensive approach that has engaged ground handlers, airline, fuel service providers and catering companies has achieved a total emissions reduction of 10.7% from 2017 to 2018. CO_2 per passenger has also been reduced by 7.8% from 2014 to 2016, resulting in a saving of $1.5m.

[92] Downar et al (2021) *The impact of carbon disclosure mandates on emissions and financial operating performance.* Available at: The impact of carbon disclosure mandates on emissions and financial operating performance (springer.com) (Last accessed March 2022)

[93] ACI (2020) *APPLICATION MANUAL*. Available at: Airport Carbon Accreditation Application Manual Issue 12.pdf (Last accessed March 2022)

and 3 but also Scope 2 in terms of encouraging airports to purchase energy from renewable sources. Funding support or tax-breaks could help incentivise airports to invest earlier before 2040.

7.5.3 Knowledge Base of Best Practice for Airport Infrastructure Requirements

Sharing best practice information and studies in a central location will provide a resource base of information which could help reduce the amount of duplicated work airports will need to do to develop their carbon zero strategies. This will be particular important for smaller airports who have less resources available to commit. Developing standards and modular solutions based upon latest Design for Manufacturing and Assembly (DfMA) processes will also help to simplify work and reduce cost for infrastructure that can be approached in that way.

7.5.4 Commercial Platform to Support Transition

Establishing a commercial platform which provides support to airports, airlines and stakeholders to invest in the technology needed to achieve carbon zero by 2040 is critical to establish early, given lead in times and the phasing practicalities of getting large amounts of infrastructure in place in a similar timeframe. This needs to consider the key commercial factors and incentives to invest including:

- Support to address balance sheet losses if assets need to be replaced earlier than planned
- Regulatory model that is flexible to support change and encourage green investment.
- Access to finance e.g. Green Investment Funds
- A commercial model that is fair and affordable for all parties to invest. Needs to work for airports, airlines, pax and third parties such as ground fleet handlers.

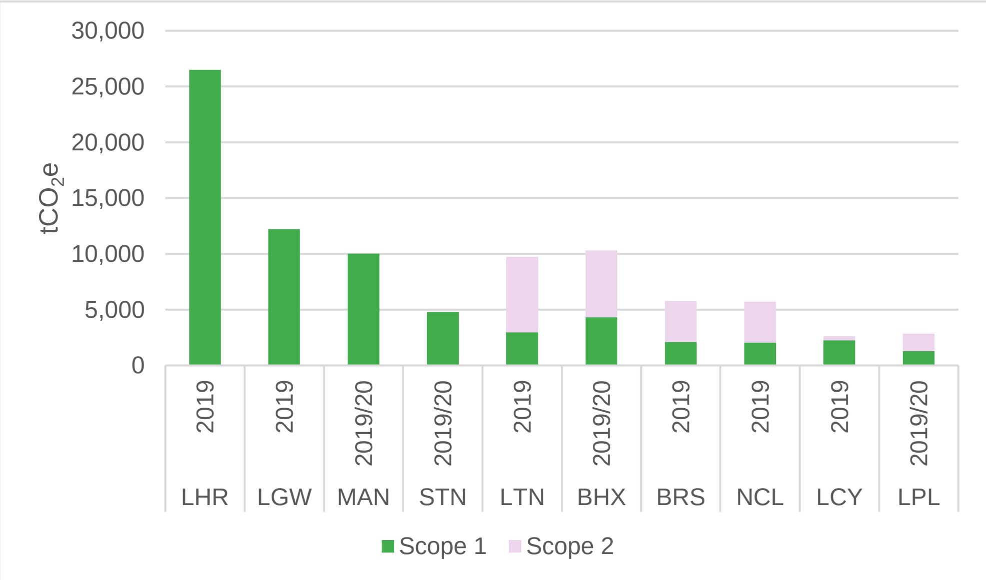
8 Conclusion

The aviation industry is taking steps to decarbonise and reduce its impact on the environment, whilst maintaining the positive social and economic impacts which aviation brings to and society. Whilst focus and investment has increased significantly in recent years, this increase in investment must be maintained and intensified, in order to meet future policy objectives and targets.

English airports are ramping up their investment and resources to look for ways to decarbonise across their Scope 1 and 2 emissions, and stakeholders are also doing similar for Scope 3 airside operations. Larger airports or larger airport operating companies, with their increased resource levels, have been reporting their emissions in a more developed and structured way, although reporting of data is not done in a uniform manner.

