Building energy simulation in practice

Seminar of the CIBSE Building Simulation Group 30th September 2009

Sustainable design of lower carbon buildings in a changing climate

EngD in Environmental Technology

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CEng MEng MCIBSE MIMechE

CIBSE

UNIVERSITY OF SURREY

PB PARSONS BRINCKERHOFF 100 YEARS

Creating balanced environments

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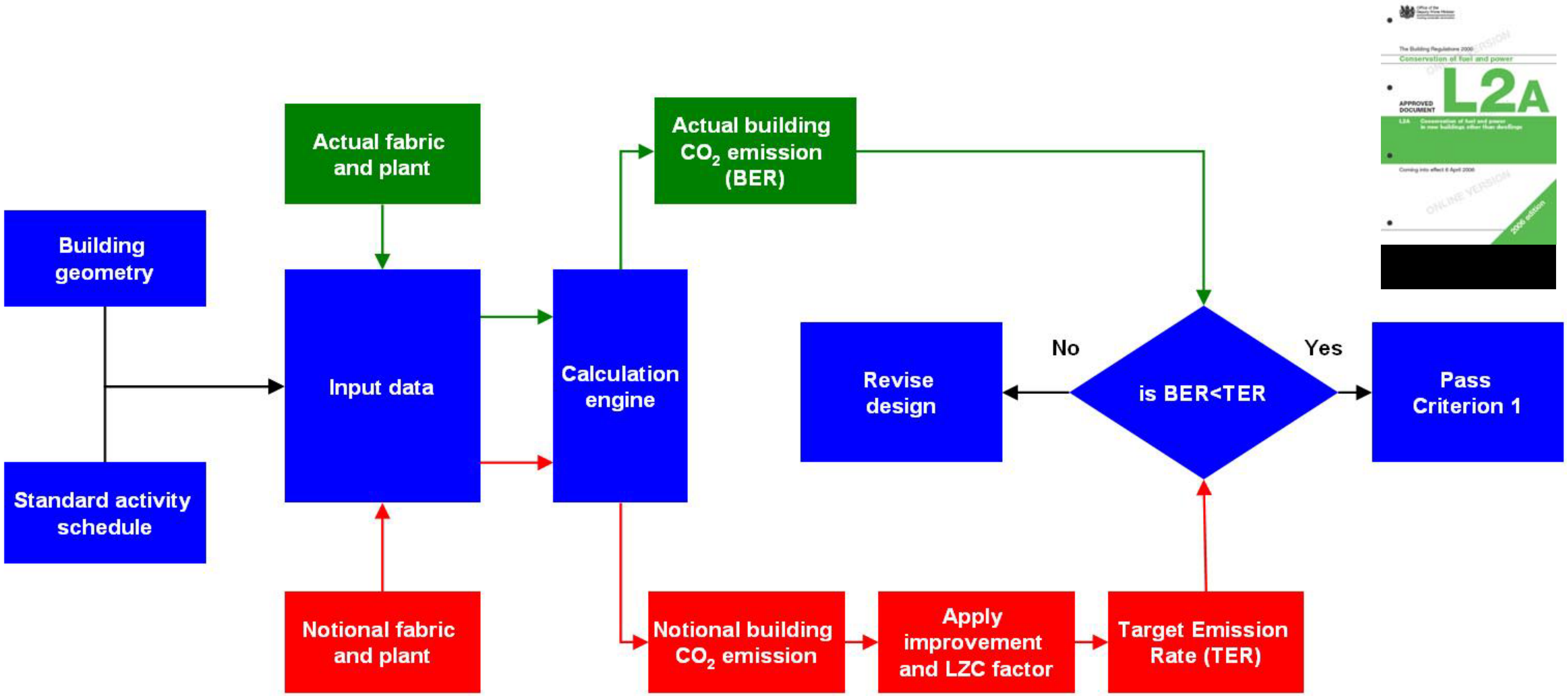
Overview

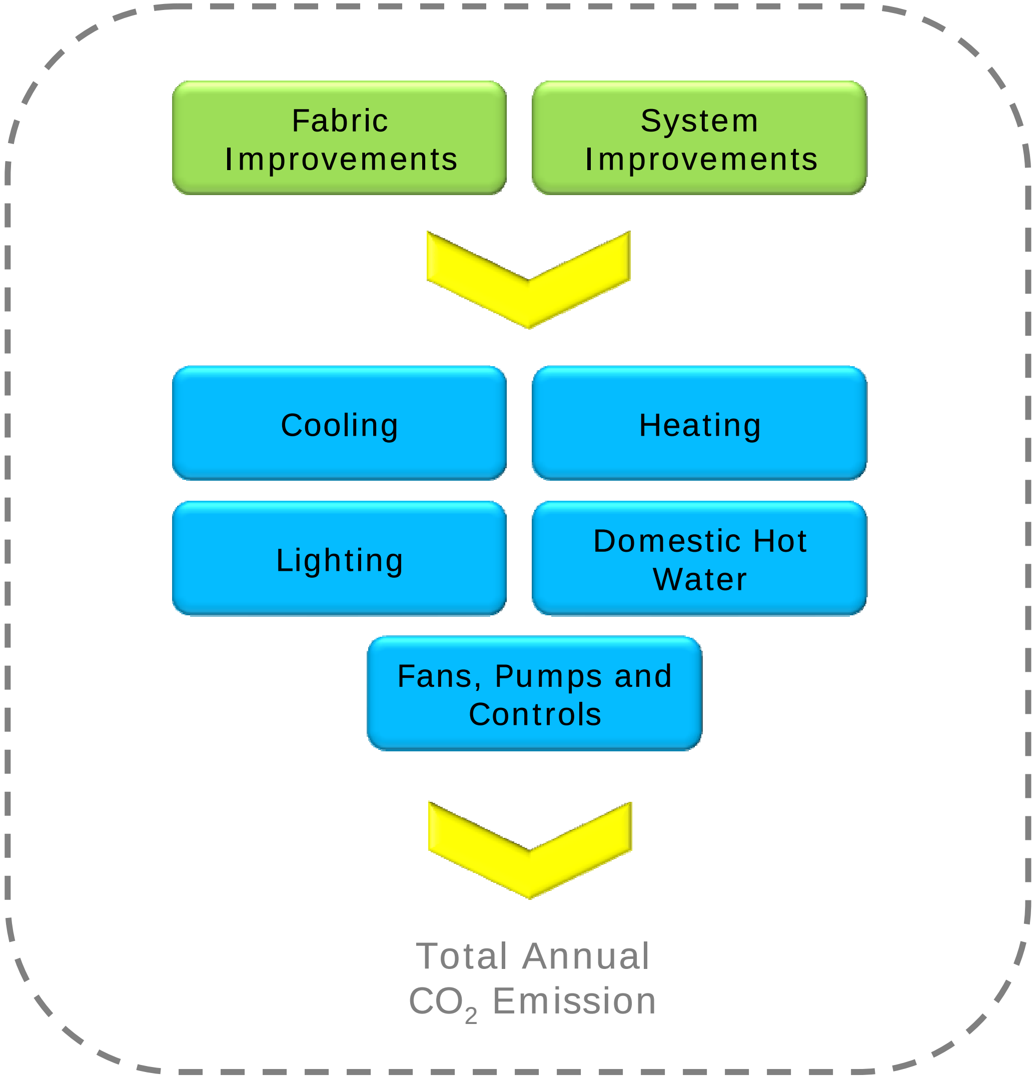
- Limited perspective of regulated building energy analysis
- Life cycle thinking applied to construction
- Influence of climate change on energy demand and comfort

Regulatory requirements



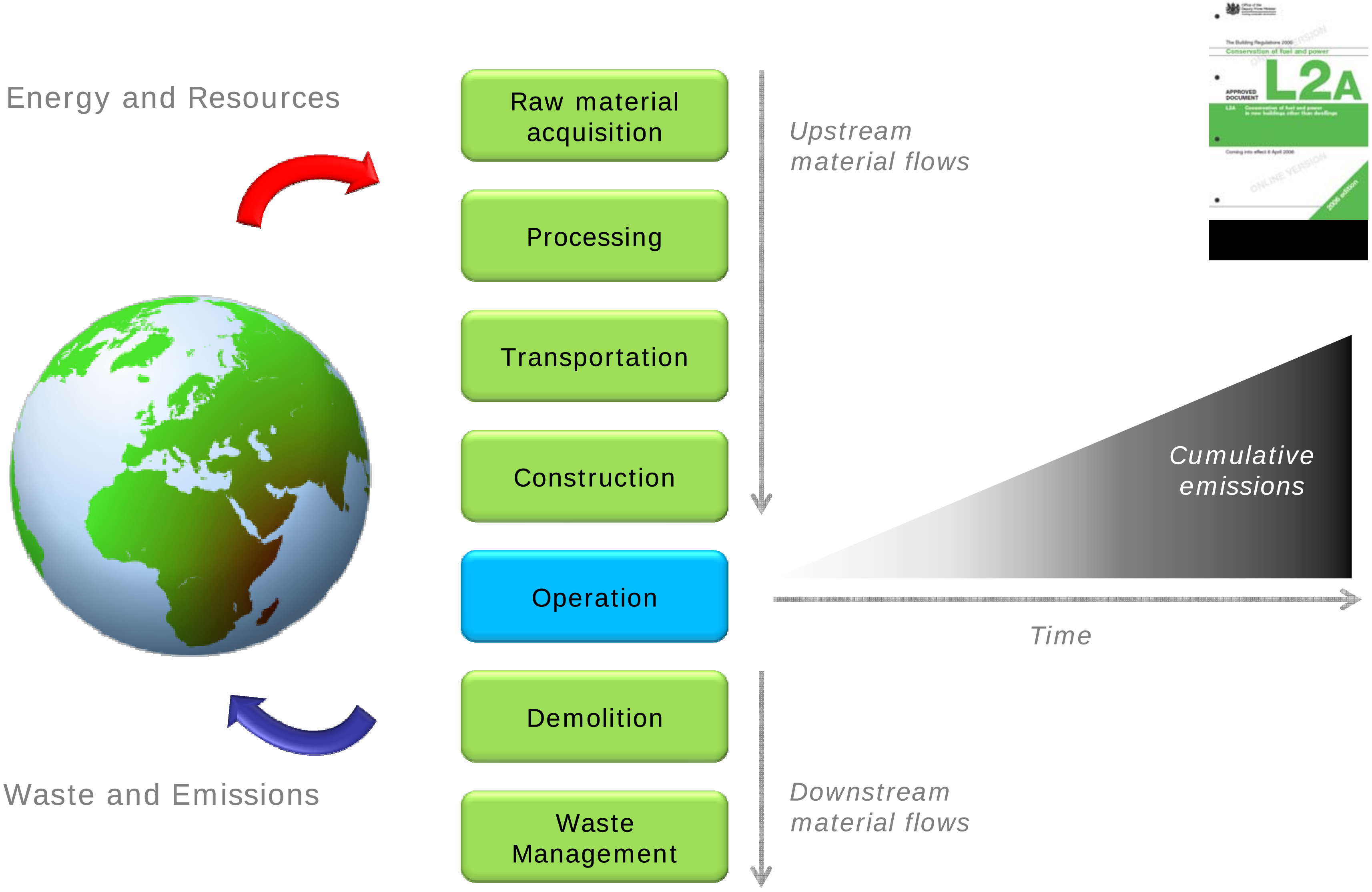
1990	1995	2002	2006	2010	2013	2016
20% improvement over 1985 regulations	25% improvement over 1990 regulations	20% improvement over 1995 regulations	25% improvement over 2002 regulations	25% improvement over 2006 regulations	44% improvement over 2006 regulations	Zero Carbon

Regulatory requirements



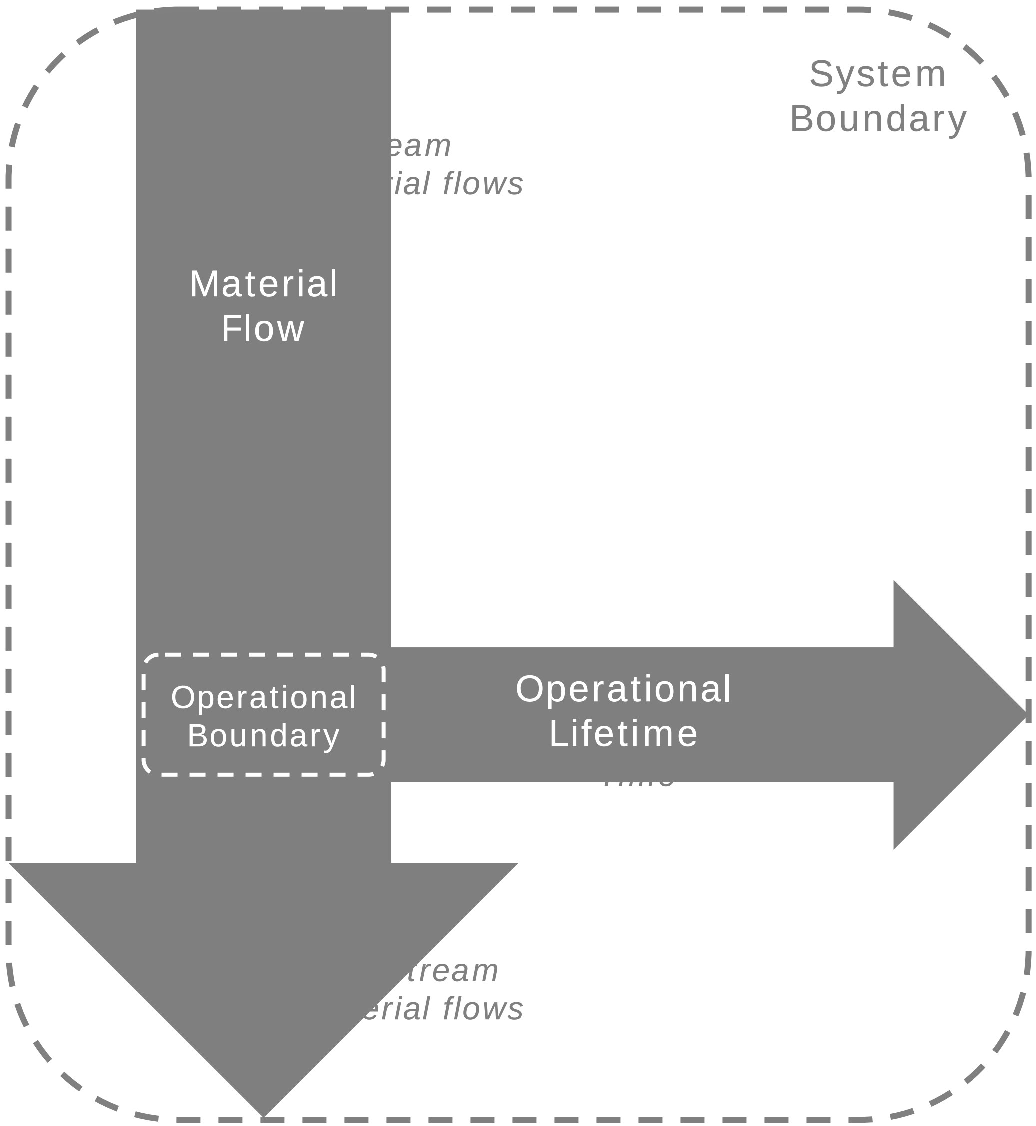
Operational System Boundary

Life cycle perspective



Life cycle perspective

- How significant are these additional flows to building design?
- Does regulation deal with these issues in other ways?
- What is the extent of the ‘system boundary’?
- What impacts on the environment should be considered?



