cefc

Clean energy and infrastructure:
Pathway to airport sustainability

Transitioning Australia's airports to lower emissions with 15 best practice initiatives

AECOM

About this report

This report focuses on 15 best practice emissions reduction and sustainability initiatives for major airports, covering both landside and airside opportunities.

Additional information on initiatives to improve the emissions and sustainability profile of airport terminal assets can be found in a companion CEFC publication, Energy in Buildings: 50 Best Practice Initiatives, available at cefc.com.au

In this report

Sustainable infrastructure and the CEFC

The smooth operation of Australia's major infrastructure assets is vital to our nation's economic wellbeing, as well as our ability to achieve significant reductions in our greenhouse gas emissions.

As a specialist investor in clean energy opportunities, the CEFC has a particular focus on working with infrastructure asset investors, owners and operators. Our goal is to accelerate the achievement of lower emissions outcomes for these long-lived assets.

Across the infrastructure sector the emissions challenge is clear, and the potential benefits considerable: ClimateWorks Australia estimates that around 70 per cent of Australia's emissions can be influenced by infrastructure projects.

We see significant opportunities to reduce these emissions, using a broad range of clean energy technologies and operating practices which can also lower energy use and lift productivity.

Airports are complex infrastructure assets, with the implementation of new emissions-reducing initiatives typically requiring endorsement from multiple stakeholders. A lack of information or awareness of clean energy opportunities can be a major barrier to the required investment.

Clean energy and infrastructure: Pathway to airport sustainability helps bridge this gap, providing practical information for asset owners, operators and investors.

Of the 15 best practice initiatives discussed in this report:

- More than half address Scope 1 emissions
- The total capex for 70 per cent of these initiatives is less than 0.5 per cent of the total asset value.

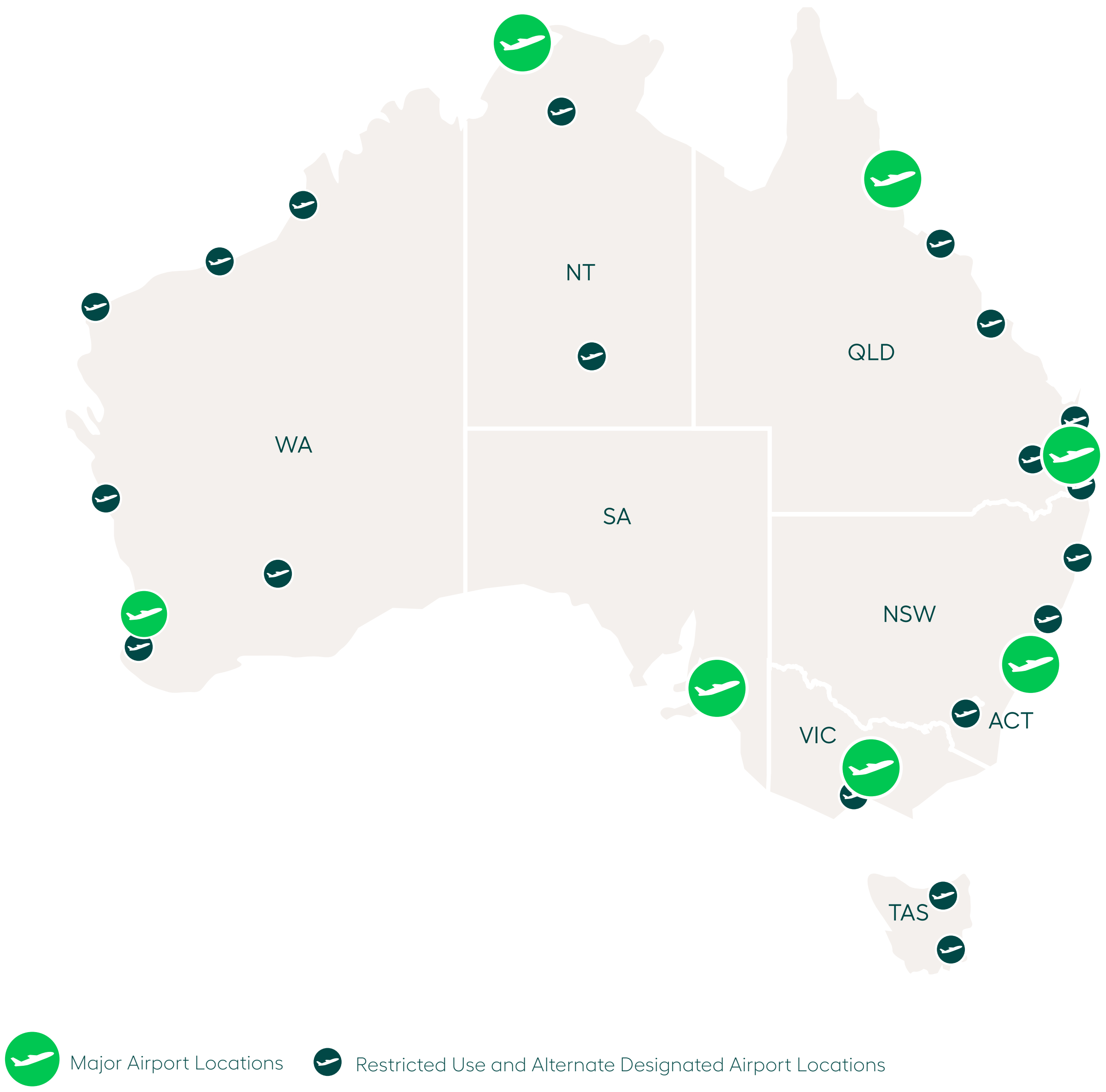
We thank the team at AECOM for their expertise in the development of this report.

We also encourage airport owners and operators to contact the CEFC to discuss financing options for your clean energy transition.

Ian Learmonth
CEO,
Clean Energy Finance
Corporation

Australia and aviation

103.2M passengers in Australia in 2019[1]	4.4B passengers globally in 2018	2% of global carbon emissions[2]	8.2B passengers globally by 2037[3]	3% of Australian carbon emissions[4]



This map is indicative only and shows the Major, Restricted Use and Alternate Designated International Airports in Australia from the Australian Government Department of Infrastructure, Transport Cities and Regional Development.

1. Department of Infrastructure, Transport, Cities and Regional Development
2. Air transport Action Group (ATAG) 2018, https://www.atag.org/facts-figures.html
3. International Air Transport Association (IATA) 2018 20-year Passenger Forecast
4. Air transport Action Group (ATAG) 2018, https://www.atag.org/facts-figures.html

Where to act: Best practice initiatives

Renewable energy and storage

1. Central utility plant
2. Onsite solar PV and battery energy storage
3. Purchasing renewable energy

Electrification and fuel switching

4. Electrification of ground support equipment
5. Fixed electrical ground power and pre-conditioned air
6. Sustainable aviation fuel
7. Surface access improvements

Energy efficiencies

8. Aircraft and airside upgrades
9. Building analytics technologies
10. Low energy baggage handling systems
11. Terminal initiatives
12. Airfield lighting upgrades
13. Ground source heat pumps

Waste management

14. Energy-from-waste
15. Waste minimisation

Airports and sustainability: The big picture

The global aviation industry is responsible for 2 per cent[4] of the world's total carbon emissions. To put this in context – if the aviation industry was a country, it would be ranked in the top 10 CO_2 emitters in the world[5].

Airport-controlled activities account for around 2-3 per cent[6] of total aviation industry emissions. Though this may seem insignificant, this represents 15–20 mt of CO_2-e emissions per annum globally. Furthermore, global air travel activity is predicted to grow from 2017 levels at a compound average growth rate of 3.5 per cent per annum and could double to 8.2 billion passengers in 2037[7]. While many airports are already showing a reduction in CO_2-e emissions per passenger, this future growth trajectory raises several concerns regarding the absolute greenhouse gas (GHG) emissions of the industry and the resulting impact on the environment.

Global concern about the effects of climate change and the impact on infrastructure is becoming increasingly prevalent. From sea level rise to changes in temperature, weather, wind and storm patterns, the impacts of climate change are predicted to pose a serious risk to airport operations if unaddressed.

It is estimated that inclement weather results in around 70 per cent of annual flight delays[8] and future weather changes could exacerbate these challenges.

Other economic challenges include volatile electricity prices and a volatile jet fuel market. Increasing consumer and investor awareness of the social and environmental impacts of the aviation industry's operations is compounding this pressure to move towards a low carbon economy. Globally, this has led to a rise in commitments to net zero carbon emissions or emissions reduction schemes.

The Paris Agreement under the United Nations Framework Convention on Climate Change established a global action plan to reduce the impacts of climate change by limiting global warming to below 2°C and pursuing efforts to keep warming below 1.5°C above pre-industrial levels.

Keeping the global average temperature increase to within 1.5°C requires all sectors of the economy to achieve net zero emissions by 2050. In response to the Paris Agreement, Australia has set a target to reduce emissions by 26-28 per cent below 2005 levels by 2030.

Airports and climate risk

Physical risks

- Sea level rise
- Increased rainfall and flooding
- Increased temperatures
- Extreme weather events (heatwaves, extreme rainfall, wind, storms, lightning and bushfire)

Transition risks

- Changing legislation and policy
- Investor expectations
- Tourism trends and passenger preference
- Market and technology shifts
- Reputation

Why airports?

There is a global movement toward climate neutrality within the aviation industry. In June 2019, the Airport Council International – Europe committed to net zero carbon emissions by 2050[9]. Several airports in countries outside of Europe are also working toward significant carbon emissions reduction goals, including the over-270 members of the Airport Carbon Accreditation program.

Increasing investment is enabling research and development into new low emissions technologies, while existing technologies are also becoming more commercially viable. Recent global trends enabling the transition toward low carbon airport operations include:

- Increased market share in the use of electrified and smart ground support equipment and vehicles[10]
- The levelised cost of generating electricity from wind and solar has globally fallen by 67 per cent and 86 per cent respectively since 2010[11]
- Airlines are introducing more fuel-efficient aircraft that are, on average, 20 per cent more fuel efficient than earlier models[12]
- Voluntary rating initiatives are driving investment in energy efficiency and low emissions technologies, particularly in airport buildings
- Increased smart metering and automatic building analytic technologies allowing for real-time energy efficiency performance enhancement
- Development of smart, energy efficient critical airport technologies including baggage handling and airfield lighting systems.

5. Reducing emissions from aviation, https://ec.europa.eu/clima/policies/transport/aviation_en
6. Airport Carbon Accreditation Annual Report 2017-2018, ACI-Europe
7. International Air Transport Association (IATA) 2018 20-year Passenger Forecast
8. US data 2018, Fact Sheet – Inclement Weather, https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=23074
9. Europe's airports commit to zero CO2 emissions by 2050 2019, http://www.airport-world.com/news/general-news/7225-europe-s-airports-commit-to-zero-co2-emissions-by-2050.html
10. Global Ground Support Equipment Market Study 2019
11. Global renewable energy trends 2018, https://www2.deloitte.com/insights/us/en/industry/power-and-utilities/global-renewable-energy-trends.html
12. Aviation Emissions 2019, https://www.infrastructure.gov.au/aviation/environmental/emissions/index.aspx

Global leadership

Copenhagen Airport, Denmark

In 2018, more than 30.3 million passengers travelled through Copenhagen Airport, an increase of 1.1 million from 2017.

This was combined with an expansion of the Airport's terminals and buildings, with an investment of over $440 million. Notwithstanding, the Airport was able to continue to reduce its energy consumption and emissions. In 2018, the Airport implemented a range of measures, including LED lighting, replacing heating systems and establishing a groundwater cooling system, that resulted in 7.2 GWh per year in energy savings, with a total savings of 30.8 GWh since 2013. As a result, the Airport's CO_2 emissions have reduced by 26 per cent per passenger since 2013[13].

Copenhagen Airport's Climate Strategy, released in 2019, has set a goal of eliminating all carbon emission from the Airport – including surface access – by 2050[14].

From 2019, until all Airport carbon emissions have been eliminated, Copenhagen Airport will make their Scope 1 and Scope 2 emission operations carbon neutral by compensating for emissions through purchasing offsets. Ultimately, Copenhagen Airport aims to eliminate emissions from Scope 3 sources[15].

Copenhagen Airport are installing a new ventilation system, expanded solar-powered heat pump system and a further transition to LED lighting. Their current 125kW solar panel system only produces 0.4 per cent of total energy consumption, but in 2019 they invested $2.1m to install additional panels to create a 1.4MW system to cover around 3.5 per cent of energy consumption. This will complement a $4.4m investment in energy management and savings.

