UNIVERSITY OF EXETER

PROMETHEUS

The Use of Probabilistic Climate Change Data to Future-Proof Design Decisions in the Building Sector

The project

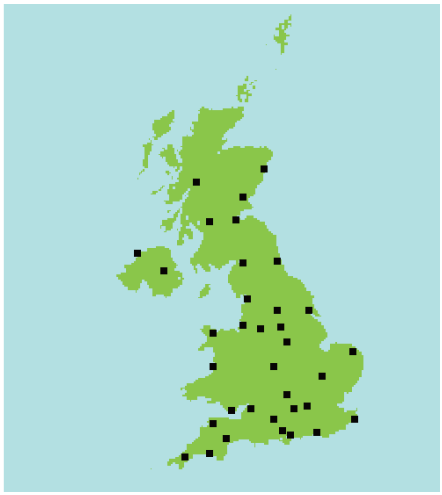
Predicted temperature rises as a result of climate change are large enough to cause buildings to fail building regulations and to become places of discomfort for occupants. This could have an adverse impact on human health, particularly for the elderly in high summer. For buildings to be considered truly sustainable, they need to be resilient to climate change. And in order to produce designs for sustainable buildings on a daily basis, architects and engineers need to be able to model the effects of climate change on buildings using standardised, consistent sets of weather data.

Based at the University of Exeter's Centre for Energy and the Environment, PROMETHEUS is a project funded by the Engineering and Physical Sciences Research Council aimed at helping the building sector adapt to the challenges of climate change through the provision of freely available, probabilistic weather files. The project belongs to the Adaptation & Resilience in a Changing Climate (ARCC) Coordination Network.

Background

The UK Climate Projections 2009 (UKCP09) present an opportunity not only for building simulation experts and architects and their clients, but for society as a whole. Unlike the previous climate data (UKCIP02) produced by the UK Climate Impacts Programme, the UKCP09 projections are probabilistic, providing a range of future climate scenarios which allow users to assess the level of risk according to a specific building design.

Crucially, they allow designers to conduct a cost-benefit analysis of architectural/structural design alternatives to minimise the risk of building failure in the face of climate change.



Locations currently served by PROMETHEUS

The PROMETHEUS weather files

The PROMETHEUS project has created a methodology for the creation of probabilistic reference weather years using UKCP09. These weather files are downloadable free of charge from the project website: www.exeter.ac.uk/cee/prometheus. The files cover 35 locations across the UK. The weather files for each set consist of two emissions scenarios (medium and high), three time slices (2030s, 2050s, 2080s) and five percentiles referring to the severity of the potential climate change (10%, 33%, 50%, 66%, 90%).

The weather files are presented in the .epw weather format, which is compatible with most building performance simulation programmes. Both test reference years and design summer years are provided to enable overheating and energy performance calculations.

Case Studies

The PROMETHEUS weather files are being used by the UK's leading engineering and architectural firms to test the resilience of their building designs to climate change for projects totalling £1.8 billion, including schools, hospitals and an eco-town. The designers of the following four building projects consulted the PROMETHEUS data.

Dolcoath Offices, Cornwall County Council

Project overview

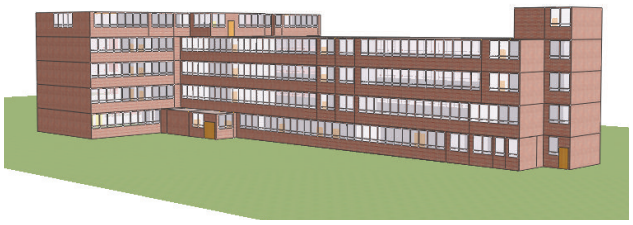
Cornwall County Council is seeking to reallocate staff from 78 buildings to just 30 through the refurbishment of three existing buildings and the construction of one new building. The £4m project, based on a 1960s concrete frame T-shaped building with an inside area of 4,800m^2 over four floors, calls for a major rethink of office layout and working conditions.

