Energy Reduction in Airports

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CIBSE

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Definitions and Abbreviations:

AAAE: American Association of Airport Executives
IATA: International Air Transport Association
IATA Airport Code: is a 3 letter code given by the IATA to airports around the world
BHS: Baggage Handling System
CIBSE: The Chartered Institution of Building Services Engineers
MDPI: MDPI.com is a platform for peer-reviewed, scientific open-access journals.
Workload Unit: benchmark for measuring energy consumption reduction in airports, it is equal to 1 passenger or 100 kg of cargo
HKIA: Hong Kong International Airport
SFO: San Francisco International Airport
IPCC: Intergovernmental Panel on Climate Change
LEED: Leadership in Energy and Environmental Design
BREAM: Building Research Establishment Environmental Assessment Method
Köppen: the Köppen climate classification is one of the most widely used climate classification systems
APU: Auxiliary Power Unit
VAV: Variable Air Volume

1. Introduction

1.1. The Ken Dale Travel Bursary

The Ken Dale travel bursary has been established by the Chartered Institution of Building Services Engineers to commemorate Kenneth William Dale's contribution to the institution and the building services industry. One of the CIBSE founders, a traveller, a teacher and a building services engineer, Kenneth left a great mark on the industry in several countries and continents from the United Kingdom, to Europe then India, the Middle East and all the way to the Antarctic.

Through this bursary, CIBSE offers young building services engineers the opportunity to experience technical, economic, environmental, social and political conditions in another country and to examine how these factors impact the practice of building services engineering and the environment. This is in line with two of CIBSE's main focus areas; supporting young engineers in the developmental stages of their career and promoting environmental awareness.

1.2. Study Background

Due to their large size and dynamic mode of operation, airports are heavy energy consumers. In recent years, there has been an increased interest in sustainability and energy reduction in the aviation sector. Whether driven by cost reduction targets or environmental concerns, a large shift towards sustainable design and operation is being adopted by some of the biggest aviation groups and airports around the world. In fact, at the beginning of this decade we started witnessing an increasing number of airport projects achieving green building certifications such as LEED and BREAM, existing airports setting ambitious energy reduction targets such as the Dubai airport's 20% energy reduction plan by 2020 and international conferences dedicated to green airports such as the Airports Going Green Conference organised by the American Association of Airports Executives AAAE.

According to the 2010 Airport Energy Efficiency and Cost Reduction report by the Airport Cooperative Research Program[1], the energy consumption in airports can contribute up to 15% of the total annual operating costs. For this reason, energy reduction is often set as a priority by respondents in current long term plans. The research also suggests that, as a result of the complicated systems required for thermal conditioning, ventilation and other mechanical and electrical systems, building services consume roughly half of the total electrical energy in an airport and most of the natural gas consumption. Within these two areas of high consumption and energy cost comes many of the opportunities for significant energy savings.

In the last five years, the Middle East has had a big surge in infrastructure projects, including several iconic airports. Personally, I was involved in the building services design of the King Abdul Aziz international Airport, one of the biggest construction projects in the world at the time. During that period, I learned about various airport specific design strategies with direct and indirect impact on energy consumption in an airport, including but not limited to:

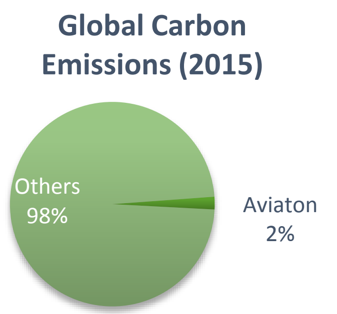
- Implementing the flight schedule in the zoning and heat load calculations process
- Adequate equipment sizing for maximum efficiency and reduction of the energy used in equipment start-up
- Chilled water storage during off-peak hours
- Displacement ventilation

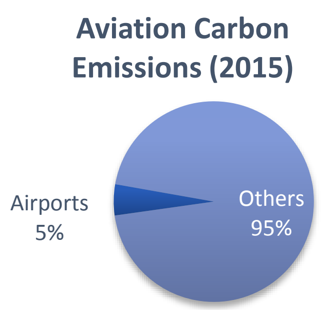
Some of those strategies were implemented in the final design, others were disregarded for various time and cost reasons. Through this research I wanted to bring together data from around the world on practical methods to approach energy reduction in airports, including and going beyond the above mentioned strategies.

2. Objective and Methodology

2.1. Why should airports cut their energy consumption?

The aviation industry is responsible for roughly 2% of the world's carbon emissions[2], of which 5% come from airports[2], this statistics highlight the reason why so far the aviation industry has given more focus and funding for reducing energy consumption and carbon emissions from aircrafts rather than airports. However, this results in airports emitting 0.1% of the global carbon emissions, this might not seem like a high percentage, however with the expected growth of airports worldwide, their operational cost and carbon emissions will increase if not given attention. Now if we consider the fact that the existence of most airports around the world is not driven by profits but rather by a need to provide air travel infrastructure as part of a governmental vision, we get closer to the conclusion that airports should become more sustainable and reduce their operational cost, especially that their unique method of operation provides great energy reduction opportunities.





