An annotated bibliography of comfort research

Heather Chappells and Elizabeth Shove
Department of Sociology
Lancaster University

October 2003

Our aim in compiling this bibliography was to take stock of existing ideas, arguments and resources that are available to understand key issues and concerns relating to thermal comfort and the construction of sustainable indoor environments. Although we have included key texts from the engineering and building sciences, we wanted to go beyond these and consider inputs from across the social sciences. As such, our list includes contributions from and eclectic and extensive range of disciplines - including sociology, geography, epidemiology, anthropology, history, physiology and psychology, architectural science and urban planning.

Aaland, M. (1978). Sweat: The Illustrated History of the Finnish Sauna, Russian Bania, Islamic Hammam, Japanese Mushi-Buro, Mexican Temescal and American Sweat Lodge., Capra Press.

An historical account of practices of 'sweat bathing' in different cultures, and of the medicinal, spiritual and social value of sweating. Aaland describes how, in some countries, social sweating is favoured (over private forms) with sweat bathing viewed as an important communal event. The author considers whether people sweat enough in this 'sedentary age' of anti-perspirants, artificial environments and synthetic clothing that serve to inhibit the 'healthy' flow of sweat.

Ackermann, M. E. (2002). Cool Comfort: America's romance with air conditioning. Washington, Smithsonian Institution Press.

Ackermann explores how the idea of 'cooling' became embedded in the social perceptions and expectations of Americans, transforming definitions of comfort and ways of life. She begins by discussing the deterministic theories of early geographers, many of whom viewed 'inferior' climates (e.g. those in hot and humid regions) as something to be colonised and controlled. Such ideas were enrolled and promoted by US air-conditioning engineers, supporting the development of artificial cooling. Describing the expansion of air-conditioning into all areas of everyday life (movie theatres, department stores, workplaces and homes), Ackermann suggests that for many air-conditioning has come to be viewed not as a solution to discomfort, but as part of the problem.

Aghemabiese, A., J. Berko, et al. (1996). Air Conditioning in the Tropics: Cool Comfort or Cultural Conditioning. ACEEE Summer Study, Asimolar, California, ACEEE.

The authors suggest that the wholesale adoption of air-conditioning as a primary cooling strategy throughout the developing world can be avoided. The paper considers the implications of the mass marketing and socialisation of air-conditioning and the importation of Western clothing standards in Ghana and Thailand alongside more traditional approaches to keeping cool. Given that many people from tropical climates are 'uncomfortable' with air-conditioning more climatically and culturally sensitive futures involving daily adjustment, clothing habits and climatically sensitive design are advocated.

Angus, T. C. (1968). The Control of Indoor Climate, Pergamon Press.

A guide to the technical standards affecting human comfort and efficiency and how these thermal needs can be met by engineers. A variety of physiological studies are reviewed to support the proposition that artificial heating and air conditioning have an essential contribution to make to modern industrial civilizations.

Aronin, J. E. (1953). Climate and Architecture. New York, Reinhold Publishing Corporation.

Aronin describes the science of "airchitecture": how macro and micro climate influences building design. He explains how interest in the relation between climate and architecture can be traced back to the time of Vitruvius (3rd century BC). The book describes a variety of culturally and historically distinct building forms, including the eskimo igloo and traditional Japanese homes, which are designed to work with prevailing climatic conditions in order to provide warmth in winter and coolness in summer.

Auliciems, A. (1972). The Atmospheric Environment: A study of comfort and performance. Toronto, University of Toronto Press.

A study of the dynamic interaction between internal physiological processes in humans and perpetually changing weather - the science of 'biometeorology'. Existing research on physiological thermoregulation (bodies and thermal balance) and behavioural thermoregulation (conscious adaptations to 'private climate' through clothing, shelter or technologies) is reviewed. Auliciems argues that more information is needed on the atmospheric influences affecting human productivity "in order that humans may capitalise on their innovations and achieve optimal thermal conditions". A study of schoolchildren in Reading, UK, is described which explores how comfort and work efficiency is influenced by meteorological conditions. The need for more individual control over classroom conditions is noted, as is the need for private adjustment e.g. revising "the entrenched and archaic concept of 'proper clothing' (both in schools and elsewhere)".

Baker, N. and M. Standeven (1996). "Thermal comfort for free-running buildings." Energy and Buildings 23: 175-182.

The notion that thermal neutrality is optimal is questioned. Comfort monitoring surveys in passively controlled office buildings in Athens are described that show how subjects adapt and modify their personal and immediate surroundings to achieve comfort. The authors suggest that adaptive activity/exercise is a fundamental need and consider adaptive opportunities that might allow the neutral thermal comfort zone to be extended.

Baker, N. and K. Steemers (1999). Energy and Environment in Architecture: a technical design guide. New York, E & FN Spon.

The authors consider how to create comfortable, healthy and sustainable environments within buildings. Issues of comfort and thermal delight are important to building design but not the "obsessive application of narrow 'optimised' environmental parameters". Providing temperatures of 21oC it is argued does not guarantee comfort. Instead comfort must be understood as a far more holistic experience dependent upon the interaction of many factors - including the variability and options that the environment offers and the ability of the occupant to determine these options. The challenge for building designers is to provide options for "adaptive opportunity" (e.g. pulling down blinds or opening windows) and thus to extend the 'comfort zone'. Practical advice on how this might be achieved is given and a variety of case studies considered.

Banham, R. (1969). The Architecture of the Well-Tempered Environment. London, Architectural Press.

Bedford, T. (1964). Basic principles of heating and ventilation. London, H.K. Lewis Ltd.

Describes Bedford's pioneering work from the 1930s on the comfort of factory workers. The "Bedford scale" was subsequently used as basis for measurement of thermal comfort in homes and workplaces.

Berger, A. and A. J. McMichael (1999). "Climate change and health: Evidence and prospect." European Review 7(3): 395-412.

Reviews direct and indirect climatic impacts on health in light of climate change including variations in physical comfort and heat and cold stress.

Boardman, B. (1991). Fuel Poverty: From cold homes to affordable warmth. London, Belhaven Press.

Boardman asks how the "fuel poor" might achieve homes that are warm, affordable and energy efficient. Comfort is defined in line with the standard daytime average temperature of 21oC, a target that many fuel poor households currently fail to meet. In assessing how these comfort standards might be achieved, the book examines a variety of economic, technical and social constraints that might influence the ability of households to achieve warmth and suggests how these might be overcome.

Brager, G. and R. de Dear (1998). "Thermal adaptation in the built environment: a literature review." Energy and Buildings 27: 83-96.

Assembles the results of over fifty studies concerned with thermal comfort as a function of adaptation to the thermal environment. Research undertaken in comfort chambers shows fairly consistent and similar temperature preferences even across cultures with highly variable climates. Field studies of comfort reveal much more variation, especially in the case of occupants of "naturally ventilated" or "free running" buildings without centralised heating and cooling systems.

Brager, G. and R. de Dear (2000). "A Standard for Natural Ventilation." ASHRAE Journal: 21-27.

Provides a critique of ASHRAE standard 55 and discusses the contemporary case for an adaptive standard for thermal comfort that accounts for physiological, behavioural and psychological variation.

Brooks, C. (1950). Climate in Everyday Life. London, Ernest Benn Ltd.

A deterministic account of everyday life (and comfort) as governed by energy and climate. Brooks argues that the economic performance and happiness of people is directly bound up with the climatic conditions in which they live and work. Climate is represented as "an enemy" of economic efficiency and productivity and must be controlled. "Difficult" climatic conditions are represented as a challenge, the ill effects of which must be minimised by air conditioning, clothing or sanitation. By "altering the weather", it is argued that even the most notoriously unhealthy places can be "brought up to a level little inferior to that of the centres of civilisation".

Busch, J. (1992). "A tale of two populations: thermal comfort in air-conditioned and naturally ventilated offices in Thailand." Energy and Buildings 18(3-4): 235-249.

Describes a field study of 1,100 office workers in NV and AC buildings in Bangkok designed to explore whether there is justification for adopting a comfort standard that differs from those developed for more temperate climates. Study findings suggest that interior spaces in Thailand can be cooled to a far lesser degree than in temperate regions without sacrificing comfort.

Canter, D., J. Gilchrist, et al. (1974). An empirical study of the focal point in the living room. Psychology and the Built Environment. D. Canter and T. Lee, The Architectural Press.

The chapter considers the changing role of the open fire or hearth as the focal point of the living room. Although alternative heating systems are now available, the authors describe how households are still often encouraged to use these in a traditional manner e.g. a glowing gas fire or imitation logs/coals on electric fires. They argue that despite technological changes the hearth is still important in the social make-up of our homes and important as a meeting place: "Over 2000 years we have accepted the hearth as part of our lifestyle and perhaps no longer as a source of heat". A substantial fireplace, it is argued, assures us that the room will be cosy and that it is comfortably heated "the glow, the flicker of light".

Cena, K. (1994). Thermal and non-thermal aspects of comfort surveys in homes and offices. Thermal Comfort: Past, Present and Future. N. Oseland and M. Humphreys. Watford, Building Research Establishment: 73-85.

Discusses conceptual and methodological issues in undertaking multi-disciplinary field studies to investigate the interaction of physical, physiological and psychological aspects of thermal comfort. A review of existing literature reveals important considerations in the selection of subjects, choice of building and the evaluation of cultural/climatic difference. Cena calls for a standardised methodology that can allow for comparison between different field studies of thermal perception.