Copenhagen Airport is also expanding the terminal building by 80,000m^2 through a $870m investment, with the first phase to be completed in 2023 and the second in 2028. The building will incorporate passive design, while lighting features, internal plants and trees will further boost Copenhagen Airport's sustainability credentials.

By 2030, Copenhagen Airport aims to be emissions-free, including emission-free transport to and from the airport through investment in solar panels and charging infrastructure for electric vehicles. The Airport will also install super-chargers for electric taxis at the airport and invest in testing an electric bus to replace the diesel-powered busses. Their longer-term plan involves developing and leveraging strategic partnerships and increasing the availability of sustainable fuel. This stems from a recognition that flights and surface access transport make up 93 per cent[16] of Copenhagen Airport's emissions.

13. Sustainability Series: Copenhagen's green ambitions 2019, https://www.internationalairportreview.com/article/82563/sustainability-series-copenhagens-green-ambitions/
14. CPH Group Annual Report 2018, https://cph-prod-cdn.azureedge.net/495470/globalassets/8.-om-cph/6.-investor/arsrapporter/2018/cph-annual-report-2018_uk_web.pdf
15. Ibid
16. New climate strategy 2019, https://www.cph.dk/en/about-cph/press/news/2019/3/new-climate-strategy-copenhagen-airport-to-be-co2-neutral-this-year

Technology dashboard

Clean energy and infrastructure: Pathway to airport sustainability provides an overview of current best practice initiatives, for both major and regional airports.

This report uses global case studies to highlight practical initiatives that airports and industry can adopt to lower emissions. Whilst directly applicable to airports, these initiatives also present an opportunity to guide and influence emissions from airlines, passengers, and commercial airport users.

Initiatives advantages, key considerations and recommendations for successful planning and implementation are detailed in this report. These are underpinned by case studies demonstrating how selected initiatives have been applied globally.

This report recognises the characteristic differences in airports and uses indicators to highlight typically suitable airport locations and sizes to maximise initiative benefits.

Indicative emissions savings and financial benefits in the context of typical asset value are outlined, with all financials provided in Australian dollars. Emissions scopes are defined in the context of the airport operator/owner and may be viewed differently in the eyes of other airport stakeholders.

A glossary of key terms used can be found at the end of the report.

Assessment criteria

Each initiative has been assessed using six focused criteria:

1. Airport size

- **Major** (e.g. international)
- **Regional** (e.g. domestic)

2. Location at airport

- **Terminal**
- **Airside**
- **Landside**

3. Typical emissions scope

- **Scope 1:** Direct emissions released due to activities owned or controlled by the airport (for example, airport-owned heating, cooling and electricity production).
- **Scope 2:** Indirect emissions generally associated with the airport's use of electricity from the grid or third-party supplier. Although not directly controlled by the airport, an airport has the opportunity to source or produce renewable electricity to reduce these emissions.
- **Scope 3:** Indirect emissions generated by third parties. These are generally the largest category of emissions at airports. Airport operators can guide and influence initiatives that potentially reduce Scope 3 emissions.
- **NB:** These emission scopes are 'typical' in airports but depend significantly on the ownership and operation structure: a smaller airport may control more initiatives and therefore have greater Scope 1 and 2 emissions. Conversely, a larger airport may outsource initiatives to other organisations, impacting Scope 3 emissions.

4. Emissions impact

- **Per cent emissions**
  Reduction against typical business as usual technology/approach

5. Capital expenditure

- <0.1% asset value
- <0.3% asset value
- < 0.5% asset value
- >0.5% asset value
- **NB:** Costs are indicative estimates from existing industry case studies and not specific to any one airport, climate, size (passenger, physical or geography), use/type, land use mix, etc.

6. Payback period

- **Years** (based on minimum payback periods)

Best practice initiatives: Snapshot

Best practice initiative	Emissions impact as % on BAU	Capex as % asset value	Payback in years	Emissions scope	Location	Airport applicability
1. Central utility plant	Up to 25%	>0.5%	<20	1, 2	Landside Terminal Airside	Major airports
2. Onsite solar PV and battery energy storage	Up to 100%	<0.3%	<5	1, 2	Landside Terminal Airside	Major airports Regional airports
3. Purchasing renewable energy	Up to 100%	N/A	Variable	2	Landside Terminal Airside	Major airports Regional airports
4. Electrification of ground support equipment	Up to 100%	<0.5%	>10	1, 2	Airside Landside	Major airports
5. Fixed ground power and pre-conditioned air	Up to 40%	<0.5%	>20	2, 3	Airside	Major airports
6. Sustainable aviation fuel	Variable	<0.5%	Variable	3	Airside	Major airports Regional airports
7. Surface access improvements	Variable	>0.5%	>20	3	Landside	Major airports
8. Aircraft and airside upgrades	Variable	>0.5%	Variable	3	Airside	Major airports Regional airports
9. Building analytics technologies	Variable	<0.3%	<5	1, 2	Terminal	Major airports Regional airports
10. Low energy baggage handling systems	40-75%	<0.5%	>20	2	Terminal	Major airports Regional airports
11. Terminal initiatives	Variable	Variable	Variable	1, 2	Landside Terminal	Major airports Regional airports
12. Airfield lighting upgrades	Up to 50%	<0.3%	>5	2	Airside	Major airports Regional airports
13. Ground source heat pumps	20-50%	<0.3%	>5	1, 2	Landside Terminal Airside	Major airports Regional airports
14. Energy-from-waste	Variable	<0.5%	Variable	1, 3	Terminal Airside Landside	Major airports Regional airports
15. Waste minimisation	Variable	<0.3%	>5	1, 3	Landside Terminal Airside	Major airports Regional airports

Best practice initiatives: In detail

1 Renewable energy and storage

Central utility plant

Airport applicability:
Major

Typical emissions scope:
Scope 1, 2

Capital expenditure:
>0.5% asset value

Location in airport:
Airside, Terminal, Landside

Emissions impact:
Up to 25% reduction on BAU

Payback period:
<20 years

Airports require large amounts of energy for cooling and heating, including heating water. The business-as-usual approach has historically been systems of multiple decentralised boilers and chillers. Depending on the size of the airport, this can require as much energy as powering a small town[17].

A Central Utility Plant (CUP) is an integrated alternative to using several decentralised systems. CUPs deliver power, chilled and hot water and steam to buildings. They are designed to maximise efficiencies from economies of scale, providing large energy and operational cost savings.

New CUPs can be designed to provide increased resilience to power outages and extreme temperatures associated with climate change.

Although cogeneration/trigeneration systems currently in the market are largely based on electricity and natural gas, there are opportunities for further emissions reductions through powering CUPs with renewables and biomass (refer to initiatives on Onsite solar PV and battery energy storage; Purchasing renewable energy; and Energy-from-waste).

Advantages	Considerations
– Energy capture and reuse means less wasted energy. – CUPs are scalable with system modularity and can be adjusted to meet an airport's changing demands. – Larger systems will typically lead to greater efficiencies per passenger through economies of scale. – Reduced maintenance (vs multiple systems). – Reduced total airport spatial provision (vs multiple systems). – Often integrated within Building Management System for 'on-demand' heat and cooling. – Can be designed to reduce peak electricity demand.	– Significant capital cost and typically long payback periods for a completely new system. – Multiple plant and equipment may be required in airports with a large footprint to reduce thermal losses. – May require specialist maintenance. – Often requires a designated CUP building. – Potential increased complexity due to extensive distribution network required.

Planning recommendations

- Assess the efficiency of existing utilities and plant, such as chillers and boilers, and identify opportunities for replacement and consolidation.
- Identify optimal locations for a CUP and consider the necessary routing of distribution pipes. This should be considered in the context of the airport and energy master plan.
- Assess options for adaptability, scalability, redundancy and resilience in the context of existing and future climatic conditions and use.
- Consider the CUP in the context of existing/proposed Building Management System, sub-metering and smart sensors.

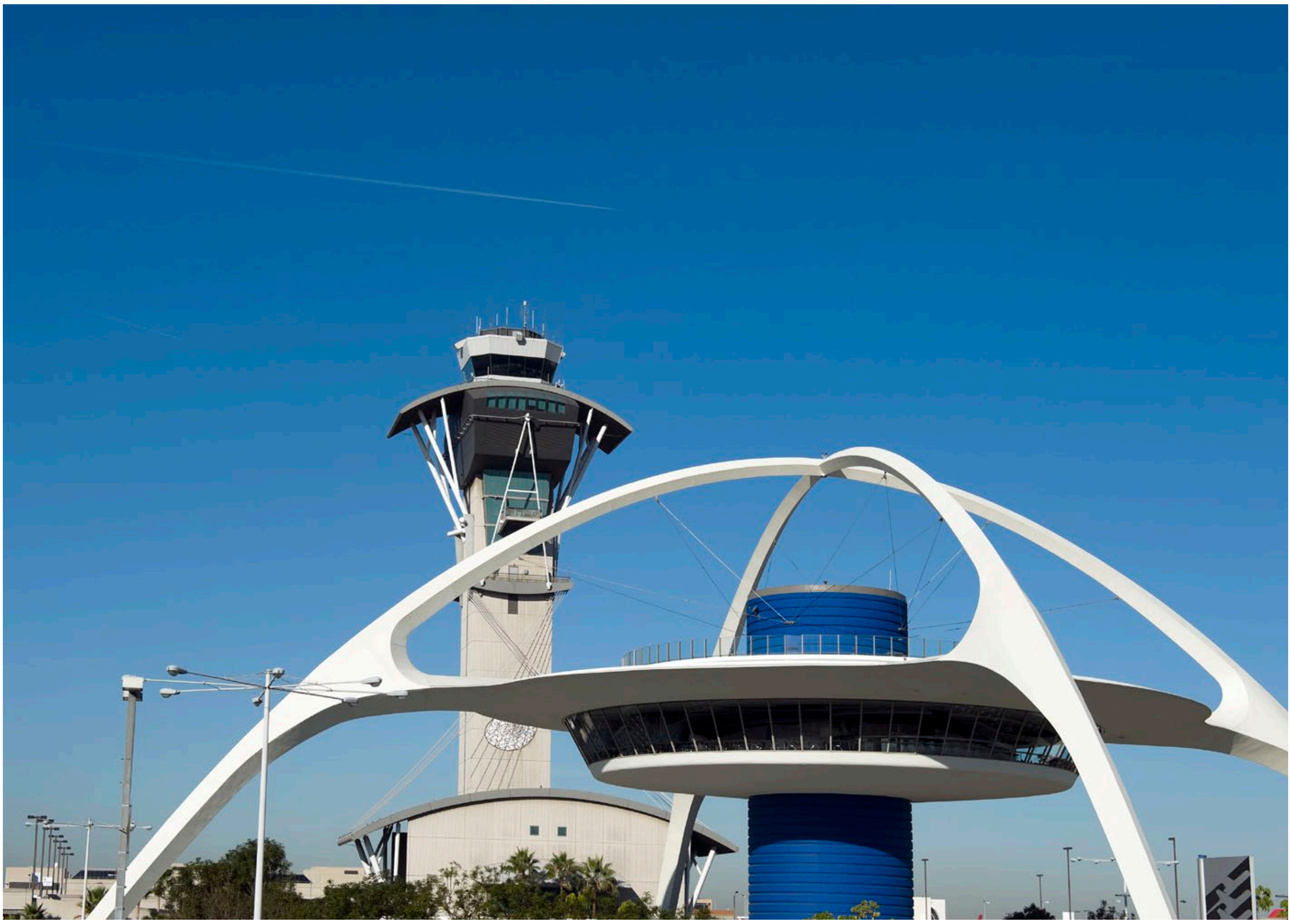
17. Energy efficient airport buildings 2012, https://www.internationalairportreview.com/news/10719/energy-efficient-airport-buildings/

Los Angeles Airport, United States

In 2015, Los Angeles Airport (LAX) completed the installation of a new CUP. The new CUP consisted of a 4-storey building for plant and staff offices, above ground cylindrical chilled water storage tank and a low-rise structure with maintenance shops and cooling towers.

The CUP is a LEED Gold standard, 8.4MW cogeneration plant including electric-driven centrifugal chillers, heat recovery boilers, primary and secondary chilled water pumps, cooling towers, and thermal energy storage. It has around 20,000 tonnes of cooling capacity to supply nine terminals[18].