Life cycle perspective

How significant are other material flows?

A 1996 study showed an office's operational phase represented 80-90% of all primary energy demand…

…However this could be reduced by 50% by including low energy features *(Cole and Kernan, 1996)*

In a 2002 study embodied energy represented 67% of the operation phase *(Yohanis and Norton, 2002)*

2016 – Zero carbon homes

2019 – Zero carbon non-domestic buildings

- Raw material acquisition
- Processing
- Transportation
- Construction
- **Operation**
- Demolition
- Waste Management

Life cycle perspective

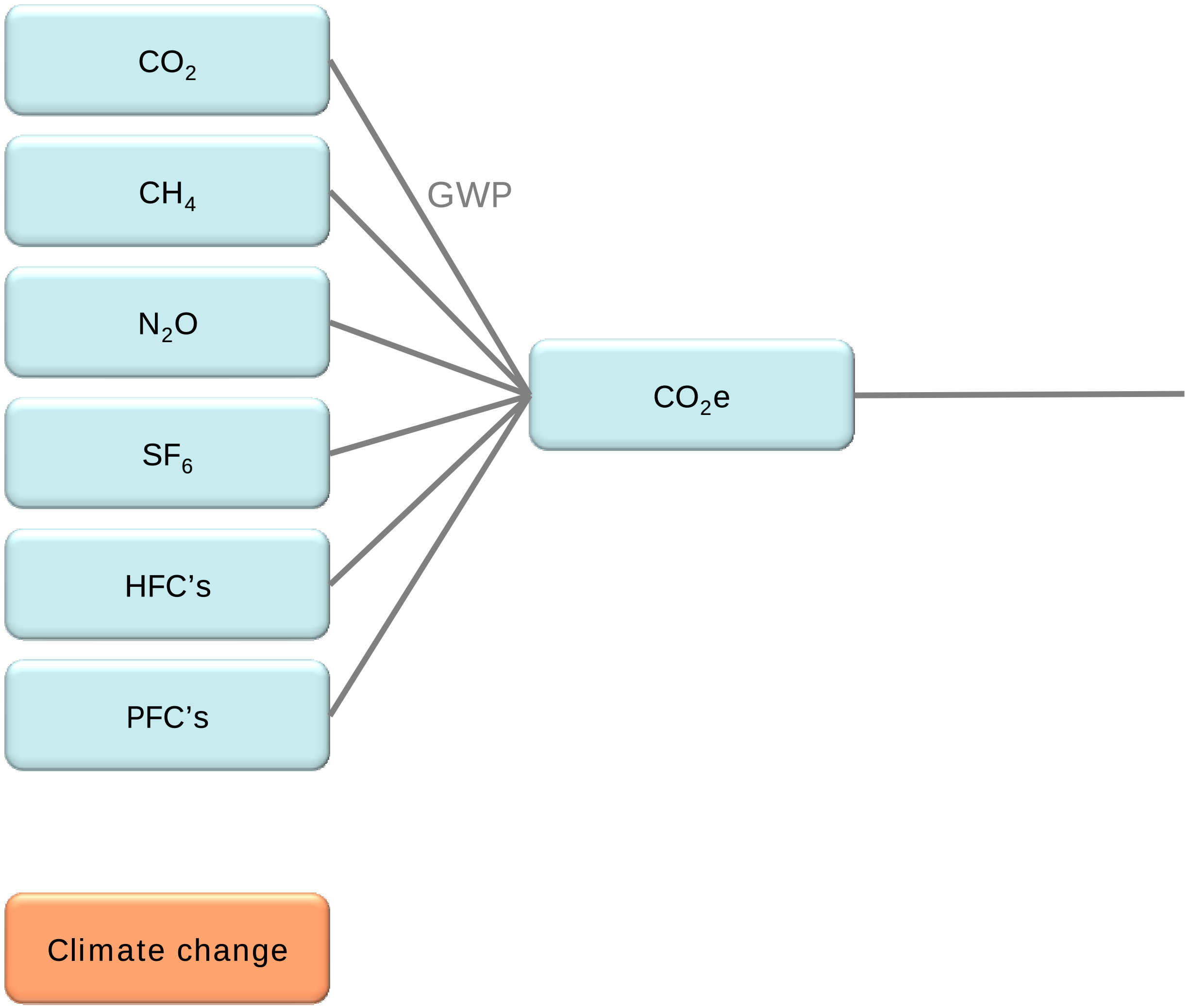
- How are material flows currently regulated?
  - BREEAM
  - BRE Green Guide / Environmental Profiles
  - Site Waste Management Plans
  - Invest2 Software…
  - *No cohesive tool to think of material flows in the same way as operational demands*

- What environmental impacts should we consider?

Extraction of resources	Water use	Acidification
Photo-oxidant Formation	Ozone Depletion	Human-toxicity
Climate change	Eco-toxicity	Eutrophication

- Raw material acquisition
- Processing
- Transportation
- Construction
- Operation
- Demolition
- Waste Management

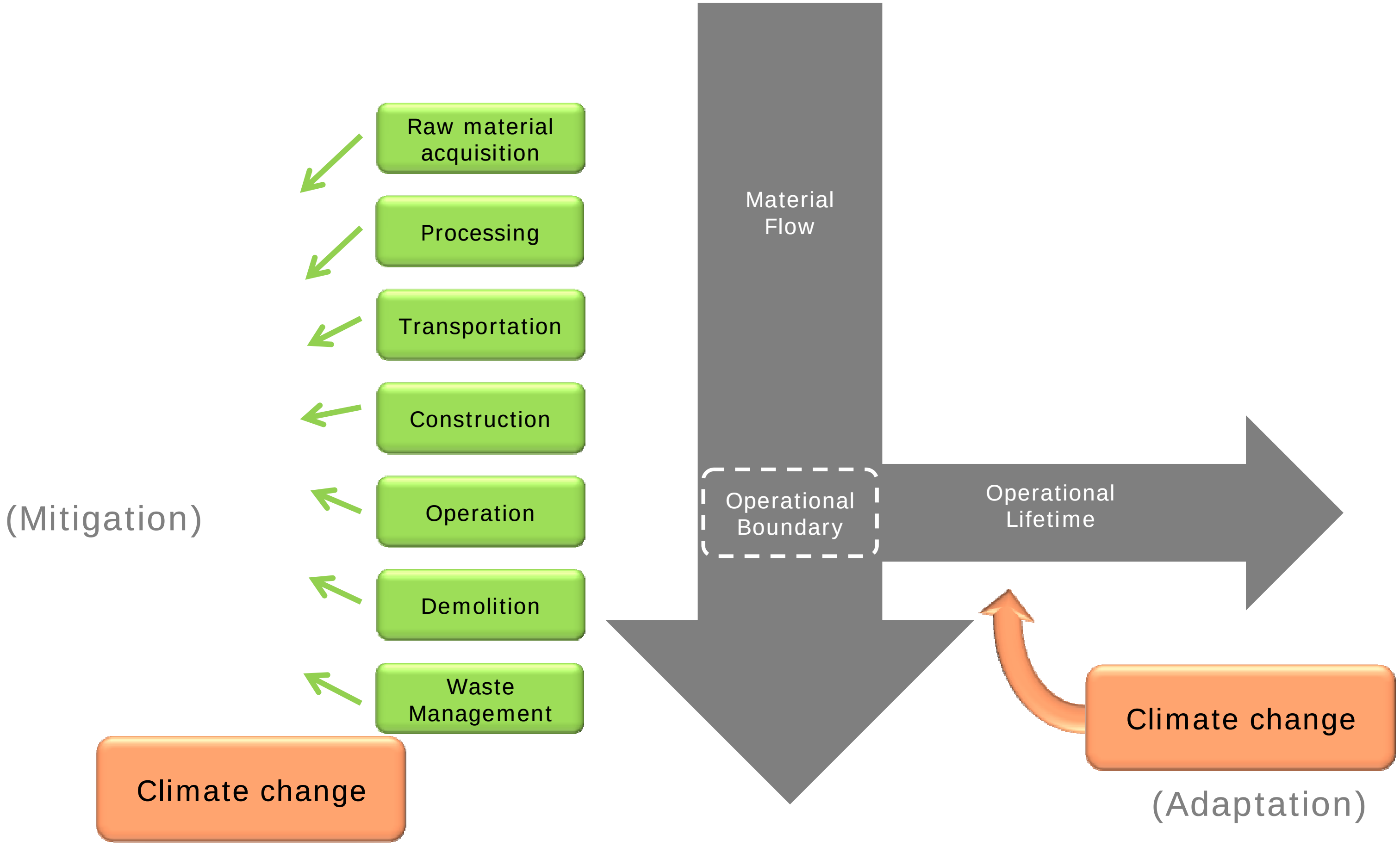
Life cycle perspective



Life cycle perspective

Protecting the environment from us…

… or protecting us from the environment?

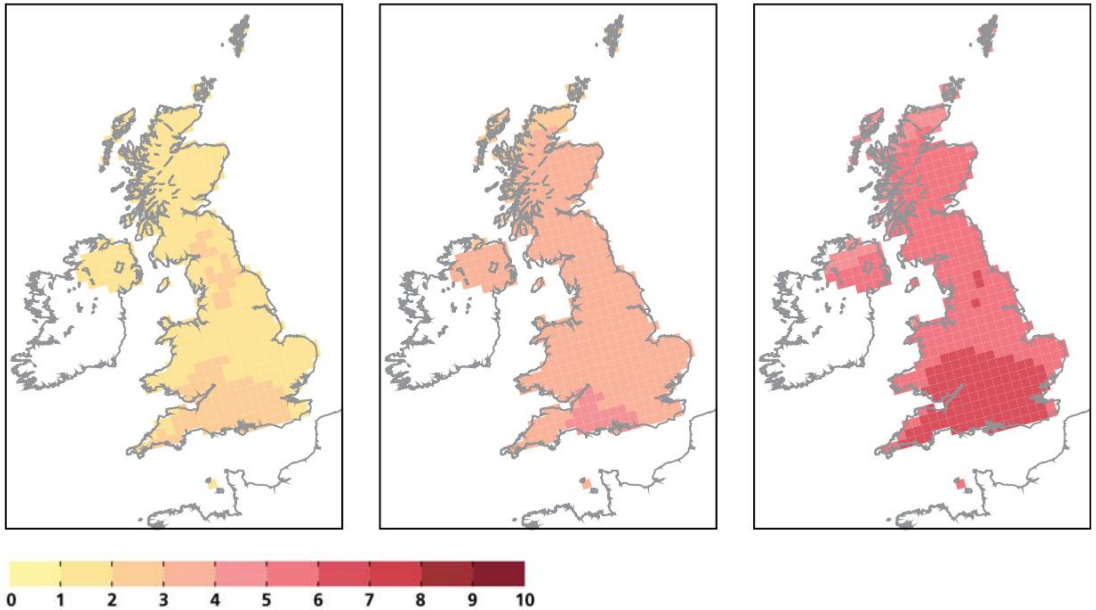


- Adaptation to climate change

10% probability level. Very unlikely to be less than

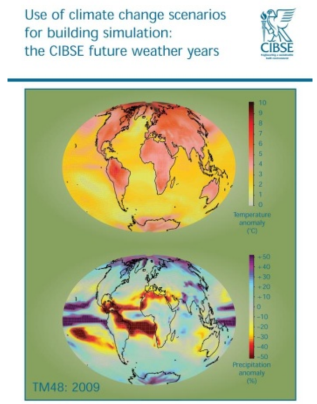
50% probability level. Central estimate

90% probability level. Very unlikely to be greater than



Change in mean temperature / °C

CIBSE TM48:
Use of climate change scenarios for building simulation
Using UKCIP02 data



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Life cycle perspective

1. We must build an understanding of the wider life cycle impacts on climate change caused by construction

   - Is zero carbon really life cycle optimised?

   - Should we replace existing air conditioned buildings with new naturally ventilated alternatives?

