Using Future Climate Data in PHPP

A step-by-step guide to obtaining predicted climate data from the UK Climate Impacts Programme UKCP-09 datasets and formatting it for use in the Passiv Haus Planning Package.
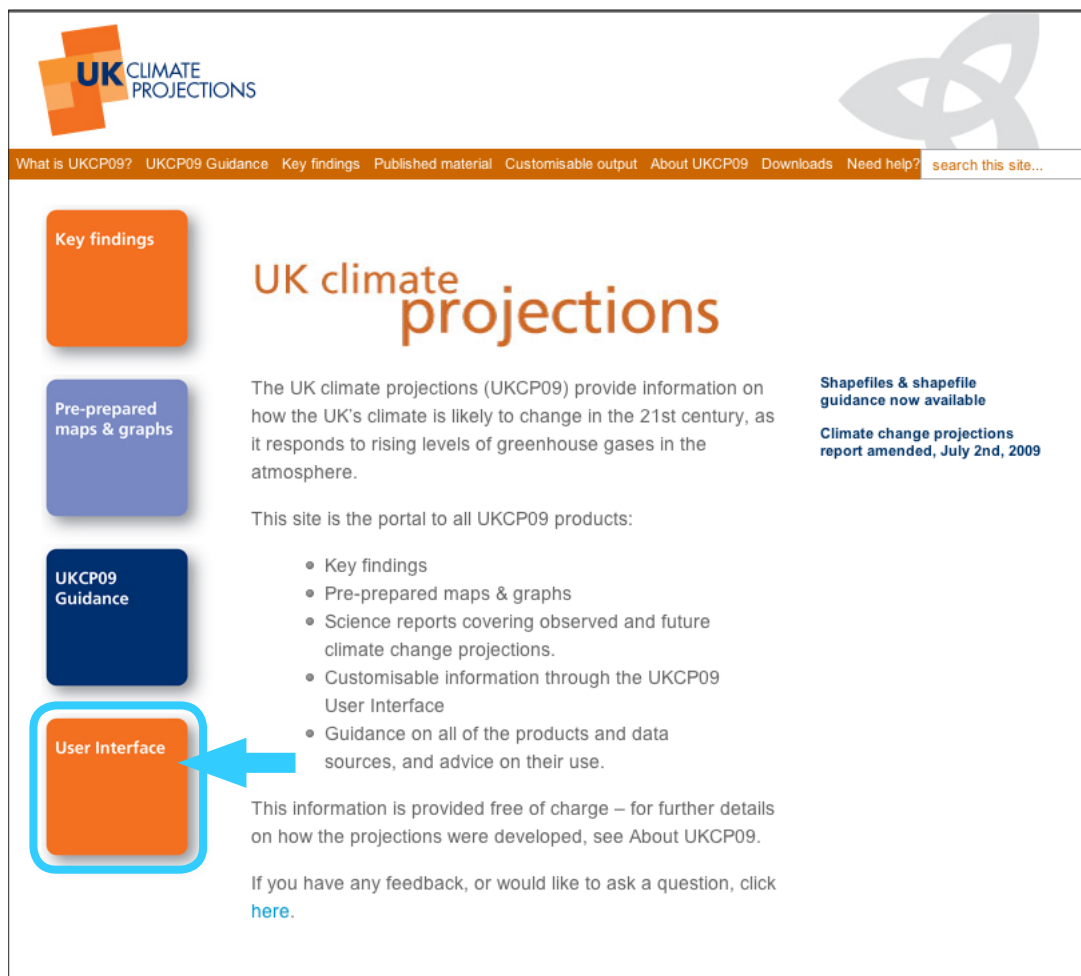
David Edwards, david.mi.edwards@gmail.com
University of East London
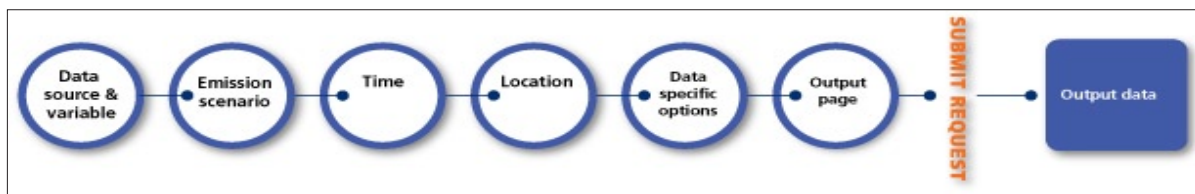
UKCP09: The User Interface

Climate data can be accessed from the UKCP-09 technical website:

http://ukclimateprojections.defra.gov.uk/

To select and download climate data click the *"User Interface"* facility. After clicking here you will be prompted to login or register. Registration is free.

