USE OF RENEWABLE ENERGY IN AEROSPACE INDUSTRY BUILDINGS

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Abstract

In developed countries approximately 50% of all energy sue is associated with buildings - to provide comfort by use of heating and cooling systems, to provide ventilation, to provide lighting and also in the provision of many ancillary facilities and services. The aerospace manufacturing industry has a number of specific issues to address, not least of which is the fact that the energy costs are relatively small by comparison with other costs. This could lead to a disregard for such issues however there are many opportunities afforded at little or no additional cost, particularly with regard to management of energy supply and management of energy demands. This paper takes as its theme an investigation into options and opportunities to utilise both energy supply enhancement and energy demand control techniques through the study of one particular site. The types of technology considered include photovoltaic solar energy, biomass fuels and use of thermal mass.

Keywords: renewable energy, green operations, aerospace industry.

1. Introduction

Owing to growing demands for air travel and increased competition, the aerospace industry has grown rapidly in recent years. This directly results in a stress on resources, especially on primary energy sources both for aviation fuel and for other operations necessary for the functioning of the industry, such as manufacturing facilties. The overheads to run a building can amount to a significant expenditure on energy costs. A major part of these costs can be avoided by the industry if they proactively plan their energy use and efficiency strategies. As stated in the Neo-classical Theory of the Firm [1], the aerospace industry, as a business has income generation as their prime priority. Often in prioritising this, other issues such as environmental design (which can offer associated energy benefits) come as a late thought. Two approaches can be applied, namely supply side and demand side energy management.

Dimetri [2] believes that buildings can usually be significantly improved in terms of their thermal and electrical performance. Use of various techniques for energy supply and conservation such as photovoltaics, thermal mass and biomass, contrary to the general assumption, can generate revenue for the users and prove to be beneficial. In an industrial building, heat transmission loss through building fabric, infiltration loss through air leakage and inefficiencies incurred by poor building usage are the three primary sources of heat loss [3]. Life cycle assessments conducted by Knapp and Tehresa [4] on energy pay back periods have shown that energy and environmental performances of photovoltaic systems become more interesting as the system design is more integrated with the whole building design, and as the module is more fully exploited as a dual-output device.

Kalogirou et al [5] explain that the principal thermal mass effect on heating and cooling systems serving spaces in heavyweight buildings is that a greater amount of thermal energy might need to be removed or added to bring the room to a suitable condition than for a similar lightweight building, though thermal mass can also be used in certain situations to even out temperature fluctuations. An earth-air heat exchanger system, based on the above mentioned concept uses the storage capacity of the earth and conditions the air [6].

In Finland biomass provides for 20% of energy needs and 15% in Sweden [7]. Day [8] explains the carbon-neutral character of biofuels and mentions that the carbon produced by combustion of these fuels is balanced out by growing the replacement crops. Boyle [9] Explains that biomass gasification can be used to fire an engine to develop power in the range of 20-100MW.

This background indicates that there is an increased need for research on the development and application of renewable energy in *new* buildings. However, little research discusses the integration of renewable energy into *existing* facilities.

The research described in this paper has had the aim to examine the integration of renewable energy in an aerospace manufacturing facility. The cost implications and details of how 'greening' of a building can save money in the long run are investigated. This research exhibits an exploratory paradigm and adopts both, qualitative and quantitative methodologies to conclude that energy efficiency being a key driver, can lead to both, environmental and financial gains.

2. Problem formulation

In the international markets of civil aerospace, defence aerospace, energy and marine power, “Company Aero” is one of the world leaders, they follow ISO 14001 throughout their sites as a part of their environmental obligations, but a wider use of environmentally sound activities through out their processes and buildings is yet to be achieved.

With regard to their facility buildings, ‘build fast and build cheap’ strategies have impaired them from harnessing building efficiency. This has resulted in a very chaotic site layout. Most of the office and plant buildings are heated using steam generated at one corner of the site. This steam is transferred to all the buildings on the site using very rudimentary methods, leading up to 60% [9] loss in efficiency. As a direct result of this the buildings remain improperly heated and ventilated. “Company Aero” has to back up the system using stand alone electric heaters. This results in large expense on electricity.

