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Sustainable Energy Options for the Future Airport Metropolis

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Abstract: **-** The general scientific opinion on climate change is that most of the global warming observed over the last 50 years is attributable to human activities [1]. The aviation industry is one such activity and is one of the main contributors to greenhouse gas emissions [2]. Recently the industry has experienced unprecedented growth both on the airside (in terms of increased aircraft movements) and on the landside (in terms of the development of large Airport Metropolises).

Current aircraft design has seemingly reached a point of diminishing returns with regard to improving the energy efficiency of jet engines (at least in the short-term) [3]. Consequently one of the main strategies for mitigating global warming within the aviation industry is to reduce the amount of energy use on the landside (i.e. at airport facilities). To achieve this goal, more sustainable energy use practices must be employed. This paper presents a variety of sustainable energy options that are suitable for airport facilities. The significance of this research is that it will assist airport operators to make sustainable energy decisions concerning the future development of their airport.

Key-Words: **- Airport Metropolis Energy Sustainable Renewable Efficiency**

1 Introduction

Recently the aviation industry has experienced unprecedented growth, driven by strong global economies and low cost airlines. This trend is expected to continue given the predicted growth in both China and India and the continued demand of new global market economies that require goods to be shipped quickly. Given the increased passenger, freight and aircraft movements through airports, it is not surprising that some airports have undergone major changes. For some of the world's most successful airports, the changes are so dramatic it has given rise to a new type of airport. This new type of airport is best described as the emergence of a city metropolis around an airport transport infrastructure hub [4, 5] and will be referred to as an Airport Metropolis throughout this paper. The planning philosophy behind the Airport Metropolis allows the generally vacant land immediately adjacent the airport terminals and runways to be developed into commercial and industrial activities that either support the aviation industry or support the new economy industry or improve amenities for passengers. This philosophy has been successful and has seen some airports transform themselves into self-sustaining economies which are independent of the neighbouring city they once relied upon. Of course all this increased development activity at airports increases their potential environmental impact. This in turn has ramifications for the aviation industry which is seeking to reduce its greenhouse gas emissions and present itself as a sustainable global industry.

It is no secret that the airside of the aviation industry is a large contributor to greenhouse gas emissions [6]. In addition, it would appear that no significant energy efficient jet engine technology improvements are likely in the near future [3]. Therefore any immediate sustainability gains are more likely to come from the landside of the industry. Consequently one of the main strategies for mitigating global warming within the aviation industry is to reduce the amount of energy use on the landside (i.e. at airport facilities). To achieve this goal, more sustainable energy use practices must be employed. This paper presents a variety of sustainable energy options that are suitable for airport facilities. The significance of this research is that it will assist airport operators to make sustainable energy decisions concerning the future development of their airport.

2 Background

This section will examine the energy use characteristics of an Airport Metropolis. It will then address the question of what is sustainable energy.

2.2 Energy use characteristics specific to an Airport Metropolis

A large airport can consume the same amount of electricity as a city of 100,000 people [7]. In 2005, Brisbane Airport was one of the top ten electricity consumers in the state of Queensland with electricity consumption of 110 GWh. Energy consumption in 2005 at Frankfurt Airport, one of the world's largest, was ten times this amount at 1084.4 GWh [8].

As a consequence, airports budget for large bills from utility companies. The annual electricity budget for Seattle-Tacoma International Airport in the year 2000 was USD $6 million [9]. In addition to electricity, airports are consumers of other energy sources. For example, natural gas can be used as a source for heating, and for powering onsite combined heat and power plants (CHP, referred to as cogeneration), and oil-based products can have uses such as heating and powering landside transportation.

These airports tend to occupy large, flat land areas. Brisbane Airport occupies land totalling 2,700 hectares [10]. They are also characterised by the type of buildings that are typically constructed. These are large buildings such as terminals, hangers, multi-story carparks, office and/or retail space, freight and logistics areas, and hotels. They are voluminous and require energy consumption for HVAC services, in addition to lighting and other electrical devices, and they also have extensive roof areas.