UKCP09: Navigating the User Interface

There is a choice of different "pathways" through the user interface to select the data that is required. Navigating the interface according to the example illustrated here resulted in the output data being delivered in a format most suitable to import into PHPP.

Choice of route and data source

Firstly the route *"by selecting Data source"* is chosen and then the data source, which is *"UK Probabilistic Projections of Climate Change over Land"*.

Starting point for my request

- ● Start a new request
  - ● by selecting Data source **i**
  - ○ by selecting a Climate variable **i**
  - ○ by selecting a UK location **i**
- ○ Resume last saved request (see req

Selecting your data source

- ● UK Probabilistic Projections of Climate Change over Land **i**
- ○ UK Probabilistic Projections of Climate Change over Marine Regions **i**
- ○ Weather Generator Simulations **i**
- ○ Past and Future Multi-level Ocean Model Simulations for UK Waters **i**
- ○ Projections of Trend in Storm Surge for UK Waters **i**
- ○ Projections of Sea Level Rise for UK Waters **i**

Climate Change Type

"Future Absolute Climate Values", are used because actual temperatures are needed for PHPP and not the change in temperature.

Climate Change Type

- ○ Future Climate Change Only **i**
- ● Future Absolute Climate Values **i**

Variable

The variable selected here is *Mean temperature*. Maximum and minimum temperatures would be of interest but cannot currently be used in PHPP.

Variable

- ☑ Mean temperature (°C) **i**
- ☐ Mean daily maximum temperature (°C) **i**
- ☐ Mean daily minimum temperature (°C) **i**
- ☐ Precipitation (mm/day) **i**
- ☐ Mean sea level pressure (hPa) **i**
- ☐ Total cloud (%) **i**
- ☐ Relative humidity (%) **i**

Emissions Scenario

Multiple scenarios can be selected in one request, but in this example only *"Medium"* emissions is selected for simplicity.

Emissions Scenario

- ☐ Low **i**
- ☑ Medium **i**
- ☐ High **i**

Time Selections page

Time Period
Here the *"2040s"* time period has been selected. This is a shorthand for the 30 year period covering 2030 to 2059. 30 years is the standard frame of reference in climatology for distinguishing long-term trends in "climate" from short-term fluctuations in "weather". So the data obtained will be a prediction of the 30-year long term average for that period.
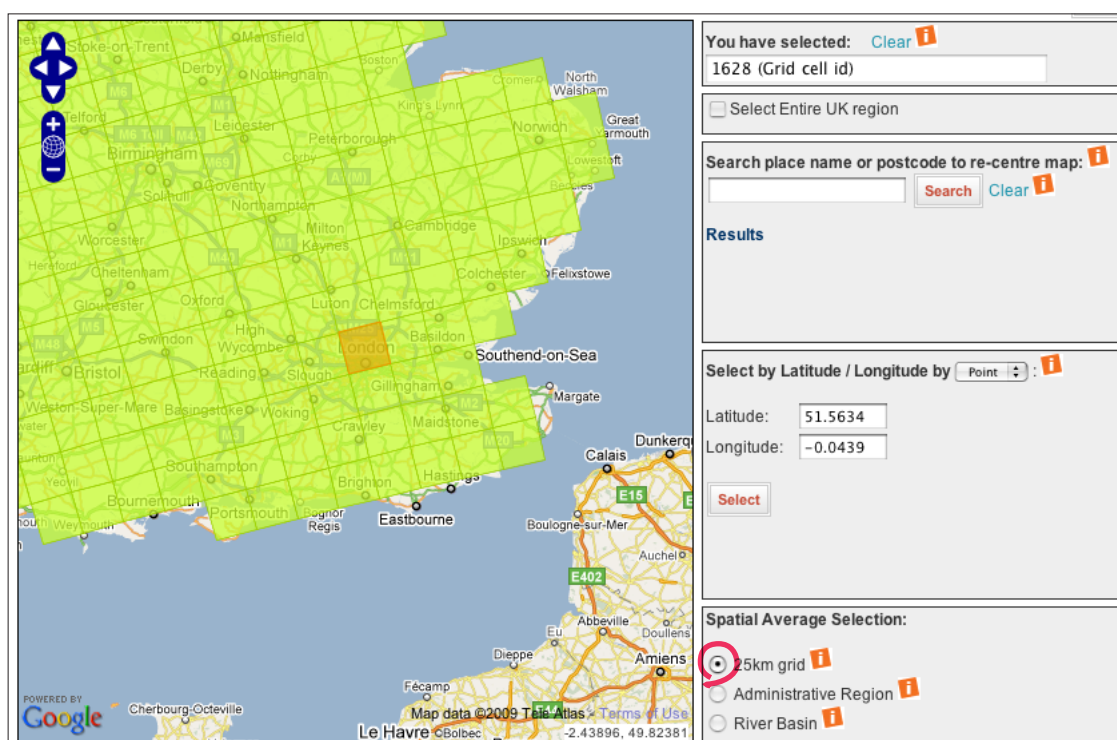