The study aims at exploring the various demand and supply side options such as using concepts like thermal mass air-conditioning, electricity generation by photovoltaics and biomass gasification at “Company Aero”; it also considers related costs for the engine building facility. Following the recommendations for a suitable combination of the above-mentioned technologies, the study also, wherever possible, comments on the economic and environmental benefits of these systems.

3. Systems review

The goal of almost all governments is still economic growth

> “*Economics is the state religion to which policies are aligned.”*
>
> [10]

‘Ecology or Economics?’ has always been the question of priority. This issue has been a part of political debate all over the globe, yet various techniques such as photovoltaics, thermal mass and biomass, contrary to the normal assumption, can be evaluated and assessed in ways that can demonstrate better revenues for the users and prove to be beneficial when all factors are taken into account. A large industrial has great potential to benefit from these technologies.

3.1. Photo-Voltaics

“*Electricity is now a carbon market with tradable certificates. New EU Buildings Directives for 2005 will bring compulsory energy labelling to every public building. All commercial organisations will need to set corporate sustainability targets and to monitor energy performance.”*

[11]

Cross [12] and Nigro [13] emphasise that the energy value credited to a photovoltaic (PV) system is a function of the PV's array size, efficiency and the incident solar radiation. It is possible to replace some part of building's energy needs by producing energy from roof-top arrays, with a marginal drop in the efficiency of these units even if the sunlight is very dim. Given the average daily solar energy available of 10MJ/m2 for the Midlands area of England [14], photovoltaics can be a lucrative option. Up to 12% savings have been achieved over conventional systems, apart from tax benefits claims [15]. These savings have been recorded before finishing of the declared pay-back period.

3.2. Thermal mass

Building materials and the earth have very good thermal properties. A proposed system uses concrete [16] and an Earth-Air Tunnel system (EAT) for cooling and conditioning buildings using the thermal mass of the earth. In some circumstances it is also possible to use the thermal mass of buildings for the same effect[5], but care must be taken that large amounts of energy are not simply used to maintain the large mass of the building at a particular temperature.

An earth-air heat exchanger system, based on the above mentioned concept uses the storage capacity of the earth and conditions the air [6]. Experiments conducted show that earth air tunnels were able to maintain temperatures inside the building in the range of 17 degrees to 25 degrees centigrade during summers with ambient outside temperatures ranging from 28 degree to 43 degree Centigrade. These experiments were carried out on a tunnel 80 meters in length, this sufficed for 512 kWh of cooling requirements per day. Also a Passive Annual Heat Storage (PAHS) system at Mile End Park in London is use to build up a 'thermal charge' over a long period [17].

3.3. Biomass gasifiers

Biomass is now becoming popular worldwide for its flexibility of using municipal waste combustion, sewage gas, agricultural residues, and also sources from specially grown willow and miscanthus grass, gasified to produce biofuels. Day [8], explains the carbon-neutral character of biofuels and mentions that the carbon produced by combustion of these fuels is balanced out by growing the replacement crops.

A down-side of biofuels is the storage problem they pose. Apart from being fired for immediate requirement, biofuel sources can also be coupled with a Combined Heat and Power (CHP) system. Another potential source is usage of bio-diesel as a fuel. It can be used on its own, or mixed with conventional fuel to run diesel engine CHP units; the calorific value is low at 22MJ/litre against 39MJ/litre of conventional fuel, but is still more than wood chips [8]

4. Research methodology

This research exhibits an exploratory paradigm, and has the following three objectives, as understood from the work of Zigmund [18].