The top 10 English airports by passenger volume have been reviewed from a current carbon emission and future decarbonisation planning perspective. The Scope 1 and 2 emissions (based upon 2019 data) are shown in Figure 8-1. The reported emissions relate to market-based accounting methods, with Scope 3 omitted because the reported emissions are non-comparable between airports.

Figure 8-1: Comparison of studied airport Scope 1 and 2 emissions (based on 2019 or 2019 financial year data- market based emissions) [94]



The English airports researched have published plans to become net zero by the following timeframes. Net zero is determined to be a state where emissions have been reduced as far as possible (~85-95%) through mitigation measures, with the remaining emissions offset through verified carbon offsets.

- 2033 BHX
- 2035 NCL

[94] Mott Macdonald analysis of publicly available emission data for England's 10 largest airports by passenger volume (2019). Emission data has been selected for 2019, where the company reports in financial years the 2019-20 financial year has been selected.

- 2038 MAN, STN
- 2040 LTN
- 2050 LHR, BRS, LCY

LGW and LPL have pledged to reduce their carbon emissions over this timeframe but have not explicitly stated that they would become net zero by a given year. It is important to note that these are net zero plans rather than having zero carbon emissions, however the plans may also be taking into account other Scope 3 emissions.

There has been significant investment by energy companies and airport vehicle manufacturers to create carbon zero technology solutions. A lot of technology now exists commercially or at a prototype level and it appears technologically feasible to have zero carbon solutions at English airports by 2040. Emission sources which do not have currently have a zero carbon solution available (but should be available by 2040) include:

- Some Scope 1 Airport operations vehicles:
  - Fire tenders
  - Airport de-icing rigs
- Scope 2 Energy, heating and cooling via Hydrogen (although alternative zero carbon energy sources exist including electricity generation from renewable sources)
- Scope 3 Aircraft engine testing (requires electric or hydrogen fuelled aircraft)
- Some Scope 3, 3rd party airside operations vehicles:
  - Catering trucks
  - Re-fuelling trucks
  - Servicing trucks
  - Aircraft de-icing rigs

Sizing of the new infrastructure requirements to support the supply of energy to these new building and vehicle energy sources is key. This will be influenced by the aircraft fuelling technological advancements as well, which are more complex to resolve and are less developed because of these complexities.

As zero carbon emission technology for airport operations either exists today or will exist by 2040, the key success factor in determining the feasibility of airport operations being able to be carbon zero by 2040 will be commercial and programme factors. This is because the cost of implementing new technologies will be higher in certain areas than today, and that there is a lot of transition work which will be required which will take time. If the right commercial model and incentives can be put in place in time, then it is feasible to reach zero carbon by 2040, but it will require a concerted effort by all stakeholders, including Government, Regulator, Airports, Airlines, Ground Handlers and Energy suppliers, to create an integrated and achievable strategy which works for all.

There are 4 key commercial factors which will need to be addressed and supported in a future commercial strategy:

- Balance Sheet – airports have a variety of assets with different lifespans and book values. Whilst new vehicles, with a lifespan of 5-10 years, could be readily replaced by 2040, boiler plants with a 15-20 year typical lifespan may be more borderline and large, fixed building structures can have up to 50 year lifespans. Airports will need support if they are to replace some of these longer life assets by 2040.
- Regulatory Model – the regulatory model (if airports are formally regulated) or airport charging model (if not regulated), needs to support investment in green technology. Given the regulatory cycle programme, as well as planning, design and construction lead-in times,

getting an agreed strategy to deliver carbon zero infrastructure by 2040 is likely to be needed to be agreed in the next 5 years. If the solution has not been agreed by then, then having a change control mechanism in the regulatory or airport charging model is important for being able to respond in an agile manner.

- Access to Finance – the aviation industry has been one of the worst hit industries by Covid. Airport and airlines have suffered major losses over the past two years and they are not as safe an investment as they once were. Access to bridging finance or green investment funds may offer support to help incentivise investment and early adoption of carbon zero technologies. Policy support which can be incorporated into commercial agreements e.g. CORSIA targets, could also help airports gain better access to finance.
- Affordability – ultimately, is the large-scale investment required affordable for airports, airlines, ground handlers and the passenger? How will the carbon credit and offset pricing strategy fit with other airport charges and duties? For it to be a success, it will require airlines and ground handlers to invest, as well as airports. The success of whether airports can achieve carbon zero emissions for Scope 1, 2 and 3 airport operations by 2040 will also be influenced by other Scope 3 emission sources outside of this study such as future aircraft fuels. Understanding future hydrogen and electricity demand, cost and availability, at both an airport as well as wider network level, will play a significant part in determining the overall affordability.