Temporal Averages
Monthly temperature data is required for PHPP. In this example each month is selected in a separate data request (so for two different time periods this will result in 2 x 12 = 24 separate data requests). This might seem quite cumbersome, but it means less processing of the data will be required later on.

Location
The location can be selected by simply clicking on the map, entering a placename, a postcode or grid reference. For the *"Future Absolute Climate Values"* dataset (as chosen earlier) the data is only available in 25km grid squares. For other datasets it is available by administrative areas.

Data options (sampled data)

If several months were selected in one request this option would appear next. Only the *"Sampled data"* option is available. Following this route is only suitable for those with a good understanding of statistical methods.

Type of probabilistic projection data

- ○ CDF data **i**
- ⦿ Sampled data **i**

Sampling method

- ○ Select All **i**
- ○ Random sampling of model variants **i**
- ○ Select a specific set of model variants **i**
- ○ Sampling a particular sub-set of the probabilities **i**

Data options (CDF data)

If only one month is selected on each request, the *"CDF data"* (Cumulative Distribution Function) option is available. This will deliver a range of predicted temperatures against their cumulative probability of occurring.

Type of probabilistic projection data

- ⦿ CDF data **i**
- ○ Sampled data **i**

Data output

Depending on the choices made this page may appear next. Select *"Raw data"* to generate a *CSV* file (Comma Separated Value) which can be opened by most spreadsheet applications.

Output Type

- ○ Map **i**
- ⦿ Raw Data **i**
- ○ Joint Probability Plot **i**
- ○ Plume Plot **i**
- ○ Return Periods Plot **i**
- ○ Cumulative distribution function (CDF) **i**
- ○ Probability density function (PDF) **i**

Select the Output Format of your data file(s)

- ⦿ CSV **i**
- ○ CF-netCDF **i**
- ○ Shapefile **i**

UKCP09: Preparing Data for PHPP

Opening the data files

The content of the downloaded data files from UKCP09 will look something like this. Here row 62 has been enlarged to make the column headings visible. The second column gives the cumulative probability of each temperature occurring. The header of the file (rows 0 - 61 here) gives details of your request parameters, so it is useful to keep as a record of what was requested.

57	Additional UKC	References = Murphy; J.M.; B. B. B. Booth; M. Co
58	Additional UKC	A methodology for probabilistic predictions of regio
59	Additional UKC	Phil. Trans. R. Soc. A; 365; 1993-2028.
60	Additional UKC	Source = Probabilistic climate prediction based on
61	Additional UKC	HadRM3 and HadSM3; plus climate models from o

62	Additional UKCP09 information 22	cumulative distribution function	Mean air temperature at 1.5m for Emissions Scenario A1B (degC)
63	Data section	0.1	2.983
64	Data section	0.25	3.281
65	Data section	0.5	3.531
66	Data section	0.75	3.685
67	Data section	1	3.795
68	Data section	2	4.071
69	Data section	3	4.25
70	Data section	4	4.384

Monthly summary

In the example here the temperature data columns were cut & pasted to a new spreadsheet with data from each month. Significant rows (**10%**, **33%**, **50%**, **67%** and **90%** cumulative probabilities) have been highlighted here to illustrate the statistical range of the values. On the right some of the middle rows have been removed so the wide range of predicted temperature values is legible.

