The Windsor Conferences in Context

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Abstract: The context of the eleven Windsor Conferences on thermal comfort is set within two horizons. The first is that of the long history of the building regulations our civilisations have invented to control the living and working conditions of it citizens over time. Over centuries these have been gradually moulded by shifts in the demographic, social, economic and political structures of nations. Regulations were also changed rapidly by extreme events like plagues, fires, floods or extreme storms. The second, shorter, horizon is that of the unprecedented pace of change that has shaped all our lives since the first Windsor Conference in 1994. Important stepping stones that have occurred in the intervening years are outlined, and in light of the step changes experienced in those twenty-six years, key lessons are reviewed. It is then proposed that the current system of developing international and national standards are changed in order to be Fit for Purpose in the very different world we live in, in our heating world.

Keywords: Comfort, Adaptation, Resilience, Affordability, Climate Change

1. Comfort: The Long View

Why exactly are we interested in Thermal Comfort? Essentially, because the temperatures people occupy in their living and working lives can have an enormous effect on the physical and mental health, well-being and productivity of individuals, societies, economies and entire political systems. The extent to which societies experience, or avoid, thermal stress is an under-recognised attribute of their own, overall, success.

What role does politics play in shaping the thermal conditions experienced by populations? '*Civilisation'* is commonly measured, in part, by the level of control held by the centre, over its civilians, through the activities of its armed or active services, or through judicial controls like regulations. The COVID-19 pandemic has clearly shown us how national control responses to such a threat range widely from 'troops on the streets' to optimistic 'social conditioning' strategies, from a spectrum of regimes ranging from Totalitarian states to Liberal Democracies. The impacts of political choices made on the outcomes of COVID outbreaks in different countries are now being measured in mortalities on one hand, and money on the other. Political decisions are demonstrably arrived at using a balance, on which the health and well-being of a population weighs down one end, and the health of an economy, and the Status Quo of the financial and political interests that prop it up, the other. The cry of *Quis custodiet ipsos custodies* sounds out now, as it has done through the centuries: *Who guards the guardians*? Because the answer to that question ultimately determines which way that balance swings.

Since earliest records, we see building regulations being used to manage contemporaneous priorities in successive civilisations. The Babylonia *Code of Hammurabi*, carved into a stone stele in around 1754 BC[i], proclaimed that the law of 'an eye for an eye' -

'a life for a life' - would be applied to builders and their upper class clients, while a mere silver coin was required to be paid out for the death of a worker. The laws of Rome and Byzantium largely dealt with land ownership and its infringements, keeping the moneyed urban classes managed and controlled. The 6th century AD *Institutes of Justinian*[ii] still underpin much of modern Western property law today showing that still to be a priority.

For three millennia the European legal system evolved slowly, gaining pace as cities expanded rapidly with increasing trade and the industrial revolution, resulting in ever more crowded settlements and new work settings that fed the need for new regulations to protect the health of the working classes, and the wealth of those who benefitted from their labour.

An early example of urban regulation in Britain was the 12th century London *Assize of Building,* that dealt largely with disputes between neighbours, and remained little changed until the 15th century when Dick Whittington was Mayor. What changed it then?

The flea born, bacterial pandemic, Bubonic Plague, arrived in London in 1347 and continued to intermittently infect its citizens for the next three and a half centuries. It culminated in The Great Plague, an outbreak in 1665-66 that killed an estimated 100,000 Londoners within 18 months, almost a quarter of the population. New ordinances dealt with the risk of fire, and disease emanating from unsanitary timber framed, thatched roofed buildings with wattle and daub walls, ideal breeding grounds for vermin such as rats and mice on which the plague bearing fees could thrive. Citizens were ordered to build in cleaner brick with tiled roofs, but the temptation, as always, was to build cheaply as possible. It was not until after the Great Fire of London in 1666[iii] that the London building codes were fully revised, and then rigorously enforced to require solid Party Walls between all buildings[iv].

The Plague had petered out by the end of the 17th century, by which time it had killed around a third of Europe's population, and led to a heightened awareness of the high costs of uncleanliness. Tougher sanitary enforcement resulted across Europe. There grew a great fear of health effects of the *miasma*[v], the great stink, manifested in outbreaks of fetid air. Health boards and local government adopted rigorous control of street cleaning and the disposal of dead bodies, opened public baths and regulated water supply and maintenance.

By the early 1700s Scientists began to look in detail at the constituents of air, its toxicity, and the *effects of air on human bodies*[vi]. Over the next century, assisted by the growth of analytical medicine, work began on the thermo-regulatory systems of the body with a pioneering publication in 1814 by John Davey on his experiments on body heat[vii].

By the 19th century, novel and often expensive engineering approaches were being built by trade-rich nations to systematically improve the outdoor street environments and air within cities through better ventilation, drainage, street cleaning, clean water supply, and the burial of garbage[viii]. For those within buildings three approaches were applied to the effort to decrease indoor air pollution, and improve the thermal comfort of occupants.

The first was to improve open fire, boiler and stove efficiencies and create efficient water based heat circulations systems within buildings. The second was to develop more advanced internal natural ventilation systems to exclude and expel indoor air pollution, and manage the movement of heat and coolth around buildings. As commercial and government buildings grew ever larger, so did the need for, and sophistication of, these systems in the increasingly factory littered, and open-fire heated, cities of Europe and America[ix].

The third was to fast track the design of climatically better buildings to enhance indoor thermal comfort, notably across suburban America. Between 1850 and 1950, and often building on the design knowledge from their native lands, or the experiences garnered from three centuries of European colonisation of lands with unfamiliar climates, immigrants from

Europe rapidly evolved a new vernacular vocabulary of climatically, and locally, appropriate buildings forms and construction practices, across the sub-continent. Shading and ventilation strategies, and the thermal landscaping[x] of the rooms within a building, were key to the ability of occupants to make and keep themselves affordably cool, or warm, at different times of day, and different seasons of the year in the very different climates across America[xi].

The early 20th century also saw an explosion of research into the thermal conditions of building occupants in relation to their ventilation[xii], heating and cooling systems[xiii], and health in buildings[xiv]. Mill and factory workers were at high risk of ill-health and early death, and so became the focus of pioneering studies published in 1929[xv], 1926[xvi] and 1929[xvii] by bodies like the Industrial Research Boards on Fatigue and Health in London. The deaths of soldiers on military parade grounds[xviii], and workers in factories[xix] and deep mines[xx] sparked many studies examining the physiological limits of heat stress at work.

Children were always seen as a key cohort for investigation because of their physiology, immaturity and vulnerability[xxi]. The Elderly were not of particular interest to early comfort researchers, possibly because there were fewer of them, or perhaps because they had a short life expectancy then anyway. Hospital patients were another vulnerable group of particular interest, with research accelerated by the rapid development of new treatment approaches, for instance for Tuberculosis, and new approaches to hospital design[xxii].