It replaced a 50-year-old plant and cost $615m to implement, phased in to not disrupt existing operations. It currently saves around $10m a year and is 25 per cent more energy efficient than the plant it replaced, saving an estimated 4,890tCO_2-e per annum (Scope 1 and 2). While it is currently powered with electricity and gas, if the CUP was powered entirely using renewable-generated electricity, the CO_2 emissions savings would be significantly greater.



18. LAX Unveils Sustainable Utility Plant 2015, http://greenbuildingnews.com/2015/05/05/lax-unveils-sustainable-utility-plant/

2

Renewable energy and storage

Onsite solar PV and battery energy storage

Airport applicability:
Major, Regional

Typical emissions scope:
Scope 1, 2

Capital expenditure:
<0.3% asset value

Location in airport:
Airside, Terminal, Landside

Emissions impact:
Up to 100% reduction on BAU

Payback period:
<5 years

Solar photovoltaic (PV) panels capture and convert sunlight into electricity. They can be either roof-mounted or ground-mounted, with both often feasible in most Australian airports due to the airports' large footprint.

Building Integrated PV (BIPV) systems also present an alternative opportunity to maximise solar PV generation in new terminal/building design. BIPV integrates photovoltaic technology into the building envelope, replacing conventional building materials and generating electricity.

Airports have a predictable baseline electricity load that can be aligned to solar PV generation. Depending on the size and design of the PV system, excess generation can be stored in batteries. The stored energy can be used during times of low energy generation or used to manage peak electrical demand. Battery systems also provide resilience as a back-up power supply for critical assets during brownouts or blackouts.

Traditionally, most (over 70 per cent, often over 90 per cent) airport-controlled emissions are Scope 2 emissions from purchased off-site electricity.

Onsite solar PV systems, coupled with battery storage, can reduce these emissions by as much as 100 per cent, subject to the size of system and demand of the airport.

Solar PV

Advantages	Considerations
– Established technology with defined returns on investment. – Takes advantage of previously unutilised areas. – Scalable to meet anticipated electrical demand and available space. – Low maintenance and a typical lifespan of 25+ years. – Government rebates available in some jurisdictions.	– Limited to the availability of space for installation. – Weight of PV panels may require additional structural reinforcement for roof-mounted panels. – Orientation of roof space and localised shading can be limiting factors to optimal energy generation. – Relatively high up-front capital cost and extended payback periods associated with BIPV systems.

Battery storage

Advantages	Considerations
– Can reduce peak demand energy consumption and avoid peak demand tariffs. – May reduce the need for alternate electrical infrastructure required to meet peak demand. – Improves energy supply resilience and reliability by powering critical assets during brownouts or blackouts. – Technology continuously evolving and systems becoming cheaper.	– Relatively high up-front capital cost. – Payback periods can vary, depending on use. – Large spatial provision required – typically a 40ft shipping container houses 1MWh of storage. – Typically, less suitable for large energy consumers due to size of system required.

Planning recommendations

- Analyse the airport's energy demand profile to identify demand and supply requirements.
- Compare the airport's energy demand profile to a projected PV generation profile, including battery storage potential, to determine financial feasibility and business case.
- Consider structural and maintenance access implications of PV panel placement on building rooftops.
- Consider material lifecycle choice to assess implications of BIPV integration into building envelope.

Darwin International Airport, Australia

In May 2016, Darwin International Airport (DIA) completed Stage 1 of a $13m, 5.5MW solar project involving 15,000 PV panels. At the time, it was the world's largest airside solar PV array. Stage 1 saw a 4MW solar PV array installed at the eastern end of the runway, over a 6 hectare site. In December 2016, Stage 2 saw a 1.5MW solar array installed west of the General Aviation northern apron[19].

The system reduces DIA's total annual electricity consumption by 25 per cent per annum and can meet up to 100 per cent of the Airport's peak energy demand in the middle of the day[20].

This equates to a saving of around $1.5m per annum. In 2017-18 over 8,700,000 kWh of solar energy was produced.

Since 2016, the cost to install solar has significantly decreased which presents further opportunities. In September 2018, the Northern Australia Infrastructure Fund announced it would loan funding to increase the capacity of the DIA solar project to 40MW as well as fund an off-site multi-user battery to store renewable energy.

19. Airport Development Group (Darwin International Airport) Annual Report 2016-2017, https://www.darwinairport.com.au/node/641/attachment
20. Darwin Airport completes 4MW large scale solar power facility 2016, https://www.darwinairport.com.au/news/darwin-airport-completes-4mw-large-scale-solar-power-facility

3

Renewable energy and storage

Purchasing renewable energy

Airport applicability:
Major, Regional

Typical emissions scope:
Scope 2

Capital expenditure:
N/A

Location in airport:
Airside, Terminal, Landside

Emissions impact:
Up to 100% reduction on BAU

Payback period:
Variable

Purchasing renewable energy works much the same as purchasing any kind of electricity from a utility provider, however the electricity source can be up to 100 per cent renewable.

Traditionally, most (over 70 per cent, often over 90 per cent) airport-controlled emissions are Scope 2 emissions from purchased off-site electricity.

Power Purchase Agreements (PPAs) are long term agreements for energy buyers to purchase electricity generated by offsite renewables. They can assist an airport to reduce up to 100 per cent of these emissions through agreements with an energy retailer.

Other alternatives include GreenPower, which enables the consumer to buy accredited energy that can drive renewable energy investment.

Advantages	Considerations
– Significant reduction in Scope 2 emissions from electricity use.	– Potential for increased cost of purchase (compared to non-renewable electricity sources).
– Does not require the airport to have their own renewable energy generating infrastructure.	– Depending on scale purchasing renewable energy may not be the most cost-effective means of implementing renewable energy and reducing emissions.
– PPAs can guarantee supply of renewable energy.	– Fixed term PPAs may lead to buyers paying more than the retail price if electricity prices decline over the medium to long term.
– PPAs enables buyers to hedge against future energy cost risks.	
– Buyer may secure lower energy prices below typical retail offers with PPAs.	

Planning recommendations

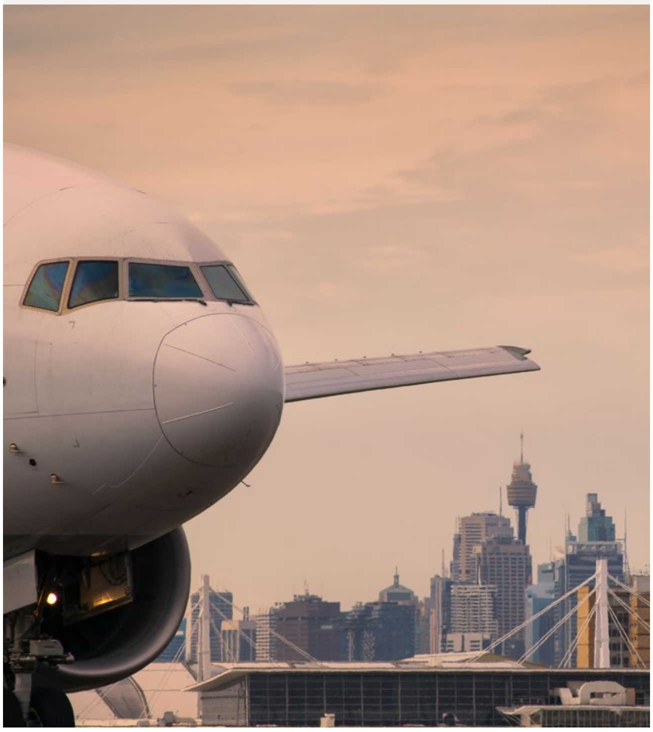
- Analyse the airports existing use and future use electrical profile to determine financial feasibility and business case.
- Assess the energy market and identify suitable renewable projects and PPAs to meet the airports anticipated future electricity consumption and demand profile.

Sydney Airport, Australia

In late 2018, Sydney Airport signed an eight-year power purchase agreement with Grassroots Energy Group and Origin Energy to power the airport with renewable wind energy.

Under the agreement, Sapphire Wind Farm and, when operational, Crudine Ridge Wind Farm, both in NSW, will provide up to 75 per cent of Sydney Airport's electricity[21].

In 2018, Sydney Airport's Scope 2 emissions decreased slightly, however the project is expected to play a significant part of Sydney Airport's commitment to reduce its carbon intensity by 50 per cent by 2025. The Airport is also expecting to save millions of dollars off its annual energy bill[22].



Royal Schiphol Group, Netherlands

Since 2018, all Royal Schiphol Group's Dutch airports (Amsterdam Airport Schiphol, Rotterdam The Hague Airport, Eindhoven Airport and Lelystad Airport) have been running on 100 per cent Dutch wind power[23].

Royal Schiphol Group entered into a power purchase agreement with energy company Eneco to supply renewable energy to all four airports, which annually consume around 200 GWh of power combined. The use of renewable energy means the airports will achieve a combined reduction in CO_2 emissions of around 92 thousand tonnes.

Part of the agreement focuses on electricity sourced from newly built wind farms. While some of the energy is still coming from older wind farms, the aim is that by 2020 the airports will be using electricity from wind farms built since 2017.

21. PPA between Sydney Airport, CWP Renewables and Origin Energy 2019, https://www.australasianlawyer.com.au/news/allens-advises-ppa-between-sydney-airport-cwp-renewables-and-origin-energy-258982.aspx
22. Sydney Airport to source power from wind farms, https://www.afr.com/business/infrastructure/airports/sydney-airport-to-source-power-from-wind-farms-as-interim-profit-rises-4pc-20180821-h1492e
23. Energy Projects, 100% Dutch Wind Power, https://www.schiphol.nl/en/schiphol-group/page/100-procent-dutch-wind-power/

4

Electrification and fuel switching

Electrification of ground support equipment

Airport applicability:
Major

Typical emissions scope:
Scope 1, 2

Capital expenditure:
<0.5% asset value

Location in airport:
Airside, Landside

Emissions impact:
Up to 100% reduction on BAU

Payback period:
>10 years

At major airports, there can be several hundred airside ground support equipment (GSE) and vehicles in operation. They provide a multitude of services from transporting baggage and passengers to taxiing aircraft and refuelling.

GSE typically use diesel or petrol fuels, which collectively contribute to a significant proportion of airport emissions, including carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur oxides (SO_x) and particulates.

Electric GSE (eGSE) technologies are a cleaner alternative to using combustible fuels and can reduce emissions by up to 100 per cent when powered by renewables (refer to initiatives on Onsite solar PV and battery energy storage; Purchasing renewable energy; and Energy-from-waste).

Advantages

- Co-benefits associated with improved local air (when compared with combustible fuel alternative) and noise quality.
- Lower operational cost of refuelling and reduces risk from petrol price volatility.
- Lower operational cost over lifespan due to longevity of the motor and low maintenance cost.
- Vehicles can be linked together to transfer power from one vehicle to another or act as a localised battery.
- Reduction in Scope 1 and 2 emissions when powered with renewable energy.
- Reduction in emissions from operation – diesel engines take time to warm up, most GSE travel short distances with multiple stops resulting in excessive exhaust gases.

Considerations

- May require upgrade of airport electrical infrastructure, which can be costly.
- Need to recharge fleet batteries – therefore may be less suitable in a 24-hour airport (for example, this may require a larger vehicle fleet for charging rotations).
- Need to consider charging times to limit an increase in overall peak energy demand. Stationary energy storage may be required to complement renewable energy sources for charging.
- Governance challenges due to operation of GSE by multiple airport stakeholders. This may require an operations and maintenance strategy or the airport taking ownership of some operations.

