



1 Energy Strategy Summary

This Appendix has been prepared to demonstrate how carbon emissions can be reduced from SG2 by the energy strategy.

The energy strategy is dependent upon an approximate balance of heating and cooling throughout the year; any imbalance must be met by alternative means. The load balance will change as the airport is progressively developed and it is possible that the site will go through phases of nett cooling and/or nett heating.

The sustainability target for Stansted Airport is that the combination of existing (G1) and proposed (G2) airport buildings and infrastructure will not generate more carbon dioxide emissions (based on current forecasts and standards) than the carbon emissions of the airport buildings and infrastructure in 2006..

The strategy to deliver this target as part of the G2 development has been:

- reduce energy demand through building and infrastructure design
- reclaim waste heat
- provide heating and cooling from renewable sources
- use distributed renewables – e.g. for car park lighting
- improve the waste strategies.

The carbon footprint of the proposed G2 development has been assessed using the UK's current electricity generation technology mix. However the government is committed to a 60% reduction in over-all carbon dioxide emissions by 2050, and this will necessarily involve significantly cleaner electricity generation.

A ground coupled chiller heat-pump system capable of generating 30MW is proposed. This will comprise between 1,300 and 1,500 energy piles bored 200-300m deep into the chalk layer below Stansted, connected just below ground-level by a matrix of pipes so that water pumped below ground through the closed-loop system will permit heat to be drawn from or dissipated into the chalk. A pipework loop will link the boreholes to the energy centre in development zone 10 and the new SG2 buildings

It is intended that all waste that cannot be usefully recycled is disposed through gasification, pyrolysis or a similar technology. This process releases gas which is used to power an electrical generator. The electricity contribution is comparatively modest, but this technology also avoids waste to land fill, captures methane and produces a residue which can be usefully employed in some industries.

These measures still leave an estimated annual residual of circa 17,127 tonnes CO₂ left to abate.

The study has been informed by a computer model. All computer models are approximate and not precise but their answers are adequate at this stage in the project.



2 Introduction

This appendix informs the design in terms of carbon reduction strategies, targets and aspirations. A description is provided as to how the annual energy consumption has been predicted - building geometry, system design and occupancy – and the resulting likely loads.

3 Energy Report

3.1 INTRODUCTION

The sustainability target for Stansted Airport is that the combination of existing (G1) and proposed (G2) airport buildings and infrastructure will not generate more carbon dioxide emissions (based on current forecasts and standards) than the carbon emissions of the airport buildings and infrastructure in 2006.

The delivery of this ambition will be supported by a ground-coupled chiller heat-pump system. To further reduce the carbon emissions associated with the use of electricity for lighting and equipment the following are considered:

- reduce energy demand
- reclaim waste heat
- provide heating and cooling from renewable sources
- use distributed renewables – say for car park lighting
- improve the waste and water strategies.

3.2 SG2 BUILDING MIX

WSP were instructed to re-model SG2 on the basis of the following input data, which is based on the most likely scenario available at the time of writing. These areas do not replicate those given in the development specification. The areas used for the energy study represents a more likely outcome being between the maximum and minimum values.

Building Type	Quantity	Comment
Offices	35,570 m ²	Note 3
Terminal	35,048 m ²	Note 1

Building Type	Quantity	Comment
Piers & links	88,996 m ²	Note 1
Car parks	1,716,000 m ²	Note 2
Retail	18,400 m ²	Note 1
Hotels	2,800 rooms @ 32 m ² each	
Cargo	81,395 m ²	Note 6
Catering warehouses	16,380 m ²	Note 5 Ref. 2
General Aviation (hangars etc)	71,000 m ²	Note 4
Table 3.2.1 Floor Areas		

Note 1.

Terminal to be 96,000m²,

Passenger Areas 35,048

Retail Areas 17,000

Back of House 43,952

Retail space in piers and links is 1,400m².

Note 2.

Total car parking spaces area of 85,800. Typical space per bay is 20m²

Note 3.

Includes terminal operation support areas. Main office accommodation is 29,200m²

Note 4.

General aviation, comprising hangars and similar maintenance areas are located in zones 7 and 8.

Zone 7 = 34,000m².

Zone 8 = 37,000m²

Note 5.