Figure 1. Cover of the Aerologist Magazine, December 1931 showing the Crossroads of comfort, with either / or choices of ways to go, giving no possibilities of having both AC and Natural Ventilation together in the sales pitch. The fight was on to either keep the windows open or closed. Closed won! (Source: the cover of Gail Cooper, 1998).

2. Mechanical Comfort

By the middle of the 20th century America had careered, headlong, into the air-conditioning age. Dirty outside air could be shut out, filtered, heated or cooled and even humidified to provide healthy and comfortable indoor conditions. The technology was expensive, and was initially installed in high value buildings in the Roaring 1920s when people flocked to air-conditioned hotels, bars, cinemas, banks and shops for the 'Zest' delivered from machines and ducts, in places that encouraged people in America to spend, spend, spend[xxiii]. In offices and factories, sales of air-conditioning systems were fueled by promises of more *productivity,* and reduction of waste in produced products[xxiv]. It also had a less wholesome backstory, founded in the work of American 'climate determinists' on the early 20th century like Ellsworth Huntington who claimed that white men exposed to very hot conditions would inevitably be reduced to nothing more than backward natives[xxv], an incentive to spend, then, indeed.

By the 1950s the increasingly affluent middle classes were being sold the dream that their hard work should also bring them enhanced *Quality of Life* in their own air-conditioned (AC) homes. Some were even being persuaded they no longer needed opening windows, but could rely on AC for comfort 24/7/365[xxvi]. The multiple benefits of having climatically appropriate buildings went out the window. They were no longer needed. Comfort research in the last half of the 20th century was largely dominated by the drive to refine the language, and technologies that described and produced thermal comfort as a product deliverable as air from machines via ducts and vents. Increasingly architects were persuaded that windows had to be fixed shut to make the AC Dream, the American Dream, happen 'efficiently'.

Figure 2. The air-conditioned dream, and possibly an argument about the thermal settings of the AC or the cost of the bill for it? She, in her attractive dress, is obviously cold with folded arms, while he, in his wool suit, is more relaxed, unconcerned about conserving body heat (Source: www.gottman.com).

Related research in the last half of the 20th Century was largely done in laboratories in the US and Europe. It was aimed at providing clear evidence for the best temperature settings for thermostats, adjusted to ensure that as few people as possible complained about their thermal environment, and that productivity levels remained high. The numbers needed by engineers supplying, fitting and servicing the machines needed to be simple enough to be

understood and correctly applied. Much effort, and expensive lobbying, went into writing very simple temperatures into national and international standards. Where once AC managers were advised by ASHVE (later ASHRAE) to adapt the settings to the local climate and conditions over the year, as shown in Figure 3, the industry then moved to requiring and promoting fewer, less flexible settings. Thermostat temperatures were typically changed from summer to winter settings on fixed dates, regardless of the weather outdoors, and sometimes not changed at all. This use of the same comfort temperature all year, or season, relies on the proven ability of buildings occupants to adapt to the experienced indoor temperatures provided, largely by using clothing choices, where permitted. Such inflexible thermostat setting regimes not only often lead to discomfort, but also to energy wastage.

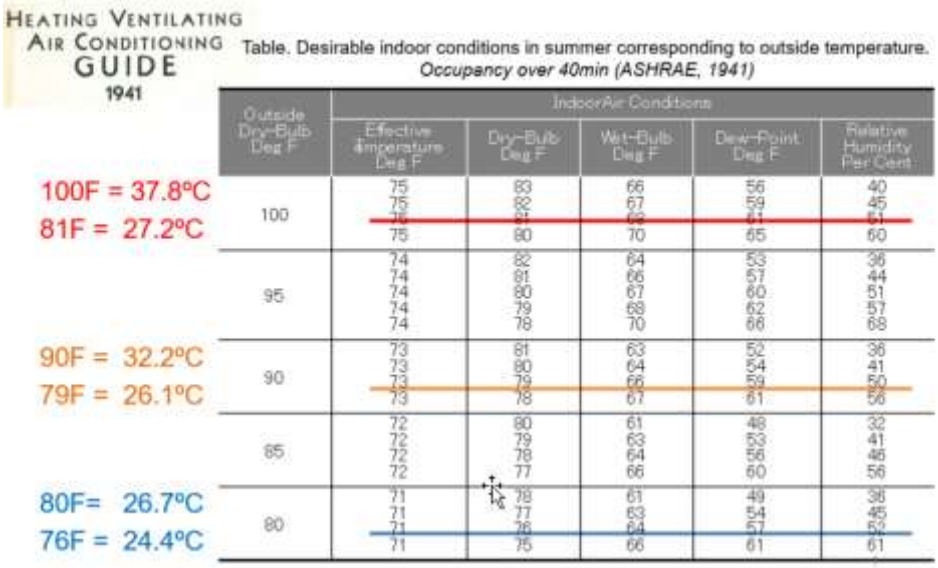
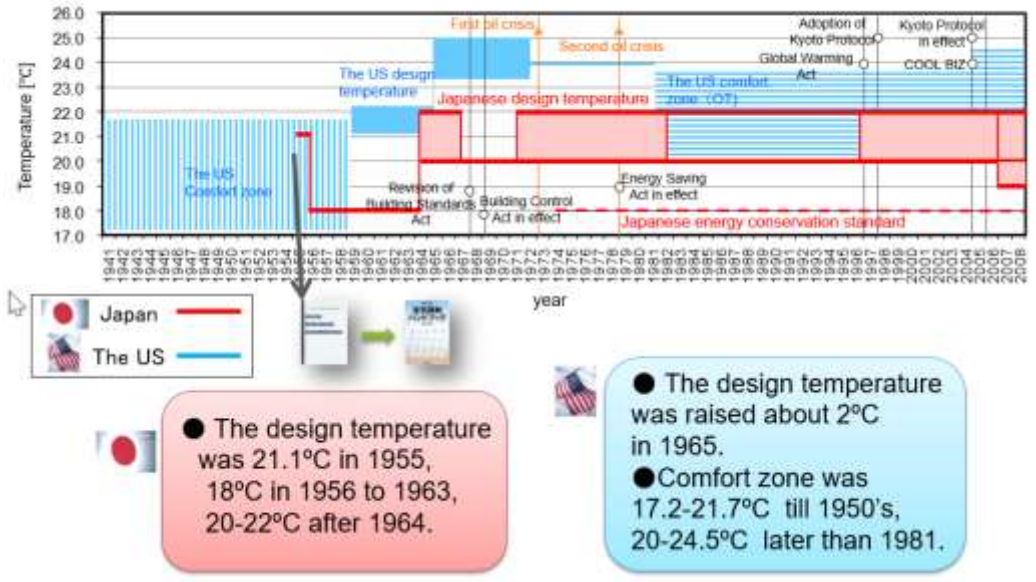