2. We must understand how buildings will respond to climate change over their lifetimes

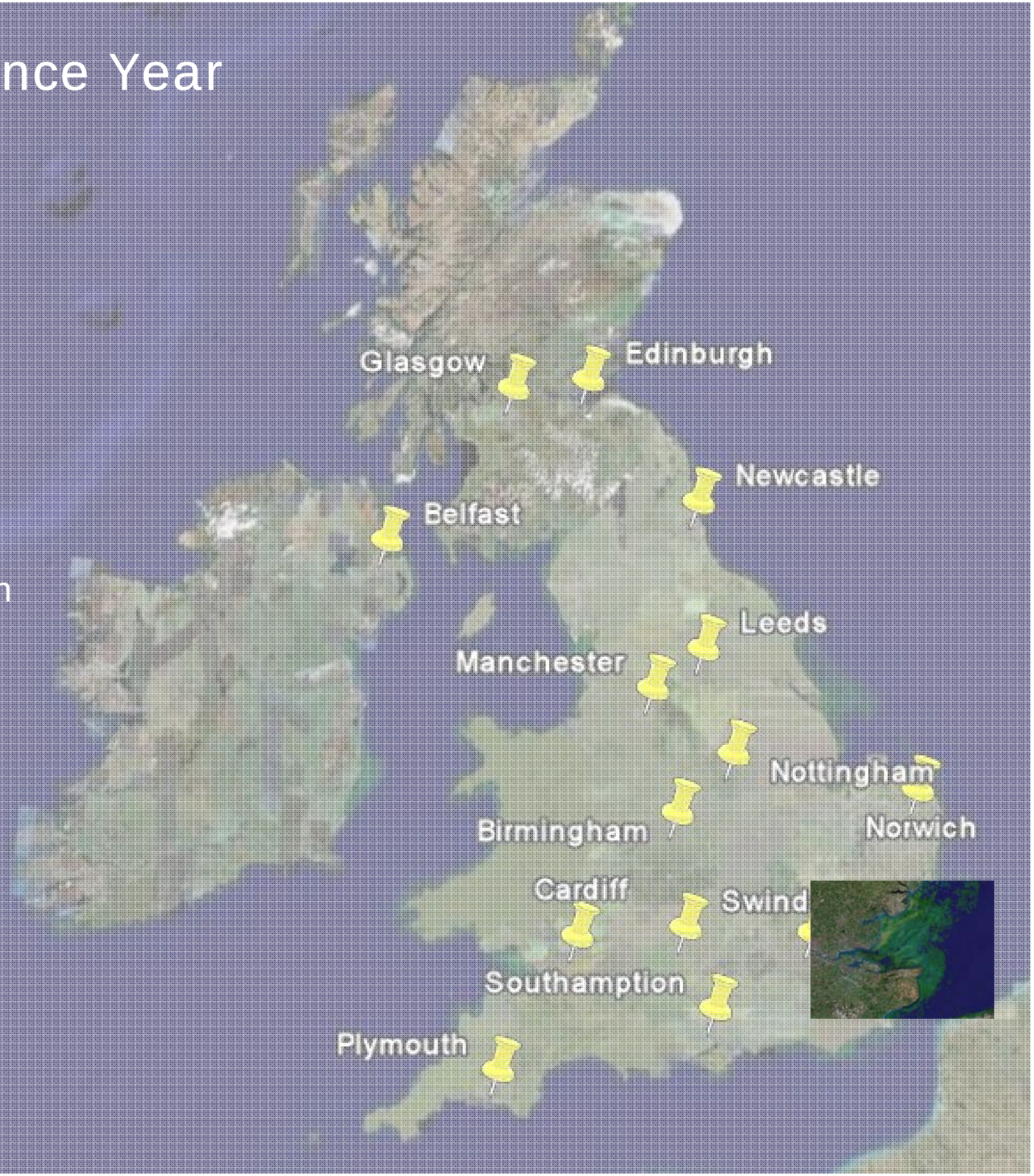
   - How will zero carbon buildings perform in the future? Will they still be zero carbon?

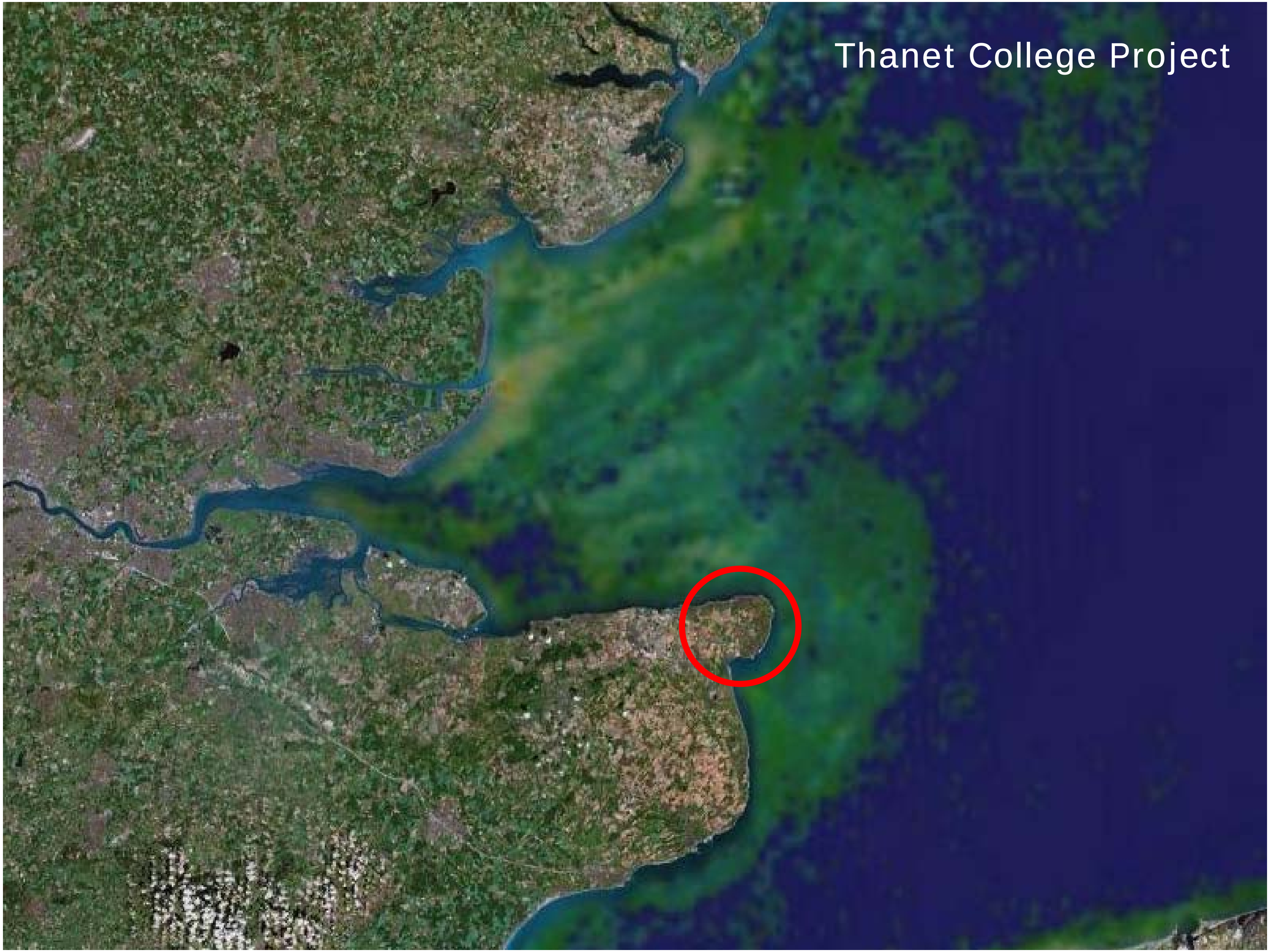
Design for Climate Change

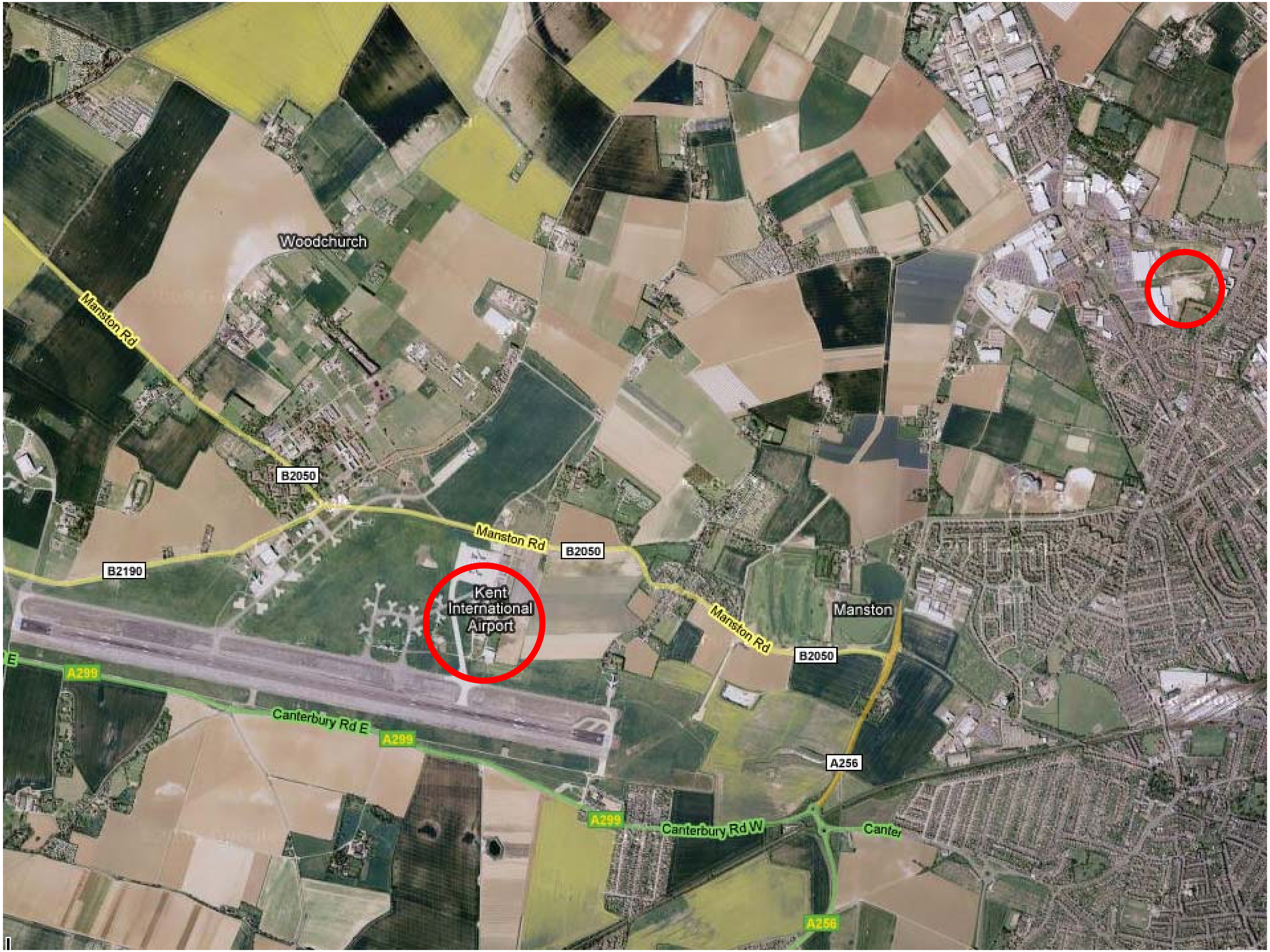
Creating balanced environments

CIBSE Test Reference Year Weather Sites

- Dry Bulb Temperature
- Wet Bulb Temperature
- Wind Speed
- Wind Direction
- Global Horizontal Irradiation
- Global Diffuse Radiation
- Atmospheric Pressure
- Cloud Cover




Thanet College Project


Woodchurch
Manston Rd
B2050
Manston Rd
B2050
B2190
Kent International Airport
Manston Rd
Manston
B2050
A299
Canterbury Rd E
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A256
A299
Canterbury Rd W
Canter
A256

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**MANSTON**															
2	**NGR = 6324E 1661N**															
3	**Altitude = 49 metres**															
4	**Latitude = 51:35 N Longitude = 01:34 E**															
5																
6	Date	Time	Temperature - Dry Bulb (°C)	NB1	Temperature - Wet Bulb (°C)	NB2	Relative Humidity %	NB3	Wind - Mean Speed (knots)	NB4	Wind - Mean Direction	NB5	Solar Radiation - Global (KJ/sq m)	NB6	Cloud - Total Amount (oktas)	NB7
7	01/03/2008	00:00	11.1		10.2		88.7		27		240		0		8	
8	01/03/2008	01:00	11.3		10.4		88.9		27		250		0		8	
9	01/03/2008	02:00	12.4		10.6		78.9		27		250		0		8	
10	01/03/2008	03:00	12.5		9.8		68.8		32		270		0		8	
11	01/03/2008	04:00	10.5		8.0		68.8		25		290		0		7	
12	01/03/2008	05:00	9.7		6.9		64.0		30		290		0		0	
13	01/03/2008	06:00	8.7		5.7		60.1		30		290		0		0	
14	01/03/2008	07:00	8.1		5.4		63.1		25		290		9		0	
15	01/03/2008	08:00	8.1		5.4		63.0		25		280		157		0	
16	01/03/2008	09:00	9.0		6.3		64.3		26		280		637		0	
17	01/03/2008	10:00	9.9		6.8		60.5		26		280		1176		0	
18	01/03/2008	11:00	10.7		7.5		60.5		25		280		1588		0	
19	01/03/2008	12:00	11.3		8.0		60.3		23		280		1830		1	
20	01/03/2008	13:00	10.9		7.6		59.7		23		280		1684		5	
21	01/03/2008	14:00	11.1		7.3		54.2		19		280		971		8	
22	01/03/2008	15:00	11.7		7.6		51.9		16		270		763		7	
23	01/03/2008	16:00	11.7		7.4		49.7		21		270		1067		7	
24	01/03/2008	17:00	10.4		6.8		55.2		17		260		456		1	
25	01/03/2008	18:00	9.2		6.4		63.2		13		250		82		2	
26	01/03/2008	19:00	8.6		6.3		68.8		14		250		0		1	
27	01/03/2008	20:00	9.1		6.7		68.2		14		250		0		7	
28	01/03/2008	21:00	9.5		6.7		63.6		16		240		0		8	
29	01/03/2008	22:00	9.1		6.7		68.2		15		230		0		7	
30	01/03/2008	23:00	9.7		7.9		76.5		17		230		0		7	
31																