1. *Diagnose a situation*: here the research is aimed at diagnosing the energy demand problems inherent in "Company Aero" manufacturing and office facilities. This would further look into the root causes of the current stand of energy inefficiency.
2. *Screening alternatives*: this could have two approaches.
   - Looking from the problem identification, this research would identify demand side and supply side issues.
   - From the solution perspective it would look into giving various options.
3. *Discovering new ideas*: this explores the various means and technologies that could help sustain a more eco-efficient state of existence.

There are two main research paradigms which are positivistic (quantitative) and phenomenological (qualitative) [19]. Considering the two paradigms as a continuum, this research would adopt a Phenomenological approach. The research is carried out by looking into qualitative literature and deriving conclusions.

The conclusions are derived by looking at relevant literature and also by looking at certain scientific and quantified datasets. Primary data, collected at source was obtained from the "Company Aero" site, including interviews, site tours, photographs and site drawings For the intended purpose of the study, methods such as questionnaires, protocol analysis, focus groups and critical incident techniques were not appropriate. Robson [20], points out that a combination of observations and interviews is the most relevant technique for action research like this.

5. Discussion, observation and analysis

The government has indicated in its energy white paper that 10% of total energy should be sourced from renewables as a target in the short term, partly provided for under the renewables obligation by the electricity producers. This cost would eventually be separately subsidised for individuals and industries. Further the UK is involved with an economy-wide carbon trading system [21]. There are also various subsidies available to promote the use of renewables like photovoltaic generators, biomass and tidal industries.

The 2004, Sustainable Buildings Act [22] requires monitoring of supplies like fuel, power and heat to industrial buildings. Further these regulations also specify the monitoring equipment needed. This is giving a 'push' to the industry drivers for eco-efficiency as a serious proposition in their buildings. From 22 March 2005 [23], the Operating and Financial Review (OFR) regulations have come into force. This is far from voluntary approach and would be binding. This OFR would introduce newer and more user-friendly ways of corporate reporting. It aims at making sure that the companies are doing a balanced and comprehensive analysis of the company's activities. Also is would lay special emphasis on the company's impact of current activities.

5.1. Factors affecting energy demand

In a typical average sized factory unit at "Company Aero" site, a good amount of heat is lost through various sources, which would probably have been ignored during the design phase. It loses heat by air infiltration, and transmission through roof-lights and glazing. It is not clear from the information available what the exact source of heat supply is at the building under consideration (which is a production facility). The site is heated using a combined heat and power plant as well as a steam boiler. Apart from this the site studied also had a large number of stand-alone heaters.

One option that might be considered is a move from a centralized to a decentralized system of heat generation and supply. Also it is beneficial to look at the option of fuel supply from biomass to the CHP unit. A decentralized system can have added advantages of a smaller plant size, higher efficiency on full load, and localised controls; hence chances of space overheating and heat loss are eliminated.

5.2. Ventilation

Apart from maintaining optimum temperatures for both humans and machinery, it is essential to effectively ventilate the operational premises. The sites visited had poor ventilation systems, the engine building facility had louvers on the side walls up to ceiling height. There were no other ventilation systems specifically designed for the need of the facility. Air circulation was facilitated by ceiling fans, which again did not provide much comfort to the occupants. Apart from this there were no means of forced ventilation and air-conditioning. Air conditioning premises of this size could often lead to massive energy costs and carbon emissions. The following options for temperature conditioning strategies should be considered.

5.3. Thermal mass

Also known as Fabric Energy Storage, FES [16], thermal mass is a less exploited and effective sustainable alternative to air-conditioning for combating temperature fluctuation. Thermal mass of the fabric, i.e. concrete or ground is effective in maintaining the desired comfort levels. They work on a principle that buildings with high thermal mass have a slow response rate to changes in ambient climate. It benefits the buildings particularly in summer times, when concrete absorbs internal heat gains to avoid over heating. This heat sink builds-up towards accumulating higher temperatures at evening times.