1 'Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report
2 'Airport Carbon Accreditation Annual Report 2010-2011', ACI-Europe and WSP

2.2. Research Objective

The objective of this study is to document proven energy reduction strategies in airports in different geographic and operational conditions based on actual case studies and to highlight the obstacles and opportunities, in order to guide future sustainable building services airport design and operation, through the following:

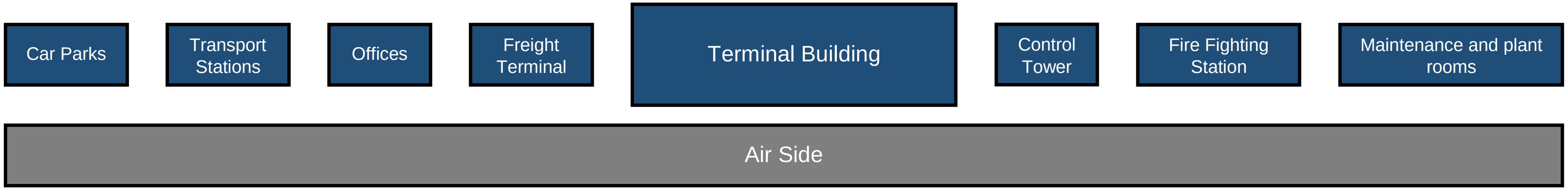
- Identifying the major areas of energy consumption in an airport
- Developing energy consumption benchmarks
- Identifying effective energy reduction strategies in the design and operation of an airport
- Testing the applicability of existing energy reduction strategies
- Highlighting methods of pushing the boundaries of energy reduction in airports
- Increasing awareness on the importance and feasibility of energy reduction in airports

2.3. Methodology

The methodology to achieve the above stated objective is based on a series of theoretical and practical studies:

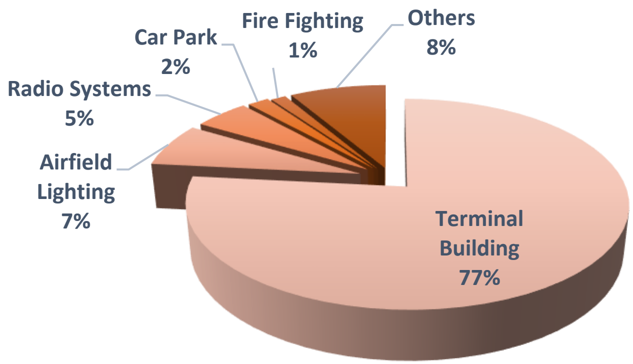
- Identification of airports that have a track record in energy efficiency in both design and operation
- Collecting energy performance data from the identified airports
- Arranging site visits to meet with the designers and operators and document the energy reduction strategies
- Compiling the data in a consolidated report
- Drawing conclusions
- Sharing the knowledge through seminars and presentations

3. Energy Consumption in Airports



3.1. What do airports comprise of?

From an operational point of view, it is traditional to divide an airport into two main areas of activity, the landside and airside. Landside areas include terminal buildings, parking lots, public transportation and access roads. Airside areas include all areas accessible to aircraft, including runways, taxiways and aprons.

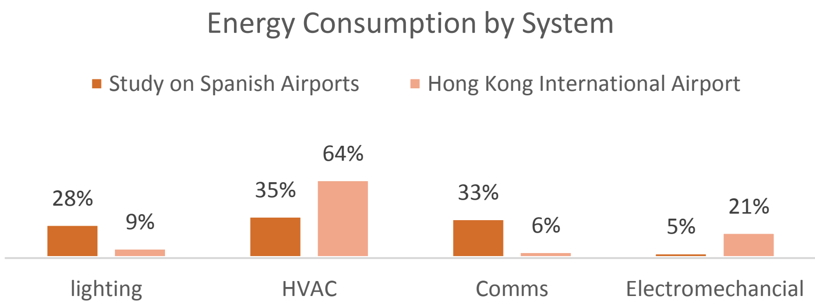


From the 2016 Energy Research in Airports by MDPI on Spanish Airports

Considering its dominance in energy consumption compared to the other airport facilities, this study focuses mainly on the landside section of the airport and specifically the terminal building.

3.2. Energy Consumption Profile

Under certain weather conditions, the energy consumption for the temperature control of an airport is so dominant that the other systems such as lighting and baggage handling system appear insignificant and therefore not targeted for energy reduction projects. However, one of the objectives of this research is studying the differences in airports operating in very different climatic and geographical conditions showing how different that split can be.