Catering warehouses have a floor area of 44,000m². 16,380m² is for catering and the remainder is general warehousing and freight.

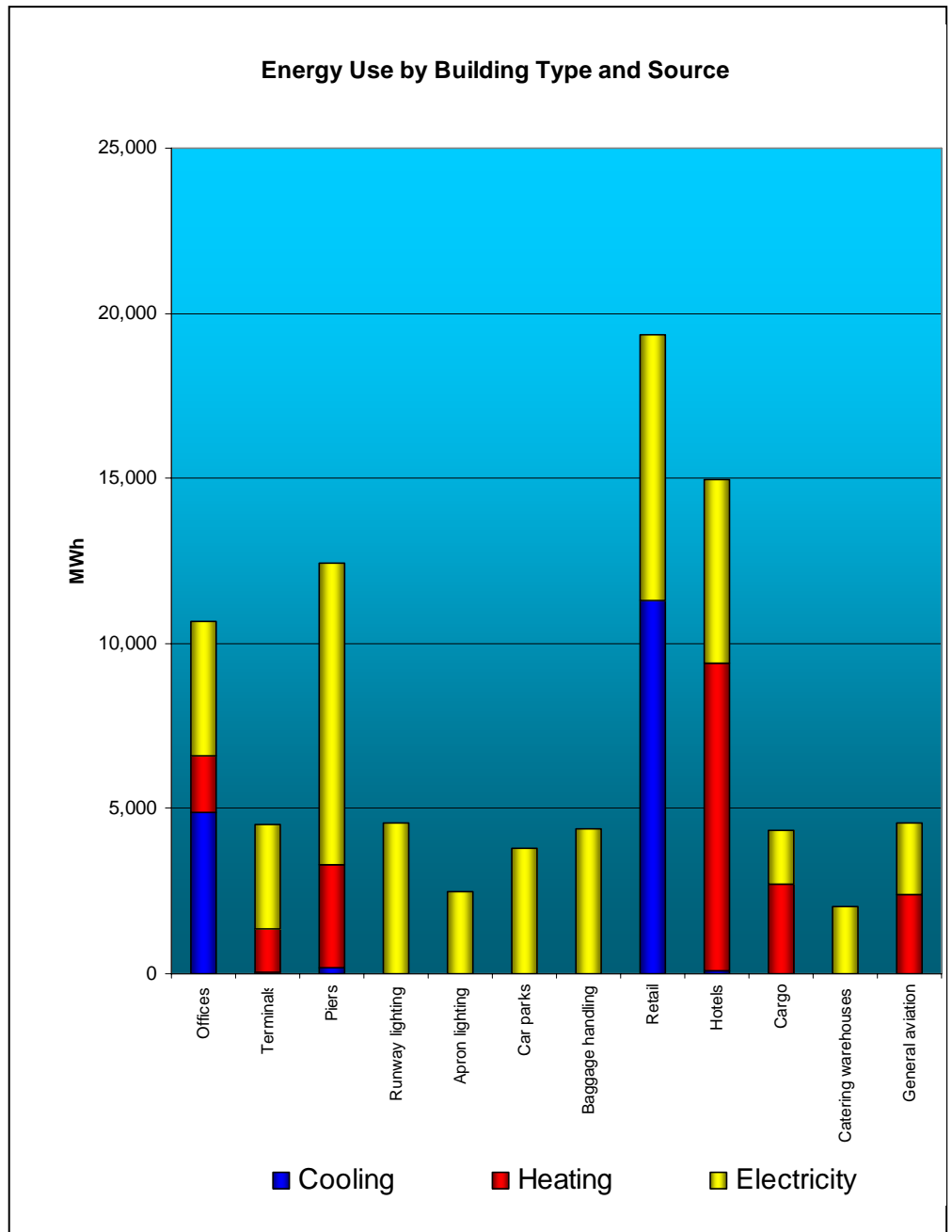
Note 6

This indicates a cargo floor area of 53,775m², however added to this should be the non-catering warehousing and freight:

$$53,775 + (44,000 - 16,380) = 81,395 \text{ m}^2$$

3.3 ENERGY USE

Based on the provisions of Table 3.1.1, the energy load profiles of the SG2 Phase have been predicted using a modelling tool to assess the loads.