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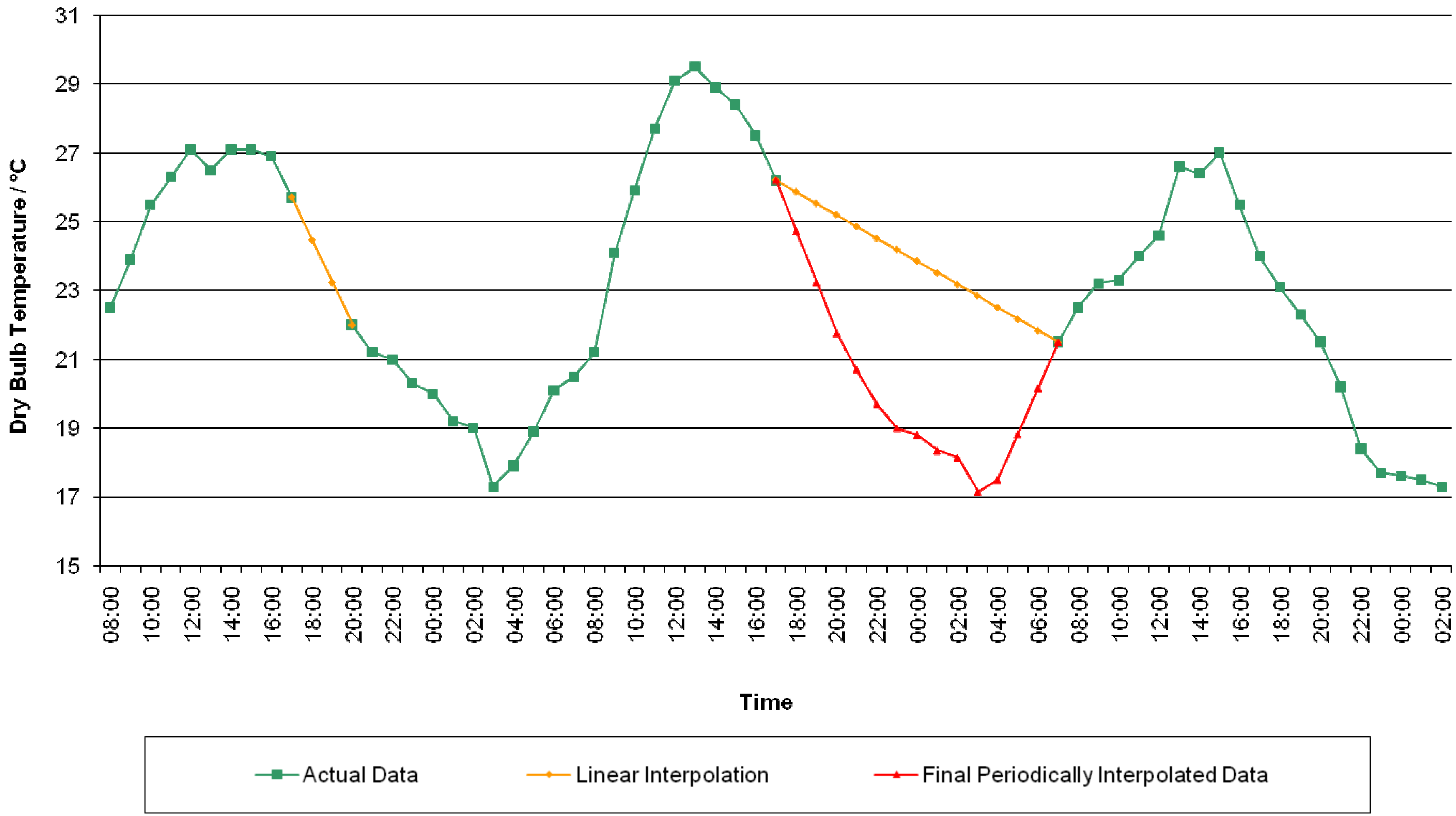
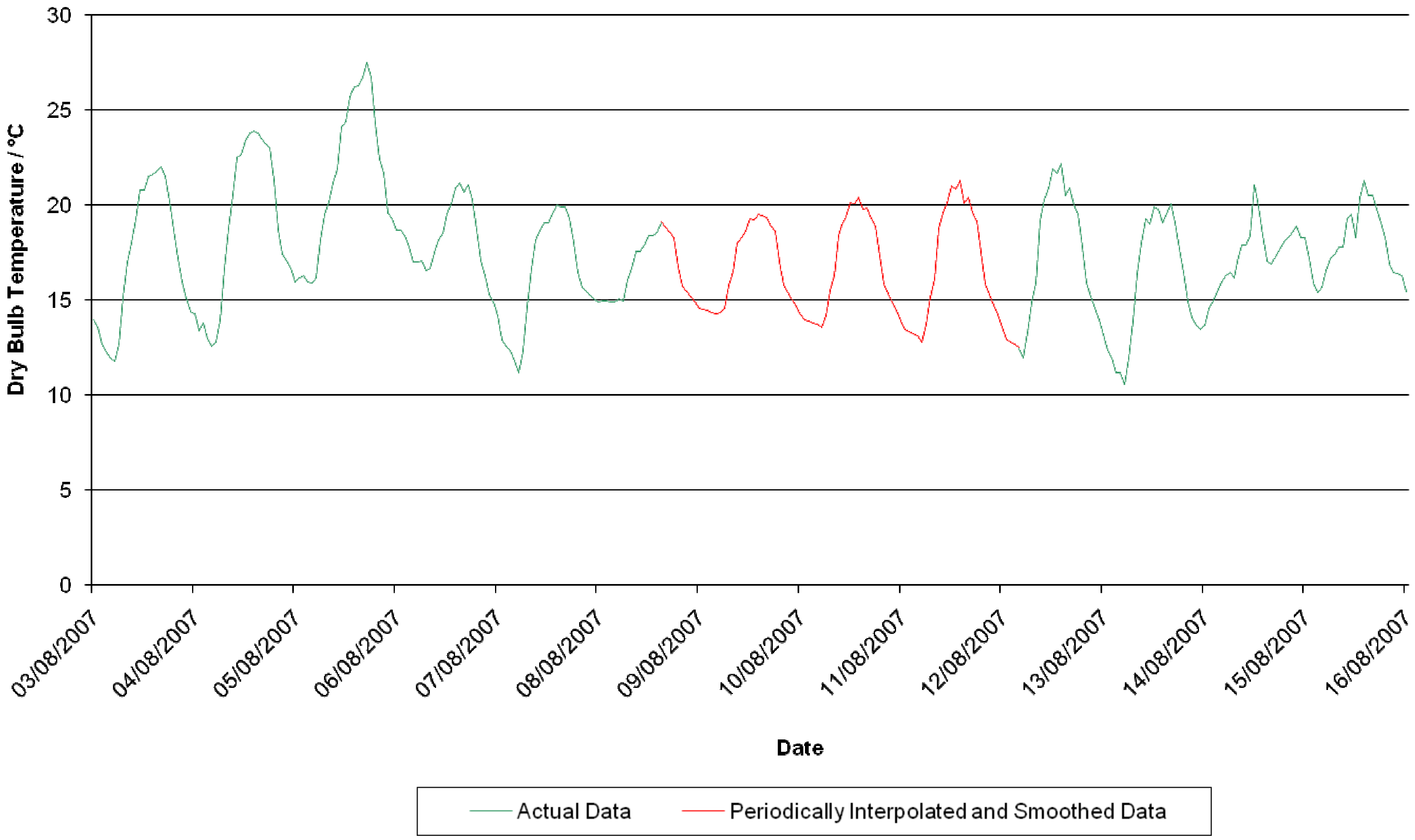
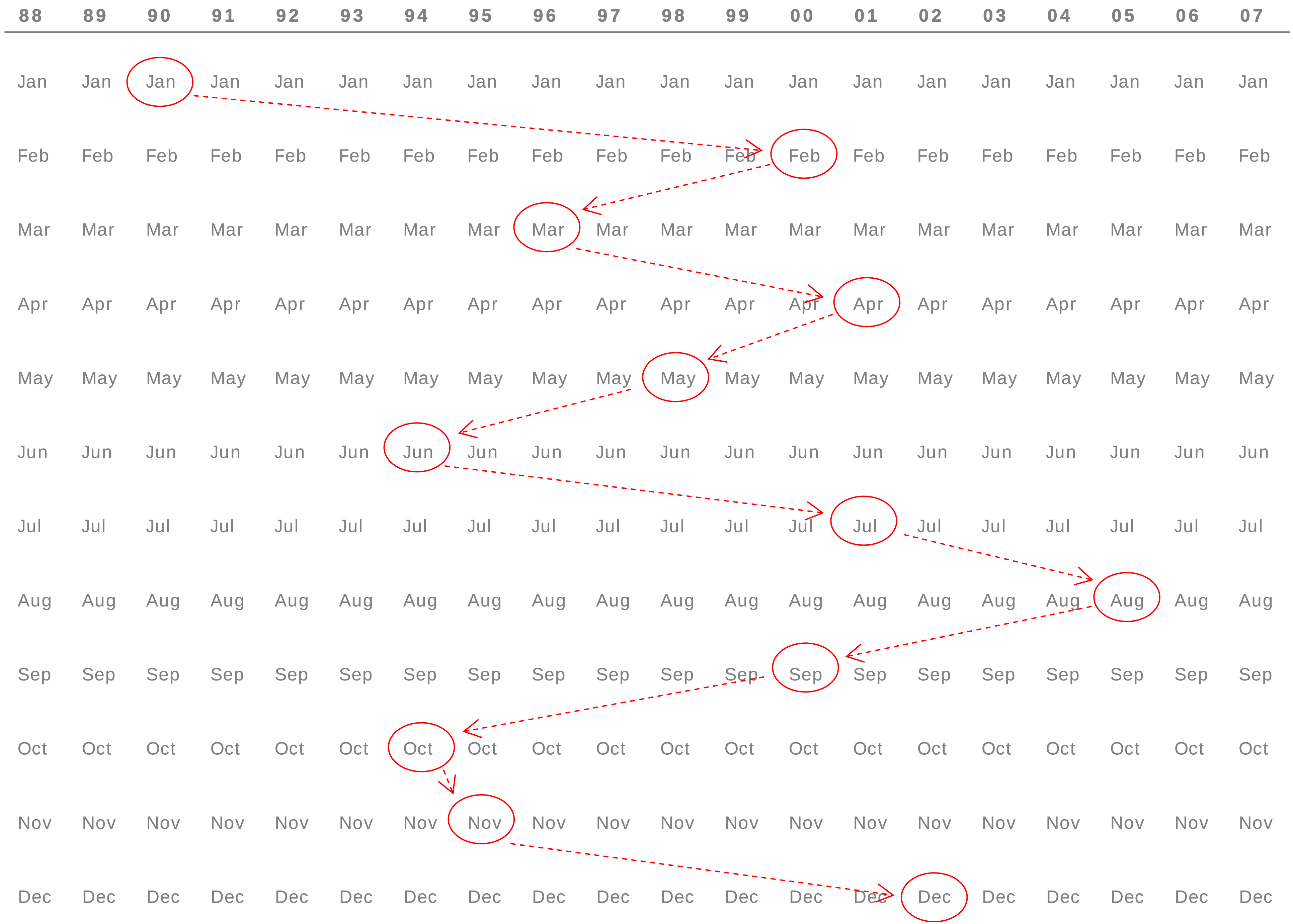
Missing Data



Missing Data



Building a Test Reference Year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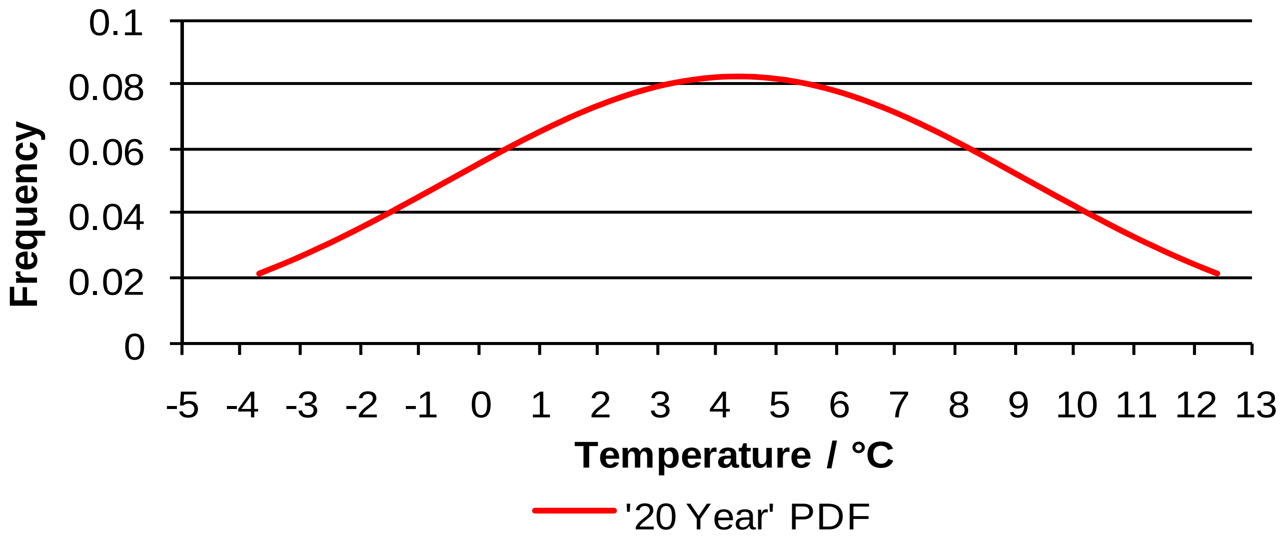
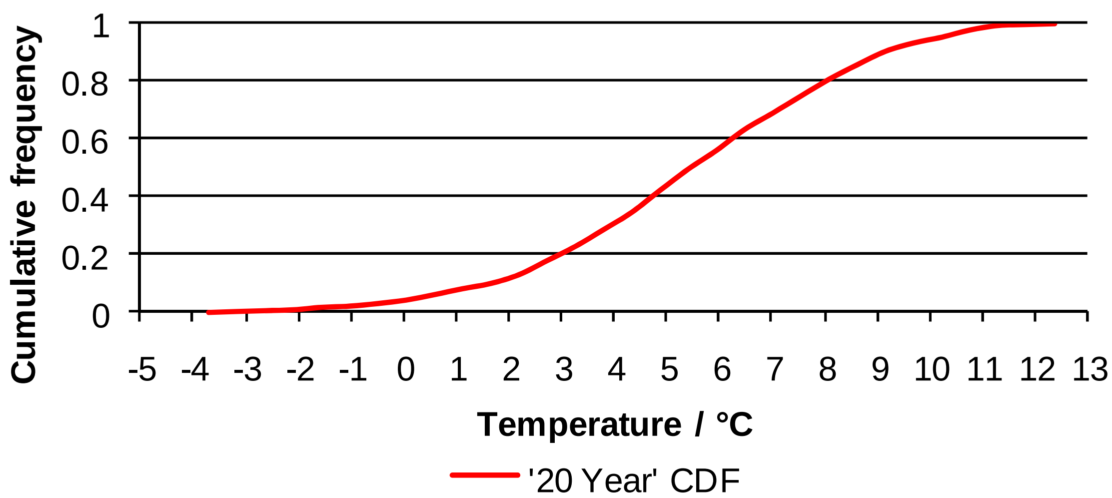
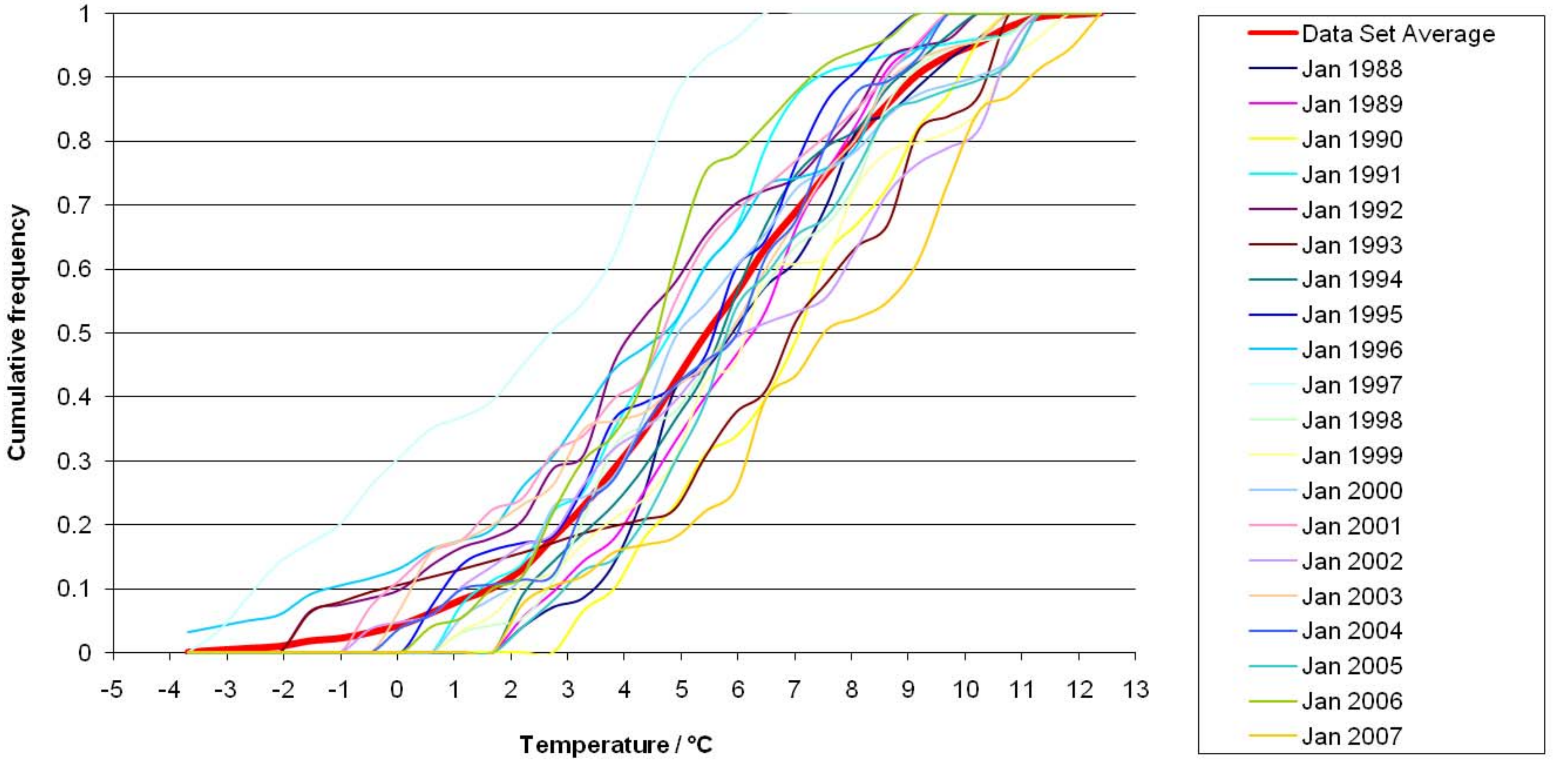
Cumulative Distribution Function