Planning recommendations

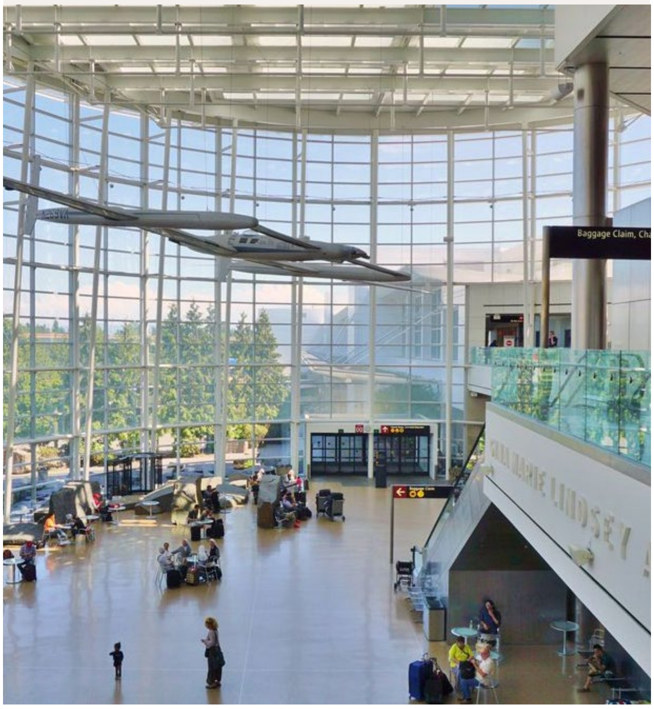
- Assess the needs of GSE operators and owners to establish feasibility and formulate a strategy for gradual roll out of eGSE.
- Assess the impacts of increased electrical demand on existing electrical infrastructure.
- Consider increased electrical demand as part of a broader airport energy master plan to identify pathways for further reductions in energy demand and emissions. For example, use of microgrids and renewable generation to compliment uptake of eGSE.

Seattle-Tacoma Airport, United States

In 2015, Seattle-Tacoma Airport started a program to install nearly 570 electric vehicle charging points[24], with the aim to have them available at every gate by 2021, costing around $45m[25].

The finalised project is expected to reduce operational fuel costs by over $4m per annum, prevent 10,000 tonnes of GHG emissions per annum and reduce annual petroleum consumption by nearly 1 million gallons.

This has led to airlines (who operate the GSE) adopting eGSE vehicles at the airport. Alaska Airlines was the first to introduce electric vehicles at Seattle-Tacoma Airport, eliminating around 2,000 tonnes of CO_2 emissions. The Airline is aiming to convert 44 per cent of its ground fleet to electric by 2020.

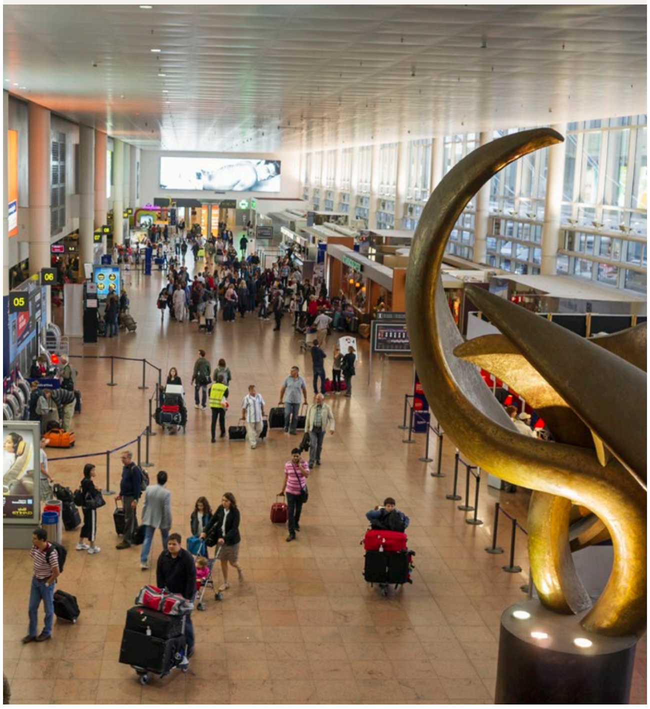


Brussels Airport, Belgium

In 2019, Brussels Airport invested $21m and introduced thirty electric e-buses to move passengers between the gate and their plane.

The e-buses emit no CO_2 emissions, are almost silent and are expected to save around 600 tonnes of CO_2 annually. The e-buses are charged using green electricity in around 3 hours and can travel around 150km fully charged – highly beneficial given an airport bus at Brussels Airport averages around 12km per day[26].

In 2016, following stakeholder consultation, Brussels Airport took over tarmac passenger transport from handling agents. This has enabled the Airport to directly influence the electrification of the bus fleet, which they now own, and will help Brussels Airport achieve their goal to reduce CO_2 emissions by 40 per cent by 2030 (as of 2018, they are 7 per cent off their goal[27]).



24. Climate and Air Quality Port of Seattle, https://www.portseattle.org/environment/climate-air-quality
25. Sea-Tac Airport Unveils Electrification Project 2014, https://www.prnewswire.com/news-releases/sea-tac-airport-unveils-electrification-project-to-save-airlines-millions-in-fuel-and-dramatically-reduce-greenhouse-gas-emissions-250857101.html
26. On board our 30 new e-buses 2018, https://environment2018.brusselsairport.be/en/on-board-our-30-new-e-buses
27. Brussels Airport Environmental Report 2018, https://environment2018.brusselsairport.be/assets/PDF/environmental-report-2018.pdf

5

Electrification and fuel switching

Fixed electrical ground power and pre-conditioned air

Airport applicability: **Major**

Typical emissions scope: **Scope 2, 3**

Capital expenditure: **<0.5% asset value**

Location in airport: **Airside**

Emissions impact: **Up to 40% reduction on BAU**

Payback period: **>20 years**

Many large aircraft use a self-contained auxiliary power unit (APU) as an additional energy source to power onboard lighting, electronics and air conditioning when the aircraft is parked at the gate.

While waiting for passengers, an APU removes the need to start one of the aircraft's main engines.

However, APUs consume an average of 150 litres of aviation fuel per hour resulting in significant CO_2 and particulate emissions as well as noise and air quality impacts.

As an alternative, many airports are now installing Fixed-Electrical Ground Power (FEGP) and Pre-Conditioned Air (PCA) at the gate. Aircraft can 'plug in' and get electricity straight from the local grid (or airport based renewable sources, refer to initiatives on Onsite solar PV and battery energy storage and Purchasing renewable energy) and use the airport's air conditioning to provide ventilation and control the aircraft's internal temperature. This allows the aircraft to continue pre-passenger onboarding operations without the need to run APUs.

Advantages	Considerations
– Improved local air quality and reduced noise (compared with APU alternative).	– May require upgrade of airport electrical infrastructure.
– Reduced aircraft fuel use and associated emissions.	– Less suitable for aircraft with quick turnaround times.
– The airport operator has greater control over energy consumption.	– If relying on on-site renewables, battery storage may be required to reduce electricity demand peaks and allow charging at low generation times.
– Potential for further reduction in Scope 2 emissions when powered with renewable energy.	– Stakeholder engagement required to ensure compliance as airlines may prefer to run APUs instead. Adoption can be increased through incentives or mandated use.

Planning recommendations

- Identify the demand or need for pre-conditioned air at each bay. This may be based on typical aircraft use and turnaround times.
- Consider spatial provision for installation and connectivity to a centralised power unit (if available) to provide centralised system efficiencies.
- Assess the impacts of increased electrical demand to existing electrical infrastructure and consider as part of a broader airport energy master plan.

Hong Kong International Airport, Hong Kong

In December 2014, Hong Kong International Airport enforced a ban on using APUs for aircraft parking at frontal stands[28].

The Airport invested $7.8m[29] to make FEGP and PCA available at all frontal and remote stands. The airport also put significant effort into engaging airline operators in the implementation of the new policy position. Data from 2017-2018 found the ban has reduced NO_x emissions by 20 per cent.

Heathrow International Airport, United Kingdom

Under the Heathrow Airport Air Quality Strategy 2011-2020, Heathrow has implemented both FEGP and PCA to reduce the use of APUs. By 2018, $36.5m[30] had been invested on infrastructure to support FEGP and PCA with over 90 per cent of Heathrow's stands fitted with FEGP[31].

In 2018 Heathrow recorded a slight increase in Scope 3 emissions during the landing and take-off cycle caused by an increase in the use of APUs. In response, Heathrow are reworking the way they monitor APU use and are investing to improve the FEGP and PCA functionality[32]. The airport currently measures APU use through manual surveys on certain flights. Heathrow is piloting an automatic system that detects and records APU use. The airport will use this data to intervene and provide improvement opportunities through their FEGP network.

28. Airport Operations Manual 2018, https://extranet.hongkongairport.com/aom/Part%20E/AOM%20E2%20-%20Airbridges.pdf
29. Fixed Electrical Ground Power, https://aviationbenefits.org/case-studies/fixed-electrical-ground-power/
30. Heathrow Emissions Strategy and Action Plan 2018, https://www.heathrow.com/file_source/Company/Static/PDF/Communityandenvironment/Heathrow_Emissions_Strategy.pdf
31. Aircraft power at the stand 2018, https://www.airsideint.com/issue-article/aircraft-power-at-the-stand/
32. Heathrow Carbon Footprint 2017, https://www.heathrow.com/file_source/Company/Static/PDF/Communityandenvironment/Heathrow-Carbon-Footprint_2017.pdf

6

Electrification and fuel switching

Sustainable aviation fuel

Airport applicability: **Major, Regional**	Typical emissions scope: **Scope 3**	Capital expenditure: **<0.5% asset value**
Location in airport: **Airside**	Emissions impact: **Variable**	Payback period: **Variable**

The burning of aviation fuel is the main contributor to airport Scope 3 emissions. Every year approximately 1.5 billion barrels of jet fuel is burnt for global air travel[33]. While today's jet aircraft are over 80 per cent more fuel efficient per seat kilometre than aircraft in the 1960s, over a third of airline operating costs are still spent on fuel – a proportion that is likely to rise with increased fuel prices in the future[34].

This context presents an opportunity and incentive for airlines to explore fuel alternatives and for airports to support this transition.

Aircraft design aims to maximise fuel efficiency and increasingly to utilise more sustainable, alternative fuels. Sustainable aviation fuel or 'biofuels' can be made from a range of organic materials, including sugarcane bagasse, molasses, wood waste, animal fats, vegetable oils and agave. Some sources have been shown to reduce the carbon footprint of aviation fuel by up to 80 per cent[35].

Airports can facilitate the transition to biofuels by ensuring that their fuel delivery infrastructure is compatible with biofuels. Biofuels can often be added into the existing fuel pipelines, including by blending biofuels with jet fuel as an interim measure. With this existing infrastructure in place, airports can further incentivise aircraft biofuel uptake by removing internal or contractual barriers to the use of biofuels.

Advantages	Considerations
– Potential for significant reductions in airport Scope 3 emissions from reduced use of fossil fuels. – Potential reduction in fuel cost volatility. – Biofuels can often use existing pipelines and fuel infrastructure. – Opportunities to use organic waste (rather than virgin) materials as a feed source, such as from airport on-site waste management processes. – Possible financial benefits by facilitating access for airlines to biofuels.	– Biofuel costs are currently higher than jet fuel costs and vary significantly depending on biofuel source. – Sustainability benefits associated with biofuel production can vary – not all biofuels are the same and the production of some types produces high GHG emissions or other negative environmental impacts, such as deforestation. – Need to establish governance and ownership responsibilities in delivery of biofuel through existing fuel hydrant infrastructure.

Planning recommendations

- Identify required infrastructure at airports to enable biofuel use. This may include provision of biofuel in existing pipelines or development of new pipelines.
- Identify opportunities to promote the uptake of biofuel through contractual arrangements and investigate renegotiation of aviation fuel supply agreements to include biofuel supply.

Virgin Australia Airlines and Brisbane Airport, Australia

In October 2017, Virgin Australia Group announced a trial of sustainable biofuel through Brisbane Airport's jet fuel supply infrastructure[36]. This was the first time a sustainable fuel type would be delivered through a traditional fuel system at an Australian airport.

The trial was a partnership between Virgin Australia, the Queensland Government, Brisbane Airport Corporation, a biofuel provider (Gevo, Inc), Caltex and DB Schenker.

In September 2018, Virgin Australia announced the completion of the trial, with the biofuel blend fuelling 195 domestic and international flights out of Brisbane Airport. They intend to continue to fuel more flights with the blended fuel, hoping to boost the Australian biofuel industry. Brisbane Airport's Draft 2020 Master Plan highlights their intention to continue to work with airlines to expand the use of biofuels for aviation[37]. This partnership and trial demonstrates the capacity for airport stakeholders to co-deliver emissions reduction initiatives.

Avinor Airports, Norway

Norway's airport operator Avinor will invest $16.5m from 2013-2022 to develop the country's aviation biofuel capacity. In 2016, Oslo Airport became the first airport in the world to offer biofuels to all airlines and the first airport to offer them through the airport's main fuelling system[38].