Graph 3.3.1 – Energy Use by Building Type and Source

Building Type	Floor area m ²	Cooling MWh	Heating MWh	Electricity (excluding any chillers) MWh
Offices	35,570	4,883	1,701	4,086
Terminal	35,048	65	1,295	3,173
Piers	88,996	163	3,135	9,117
Runway lighting				4556
Apron lighting				2474
Car parks	1,716,000			3787
Baggage handling				4380
Retail	18,400	11,283		8,059
Hotels	112,000	82	9,304	5,600
Cargo	81,395		2,728	1,628
Catering warehouses	16,380			2,047
General aviation	71,000		2,380	2,201
Total	2,145,132	16,475	20,543	51,109

Table 3.3.1 - Energy Use by Building Type and Source

The various factors associated with each building type are identified. In all instances the 'U' values exceed the requirement of Part L 2006 in anticipation of more stringent regulations.

3.3.1 OFFICES

The energy consumption for typical offices is calculated by the preliminary energy model and has a good correlation with ECG19 published by the Energy Best Practice scheme. The principal input data is listed below.

Building Geometry

Slab-to-slab height	: 3.5m
Building height	: 4 storeys
Building aspect ratio	: 3:1
Orientation	: glazing equally distributed between north, south, east & west

Building Construction

U-values

Ground floor	: 0.10 W/m ² .K
Roof	: 0.15 W/m ² .K
External walls	: 0.25 W/m ² .K
Windows	: 1.8 W/m ² .K
Air-tightness	: 3 m ³ /h at 50Pa.



Lighting

Internal illuminance : 400 lux
 Luminous efficacy : 45 lm/circuit-Watt
 Mean surface refl. : 0.5
 Control : photocell, occupancy and time-scheduled.

Fresh Air Air-handler

Specific fan power : 3 Watts per l/s fresh air supply (allows for extract fan)
 Fresh air flow rate : 12 l/s per person
 Heating set-point : 21°C
 Recuperator efficiency : 65 percent
 Extract air temperature : 24°C
 Min. relative humidity : none
 Max. suppl. moist. Content: 0.0100 kg/kg da
 Apparatus dew-point : 10°C

Space

Space heating to : 22°C
 Room latent fraction : 0 W/m² dry terminals allowed (i.e. chilled beams)
 Equipment loads
 Occupied : 12 W/m²
 Unoccupied : 5 W/m²

Occupancy Diversities

Occupation.																									
Monthly factor												9.5		m ² /person		Days per week				5					
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	622		Persons											
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	85		W/person											
Hourly factor																									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	T	
0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.3	0.0	0.0	0.0	0.0	0.0	10.6	

Plant

Variable speed pumps? : yes
 Vertical transportation is included within the equipment loads and is minor.

3.3.2 TERMINAL

The energy consumption for the terminal building is calculated by the preliminary energy model. The energy consumption is comparatively low; however it excludes baggage handling and retail which are considered separately. It assumes that reasonable measures are taken to reduce solar gain whilst achieving excellent daylight penetration with photocell light switching. Displacement air conditioning with *enthalpy optimisation*¹ and fresh air heat recovery combine to exclude mechanical cooling for most of the year.

The principal input data is given below.

Building Geometry

Slab-to-slab height	: 10.5m
Building height	: 1 full storey with mezzanine and basement area.
Building aspect ratio	: 2:1
Orientation	: glazing 40% north, 20% south, 20% east & 20% west
Rooflights	: 10% roof area.

Building Construction

U-values

Ground floor	: 0.10 W/m ² .K
Roof	: 0.15 W/m ² .K
External walls	: 0.25 W/m ² .K
Windows	: 1.8 W/m ² .K
Rooflights	: 1.8 W/m ² .K

Air-tightness	: 3 m ³ /h at 50Pa.
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Lighting

Internal illuminance	: 200 lux
Luminous efficacy	: 45 lm/circuit-Watt
Mean surface refl.	: 0.5
Control	: photocell and time-scheduled.