For the purposes of this model, the temperature values from the **50%** row were used. Statistically, this is known as the "central estimate"; it shou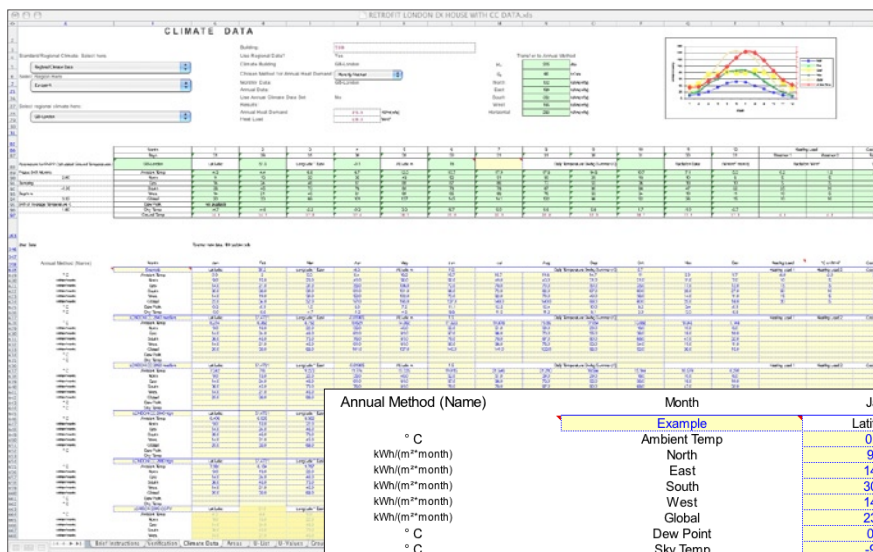ld not be thought of as the "most likely", but is equally likely as it is unlikely that the mean temperature will be up to this level.

80	Additional UKCP09 information	cumulative distribution function	Mean air temperature at 1.5m for Emissions Scenario A1B "Medium" (deg			
81			January	February	March	April	May
82	Data section	0.1	2.983	3.477	5.944	8.371	11.7
83	Data section	0.25	3.281	3.764	6.159	8.572	11.953
84	Data section	0.5	3.531	3.997	6.33	8.736	12.158
85	Data section	0.75	3.685	4.138	6.434	8.838	12.283
86	Data section	1	3.795	4.239	6.51	8.912	12.375
87	Data section	2	4.071	4.493	6.701	9.103	12.607
88	Data section	3	4.25	4.654	6.823	9.225	12.753
89	Data section	4	4.384	4.775	6.915	9.318	12.863
90	Data section	5	4.493	4.873	6.989	9.393	12.951
91	Data section	6	4.585	4.954	7.053	9.458	13.027
92	Data section	7	4.666	5.027	7.108	9.515	13.093
93	Data section	8	4.737	5.09	7.158	9.565	13.152
94	Data section	9	4.803	5.148	7.204	9.612	13.206
95	Data section	10	4.863	5.202	7.245	9.655	13.255
96	Data section	33	5.736	5.96	7.856	10.282	13.972
97	Data section	50	6.214	6.362	8.192	10.629	14.362
98	Data section	67	6.716	6.776	8.542	10.996	14.767
99	Data section	90	7.771	7.616	9.271	11.772	15.608
100	Data section	91	7.851	7.678	9.327	11.831	15.671
101	Data section	92	7.94	7.747	9.388	11.895	15.74
102	Data section	93	8.038	7.823	9.457	11.966	15.818
103	Data section	94	8.151	7.909	9.535	12.047	15.906
104	Data section	95	8.281	8.008	9.627	12.141	16.009
105	Data section	96	8.439	8.127	9.738	12.253	16.132
106	Data section	97	8.64	8.276	9.879	12.395	16.288
107	Data section	98	8.926	8.478	10.074	12.588	16.5
108	Data section	99	9.358	8.798	10.385	12.89	16.845
109	Data section	99.25	9.561	8.929	10.52	13.013	16.985
110	Data section	99.5	9.866	9.116	10.722	13.19	17.183
111	Data section	99.75	10.376	9.43	11.054	13.49	17.506
112	Data section	99.9	10.975	9.821	11.437	13.867	17.893

It is important to remember that these are 30-year averages phf mean temperature, not day to day temperatures. Some predictions suggest that short-term fluctuations in temperature are likely to become more extreme as global weather systems become more chaotic. Therefore, short localised periods of extreme cold are not contra-indicative of a general trend of so-named "global warming".

PHPP: Importing Climate Change Data

The central estimate data values from the previous step provide a single row of temperatures, by month, which can easily be imported into PHPP.

This is the "Climate Data" sheet in PHPP. The custom climate data has been inserted into the yellow area labelled "user data".