The use of biofuels expanded to Bergen Airport in 2017, so now Norway's two busiest airports have a blend of jet fuel and biofuels available to all aircraft. Avinor continue to invest in the technology to support biofuel in aircraft and have started to investigate the infrastructure required to power electric aircraft.

With Norway having banned the use of palm-oil based biofuels, Oslo Airport's biofuel feed sources come from farm and forestry waste and used cooking oil.

33. Norway's airports refuel aircraft with biofuels 2017, https://www.weforum.org/agenda/2017/11/norway-airports-biofuels-avinor/
34. 3ATAG Facts and Figures 2018, https://www.atag.org/component/factfigures/?Itemid
35. Ibid
36. Virgin Australia Group leads world-first initiative 2017, https://newsroom.virginaustralia.com/release/virgin-australia-group-leads-world-first-initiative-supply-sustainable-aviation-fuel
37. https://www.bne.com.au/sites/default/files/no-index/Brisbane-Airport-2020-Preliminary-Draft-Master-Plan-Chapter-8-Aviation-Strategy.pdf
38. Norway's airports refuel aircraft with biofuels 2017, https://www.weforum.org/agenda/2017/11/norway-airports-biofuels-avinor/

7

Electrification and fuel switching

Surface access improvements

Airport applicability: **Major**	Typical emissions scope: **Scope 3**
Capital expenditure: **>0.5% asset value**	Location in airport: **Landside**
Emissions impact: **Variable**	Payback period: **>20 years**

Airport surface access refers to the non-aviation journeys to and from the airport by passengers, greeters, farewellers and staff.

Major airports affect the traffic on roads surrounding them as surface access to most Australian airports is dominated by cars. This contributes significantly to the airport's total carbon emissions (with estimates ranging from 25-50 per cent contribution to Scope 3 emissions).

Upgrades to airport surface access and promotion of low emissions transport modes can have a significant impact on reduction of emissions and alleviate traffic problems.

Access enhancements may include providing public transport interchanges, improved cycling and pedestrian connectivity, electric vehicle parking and charging infrastructure and road redesign, such as express lanes for electric vehicles.

Advantages	Considerations
– Potential for greater airport user efficiency, leading to increased airport revenue. – Potential for reduction in local traffic jams leading to reduced emissions. – Increased safety through reduced transportation and user conflict. – Wider benefits to local and regional populations. – Provides an opportunity to incentivise electric vehicle use through charging infrastructure linked to renewable energy, reducing emissions. – Ability to align with future transport infrastructure upgrades.	– Improved road accessibility may promote the use of personal vehicles over public transport, leading to an increase in emissions. – May require input and/or approval from government and transport authorities. – Funding agreements may be required between airports, government and transport authorities.

Planning recommendations

- Analyse how the passenger population is travelling to and from the airport and identify carbon emissions by transport mode.
- Plan for holistic surface access improvements as part of a wider transport master plan.
- Engage with transport authorities (where necessary) to plan for transport infrastructure upgrades.
- Investigate potential options and initiatives to promote low emission forms of transport such as public transport, inclusion of electric vehicle charging infrastructure, electric buses for ground access and car park shuttles.

Perth Airport, Australia

In 2018, construction began on infrastructure to support the new train station being built near Terminal 1 at Perth Airport[39]. The Skybridge, an elevated 280m walkway with travellators will connect rail passengers to the airport's Terminal 1 and is expected to encourage more public transport to and from the airport.

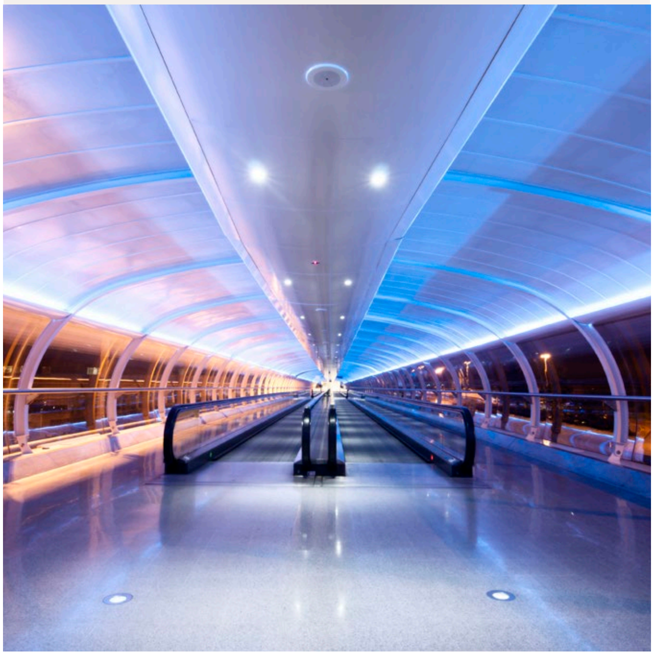
Expected to open in late 2021, the Skybridge and the new Airport Central Station rail link are part of a $2 billion jointly funded WA Government and Perth Airport redevelopment.

Manchester Airport, United Kingdom

Manchester Airport's Sustainable Development Plan 2016 includes a Surface Access Plan[40]. The Plan recognises the importance of partnerships to influence surface access improvements.

In 2014, around 75 per cent of passengers and 78.5 per cent of staff accessed the airport by car. The Airport has set ambitious targets to encourage 50 per cent of passengers using public transport and to also increase the amount of staff using public transport. To achieve this, the Airport has worked with tram and train providers to introduce new services at the start and the end of the day and provide discounted fares on public transport for staff[41].

Improved surface access is also part of the Airport's $1.8 billion ongoing Transformation Program, that commenced in 2017. The Program includes shifting the main Terminal's "centre of gravity" to directly connect to the rail, tram and coach stations and next to the proposed new HS2/Northern Powerhouse Rail station site[42].



39. Perth Airport Skybridge 2018, https://www.watoday.com.au/national/western-australia/first-peek-at-new-perth-airport-skybridge-for-train-passengers-20181125-p50i81.html
40. Manchester Airport Sustainable Development Plan – Economy and Surface Access 2016, https://live-webadmin-media.s3.amazonaws.com/media/3970/man_sdp_economy-and-surface-access_online-2016-final-190716.pdf
41. MAG CSR Report 2017/18, https://www.magairports.com/media/1553/csr-2018-pdf.pdf
42. Manchester Airport transformation Programme https://www.mantp.co.uk/about/#panel_2

8

Energy efficiencies

Aircraft and airside upgrades

Airport applicability: **Major, Regional**	Typical emissions scope: **Scope 3**
Capital expenditure: **>0.5% asset value**	Location in airport: **Airside**
Emissions impact: **Variable**	Payback period: **Variable**

Aircraft design consistently seeks to maximise fuel efficiency and reduce emissions and operating costs. This includes developing more efficient engines, lighter materials and enhancing aerodynamic design.

Airports can facilitate these upgrades by ensuring their runways, taxiways, support services and terminals can service current and future aircraft needs.

Advantages	Considerations
– Significant Scope 3 emissions reductions and lower operational costs with new aircraft models. – Airport master planning presents an opportunity to plan for future aircraft. This can reduce emissions and costs associated with retrofitting.	– Limited certainty to anticipate future aircraft trends and requirements. – Limited control for airports over embodied energy, design and operation of aircraft.

Planning recommendations

- Future forecasts in passenger numbers, industry innovation and new aircraft technologies built into master plans.
- Analyse per passenger/per tonne emissions savings with different aircraft manufacturers to determine the most efficient technology. Ensure the airport can accommodate these aircraft.
- Plan for future retirement or expansion of existing fleet early as aircraft orders can take several years to fulfil due to time needed for construction, delivery and testing.

Brisbane Airport, Australia

Brisbane Airport's draft 2020 Master Plan recognises changes in designs of aircraft that are currently being manufactured and the demands these aircraft will place on the airside infrastructure.

It also recognises that aircraft upgrades will facilitate an increase in certain types of services (such as a growing number of middle-distance flights) and anticipates the introduction of larger aircraft into the market.

Brisbane Airport is in Phase 2 (2016-2020) of building a major new runway, including a four-lane underpass, to allow traffic to access the airport under the new taxiways. The underpass will be able to bear aircraft over 700 tonnes – 140 tonnes more than the current heaviest passenger plane[43]. This will ensure the taxiway will be able to service future aircraft.

43. Brisbane Airport 2020 Preliminary Draft Master Plan, https://www.bne.com.au/sites/default/files/no-index/Brisbane-Airport-2020-Preliminary-Draft-Master-Plan.pdf

9

Energy efficiencies

Building analytics technologies

Airport applicability:
Major, Regional

Typical emissions scope:
Scope 1, 2

Capital expenditure:
<0.3% asset value

Location in airport:
Terminal

Emissions impact:
Variable

Payback period:
<5 years

Inefficient airport building infrastructure contributes to GHG emissions and can be costly to replace.

Performance degradation, poorly tuned controls and heating, ventilation and air conditioning system malfunctions are estimated to waste up to 16 per cent of whole building energy[44].

Fault detection and diagnosis[45], or automatic building analytics, provides an opportunity to ensure an airport is operating efficiently. The software searches for patterns that indicate poor equipment performance or inefficiencies, without having to wait for equipment failure.

The technology is smart and uses machine learning to improve the building analysis over time. Early detection of faults and identifying opportunities to improve energy efficiency can reduce emissions and energy consumption, manage peak demand, lower maintenance and repair costs and improve asset life cycles.

Advantages	Considerations
– Significant Scope 1 and 2 emissions reductions and lower operational and maintenance costs from detecting issues upfront.	– Need to establish key roles and responsibilities internally to understand and prioritise the information being received.
– Certain technologies can pin-point specific failures at equipment level, leading to more effective maintenance and reduced maintenance cost.	– Effectiveness of the system depends on the useability of the information available and the implementation of solutions.
– Potential to reduce expensive building and equipment upgrades and retrofits, such as by upgrading a system before total failure.	– Retrofitting for existing terminals may require additional supporting infrastructure and reallocation of space.
– Potential to provide a real time, integrated view of building performance to identify changes, patterns and opportunities.	

Planning recommendations

- Determine whether the preferred system can integrate and utilise current building management system data, energy/power submeter data, and other building and external systems data.
- Identify opportunities for the results to be shared and used to benefit all airport stakeholders.

44. Low Carbon Living CRC – Evaluation of Next- Generation Automated Fault Detection & Diagnostics (FDD) Tools for Commercial Building Energy Efficiency 2018, http://www.lowcarbonlivingcrc.com.au/sites/all/files/publications_file_attachments/lclcrc_report_rp1026-parti-fddcasestudies_published.pdf
45. Ibid

Adelaide Airport, Australia

In 2018, Adelaide Airport partnered with a provider of automatic building analytics (CIM Enviro) to reach its goal of becoming one of the most sustainable airports in the world.

The partnership allowed the airport to determine that outside air temperature has the greatest effect on the energy consumption of Terminal 1, influencing 81 per cent of energy consumption[46].

Adelaide Airport used the building analytics system to address complex internal heating, ventilation and air conditioning system inefficiencies. The technology was able to identify gaps between the basic faults being identified by the existing building management system and more complex issues.

Live emissions saving potential is now ranked across the terminal, to prioritise maintenance. Internal teams are notified about where they need to go and what they need to fix in real-time as the faults occur. This means the faults contributing the most to the terminal's emissions are identified and prioritised.

Since February 2018, the airport is on track to saving 600tCO_2-e and 933MWh a year, with a payback period of only 7 months. The system will continue to improve the emissions savings potential through machine learning, as well as improving the lifecycle of equipment.

46. Making Adelaide Airport a Global Leader in Sustainability 2018, CIM Enviro

10

Energy efficiencies

Low energy baggage handling systems

Airport applicability: **Major, Regional**	Location in airport: **Terminal**
Typical emissions scope: **Scope 2**	Emissions impact: **40-75% reduction on BAU**
Capital expenditure: **<0.5% asset value**	Payback period: **>20 years**

Baggage Handling Systems (BHS) are generally conveyor systems that primarily function to sort and transport passenger luggage to the correct airport location, both before and after the flight.

BHS can vary in length and can reach up to several kilometres at major airports. Typically, the conveyor tracks are propelled by hundreds of small motors and can be very energy intensive, accounting for as much as 20 per cent of an airport's total electricity consumption per annum.

Low energy BHS technologies include Independent Carrier Systems and Multi-Carrier Systems that typically enable faster baggage movement, enhancing the efficiency of the entire system. The technologies often include lighter baggage carry-trays to lower the carry-load and reduce friction between conveyors and belts. They work in tandem with automated check-in services to further improve efficiency.