HEATING VENTILATING
AIR CONDITIONING
GUIDE
1941

Table. Desirable indoor conditions in summer corresponding to outside temperature.
Occupancy over 40min (ASHRAE, 1941)

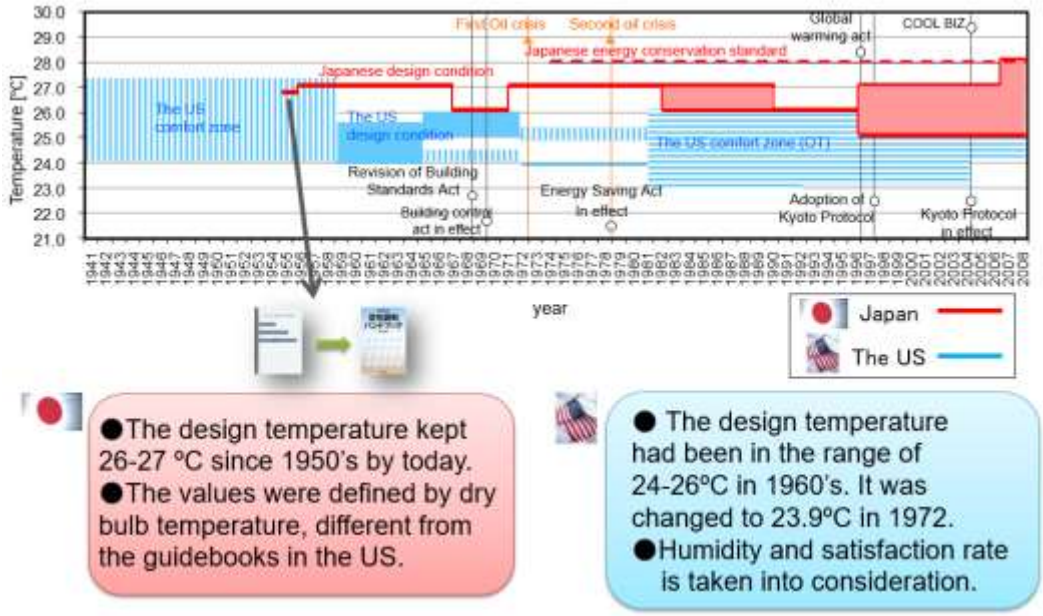
Outside Dry-Bulb Deg F	Indoor Air Conditions				
	Effective Temperature Deg F	Dry-Bulb Deg F	Wet-Bulb Deg F	Dew-Point Deg F	Relative Humidity Per Cent
100	75	83	66	56	40
	75	82	67	59	45
	75	81	68	61	51
	75	80	70	65	60
95	74	82	64	53	36
	74	81	66	57	44
	74	80	67	60	51
	74	79	68	62	57
	74	78	70	66	68
90	73	81	63	52	36
	73	80	64	54	41
	73	79	66	59	50
	73	78	67	61	56
85	72	80	61	48	32
	72	79	63	53	41
	72	78	64	56	46
	72	77	66	60	56
80	71	78	61	49	36
	71	77	63	54	45
	71	76	64	57	52
	71	75	66	61	61

Figure 3. The 1941 American ASHVE Guide on desirable indoor summer temperatures. These were recommended to track the outdoor temperatures, to be manually adjusted at the building level to adapt to the weather conditions locally (Source: Professor Shinichi Tanabe[xxvii]).

Comfort standards were not immune from political pressures, and Figure 4 shows how standards over time have been amenable to alteration as a result of geo-political 'events'. The comfort zones in the US and japan are shown to have moved over time between 17^0C and 28^0C for acceptable winter and summer settings. Step changes in the standards notably happen suddenly as the result of major global shocks like an Oil Crisis, Climate Change imperatives and accidents like the Fukushima nuclear disaster in Japan. However, at any one time the actual acceptable temperature limits allowed by the standards can be as narrow as one or two degrees. Obviously, such narrow comfort zones are only achievable in summer in fully air-conditioned buildings, with the windows closed. Building design has been hugely affected by the premise that there is a single comfort temperature, or zone. This thinking validates the 'International Style' of architecture, in which the building is almost irrelevant and HVAC systems can be used from the steppes of Siberia, to the desert cities of the Gulf States, with the same comfort zones applied to the controls. Exemplified by hugely energy profligate, glass, steel and concrete structures[xxviii], such building types were born in the fossil fuel and nuclear ages, when people were promised that energy in the future would be 'too cheap to meter'. Energy from non-renewable sources now becomes more environmentally costly year on year, and it's devastating emissions are on a fair way to destroying the global climate. Things had to change, and the Windsor Conferences have informed that change.



a)



b)

Figure 4. Comparison between the recommended a) Winter and b) Summer indoor temperatures in the Japanese (Red) and US (Blue) Standards (Source: Shinichi Tanabe, Tanabe Laboratory, WASEDA University, Japan[xxix]).

By the early 1990s it was widely believed, and promoted, that Ole Fanger's steady-state heat balance equation method[xxx] involving Predicted Mean Votes (PMV) and Predicted Percent Dissatisfied (PPD) could be used without modification, anywhere in the world. This global scope was further reinforced by the inclusion of PMV/ PPD in various comfort standards, most notably ISO 7730 (1984) and ASHRAE 55-1992, lending the model an authority that HVAC engineers, and others responsible for delivering thermal comfort inside buildings, strongly needed in an increasingly litigious age[xxxi]. There is no doubt that the very limited range of temperatures allowed for indoors in such standards (c. 20^0C-26^0C) can be relied upon to be relatively safely adapted to, even by populations to whom such

temperatures may be alien, but the cost in heating up, or cooling down, whole buildings to the narrow comfort bands prescribed by the standards, was being increasingly questioned.

3. Adaptive Comfort

In parallel to the PMV and laboratory research, a small group of researchers based at the Building Research Establishment (BRE) outside London were quietly working on a different approach to comfort. Building on the pioneering thermal research done in outposts of the British Empire in the very different climates of Australia[xxxii], Singapore, Iraq and India, they were looking at the temperatures occupied by real people in the homes and offices they lived and worked in[xxxiii],[xxxiv]. The first international conference dedicated to Thermal Comfort was held at the BRE in 1972[xxxv] when Fergus Nicol and Michael Humphreys[xxxvi] showed for the first time their graph demonstrating the huge range of temperatures found to be acceptably comfortable by adapted populations in different climates, to a noticeably incredulous audience. They suggested that thermal comfort was part of a feed-back system which helped maintain the thermal balance of bodies with their occupied environment.