Annual Method (Name)		Month	Jan	Feb	Mar	Apr
		Example	Latitude:	50.2	Longitude ° East	-8.3
° C		Ambient Temp	0.9	2	5.3	8.4
kWh/(m²*month)		North	9.0	15.0	23.0	41.0
kWh/(m²*month)		East	14.0	21.0	31.0	55.0
kWh/(m²*month)		South	30.0	33.0	39.0	61.0
kWh/(m²*month)		West	14.0	19.0	30.0	52.0
kWh/(m²*month)		Global	23.0	34.0	52.0	97.0
° C		Dew Point	0.3	-0.9	1.5	3.0
° C		Sky Temp	-9.0	-8.6	-4.7	-1.2
		LONDON CC 2040 medium	Latitude:	51.4721	Longitude ° East	-0.81865
° C		Ambient Temp	6.214	6.362	8.192	10.629
kWh/(m²*month)		North	9.0	13.0	22.0	35.0
kWh/(m²*month)		East	14.0	24.0	46.0	61.0
kWh/(m²*month)		South	36.0	45.0	73.0	76.0
kWh/(m²*month)		West	14.0	21.0	45.0	61.0
kWh/(m²*month)		Global	20.0	33.0	68.0	101.0
° C		Dew Point				
° C		Sky Temp				
		LONDON CC 2080 medium	Latitude:	51.4721	Longitude ° East	-0.81865
° C		Ambient Temp	7.242	7.6	9.223	11.774
				13.0	22.0	35.0
				24.0	46.0	61.0
				45.0	73.0	76.0
				21.0	45.0	61.0
				33.0	68.0	101.0
				51.4721	Longitude ° East	-0.81865
				8.525	8.382	10.868
				13.0	22.0	35.0
				24.0	46.0	61.0
				45.0	73.0	76.0
				21.0	45.0	61.0

	Additional UKCP09 information	cumulative distribution function	January	February	March	April	May	
81								
93	Data section	8	4.737	5.09	7.158	9.565	13.152	
94	Data section	9	4.803	5.148	7.204	9.612	13.206	
95	Data section	10	4.863	5.202	7.245	9.655	13.255	
96	Data section	33	5.736	5.96	7.856	10.282	13.972	
97	Data section	50	6.214	6.362	8.192	10.629	14.362	
98	Data section	67	6.716	6.776	8.542	10.996	14.767	
99	Data section	90	7.771	7.616	9.271	11.772	15.608	
100	Data section	91	7.851	7.678	9.327	11.831	15.671	

The figures are simply cut and pasted from the monthly summary spreadsheet seen in the previous slides into the "Ambient Temperature" row.

The incident solar radiation figures in the rows labelled "North", "South", "East", "West" and "Global" are copied from the standard PHPP climate data for the location. The amount of solar radiation recieved is mainly dependant on the sun-path which is a function of global position and is therefore not affected by climate change.

A climate data set could be created in PHPP for each of the emissions scenarios, time periods or even different probability ranges.

PHPP: Switching between scenarios

To use the different climate scenarios in the PHPP model, we use the drop-down menus at the top left of the "Climate Data" worksheet.

The second drop-down menu *Select Region Here* is set to *"User Data"*.

The user-defined climate scenarios should now be available from the third drop-down menu.

Now it is possible to switch quickly between the different climate scenarios and the data will automatically update throughout the model:
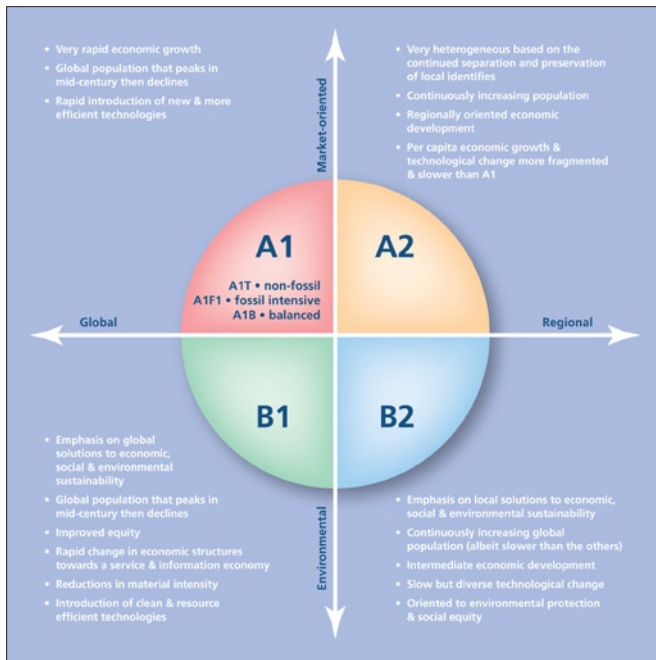

Month	1	2	3	4	5	6	7	8	9	10	11	12
Days	31	28	31	30	31	30	31	31	30	31	30	31
LONDON 2009 COPY	Latitude:	51.5	Longitude ° East	-0.1	Altitude m	2		Daily Temp Swing Summer (K)			Radiation Data:	kWh/(m²
Ambient Temp	4.3	4.4	6.8	8.7	12.3	15.7	17.9	17.6	14.6	10.7	7.1	5.3

