

A case study in carbon management during the design process Satellite 3, Stansted Airport, UK

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Abstract: Set within the context of China's growing need to develop a cleaner and more efficient energy supply infrastructure, this paper describes a procurement process for evaluating and reducing the carbon dioxide emissions arising from operational processes within buildings during the design stage when key decisions affecting long-term energy demand are often made but frequently not understood.

The focus of the study is a case-study building, the 8275m² two-storey arrivals/departures building, Satellite 3, at Stansted Airport, UK. The client set a challenging design performance target of a 20% net CO₂ reduction below British Airways Authority's (BAA) current most energy efficient building, Satellite 1, Stansted. This reduction was to be achieved without compromising the BAA corporate standards on passenger and staff comfort perceptions or appreciable increases in capital costs.

The carbon assessment methodology involved the following stages:

- Establish baseline CO₂ footprint and target from real-time energy data for Satellite 1 of 103kg CO₂/m²/a.
- Review of the 'base-case' building performance assessment for Satellite 3 using BAA's standard specification criteria.
- Assess the impact on energy demand and CO₂ emissions of a number of variations to the 'base-case' design parameters ranging from solar shading, insulation levels to control systems and occupancy patterns.
- Develop an evaluation methodology that iteratively balances capital cost and revenue expenditure with environmental benefits to enable informed choices to be made by the client on where the most 'environmentally effective' design responses lie.

Outcomes:

- A 23% net CO₂ reduction by design was achieved at no additional capital cost.
- Learning and environmental costs benefit methodology disseminated to the BAA supply chain and adopted at Gatwick and Heathrow Airports.
- CO₂ is now a new key performance indicator for design efficiency within BAA.

Keywords: carbon management by design, environmental cost accounting, carbon as a new indicator for design efficiency, energy and CO₂, global warming

1. Energy, climate change and China

In a real sense, the limits to economic prosperity and social development are increasingly environmental factors and the availability of clean and reliable energy supply is crucial to China's continued development.

Currently, 'power outages' are common on mainland China: this summer there have been several occasions when temperatures exceeded 35°C and power cuts occurred, as the utility providers failed to meet the peak electrical demand due to increased use of air conditioning and ongoing manufacturing processes [1].

These supply side difficulties are set to grow as China's urbanisation strategy is implemented. The strategy will result in an increase in the number of cities from 668 in 1997 to an estimated 1000 cities by

2010 (of which over a 100 will be over 1 million people) and will greatly increase demand [2].

Currently, 93% of China's energy production is fossil fuel based with only 2% from natural gas. Moreover, the quality of fuel is low grade sulphurous coal which creates significant air pollution and makes China responsible for 9% of the world's global greenhouse gas emissions [3]. Growing international consensus on the need for GHG emission reductions and the fact that China ratified the Kyoto Protocol in August last year, is driving change on restructuring the supply side in China.

Energy demand management through Building Regulations and construction codes is still under development in China. At present there are two sets of

energy codes on the mainland; one for residential buildings, the other for tourist hotels. These codes tend to focus on thermal insulation to reduce heating demand. A building code for commercial and office buildings is being developed by the Chinese Academy of Building Research in Shanghai, and Chongqing is developing a code which includes heating and cooling requirements [4]. No code currently uses CO₂ emissions criteria.

An evaluation tool which allows the assessment of CO₂ rather than energy could be a contributor to establishing best practice for the rapidly growing property development sector in China.

In a highly capital cost sensitive market, such as construction, demonstrating environmental gains with operational cost savings over time, without increasing construction costs will be key to effecting meaningful change. This case-study offers directly relevant experiences from the UK which could be applicable to procurement in China.

2. The case-study – satellite 3, stansted airport

Satellite 3 is a new arrivals/departures building for Stansted airport and forms part of the phase 2 airport expansion plan, approved in 1985 which would increase capacity from 8 million to 15 million passengers per annum, making Stansted the fourth largest airport in the UK. Among the strategic objectives is 'environmental efficiency' and specifically reduced CO₂ emissions. These goals were enshrined in BAA's mission statement, Fig.1.