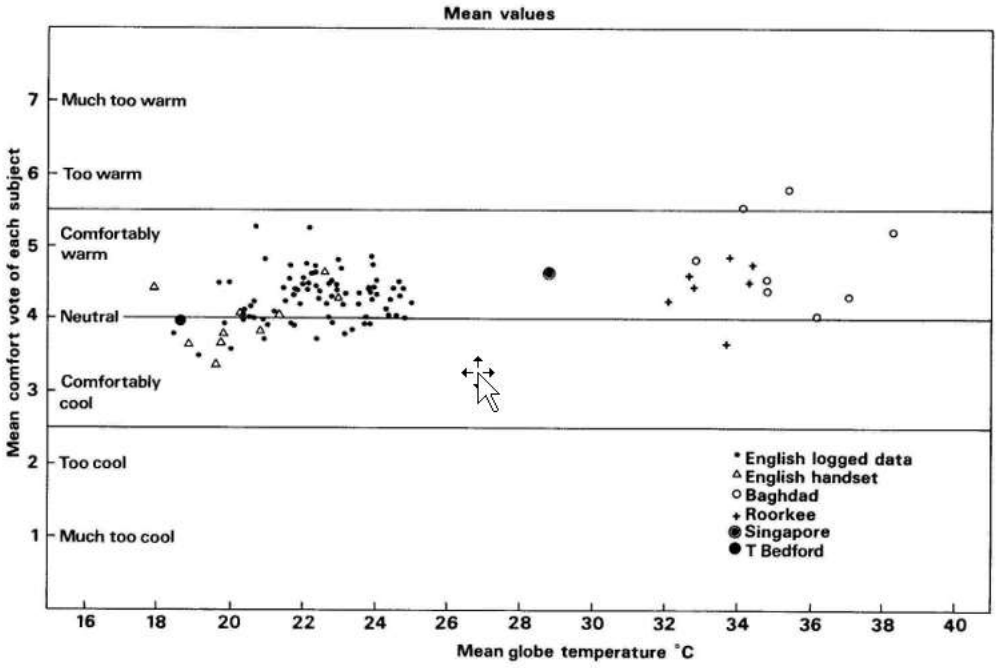


Fig. 8. Monthly mean comfort votes including data from various sources

Figure 5. This influential diagram showing the wide spread of comfort votes in surveys from different cultures and climates was shown at the 1972 conference at the BRE (Source: Nicol and Humphreys, 1973).

Humphreys went on in 1978 to propose the link between outdoor temperatures and indoor comfort[xxxvii] which has informed so much of the subsequent work on adaptive comfort and related standards. This conference really marked the beginning of what has become known as adaptive thermal comfort, and underpinned its founding premise that:

If change occurs such as to produce discomfort, people react in ways which tend to restore their comfort.

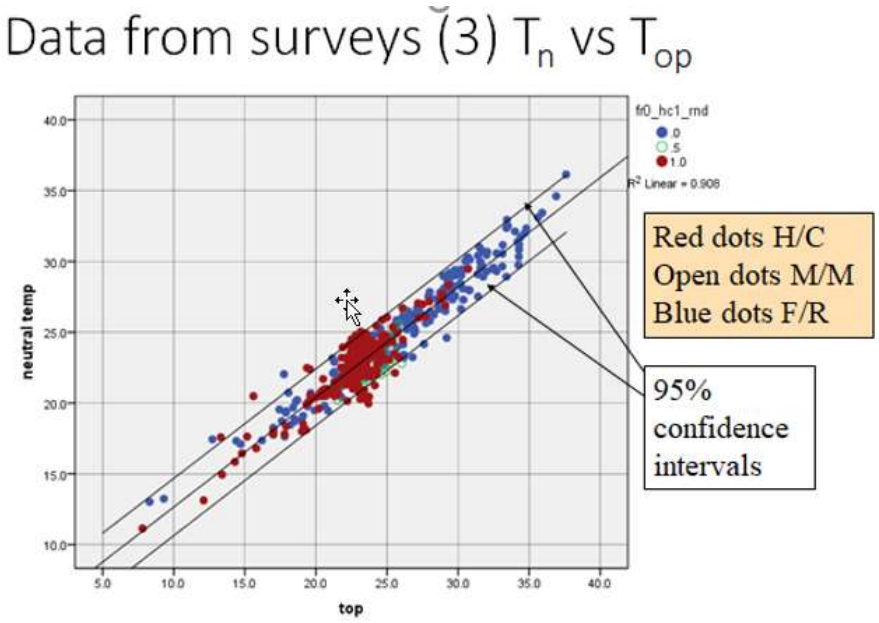


Figure 6. Neutral temperatures and the mean operative temperatures (top) for buildings operating in (blue) Natural Ventilation (FR) mode; Mixed Mode (open points) and (red) in Heating or Cooling modes. (Based on Humphreys et al., 2013[xxxviii]).

By the late 1970s both Michael Humphreys and Fergus Nicol, had retired from the field to pursue other careers. Meanwhile excellent work on adaptive comfort was carried forward by Andris Auliciems and Richard de Dear in Australia[xxxix] and Gail Brager and Ed Arens at the University of California, Berkeley.

Twenty-one years after the first conference, in June 1993 Nigel Oseland and Gary Raw hosted a second international conference at the BRE on 'Thermal comfort: past, present and future'[xl]. There proved to be a healthy interest in the subject, and a number of interesting papers were submitted and published in the proceedings of the event, with only a few on the subject of adaptive thermal comfort. A notable exception was the paper by Richard de Dear using ASHRAE-sponsored research to show how laboratory-based comfort models were unreliable in naturally ventilated buildings.

Climate Change was becoming a global concern, not least in the spotlight of the Rio Conference on the Environment in 1992. Greenhouse gas emissions became the focus of research and legislation, just as the fashion for ever more highly glazed and serviced buildings exploded, despite the fact they were clearly shown to emit the most greenhouse gases of any building type[xli]. London, for instance, had few air-conditioned, fixed window, buildings in 1980. By the 1990 nearly all new office blocks were highly serviced, with thin tight-skinned envelopes. Building regulations over the next three decades were to push new commercial buildings into using ever more highly serviced systems to meet ever narrower temperatures requirements, driving up emissions from them[xlii], and ensuring that national greenhouse gas emission targets could never be met, as has now been proved to be the case[xliii].