These figures can change depending on the geographic location, climate, airport type, etc. however a common trend can be deduced regarding the largest areas of consumption and that is the HVAC systems which this study will focus on.

3.3. Benchmarking

Compared to commercial buildings, airports are generally large in floor areas. They also have multiple stakeholders that occupy and operate conditioned spaces within the airport boundaries, this can include, airline companies, hotel operators, governmental buildings, etc. Also, airports are constantly expanding, and subsequently floor areas vary within one operational year. For these reasons, it is risky to consider the floor area alone when it comes to measuring and benchmarking energy consumption.

Another relevant parameter that is regularly and accurately recorded in airports is the yearly number of passengers. This parameter is directly related to energy consumption and should therefore be a key parameter in the benchmarking calculations.

Recently, airports have been setting energy reduction targets as part of their sustainability and cost reduction strategies. For example, an airport can set a target of 20% reduction over the next 5 years. It is important to define the baseline this reduction should to be compared against.

In traditional buildings, a baseline is constant and is calculated at the start year, however, in an airport, the size of the airport and its number of passengers can increase during the period of implementing energy reduction strategies, therefore, progress in reducing energy can be offset by the increasing energy consumption due to increased capacity. For this reason, the baseline should be the energy consumption per **workload unit**. A workload unit consists of 1 passenger or 100 kilograms of cargo.

The number of passengers travelling through an airport is calculated by counting each entry as 1 passenger, therefore a passenger travelling to a city and then leaving from the same airport will count as 2 passengers.

In summary, the energy consumption benchmark are measured in 2 methods:

1-Energy consumption per floor area

$$energy\ consumption\ per\ m2 = \frac{total\ energy\ consumption\ (kWh)}{Total\ floor\ area\ of\ occupied\ spaces\ (m2)}$$

In the above formula we use the floor area of the occupied space instead of air-conditioned space to account for naturally ventilated areas.

Since this study focuses on the terminal building, then whenever sub metering is available, the above formula becomes

$$energy\ consumption\ per\ m2 = \frac{terminal\ energy\ consumption\ (kWh)}{total\ terminal\ floor\ area}$$

2-Energy consumption per workload unit

$$energy\ consumption\ per\ workload\ unit = \frac{energy\ consumption\ (kWh)}{workload\ units\ (passengers)}$$

Where a workload unit is equal to one passenger or 100 kilograms of cargo weight. The same principle of separating the terminal from the other support building applies here, and the second formula becomes

$$energy\ consumption\ per\ workload\ unit = \frac{Terminal\ energy\ consumption\ (kWh)}{workload\ units\ (passengers)}$$

4. Case Studies

The selection of airports that took part in the study was made in a way to ensure variety in climate conditions, airport's age, size and approach to energy reduction:

1- The Hong Kong International Airport: modern existing airport with newly introduced energy reduction measures
2- Stavanger Airport: existing airport with newly introduced energy reduction strategies
3- Bergen Airport Terminal 3: new airport designed for low energy consumption, currently under construction
4- The Galapagos Islands airport: new airport designed for low energy consumption, operating for 2 years
5- San Francisco Airport Terminal 2: additional terminal to an existing airport, designed for low energy consumption

All five airports were approached through the support of the Airport Carbon Accreditation organisation, site visits were arranged and undertaken within a period of 5 weeks in August and September 2016. The site visits included walking around the airport and plant rooms, discussions with the operator's engineering team and the designer in some cases. Data was collected for benchmarking calculation. The discussions highlighted the obstacles and opportunities met throughout the energy reduction journey.

Things I did not know about airports

I. Airports do not necessarily operate 24 hours per day, daily runway maintenance requires a period with no incoming or outgoing flights, during this period the terminal can remain open, which is the case for larger airports, whereas smaller airports with a limited number of flights per day can shut off completely.

II. The airport's baggage handling system is much larger than you think, what you see in the baggage collection area is the tip of the iceberg that lies in the back of the airport and manages the baggage transport to and from the aircraft as well as the baggage storage system.

III. Airports affect and are affected by their surroundings, most airports visited in this study had a big influence on the introduction of new sustainable technologies into their surroundings, also, most of those airports benefited from the environmental awareness available in the building services industry they operate in.

IV. The Hong Kong International Airport is so large it boasts a nine-hole USGA-approved course next to Terminal 2, and it is open to travellers.

V. Bird strikes are a real threat to aircraft safety, airports invest time and money into finding the most effective bird scaring technologies, including drones, falcons and cannons.

VI. Bee hives raised in the vicinity of an airport can give an insight into to the air quality of the area by measuring certain qualities in the honey produced, Stavanger airport uses this technique to monitor the air quality and promote sustainable agriculture on site.