2.1 Setting the Brief

Following a workshop on energy efficiency funded through the DETR's Design Advice Scheme, WSP Environmental Ltd were appointed to develop a carbon reduction strategy for Satellite 3, based on a 20% CO₂ reduction target for the new building below BAA's most energy efficient building, Satellite 1, Stansted Airport. The target was to be expressed as:

- 1) predicted energy consumption (electrical and gas) kwh/m²/yr; and
- 2) CO₂ generation for on-site gas combustion and primary electrical energy generation as kgCO₂/m²/yr.

Prior to carrying out predictive assessments and analysis; a review of BAA's generic building specifications and operational standards detailed indicated a likely CO₂ reduction strategy which is

summarised in Fig 2.

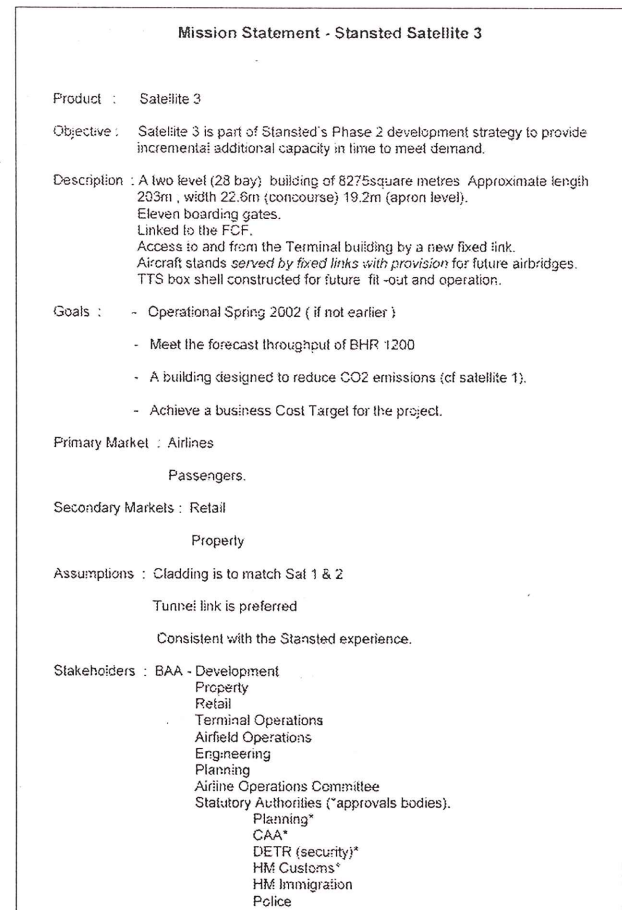


Fig. 1 BAA's Mission Statement

"BAA Stansted is committed to integrating the principles of its environmental policy into its procurement practices. This will be achieved by working suppliers towards 'a whole life' consideration of the environmental impact of goods and services."⁵

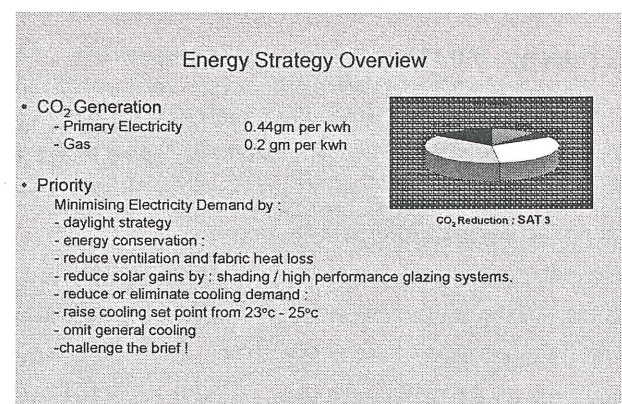


Fig. 2 Energy Strategy Overview

Reducing electrical demand would be twice as significant as reducing gas combustion in terms of CO₂ emissions: reducing electrical lighting and mechanical cooling would be more significant than reducing winter heating, for example.