Another point to consider is that these airports have expanses of land covered in pavement-based surfaces - runways, roads, carparks, walkways and so on. These are often dark surfaces, such as asphalt-based ones, and along with any dark building roofs they will contribute to the urban heat island effect - increasing cooling costs for the airport during summer, yet only marginally decreasing heating costs during winter [11].

2.2 Sustainable Energy

Sustainable energy refers to energy sources which can produce energy without adversely affecting vital human ecological support systems (i.e. the planet's climatic system). Previous research points to renewable energy and energy efficiency as the twin pillars of sustainable energy use [12]. Renewable energy focuses on the supply side of the energy equation, while efficiency relates to the demand side. Both pillars are potential options for Airport Metropolis type developments. The next section will outline the methodology used to examine the various renewable supply and demand reduction options given the Airport Metropolis context.

3 Materials and Methods

As mentioned previously, there are two main sustainable energy techniques. The first is to use renewable energy technology and second is through reduction of demand. A desktop study of current literature into these sustainable energy techniques was conducted. The aim of the study was to determine which techniques would be suitable for Airport Metropolis type developments. The relative merits and disadvantages of each technique are discussed in the next section.

This process will narrow the scope to focus on a small number of areas that have the greatest potential significance to landside sustainable energy practices at an Airport Metropolis. Future work will be framed within this scope and will aim to develop an energy model and decision support system so that various energy use scenarios can be evaluated against a Business As Usual approach.

4 Results and Discussion

This section will first discuss the alternative renewable energy technologies and their relative suitability to an Airport Metropolis application. This will be followed by a discussion on the methods that can be used at an airport to reduce the demand side energy use.

4.1 Renewable Energy Technologies

Renewable Energy Technologies (RET) are fast becoming commonplace as the effort to increase sustainable energy use practices intensifies. Many RET are available as mature commercial products and potentially should offer a real alternative to energy generation as part of an Airport Metropolis development. RET harness energy from the following sources [13]:

- Hydropower
- Biomass energy
- Solar energy
- Wind energy
- Geothermal energy

4.1.1 Hydropower

Hydropower, the capture of the energy of moving water, has three primary types: run-of-river, tidal and wave. A typical large hydroelectric scheme is not possible in an airport context, unless the airport is located near a large body of water that contains usable kinetic energy potential. However, small-scale run-of-river, or similar turbine based schemes, may be of relevance to airports located near rivers or streams.

Tidal barrage systems are environmentally complex given the need for structural alteration to the tidal area. Tidal stream turbine systems and wave systems do not have the same environmental complexities, and they do have proven commercial ability. The Portugese Pelamis project is reported as the world's first commercialisation of wave energy. It is expected to generate 2.25 MW [14].

All hydropower generation options are heavily dependent on the individual airport's geographic location and right-of-access to the water deployment zone. Additionally, the environmental impact of developing a hydropower system near airports would make it unsuitable for most airport situations. Some Asian airports on reclaimed land surrounded by large ocean frontages could benefit from hydropower provided all environmental sustainability criteria were met.

4.1.2 Biomass

Biomass derivatives such as biogas and liquid bio-fuels can be purchased for onsite use. Bio-diesel (e.g., B5 or B20) can be used to power onsite transportation devices. For example, Munich Airport with 20 million passengers per year has developed into a medium sized Airport Metropolis. It currently uses approximately 6 million litres of diesel fuel per year. In 2007, the airport intends to replace up to one-third of this fuel through canola oil. This represents approximately 1.2 million litres of canola oil [15].

Biogas can be used as an alternative to natural gas, for example as the combustion source for heating (or cooling) of buildings and water.

Solid biomass, such as food waste, can be harvested by an airport and recycled onsite as an energy source, for example via gasification. Such a scheme could even be expanded to include the receipt of waste from surrounding areas.

Biomass energy is well suited to airport applications and numerous airports have successfully applied this technology. London's Stansted airport has signed contracts for the implementation of a 2MW woodchip boiler in order to provide biomass supplied heating and hot water [16].