In 1992 the Thermal Comfort Unit at Oxford Brookes University was set up by Fergus Nicol, Susan Roaf and Michael Humphreys, with a view to widening the horizons of comfort research by promoting the adaptive approach, and re-enabling the natural ventilation of buildings. It was against this backdrop that the 1st Windsor Conference was held, from which ten subsequent conferences evolved, each addressing the evolving challenges of their times. The Proceedings for the conferences can be accessed online from: www.windsorconference.com

Figure 7. Cumberland Lodge

4. Comfort: The Windsor View

The 1st Windsor Conference on *Standards for thermal comfort* was held at Cumberland Lodge in August 1994, over three days and set in a luxurious country house, donated by the Late Queen Mother to the nation as a venue for 'change making' events after the 2nd World War. This historic location and ethos of the Lodge, the wonderful food and close social proximity of delegates, have all contributed to the forging of ideas and forming of friendships that have fostered and disseminated influential new approaches to the growing challenges of providing comfort in the 21st Century. Notable at this first meeting was the diversity of cultures and climates represented. There were architects, engineers and researchers present approaching the subject from their many different angles. It was a forum where regional voices emerged clearly, telling their own very different comfort stories, recorded in their fieldwork. It was really exciting first hearing of people in Bangkok being perfectly comfortable in temperatures of 35^0C, and to see the incoming tide of new datasets that would later be included in the 1998 ASHRAE database of field studies. Research reflecting work done in laboratories still prevailed, but a door opened at Windsor into a much richer range of discussions on comfort. Key papers, and discussions, were captured in a resulting book on *Comfort Standards* published in 1995[xliv].

Seven years later in 2001 the 2nd Windsor conference on *Thermal comfort standards for the twenty-first century* was held. Set against the optimism of the new century, and still growing global economies the second conference attracted delegates from all branches of the thermal comfort world including Ole Fanger and Bjarne Olesen from the Danish Technical University. Selected papers from the conference were developed as a special issue of *Energy and Buildings* (Volume 34 (6) 2002), jointly edited by Fergus Nicol and Ken Parsons of Loughborough University. One highlight of the conference was the presentation by Gail Brager and Richard de Dear on the meta-analysis of data on which was based the new adaptive standard in ASHRAE Standard 55-2004. This marked the historic loosening of the growing hold of prescriptive temperature standards on designers, enabling them to open the windows of their buildings again, while still adhering to regulated comfort limits.

In 2004 the world was still reeling from the 9/11 triggered war in the Middle East, and the catastrophic impacts of 2003 European heatwave, in which buildings had failed to keep their occupants thermally safe and over 52,000 excess deaths were recorded[xlv]. The focus of the 3rd Windsor Conference in 2004 was on the Post Occupancy Evaluation (POE) of Buildings, the systematic evaluation performed in terms of energy use and occupant satisfaction.

A special Issue of *Building Research and Information* (BRI) on 'Building Performance Evaluation' resulted (Volume 33(4), 2005), edited by Nicol and Roaf. It included important papers by Bill Bordass and Adrian Leaman and many other POE stars including Wolfgang Preiser, Jacqueline Vischer and George Baird who have all written influential books on the subject. Fun was provided in a Saturday evening POE Challenge set by the delegates from the US Society of Building Science Educators (www.sbse/org). This conference established a clearer, practical, link between building design, facilities management and comfort research.

In 2004 the Network of Comfort and Energy Use in Buildings was also started at the LEARN Unit at London Metropolitan University (NCEUB – www.nceub.org), originally with around 300 members, about one third of them from outside the UK and about two thirds of them from an academic background. Membership is now over 700. The site continues to promote ideas, opportunities and events on the environmental performance of buildings.

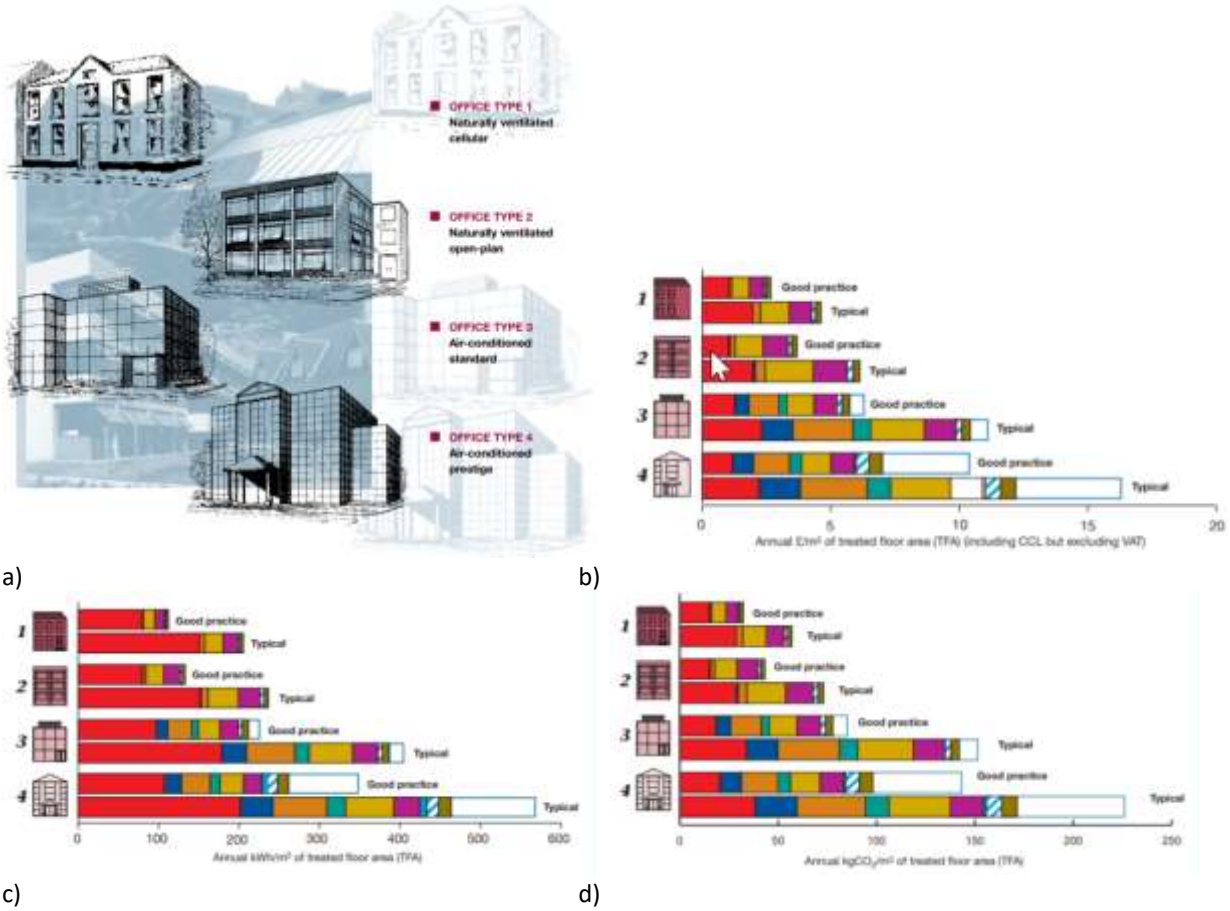


Figure 8. For four different office types from naturally ventilated (NV) cellular; NV open plan; Air-conditioned (AC) standard and AC prestige showing b) energy costs; c) energy use and carbon dioxide emissions in and from each, in the 1992 ECON 19 document of the UK best Practice Programme written by Bill Bordass[xlvi]