Cena, K. M., P. G. Ladd, et al. (1990). "A Practical Approach to Thermal Comfort Surveys in Homes and Offices: Discussion of methods and concerns." ASHRAE Transactions 96(1): 853-857.

The paper discusses techniques involved in thermal comfort studies conducted in the field, with the aim of developing more standardised methodologies that will allow comparison of findings. A variety of surveys of different sorts of populations in homes and offices are reviewed and important lessons for the design of future surveys noted. One important consideration is to recognise cultural and climatic differences in interpretations of standard comfort scales. For example, the term "hot" in Western Australia was more obviously extreme than for counterparts in the northern hemisphere. The need for differences in methodological approach when conducting survey in homes, compared to office environments is also emphasised.

Clements-Croome, D., Ed. (1997). Naturally Ventilated Buildings: Building for the senses, economy and society, E&F Spon Press.

Although there are many historical examples of successful naturally ventilated buildings, it is argued that standards for indoor climate have tended to emphasise active, mechanical airflow systems rather than passive, natural systems. As such, knowledge about the performance of naturally ventilated buildings has remained comparatively sparse. The papers in this edited collection seek to address this lack of information.

Clements-Croome, D., Ed. (2000). Creating the Productive Workplace. London, E & FN Spon.

The book sets out important issues concerning productivity and the work environment. Contributions are made by international experts in building design, environmental engineering, architecture and construction management. Themes include: creativity in the workplace, comfort and CO2 reduction; productivity and indoor air quality, individual control and the future of working. It offers solutions to providing creative and comfortable work environments that are conducive to productivity.

Cole, R. (2000). "Fuel Poverty: A Costly Lesson." Building Research and Information 28(5/6): 419-425.

The paper reviews historical ideas about appropriate indoor air temperatures in buildings (e.g. in mid-1800's according to the best medical opinions, 15.5^{O}C. was deemed appropriate for children's nurseries and sick chambers and 10^{O}C in rooms where people were employed in sedentary occupations). In the early 1990s, some commentators arguing that "we have accustomed ourselves to live in rooms that are too warm" (i.e. above 15^{O}C). More recent focus on "fuel poor", defined by the DETR as those who spend more than 10% of household income to achieve acceptable indoor temperatures of 21^{O}C in the living room and 18^{O}C elsewhere. According to 1991 English House Condition Survey, only 70% of homes met minimum regime of 18OC in living room, 16^{O}C elsewhere, and 25% had 21^{O}C in the living room.

Cooper, G. (1998). Air Conditioning America: Engineers and the Controlled Environment, 1900-1960. Baltimore, The Johns Hopkins University Press.

Cooper examines the history of mechanical air conditioning in the US, describing engineering practice and how "man-made weather" came to be accepted by consumers. She

argues that air conditioning was initially resisted because it challenged the established social rituals of hot weather (e.g. light clothing, cold drinks, vacations, swimming). However, after the 1950s passive forms of climate control in the home were in decline with the rise of air conditioners and the mass commodification of comfort.

Cooper, I. (1982). "Comfort and energy conservation: a need for reconciliation." Energy and Buildings 5(2): 83-87.

The paper considers the issues underlying efforts to reconcile comfort with reduced consumption of energy in buildings. He argues that "physiologically grounded, orthodox comfort research" is an inadequate basis for how people judge internal environments in the buildings they occupy, since social issues are also significant. Outlining the basis on which current design decisions in the UK have come to rest, Cooper describes how creating habitable spaces has become synonymous with the consumption of finite fossil fuels, partly as a result of the drive for optimal internal conditions. Instead, he suggests that more attention is needed on how people assess what is appropriate in buildings and on the social, political and economic judgements on which these decisions are based.

Crowley, J. (2001). The Invention of Comfort. Baltimore, Johns Hopkins University Press.

Crowley examines the concept of comfort as a means of understanding the evolution of Anglo-American consumer culture and ways of life. He suggests that original associations of comfort with spirituality and morality have gradually been redefined to relate to physical conditions (e.g. relationship between human body and immediate physical environment). The changing artefacts of comfort (e.g. fireplaces, candles, stoves, etc.), their association with different meanings of comfort, and with the alleviation of discomforts (e.g. modern conveniences) are examined. The book emphasises the extent to which notions of comfort are tied up with the evolution of domestic architecture, technology and everyday life.

Cullen, N. (2001). "Climate change: designing buildings with a future." Proceedings of CIBSE National Conference.

Buildings now under construction will experience the effects of climate change over the next 50 years. In light of such trends, Cullen asks how we might provide productive, healthy indoor climates that can be readily adapted to changing conditions. The paper discusses the use of a weather file representing the future impact of climate change in the UK and evaluates the implications for building regulations (e.g. revisions to Part "L") and for changing power loads in air-conditioned and naturally cooled buildings.

de Dear, R. (1994). Outdoor climatic influences on indoor thermal comfort requirements. Thermal Comfort: Past, Present and Future. N. Oseland and M. Humphreys. Watford, Building Research Establishment.

Reviews "adaptive" and "heat-balance" hypotheses concerning the interaction between indoor temperature, outdoor climatic conditions and thermal comfort. The former approach points to the possibility of changing thermal expectations and processes of acclimatisation, the latter offers a more constant hypothesis of comfort (adjustment only of recognised heat-balance variables). For "free running" buildings, de Dear argues that an adaptive hypothesis is more appropriate.

de Dear, R. and A. Auliciems (1988). "Air conditioning in Australia II: User Attitudes." Architectural Science Review 31: 19-27.

The paper reports on the attitudes and perceptions of building occupants towards their immediate thermal environments in three climatically disparate Australian cities (Darwin, Brisbane and Melbourne). Asked about their satisfaction with air-conditioned office, building occupants describe a variety of concerns related to sick building syndrome and the discrepancy between indoor and outdoor environments (e.g. the need to wear cardigans on hot days and the sudden chill in re-entering buildings from warm streets). The study shows that occupants of air-conditioned buildings tended to prefer them, whilst those in non air-conditioned buildings preferred to work in passively ventilated buildings - even when these recorded the hottest

temperatures. Differences in benchmarks of thermal comfort between occupants in different cities are also noted. The authors conclude that the psychological dimensions of thermal perception and indoor climate evaluation require closer examination if comfortable, yet energy conserving built environments are to be realised.

de Dear, R. and G. Brager (1998). "Developing an adaptive model of thermal comfort and preference." ASHRAE Transactions 104(1): 27-49.

Reports on an ASHRAE group effort (RP-884) to develop an alternative to ASHRAE 55-1992 that will account for the adjustment to seasonal highs and lows seen in a number of field studies. ASHRAE 55-1992 assumes comfort is maximised at a constant year-round temperature varied somewhat to allow for seasonal changes in clothing. Outdoor climate and the degree of a building occupant's control over their thermal environment are brought into the mix of factors affecting the proposed adaptive comfort standard.

de Schiller, S. and J. M. Evans (1998). "Sustainable urban development: Design guidelines for warm humid cities." Urban Design International 3(4): 165-184.

The authors argue that urban design often ignores local requirements as a result of global trends and international influences with negative implications for energy use and for comfort in indoor and outdoor spaces. The paper presents a case study of urban design guidelines for warm humid climates, based on the analysis of climatic variables and comfort requirements. It is argued that such climates require new urban design approaches in the present situation of rapid economic and social development and in the context of globalisation.

Diamond, R. (1987). Energy Use Among the Low-income Elderly: A Closer Look. Energy Efficiency: Perspectives on Individual Behaviour. W. Kempton and M. Neiman. Washington DC, ACEEE.

The study investigates energy use and comfort needs of low-income elderly tenants of public housing in California. Large variations in energy use are recorded among what were assumed to be identical apartments with similar residents. Technical indicators such as reported thermostat settings and measured air leakage are unable to explain these variations. In-depth case studies of individual tenants reveal differences relating to perceptions of health and comfort, levels of satisfaction with heating and cooling systems, degrees of individual control and attitudes towards conservation.

Diamond, R. (2003). "A lifestyle-based scenario for US buildings: Implications for energy use." Energy Policy 31(12): 1205-1211.

Explores future energy use scenarios connected to changing lifestyles. Thirty energy experts were asked to imagine a day in the life of a family in year 2020 and to consider the energy implications of such changes. The paper discusses possible changes in the provision of comfort and heating and cooling technologies and discusses the energy use and policy implications of such changes.

Diamond, R., J. Remus, et al. (1996). User Satisfaction with Innovative Cooling Retrofits in Sacramento Public Housing. ACEEE Summer Study.

Describes an attempt by a utility company to reintroduce evaporative cooling systems in public housing. Such cooling systems are less energy intensive that compressor-based air-conditioning and might offer a way for utilities to reduce peak summer demand in some areas. The paper describes an interview-based survey of 7 households that offers insights into resident use, comfort and satisfaction associated with the coolers. It is suggested that such systems can offer alternatives to compressor based cooling in hot dry climates and realise energy savings.

Donaldson, B. and B. Nagengast (1994). Mastering the Heat and Cold, ASHRAE Transactions.

Egan, M. D. (1975). Concepts in thermal comfort. Englewood Cliffs, N.J., Prentice-Hall.

Synthesises and simplifies technical conceptualisations of thermal comfort into a comprehensive guide for architects and designers. A variety of diagrams, sketches and graphs are used to help illustrate the significance of climate, materials and mechanical systems in the design of buildings.