4.1.3 Solar

Solar energy is very relevant to airports, and indeed there are numerous working examples of utilisation of this form of energy in an airport setting. Solar energy can be harnessed via photovoltaic cells, which directly produce electricity, and via solar thermal systems, which produce heat, usable for onsite electricity generation, or space and/or water heating.

An example of solar photovoltaic use in an airport context is the installation of 111 kW of solar capacity at Austin-Bergstrom International Airport. A strategy implemented at this airport was to install the solar panels over a car park, providing an added shading benefit [17].

Another example along similar lines is the rental car parking lot project currently under construction at Fresno Yosemite International Airport and due for completion in August 2008. The panels installed over this new parking lot will provide 2MW of capacity and 40% of the airports total electricity requirements from a coverage area of around 10 hectares. This project represents the largest single provision of renewable energy to an airport in the United States [18].

Solar thermal energy could be used in an onsite Concentrated Solar Power (CSP) system, or Compact Linear Fresnel Reflector (CLFR) system. These systems concentrate solar energy to maximise the heating capability and then generate electricity via a steam turbine.

The physical characteristics of airports support the harnessing of solar energy. Large land areas are potentially available for solar farms, and large buildings exist with roof areas that can be equipped with solar collectors. In addition, passive solar systems are also relevant for use at airports, and these are discussed in the energy use minimisation section.

4.1.4 Wind

Wind energy is potentially a very useful source of renewable energy for airports, again because the land-rich nature of airports provides many feasible onsite locations. However, airport safeguarding regulations may limit the practical application of building wind turbines on, or near, airport land, for reasons of both being a physical obstacle, and radar interference. Micro-turbine devices might have more practicality.

For example, the British Civil Aviation Authority (CAA) dictates that it be notified of any planning application for a proposed wind turbine development within a 15 km radius of any aerodrome in its jurisdiction so that it and the aerodrome can carry out investigations and analysis of any potential interference [19].

4.1.5 Geothermal

Geothermal energy utilises the heat difference available above and beneath the earth's surface.

Onsite geothermal electricity production at airports is not as conveniently achievable as some of the other RETs addressed above such as solar as it is dependent on specific geological structures existing beneath the airport such as reservoirs of hot water, or hot rocks. This is another niche scenario to be treated on its individual merits and outside the scope of this research.

Geothermal based heating and cooling, much more widely available as it takes advantage of the relatively uniform temperature of the ground by using it as a heat sink or source, has well proven applicability within an airport context. For example, a feasibility study has been conducted for the Macedonia Airport in Thessaloniki. This study concluded that a geothermal system could provide 8 MW(t) of heating or 7MW(t) of cooling capacity, with annual production of 16,800 MWh(t) [20]. The study included a method for comparing the costs of this system with a natural gas and diesel system and concluded that the geothermal system was characterised by high energy efficiency and competitive costs (pg. 22).

An example of an airport tenant utilising geothermal energy is the Caltex Airport StarMart at Canberra Airport. This was another greenfield site, where the payback period on installing a geothermal air conditioning system was one year [21].

4.1.6 Offsite RET Generation

An alternative to onsite RET generation is the purchasing of energy from offsite RET generation. For example, some organisations such as utility companies and energy retailers offer their customers the opportunity to purchase a proportion of their energy from renewable sources, usually branded along the lines of "Green Power". This option is only available to airports that have connectivity to "Green Power" utility companies.

4.2 Energy Consumption Minimisation Considerations

Energy consumption minimisation can be broken down into three separate considerations [22]:

- Has less energy been used (reduction through less use)?
- Or, have alternatives to energy use been utilised (reduction through substitution)?
- Or, has energy been used more efficiently (reduction through more efficient use)?

The first two points cover a whole range of considerations such as work from home schemes, adjusting A/C systems to less energy intensive temperatures, and increased usage of bicycles or public transportation. But it is the third option – energy efficiency – that holds the greatest potential for increasing the sustainability of energy use at an Airport Metropolis.

