BUILDING EMISSIONS

Female thermal demand

The temperature in many office buildings is set according to a method from the 1960s. Consideration of the different metabolic rates of male and females is necessary to increase comfort and reduce energy consumption.

Joost van Hoof

Gender inequalities are increasingly being exposed. But many of us are surrounded by one such discrepancy much of the time without even knowing it — thermal comfort standards in office buildings. Changing the way buildings are heated and cooled to account for gender differences could significantly cut energy consumption, and ultimately reduce greenhouse gas emissions. In this issue of *Nature Climate Change*, Boris Kingma and Wouter van Marken Lichtenbelt[1] show that current comfort models intrinsically misrepresent female thermal demand, and consequently add bias to predictions of the energy consumption of office buildings.

Current standards dictate the thermal indoor climate based on the prediction and evaluation of thermal comfort[2,3]. These regulations specify comfort zones in which a large percentage of occupants with given personal parameters will regard the environment as acceptable. These standards rely on the predicted mean vote (PMV) model[4], a method prescribed for evaluating whole-body thermal comfort, developed by Danish researcher P. Ole Fanger. The model's outcome parameter of comfort is the PMV, which is expressed on a seven-point scale of thermal sensation, ranging from cold (−3) to hot (+3).

In the 1960s, Fanger[4] carried out a series of experiments to investigate the effects of individual differences on thermal comfort levels. From these studies, Fanger concluded that the neutral temperature of a large group of people was independent of many parameters including gender, although it was found that women were more sensitive than men to fluctuations in the optimum temperature.

Kingma and van Marken Lichtenbelt's research adds to recent literature further exploring gender differences in thermal comfort. For instance, a comparison of the actual and predicted mean votes by Parsons[5] showed that for cool conditions (PMV = −2), women tended to feel significantly cooler than men, and the women's responses were close to the PMV. Parsons concluded that for identical clothing and activity, there are few gender differences in thermal comfort responses for neutral and slightly warm conditions, although women tend to be cooler than men in cool conditions.

The metabolic rates of male and females mean they feel comfortable at different temperatures. Setting office temperatures according to standards that account for this difference could cut energy consumption and reduce greenhouse gas emissions.

In Japan, Nakano and colleagues[6] found gender differences in the neutral temperature among multinational office workers. They found that the neutral temperature for Japanese women was 25.2 °C, whereas it was 3.1 °C lower for European and North American men under the same conditions. In a Finnish study by Karjalainen[7], women were less satisfied with room temperatures, preferred higher room temperatures, and felt both uncomfortably cold and uncomfortably hot more often than men.

Recent work by Schellen *et al.*[8,9] shows that under equal non-uniform conditions, women are significantly more uncomfortable and dissatisfied than men. They found that significantly lower skin temperatures of hands and underarms in the participating women could explain the differences in thermal comfort between genders. Schellen and colleagues were the first to show the effects of physical differences — that is, lower local skin temperatures — between genders on local and whole-body thermal comfort.

So far, however, these findings have not led to distinctions between men and women in the design of buildings and building services, including heating, ventilation and air-conditioning systems, that account for thermal comfort. Kingma and van Marken Lichtenbelt[1] call for an adjustment of the current metabolic standard in thermal comfort standards by including the actual values for women. In addition, they say that thermal comfort models need to be either recalibrated or enhanced using a biophysical approach.

They show that the mean skin temperature and thermal environment of young adult women performing light office work falls within their thermoneutral zone when the true metabolic rate is used, whereas current practice dictates the use of standardized tables. This, in turn, may lead to more comfortable and better estimated thermal conditions, and a lower energy consumption in summer, as less cooling capacity may be required for female office workers. The biophysical approach would enable the study of thermal comfort for specific subpopulations or individuals.

This would, in practice, mean that building services engineers have to abandon their current practice of applying the PMV model which was based on tests with approximately 1,300 students mainly engaged in sedentary activity and represents a mean comfort prediction for groups.

Kingma and van Marken Lichtenbelt[1] say that an accurate representation of the thermal demand of all occupants leads to real energy savings for buildings that are designed and operated by the buildings services community. The effects on energy consumption of increasing the design indoor temperature will become greater over time as climate change leads to increased outdoor temperatures, requiring more intense cooling of buildings. Apart from saving energy, the improved comfort of both male and female office workers may improve productivity in some of their tasks[10].

These findings could be significant for the next round of revisions of thermal comfort standards — which are on a constant cycle of revision and public review — because of the opportunities to improve the comfort of office workers and the potential for reducing energy consumption.

Although Kingma and van Marken Lichtenbelt[1] provide concrete clues for practice and consistency in the direction of change in standards, the overall study samples of the work they build on are small. A large-scale re-evaluation in field studies may be needed in order to sufficiently convince real-estate developers, standard committees and building services engineers to revise their practices. In addition, the building services community needs to come up with solutions for dealing with different preferences in practice, for instance with the emergence of individualized micro-climatization systems. ❐

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EARTH SYSTEM MODELLING

Restoration of the oceans

Undoing the effects of continuing high carbon dioxide emissions on the oceans could take centuries, if it is possible at all.

Richard Matear and Andrew Lenton

Evidence is mounting that the climate is changing because of rising atmospheric carbon dioxide[1] with the potential that global warming and ocean acidification may significantly harm the ocean environment and the ecosystem services we depend on[2]. In the absence of a global agreement to limit emissions, all options must be considered to minimize these potential impacts[1]. Carbon dioxide removal (CDR), which requires the capture and storage of atmospheric carbon, is one potential technological solution to help mitigate high atmospheric carbon dioxide. Writing in *Nature Climate Change*, Sabine Mathesius and colleagues explore the ability of CDR to mitigate global warming and ocean acidification[3]. Although the thought of deliberately manipulating the climate by CDR may be unpalatable to many, it is necessary that such options be evaluated to enable informed choices of the viable ways to tackle our carbon dioxide problem.

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The study by Mathesius *et al.*[3] explores whether CDR under high CO_2 emissions can achieve an environmental outcome similar to a rapid transition to low-carbon energy use (that is, the Representative Concentration Pathway (RCP) 2.6 scenario). For their reference simulation with CDR they use the 'business as usual' high carbon emissions scenario (RCP8.5 extended[4]) from the present day to 2700. They show, consistent with other computer simulations, that under such a scenario the ocean environment will undergo substantial changes. By the year 2500, the global surface ocean warms by more than 5 °C and the global surface pH declines by more than 0.6 units from the pre-industrial values. Such large changes in the ocean