The need for adaptation

The aim of the refurbishment is to create a contemporary office environment that can accommodate a marked increase in occupation density. Adaptation strategies were chosen, based on the PROMETHEUS data, to allow for an increase in internal gains, while limiting the potential for overheating without the use of active cooling. Large open-plan office spaces were recommended to offer a more modern working environment and the potential for cross ventilation. Increasing the exposure of the thermal mass was found to limit overheating by using perimeter gaps on suspended ceilings. Reducing solar gains through the installation of solar films on south-facing windows improved thermal comfort inside the offices.

Conclusions

The adaptation strategies delivered significant improvements to the building design prior to refurbishment. The hours of overheating (>25°C) were limited to 78 hours in the current climate and 342 hours according to the worst-case climate change scenario in 2050. A provision for night cooling during the summer would further lower these figures.



Montgomery School, Devon County Council

Project overview

The UK's first 'zero carbon in use' school, Montgomery Primary School is being funded by Devon County Council, with an additional award from the Zero Carbon Task Force. The total budget is approximately £9m. The school is also aiming for Passivhaus accreditation.

The need for adaptation

The school will exist in its current form for at least 60 years and a commitment has been made to ensure it can cope with likely climate change through to 2080. When considering the school's Passivhaus aspirations, it was decided that a heavyweight structure was best suited to withstanding the effects of climate change. This will give the school a high thermal mass, which will mediate internal temperatures in both hot and cold conditions. To reduce solar gain, all south-facing windows were shaded to allow only diffuse light to enter the rooms. The building is also raised above ground level as it is situated on a flood plain.

Conclusions

Initial studies have shown that the adaptation strategies can comfortably limit overheating under a changing climate. The PROMETHEUS files informed the design process from the beginning and highlighted the factors that need the most careful consideration during any value engineering.

MyPlace Youth and Community Centre, London

Project overview

A £4.7m project to build a youth and community centre located in London with a total floor area of 1,800m^2. The project designers intend to create a zero carbon building with a BREEAM rating of at least 'very good' with aspirations of 'outstanding'.

The need for adaptation

Given the environmental sustainability focus, it was crucial to evaluate how sustainable the building would be in 2050. The PROMETHEUS data showed that areas with large internal heat gains, such as the proposed IT hub, would be susceptible to overheating. The adaptation strategies that were subsequently considered included increasing solar shading and the solar reflectivity of the roof, removing sun pipes and increasing roof insulation. Other recommendations were the introduction of night cooling, increasing the thermal mass of the building envelope and the replacement of glazing with polycarbonate around the entrance. These measures were predicted to increase the cost by a maximum of 7.6%.

Conclusions

Recommendations based on the PROMETHEUS files would result in improvements under current conditions and under climate change. However, the adaptation strategies did not fully mitigate against overheating, suggesting that changing the building shape, orientation and internal planning would help to adapt the building further.

Leeds Arena, Leeds

Project overview

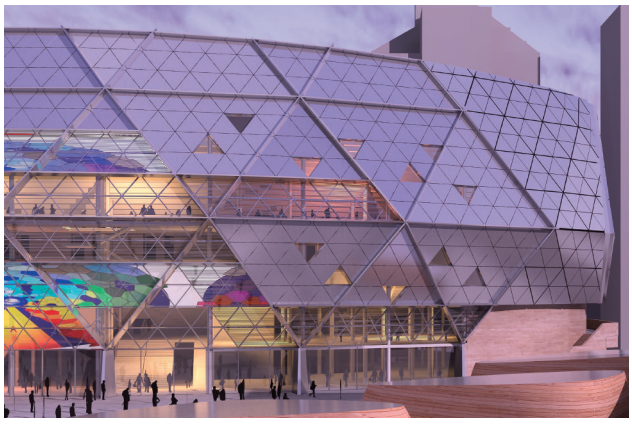
A £55m project to build a 12,000-capacity arena to host entertainment and sporting events. The building will cover 26,100m^2 over five stories.