4.1. **Hong Kong International Airport**

The Hong Kong International Airport is the largest in the world in cargo traffic, 8th largest by passenger traffic and 10th largest by surface area. In 2010, HKIA set a target to reduce its energy consumption by 25% per workload unit, since then, they have implemented over 400 energy and carbon reduction strategies.

IATA	Country	Köppen	Floor Area	Passengers/year	kWh/m^2	kWh/passenger
HKG	Hong Kong	Humid Subtropical (Cwa)	746,000 m^2	69.7 million	374	4.01

Energy Reduction

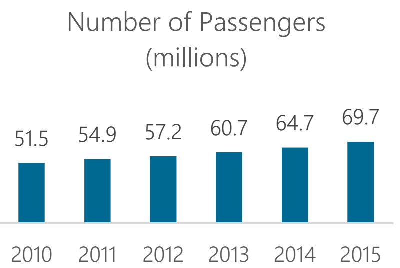
The weather in Hong Kong is hot and humid, with temperatures exceeding 31^{o}C in the summer. The air conditioning system is a water chilled system with VAVs, the air distribution is carried out through vertical pinnacles that save energy by cooling only the lower part of the high ceiling areas. Heat recovery is not popular in Hong Kong due to space limitations, it was considered for this airport but disregarded due to the great distance between the air supply and return.

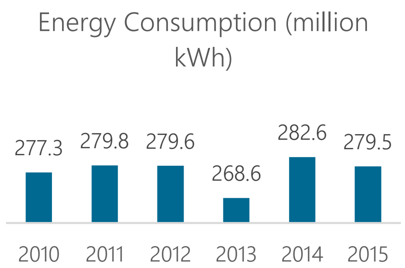
- The main and biggest reduction in energy consumption and carbon emissions was achieved by changing 100,000 lights into efficient LED lights, saving 18.2 million kWh/year. The LED replacement project took 4 years to complete and has an estimated payback period between 2 and 4 years. This initiative reduces energy on many levels; less electricity use at start-up and operation as well as reduced heat emissions.
- A chillers integration initiative was done by joining two chiller systems that used to individually supply two different terminals, into one system that supplies both terminals. With the varying temperatures and heat loads in each terminal, the integration provides a more optimised and flexible chilled water supply and chiller restoration time, saving 6.1 million kWh per year.
- As an initial step in the energy reduction project, sub-metering was installed in 2010 to provide information on areas to target. Currently the airport's engineering team is considering intelligent cloud based systems to use the recorded information and manage the different energy consuming systems.
- Fixed ground power unit were banned in HKIA in 2014, the airport now provides pre-conditioned air and power through Auxiliary Power Units (APU) to aircrafts during their parking time at the airport. This increases the energy consumption of the airport itself, however it reduces the carbon

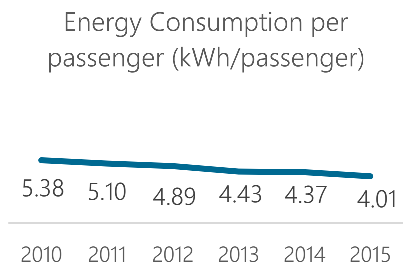
emissions from the aircrafts. This is one of the examples of how the Hong Kong International Airport has been the pioneer of sustainable solutions in Hong Kong and has influenced its surroundings by being the first to implement and encourage the use of sustainable technologies.

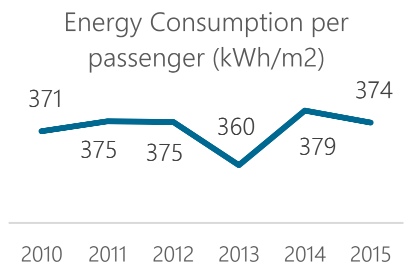
Benchmarking

Over five years the number of passengers travelling through the airport increased by 18 million or 35%, the energy consumption however only increased by 2 million kWh per year, this equates to a drop of 25.4% in energy consumption per workload unit which is in this case per passenger. As the floor area remained constant, the energy consumption by floor area slightly increased from 371 to 374 kWh/m^2.









The above graphs are based on data received from the Hong Kong Airport engineering team and are for the terminal buildings only.

Key Learnings

Lighting is an essential element of a terminal buildings' energy consumption, due to their large size and structural limitations in utilising daylight. While new airport designs are more frequently specifying the use of LED lights, existing airports can achieve great reductions in short payback periods through LED light replacement.

The original chilled water system design of an airport might not allow room for expansions, however, these expansions are inevitable and new systems are required to meet the increased cooling load. Therefore, the original and the additional systems can be linked together to create a more efficient supply to meet the variable load. HKIA have proven this is possible through the chiller integration initiative.