Advantages	Considerations
– Improved overall passenger processing efficiency. – Opportunity to streamline baggage logistics process through consolidating baggage sorting, screening, and transporting to eliminate bottlenecks and reduce loss of luggage. – Can reduce physical footprint size of the system. – Reduces idling of motors, for example using a tote-based system. – Cooler operating environment for staff and may therefore reduce air conditioning load.	– High upfront capital cost. – Potentially disruptive to airport operations during upgrade. – Large amount of space required during construction as airports may need to build new systems adjacent to old systems to ensure continued operation.

Planning recommendations

- Assess the performance of existing BHS and identify bottlenecks in baggage handling process.
- Redesign new baggage network with a focus on consolidating and streamlining elements while reducing physical footprint.
- Develop an implementation plan and schedule to minimise disruption and to align upgrade timings.

Rotterdam The Hague Airport, Netherlands

In 2018, Rotterdam The Hague Airport became the first airport in the world to use a baggage handling system with intelligent autonomous vehicles for individual luggage transport instead of traditional conveyor belt systems.

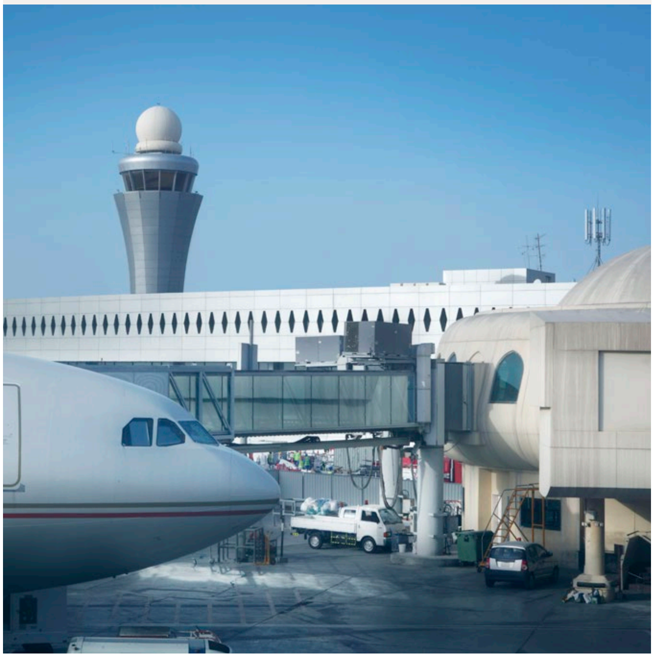
In 2019, the trial was announced as successful and is being further rolled out in the airport. The aim is to expand it to other airports in the Netherlands.

Each individual vehicle carries a single bag and the system is designed to grow alongside the airport. The system has been designed to consume up to 50 per cent less energy compared to traditional systems[47], however at Rotterdam The Hague the vehicles are largely powered by renewable energy[48], helping to create a zero-emissions baggage handling system. The system also enables a complete track and trace of each piece of luggage.

Abu Dhabi International Airport Midfield Terminal Complex

The Midfield Terminal Complex (MTC) is a new terminal being built at Abu Dhabi International Airport to service the forecasted increased traffic. It has been designed with a maximum capacity of 30m passengers per year[49].

The MTC will feature 25km of baggage conveyor belt and is capable of handling 19,200 bags per hour. Compared to an older baggage handling system which had an electrical demand of up to 520W/m of conveyor, the MTC's baggage handling system will require only 124W/m of conveyor. The cost of the new baggage handling system was approximately $12,000 per metre.



47. Rotterdam The Hague Airport signs agreement 2018, https://www.airport-technology.com/contractors/baggage/vanderlande/pressreleases/rotterdam-agreement-fleet/
48. Rotterdam The Hague first airport with autonomous vehicle baggage handling 2019, https://www.bluebiz.com/en/bluebook/bluebook/rotterdam-the-hague-nl-first-airport-with-autonomous-vehicle-baggage-handling/
49. Midfield Terminal Complex, https://www.aecom.com/projects/midfield-terminal/

11

Energy efficiencies

Terminal initiatives

Airport applicability:
Major, Regional

Typical emissions scope:
Scope 1, 2

Capital expenditure:
Variable

Location in airport:
Landside, Terminal

Emissions impact:
Variable

Payback period:
Variable

Terminals typically contribute to over half of an airport's energy use.

Many energy efficiency measures relating to Terminal energy efficiency initiatives can be found in the CEFC's Energy in Buildings: 50 Best Practice Initiatives Report[50]. These include:

- Colour and reflectivity of external materials
- External shading
- Enhanced daylighting
- High performance glazing
- LED lighting and daylight dimming
- Sub-metering systems
- Building management systems

As with any other building, passive terminal design can lead to significant energy savings and therefore should be prioritised in the architectural design for new terminal buildings.

Planning recommendations

- Terminal design to be based on modelled or forecast energy demand and functional terminal specifications. Prioritise adaptable designs to meet future terminal demand and upgrades.
- Model the terminal's energy performance and design to optimise passive design, thermal performance and energy efficiency.

50. CEFC Energy in Buildings 50 Best Practice Initiatives https://www.cefc.com.au/media/290052/NDY_CEFC_BestPracticeGuide.PDF

San Diego International Airport Green Build Terminal, United States

The Green Build Terminal replaced and expanded upon the ageing Terminal 2 at San Diego International Airport. When it was completed in 2013, it became the world's first airport terminal to achieve LEED Platinum certification.

The Green Build Terminal features a range of sustainability initiatives including maximised natural daylighting, high performance glazing, and a reflective roof design to reduce solar thermal gain[51].

The new parking lot features a stormwater runoff capture system for reuse in the terminal cooling plant. The Green Build Terminal also collects air conditioning condensate which is used for cleaning and maintenance purposes, saving around 39,000 litres of water per year[52]. With the sustainability measures combined, the Green Build Terminal is 32 per cent more energy efficient than the standard building code.

51. San Diego now home to world's first LEED Platinum certified commercial airport terminal 2014, https://www.san.org/News/Article-Detail/ArtMID/952/ArticleID/42/San-Diego-Now-Home-to-World%E2%80%99s-First-LEED-Platinum-Certified-Commercial-Airport-Terminal
52. San Diego international airport is unique 2018, http://www.airportmagazine-digital.com/airportmagazine/april_may_2018/MobilePagedArticle.action?articleId=1374051#articleId1374051

12

Energy efficiencies

Airfield lighting upgrades

Airport applicability: **Major, Regional**

Typical emissions scope: **Scope 2**

Capital expenditure: **<0.3% asset value**

Location in airport: **Airside**

Emissions impact: **Up to 50% reduction on BAU**

Payback period: **>5 years**

Airfield lighting is the system of lights that aid in aircraft navigation during landing, take-off and taxiing.

Types of airside lighting include, but are not limited to, obstacle lighting, high-intensity approach lighting systems, precision approach path indicator systems and visual approach slope indicator systems, runway and taxiway lighting, and apron floodlighting. Airfield lighting can account for up to 10 per cent of an airport's total energy consumption.

Airfield lighting technology has continuously evolved with the increased use of energy-efficient LEDs and smart fixtures controlling light intensity.

Lighting systems are also starting to complement aircraft vision systems through infrared energy radiation. Efficient and increasingly intelligent lighting systems have the potential to reduce lighting emissions by up to 50 per cent.

Advantages	Considerations
– Reduction in ongoing maintenance costs associated with longer life spans – for example LEDs can last up to 100 times as long as halogen lamps. – Can reduce up to 50 per cent of lighting emissions and operational costs. – Short payback period.	– Potentially higher upfront capital costs compared to replacing with halogen lamps. – Temporary disruptions to airport operations during upgrades - runway and taxiway lighting.

Planning recommendations

- Lighting technologies must comply with the relevant regulations enforced by the Civil Aviation Safety Authority (CASA).
- Airports should consider replacing all airfield lights with LEDs and not retaining a mixture of lighting technologies, such as halogen, as the inconsistent light colours and lumens may breach CASA regulations.

Dubai International Airport, UAE

In 2015, Dubai International Airport installed the world's first complete LED airfield lighting system with more than 8,200 LED lights and 1300km of cabling. The airport remained operational throughout completion of the work.

In 2019, the airport is expanding the use of LED lighting and replacing 15,000 conventional lamps, including high-mast apron floodlights, with energy efficiency LED bulbs. The retrofit is scheduled to take around 18 months and to save the airport around $2m annually[53].

53. Lighting retrofit at Dubai DXB airport 2019, https://www.constructionweekonline.com/projects-tenders/182598-lighting-retrofit-at-dubais-dxb-airport-to-result-in-10m-savings

13 Energy efficiencies

Ground source heat pumps

Airport applicability:
Major, Regional

Typical emissions scope:
Scope 1, 2

Capital expenditure:
<0.3% asset value

Location in airport:
Landside, Terminal, Airside

Emissions impact:
20-50% reduction on BAU

Payback period:
>5 years

Traditional heat pumps are often air source heat pumps that use air as a heat source or heat sink (absorbing heat), for example reverse cycle air conditioners. A ground source heat pump uses the earth's relatively stable ground temperature to provide heating and cooling.

The system consists of a heat pump and loops of refrigerant or water buried underground (ground loops). The heat pump transfers the heat between the ground loop and the building to provide hot water, cooling and heating. Ground source heat pumps consume less energy than conventional systems and can be twice as efficient.

Their efficiency is more stable throughout seasonal temperature changes and installation prices are gradually decreasing due to ongoing technical improvements.

Advantages	Considerations
– One of the most energy and emissions efficient means of heating and cooling available on the market. – Performance is not dependent on weather conditions (unlike air source heat pumps). – Scalable system size, dependent on the number and length of loops. – Lower maintenance requirements (compared to traditional systems) due to few moving parts. – Can provide significant energy savings when incorporated as part of a CUP or in buildings without strict thermal comfort thresholds (e.g. aircraft hangers).	– Loops can experience 'burn-out' if the earth surrounding the loops is not allowed sufficient time to dissipate energy. – Large spatial requirements for placement of loops. – May be difficult to retrofit in existing buildings. – Relatively new industry and technology in Australia. – May require additional mechanical heating/cooling to boost output during periods of intense heat and cold.

Planning recommendations

- Assess building thermal comfort demands to determine requirements for heating and cooling.
- Evaluate site suitability by assessing geology, soil profile and soil heat conductivity to establish feasibility.

Christchurch International Airport, New Zealand

Opened in 2013, Christchurch International Airport's new $225m, three-storey "Integrated Terminal" uses artesian bore water ground source heat pumps to provide heating and cooling.

Testing on the system in 2014/2015 determined that it was providing 6.7 MWh of energy for every 1MWh of energy of energy consumed for the central chiller system, excluding pumping energy, and that certain modifications could further improve the efficiency by around 11 per cent.

The cost of the system at the time, above a conventional boiler system, was approximately $712,000[54] with a payback of around two years due to the energy efficiency of the system. Since then, installation prices have dropped.

By 2019, Christchurch Airport estimated that the system and associated operational processes has reduced emissions by 31 per cent since 2013[55]. Because of this success, the airport is replicating the technology in the rest of the terminal, decommissioning two diesel and two liquefied petroleum gas boilers. The airport predicts future savings of $522,000 annually and a 25 per cent reduction on current emissions.

54. CIBSE Journal 2015, https://www.cibsejournal.com/archive/PDFs/CIBSE-Journal-2015-05.pdf
55. Interview with Brodie Akacich 2019, https://www.airportco2.org/component/interviews/interviews.html?id=17

14 Waste management

Energy-from-waste

Airport applicability: **Major, Regional**	Typical emissions scope: **Scope 1, 3**	Capital expenditure: **<0.5% asset value**
Location in airport: **Terminal, Airside, Landside**	Emissions impact: **Variable**	Payback period: **Variable**

Airports should prioritise waste management through elimination and minimisation (refer to Waste minimisation initiative) according to the waste hierarchy. However, waste categorised as "quarantine waste" is subject to strict regulation under Australian law. This waste must be collected and treated in line with biosecurity regulations[56].

Often, the waste is incinerated in autoclaves to destroy any contamination. Due to these regulatory requirements, disposal of quarantine waste is more expensive, contributes to Scope 3 emissions and prevents opportunities for reuse and recycling.