Air-handler

Specific fan power	: 2 Watts per l/s fresh air supply (allows for extract fan) with variable supply rate
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¹ Enthalpy optimisation means adjusting the fresh air rate to maximise energy efficiency subject to the minimum necessary for the occupants

Min. Fresh air flow rate : 8 l/s per person
 Supply set-point : 20°C
 Recuperator efficiency : 65 percent
 Min. relative humidity : none
 Max. suppl. moist. Content: 0.0125 kg/kg da
 Apparatus dew-point : 14°C

Space

Space heating to : 20°C
 Room latent fraction : 0 W/m² dry terminals allowed (i.e. chilled beams)
 Equipment loads
 Occupied : 2 W/m²
 Unoccupied : 1 W/m²

Occupancy Diversities

Occupation.																								
Monthly factor												5.0	m ² /person	Days per week	7									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	7010	Persons											
0.6	0.6	0.6	0.7	0.8	0.9	0.9	1.0	0.8	0.5	0.5	0.7	85	W/person											
Hourly factor																								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	T
0.5	0.5	0.6	0.7	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.7	0.5	0.5	0.5	20.0

Plant

Variable speed pumps? : yes
 Vertical transportation is included within the equipment loads and is minor.

3.3.3 PIERS

The energy consumption for the piers is higher than the terminal building because the floor area is much higher and the aspect ratio much less thermally efficient. Otherwise the approach is identical. Glazing is restricted to 40 per cent of the external wall area.

The principal input data is given below.

Building Geometry

Slab-to-slab height : 4.5m
 Building height : 2 storey
 Building aspect ratio : 80:1

Orientation : glazing 50% east, 50% west
Rooflights : 0% roof area.

Building Construction

U-values

Ground floor : 0.10 W/m².K
Roof : 0.15 W/m².K
External walls : 0.25 W/m².K
Windows : 1.8 W/m².K
Rooflights : 1.8 W/m².K

Air-tightness : 3 m³/h at 50Pa.

Lighting

Internal illuminance : 200 lux
Luminous efficacy : 45 lm/circuit-Watt
Mean surface refl. : 0.5
Control : photocell and time-scheduled.

Air-handler

Specific fan power : 2 Watts per l/s fresh air supply (allows for extract fan) with variable supply rate
Min. Fresh air flow rate : 8 l/s per person
Supply set-point : 20°C
Recuperator efficiency : 65 percent
Min. relative humidity : none
Max. suppl. moist. Content: 0.0125 kg/kg da
Apparatus dew-point : 14°C

Space

Space heating to : 20°C
 Room latent fraction : 0 W/m² dry terminals allowed (i.e. chilled beams)
 Equipment loads
 Occupied : 2 W/m²
 Unoccupied : 1 W/m²

Occupancy Diversities

Occupation.																								
Monthly factor												5.0	m ² /person	Days per week	7									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	7010	Persons											
0.6	0.6	0.6	0.7	0.8	0.9	0.9	1.0	0.8	0.5	0.5	0.7	85	W/person											
Hourly factor																								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	T
0.5	0.5	0.6	0.7	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.7	0.5	0.5	0.5	20.0

Plant

Variable speed pumps? : yes
 Vertical transportation is included within the equipment loads and is minor.

3.3.4 RUNWAY LIGHTING

The lights are assumed to extinguish if the external illuminance exceeds 1000 lux. When the lights are on, the power consumption is 1 MW.

3.3.5 APRON LIGHTING

The lights are assumed to extinguish if the external illuminance exceeds 1000 lux. When the lights are on, the power consumption is 543 KW.

3.3.6 CAR PARKS

The lights are assumed to extinguish if the external illuminance exceeds 30 lux. The luminous efficacy is assumed to be 60lm/W.

3.3.7 BAGGAGE HANDLING

Assumed to be a constant 500 kW.

3.3.8 RETAIL

Shop type	Electricity kWh/m ² p.a
Book stores	210
Clothes shops	234
Electrical goods retail	172
Shoe shops	197
Mean	203
Source: CIBSE Guide F, Table 20.1	

Using national benchmark data from table 20.1, the mean energy consumption from a range of shop outlets is 203 kWh/m²/p.a. Assuming that the benchmark data is based on 12-hour days, six days per week (includes non-public periods, such as cleaning, stacking, etc.), that equates to: 203 kWh / 3744 hours = 54 W/m². Cooling is allowed at 70 W/m². The occupancy period allowed in the model is extended to 22-hours per day, seven days per week, to allow for airport conditions.