Further Readings

http://www.hongkongairport.com/eng/media/publication/annual-reports-2015-16.html

http://www.hongkongairport.com/eng/media/publication/sustainability-report/SD-reports-2015_16.html

http://www.hongkongairport.com/eng/media/facts-figures/facts-sheets.html

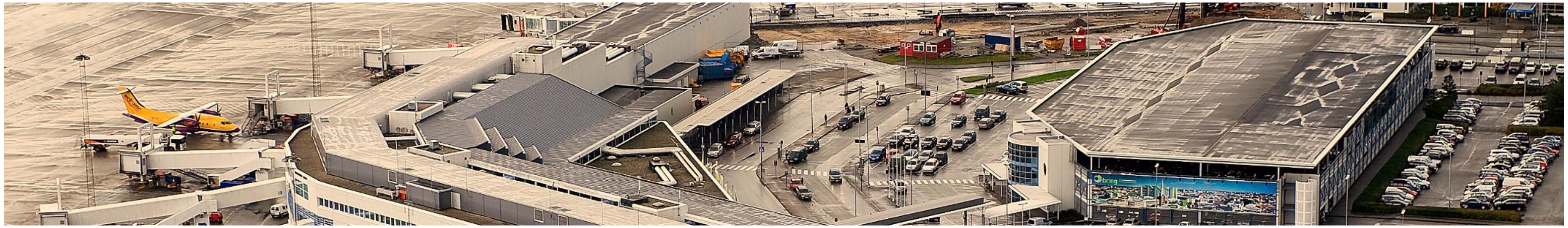
4.2. **Avinor Group – Norway**

Extending over 1,752 km in length and only 430 km in width, Norway is the longest and narrowest of all European countries. On top of that, Norway's coastline, is broken by huge fjords and thousands of islands making land travel impossible without time consuming water ferries transfers. For these reasons we find that Norway's public land transportation system is less developed then many of other European countries.

Avinor group, Norway's airports operator, has put an objective to facilitate air travel, allowing occupants and tourists to navigate easily between the different parts of the country, this means building more airports, which do not necessarily generate profit; in fact, out of a few dozen Avinor airports, only a few major ones generate yearly profits. This is one of the reasons Avinor is very interested in building sustainable airports to reduce the operational cost and carbon emissions.

4.2.1. **Stavanger Airport**

The Stavanger airport is the 3rd largest and oldest airport in Norway. The energy management team at the airport believes that the aviation sector is an easy target for sustainable operation, and that carbon accreditation is essential to document the progress.



IATA	Country	Köppen	Floor Area	Passengers	kWh/m^2	kWh/passenger
SVG	Norway	Oceanic (Cfb)	46,000 m^2	4.5 million	349	3.57

Stavanger is located in the south west cost of Norway, classified as a subarctic area, with temperatures reaching a minimum of -21 ^{o}C and an average of 7.2 ^{o}C. Nevertheless, cooling in the airport is required due to the lighting and people loads. In two years of implementing green solutions, the energy consumption at the Stavanger airport was reduced by 11%.

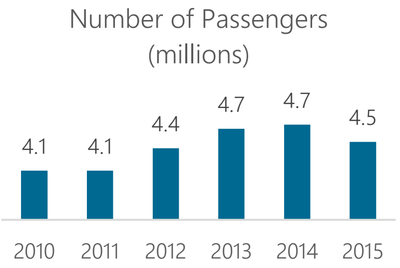
Energy Reduction

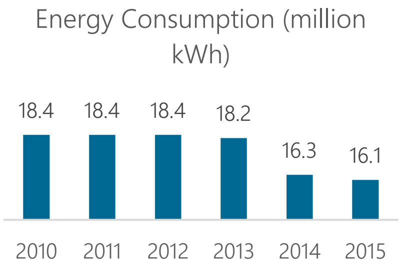
- Although major airports do sometimes require simultaneous heating and cooling due to the large difference in occupancy and heat loads between different areas, this was not the case for Stavanger Airport. Faulty sensors and overlapping temperature set points caused the cooling and heating systems to operate simultaneously, wasting energy. To solve this problem, the engineering team at Stavanger with the help of external consultants re-commissioned the HVAC system by replacing faulty sensors and introducing more efficient control systems. Other initiatives followed included: switching all the lights to LED and adding a heat recovery wheel to the air handling units to improve their efficiency.
- The airport environmental team wanted to explore the renewable energy path, therefore they installed a recycled wood burning hot water plant that supplies 1/3 of the hot water demand, using sustainably sourced wood chipping.
- Solar photovoltaic panels were installed on top of the car park roof and in different angles and orientation to test for maximum output. The energy output from the panels is being monitored and recorded to determine the most effective angle and orientation. Once determined, the same installation will expand to cover an area of 3,000 m2.