From extreme heatwaves to super-storms, Hurricane Katrina in 2005 awoke concerns about the scale and pace of climate change, and the role of buildings in driving global emission was increasingly under scrutiny. The 4th Windsor Conference in 2006 on *Comfort and energy use in buildings* looked at the energy implications of comfort paradigms, and was attended by 66 delegates from 22 countries. A special issue of *Energy and Buildings* with the same title and edited by Fergus Nicol, was published (Volume 39, no 7, July 2007), based on selected papers from the conference.

Figure 9. Delegates from the 5th Windsor Conference in 2008

In 2008 the Global Economic Crisis was peaking, and the focus of the 5th Windsor Conference was on *air-conditioning and the low carbon challenge.* Inherent in the discussions was the growing issue of how to provide affordable comfort to the many, as even the US middle classes began to disappear in the wake of their housing crisis[xlvii]. The fastest, and most effective way to lower emissions is, of course, to open the windows in an office or home condition or ventilate it [xlviii]. How is that to happen in the US now when some 80% of all homes and nearly 100% of offices have air-conditioning, and new buildings are made largely of chipboard, steel, timber and glass? The conference, part funded by the EU Common Sense project had 77 delegates. A special issue of *Building Research and Information* on 'Cooling in a low carbon world', was published, edited by Fergus Nicol (Volume 37 (4) 2009). The growing contributions of the Chinese scientists was much appreciated, as they presented their own national, evolving, thermal comfort standards that sensibly encourage natural ventilation.

By 2010 the wider impacts of the global recession concentrated thinking for the 6th Conference in 2010 on *Adapting to Change – New Thinking on Comfort*. Held in April, it was attended by 88 delegates. The new thinking began with the opening evening keynotes when Ed Arens from the University of California spoke on 'California Dreaming – Future directions for Thermal Comfort' and Richard de Dear from the University of Sydney on 'Thermal Comfort in Natural Ventilation – A Neurophysiological Hypothesis'.

Two major emerging themes were thus sewn into the minds of the audience: the common sense and ultra-low energy benefits of using local *personal environmental technologies* like local fans of heaters, to heat and cool people where appropriate, rather than resorting to conditioning whole buildings to keep a few people happy. De Dear fascinated on subject of Allesthesia, the sensual driver for rewarding the body for returning to homeostasis, thermally safe conditions. Both talks set the tone for the following sessions, and were complemented in the other keynote by Michael Humphreys on the relationship between indoor and outdoor temperatures. A special issue of *Building Research and Information* called 'Adaptive Comfort' was published (Volume 39 (2) 2011).

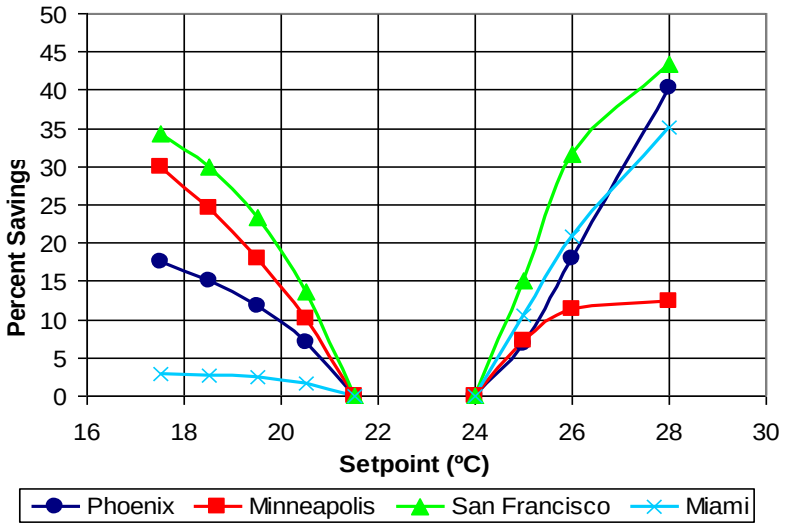


Figure 10. An influential diagram presented by Arens showed the possibility of huge energy, and hence cost savings by widening the heating and cooling set points in four different US cities in different climates. Temperatures between 18^{0}C and 28^{0}C are widely recognised as being suitable for natural ventilation of spaces. (Source: T. Hoyt et al. 2009[xlix]).

The Fukushima Daiichi nuclear disaster on the 11th March 2011 was the wake-up call for genuine *Resilient Comfort* thinking. The 7th Windsor Conference in April 2012 aptly flagged the importance of *The changing context of comfort in an unpredictable world.* Shinichi Tanabe presented a paper showing how Japan had immediately responded to the threat to the whole Japanese energy system by limiting the use of AC in government buildings to indoor temperatures over 28^{0}C, leaving people to cope using changes in behaviours, clothing, working practices etc. Having more than 100 delegates for the first time meant a change from the practice of every paper being heard by all delegates. There were four workshops on the hot topics of *Standards for the Indoor Environment*; *Designing Comfortable Buildings for the Future*; *Personal Control in Office Buildings* and *How to Make Low energy buildings that Really Work*. Special issues of *Architectural Science Review* on 'The wicked problem of designing for comfort in a rapidly changing world' (Volume 56 (1)) and *Building Research and Information* on 'Adaptive comfort' were published (Volume 41 (3) 2013).

Figure 11. Delegates at the 7th Conference in 2012

Three strong themes that stood out in 2014 at the 8th Windsor Conference on *Counting the Cost of Comfort in a Changing World:* the need to affordably address the problem of overheating in buildings; the need to look at affordably protecting vulnerable populations like children and the sick and elderly and a welcome revival of papers on the physiology of comfort. 120 people attended the 8 sessions and 9 workshops on subjects including field work from cold and hot climates, and the ongoing debate on comfort standards, particularly in relation to expectations. A highlight paper was on 'thermal mavericks' in Melbourne and Darwin in Australia, whose environmental zeal was reflected in the greatly expanded comfort zones they occupied, reinforcing the importance of attitude in comfort experiences and costs.