Eliasson, I. (2000). "The use of climate knowledge in urban planning." Landscape and Urban Planning 48(1-2): 31-44.

Urban landscapes are widely acknowledged as creating a climate which influences human comfort, air quality and energy consumption. Eliasson considers why knowledge about local climate generally has a low impact on the urban planning process despite the abundance of scientific studies in urban climatology and climatic design. A questionnaire survey and interviews with municipal urban planners in three Swedish cities suggests that although planners are interested in climatic aspects there are a variety of conceptual, technical, policy, organisational and market constraints. Many of these constraints, it is suggested, cannot be counteracted through improved awareness or education, but also require improved institutional capacity in the social context of planning.

Erickson, R. (1987). Household Energy Use in Sweden and Minnesota: Individual Behaviour in Cultural Context. Energy Efficiency: Perspectives on Individual Behaviour. W. Kempton and M. Neiman. Washington DC, ACEEE.

Erickson reflects on the 'tantalising' findings of previous studies that Swedes only use 60% as much energy per capita as Americans, and asks how this remarkable efficiency might have been achieved while maintaining the notoriously high Swedish standard of living. Although the ubiquitous term 'lifestyle' is often invoked to explain differences, the meaning of the term is rarely defined or documented. Anthropological studies of energy using household activities in American and Sweden single family dwellings in two towns are described. These studies suggest that Sweden's lesser household energy consumption relate more to issues of collective convention rather than individual behaviour. For example, the Swedish concept of 'lagom' (understood as a moral code about communal rights) may be responsible for tempering energy use, with many households only taking what they regard as a 'fair share' of resources.

Evans, M. (1980). Housing, Climate and Comfort. London, The Architectural Press.

The book offers recommendations for house design in different climates, taking into account a variety of qualitative and quantitative comfort factors. A key consideration is how current building designers might learn from the past in designing houses suited to different environmental conditions. Evans describes how the past builders of traditional or vernacular houses were familiar with climate and environmental conditions, having experienced its rhythms and variations since birth. As a consequence houses represented the result of many years or centuries of optimisation in relation to materials, labour, the social organisation of the household and the climate. However, Evans also argues that it is important not to romanticise traditional forms of housing and acknowledge that they may be a misleading source of design solutions for the present (e.g. incompatible with modernisation or utilising lower quality and more hazardous materials). Furthermore, designers need to appreciate how occupants modify homes and take account of their personal experiences of climatic conditions and individual needs.

Fanger, O. (1970). Thermal Comfort Analysis and Applications in Environmental Engineering. New York, McGraw Hill.

Fanger's aim is to provide a rational theoretical basis for the establishment of thermal comfort conditions by environmental engineers and the heating/air-conditioning industry. Comfort is defined as "that condition of mind which expresses satisfaction with the thermal environment". Accounting for recognised biological variance, Fanger develops a method with which to define an optimal thermal comfort zone in which the highest possible percentage of building occupants is thermally comfortable.

Fanger, O. (2001). "Human requirements in future air-conditioned environments." International Journal of Refrigeration 24(2): 148-153.

The paper explores how future air-conditioned environments might be provided that enhance productivity, reduce sick building syndrome symptoms and are compatible with energy efficiency and sustainability. Fanger suggests that a paradigm shift is required, based on the premise of individual control, in which the provision of "personalized air" is served to wherever it is needed.

Fisk, D. (1976). "Microeconomics of space heating." Energy 2(4).

Fisk analyses the relationship between the energy performance of UK dwellings in the 1950s, as external temperatures fall, and the income elasticity of demand. Findings show that some of the potential savings from energy conservation methods are absorbed in higher internal temperatures.

Fitch, J. M. (1972). American Building: The Environmental Forces That Shape It. Boston, Houghton Mifflin Company.

The book sets out an holistic approach to architecture that appreciates the "multi-dimensional totality" of relations between man and buildings and their submergence in the natural, social and cultural environment. Fitch argues that the design of many modern American buildings reflects an architectural "obsession" with aesthetics rather than with what is good for human productivity in a broader sense. Architecture is represented as a "third meso environment" (between the individual micro-environment of humans and the external macro environment), which is important in constructing a productive individual and social life. Buildings need to be designed not just to avoid absolute and traumatic levels of thermal stress (as defined by physiology), but to account for socially defined and culturally relative standards of health, amenity and efficiency. The "paradox" of modern approaches to building design, Fitch argues, is that "the same mechanical systems which give us clean, conditioned air inside the building are simultaneously polluting the outside atmosphere". Rather than attempting to engineer out nature, he suggests that: "With the complexity of modern building we need nature more than ever before. It is not a question of air-conditioning versus sea-breezes, or fluorescent tubes versus the sun. It is rather a necessity for integrating the two at the highest possible level".

Fountain, M., G. Brager, et al. (1996). "Expectations of indoor climate control." Energy and Buildings 24: 179-182.

Reflecting on the limitations of currently accepted comfort models and standards (e.g. a single temperature set-point), the authors examine how people's thermal sensation and preference may be influenced by culture and climate, and associated issues of thermal expectation and adaptation. For air-conditioned buildings, where people do not expect to self-regulate, it is argued that current standards may be acceptable. But, for naturally ventilated buildings, prescriptive standards are unsuitable. Here the need is for adaptation by behavioural adjustment. Standards of comfort, it is suggested, must be based on psychological and not only physiological assessments of thermal requirements.

Fourt, L. and N. Hollies (1971). Clothing: Comfort and Function, Dekker.

Foxon, T. J. (2000). "Resource efficiency and service provision." Energy and Environment 11(5): 587-595.

Explores the possibility that improvements in energy and resource efficiency together with the move towards the service economy could help to stimulate more profound social changes needed for sustainable development. It is argued that the key novel ingredient of debates about "factor four" and "natural capitalism" is the idea of moving towards a service economy, based upon the provision and sale of services such as thermal comfort instead of energy.

Fujii, H. and L. Lutzenhiser (1992). "Japanese residential air-conditioning: natural cooling and intelligent systems." Energy and Buildings 18(3-4): 221-233.

The paper discusses the implications of innovations in Japanese air conditioning for users and for energy consumption. Studies of the design and use of Japanese air conditioning

technologies reveal distinctive behavioural and conceptual concerns, dissimilar to trends in US markets. The authors suggest that cultural factors - such as the Japanese emphasis on heating bodies rather than spaces - may account for some of these differences.

Givoni, B. (1976). Man, climate and architecture. Barking, Essex, Applied Science Publishers.

One of the first attempts to synthesise research on the physical environment with physiological research on human comfort. The book examines the relationship between physiological responses to thermal stress, variations in climatic elements and the thermal properties of different building materials. Since the publication of an earlier edition in the early 1960s, Givoni notes that there is a new context for understanding the relationship between humans, climate and architecture - including an awareness of the need to conserve energy and minimise needs for heating and air-conditioning as a result of the energy crisis.

Givoni, B. (1998). Climate Considerations in Building and Urban Design. New York, Van Nostrand Reinhold.

A comprehensive review of research and practice in the field of building and urban climatology with design guidelines for different climates. Moving from studies of bodies to those of urban microclimates, Givoni considers the relationship between individuals, buildings, communities and the environment. The aim is to promote more natural forms of design (e.g. passive solar), especially for hot climates where current ASHRAE standards are seen to offer an inappropriate design guideline, by failing to consider the actual comfort needs of the local population.

Golany, G. S. (1996). "Urban design, morphology and thermal performance." Atmospheric Environment 30(3): 455-465.

Golany argues that whilst there has been considerable literature published on the subject of climate and single building design, there are few contributions focused at the neighbourhood or city level. This means that outdoor space receives relatively little design attention resulting in climatically deficient designs that that have a detrimental influence on human comfort, health and social conditions. Furthermore, cities exhibiting very different climatic conditions worldwide are designed in the same ways. Golany shows how theories from urban climatology, botany and environmental geography, and lessons learnt from indigenous urban design, might be incorporated into urban design processes in order to enhance human comfort and provide a pleasing and protective atmosphere for a city.

Goldsmith, R. (1960). "Use of clothing records to demonstrate acclimatisation to cold in man." Journal of Applied Physiology 15(5): 776-780.

Gomez, F., N. Tamarit, et al. (2001). "Green zones, bioclimatics studies and human comfort in the future development of urban planning." Landscape and Urban Planning 55(3): 151-161.

The paper considers the role of green spaces in making the life of city dwellers more comfortable. Parks and other "green zones" are seen to act as coolers and regulators of the air and temperature exchange as well as contributing to the psychological well-being of humans. Several well-know 'comfort indices' are used to evaluate the performance of Valencia's green zones in providing comfortable conditions. The value of such bioclimatic methods for use in urban planning is assessed.

Guy, S. and E. Shove (2000). A Sociology of Energy, Buildings and Environment: Constructing Knowledge, Designing Practice. London, Routledge.

The authors consider how techno-economic representations of the energy problem underpin policy and practice concerning energy efficiency in buildings. Presenting case studies of building practice, they examine how sociological methods and arguments might fare

alongside more conventional representations of the 'energy problem' and offer different understandings of indoor thermal comfort.

Hackett, B. and L. Lutzenhiser (1991). "Social Structures and Economic Conduct: Interpreting Variations in Household Energy Consumption." Sociological Forum 6: 449-470.