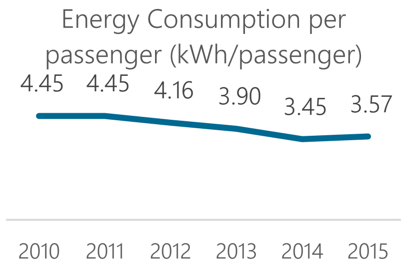
- Further investigation into using geothermal energy for heating and cooling and heat cameras to detect heat gaps in the building façade are being investigated.

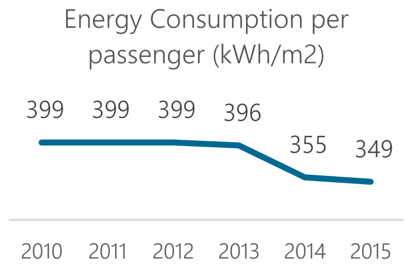
Benchmarking

Through the introduction of the energy reduction initiatives, Stavanger airport reduced their energy consumption by 2 million kWh per year or 12.6% reaching 3.57 kWh/passenger and 349 kWh/m2 of occupied area. Since the sub-metering does not exist in the airport, the data used was for the entire facility, this includes on top of the terminal building, the firefighting station, the car park helicopter terminal and the runway lights.









The above graphs are based on information provided by the Stavanger airport engineering and environmental management team

Key Learnings

One of the biggest challenges existing airports face in the process of reducing their energy consumption is the lack of stable funding. Energy management teams often have to provide tangible data to give confidence to the decision makers by showing the positive economic and environmental impact of energy reduction strategies. Following the same approach of Stavanger airport's solar panel trial project, airports can combine sub-metering with a short test period to identify the most effective configuration of the proposed technology as well as recording its impact on the total energy consumption and carbon footprint.

Further readings

https://avinor.no/en/corporate/airport/stavanger/community-and-environment/honey-production/

4.2.2. **Bergen Airport Terminal 3**

Bergen's new terminal is designed for smooth passenger and baggage flow, offering uninterrupted views from the entrance to the gates. This allows an immense amount of daylight to enter the terminal, improving visual comfort and saving energy.

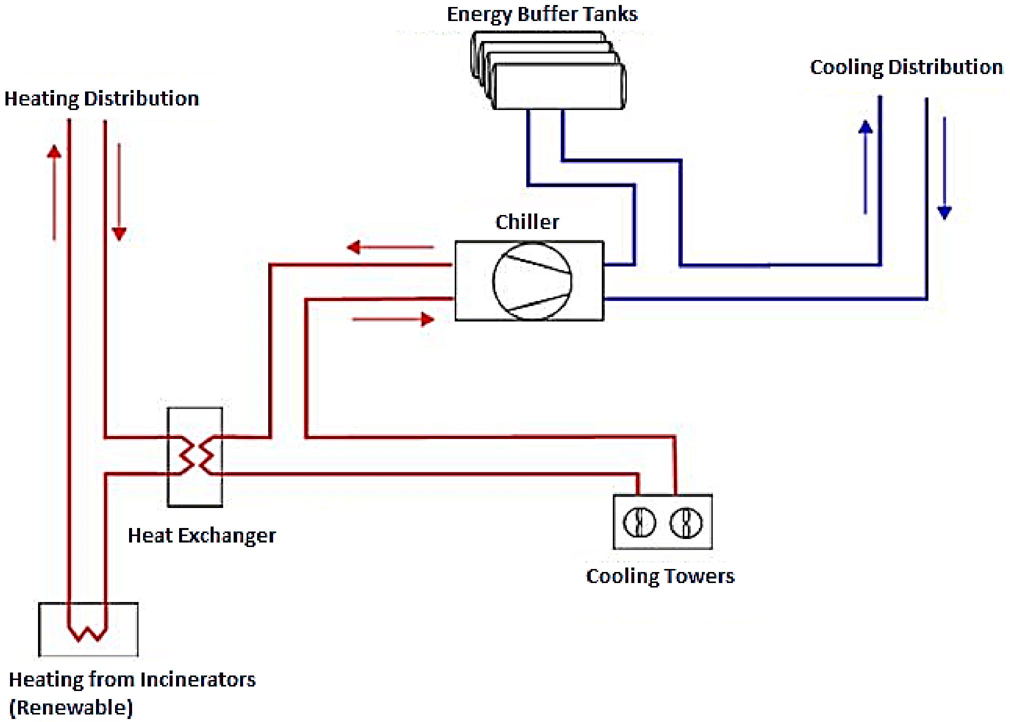
IATA	Country	Köppen	Floor Area	Passengers	kWh/m^2	kWh/passenger
BGO	Norway	Oceanic (Cfb)	52,500 m^2	7 million	144	1.08

The 4.5 MW cooling demand is met through water cooled high pressure chillers, a chilled water storage system using Phase Changing Materials (PCM) and an air handling unit system with heat recovery wheels with an efficiency reaching 85% and a VAV system. The 5.5 MW heating demand is met through the use of heat exchangers and hot water from a district heating plant. The heating and cooling of the main terminal area is done through an underfloor piping system with a maximum heating capacity of 50 W/m2 and a maximum cooling capacity of 20-25 W/m2. At peaks, cooling through ventilation is added to meet the load. Snow cooling was considered as a sustainable solution however, disregarded.