Cumulative Distribution Function

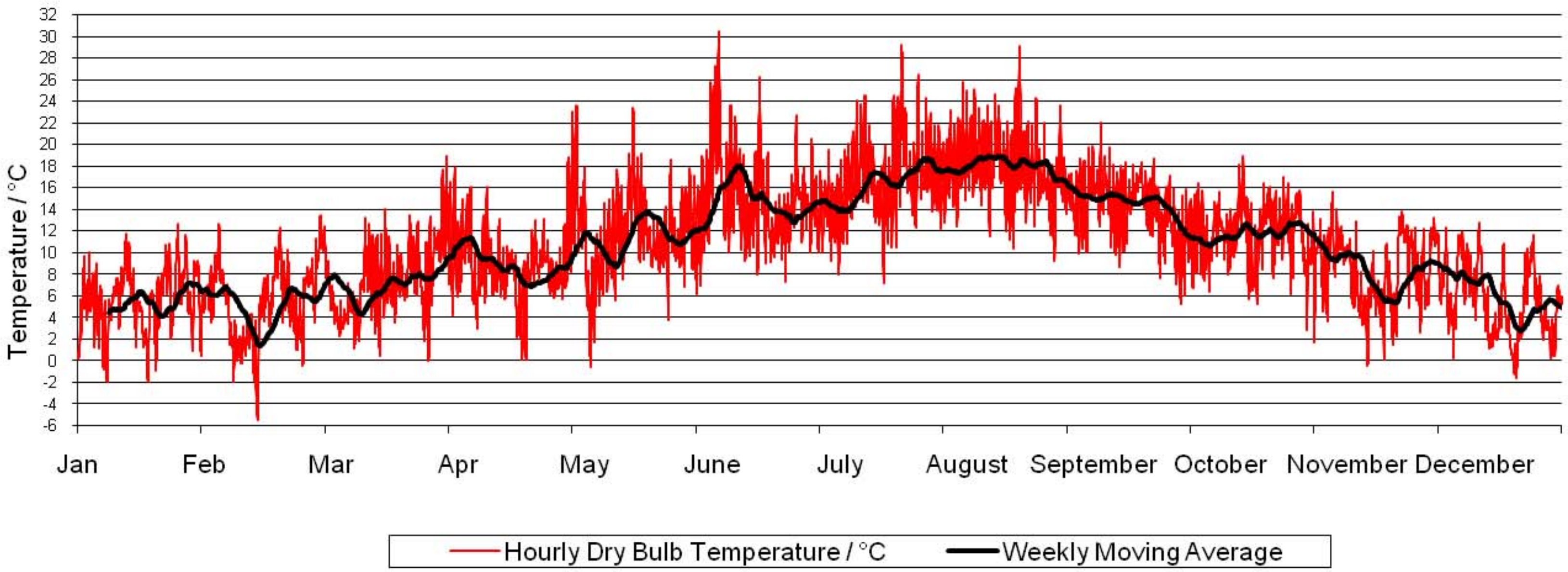


$$FS(p,m,y) = \sum_{i=1}^{N} \left| CDF(p,m,y,i) - CDF(p,N_y,m,i) \right|$$

$$FS_{sum} = w_1 FS(DryT) + w_2 FS(GlRad) + w_3 FS(Wind)$$

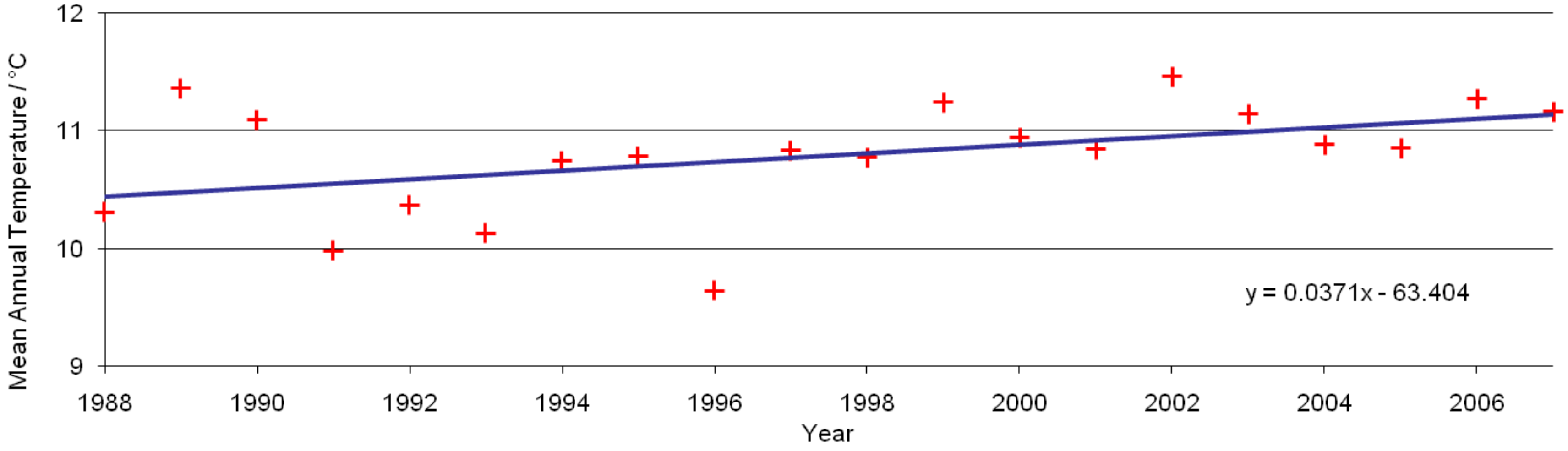
Assembling the Test Reference Year

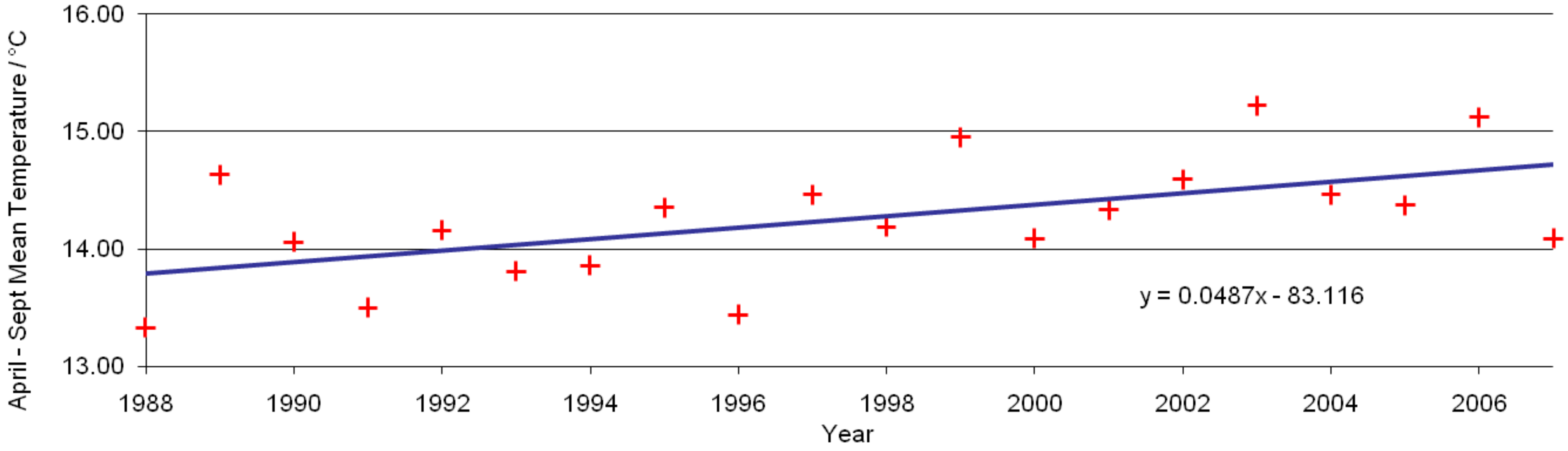
Month	Adopted Year	Month	Adopted Year
January	1994	July	1996
February	1999	August	1989
March	1999	September	1995
April	2005	October	1996
May	1997	November	1992
June	1996	December	2004



Historical Climate Trends

Historical Climate Trends





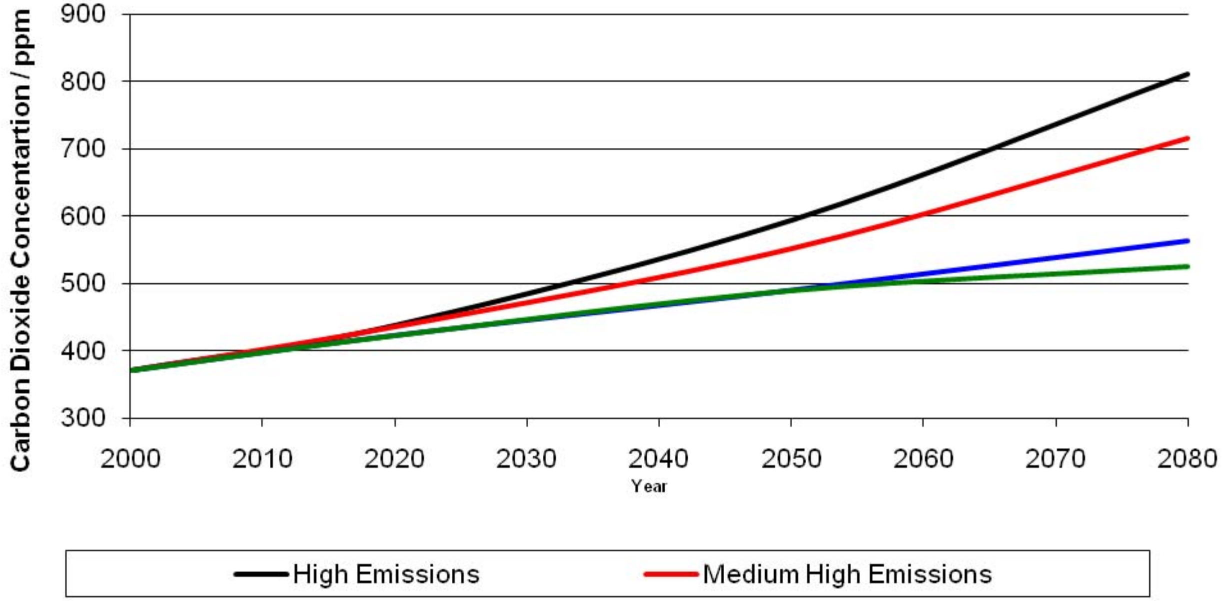
Future Climate Trends

Climate Scenarios

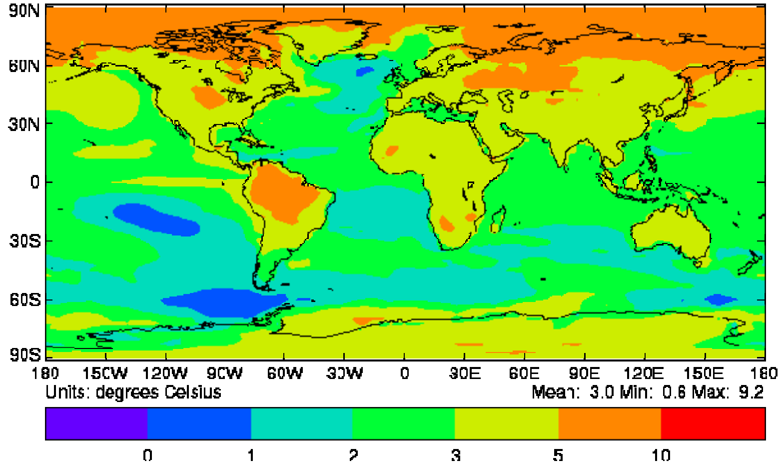
Economic

Global	A1 World Markets High Emissions	A2 National Enterprise Medium-High Emissions	Regional
	B1 Global Sustainability Low Emissions	B2 Local Stewardship Medium-Low Emissions	