3.3.9 HOTELS

As hotels are significant users of both gas and electricity each energy source is identified separately.

Gas


Peak cooling and heating allowances are 40 W/m² and 30 W/m² respectively.

The peak cooling load of 40 W/m² is applied in proportion to how far the ambient temperature is above 23°C.

The peak heating load is taken as 30 W/m², applied in proportion to how far the ambient temperature is below 17°C: this results in an annual heating load of 72 kWh/m² p.a.

The government's Energy Efficiency Best Practice Programme, Energy Consumption Guide 36 (ECG 36), shows that the lower (best) quartile of over 300 business and holiday hotels have gas consumption within the range of 100 to 260 kWh/m² p.a., of which 47 percent is heating and 20 percent is domestic hot water (DHW). If 47 percent equals 72 kWh/m² p.a., then the total gas load would be 153 kWh/m² p.a. – towards the lower end of the lower quartile, which is where the design ought to be. Reductions in space heating loads can be achieved by: improved U-values, restricting glazing areas in bedrooms to 30 per cent of floor area at a maximum U-value of 1.6 W/m².K and 65 percent efficient heat recovery devices on all ventilation systems.

At 20 percent of 153 kWh/m² p.a., the DHW load would equal to 30 kWh/m² p.a. - equivalent to a daily consumption of 82 litres for each and every room.



The DHW load would be further reduced from 60 kWh/m² to 20 kWh/m² through use of solar-thermal systems and/or ground-source heat pump pre-heating.

Electricity

The government's Energy Efficiency Best Practice Programme, Energy Consumption Guide 36 (ECG 36), shows that the lower (best) quartile of over 300 business and holiday hotels have electricity consumption within the range of 50 to 80 kWh/m² p.a. The lower figure should be used in the model because the best performance should be sought and because cooling shall be from the energy piles. Spread equally across the whole year, 50 kWh/m² p.a. corresponds to 6 W/m².

3.3.10 CARGO

The government's energy good practice guide for industrial buildings, ECG 18, suggests electricity consumption of 20 kWh/m² p.a. – refer to table 3, distribution. This is applied uniformly across the whole year at the rate of 2.3 W/m².

A peak heat loss of 10 W/m² has been assumed for a space set-point of 13°C.

3.3.11 GENERAL AVIATION

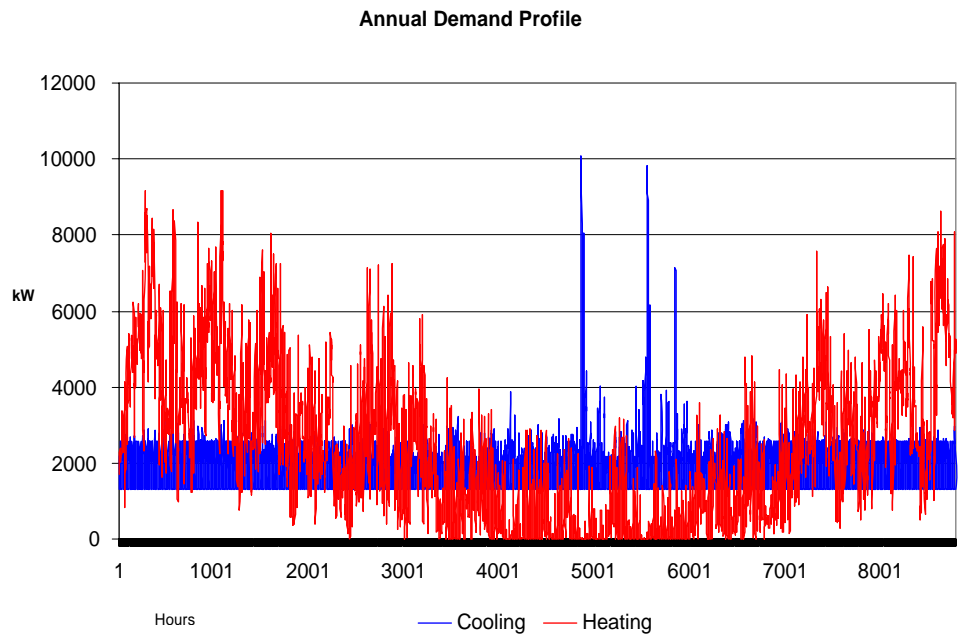
There is no specific benchmark for General Aviation facilities however the government's energy good practice guide for industrial buildings, ECG 18, suggests electricity consumption of 31 kWh/m² p.a. – refer to table 3, light manufacturing. This is applied uniformly across the whole year at the rate of 3.5 W/m².