The paper studies reactions to changes in the way tenants pay for energy in a California apartment complex. When tenants paid for their own energy use (rather than sharing the cost equally with other tenants) their energy use tended to drop even if their bill was now lower. Reduced air-conditioner use accounted for almost all of the reduction in energy consumption, and there were few expressions of discomfort. The findings suggest that the use of air conditioning may have less to do with cost than is often assumed and that comfort assessment criteria might be quite variable, flexible and adaptive.

Healy, J. D. and J. P. Clinch (2002). "Fuel poverty, thermal comfort and occupancy: results of a national household-survey in Ireland." Applied Energy 73(3-4): 329-343.

Examines the relationship between fuel poverty and thermal comfort and the extent of indoor cold strain resulting from inadequately heated housing. Self-reported and objective measures of thermal comfort are utilised that pay particular attention to the age profile of those affected by thermal discomfort.

Heerwagen, J. (2000). "Green buildings, organisational success and occupant productivity." Building Research and Information 28(5/6): 353-367.

Heerwagen considers the extent to which 'green' buildings can contribute to business performance and organisational effectiveness. The paper explores how the physical attributes of green buildings affect the physiological, psychological, cognitive and social functioning of building occupants at the individual level.

Heerwagen, J. and R. C. Diamond (1992). Adaptations and Coping: Occupant Response to Discomfort in Energy Efficient Buildings. ACEEE Summer Study, Asimolar, California, ACEEE.

Post-occupancy evaluation of adaptation in 7 new energy efficient buildings in the Pacific Northwest. A workplace satisfaction survey records the "tactics and tinkering" of 268 subjects in coping with everyday stresses in the workplace (e.g. noise intrusion, lack of privacy, thermal discomfort). The aim is to consider whether behavioural, psychological or environmental adjustments work best in alleviating discomfort. The authors conclude that comfort maintenance is a highly reflexive behaviour and that people prefer to change conditions themselves rather than have the building "decide" what to do. As such, there is a need to develop different ways to enhance comfort and save energy e.g. multiple comfort zones that people can choose to work in, person-environment matching strategies. However, in some situations, too much individual control might create the phenomenon of the "desk-potato" - employees who rarely move from their desk all day.

Heijs, W. and P. Stringer (1988). "Research on residential thermal comfort: some contributions from environmental psychology." Journal of Environmental Psychology 8(3): 235-247.

The authors identify three trends in comfort research: (1) physiological lab-based and normative studies; (2) psychological and multivariate approaches using field studies; (3) an applied orientation which focuses on issues of energy conservation. Each of these is delineated in terms of concepts, methodologies and types of results. The key discrepancies and debates within these three sets of studies are reviewed e.g. differences between Fanger's comfort equation and field studies, arguments about the relative role that should be attributed to psychological variables compared to the socio-cultural background of residents, etc.

Heschong, L. (1979). Thermal Delight in Architecture. Cambridge, Massachusetts, MIT Press.

Heschong explores the many dimensions and sensations of thermal experience and delight and their expression in architecture and building design. Social and cultural variation in heating and cooling strategies (promenading, moving to foothills) and systems (fires, saunas, gardens) throughout history are explored. Such strategies and systems of thermal regulation, it is argued "should not be designed out of existence in the name of a thermally neutral world". The book considers how passive solar technologies might be developed to meet thermal needs, resurrect thermal coping and sensing strategies and open up a new dimension of architectural experience.

Hirst, E., D. White, et al. (1985). "Indoor temperature changes in retrofit homes." Energy 10(7).

Behavioural responses to energy efficiency measures in 79 US households are analysed in order to consider the extent to which households take back some of the energy savings produced from technical improvements in the form of increased comfort. Analysis of electricity billing data suggests that households increased their indoor temperature settings after retrofit by almost 1OF on average. These results suggest that approximately 10% of the energy saving due to retrofit was taken back in the form of increased comfort.

Hollies, N. and R. Goldman (1978). Clothing Comfort: Interaction of Thermal Ventilation, Construction and Assessment Factors, Ann Arbor Science.

A collection of papers from physiology and psychology about the relationship between thermal comfort and clothing. Issues addressed include the extent to which thermal properties of clothing change with activity levels and how different materials influence subjective feelings of comfort.

Humphreys, M. (1994). Field studies and climate chamber experiments in thermal comfort research. Thermal Comfort: Past, Present and Future. N. Oseland and M. Humphreys. Watford, Building Research Establishment: 52-69.

Humphreys argues that thermal comfort research is in 'crisis' on the basis of discrepancies, oddities and contradictions between the results of chamber and field studies. He argues that what's missing (and what may help to explain discrepancies in existing findings) is an understanding of the modifications people make to their thermal environment and how they try to secure comfort (both in chambers and in the field). People achieve their own dynamic equilibrium but complex feedback processes are involved. The concept of adaptive feedback which accounts for the way changing climatic conditions influence comfort is proposed as a way of contributing to the design and on-going operation of low energy buildings.

Humphreys, M. (1995). Thermal comfort temperatures and the habits of hobbits. Standards for Thermal Comfort. F. Nicol, M. Humphreys, O. Sykes and S. Roaf. London, E & F N Spon: 3-14.

Imagining a trip to Tolkein's middle earth, Humphreys describes how we might learn a great deal about the habits and preferences of comfort-seeking hobbits by observing their daily routines, practices and environments without the need for invasive measurements or tiresome physiological experiments. We might notice, for instance, in what circumstances hobbits opened or closed doors and windows or stoked up fires, or what they chose to wear from their enormous stock of clothing. This, Humphreys suggests, would be enough to know how to provide comfortable apartments for hobbits. Such an imaginary project illustrates an adaptive approach to thermal comfort, showing how people are not inert recipients of the environment but interact with it to optimise their conditions. Humphreys argues that the challenge for thermal comfort research is to provide adequate possibilities for selection and adjustment so that people will make themselves comfortable if they wish. A case for a new international thermal comfort guideline, based on this adaptive principle, is developed.

Humphreys, M. and F. Nicol (1995). An adaptive guideline for UK office temperatures. Standards for Thermal Comfort: Indoor air temperatures for the 21st century. F. Nicol, M. Humphreys, S. O. and S. Roaf. London, E & FN Spon.

The authors propose a temperature guideline for thermal comfort in office buildings that is based on experience gained from field studies of thermal comfort, rather that from the Fanger equation or its equivalents. In comparison to fixed temperature standards, the guideline is intended to be open to adjustment through experiences of heating and cooling in offices.

Humphreys, M. and F. Nicol (1998). "Understanding the Adaptive Approach to Thermal Comfort." ASHRAE Transactions: Symposia: 991-1004.

The authors develop a complex adaptive model in which comfort is viewed as a self-regulating system. Such a model starts from the biological insight that "the human being is a comfort-seeking animal who will, given the opportunity, interact with the environment in ways that secure comfort". Adaptation refers to all those physiological, psychological, social, technological, cultural or behavioural strategies that people might use to secure comfort. Thermal comfort is seen as a dynamic process or system not a fixed attribute (as in Fanger's comfort equation). Changes in conditions mean that people will react to restore their comfort dependent on the adaptive opportunities afforded by the building and social context.

Hunt, D. and M. Gidman (1982). "A National Field Survey of House Temperatures." Building and Environment 17(2): 107-1124.

Information about temperatures in houses is important in assessing the value of various energy conservation measures and gives an indication of the standards of thermal comfort enjoyed by the occupants. The paper presents the results of the most extensive survey of domestic dwelling temperatures to be undertaken in the UK. The temperature of each room in 1000 homes was recorded in February 1978 and interviews conducted with households about comfort conditions and heating practices. The average dwelling temperature was 15.8oC, with variance around the house, including mean living room temperatures of 18.3oC, with bedrooms the coldest on average. Major sources of variance related to type and operation of heating systems, dwelling age, household income, time of day and geographical location. Centrally heated houses ran 3oC warmer on average than non-centrally heated houses.

Huntington, E. (1924). Civilization and Climate. London, Oxford University Press.

One of the first geographers to explore the association between climate and human efficiency and to link issues of thermal comfort to progress and civilisation. Huntington begins from the assumption that there are certain optimum conditions (e.g. of temperature or humidity) that give rise to civilised societies and which should be striven towards. Now widely refuted, such culturally deterministic arguments were influential in the development of the air-conditioning industry in the US.

Ierley, M. (1999). The Comforts of Home: the American home and the evolution of modern convenience. New York, Clarkson Potter Publishers.

Charts the evolution of the mechanical systems that have, over the last two centuries, made American homes places of comfort (e.g. central heating, lighting, air-conditioning, etc.). Ierley describes how new technologies (and the power supply and water infrastructures that make them work) have made possible the increasing comfort and convenience of everyday life.

Janda, K. and J. Busch (1994). "Worldwide Status of Energy Standards for Building." Energy 19(1): 27-44.

A useful reference document providing a profile of energy standards in 57 countries, including information on contents, development and use. In focusing on non-residential buildings, the study supplements existing cross-national comparative studies for residential buildings in industrialised countries.

Kempton, W., D. Feuermann, et al. (1992). ""I always turn it on super": user decisions about when and how to operate room air conditioners." Energy and Buildings 18(3-4): 177-191.