2.2 Limitations

The Building design and form was largely predetermined by operational and planning authority requirements. A predominantly glazed façade for the main departures lounge, together with the requirement to seal the building against noise, and aviation fumes, dictated in large part the environmental control strategy and the design variations that could be evaluated.

Carbon and energy management at a more strategic level were assessed (Fig. 3), however, direct Carbon abatement measures were recommended over indirect methods for BAA, such as emissions tracking or carbon sequestration because the client wanted to understand the business relevance and supply chain impacts of carbon efficiency at project level.

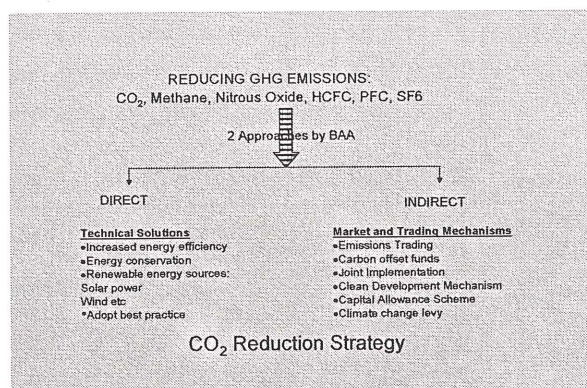


Fig. 3 Carbon and energy management

It became apparent from the energy strategy overview that operational issues have a major impact on actual CO₂ emissions. Operational factors such as flight and gate management and energy demand by franchises were identified as key issues but not assessed as part of this study, however, subsequent work for BAA is now addressing these.

A good example of how operational management can affect energy performance is that BAA design standards assume 100% capacity occupancy for the occupied period, however analysis of passenger flows revealed substantially lower occupancy levels, creating opportunities for energy saving through phased 'shut-down' of under used areas.

3. Energy modelling and dynamic thermal performance analysis

3.1 Methodology and Benchmark

A benchmark overall emission target of 103 Kg CO₂ /m² per year was set as a key performance indicator for the new Satellite 3 building at Stansted that the design team had to achieve. This represents a 20% reduction

from the SAT 1 building with a total CO₂ emission of 129 kg CO₂ /m² per year. A range of dynamic thermal simulations and daylight analysis methods were used to assess the iterative effect of adopting a series of design variables to the 'base-case'. The histogram and tables below summarises the results of the design variations outlined in the Carbon reduction strategy.

3.2 Results

The results to date indicate that a reduction of 25% approx. from the base case can be achieved if the design measures described in option 4 above are implemented. The results indicate that the most important contributor to achieve the target is the lighting control strategy, which exploits the contribution of daylight in the departures and arrivals zones. Table 1 summarises the breakdown of results and the individual contribution of each design parameter.

Table 1: Individual contribution of each design parameter

Parameter	CO ₂ Saving /(kg·m ⁻² ·a ⁻¹)	Contribution to target/%
Daylight strategy + dimmer control	17	49
Omit general cooling	9	26
Raise cooling set point from 23 – 25 °C	5	14
Reduce fabric / vent heat losses, + night venting	5	14
Improve glazing specification	4	11
Renewable power generation / photovoltaics	1	3

3.3 Design messages

Typically, the use of predominantly glazed façades in buildings carries a high energy penalty; causing overheating in the Summer and excessive heat losses in the Winter. Current advances in high performance glazing systems mean that these problems can be minimised and the base case building assumes using a Pilkingtons Antisun Green System as an optimum balance between solar control, daylight transmittance and heat loss, reduced fabric. Better performance could be achieved from Pilkingtons Suncool HP Titan system and the benefits have been assessed, although ruled out on cost grounds.

The single biggest contributor to reducing electricity consumption, and thus CO₂ emissions, is by maximising the use of daylighting and by using dimmer and zonal control of lighting. The theoretical contribution of daylighting has been assessed using

daylight computer simulation programme: the minimum design light level of 200 lux can be provided by daylight for over 70% of the year, largely due to the high degree of glazing in the facades and the introduction of skylights to the central zone.