5.4. Concrete and thermal mass

The system reacts to thermal loads in four ways:

1. Summer days: warm ambient air is cooled when it enters the pre-cooled hollow slabs. This cool concrete also absorbs heat generated from lighting machinery, people and re-radiated solar gains.
2. Summer nights: at night times, outdoor air is blown into the hollow slabs. This assists cooling down the building frame to prepare for the next day.
3. Winter days: it helps during the cold winters as the tightly sealed and highly insulated building envelope helps prevent heat loss from inside the building. Heat from the rooms is extracted from them by using extraction fans and is passed back to the slab which in turn conduits it in the other activity areas.
4. Winter nights: this works by sealing the building at night times to keep the daytime heat gains intact. If the building cools down prematurely, which might happen occasionally, the sensors in the ceiling would turn on the heating system. This would take of the load from the conventional heating system and would hence assist in reducing energy related costs.

Performance facts of FES [24]

- Reduces the capital costs of building materials by using modular components.
- Low complexity of services leads to lower maintenance costs.
- Great reduction in the amount of using ancillary mechanicals like fans and chillers.
- Reduction in moving parts outside plant rooms.
- Uncomplicated and short commissioning period.
- Different temperature zones do not demand for dedicated climate control systems. One slab takes care of temperatures and ducting for up to 16 meters.
- Slabs provide both, radiant and conductive heating/cooling, owed to the high thermal mass.
- Service and cleaning points allow for easy and cheap cleaning.
- Running costs as compared to air-conditioned buildings is lower by up to 46%.
- Maintenance costs are greatly reduced. Up to 13% for air-conditioned buildings and up to 33% for naturally ventilated buildings.

Thermal mass contributes to a great extent in regulating the building climate as compared to buildings with mechanical ventilation.
Earth air tunnels using the principle of thermal mass, a less well known use of thermal mass is the exploitation of thermal properties of the ground. One of the first attempts for using the Earth-Air Tunnels (EAT) was at a college in Pakistan. Here the outer air was drawn into a building cellar using a 35 meter long rectangular tunnel circuit. Cooled air was drawn using a central duct which cooled 10 rooms of the building [6].

Using the thermal mass of the ground and the concrete tubes, the EAT system can effectively cool or heat the premises. Study conducted by Kumara et al [25] derives a model which validates that an 80 meter long tunnel with an area of 0.528 sq. m and a passing air velocity of 4.89 m/second has a cooling capacity of approximately 512 kWh and a heating capacity of 269 kWh.

5.5. Photovoltaics

As was observed on site in "Company Aero", the roof is a thin laminar sheet and as discussed before, which leads to thermal losses. Using a PV system on the roof would help serve the purpose of insulation as well as it would generate electricity. Also it can be used as a window shading device, saving heat build-up in the building and generating electricity at the same time.

Payback on PV systems, as on any other renewable source has always been a major issue as PV systems are expensive to install. With reference to the UK climate, systems would pay back in 3.5 years rather than 2, as in America. This gives a PV system an impressive result set. The balance of system energy payback of 3 to 5 months is up to 75% [4] and [13] lower than research till date. Refer to table 1.

The life cycle studies prove that they don't have a very big payback period, rather it is small and also taking into account the environmental benefits and payback; it is one of the highly desirable ways to reduce carbon emissions.

5.6. Biomass

Biomass is used to produce a combustible gas called producer gas. This conversion is carried out in a reactor called the biomass gasifier. Most commonly it uses biofuels like agricultural residues, wood, straw and special crops grown for quick harvest. Often it is possible to convert municipal waste, manure and animal excreta into efficient fuel for energy generation. One of the most interesting case studies in biomass gasification is the Brazil Biomass Integration Gasification – Gas turbine (BIG-GT Project) [26].

This plant has been designed to generate approximately 40 MW of electricity and deliver approximately 32 MW of electricity to the grid. The wood feed is chipped and dried (using waste heat) on-site. The dried wood chips are fed to the air-blown fluidized bed gasifier (1.8 bar) [26]. For this plant operating at 85% capacity factor, the £7/MWh levelised delivered COE translate into annual savings of £5 million/year. Assuming a discount rate of 12 % per year, the cumulative 25-year present-value savings are £39 million in 2010, or £12 million after discounting back to the year 2000. If this discount rate is applied at 8%per year, the cumulative 25-year present value savings total £53.2 million in 2010, or £25 million in 2000 [26].