The paper studies room air-conditioner operation in a multi-family apartment building in New Jersey, in order to consider how energy consumption and peak power demand are

influenced by user needs and behaviour. Interviews reveal how air conditioner use is influenced by many non-economic factors including: daily schedule, folk theories and personal beliefs and preferences. A "startling mismatch" between existing air conditioner controls and user needs is noted.

Kempton, W. and S. Krabacher (1987). Thermostat Management: Intensive Interviewing Used to Interpret Instrumentation Data. Energy Efficiency: Perspectives on Individual Behaviour. W. Kempton and M. Neiman. Washington DC, ACEEE.

Thermostat management was a major component of public energy conservation appeals in the US during the 1970s. Large-scale surveys recording households self-reported thermostat management strategies generally suggest that many households have lowered their thermostat settings since the 1970s. This intensive study of 7 households aims to explore the complex household dynamics that help to explain trends in thermostat management. Thermostat settings were electronically recorded over a two year period and in-depth interviews used to elicit further details about family schedules, setting practices, etc. The authors found great diversity in average winter thermostat settings (e.g. from 64OC to 74OF) and in patterns of daily changes. Household's reported thermostat settings were also consistently below the observed settings.

Kempton, W. and L. Montgomery (1982). "Folk quantification of energy." Energy 7(10).

The study analyses the simple methods that residential consumers use to measure their energy consumption and considers how these frame energy decisions. The authors suggest that the 'folk' methods used often result in inefficient energy conservation actions that are not optimal in economic terms. However, these errors do not relate solely from a lack of information since they are also made by consumers with a reasonable understanding of technical energy measurement techniques. Instead, the persistence of consumer methods relates to issues such as their compatibility with the general budgeting techniques of households.

Kempton, W., C. Reynolds, et al. (1992). "Utility control of residential cooling: resident-perceived effects and potential improvements." Energy and Buildings 18(3-4): 201-219.

Klinenberg, E. (2002). Heat Wave: A Social Autopsy of Disaster in Chicago. Chicago, The University of Chicago Press.

During the 1995 heat wave in Chicago, more than 700 people died in the space of a week, many from heat-related illnesses (more than in the great fire of Chicago). Klinenberg argues that this "hidden disaster" was not a "natural" one, but was a social drama that played out and made visible a series of conditions that are always present but difficult to perceive. By investigating the people, places and institutions most affected by the heat wave he constructs a fascinating picture of the social systems that underpinned the city in crisis and collectively created the conditions that made it possible for so many people to die. For example, many of those that died were elderly, from poorer neighbourhoods, with few social networks and were found in apartments with tightly sealed windows without air-conditioning. In exploring the case of the Chicago heatwave, Klinenberg shows the extent to which adaptation to extreme thermal conditions and capacities to survive relate to how individuals are connected to, or disconnected from, wider social, institutional and cultural networks. He also considers how this event related to previous extreme weather situations to reveal changing strategies of coping. For example, in earlier decades people more readily made use of parks, lakes and swimming pools as natural forms of cooling. By contrast, in the 1995 disaster, more people chose to stay indoors and switch on the air-conditioning, creating pressure on electricity networks and widespread power cuts.

Lam, J. C. (1996). "An analysis of residential sector energy use in Hong Kong." Energy 21(1).

A survey of energy consumption in 200 households in Hong Kong. The study shows that the greatest increase in energy consumption is related to the high penetration of electrical appliances, especially room air-conditioners for comfort cooling. The authors explain that in

sub-tropical Hong Kong where the summer is long, hot and humid, air-conditioning has, in recent years become the single largest electricity consuming item, with ownership levels of around 90% amongst the households surveyed.

Lammers, J., L. Berglund, et al. (1978). "Energy conservation and thermal comfort." Environmental Management 2(2): 113-117.

An analysis of an energy conservation programme in a New York office building, which included re-adjusting thermostat settings (to 20OC in winter and 27OC in the summer). The study indicates that thermal comfort could be improved and energy savings achieved if occupants dressed more appropriately for the expected thermal environment of the workplace.

Laurans, V. (2002). "Comfort process and modernization of habitat in Shanghai in the 90's." Bulletin d'Association de Geographes Francais 4: 389-402.

A stated objective of a residential estate market project in Shanghai in the nineties was to ensure that modern comfort is reachable by any Shanghai citizen. The paper considers which concept of well-being in the habitat underpinned the project, with which criteria the concept of comfort was evaluated, and which actions were taken to support the standardisation and diffusion of comfort.

Leaman, A. and B. Bordass (1995). Comfort and Complexity: Unmanageable Bedfellows? Workplace Comfort Forum, 18-19 May 1995, London.

The paper considers the relationship between complexity and comfort in office environments. The authors suggest that one of the best kept secrets of comfort research is that comfort is defined as the absence of discomfort. A logical consequence of this is that good buildings should have both comfort-provision and discomfort-alleviation strategies. Naturally ventilated buildings are often richer in features for discomfort-alleviation. But the key to successful thermal performance also relates to the level of complexity. Efforts to meet individual comfort demands via flexibility increase complexity and mean that more things can go wrong. Field surveys, they explain, reveal that the best work spaces are often those where variety is not excessive, and where systems are as simple as possible for people to manage and change. In providing adaptive opportunity, the authors conclude, it is important to take into account the social context of the whole building system and how this is viewed from the different perspectives of designers, managers and occupants.

Lovins, A. (1992). Air Conditioning Comfort: Behavioural and Cultural Issues. E-Source Strategic Issues Paper. Boulder, CO., E-Source.

Lovins reviews and summarises research on comfort and cooling, identifying a variety of different "comfort paradigms". The report is primarily concerned with how anomalies in the dominant engineering comfort model and findings from field studies and social science research raise questions about its validity. This is important, Lovins argues, because buildings constructed and HVAC systems specified using this model are likely to routinely waste a considerable amount of energy.

Lutzenhiser, L. (1992). "A question of control: alternative patterns of room air-conditioner use." Energy and Buildings 18: 193-200.

A study of room air-conditioner use in 279 Californian apartments. Families were interviewed and asked if they used manual or automatic controls on their wall unit air conditioners. Interviews revealed a variety of control strategies and patterns of air-conditioner use that. The study also revealed that manual users used an average of 21% less electricity for cooling compared to automatic users.

Lutzenhiser, L., B. Hackett, et al. (1994). Alternative Cooling Technologies for California: Social Barriers, Opportunities and Design Issues. Berkeley, California, Energy Research Group, University of California.

An evaluation of the socio-technical impediments to (and opportunities for) the adoption of alternative cooling technologies in California. The study is based on a review of existing literature/data and interviews with builders/developers, energy researchers, marketing

specialists, manufacturers and consumers. The authors emphasise that end-users are not the only influential actors in the uptake of new cooling technologies and that due regard needs to be taken of the role of organisational actors that manage the distribution networks through which technologies are transferred. New cooling technologies must also "fit into" existing building technologies, practices and settlement patterns. The report also reviews the relevance of contributions to the comfort literature in accounting for the social and cultural contexts in which cooling technologies develop.

Markham, S. F. (1947). Climate and the Energy of Nations. Oxford, Oxford University Press.

Expresses the idea that ancient civilizations developed in areas of equable climate (along 70o isotherm) and discusses the heating arrangements of early civilisations.

Markus, T. and E. Morris (1980). Buildings, Climate and Energy. London, Pitman.

McGeever, P. (1982). "The active pursuit of comfort: its consequences for energy use in the home." Energy in Buildings 5(103-107).

The paper provides field evidence to point out some discrepancies between laboratory predictions of thermal comfort and actual responses. Some discrepancies may be due to seasonal distortions of the rating scales in common use. McGeevor shows how people are active and adaptive agents, capable of constructing their own definitions of what comfort means to them and of controlling their own immediate environment. He concludes that more than a 7 point scale is needed to define and tackle the problem of indoor comfort.

McIntyre, D. (1980). Indoor Climate, Applied Science Publishers.

An historical review of technical research on thermal comfort that summarises the state of physical, physiological and psychological knowledge about the effects of indoor climate on man.

Meyer, W. B. (2002). "Why indoor climates change: A case study." Climatic Change 55(3): 395-407.

Meyer considers the relationship between indoor climate and climate change. Two schools of thought in thermal comfort research are reviewed: one which sees comfort as governed by a common and fixed human preference, the other as strongly influenced by highly variable habits and expectations. The paper examines these theories in respect of an episode of major and rapid indoor climate change - a sharp rise in winter temperatures that occurred in the northern US in the first half of the nineteenth century. The validity of different thermal comfort perspectives is considered and the value of such a study for informing projections of future climatic change is discussed.

Milne, G. and B. Boardman (2000). "Making cold homes warmer: The effect of energy efficiency improvements in low-income homes." Energy Policy 28(6-7): 411-424.

It has been reported that low income households often take a high proportion of potential energy savings as improvements in comfort - the so-called "takeback" effect. For example, energy efficiency improvements such as cavity wall insulation or double glazing may mean that households are able to heat their homes to a higher level for the same cost. This paper examines the results of a number of energy efficiency projects in the UK over the past 20 years to try and determine the most important influences on temperature takeback. It is estimated that in houses warmed to about 16.5^{o}C, 30% of the potential energy saving will be taken as an increase in the comfort temperature. Further, it is not until around 19^{o}C that 80% is taken as energy saving. The authors suggest that current low levels of warmth for many low-income households will mean that investment in the energy efficiency of the UK housing stock will fail to achieve predicted energy savings for at least another 15 years.