The need for adaptation

The building is intended to set a benchmark for sustainable arenas, with features such as air source heat pumps and rainwater harvesting. The building has to be completely sealed for acoustic reasons and is therefore fully air conditioned. The high density of occupants during events could cause problems during current heat waves. As a result, adaptation strategies that were considered included increasing wall and roof insulation, as well as the solar reflectivity of the roof. It was also recommended that 15% of the roof could be opened for night cooling and more efficient lighting could be installed. These measures were predicted to increase the cost by a maximum of 4.5%.

Conclusions

Results showed that, in the current climate, the adaptation strategies would reduce the proportion of occupied hours during which the internal temperature exceeded 28°C from 1.5% to zero. When tested under the upper end of climate change in 2050, the occupied hours over 28°C fell from 9.3% to 2.6%. The introduction of night cooling was found to exert the most significant impact and could be retrofitted at any stage quite easily.



Climate and Weather

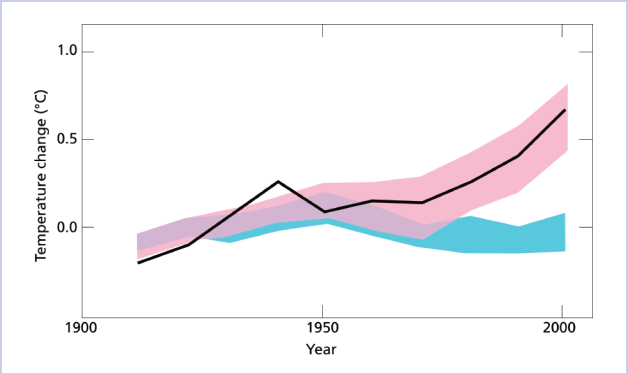
Recent temperature trends

Global warming is unequivocal. Average temperatures have increased by 0.8°C since the late 19th century. The ten warmest years on record have all been since 1995. In the UK, temperatures have increased by about 1°C. The mean annual temperature difference between London and Nice is only 5°C and predictions show that the average temperature of the UK in 2050 will only be 2.5°C less than Nice's current temperature.

The recent changes in temperature have been caused by both natural – for example changes in output from the sun and volcanic eruptions – and man-made factors. Numerous models have demonstrated with a greater than 90% confidence that the recent rises could not be due to natural causes alone.

Recent climate models

Uncertainty in climate models has long been a major headache for those planning to adapt the built environment to climate change. Overcompensating for climate change could waste money. Fortunately, recent climate models have been used to capture this uncertainty by including the natural climate variability, modelling uncertainty and future emissions. This uncertainty is presented as probabilistic climate change projections. These projections give the relative likelihood of different future outcomes for key climatic variables such as temperature and rainfall.



Projections

Global temperatures are projected to increase between 2.8°C and 4°C this century. In the UK, mean temperatures are projected to increase by 4.2°C in southern England and 2.5°C in the Scottish islands by 2080.

Weather not climate

Although most projections are presented in terms of the climate, it is the weather that has the biggest impact on buildings and people. Climate change will lead to maximum temperatures much hotter than we have ever experienced in the UK. For example, the heat wave of 2003, which resulted in about 35,000 deaths across Europe, is considered a one-in-a-thousand-year event in the current climate. By 2040 these temperatures are expected to constitute an average summer and could even be regarded as relatively cool by 2080.

The UKCP09 weather generator

To predict the impacts of climate change, the UK Climate Impacts Programme produced a weather generator to construct synthetic hourly time series for a number of climatic variables. The weather generator has a resolution of 5km, which allows for changes in topography and distance from the sea to be taken into account and reflects the fact that an upland region experiences different weather to a nearby coastal region.

This marks a huge improvement on the weather files currently used by engineers to model buildings – the current files only cover 14 UK locations The tool has been used to produce synthetic weather up to 2080 for use in the thermal modelling of buildings.

Left: Comparison of observed (black line) and modelled changes in temperatures using only natural forcing (blue) and natural plus man-made forcing (pink).

Download free weather files from www.exeter.ac.uk/cee/prometheus

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