Setting out a programme with realistic timescales will be critical to fulfilling the 2040 carbon zero plan, as well as identifying differences in approach according to whether the airport size is large, medium or small, as the different business models of airport scale will have different drivers and financial pressures.

Several other initiatives would also help to achieve a carbon zero pathway by 2040, including:

- Standardising emission reporting, to track progress and compare
- Incentivisation for early adoption

Establishing a knowledge base of best practice for airport infrastructure requirements

To conclude, it is feasible from a technology and commercial perspective for airports to achieve zero carbon emissions for Scope 1, 2 and 3 airport operations by 2040. Whilst this is still 18 years away at time of writing, the next few years are critical. The Government and the aviation industry must work together to create and agree a plan which addresses the challenges identified in this report and ensure the plan is adopted by all stakeholders and delivered.

A. Further data

A.1 Emission data sources

Airport	Source	link
Heathrow	Heathrow 2.0 2019 Sustainability Progress	https://www.heathrow.com/content/dam/heathrow/web/common/documents/company/heathrow-2-0-sustainability/futher-reading/Sustainability-Report-2019.pdf?msclkid=1e61b367b0f811ec95d71aa0c3df8eb7
Gatwick	2020 Performance Summary	https://www.gatwickairport.com/globalassets/company/sustainability/reports/2020/decade-of-change-2020-report.pdf?msclkid=2df5e3c8b0f811ec881448db829f1e72
Manchester	MAG GHG Emission report 2020/21	https://www.magairports.com/media/1688/mag-emissions-report_2019-20_final.pdf?msclkid=45ca32b6b0f811ec96ad705c885b3cda
Stansted	MAG GHG Emission report 2020/21	https://www.magairports.com/media/1688/mag-emissions-report_2019-20_final.pdf?msclkid=45ca32b6b0f811ec96ad705c885b3cda
Luton	2020 Sustainability Report	https://www.london-luton.co.uk/LondonLuton/files/a0/a0dcedc4-6499-4f7f-8cef-c18005379ae8.pdf
Birmingham	GHG Emissions 2020-21	https://authoring.birminghamairport.co.uk/media/6697/greenhouse-gas-emissions-2020-21.pdf?msclkid=85aabcacb0f811ec945723dcb05212e0
Bristol	Annual Monitoring report 2020	https://www.bing.com/ck/a?!&&p=cacf084bb84e8f550fdd0475d49a28259c51cd96cc73716fdc08cc089bd90ca6JmltdHM9MTY0ODczNDIyOCZpZ3VpZD05NjExY2M1MC00MjhkLTQ5MTEtYWUyZi1mODg1M2U2OThhNmMmaW5zaWQ9NTE2NQ&ptn=3&fclid=973ebbdf-b0f8-11ec-8b3e-16d3ca38c507&u=a1aHR0cHM6Ly93d3cuYnJpc3RvbGFpcnBvcnQuY28udWsvLS9tZWRpYS9maWxlcy9icnMvYWJvdXQtdXMvZW52aXJvbm1lbnQvYW5udWFsLW1vbml0b3JpbmctcmVwb3J0LTIwMjAuYXNoeD9sYT1lbiZoYXNoPThGRTc4RDBCREEzRUIyMjk0MkE5NUZBOUVDQ0VGOEVEQ0IyNTYyODgmbXNjbGtpZD05NzNlYmJkZmIwZjgxMWVjOGIzZTE2ZDNjYTM4YzUwNw&ntb=1
Newcastle	Net zero Carbon 2035	https://www.newcastleairport.com/about-your-airport/environment/net-zero-carbon-2035/?msclkid=adfb098cb0f811ecaced29c55a8f64c0
London City	Full Accounts 2020	https://find-and-update.company-information.service.gov.uk/company/01963361/filing-history
Liverpool (John Lennon)	Full Accounts 2020	https://find-and-update.company-information.service.gov.uk/company/02116704?msclkid=c8d13472b0f811ecb9d7a7cfeafd0216

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