Newburgh, L. H., Ed. (1968). Physiology of heat regulation and the science of clothing. New York, Hafner Publishing.

An edited collection of physiological studies that examine the relation between the heat balance of bodies and clothing in a variety of climates and contexts (e.g. military and civilian). The book examines how unfavourable environmental conditions can be mitigated by the use of protective clothing.

Nicol, F. and M. Humphreys (2002). "Adaptive thermal comfort and sustainable thermal standards for buildings." Energy and Buildings 34(6): 563-572.

The paper explains the origins and development of the adaptive approach to thermal comfort. Recent developments in the theory of adaptive comfort are described and recommendations made about how these might be applied in the field of building practice and in designing thermal standards for sustainable buildings.

Nicol, F., M. Humphreys, et al., Eds. (1995). Standards for Thermal Comfort: Indoor air temperature standards for the 21st Century. London, E & F N Spon.

A collection of papers contributing to the representation of thermal comfort as an adaptive and dynamic process in which individuals regulate their own micro-environment. The scope for incorporating climatic, cultural and environmental variables into the assessment of thermal comfort is discussed as are methodologies through which future adaptive standards of thermal comfort might be developed and established.

Nicol, F. and M. Kessler (1998). "Perception of Comfort in Relation to Weather and Indoor Adaptive Opportunities." ASHRAE Transactions: Symposia: 1005-1017.

An occupant survey of perceptions of summertime comfort among staff in an Open University building. The survey compares the success of different cooling strategies (with different forms of natural/mechanical ventilation and cooling) on three floors of the building, using the results of staff satisfaction questionnaires and building thermal performance monitoring conducted in 3 consecutive months (August to October 1995). Perceptions of comfort and buildings are shown to change with time and weather. Well-designed natural ventilation systems that allow staff to self-regulate are considered better overall. Potential for adaptation and perceptions of thermal control change over time.

Nicol, J. F. and K. J. McCartney (1999). "Assessing adaptive opportunities in buildings." Proceedings of CIBSE Conference.

An assessment of the scope for 'adaptive opportunity' (the ability of occupants to avoid discomfort) in 5 air-conditioned and naturally ventilated office buildings in Oxford and Aberdeen. The authors ask whether the scope for adaptive opportunity relates to physical control options or social context (e.g. dress code, management style). Longitudinal and transverse survey responses reveal that a complex interaction occurs involving the building, the changing attitude of occupants and the availability of controls. Impressions of levels of discomfort are also shown to relate to the type of survey method used. The possibility of developing an adaptive algorithm to control indoor temperature in buildings is explored.

Nicol, J. F., I. A. Raja, et al. (1999). "Climatic variations in comfortable temperatures: the Pakistan projects." Energy and Buildings 30: 261-279.

Examines the premise that people adapt to the temperatures they experience and are comfortable over a greater range of temperatures than current international standards suggest (e.g. 26oC in cooling season and 21oC in heating season). Evidence is presented from a longitudinal study (summer 1993/winter 1994) of office buildings in 5 cities in Pakistan (each in a defined climatic zone). The study shows how workers experience a wide range of temperatures and reviews strategies of adaptation (changing clothes, switching on fans, opening windows) taken to alleviate discomfort. Results are used to help develop guidelines for setting standards that account for local climatic conditions, fashions and customs.

Nikolopoulou, M. and K. Steemers (2003). "Thermal Comfort and psychological adaptation as a guide for designing urban spaces." Energy and Buildings 35(1): 95-101.

Investigations of thermal comfort conditions in outdoor spaces have revealed that whilst quantitative microclimatic parameters strongly influence thermal sensation, they cannot

fully account for the wide variation between objective and subjective comfort evaluation. The paper considers parameters of psychological adaptation (e.g. expectations, experiences, perceived control, length of exposure) to help explain such variations in outdoor thermal sensation.

Olgyay, V. (1963). Design with climate: bioclimatic approach to architectural regionalism, Princeton University Press.

One of the key texts exploring the influence of climate on building principles. Olgyay synthesises biological, meteorological and engineering concepts to develop a framework for architectural design. The importance of different both physiological and cultural influences on the development of building styles in different bio-climatic regimes is discussed.

Oseland, N. (1995). "Predicted and reported thermal sensation in climate chambers, offices and homes." Energy and Buildings 23(2): 105-115.

Oseland notes that past thermal comfort research has shown differences in the thermal sensation votes given in laboratories and field settings, but that such studies tend to compare the votes of different groups of people in different environments rather than comparing the same people in each. To address this issue, a study of 30 employees from the UK's Building Research Establishment is described that examines the thermal comfort sensations of the subjects in their homes, offices and in comfort chambers. Each employee is required to spend 3 hours engaged in only sedentary activities and wearing the same clothing in each environment, with temperature adjusted in the range 18-25^{o}C. The study shows that the observed neutral temperature for each of the subjects differed by up to 2^{o}C and were up to 1^{o}C different to those predicted (using ISO 7730). In a second phase, clothing and activity restrictions were removed and observed thermal comfort sensations were very poorly correlated with those predicted.

Oseland, N. and M. Humphreys (1994). Trends in Thermal Comfort Research. Watford, Building Research Establishment.

A review of thermal comfort research from the 1980s and early 1990s. Developments in physiological and psychological research are discussed that raise questions about the validity of existing models (e.g. the Fanger equation) and standards (e.g. ISO and ASHRAE). The report also evaluates more recent studies that explore the relation between thermal comfort and energy conservation, in light of the energy crisis of the 1970s and concerns over global warming.

Oseland, N. and M. Humphreys (1994). Thermal Comfort: Past, Present and Future. Watford, Building Research Establishment.

Oyeniyi, M. A. O. (1997). "Architectural design and climate: an overview." International Journal of Environmental Studies 53(4): 311-324.

Describes how climate and requirements for thermal comfort influence building patterns in different climatic regions. It is argued that standards of comfort are relative and are influenced by a variety of social, cultural and economic factors.

Paciuk, M. (1990). "The role of personal control of the environment in thermal comfort and satisfaction at the workplace." Journal of the Environmental Design Research Association 21: 303-312.

A study of occupants in ten office buildings in Haifa, Israel shows how personal comfort is regulated using mechanisms of individual control over the thermal environment. The analysis shows a strong relationship between perceived control of the thermal environment and occupant satisfaction. Thermal comfort is viewed as a situation specific process that is constantly redefined by individuals.

Parsons, K. (1993). Human Thermal Environments: the effects of hot, moderate and cold environments on human health, comfort and performance. London, Taylor and Francis.

Pauken, M. (1999). "Sleeping soundly on summer nights - the first century of air-conditioning." ASHRAE Journal 41(5): 40-47.

A historical account describing the progression of cooling and air-conditioning technologies in the home. Pauken suggests that the development of air-conditioning was linked to major shifts in the demographics of the US (e.g. since 1940s growth of home construction in Southern states coinciding with growth and availability of air-conditioning to the homeowner). Air-conditioning is seen to have "tamed" hot and humid summer conditions bringing prosperity to business owners and individuals. The paper describes the application of a variety of cooling innovations (e.g. table/ceiling fans, ice-boxes/refrigeration) and discusses how technical hurdles were overcome along the way to air-conditioned comfort in the home. Most people, Pauken concludes, can now afford to sleep comfortably on the hottest summer nights and feel refreshed throughout the day thanks to the efforts of countless people working in the air-conditioning industry.

Peach, J. (1982). "Environmental comfort and energy conservation." Royal Society of Health Journal 102(4): 162-168.

The author considers how 'conscious conservation' in naturally ventilated buildings can be achieved whilst maintaining comfortable conditions.

Pretlove, S. and T. Oreszczyn (1998). "Climate change: impact on the environmental design of buildings." Building Services Engineering Research and Technology 19(1): 55-58.

Buildings are designed for a specific climate, yet they often have a lifetime of more than 100 years. Climate change may require buildings to operate over a range of climatic conditions. The paper investigates the impact that climate change may have on the design and performance of buildings, examining the specific effects of changes in temperature and solar radiation on energy use. Evidence is presented that suggests a proportion of the benefits of milder winters may be taken as improved comfort rather than reduced energy use. If such trends are not taken into account, it is argued that designers may adopt solutions that are inappropriate for future energy use.

Prins, G. (1992). "On condis and coolth." Energy and Buildings 18: 251-258.

An essay about the cultural origins of American society's large-scale conditioning of air. Prins presents an argument about the moral and philosophical implications of America's "addiction" to coolth and how it might be possible to move onto more environmentally-friendly "post-coolth" technologies.

Quigley, J. M. and D. L. Rubinfeld (1989). "Unobservables in consumer choice - residential energy and the demand for comfort." Review of economics and statistics LXXI(3): 416-425.

The paper examines the effects of changes in energy prices on residential energy consumption and on the production of thermal comfort. The authors show how households substitute between comfort and other forms of household consumption in order to maximise well being.

Rajala, N. (2000). Some Like It Hot: The Sauna, Its Lore and Stories, North Star Press.

Rapoport, A. (1969). House Form and Culture. Englewood Cliffs, New Jersey, Prentice Hall.

Rapoport considers the importance of social and cultural factors in shaping house form across the world, rejecting a "physical deterministic" view based on the idea of progressive development towards an ideal environment. To bring order to this complex field, he argues it is necessary to cross the disciplines of architecture, cultural geography, urban planning and anthropology. Alternative theories of house form are reviewed that show how issues of physical comfort or climatic adaptation are not the only forces shaping dwellings. For example, the spread of European style houses in North Africa is connected with issues of status and modernity.