A peak heat loss of 10 W/m² has been assumed for a space set-point of 13°C.

3.3.12 CATERING WAREHOUSE

CIBSE Guide F, Table 20.6 suggests an annual electrical load of 125 kWh/m² p.a. Spread equally across the whole year, this corresponds to 14 W/m². Heating is achieved with waste heat of the refrigerators.

3.4 GROUND-COUPLED SCHEME



Graph 3.4.1 – Annual Heating and Cooling Demand Profile

The energy piles should be sized for the base load. The piles are not sized on absolute peak because to do so would significantly increase the number of piles to cater for rare occurrences. The model is showing that an economic selection would not exceed 1,500 piles, 200m deep at 40W/m.

For those periods where the piles cannot cope, supplementary heating and cooling should be used. To meet the absolute peak, the chillers would need to be rated at circa 7,000kW and the boilers at circa 4,000kW, the model includes the energy use associated with this supplemental plant. When the ambient wet-bulb temperature is sufficiently low, say below 10°C, evaporative cooling may be used as an alternative form of cooling or to maintain the heating/cooling balance. .

Large ground-coupled systems require an approximate balance between their heating and cooling loads, otherwise the ground temperature will progressively warm or cool year-on-year until it becomes thermally saturated (either too warm or too cool). With the indicated floor areas and associated assumptions, the model predicts that there will be an approximate annual balance of heating and cooling.

The energy model does not include the pump power necessary to drive water through the energy piles, the pressure drop is modest and the volume variable making the power input not significant.

3.5 CARBON EMISSIONS

It is estimated that if SG2 was built only to comply with the current Building Regulations (Part L), then the carbon emission arising from the modelled loads (see table 3.2.1) would be circa 42,425 t.CO₂ (see table 3.4.1 below)

Building	Floor Areas 2007	Specific Energy Consumption Notional Building			Source	Energy Consumption Notional Building 2007			Part-L Compliant Improvement	
		Elect. kWh/m ²	Gas kWh/m ²	Carbon kgCO ₂ /m ²		Elect. MWh	Gas MWh	t.CO ₂		t.CO ₂
SG2 Terminal	35,048	283	301	178	SG2 model, terminal building	9,919	10,549	6,232	28%	4,487
SG2 Piers & links	88,996	283	301	178	SG2 model, terminal building	25,186	26,788	15,825	28%	11,394
Retail	18,400	440	0	186	CIBSE Guide F, Table 20.1, Small Food Shop (electric)	8,096	0	3,417	0%	3,417
Offices	35,570	226	178	130	ECG19 - Typical	8,039	6,331	4,621	28%	3,327
Hotels	112,000	80	260	84	ECG36 - Good	8,960	29,120	9,430	28%	6,790
General Aviation	71,000	22	79	25	SG2 Model	1,562	5,609	1,747	15%	1,485
Cargo	81,395	40	79	32	SG2 Model	3,256	6,430	2,621	15%	2,228
Catering	16,380	125	79	68	CIBSE Guide F, Table 20.6, Refrigerated warehouse	2,048	1,294	1,115	0%	1,115
Car parks	1,716,000	2	0	1	SG2 Model	3,775	0	1,593	0%	1,593
Baggage handling						4,380		1,848	0%	1,848
Runway lighting						8,760		3,697	0%	3,697
Apron lighting						2,474		1,044	0%	1,044
Total SG2	2,174,789					86,454	86,122	53,191		42,425

Table 3.5.1 – Carbon Emissions for Minimum Compliance.