The use and management of local adaptive opportunities was a popular theme, including when and how people opened windows and used fans. Another interesting development was the findings by Pallubinski and van Marken Lichtenbelt that thermal change can be beneficial in our everyday lives, and that thermal stasis may be not only expensive to achieve, but can run counter to the best health interests of occupants. An unvarying environment may not just be psychologically boring, but may also reduce the ability of individuals to physiologically cope with environmental change. A range of papers developed from those presented have appeared in subsequent issues of *Building Research Information* (Vol 43.3) and *Architectural Science Review* (Vol 58.1) and an article about the conference appeared in REHVA European HVAC Journal for June 2014 (Vol 51.4).

The 9th Windsor Conference in 2016 was about *Making Comfort Relevant*. Thermal comfort issues were increasingly being recognised as playing crucial roles in keeping building occupants safe, heathy, productive but the challenge posed at this conference was how to connect the work of comfort researchers to tangible improvements in the real world. Traditionally this had been done via the medium of standards and regulations, but these were increasingly seen as detached from the lives, and comfort opportunities of most ordinary people.

Elizabeth Shove from Lancaster University spoke on the *Concept of Comfort*, questioning whether the Comfort Standards that are international espoused today are still fit for purpose in a changing world. A growing number of researchers from industry attended in in the 130 delegates who took part. 90 papers were presented in plenary sessions and 9 themed workshops. Bjarne Olesen and Ken Parsons opened the deliberations with a talk on the history of International Comfort Standards.

The breadth of the conference topics can be judged from some of the Sessions titles: Comfort in Hotter Climates; Smart Comfort; Behaviour and Aging as well as workshops called: Putting People in Building Comfort Models; the Role of Clothing, Domestic Comfort and Teaching and Tools and Statistics for Comfort. There was also welcome news of new comfort laboratories opening about the world and a Comfort Quiz on Saturday night all about Clos!

Two special journal issues were developed from some papers from the conference: *Building Research and Information* (Vol 45.7 – Rethinking Thermal Comfort) and *Architectural Science Review* (Vol 60.3 – Running Buildings on Natural Energy: Design Thinking for a Different Future).

Figure 12. Delegates at the 2018 Windsor Conference (Source: Ashak Nathwani)

Questions about the roles and relevance of comfort science raised at the 9th conference were again discussed at the 10th conference on *Rethinking Comfort*. Rising to the huge challenges posed by changing economies, societies, buildings, technologies and the heating climate this conference simply asked delegates to think hard about where comfort research had come from, and where it should be aimed at now? In 2018 the growing interest in comfort from a range of new quarters became apparent. A 125 delegates attend and the papers into seven sessions and nine workshops to provide an opportunity to discuss topics in greater depth, and to explore detailed issues of methodology, experimental design, semantics, real world constraints, impacts and new thinking and approaches.

A talk by Kris de Decker on *Low Tech Comfort: Heating People not Buildings* looked at traditional methods of providing comfort in different countries. He usefully spoke to the new interest in lower-tech means of heating and cooling buildings from radiant systems to evaporative misting systems for hot cities. Roberto Lambert's talk on his own *Economic social and cultural experiences of thermal comfort from field studies in Brazil,* shed light on a country where many are poor and low cost conditioning strategies, like simple natural ventilation strategies, and appropriate dress codes, are included as valid comfort components within the national standards. He showed that comfort standards can included provision for highly serviced building as well as promoting a low-tech range of adaptive comfort opportunities to be operationalised at the building design stage.

Sessions and workshops dealt with a range of topics from new approaches to heating and cooling people; personal control; perceptions and adaptive behaviours; usage and interpretation of comfort scales, and the evolving field of personal comfort models. Survey results were presented from hot and cold climates; different building types including schools, offices and homes and the influence of diversity factors in the experience of comfort. Studies on comfort sleep, IEQ, energy, health and physiology showing the large expansion in the scope of the subjects covered in the conference over the last 22 years.

A number of journal articles based on the papers have been published and the papers presented all appear in full, in the Windsor 2018 Conference Proceedings (on line at: www.windsorconference.com) and the deliberations of the Workshop attendees are captured and published on line in the Windsor 2018 Legacy Document.

An exciting development in 2018 was the rapid organising by some of the younger Middle East-based delegates of a satellite conference on Comfort at the Extremes. Held in Dubai on the 10th to 11th April 2019, the Proceedings and Legacy Document are available on www.comfortattheextremes.com. Speakers covered the health and mortality implications of extreme temperatures, and in particular building and city level design solutions to them.

The Legacy document on the CATE19 website showed the huge challenges for humanity in trying to keep people thermally safe in a heating world. Papers covered studies of people dying of heatstroke on city streets, on excess deaths in Australian homes during heatwaves and in the refugee camps of Jordan and Bangladesh. It is a very different world out there in the field of Extreme Comfort and importantly CATE 21 will be held in Oman in October 2021. How fitting that the work if the IEA EBC Annex 80 on Resilient Cooling also met then in Dubai, ably led by Bjarne Olesen and Peter Holzer (http://annex80.iea-ebc.org/).

5. The Windsor Stepping Stones

The papers outlined in the Introduction to these Proceedings of the 11th Windsor Conference, can be usefully looked at in the light of two very different time horizons:

The first is that of the long history of the building regulations our civilisations have invented to control the living and working conditions of their citizens over time. Over centuries these have been gradually moulded by shifts in the demographic, social, economic and political structures of nations. Much more sudden changes in regulations have been triggered by unpredicted extreme events like plagues fires, flood or extreme storms.

The second horizon is that of the unprecedented pace of global change that has shaped all of our lives since the first Windsor Conference in 1994. The stepping stones from there to here are clear in retrospect, although were not always recognised as significant at the time.

Stepping Stone 1: The Rio Conference of 1992 reset development priorities to elevate *Climate Change Mitigation* to being of primary legislative importance, due to the global need to urgently lower energy use in, and greenhouse gas emissions from, buildings.

Stepping Stone 2: The 2003 European heatwave, the first extreme climate disaster of the many that have followed, made us understand the fundamental importance of *Adapting our Buildings and Cities* to withstand the escalating force of climate related events.

Stepping Stone 3: The Global Economic Crisis showed how fragile all our economies are, even the apparently strongest of them. The phenomenon of the 'disappearing middle classes' of our societies, as inequality grows, will inevitably mean that the *Affordability* of comfort will become a primary concern for the 95% of the world's populations with falling incomes.

Stepping Stone 3: The Fukushima nuclear disaster, triggering national power outages and shortages of a catastrophic scale, demonstrated that the 20th energy supply paradigms are extremely brittle, fostering the need to design much more *Resilient* buildings that can keep people safe and healthy, even when power systems fail.