Table 2: CO₂ Results and assumptions for each option

	Model Variant	CO ₂ Emission /(kg·m ⁻² ·a ⁻¹)	CO ₂ Reduction From Base case /(kg·m ⁻² ·a ⁻¹)	Contribution to CO ₂ target /%
	SAT 1 Generation Target	103.2		
1	Base Case	127.8		
2	Improved Envelope: Modified U Values of walls and roof from 0.45 to 0.22 W/m ² /K Glazing: improved U value from 1.9 to 1.6 W/m ² /K, improved thermal transmittance from 0.31 (Antisun 6:12:10) to 0.29 (bodytint HST 12:12:13.5) Infiltration reduced from 0.25 to 0.15 ac/hr. Reduction of building height by 500mm.	127.9	0.0	0.0
3	Improved envelope plus improved HVAC strategies: Replaced fan coil units with chilled beams in Departures, Arrivals and Ramp Accommodation.	124.4	3.4	13.8
4	Improved envelope plus improved HVAC strategies plus Daylight strategy: Added dimming control at perimeter in Departures and Arrivals, based on 200 lux at 0.85m plane.	92.8	35.0	142.3

3.4 Strategy

A CO₂ footprint of Satellite 3 instead of Energy suggested priority areas for reduction, see Fig. 5.

In order to achieve the CO₂ reduction target minimising electricity consumption is the major priority: in order of effectiveness the design should address :

- 1) Natural daylighting and dimmer control systems.
 - 2) The inclusion of BEMS is considered to be an essential design component to deliver the control and feed back mechanism which will ensure ongoing operational efficiencies.
 - 3) Improve building envelopes thermal performance by reducing :
 - a) fabric heat losses : opaque U-Value = 0.22 W·m⁻²·K⁻¹
 - b) infiltration heat losses = 0.1 ac/h.
 - 4) Radiant Cooling Systems
 - 5) Night Cooling
 - 6) Raising Cooling Set Point form 23°C - 25°C
 - 7) Carbon free power generation: photovoltaics
- Additional areas for future CO₂ reduction were

identified but not assessed as part of this study:

- ♦ Hot water generation and storage efficiencies.
- ♦ Boiler efficiencies and type.
- ♦ Design modification to baggage and arrivals areas.
- ♦ Air flow and distribution patterns.
- ♦ Solar control technologies.
- ♦ System controls: movement activated escalators etc.

4. Daylighting

4.1 Background and assessment method

In order to calculate the average annual residual electrical lighting demand, it was necessary to assess the likely contribution of useful daylighting to meeting the minimum 200 lux design requirement by BAA for the key passenger lounge areas.

In addition, ensuring that the choice of glazing which is most effective for solar control and energy conservation did not compromise the daylight strategy was a key part of the study as the potential for daylighting to offset the need for artificial lighting (and thus also reduce the cooling load) is significant.

In order to establish the natural daylight availability within the space and the potential of proposed enhancement options, a set of simulations were performed for two different types of glazing: Pilkingtons 'Antisun' and 'Suncool' double glazing.

The results show the minimum, maximum and average daylight factors for the departure hall assuming a standard overcast sky of 10 000 lux. The number of hours for which each solution maintains the space above a minimum of 200 lux was also established for winter and summer. These results are summarized in table 3.

It should be noted that the effect of shading the southwest and southeast façades by means of horizontal overhangs was also studied. Additionally, opportunities for skylights were also assessed and are incorporated in the energy/CO₂ assessment.

Table 3: Results of daylight analysis

Options	Minimum D.F. /%	Maximum D.F. /%	Average /%	Need for artificial light from 6.00 a.m. to 22.00 p.m.	
				Maximum need /h	Minimum need /h
ANTISUN Glazing	5.29%	22.37%	9.59%	8	1.45
ANTISUN Overhangs	5.14%	22.36%	8.92%	8	1.45
ANTISUN Overhangs Skylights	6.38%	22.99%	10.44 %	7.45	1.35
SUNCOOL Glazing	5.65%	23.86%	10.23 %	7.50	1.40
SUNCOOL Overhangs	5.49%	23.85%	9.52 %	7.50	1.40
SUNCOOL Overhangs Skylights	6.81%	24.53%	11.14 %	7.40	1.30