Energy reduction strategies have been sequentially applied to reduce the carbon emissions to by circa 45 percent to 18,725 t.CO₂, as indicated in table 3.5.2 below:



Item	Source	Annual Tonnes Carbon Dioxide		
		Plus	Minus	Balance
Carbon emissions for Part-L compliance.	Table 3.5.1	42,425		42,425
Improved terminal design	Modelled		2,849	39,576
Improved piers and links	Modelled		6,942	32,635
Improved hotel design	Note 3.5.1		1,102	31,532
Improved office design	Note 3.5.2		864	30,668
Energy loop with piles	Modelled		6,968	23,700
Energy from Waste	Calculated		4,975	18,725
Sub-balance				18,725

Table 3.5.2 – Energy Reduction Strategies.

Note 3.5.1 The following table identifies the carbon saving achieved in the hotels through improved ‘U’ values, restricted glazing and high efficiency systems.

Hotels

Floor area 112,000 m²

Specific Energy, kWh/m ²			
Option	Gas	Elect	Source
Notional	260	80	ECG36 - Good
Part-L	187	58	28 percent reduction
Proposed (w/o piles)	153	50	Design target

Carbon emissions, t.CO ₂			
Option	Gas	Elect	Total
Notional	5,649	3,781	9,430
Part-L	4,067	2,722	6,790
Proposed (w/o piles)	3,324	2,363	5,688

Elect 0.422 t.CO₂/MWh

Gas 0.194 t.CO₂/MWh

Total annual carbon saving 1,102

Note 3.5.2 The following table identifies the carbon saving achieved in the offices through improved 'U' values, maximising daylighting and the use of efficient systems.

Offices

Floor area 35,570 m²

Specific Energy, kWh/m ²			
Option	Gas	Elect	Source
Notional	178	226	ECG19 - Typical
Part-L	128	163	28 percent reduction
Proposed (w/o piles)	48	142	Modelled

Carbon emissions, t.CO ₂			
Option	Gas	Elect	Total
Notional	1,228	3,392	4,621
Part-L	884	2,443	3,327
Proposed (w/o piles)	331	2,131	2,463

Elect 0.422 t.CO₂/MWh
Gas 0.194 t.CO₂/MWh

Total annual carbon saving 864

To eradicate the residual 18,725 tonnes of carbon dioxide, it is necessary to look beyond energy demand reductions in SG2 towards: reductions in SG1, on-site renewables, water strategy and waste strategy.

Item	Source	Annual Tonnes Carbon Dioxide		
		Plus	Minus	Balance
Improved building design, energy loop and piles.	C/over from table 3.5.2	18,725		18,725
PV- and wind-powered car park lighting	Note 3.5.3		1,598	17,127
Sub-balance				17,127



Note 3.5.3 The following identifies the carbon savings achieved by maximising the use of car park lighting fed from photovoltaic cells.

Solar & PV Car Park

Floor area	1,716,000 m ²
Illuminance:	30 lux
Luminous efficacy:	60 lm/W
Installed power	858 kW
Annual power consumption	7,516 MWh (if continuous running)
Modelled consumption	3,787 MWh (lights extinguish above 30lux)
PV & wind powered	100%
Annual saving	3,787 MWh
Annual saving	1,598 t.CO₂

Note 3.5.4 Energy From Waste

WSP were also commissioned to investigate the waste strategy for the whole of Stansted airport. The report, *SG2 Waste Management Strategy*, was issued 30th January 2007 and indicated that 4,975 t.CO₂ (equivalent) could be abated through generating energy from waste rather than sending it to landfill.



4 Conclusions

By improved building design and incorporating renewables, it is possible to reduce emissions of the modelled loads to circa 23,700 t.CO₂: a reduction of circa one-half of a “minimum compliance” scheme.

Further savings from micro-renewables (1598 t.CO₂) and the waste strategy of circa 4975 t.CO₂ brings the emissions to 17,127 t.CO₂. This represents a total reduction of circa 60 percent relative to a Part ‘L’ 2006 compliant scheme.

The estimated residual carbon emissions are sufficiently low that it is reasonable to assume that opportunities to remove the carbon emissions completely will be identified and deployed over the design period, either from new and emerging technologies.

This report, like all those before it, is based on a preliminary energy model. As individual buildings are designed, more detailed thermal models will be required and the energy model will need to be adapted accordingly.

The estimated carbon emission is for the built environment, including runways, baggage handling and all equipment within the buildings. What the figures do not include is transport and emissions from aeroplanes.