Balance of System Components	Primary Energy (kWh_{prim}/kW_p)	% of Total Energy	GHG Emissions (lbs CO2 Eq/kW_p)	Energy Sensitivity ± 25% (Payback Change)
Construction (Site Preparation and Installation)	37.4	0.3%	26.5	0.00
PV Support Structures	251.6	2.0%	138.1	0.01
PV Wiring, Conduit and Junction Boxes	293.1	2.4%	209.3	0.02
Inverters and Transformers	502.2	4.1%	214.9	0.03
Grounding Components	113.5	0.9%	61.1	0.01
Miscellaneous	88.2	0.7%	51.1	0.01
Administration, Maintenance and Security	193.8	1.6%	124.3	0.01
Sub-Total (Balance of System)	1,479.7	12.0%	825.4	0.08
Payback Time (Years)	0.33		0.31	
PV Modules				
mc-Si PV Module Manufacturing	10,789.7	87.4%	6,519.3	0.61
Module Transport from Factory to PV Plant	69.0	0.6%	41.7	0.00
Module Disposal	13.4	0.1%	8.1	0.00
Sub-Total (PV Modules)	10,872.1	88.0%	6,569.1	0.61
Payback Time (Years)	2.45		2.45	
Totals (Balance of System + PV Modules)	12,351.8	100.0%	7,394.5	0.70
Payback Time (Years)	2.78		2.76	

Source: Mason. J, 2004

Table 1: Life Cycle Embodied Energy and GHG Emissions Results for a Grid-Connected, Field PV Plant (Framed, 300 W_p, mc-Si PV Modules)

6. Conclusions and implications

The link between buildings and energy is inextricable. All the activities housed by a building require generous amounts of energy to power them. The world is one of universalised central heating and air-conditioning to maintain internal environments in the desired band of temperatures. Somehow the population has become used to the idea that energy comes from a somewhat invisible source at a price which seems a routine insignificant expenditure to most people.

Most current energy supply is from fossil fuels which are depleting fast. In the years to come, by using eco-efficient techniques, “Company Aero” would actually be adding to the value of their business and brand image as being a business which cares for the environment. Further to reduce their energy consumption on the supply side of the equation, they need to strategically identify pilot buildings where they could implement such projects. Case studies with thermal mass have revealed the enormous thermal capacity of the ground. Propriety systems such as TermoDeck are also available, which are not only designed to regulate the temperature needs of a building, but also offer a more uniform temperature distribution. They have been running successfully for several years.

Photovoltaic systems offer another option, it is true that they are expensive, but there are often various grants and part funding possibilities available for the installation of PVs. They can be designed to act as an insulating element on the roof; or they could be semitransparent and provide essential daylight in the building premises. They could also act as a shading device to reduce overheating risk for buildings. The electricity generated by these PV panels could be fed into a grid system or sent off to a common battery bank, which is also fed by the biomass gasifier.

Biomass is again a possible option in which the company might be interested which is already readily available. If needed Company Aero could team up with an external plantations authority to take care of the production of the biomass fuel. They could also team up with the local waste disposal authorities to obtain treated waste to their site as a biomass fuel. This would create a win-win situation. For the authorities this would mean reduction in the expenditure on waste management and disposal licences. This could form a mini ‘industrial ecosystem’ between the two. Energy generated could either by supplied to the existing CHP plant or, be channelled as electricity to the common battery bank which is also being charged by the PV cells.

There are numerous spin-off benefits for the company since investors and employees are becoming increasingly interested in environmental issues - in terms of working environment, company image, future investment potential, reduced waste and pollution liabilities and longevity of the site. Ethical banking and ethical insurance companies must also be considered. Going green also helps reinforce brand image and value with customers and various other stakeholders.

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