4.2 Results

If the performance of the 'Antisun' and 'Suncool' glazing are compared, it is apparent that 'Suncool' glazing has a higher transmission factor (64% compared with 60%) and therefore reduces the demand for artificial lighting. However, the differences are small. Perhaps surprisingly, the overhangs have a very small impact on daylighting within the departures hall. The most significant effect was attributed to the addition of skylights, which not only raised the minimum daylight factors (by approximately 1% for

both the 'Antisun' and 'Suncool'), but also significantly improved distribution across the section.

This suggests that roof lights would be potentially beneficial but perhaps would be most beneficial at points of vertical circulation, since the central zone is primarily used for retail outlets.

Typical output for the analysis is presented in Figs. 4 and 5.

There is little difference between the daylight performance of Pilkingtons 'Antisun' and 'Suncool' glazing. The addition of horizontal sunshades slightly reduces performance but this is perhaps most difficult to integrate unless the retail concessions can be persuaded of the merits of daylighting.

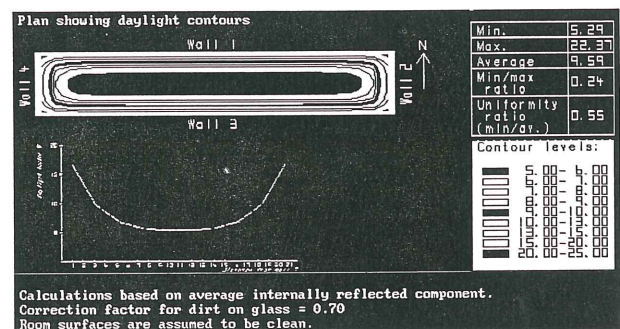


Fig. 4 Plan and section showing typical output of daylight factor distribution without skylights

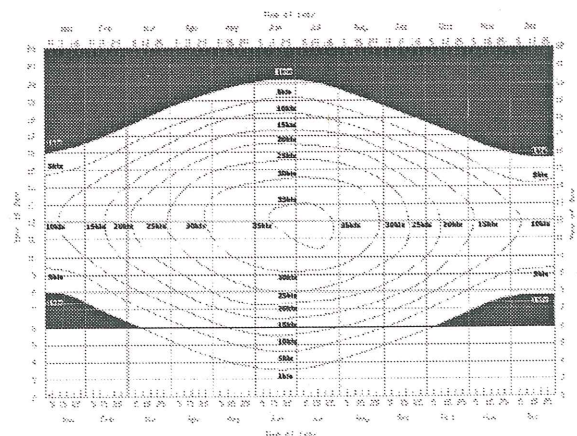


Fig. 5 Daylight availability chart for 200 lux. Shaded areas showing periods when light levels drop below 200 lux.

5. Environmental cost benefit analysis

The results of the energy/ CO₂ analysis were processed and an environmental cost benefit analysis was carried out on each of the key design parameters. The intention was to provide the client with a means of assessing the most environmentally effective design enhancements, including how much they would cost and what the likely cost savings would be over 25 years.

The results were interesting: increasing levels of insulation to the roof and glazing systems would cost £173 000 but only contribute 1/5 of the 20 % CO₂ reduction target and therefore omitted.

Investment in a higher performance glazing system was not justifiable on an environment cost benefit analysis. The studies showed that lower u-values for the glass, while reducing winter heat loss and gas consumption significantly increased the summer cooling load and hence electrical demand.

A daylighting strategy and responsive lighting strategy however, produced the largest environmental benefits of 49% contribution to the CO₂ reduction target for marginal capital cost outlay.

6. Conclusions

1) By establishing specific design performance criteria for CO₂ emissions from buildings during the design process, significant reductions below industry

norms or in the case of Satellite 3, below corporate best practice can be achieved, without necessarily increasing capital costs.

2) Furthermore, the proactive management of carbon emissions arising from the operation of buildings, if widespread, could significantly reduce the peak demand for electricity during the summer months when cooling demand is highest.

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