Month	1	2	3	4	5	6	7	8	9	10	11	
Days	31	28	31	30	31	30	31	31	30	31	30	
LONDON CC 2040 medium	Latitude:	51.5	Longitude ° East	-0.8	Altitude m	2		Daily Temp Swing Summer (K)			Radiation Data:	kWh
Ambient Temp	6.2	6.4	8.2	10.6	14.4	17.5	19.9	19.6	17.1	13.9	9.3	
North	9	13	22	35	48	52	51	39	29	18	10	

Month	1	2	3	4	5	6	7	8	9	10	11	
Days	31	28	31	30	31	30	31	31	30	31	30	
LONDON CC 2080 high	Latitude:	51.5	Longitude ° East	-0.8	Altitude m	2		Daily Temp Swing Summer (K)			Radiation Data:	
Ambient Temp	8.0	8.2	9.8	12.7	16.7	19.9	22.9	22.2	19.5	15.9	11.2	
North	9	13	22	35	48	52	51	39	29	18	10	
East	14	24	46	61	81	87	86	73	55	36	18	
South	36	45	73	76	81	78	78	87	80	68	47	
West	14	21	45	61	81	85	86	76	53	34	19	
Global	20	33	45	68	101	137	145	141	122	86	28	
Dew Point	not available											
Sky Temp	-1.0	-0.8	0.8	3.7	7.7	10.9	13.9	13.2	10.5	6.9	2.2	
Ground Temp	17.9	17.8	18.1	18.8	22.4	23.2	23.7	23.8	23.5	22.8	19.2	

For convenience, we can also add a copy of the scenario control to the "Verification" worksheet so the changes in the results can be observed as the scenario is switched.

Building:	TSB						
Location and Climate:	London	LONDON CC 2080 high			No Standard Climate	LONDON CC 2080 high	
Street:	42 Wolfe Crescent						
Postcode/City:	London						
Country:	UK						
Building Type:	semi detatched						
Home Owner(s) / Client(s):							
Street:							
Postcode/City:							
Architect:	LBA				Calculation Electricity / Internal Heat Gains		
Street:							
Postcode/City:					Building Type:	Residential	
Mechanical System:							
Street:					Internal Heat Gains		
Postcode/City:					Utilisation Pattern:	Dwelling	
Year of Construction:	1920						
Number of Dwelling Units:	1	Interior Temperature:	21.0	°C	Type of Values Used:	Standard	
Enclosed Volume Vₑ:	281.9	m³	Internal Heat Gains:	2.1	W/m²		
Number of Occupants:	3.1				Planned Number of Occupants:		
					5	Verification	
...ands with Reference to the Treated Floor Area							
Treated Floor Area:	108.4	m²			Verification:	Monthly Method	

	Applied:		Monthly Method		PH Certificate:		Fulfilled?	Verification:	Monthly Method
Specific Space Heat Demand:	9	kWh/(m²a)		15 kWh/(m²a)		Yes		Specific Space Heat Demand, Annual Method	
Pressurization Test Result:	0.6	h⁻¹		0.6 h⁻¹		Yes		Specific Space Heat Demand, Monthly Method	
Specific Primary Energy Demand g, Cooling, Auxiliary and Household Electricity):	72	kWh/(m²a)		120 kWh/(m²a)		Yes			
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	33	kWh/(m²a)							
Specific Primary Energy Demand Energy Conservation by Solar Electricity:	-1	kWh/(m²a)							
Heating Load:	12	W/m²							
Frequency of Overheating:	23	%	over	25 °C					
pecific Useful Cooling Energy Demand:		kWh/(m²a)		15 kWh/(m²a)					
Cooling Load:	7	W/m²							