4.2.1 Efficiency

At its most basic, energy efficiency is increasing the amount of useful output work obtained for an input unit of energy. There are many and varied opportunities for increasing energy efficiency, but the two that research points to as being most relevant to large airports are building and lighting efficiency, and cogeneration.

4.2.1.1 Building and Lighting Efficiency

Various studies have shown that the options that offer the quickest payback for greatest decrease in emissions are efficiency measures, particularly building efficiency measures such as insulation, and lighting system efficiencies [23, 24].

When lighting alone can account for 40% of an airports electricity consumption [25], it is apparent that this is a substantial area of focus for efficiency improvements. Numerous examples exist of substantial energy savings at airports by switching to more efficient lighting systems [26].

HVAC systems can also account for around 40% of an airport's electricity consumption [25], so general building efficiency improvements are also very important. Building design elements such as passive solar heating, light-coloured roofing, green roofs (such as the main terminal at Schiphol Airport, Amsterdam), natural ventilation, and passive lighting can be used for airport buildings. There are also many parameters of a HVAC system, and other building energy systems, that can be modified to increase efficiency. A computerised Energy Management System (EMS) may also provide efficiency gains.

4.2.1.2 Cogeneration

At airports, the contemporaneous and high demand for both power and heat makes cogeneration a viable solution for energy saving. In zones closer to the Equator, trigeneration (combined heat, power and cooling) systems can lead to even better results [27].

This technology falls under the heading of efficiency as it leads to a greater utilisation of input energy. These systems, where electricity is generated onsite, and by-product heat is harnessed, are able to achieve from 60% to 90% efficiency, compared with traditional centralised power generator systems, which achieve around 30% to 40% efficiency [28].

Cogeneration is already in use at many airports, for example [7]:

- 100 MW plant at JFK International Airport
- 50 MW plant at Heathrow Airport
- 90 MW plant at Toronto Pearson International Airport

Often, cogeneration systems are powered by natural gas, but other options include the harnessing of solar thermal energy and biomass combustion as the source powering the heat engine. Therefore cogeneration systems have great potential for reducing overall energy consumption, and also potentially increasing the utilisation of renewable energy sources.

Another example of cogeneration on a smaller scale is the 1.5MW plant installed at the Greater Rochester International Airport, Monroe County, NY, which generates about 90% of its electricity requirements (1,160 kW–1,450 kW) and saves USD$500,000 yearly on its electricity charges [29].

5 Conclusion

Solar is the most suitable broad scale RET for an Airport Metropolis. It has proven applicability in the airport context, and the extent of both land and building roof area available in a typical airport setting provides substantial opportunity for solar energy utilisation. Many of the other RET are dependent on geographic conditions that are generally not found near major airports.

In addition, both the areas of building and lighting efficiency and cogeneration have relevance within the Airport Metropolis context. However, the current state of the building and lighting efficiency industries is reasonably mature, and there exists a large body of research work as well as many artifacts to assist practitioners apply this knowledge in real-world settings. Tools exist to audit efficiency, and to model planning and design scenarios. The fact that the types of buildings constructed at an airport share characteristics with similar buildings constructed in other industries and commercial zones means that these tools are readily applicable.

By comparison, the level of assistance available to Airport Metropolis decision makers surrounding the area of cogeneration is limited, but the research has shown that proven opportunities exist for maximising energy efficiency by installing a cogeneration system.

In summary, of all the sustainable energy options reviewed in this paper, solar and cogeneration represent the most potential benefit for an Airport Metropolis type development, while also representing the best options that future work in this area can concentrate on to be of most assistance to Airport Metropolis decision makers as they seek to make their energy use more sustainable.

6 Future Work

Future work is intended to develop an energy model and decision support framework so that alternative energy use scenarios can be evaluated against a Business As Usual approach to airport operation. This will include the investigation of sustainability indicators as a means of assessing these different energy scenarios for an Airport Metropolis. A case study using Brisbane Airport will then be conducted to illustrate the effectiveness of the energy model and decision support system.

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