Rapoport, A. (1980). Vernacular architecture and the cultural determinants of form. Buildings and Society: Essays on the social development of the built environment. A. D. King. London, Routledge.

Explores the importance of folk theories in the design of the built environment. Cultural milieus, it is argued have been ignored in favour of western traditions. Moreover, there is a need to view built environments as more than shelter and appreciate their significance as safe places and as expressions of status and identity. By viewing humble dwellings as cultural phenomena, Rapoport argues that it is possible to gain a better understanding of conditions and situations where the built environment works well.

Reddy, T. A., L. K. Norford, et al. (1991). "Shaving residential air-conditioner electricity peaks by intelligent use of building thermal mass." Energy 16(7).

In the US, the residential air-conditioning load is a significant component of peak electricity demand on hot summer afternoons. The paper examines opportunities for peak shaving (shifting air-conditioning demand to off-peak periods) using modern electronics and the intelligent use of the thermal mass structure inherent in the structure and furnishings of the home.

Reynolds, J. (2002). Courtyards: aesthetic, social and thermal delight. New York, John Wiley.

The book describes the design of courtyards in different cultures and their role in supporting the rituals of everyday life. Courtyards offer a variety of ways of adapting to climatic conditions. For example, when the climate is very cold the fire and hearth are positioned at the centre of buildings, when the climate is hot and dry courtyards offer a shaded fountain at the centre.

Roberts, B. (1997). The Quest for Comfort. London, Chartered Institute of Building Services Engineers.

Rohles, F. H. (1980). "Temperature or temperament: a psychologist looks at thermal comfort." ASHRAE Transactions 86(1): 541-551.

Rohles reviews a number of field studies that address the psychology of comfort. For example, he shows how under identical temperature conditions, certain furnishings (e.g. wood panelling) made people feel warmer than in "stark, sterile conditions.

Rohles, F. H. and J. E. Laviana (1985). "Indoor climate: new approaches to measuring how you feel." In CLIMA 2000: World Conference on Heating, Ventilation and Air Conditioning 4: 1-6.

Reviews the current "state of the art" in methods for measuring how people feel in indoor environments. ASHRAE defined thermal sensation and comfort scales and recent modifications that account for thermal dissatisfaction are considered. The authors consider the effectiveness of different scales in measuring subjective feelings of comfort and discomfort.

Rohracher, H. (2001). "Managing the Technological Transition to Sustainable Construction of Buildings: A socio-technical perspective." Technology Analysis and Strategic Management 13(1): 137-150.

The construction of buildings brings about a substantial ecological load: about 40% of energy consumption and about 25% of the material moved by the economy. As such, new construction technologies and building components might reduce the ecological load of buildings to a fraction of its present value. Rohracher argues that the problem of making building stock more sustainable is only to a minor extent a technical one. More important is changing the social context and socio-technical processes involved in the construction of sustainable buildings. A number of strategies to manage technical change towards sustainability are discussed, including: better integration of supply chain actors; the shift to a market for innovative and ecological building services; and, the integration of consumers into the innovation process.

Ruck, N. C., Ed. (1989). Building Design and Human Performance. New York, van Nostrand Reinhold.

An edited collection exploring the relationship between human well-being and performance in building design. In the introduction, Ruck argues that the current theory that "perfect comfort" can be achieved by finding the temperature in which the largest number of people are comfortable is unresponsive to human needs and notes people's dissatisfaction with the "boring uniformity of air-conditioning". Further contributions discuss how buildings might be designed to allow heating, ventilation, cooling and lighting adjustments in response to people's changing needs and desires.

Rudge, J. and F. Nicol, Eds. (2000). Cutting the Cost of Cold. London, E & F N Spon.

Rybczynski, W. (1987). Home: A short history of an idea. Harmondsworth, Penguin Books.

Rybczynski comments on the poverty of architectural ideas about meanings of comfort and asks: what is comfort beyond "the comfort zone". Focusing on domestic comfort and the idea of home, he explores how comfort is a multi-faceted concept relating to the historical development of ideas about privacy, domesticity, efficiency, ease, austerity, commodity, etc. Only in the 18th Century did comfort come to be associated with the idea of 'cosiness' and thermal contentment. More recently, comfort has come to be associated with functional efficiency, related to the development of scientific theories of light and air, and technologies for ventilation and air-conditioning. Rybczynski concludes that cultural ideas like comfort have a life that is measured in centuries and to address the question "what is comfort" it is necessary to understand its complex evolution rather than accept dominant physiological or psychological definitions.

Saleh, M. A. E. (2001). "The decline vs the rise of architectural and urban forms in the vernacular villages of southwest Saudi Arabia." Building and Environment 36(1): 89-107.

The paper considers the forces behind the decline, transformation and rise of vernacular architecture and urban form in the southwest of Saudi Arabia. Saleh argues that the cultural heritage of these forms of architecture has been bypassed in the rush to modernise. A more appropriate approach to planning and design would be to renew awareness of social and cultural aspects embodied in vernacular architecture rather than rely on 'imported' notions about user requirements and individual comfort.

Salvage, A. V. (1993). Cold Comfort: A National Survey of Elderly People in Cold Weather. London, Age Concern England.

Salvage investigates the problem of the "old and the cold" in Britain: how do elderly people manage to deal with cold weather? Results of a questionnaire survey suggest that many elderly people live in temperatures lower than those officially recommended, and that many of them feel cold during the winter months. For example, although central heating ownership has increased significantly and room temperatures have improved since the 1970s, 81% of respondents had morning living room temperatures below those recommended by the World Health Organisation. Another of the issues considered is whether existing thermal comfort standards for homes are adequate for the elderly or whether older people might need higher temperatures than younger people because of decreasing metabolic heat production and reduced activity rates.

Saunders, T. (2002). The Boiled Frog Syndrome: Your health and the built environment. London, John Wiley.

"A frog jumps into a pot of water which is gradually being heated. As the water gets warmer, the frog adjusts its body temperature and continues to adjust to the increasing water temperature until, ultimately the frog is boiled alive". Saunders suggests that like the frog, human beings keep adjusting to increasing health and ecological hazards in order to satisfy expectations and demands for improved comfort, greater convenience and easier living. The book reviews some of the everyday hazards and risks associated with the built environment

(e.g. sick building syndrome, electromagnetic radiation) and the problems of spending a greater proportion of our lives in sealed air-conditioned buildings. The value of more traditional and holistic ideologies about architecture and design are explored as alternative framework for designing buildings. Saunders concludes that 'ordinary people' need to challenge architects to provide healthy environments in which to live and work.

Scott, D., P. Parker, et al. (2001). "Determinants of energy efficiency behaviours in the home: A case study of Waterloo Region." Environments 28(3): 75-96.

A study of underlying factors that influence three types of energy consumption behaviours (technology investment, management and curtailment) in 339 households in Ontario, Canada. The authors report that energy use curtailment behaviours were more strongly influenced by "personal norms" (environmental attitudes and social responsibility), while energy efficient technology investments were "predicted more by pragmatic factors like a desire for increased home comfort".

Semenza, J. (1996). "Heat related deaths during the July 1995 heatwave in Chicago." New England Journal of Medicine 335: 84-90.

An epidemiological study of the Chicago heat wave of 1995, which shows that those at greatest risk of dying were people with medical illnesses who were socially isolated and did not have access to air-conditioning. The study also found that people who lived in apartments without air conditioning had a lower risk if they had access to an air-conditioned lobby.

Sherratt, A. F. C., Ed. (1987). Air-conditioning: Impact on the built environment. London, Century Hutchinson Ltd.

A series of papers focusing on the commercial and technical development of air-conditioning and trends in the UK. In chapter 1, Gillingham explores the ever expanding market for air-conditioning, noting that "the debate is increasingly on how well air-conditioning should be done, in relation to the balance between capital and running costs, rather than on whether air-conditioning is needed". Various trends in air-conditioning applications and markets are discussed. For example, in offices the increased uptake of equipment, such as computers, is driving the demand for more ventilation and cooling. Elsewhere, in the retail sector, energy for cooling and moving air now amounts to 27.9% of the annual energy bill, and it is suggested that few retailers would now contemplate planning a new store without installing up-to-date air-conditioning systems.

Shimoda, Y. (2003). "Adaptation measures for climate change and the urban heat island in Japan's built environment." Building Research and Information 31(3-4): 222-230.

Climate change is expected to exacerbate the existing heat island effect in Japanese cities. The author examines how increases in temperature will influence urban micro-climates and patterns of energy and water consumption, human health and comfort. Some of the possible adaptation measures that might be needed to alleviate the effects of changing climatic conditions are discussed.

Shohl Wagner, B. and R. C. Diamond (1987). "The Kansas City warm rooms project: Economics, energy savings and health and comfort impacts." Energy 12(6).

The warm room retrofit study examines how to stay warm in a large poorly insulated house during the coldest parts of winter, a problem especially acute for low income and elderly . The paper describes how 9 homes were retrofitted to provide warm zones and evaluates how the measures installed helped to improve the comfort of residents.

Shove, E. (2003). Comfort, cleanliness and convenience: the social organisation of normality. Oxford, Berg.