Emissions scenarios - background information

IPCC - SRES storylines

The range of climate scenarios modelled by the Hadley Centre and provided in UKCP09 is based on the internationally agreed IPCC SRES '"storylines". These storylines describe different patterns for economic growth, population change and technological advances. They reflect tensions between global and regional scale policies and environmental or market-orientated behaviour. All of these factors can affect the rate of global carbon emissions.
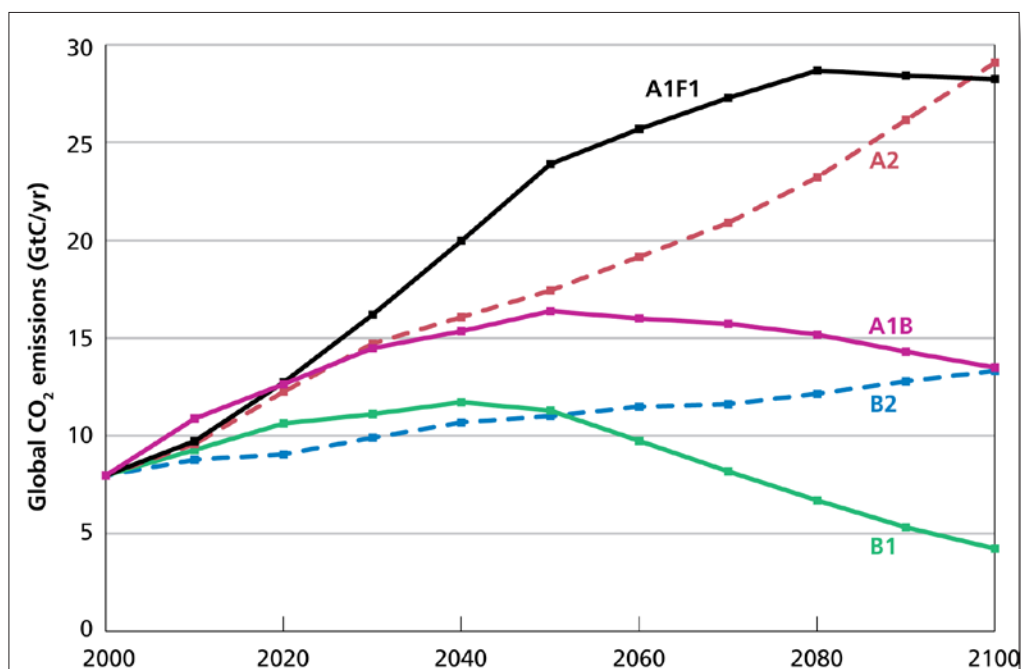
UKCP-09 emissions scenarios

The three storylines used in UKCP09 and their expected impact on global carbon emissions are:

SRES B1 storyline: "low" emissions - emissions are expected to peak around 2040 then steadily decline.

SRES A1B storyline: "medium" emissions - emissions are expected to peak in the mid 21st century then gradually decline.

SRES A1FI storyline: "high" emissions - emissions are expected to continue to rise at an increasing rate until levelling off towards the end of the 21st century.

Further considerations
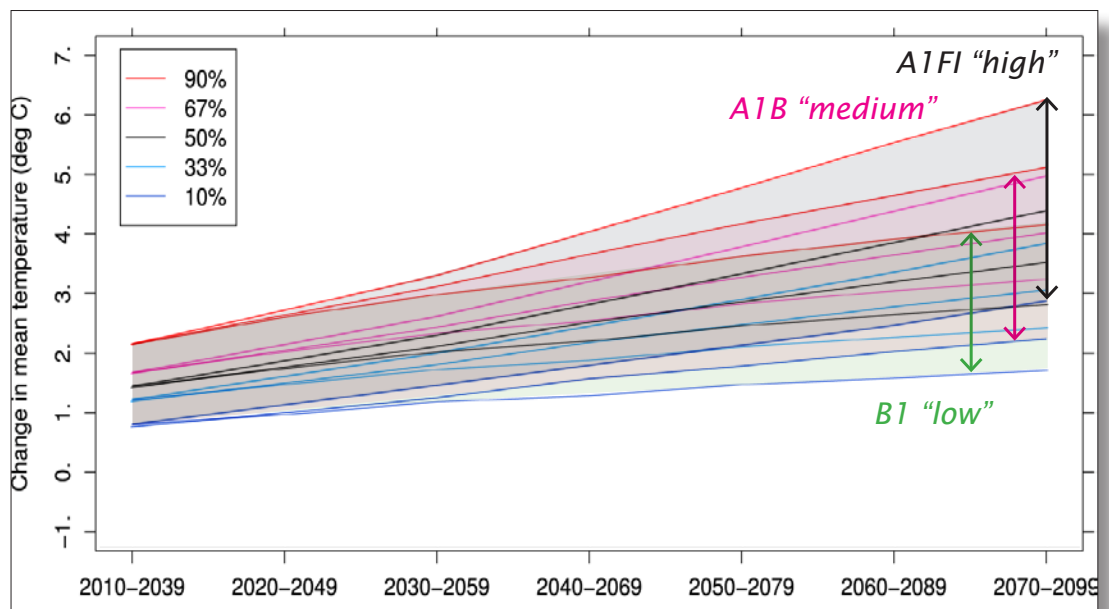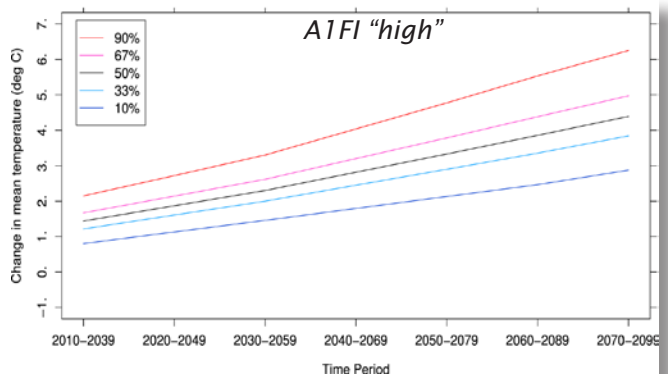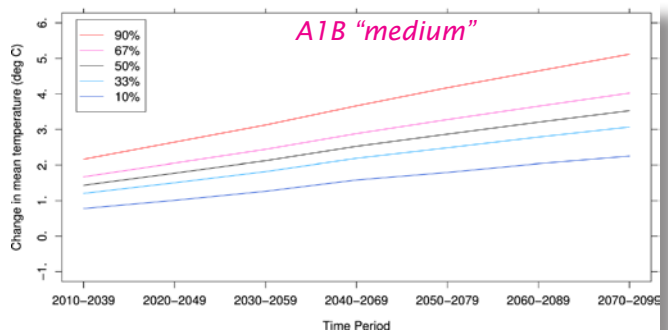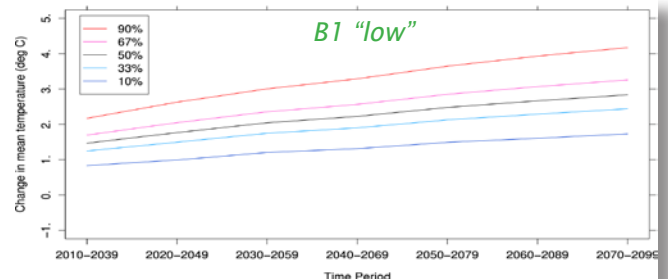
Statistical variance and accuracy