Alternatives to autoclave incineration and disposal offer an opportunity for airports to reuse the energy in quarantine waste. Possible treatments include dehydrating organic matter into dry fuel pallets, converting it into biogas through anaerobic digestion and burning it to renewable energy.

Advantages	Considerations
– Generation of renewable, baseload gas, heat or electricity for use behind the meter or grid export.	– Possible air quality issues and community concerns relating to incineration of waste.
– Potential to mitigate or offset charges associated with biosecurity waste handling and disposal.	– Potential increase in Scope 1 emissions from on-site treatment.
– Continual supply of waste from airports means there is potential for continual energy generation.	– Facility requires approval from government to accept quarantine waste.
	– Potentially constrained by the type of waste generated.

Planning recommendations

- Ascertain quantity and composition of quarantine waste that is transported for off-site processing and evaluate the business case for energy from waste or similar facilities.
- Engage with government authorities to overcome challenges to adoption associated with use of quarantine waste and air quality issues.

56. Quarantine waste 2017, https://www.epa.nsw.gov.au/your-environment/waste/industrial-waste/quarantine

Gatwick Airport, United Kingdom

In 2017, Gatwick Airport became the first airport in the world capable of disposing of biosecurity waste when it switched on its new on-site 1MW waste to energy plant.

The plant cost over $6.9m to establish and is able to treat approximately 2,200 tonnes of biosecurity waste each year, including food and packaging, which is equivalent to around 10 tonnes of waste per day. The plant is projected to save around $1,800 in energy and waste management costs every day it operates[57].

The plant has removed the need for trucks to transport the waste elsewhere, reducing local traffic and carbon emissions. It has also created an on-site location for other waste sorting to maximise recycling capability.

In 2018, the plant lifted Gatwick's recycling/reuse rate to 64 per cent, leaving them 6 per cent off their goal of 70 per cent for 2020. While the power produced currently goes back into the plant itself, Gatwick is planning for the facility to eventually help heat the north terminal.

57. Gatwick opens new waste management plant 2017, http://www.mediacentre.gatwickairport.com/press-releases/2017/17_03_24_waste_plant.aspx

15 Waste management

Waste minimisation

Airport applicability: **Major, Regional**	Location in airport: **Landside, Terminal, Airside**
Typical emissions scope: **Scope 1, 3**	Emissions impact: **Variable**
Capital expenditure: **<0.3% asset value**	Payback period: **>5 years**

Waste and recycling may not be a typical area to consider when addressing airport emissions. However, resource use (and the associated embodied energy) and landfill disposal are major contributors to GHG emissions.

An airport can play an influential role in reducing waste from tenants and airlines. Co-mingled, soft plastic, organic, paper and e-waste are all common sources of waste in airports. Reducing waste and reusing resources not only reduces emissions but also operational costs. Source-separated recycling, bio-degradable packaging, organic food reuse and composting are all available waste minimisation options for airports. Airports can also influence customer behaviour by providing re-use opportunities, through simple measures such as water bottle refilling stations.

Advantages	Considerations
– Reduced cost of waste management and disposal, including transportation and handling lower volumes of waste. – Reduced emissions from avoiding both landfill gas and consumption of new resources. – Opportunities to obtain co-benefits, such as using compost for grounds maintenance or to benefit community projects.	– Waste minimisation and recycling potential depends on the type of waste generated and whether or not it can be recycled. – Spatial constraints for on-site source separation. – Quarantine waste may limit the amount and type of waste that can be recycled.

Planning recommendations

- Ascertain the quantity and types of waste generated in the airport or from airport operations to define the opportunity for waste reduction.
- Develop a waste management strategy with specific targets and actions to reduce waste creation and improve recycling, in line with the broader airport Operational Management Plan.

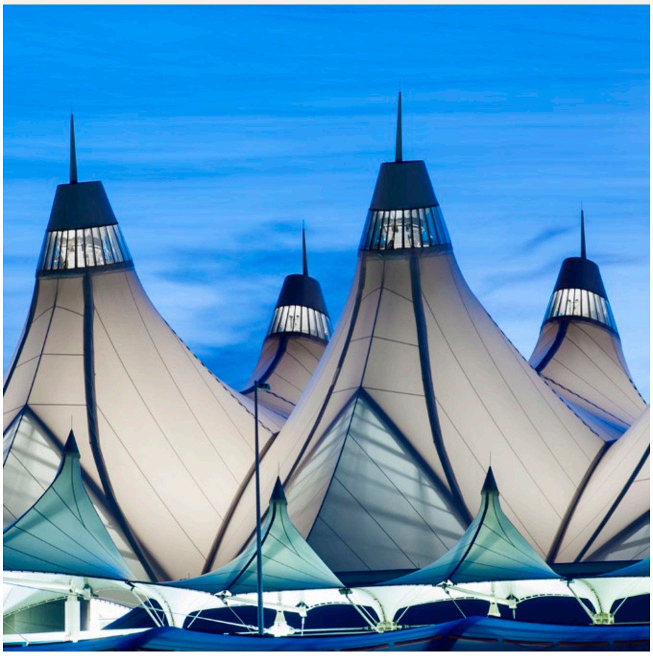
Denver International Airport, United States

Despite implementing organic food composting since 2010, Denver International Airport saw there was an additional opportunity to reduce the organic waste generated by its food and beverage outlets, which often saw 30-40 per cent of all prepared food wasted.

In 2015, the Airport started to place organic food 'coolers' to capture healthy and safe food waste that would otherwise be landfilled.

In 2016, the program expanded to restaurants, the on-site hotel and airline flight kitchens. In 2018, over 80,000kg of food was donated to a local hunger-relief charity, enough for one meal for 148,197 people[58].

This program has resulted in increased waste diverted from landfill, reducing emissions and disposal costs, as well as significantly benefiting the local community.



Qantas Waste Free Flight, Australia

Qantas has set an ambition to cut 100 million single-use plastics by end-2020 and eliminate 75 per cent of the airline's waste by end-2021.

In 2019, Qantas flight QF739 from Sydney to Adelaide was the first-ever commercial flight to produce no landfill waste. The flight would have typically produced 34kgs of waste[59]. All inflight products used were reused, composted or recycled and products that did not have a suitable alternative were removed.

Qantas partnered with Suez to compost organic material, recycle plastics into new products and use non-recyclable plastics to produce "processed engineered fuel" – a type of non-fossil fuel[60]. Qantas' action shows that airlines are seeing the importance of waste reduction and capitalising on its economic benefits as well. This example also demonstrates the opportunity for airports to investigate supporting the facilities required to enable "waste-free" flights.

58. Sustainability Series: Denver's green passenger experience 2019, https://www.internationalairportreview.com/article/90081/green-sustainability-denver-airport/
59. Qantas World's First Zero Waste Flight 2019, https://www.qantasnewsroom.com.au/wp-content/uploads/2019/05/190508-One-Page-Factsheet-Zero-Waste-Flight.pdf
60. Introducing Qantas' first landfill-free flight 2019, https://www.qantas.com/travelinsider/en/trending/new-qantas-flight-waste-free-sustainable.html

Implementation: Masterplan and retrofit

The 15 best practice initiatives highlighted in this report can be effectively applied in isolation through retrofitting. However holistic consideration of many initiatives as part of a broader airport master plan can provide a greater emissions reduction benefit.

Under the Australian Airports Act 1996, federally-leased airports (except Tennant Creek and Mount Isa) are required to prepare a master plan that sets the strategic direction over the next 20 years, to be renewed every 5 to 8 years. This provides an ideal opportunity to incorporate clean energy technologies into airport development.

Airport decision-makers will recognise that these initiatives will need to be considered in the context of the broader operating environment.

Variability in energy price
Electricity tariffs can vary on location and the tariff agreement in place between an energy consumer and the local energy provider. The volume of electricity consumption, the tariff structure, and maximum demand charges may vary from airport to airport.

Economies of scale
Scalability and implementation of multiple interdependent initiatives may provide greater cost and energy efficiencies.

Variability in airport and stakeholder interactions
The fragmented nature of stakeholders and decision makers impacts the level of collaboration and may increase the lead time for initiative implementation.

Variability in capital and maintenance costs
The supply, installation and maintenance costs associated with implementation of energy initiatives may be context and location dependant.

Variability in size and geographical location of the airport
The size of an airport influences the appropriateness of certain initiatives and its overall cost-benefit ratio, while the location and climate of the area in which the airport is situation will impact the effectiveness of each initiative.

Benefits beyond energy and emissions

In addition to the benefits of reducing energy usage and emissions and the associated costs, the 15 best practice initiatives discussed in this report may also provide the following co-benefits.

Resilience
The ability for airports to respond to shocks and stresses, including climate change, is paramount to their continued operation. Many of the initiatives in this report enhance airport resilience through the use of distributed and clean energy technologies, reducing the reliance on fossil fuels and pressure on external infrastructure.

Airport Carbon Accreditation Program
Implementation of the initiatives in this report may assist in meeting Airport Carbon Accreditation requirements and contribute towards a low carbon future.

Sustainability rating tools
Sustainability rating tools, such as the Infrastructure Sustainability Council Australia's IS ratings and the Green Building Council Australia's Green Star ratings, are paving the way for sustainable and resilient developments in major infrastructure, precinct and building projects in Australia. Implementation of initiatives outlined in this report may assist in meeting some of the requirements (notably the energy categories) of these rating tools.

Environmental Social Governance and Sustainability Reporting
Highlighted initiatives can contribute to meeting targeted emissions reductions as set out in airport Sustainability Management Plans and sustainability reporting. These targets may be driven by investor commitments to meet Task Force on Climate-related Financial Disclosure or Global Real Estate Sustainability Benchmark criteria.

United Nations Sustainable Development Goals
Initiatives adoption can be used to meet UN Sustainable Development Goals - notably 7. Renewable Energy; 11. Sustainable Cities; and 13. Climate Change.

Industry leadership
A competitive and commercial advantage may be gained from demonstrating market leadership and innovative practices. Many world leading airports and airlines place a high emphasis on promoting their sustainability credentials and accreditations.

CEFC and infrastructure: Flexible finance for your clean energy investment

The CEFC invests across the infrastructure sector to influence clean energy standards in transport, aviation and electricity generation, as well as in social and economic assets. Our finance supports best practice and market leading design, construction and operations, whether developed at the design and construction phase for new assets, or retrofitted to existing assets.

Our flexible approach to investment recognises the needs of our evolving market. Our financial products and structures help drive private sector investment in a diverse range of activities to cut emissions. We invest with commercial rigour, and work to deliver a positive return for taxpayers across our portfolio.

Direct investments: Our direct investments for small and large scale clean energy projects include flexible debt and equity finance, or a combination of both, tailored to individual projects

Debt markets: We are a leading investor in Australia's emerging green bonds market, creating new options for investors and developers

Investment funds: We invest in new and established investment funds to co-deliver clean energy developments in agribusiness, infrastructure, property and more

Asset finance: We work with banks and co-financiers to deliver discounted finance to businesses, farmers and manufacturers for their clean energy investments.

CEFC investments in focus

IFM Australian Infrastructure Fund

CEFC equity commitment of $150 million

Australia's largest infrastructure fund, the $12 billion IFM Australian Infrastructure Fund, is working with the CEFC to drive meaningful carbon emissions reductions employing a Science Based Targets approach across the fund's assets which include some of Australia's biggest and best-known ports, airports and electricity providers. The fund is currently deploying emissions reduction projects across seven major assets – Ausgrid, Melbourne Airport, Brisbane Airport, Port of Brisbane, NSW Ports, NT Airports and Southern Cross Station.

Macquarie Australian Infrastructure Trust

CEFC equity commitment up to $100 million

The Macquarie Australian Infrastructure Trust (MAIT) is adopting Science Based Targets to drive down carbon emissions at its 17 Australian assets, which includes Perth and Gold Coast Airports, Sydney Desalination Plant, Endeavour Energy and Electranet. MAIT is also seeking to invest in further Australian and New Zealand assets with a focus on energy and utilities, transport, and communication infrastructure sectors.

Morrison & Co Growth Infrastructure Fund

CEFC equity commitment up to $150 million

The specialist Morrison & Co Growth Infrastructure Fund is acquiring and developing a diverse range of essential assets where there is potential for significant improvements in their energy efficiency profile. The fund is looking to invest in assets such as hospitals, data centres, retirement and aged care accommodation, student housing and renewable energy.