Energy Reduction

- The energy consumption of the baggage handling system of an airport is not to be underestimated. To move 2500 bags/hour, the baggage handling system of Bergen airport uses two thin low friction belts with baggage trays moving at 1m/s instead of the traditional wide belt. This reduces the power usage at start-up and therefore the overall energy consumption.
- Against common misconception, airports do not necessarily operate 24 hours a day, for runaway maintenance, there's a short period of time without any incoming or outgoing flights. Bergen airport benefits from this period of low occupancy and optimum outdoor conditions to operate the chillers at high efficiency and store the chilled water at 11°C for later usage during the day. The storage is enabled through passive Phase Changing Material (PCM). This allows the selection of smaller chillers and therefore reduced initial investment and lower energy consumption at start-up. The relatively high chilled water temperature means that the AHUs need to be quite large to meet the load, in fact the air flow in each AHU is 30,000 m3/hour.

- Bergen Airport's architecture prioritizes the passenger flow which causes restrictions for building services shafts and openings, to solve this, the baggage handling openings in the floor were used to diffuse cool air to the main terminal entrance area.



Key Learnings

To account for future expansions or increase in demand, the building services systems in airports can be designed to serve a demand larger than the one at design stage. This is the case in Bergen airport.

In large airports, simultaneous heating and cooling are common, even in predominantly cold climates, this requires intelligent zoning and controls to ensure efficiency and minimise losses. Integrating both the cooling and the heating systems together will increase the overall's system's efficiency by utilising the remaining thermal energy in the return one system in the supply of the other.

4.3. **Galapagos Ecological Airport**

The Galapagos Islands are one of the most protected places on the planet, a sustainable airport that fits well within its environment was considered a necessity. This LEED Gold airport pushes the limits of energy reduction achieving one of the lowest energy consumption rates in the world.

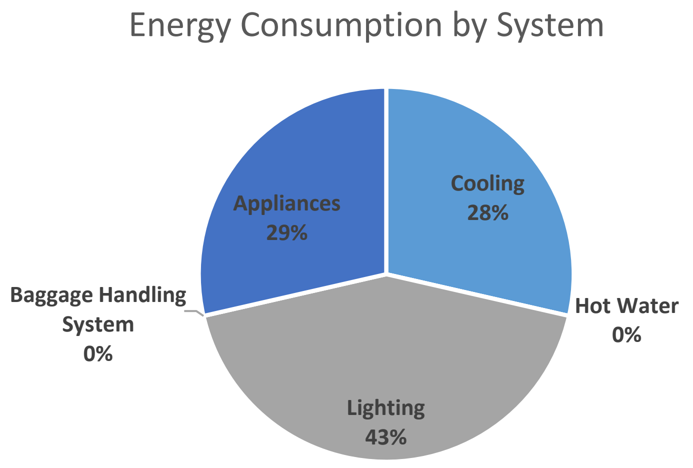
IATA	Country	Köppen	Floor Area	Passengers	kWh/m^2	kWh/passenger
GPS	Ecuador	Semi-arid (BSh)	6,027 m^2	452,447	47	1.01

The Ecogal airport is located on the Baltra Island in south Seymour, situated in a semi-arid climate it benefits from a relatively dry weather and a moderate average temperature of 23.6^{o}C. This, along with a fixed flight schedule and a specific type of passengers, creates a unique opportunity for energy reduction.

Energy Reduction

- With the exception of the management offices, data rooms and control tower, the building is entirely naturally ventilated. The energy simulation showed a short period of time during the year with temperatures above comfort levels. A bold decision was made by the operator and the designers, to exclude any cooling equipment except in the offices area, drastically reducing the energy consumption. The building orientation maximises wind flow through Co2 and temperature controlled louvres, it also minimises sun exposure by orientating the wide facades to the south and north.
- Other than the offices, the airport requires very little lighting thanks to the high ceiling, skylights and ventilation opening across the façade, this reduces the lighting load dramatically. In fact, during the site visit, only 1 fluorescent lamp fixture was switched on in the departures area.
- 350 solar PV panels situated above the passenger walkways produce 95,800 kWh/year which is 21% of the total electrical energy consumption
- Another interesting design decision, was to make the baggage handling system entirely mechanical, therefore it does not consume any energy.