For each of the emissions scenarios, time periods and climate variables in UKCP09 a full range of probabilities is available to account for uncertainties in the modelling method. It can be seen below that there is considerable overlap between the probability ranges of each emissions scenario. The likelihood of each temperature occurring is presented as a Cumulative Distribution Function.

"A CDF is useful to show the probability of climate change being less than some threshold where an impact of interest starts to occur."

Therefore it is "highly likely" that mean temperature values will fall in the range up to 90% on the CDF and "highly unlikely" they will be in the top 10% range which shows the most extreme change. Conversely, it is "highly unlikely" that mean temperatures will be in the bottom 10% range which predicts a temperature change of less than 2°C by the 2080s.

The 90% line of the CDF for the A1FI high emissions scenario shows a temperature change of over 6°C by the 2080s, whereas the 50% (central estimate) shows a 3.5°C change for the same period. In the high emissions scenario it can be seen that the range of variance is much wider, i.e. the predictability of the climate is much lower.

If we are to use PHPP as a tool to design-in resilience to extremes of climate change, then it may be more appropriate to use the extreme (but unlikely) climate change scenario for the 2080s period as the "worst case" scenario (A1FI high emissions, 90% sample).

Baseline data

For convenience, the built-in PHPP data for London was used as the baseline in this example. The Met Office have now released historical climate data (up to 2006) which is organised on the same 25km grid to match the UKCP09 data. In climate science the period 1961-1990 is generally used as the reference period, so it would be more scientifically correct to use this dataset as the baseline. Access to this dataset requires registration.

Other climate variables

This example has only focussed on ambient air-temperature, which it is assumed will have the most direct effect on building energy use and is straightforward to import into PHPP.
Other climate variables are available from UKCP09, such as predictions for relative humidity, cloud cover and others. Using other climate variables could improve the detail of the model, for example with relative humidity data dew point temperatures could potentially be calculated.

Sources

UKCP-09 technical website - disemination of data:
http://ukclimateprojections.defra.gov.uk/

Historical climate data:
http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/

Background information and publications:
http://www.ukcip.org.uk

DEFRA (2009) *Adapting to Climate Change: UK Climate Predictions*

Jenkins, G.J., Perry, M.C., & Prior, M.J. (2008) The climate of the United Kingdom and recent trends. Met Office Hadley Centre, Exeter, UK.

Jenkins, G. J. et al (2009) *UK Climate Projections: Briefing report*. Met Office Hadley Centre, Exeter, UK. Available to download from ukclimateprojections.defra.gov.uk

Murphy, J.M. et al (2009), *UK Climate Projections Science Report: Climate change projections*. Met Office Hadley Centre, Exeter.