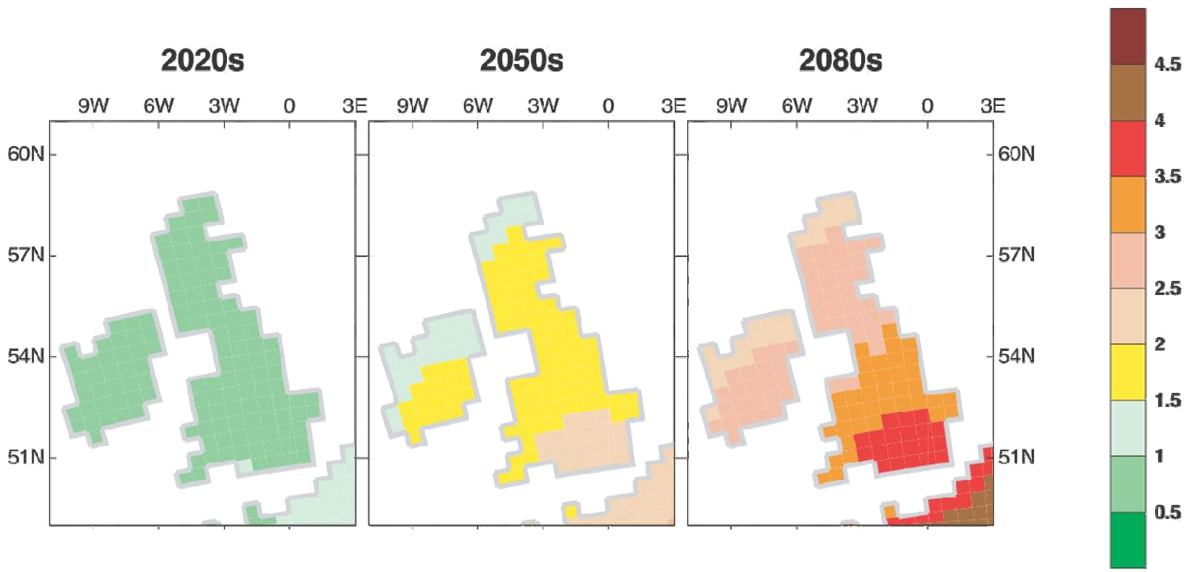
Environmental



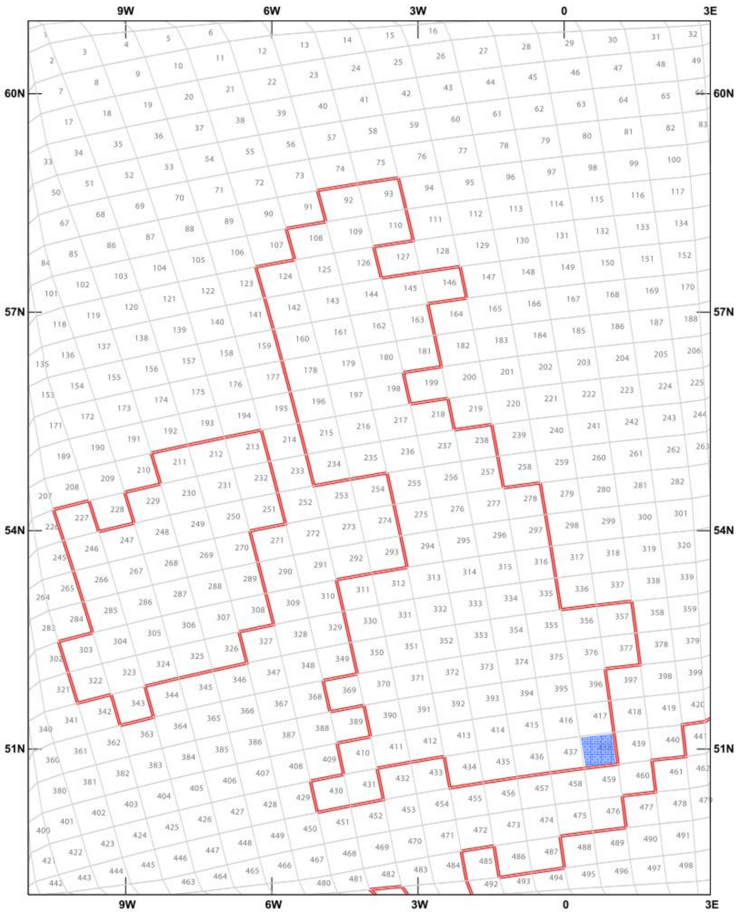
HadCM3



HadRM3

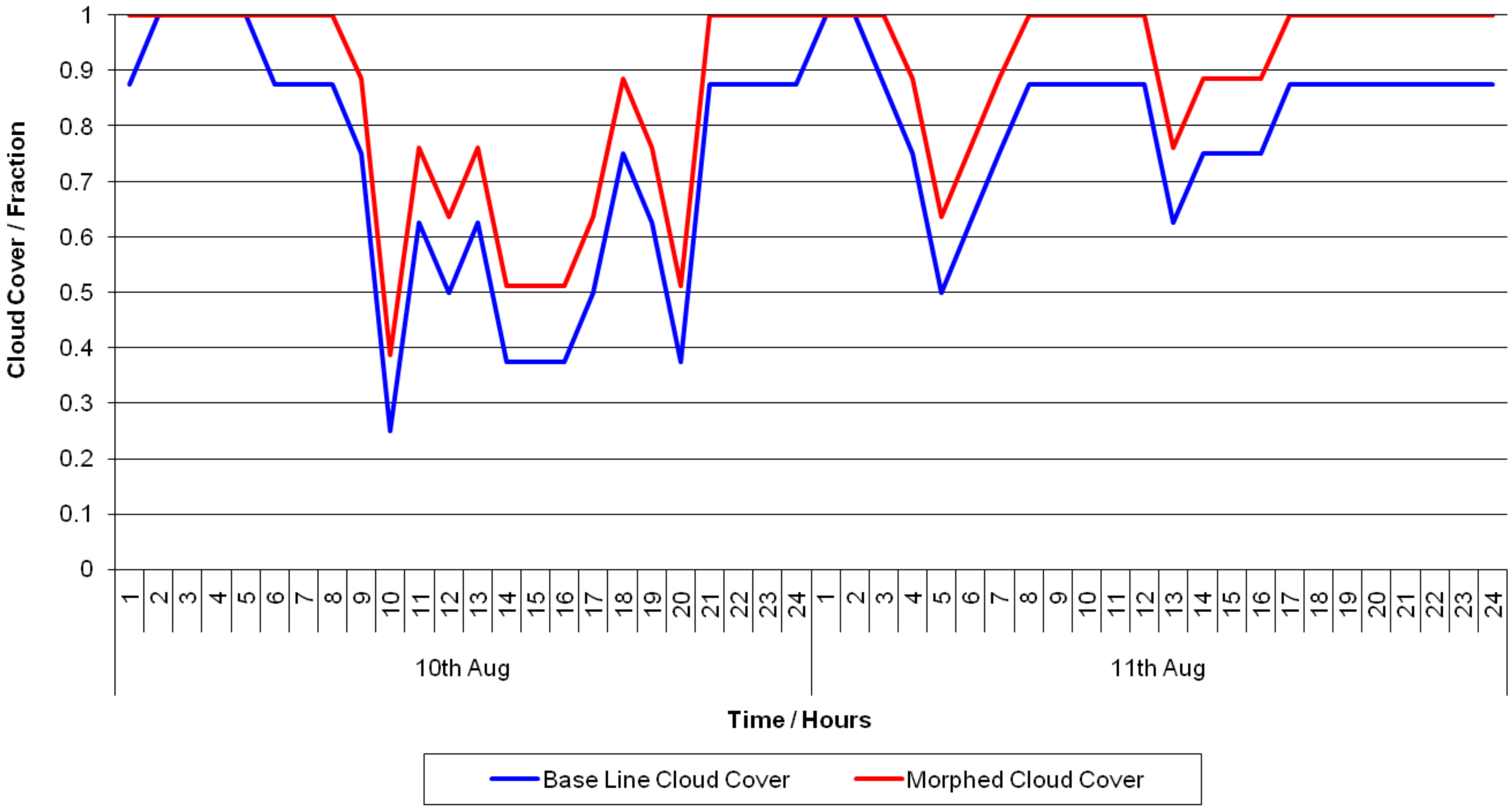


UK Climate Impacts Programme



$TEMP_m$	Mean Temperature / °C
$TMAX_m$	Maximum Temperature / °C
$TMIN_m$	Minimum Temperature / °C
$SPHU_m$	Specific Humidity / g/kg
$WIND_m$	10m Wind Speed / m/s
$DSWF_m$	Total Downward Surface Shortwave Flux / W/m²
$TCLW_m$	Total Cloud in Longwave Radiation / %
$MSLP_m$	Mean Sea Level Pressure / hPa