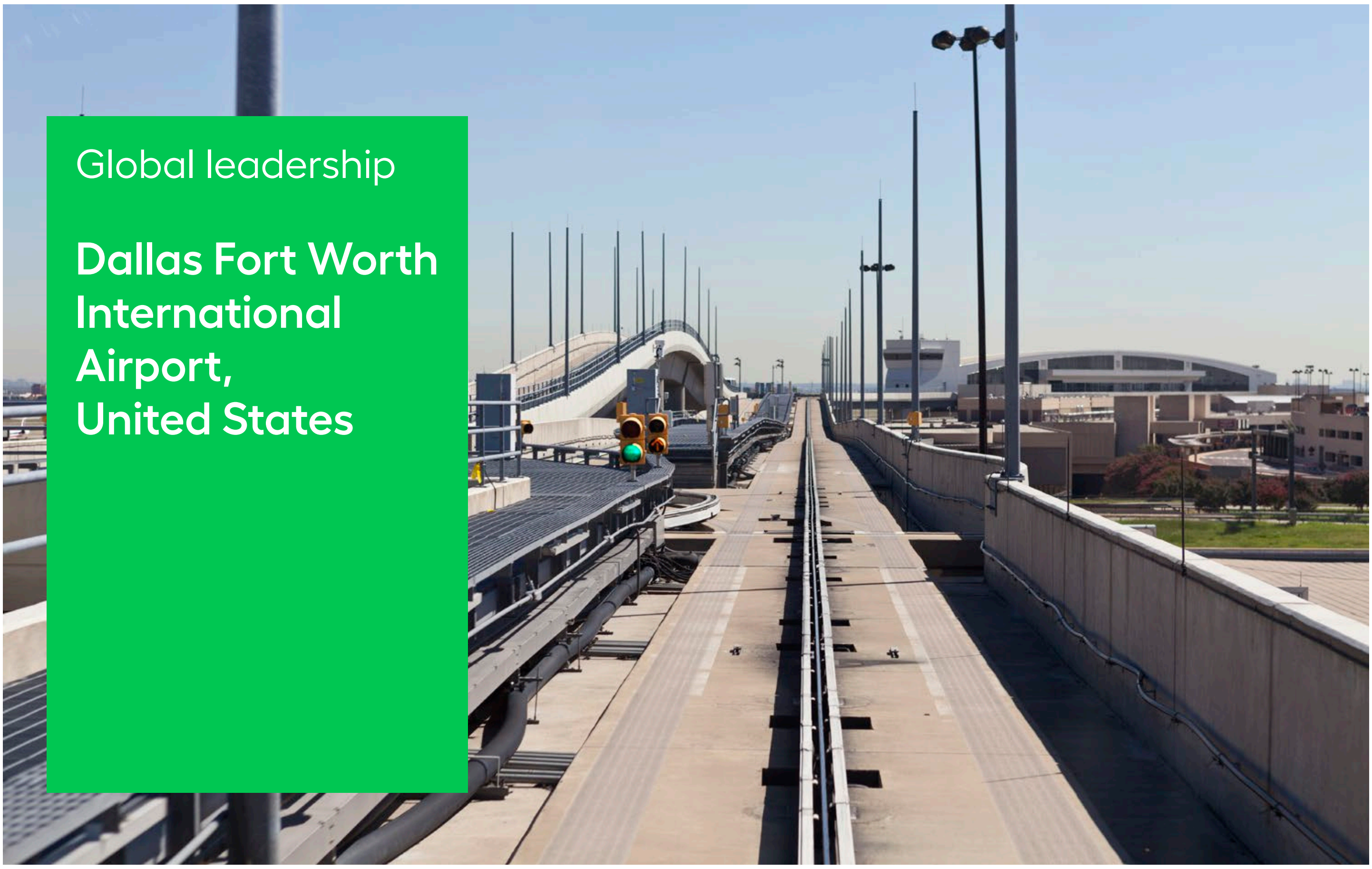
Moorebank Logistics Park

CEFC debt commitment up to $150 million

Leading freight and logistics company Qube Holdings Limited is developing the nationally-significant Moorebank Logistics Park intermodal terminal to take emissions-intensive trucks off Australian roads by increasing the use of rail networks to transport containerised freight.

Electrification and fuel switching

Switching from fossil fuels to lower emissions alternatives in infrastructure and transport is critical to the broader decarbonisation of the Australian economy. CEFC finance is available for electrifying industrial processes, adopting electric vehicles and switching to lower emissions fuel sources such as biofuels. In addition, through the Clean Energy Innovation Fund, finance is available for start-up companies focused on electrification and fuel switching solutions.



Global leadership

Dallas Fort Worth International Airport, United States

Dallas Fort Worth International Airport (DFW) was the first airport in North America to be awarded Airport Carbon Accreditation scheme Level 3+ carbon neutral and is the largest carbon neutral airport in the world.

DFW's 2014 Sustainability Management Plan set a goal to achieve a 15 per cent reduction in CO_2 emissions per passenger between 2015-2020, equivalent to a 3 per cent reduction per year compared to 2010. In 2018, DFW achieved this goal two years early, with a 5.4 per cent reduction in carbon emissions per passenger that year and a cumulative 18 per cent reduction.

Since 2010 DFW has reduced 83 per cent of emissions per passenger. Despite a 22 per cent increase in passengers from 2010-2018, DFW achieved an overall 27 per cent reduction in electricity costs in the same period[61].

Some of the measures that have been implemented by DFW include installing LED lighting, smart fixtures and faucets to conserve energy, and purchasing 100 per cent of their electricity from renewable sources (wind power from West Texas). DFW has also installed on-site solar and geothermal renewable technologies and partners with a local university to continually monitor and improve energy consumption across the airport[62]. In 2018 DFW invested $290,000 to increase the number of electric vehicle charging points at its terminals to 25, and is planning to install more in 2019. These charging points are accessible to customers, employees and tenants.

In 2018 DFW also completed an assessment of the existing glass in all the terminals to prioritise replacement to dynamic glass. Dynamic glass is coated with electrochromic metal between layers that tints darker in response to low voltage currents. It can minimise up to 67 per cent solar heat gain and improve passenger comfort. DFW will use the assessment to roll out the use of dynamic glass in the future.

In the same period the airport diverted 180,000 tonnes of waste from landfill through recycling and has set a goal to diver 90 per cent of landfill as part of its Zero Waste Program in an aim to improve the airport's overall diversion rate by 45 per cent[63].

Looking to the future, DFW, as it continues to try and lower its emissions, has teamed up with a Finnish company developing renewable fuels from waste to investigate providing a renewable jet fuel for aircraft at DFW – including logistics and supply chain options.

61. Dallas Fort Worth International Airport in Texas reach its 2020 goal two years ahead of schedule 2019, https://www.airportcarbonaccredited.org/component/news/news/821.html?view=news
62. DFW ESG Report 2018, https://www.dfwairport.com/cs/groups/webcontent/documents/webasset/p2_950004.pdf
63. DFW becomes largest airport in the world to achieve carbon neutral status 2019, https://www.travelpulse.com/news/airlines/dfw-becomes-largest-airport-in-the-world-to-achieve-carbon-neutral-status.html

Glossary

TERM	DEFINITION
Aircraft vision systems	Technology which incorporates information from aircraft-based sensors (such as infrared cameras) to provide vision displays to the pilot in limited visibility conditions.
Airfield lighting	The lighting system that provides visual guidance to pilots and aircraft approaching, departing and moving around the airfield.
Airport Carbon Accreditation	An independent global carbon management and accreditation program for airports that assesses and recognises airports' efforts to manage and reduce their CO_2 emissions.
Anaerobic digestion	Processes by which microorganisms break down biodegradable or organic material without oxygen. One of the end products is biogas.
Apron floodlighting	The airport apron is the area of an airport where the aircraft are parked, unloaded, loaded, refuelled or boarded. Floodlights are large, powerful electric lights.
Autoclaves / autoclave incineration	A pressure chamber used to carry out chemical reactions and other processes such as solid waste treatment using high pressures and temperatures.
Auxiliary power unit (APU)	A fuel-powered device used as an additional energy source to power onboard lighting, electronics and air-conditioning when the aircraft is parked at the gate.
Brownout	A reduction or restriction on the availability of electricity, can be intentional or unintentional.
Building management system	A computer-based controlled network in buildings that controls and monitors the building's mechanical and electrical equipment e.g. air conditioning, ventilation, lighting and hydraulics. They link the functionality of the individual pieces of equipment, so that they operate as an integrated system.
Carbon footprint	The amount of carbon dioxide (CO_2) released into the atmosphere from the activities of an individual person, organisation, company or particular activity.
Civil Aviation Safety Authority (CASA)	CASA is an Australian government body that regulates Australian aviation safety. They license pilots, register aircraft, oversee and promote safety.
CO_2 emissions	Carbon dioxide (CO_2) is formed by the combustion of carbon and is a greenhouse gas. CO_2 emissions are released into the atmosphere over a specific area or period of time.
Embodied energy	The energy consumed by all the processes associated with the production of a building or product.
Greenhouse gas (GHG) emissions	Greenhouse gas refers to carbon dioxide, nitrous oxide, methane, ozone and chloro-fluorocarbons occurring naturally and resulting from human activities, contributing to the greenhouse effect.
Halogen lamps	A lamp or light using a filament surrounded by the vapour of iodine or another halogen (any of the elements fluorine, chlorine, bromine and astatine, occupying group VIIA (17) of the periodic table).
High intensity approach lighting system	Provides the basic means to transition from instrument flight to visual flight for landing. They are a configuration of signal lights starting at the landing threshold and extending into the approach area. A High Intensity system often have variable intensity controls, whereas low intensity systems normally have one intensity setting.

TERM	DEFINITION
LED lighting	A light emitting diode (LED) is a semiconductor diode that converts electricity into light. It does not require the heating of a filament to create light.
Levelised cost of energy generation	Measures the lifetime costs of an electricity-generating asset divided by energy production. It allows for the comparison of different energy generating technologies.
Lumens	A unit of measurement of luminous flux (brightness) – the measure of the perceived power of light.
Particulate emissions	Very small particles of a substance suspended in the atmosphere, often emitted from the combustion of fuel. Some particles, such as soot or smoke, can be seen with the naked eye while others require detection using a microscope.
Passive design	Design that takes advantage of the climate around it to maintain a comfortable temperature range, reducing or eliminating the need for additional heating or cooling.
Precision approach path indicator systems	A visual aid that provides guidance and information to help a pilot find and maintain the correct approach to an airport runway. Often installed on the left side of the runway.
Photovoltaic cells	A photovoltaic (PV) cell is a semiconductor diode that converts visible light into direct current electricity. Some PV cells can also convert infrared or ultraviolet radiation into electricity.
Quarantine waste	Any product that has come into Australia from overseas and is deemed unsuitable for entry or use in Australia without prior treatment. This may include material used to pack or stabilise cargo, food waste from overseas vessels, imported goods which cannot meet import conditions, by-products from treatment of imported goods; and items seized during quarantine inspections.
Smart fixtures	Fixtures designed for energy efficiency. For example, automatic light dimming depending on external light levels or time of day.
Smart sensors	A device that takes input from the physical environment and uses built-in computer resources to perform certain functions depending on the detection of specific inputs.
Solar array	Large sets of PV cells that are connected or combined.
Solar thermal gain	The increase in thermal energy of a space, object or structure as it absorbs solar radiation.
Sub-metering system	Sub-metering systems use a number of carefully places meters 'downstream' of the main utility metre to pinpoint how different parts of a building are using energy.
Thermal energy storage	The technology that allows the transfer and storage of heat energy or, alternatively, energy from ice, cold air or water.
Thermal performance	How well a structure or building responds to external temperature changes, daily or seasonally.
Visual approach slope indicator systems	A system of lights on the side of an airport runway threshold that provides visual descent guidance information during approach.

Disclaimer

About the CEFC

The CEFC has a unique role to increase investment in Australia's transition to lower emissions. We invest to lead the market, operating with commercial rigour to address some of Australia's toughest emissions challenges - in agriculture, energy generation and storage, infrastructure, property, transport and waste. We're also proud to back Australia's cleantech entrepreneurs through the Clean Energy Innovation Fund. In investing $10 billion on behalf of the Australian Government, we work to deliver a positive return for taxpayers across our portfolio.

About AECOM

AECOM is a global network of experts working with clients, communities and colleagues to develop and implement innovative solutions to the world's most complex challenges. AECOM is a global provider of technical services to airport owners, investors, airlines and aviation clients – leading and supporting programs for airports of all sizes and forms.

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