Shove examines how, over the past few generations, expectations of comfort have altered radically, and considers the implications for the organisation of everyday life. Bringing together arguments from the sociology of consumption and technology, the book investigates how daily rituals and technologies, including those implicated in the heating and cooling of homes, have become 'normal' and how these developments have influenced cultural

conventions and habits. It is suggested that expectations of comfort, and associated routines and practices, are changing in ways that imply escalating and standardising patterns of consumption, which may have unsustainable consequences.

Shove, E., L. Lutzenhiser, et al. (1998). Energy and Social Systems. Human Choice and Climate Change, Volume 2: Technology and Resources. S. Rayner and E. Malone. Ohio, Battelle: 291-327.

Smith, P. F. (2001). Architecture in a Climate of Change: a guide to sustainable design. London, Architectural Press.

Steemers, K. (2003). "Energy and the city: density, buildings and transport." Energy and Buildings 35(1): 3-14.

Part of a special edition on energy and comfort in the urban environment. Moving from a focus on individual buildings and indoor comfort, the paper considers how groups of buildings and outdoor comfort (as a function of the urban microclimate) influence energy use. Steemers considers how urban form (especially building density) and patterns of transportation influence the energy use of different types of domestic or office buildings (e.g. by creating a need for air-conditioning or high intensity lighting). He suggests that the avoidance of air conditioning is a key factor in reducing office energy demand and shows how this will depend on improvements in the urban microclimate (e.g. less pollution from transportation).

Stoops, J. (2000). Environmental Conditions and Occupant Perceptions in European Office Buildings. Efficiency and Sustainability: 2000 summer study on Energy Efficiency in Buildings, Asilomar, ACEEE.

The paper presents initial results from SCATS (Smart Controls and Thermal Comfort project), including a survey of thermal perceptions of office users in Portugal, Sweden, France, Greece and the UK. The paper discusses the challenges the EU faces in developing indoor comfort standards for all European countries, given that existing thermal conditions and expectations are so different.

Stoops, J. (2002). An Illustration of Expectation Differences in Office Thermal Comfort. ACEEE Summer Study, Asimolar, California, ACEEE.

The paper reports on an extensive field examination of indoor neutral temperatures in 25 office buildings, in 5 European countries - part of the SCATS project (Smart Controls and Thermal Comfort). Existing adaptive research suggests that variations in reported patterns of thermal neutrality relate to the type of building (i.e. those with centralised HVAC compared to natural ventilation). The SCATS data suggests that country and season specific differences in reported indoor thermal neutrality may be more significant and also need to be considered in the modification of ASHRAE standards.

Svensson, M. K. and I. Eliasson (2002). "Diurnal air temperatures in built-up areas in relation to urban planning." Landscape and Urban Planning 61(1): 37-54.

Temperature changes generated by the urban landscape influence people's health and comfort, as well as energy consumption and air quality. A statistical analysis of air-temperature variations and land use (e.g. urban dense, multi-family, single homes) in Gothenburg is presented. Intra-urban temperature differences of up to 9oC are reported. The possible consequence of such temperature variations on human comfort and energy consumption (based on established physiological and energy indexes) in different sorts of urban settings (e.g. heat or cool islands) are discussed . Results suggest that the energy consumption of a household in the city centre of Gothenburg has the potential to be 15% lower that that of one situated in a single house complex further out from the city.

Vine, E. (1987). Saving Energy the Easy Way: An Analysis of Thermostat Management. Energy Efficiency: Perspectives on Individual Behaviour. W. Kempton and M. Neiman. Washington DC, ACEEE.

The paper investigates the distribution and dynamics of thermostat management in the US during the winter and summer. Existing utility surveys of self-reported thermostat settings and control strategies are analysed to develop a conceptual model that accounts for variations related to age, education, income, race, home ownership, dwelling size, heating and cooling systems, time of day, climate, etc.

Wargocki, P., J. Sundell, et al. (2002). "Ventilation and Health in non-industrial indoor environments: report from a European Multidisciplinary Scientific Concensus Meeting (EUROVEN)." Indoor Air 12(2): 113-128.

A review of scientific literature on the effects of ventilation on health, comfort and productivity in non-industrial indoor environments (offices, schools and homes) by EUROVEN - a multidisciplinary group of experts (including, engineers, medical epidemiologists and toxicologists). The group suggest that on the basis of current scientific evidence ventilation requirements embodied in many existing building standards are inadequate and that new standards for conditioning air are required in order to improve comfort, health and productivity. Specifically, there is evidence to show that in buildings with air-conditioning systems there may be an increased risk of sick-building syndrome symptoms.

Weihl, J. S. (1987). Family Schedules and Energy Consumption Behaviour. Energy Efficiency: Perspectives on Individual Behaviour. W. Kempton and M. Neiman. Washington DC, ACEEE.

Investigates the hypothesis that energy-related behaviours in residences are strongly influenced by the daily schedules of the occupants. The study focuses on two of the major energy-consuming systems in homes, space-heating and water-heating systems. Thermostat adjustment behaviours and hot water use events are monitored in 4 households during the winter of 1983-84 and ethnographic interviews used to elicit information on daily schedules. The type and complexity of daily schedules is shown to have a considerable influence on thermostat setting behaviour and on energy consumption. Such findings indicate the need to design thermostats to cope with more and less consistent or complex patterns of daily family life.

Wilhite, H., H. Nakagami, et al. (1996). "A cross-cultural analysis of household energy-use behaviour in Japan and Norway." Energy Policy 24(9): 795-803.

An ethnographic study of households in Japan and Norway that examines the role of culture in the formation of energy using habits and practices (e.g. space heating, lighting and bathing) and in the escalation of energy demand. Interviews with family members reveal significant differences between cross-cultural practices. For example, Norwegians heat all rooms creating a thermally consistent envelope they can move about without experiencing discomfort. Japanese households utilised technologies such as the "kotatsu", designed to heat individual bodies rather than surrounding spaces. The authors conclude that it is important to consider how culturally specific services (e.g. cosiness or cooling) might be provided by less energy intensive means.

Wilhite, H., H. Nakagami, et al. (1996). The dynamics of changing Japanese energy consumption patterns and their implications for sustainable consumption. ACEEE Summer Study: Human Dimensions of Energy Consumption, Asilomar, ACEEE, Washington DC.

In the last 30 years there has been a 50-fold increase in the installation of air-conditioners in Japanese residences. The paper explores changing Japanese air-conditioning and heating patterns to yield insights into the dynamics of changing consumption patterns. An ethnographic study in Fukuoka and analysis of air-conditioning advertising are used to investigate the factors behind such changes. The study finds that changing patterns of consumption relate to economic factors, but also to changing cultural and material norms, patterns of family interaction and understandings of what it is to be modern.

Wilk, R. and H. Wilhite (1987). Why Don't People Weatherize Their Homes? An Ethnographic Solution. Energy Efficiency: Perspectives on Individual Behaviour. W. Kempton and M. Neiman. Washington DC, ACEEE.

Many studies of the economics of energy use and conservation assume that, given the right incentives, consumers will change their energy using behaviour or uptake more efficient technologies. This paper reviews the deficiencies of such arguments, by reviewing the case of home weatherization (the weatherstripping of doors and windows and the caulking of joints and cracks). Whilst weatherization offers substantial savings on energy costs and improved levels of comfort for households, it is still largely ignored by consumers. The authors undertake an ethnographic study of energy decisions by households in Santa Cruz, California in order to examine why people don't weatherize. They conclude that, the reluctance to weatherize relates to social, symbolic and cultural factors, such as the relative invisibility of such improvements, rather than to a calculation of economic benefits alone.

Wilkinson, P., M. Landon, et al. (2001). Cold comfort: The social and environmental determinants of excess winter death in England, 1986-96. Bristol, The Policy Press/Joseph Rowntree Foundation.

The report presents findings of an epidemiological study of the social and environmental determinants of Britain's large winter excess of mortality, and considers the implications for the development of housing and energy efficiency policies. Results suggest that people living in homes that are difficult or costly to heat are at increased risk of winter/cold-related death. Specifically, indoor temperature and markers of thermal efficiency of dwellings, including property age, are associated with increased vulnerability to winter death from cardiovascular disease.

Winnett, R. A., J. Hatcher, et al. (1981). "Modifying perceptions of comfort and electricity used for heating: residential field experiments." ASHRAE Transactions 87(1): 555-565.

A study of the effectiveness of daily feedback on electricity consumption by 200 residents of all-electric townhouse apartments. The authors argue that video presentations motivated people to reduce indoor temperatures in winter by 2oC. Subjects voluntarily accepted an indoor air temperature of 16oC and increased clothing insulation. Thermal comfort is regarded as a function of various cultural expectations and practices and as something that can be structured by information.

Wright, L. (1964). Home Fires Burning: The History of Domestic Heating and Cooking. London, Routledge.

An historical account of the development and uptake of heating technologies. Wright begins with an examination of the culture of the open fire and the associated tools and resources needed to "keep the home fires burning". More recently, he considers the ubiquity of central heating and its implications for the organisation of domestic life.

Zacharias, J., T. Stathopoulous, et al. (2001). "Microclimate and downtown open space activity." Environment and Behaviour 33(2): 296-315.

Observations of presence levels and activities in 7 corporate plazas and public squares over a 5 month period are evaluated against measurements of changing microclimatic conditions. The study shows how sunlight, temperature, humidity and wind combine in business district open spaces to create variable sensations of outdoor human comfort and generate distinct types of behaviour.