Stepping Stone 4: The global COVID pandemic has highlighted for us that fixed window buildings with shared ductwork systems can be not only unhealthy, but can also spread infections. Only with extremely expensive mechanical systems with high, and for the many unaffordable, installation and running costs might vulnerable occupants be kept safe during disease outbreaks in them. Opening windows must now be seen as a leading design option for enabling people to *Safely Survive* during pandemics in the buildings they live and work in.

Stepping Stone 5: All of the above have highlighted the growing *inequalities* in the world today and the plights of the poor, from those who sleep on the streets, or in the refugee

camps, to the old dying in care homes, or even friends over the road who have lost their jobs or businesses in the COVID crisis. The enormous *Diversity* that exists in cultures, climates, societies, economies and political systems must now be recognised, and addressed in our comfort standards. We can no longer treat humanity as a monolithic bloc to whom one comfort single standard applies, even if it promotes the economic interests of a major global industry. The weights on the balance have now shifted. That time is over.

6. Comfort: The Future

Fergus Nicol, Michael Humphreys and Susan Roaf began the Windsor Conferences with two rather simple aims: to widen the horizons of comfort research by promoting the adaptive approach, and to enable all normal buildings to be naturally ventilated again.

Over eleven conferences we have achieved so much more than we dreamed possible. The hugely nuanced range of Windsor learnings have left us all much wiser, and better prepared to help our societies, and our shared civilisation, to affordably survive in the very different future we all face. Things will have to change radically to do this.

We must raise our ambitions far beyond the 20th Century 'Business-as-Usual' focus on comfort as something that is a thermal product from machines, via ducts, sold by the kWh. Issues of what actually constitutes comfort, discomfort and thermal stress for the diverse populations of our planet will increasingly lie at the heart the health and well-being challenges faced by all our societies in a heating world. Ways forward to new thinking on indoor environments in buildings in the future will be well informed by what we have learnt at the eleven Windsor Conferences about:

People:

- *There is no such thing as a 'comfort temperature'*. Everybody is different, the old, the young, those with different cultures, climates, physiognomies and daily lifestyles. People habituate to the thermal environments they occupy over a day and year. Children in one school adapt to different temperatures than those in an adjacent school of a different construction. People in an AC office will have different neutral temperatures to those in a naturally ventilated one next door. We adapt.
- *People adapt to a wide range of temperatures.* Nicol shows in his paper above that adapted people around the world find temperatures from 10^0C-35^0C acceptable in their own homes. We do not, and cannot, know better than they do about what they feel. We are limited in our understanding but our own experiences.
- *Thermal delight* is undervalued by lazy modern designers. The comfort ambitions of architects have almost universally been reduced to a bare minimum, as they blindly accept the engineer's definitions of comfort, validated by crude modelling tools and black box rating systems. They have been thus led to depriving people of a whole gamut of sensual delights that can arise from the interactions between sun, wind, fabric warmth and coolth, that create rich thermal pleasures in different seasons.
- *Behaviours and expectations of building occupants* are key to the management and improvement of indoor comfort, particularly where numbers of people are involved.
- *The Physiology of comfort* is crucial in explaining how temperatures affects the health and well-being of people.

Buildings:

- *Use too much energy.* The shift over the past half century toward highly serviced, over glazed and fixed window buildings means they both use too much energy, and they consequently emit too many greenhouse gases. Inherent in most building regulations

is the *Energy Efficiency Fallacy*. To hide the truth of unacceptable levels of energy use in buildings, they are cleverly classified for their consumption within 'classes'. An efficient Prestige AC building is judged only against others of its type. Absolute performance of energy use in, and emissions from, every building should be put on a common scale eg. kWh/m^2/a, and annual energy use reported and published.

- *Overheating.* Extremes of temperature are now being experienced in many modern buildings, even in colder climates, due to persistent and costly flaws in modern design practices that are promoted with crude simulation packages and licenced by current comfort standards and rating systems. Catastrophic consequences may result during power outages, population Lockdowns or when people can no longer pay for comfort.
- *Next generation buildings will be different*. The idea that it is sensible, or acceptable, to mechanical condition buildings all year, 24/7/365, cannot continue. Windsor has demonstrated the economic, and comfort sense of designing buildings that can be run for as much of the day, or year, as possible, heating and cooling people in buildings, not just spaces in them, using energy storage, radiant and personal technologies etc.
- *The New vernacular.* The form, fabric and construction of buildings themselves must be culturally, climatically, and economically appropriate to their local context so buildings can be part of successful climate solutions, not just major climate problem.

Comfort Standards:

- *International Standards should be re-thought.* The idea that the same temperature that is applied to an office, or home, in North America is appropriate in Sri Lanka or Bangladesh is simply wrong. Cynically, this idea serves only the international air-conditioning industry who largely control the process of writing standards, at huge such a huge cost to humanity, particularly in poorer, warmer climates.
- *Local city level or national standards should replace them.* The energy profligacy of having the same European indoor temperature standard for northern Sweden as for Southern Spain is no longer affordable financially, or in greenhouse gas emissions.
- *Opening windows are essential*. All buildings should have at least some opening windows, and be habitable in natural ventilation mode, at the very least during periods of overheating, during power outages and during pandemics when recirculated air from mechanical systems can spread infection between rooms.

Civilisation is about control, and who has it. For the last half century, we have largely ceded control of national and international comfort standards to those who are either paid by the mechanical conditioning industry to research, or write the comfort standards, or those who are paid for their work according to how much servicing equipment they include in buildings. It is now up to the politicians to put together a new cohort of standard makers, who can reshape fairer comfort standards and regulations that benefit all, not least by helping to avoid climate catastrophe. These may be physiologists, doctors, behavioural psychologists, technologists, and those who will design the *New Normal* for the construction industry.

In 2020 control is shifting: to the angry young people from Extinction Rebellion who want save the global climate and their futures in it; to the people who are helpless in COVID lockdown as their spaces overheat; to those losing faith in politicians; to the people desperate because they have lost their jobs and can no longer keep their families adequately fed, let alone pay for comfort; to the religious leaders who can call people en masse to prayer and to action. The balance of history is shifting and the weights on the scale are moving fast – people v. economy – profit v. survival. Change is coming.

The last twenty-six years of comfort research presented at the Windsor conferences has laid solid foundations from which to build such change. Thank you all for your contributions.

Figure 13. Looking through the great window at Cumberland Lodge, to the benches that we should have sat in April 2020 for our team photo, the croquet lawn we should have played on, out to Windsor, and the world beyond (Source: Sue Roaf).

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Figure 14. The future: Delegates at the 2019 Comfort at the Extremes Conference in Dubai share a meal in a traditional Arab house in Bastakiyah, Dubai (www.comfortattheextremes.com)