Benchmarking



Darwin's Theory of Evolution and Energy Reduction

Cactus plants are widely abundant in the Galapagos Islands. Their round flat shape allows them to collect humidity from the air to survive in low water conditions. In a form of adaptation, and across several years of a cactus's life, individual leaves twist to face the direction of the wind in order to collect maximum amount of humidity. In a similar way, the Galapagos airport, which is heavily surrounded by cactus plants, is orientated in the direction of the most prevalent wind to collect maximum wind throughout the year for natural ventilation and cooling.

Key Learnings

- Due to the high security risk, airports have to follow stringent design regulations set by airport authorities. This creates less room for flexibility in energy reduction targets. Serious discussions with the authorities should be expected in order to obtain approval for unconventional energy saving strategies.
- Suitable design and installation of a modern sustainable technology is not the only parameter determining its success; efficient operation is another crucial element that should not be overlooked. Technical knowledge in the integration and maintenance of modern technologies such as PV panels is still not widely abundant, especially in remote areas, but is necessary to ensure these systems are working to their full potential.
- Airport systems are designed for redundancy, in order to ensure that the airport operations continue in case of a system failure, reliability might come ahead of efficiency in the system selection criteria.

Further Readings

http://www.ecogal.aero/

4.4. **San Francisco International Airport**

The Terminal 2 at the San Francisco International airport is the first LEED Gold certified airport in the US. The determination to achieve energy reduction in this airport has raised the limits. From NASA cooling technologies, to 100% efficiency in cooling towers and

IATA	Country	Köppen	Floor Area	Passengers	kWh/m^2	kWh/passenger
SFO	USA	Mediterranean (Csc)	n/a	n/a	n/a	n/a

The cooling system at SFO is a Genesis high pressure low speed system; it is commonly used in hospitals for its good air quality and comfort, also very convenient in busy airports. The air handling units include an economiser and operate through fans with modular blades that supply air between 2 and 3 inch of static pressure. The air is supplied to the terminal area through perforated walls named “Fan Walls”.

Energy Reduction

- The return fans do not operate until the static pressure in the building exceeds 300 PSI; this reduces the energy used by the return fans compared to traditional continuous return.
- All the pumps in the terminal building are equipped or being replaced to be equipped with Variable Flow Drive VFD to improve their efficiency.
- The chilled water is supplied through electric chillers carefully sized for maximum efficiency and minimum start-stop, ensuring they operate close to full load. The water return pipes going back to the chiller are passed to the water supply to the boiler for heat exchange. The cooling tower’s efficiency has improved to a point that one of the two original cooling towers can be removed to save water without effect on the cooling system.

Key Learnings

- Comfort and energy reduction can go hand in hand; SFO’s method in supplying air at a very low velocity through a bigger perforation area has a noticeable positive effect on internal comfort and air quality while reducing the energy consumption.

5. **Conclusion**

Working in one of the most culturally diverse cities in the world and the home of over 300 nationalities for the last seven years, I thought I have learnt all there is about cultural differences in the approach to engineering and environmental awareness. However, visiting the five airports during this study has been an eye opening experience to how different the sustainable design approach can be, and how some places push the limits in a different way than others.

A huge effort is being made towards reducing airport's energy consumption and carbon footprint. The data analysis and the site visits have shown us the different ways to achieve that depending on the location, climate and organisational parameters. The main lesson learnt is that airports are a world on their own, but at the same time they should take advantage of their surroundings as well as influence it. The limits can be pushed.

We also learned about the barriers airports are facing in their journey to achieving reduced energy consumption. Many of which are internal barriers due to the demanding nature of their operation. Design for redundancy and the necessity for emergency backup systems makes it challenging to eliminate traditional fuel based generators and cooling systems, the integration of renewable energy systems such as solar panels with the existing system requires extensive testing and expert staff, and the continuous expansions make it difficult to design a fixed system.

The air-conditioning is, as anticipated, the main area of consumption among an airport's mechanical and electrical systems. The sizing of chillers and boilers in an airport is as tricky as it is important; while it is very important to ensure maximum efficiency by avoiding oversizing, it is wise to account for future expansions; this can be done through integration of the old and new systems. Heating and cooling are in some airports required to operate simultaneously due to the combination of cold climates and high occupancy loads, this creates an opportunity for integration to increase the overall efficiency of the resulting combined system.

6. Appendix

6.1. About the author

Elie El Choufani is a mechanical engineer at Atkins Dubai, with experience in major projects and energy management consulting. He worked on the Abu Dhabi green hotels initiative and several other government projects with emphasis on improving energy performance and awareness. Elie is registered with the Abu Dhabi Urban Planning Council as a Pearl Qualified Professional (PQP) qualified to administer green building rating application under the pearl building rating system.

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