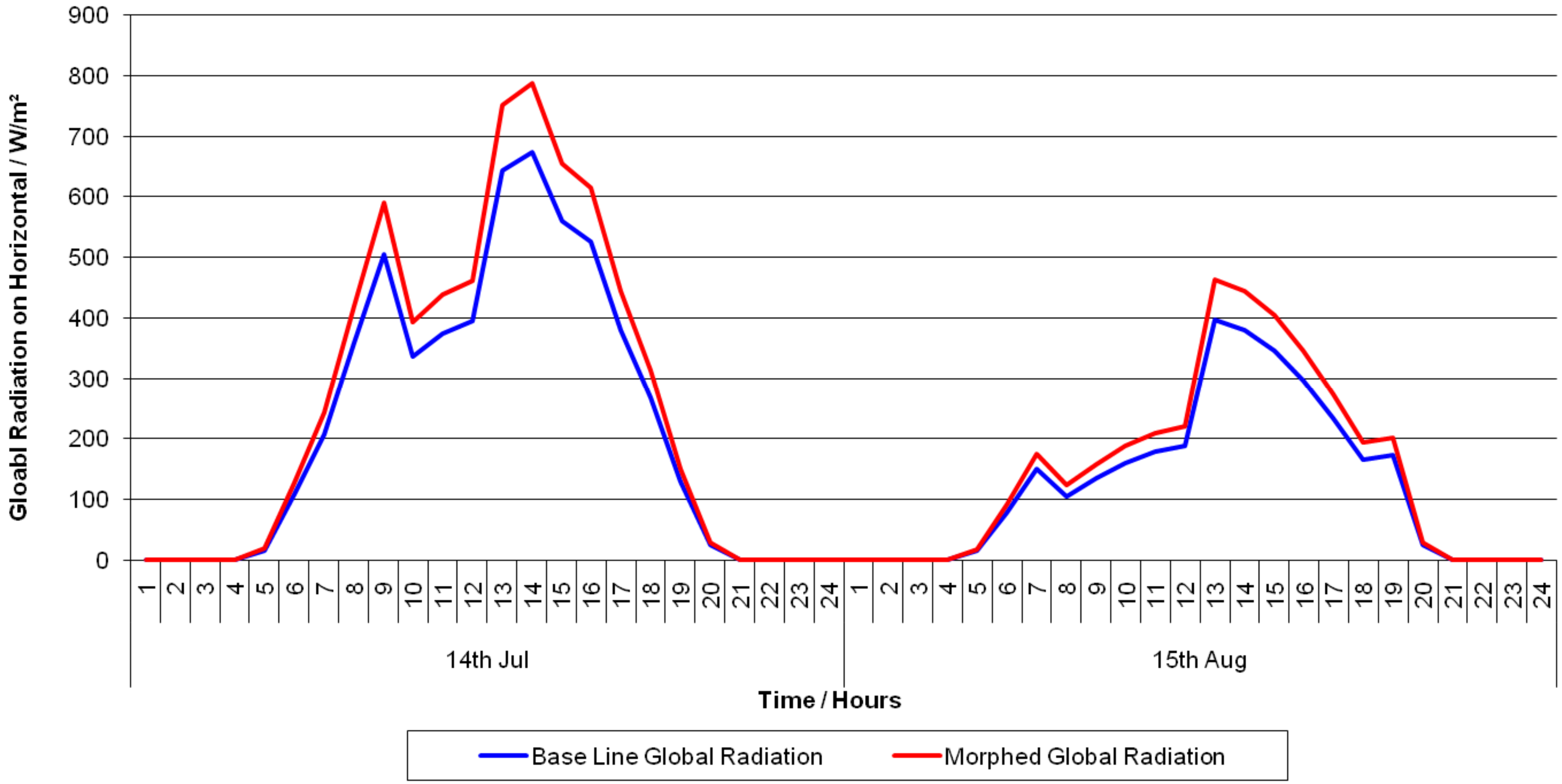
Data Shift



Atmospheric Pressure

Cloud Cover

Data Stretch

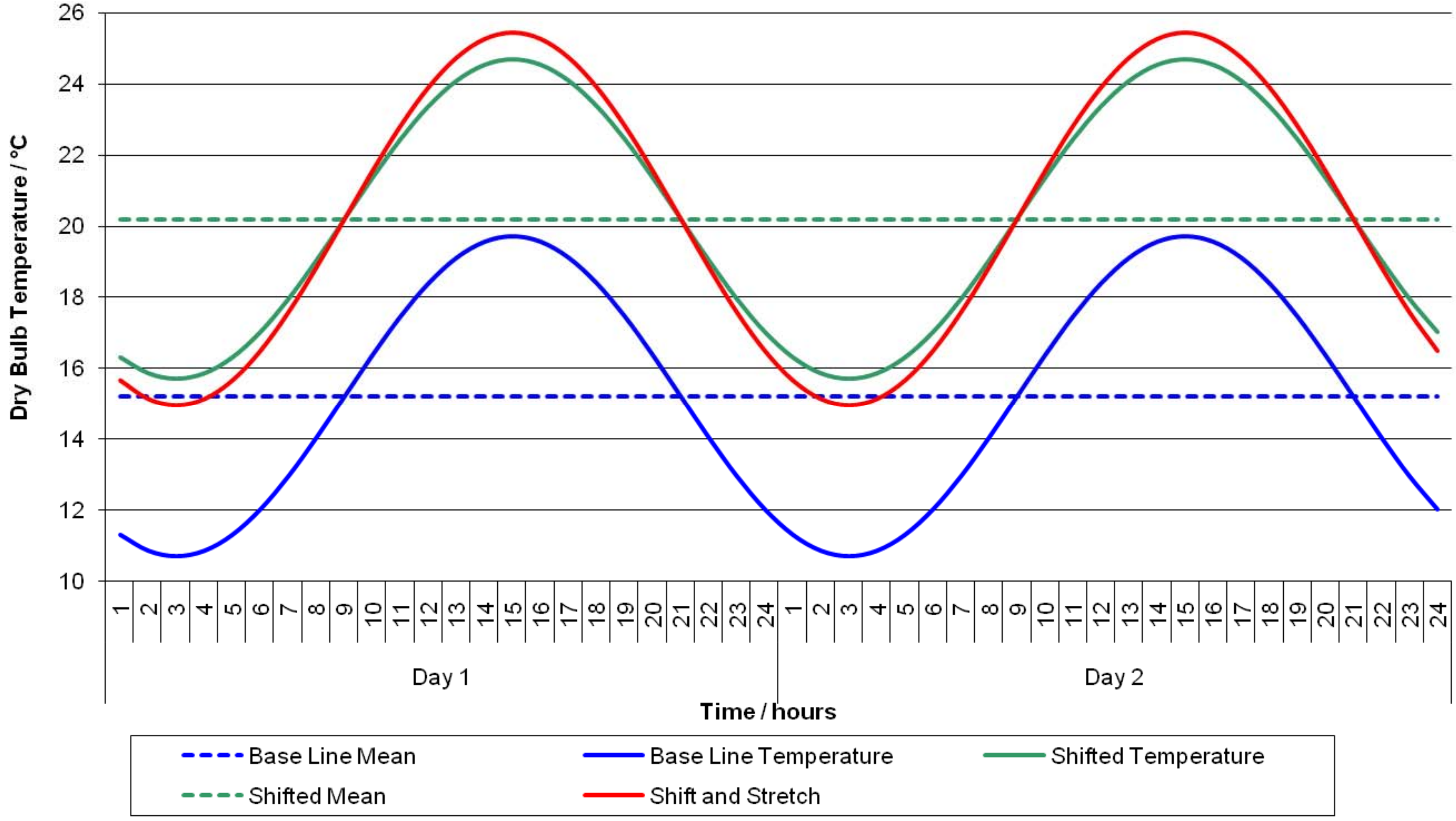


Global and Diffuse Solar Radiation

Humidity

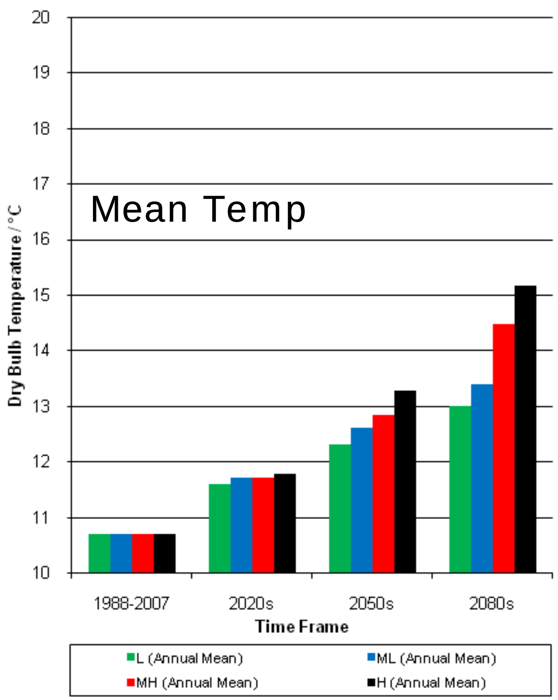
Wind Speed

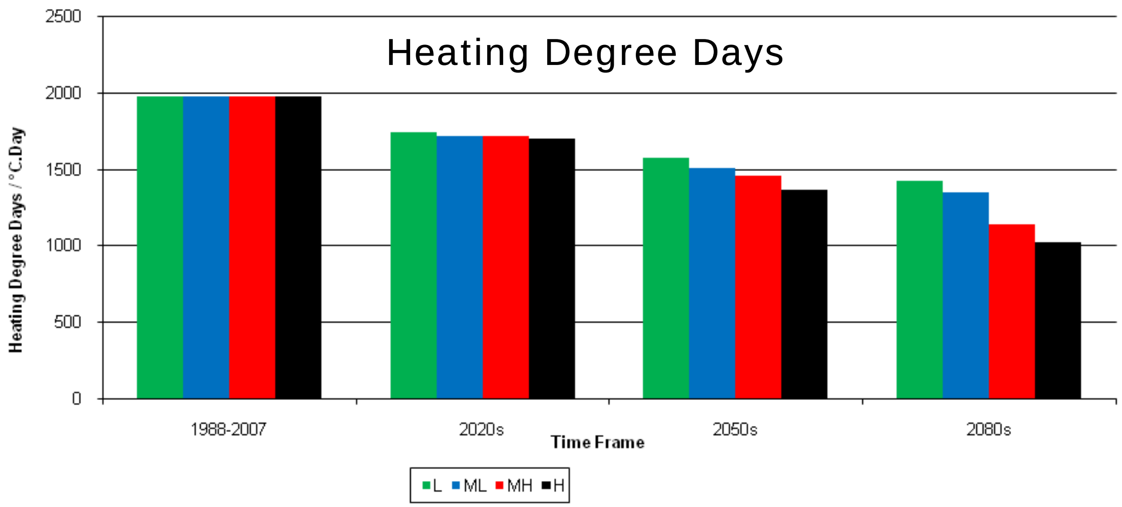
Data Shift and Stretch

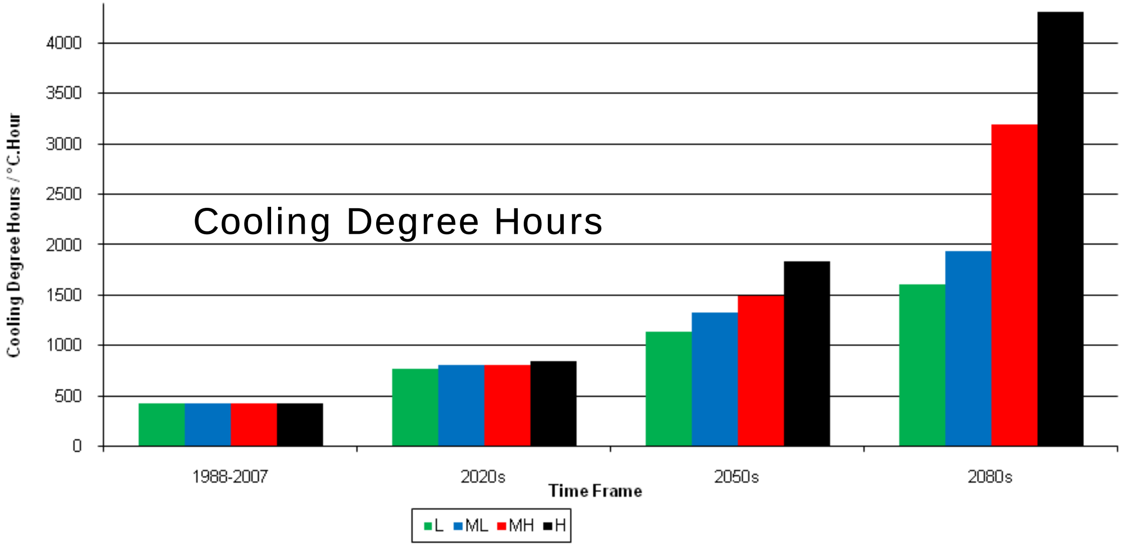


Dry Bulb Temperature

Future Predictions

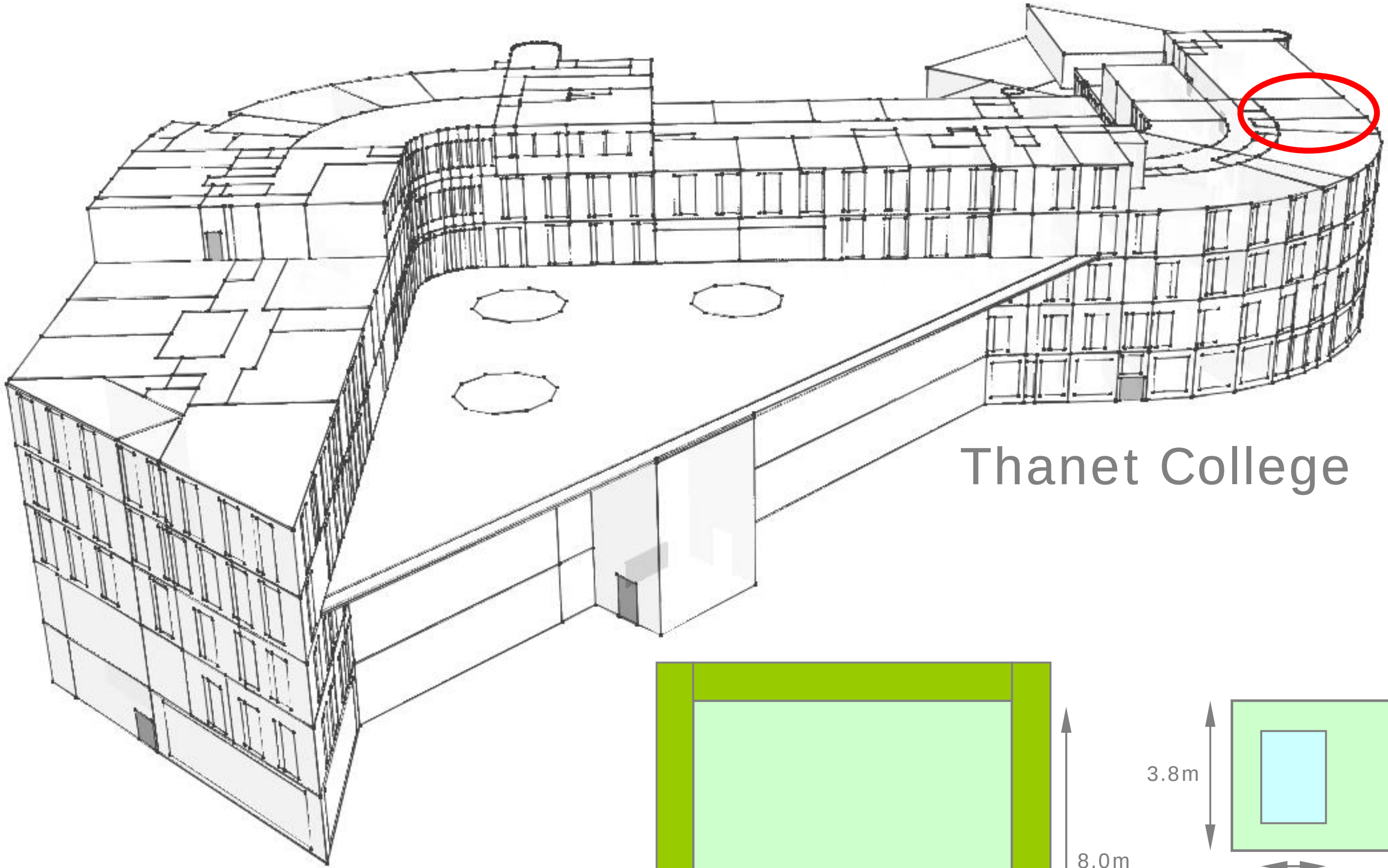






Creating balanced environments

Test Model



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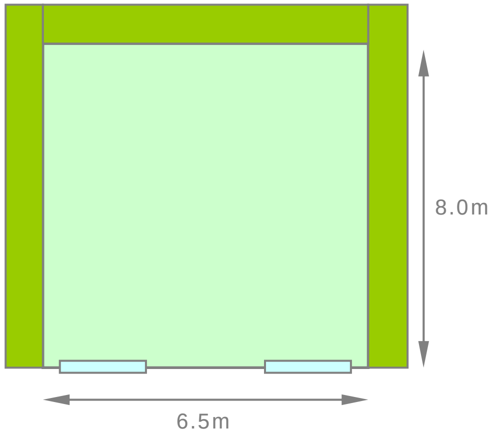

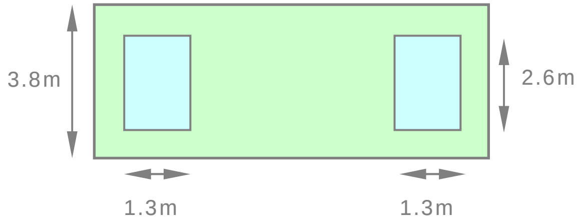

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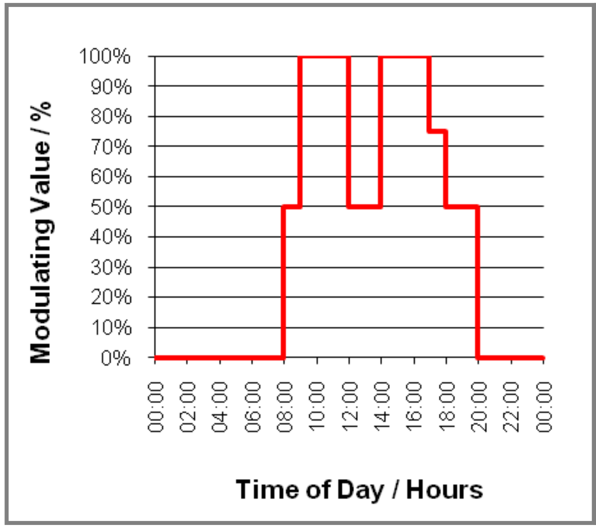
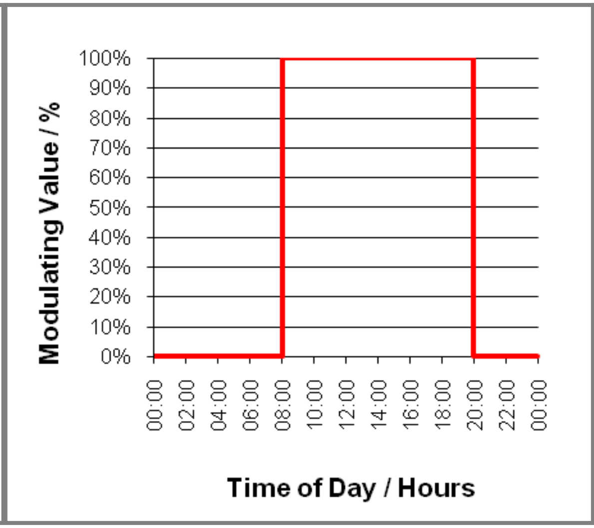
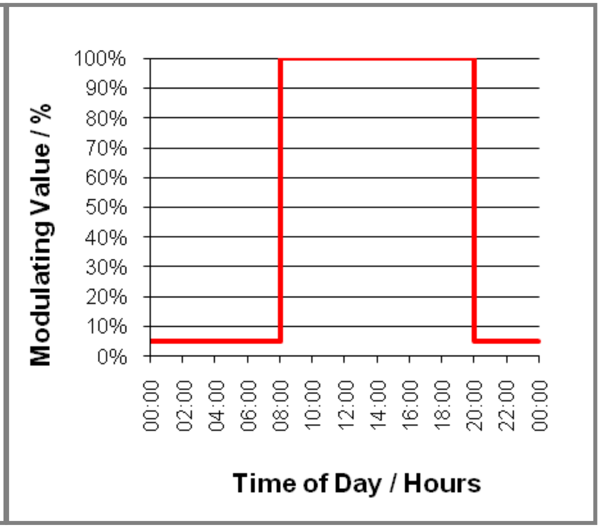


People



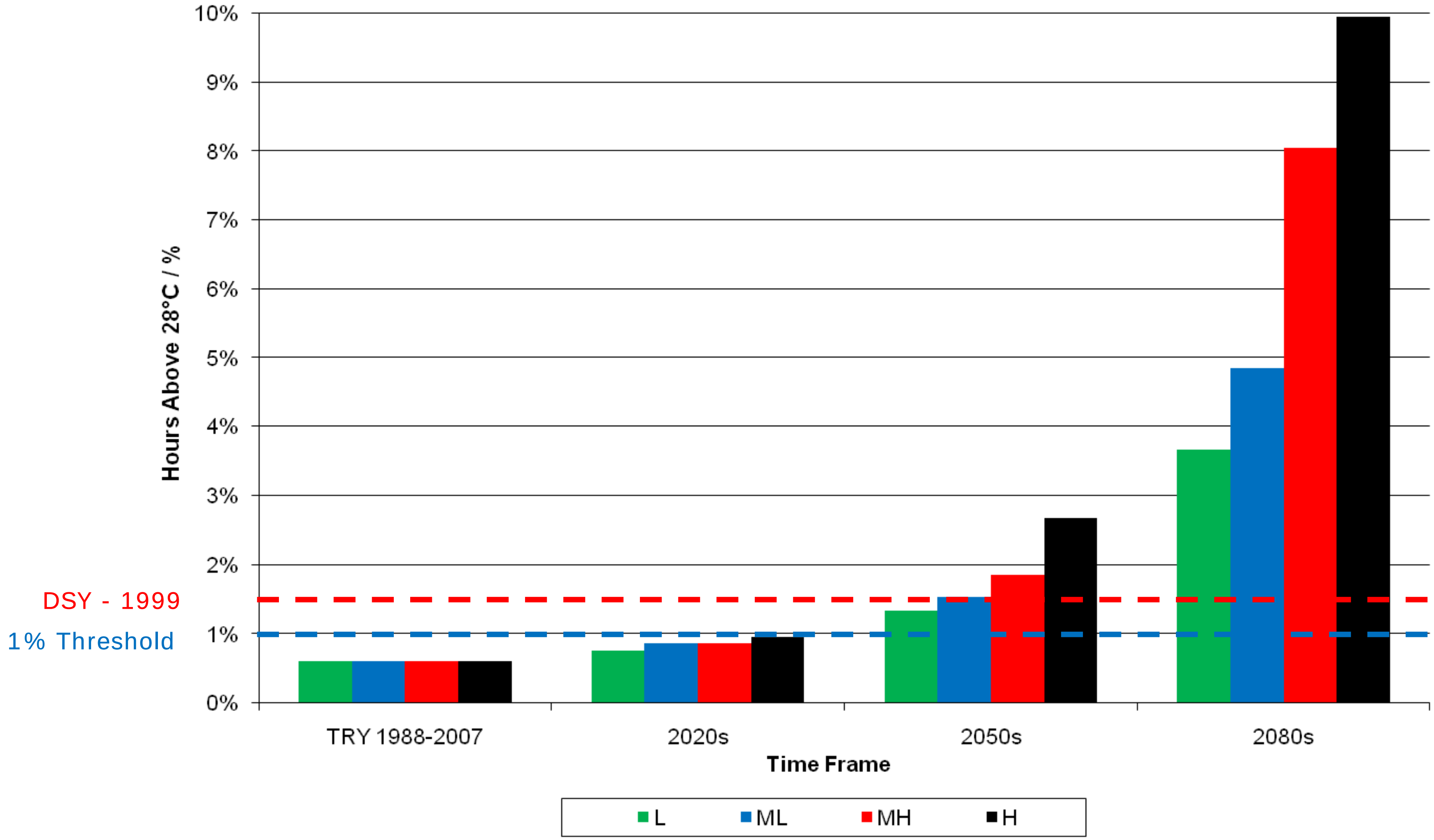
Lighting



Computers & Equipment

Gain Type	Gain Description	Profile Followed	Total Sensible Gain / W	Total Latent Gain / W
People	20 People with 70W/person sensible and 45W/person latent	Occupancy	1400	900
Lighting	500lux of lighting at 2.4W/m² per 100lux efficacy	Lighting	624	-
Computers	2 desktop PCs at 100W each	Equipment	200	-
Equipment	5W/m²	Equipment	260	-

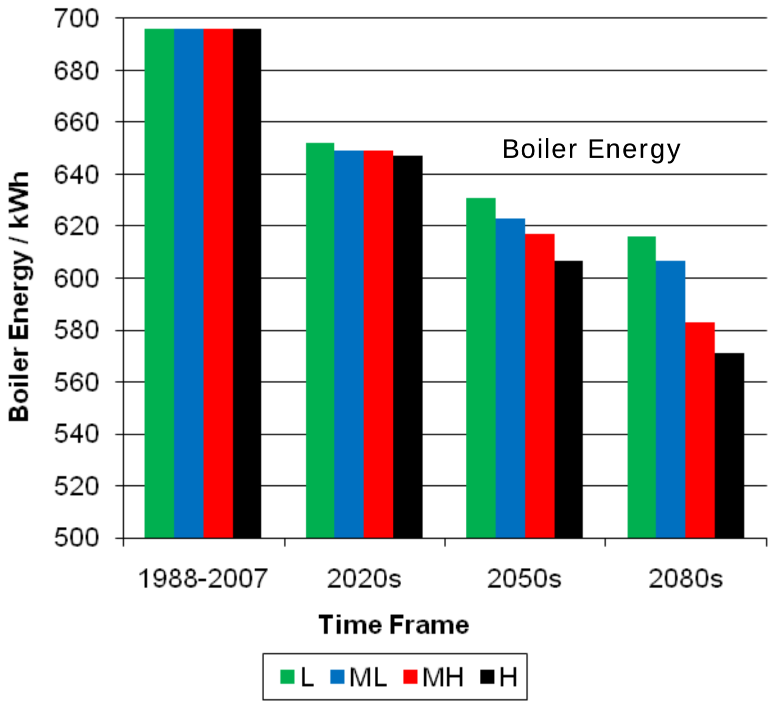
Overheating Results

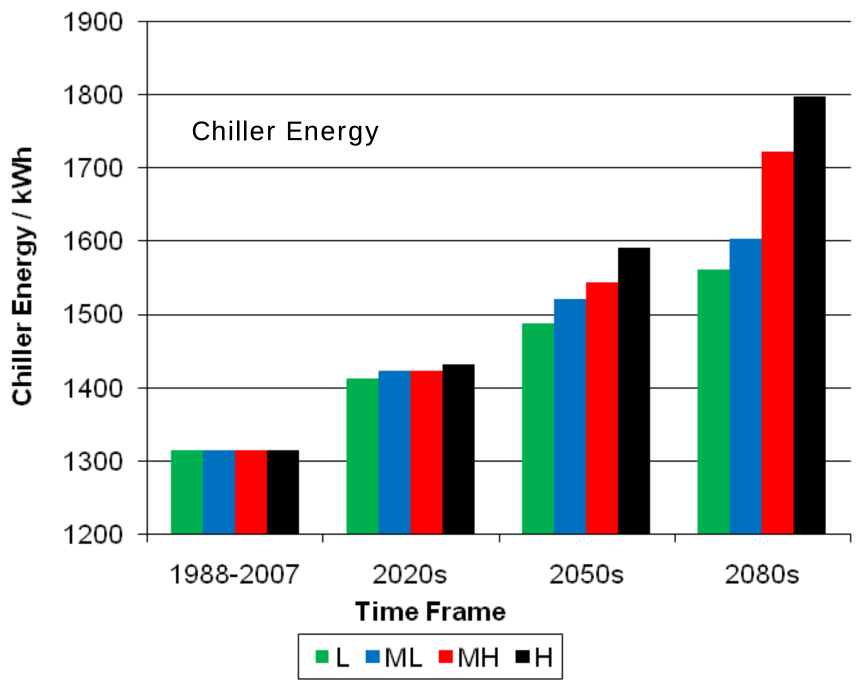


Energy Demand

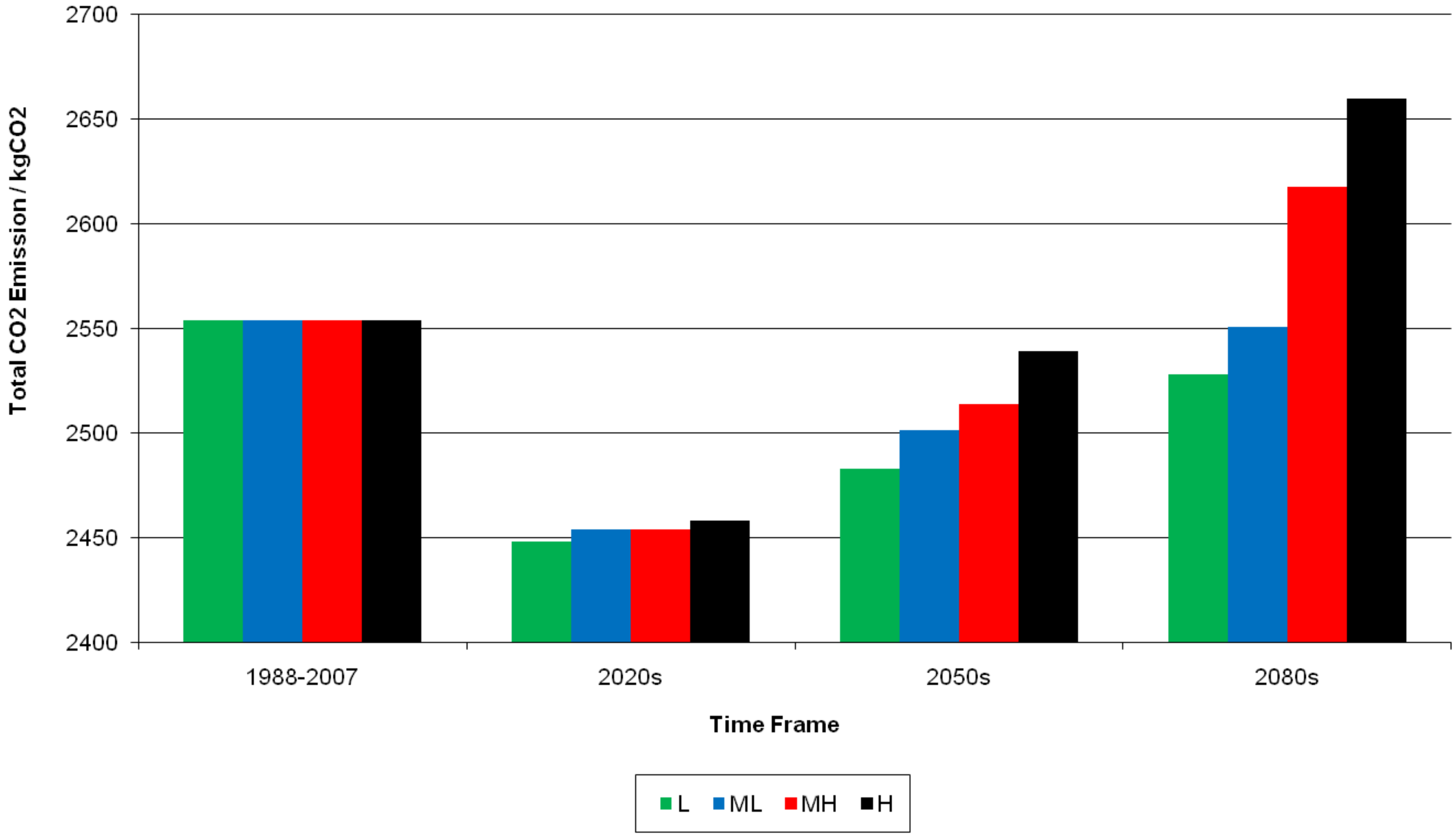
- Heat generation efficiency 92.00%
- Heat delivery efficiency 93.92%
- Total heating system efficiency 86.41%

- Cooling generation efficiency 300%
- Cooling delivery efficiency 99%
- Heat rejection fan and pump power 10%
- Total cooling system efficiency 212%





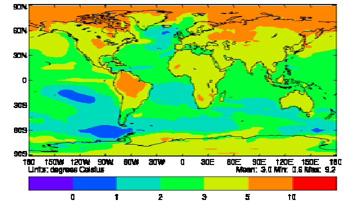
CO_2 Emission

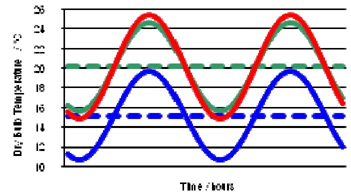


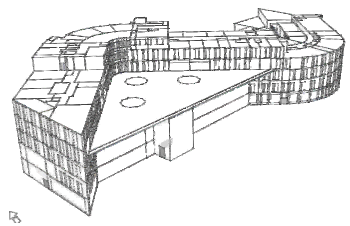
Conclusions

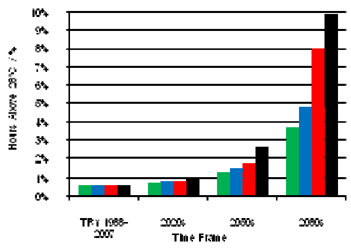
- Cooling demand dominates over longer life spans
- Overheating risk is of concern
- Reference to UKCIP 2009 data is needed
- Requirement for move to life cycle thinking

Sustainable design of lower carbon buildings in a changing climate









Creating balanced environments