



**International Conference on Climate Change Impacts on Tourism**  
**Lisbon, Portugal - 7-8 September 2007**

on behalf of  
Prof. Geoff  
Levermore



# **Energy Demand Changes** **under Climate Change:** **Buildings**

**Geoff Levermore, Professor of the  
Built Environment,  
Manchester University, UK**



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<http://www.mace.manchester.ac.uk/aboutus/staff/academic/profile/index.html?staffId=184>



**Prof Geoff Levermore**

Professor of Built Environment



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**Professional biography**

Geoff read Physics at Imperial College, London gaining his BSc, ARCS in 1971 and his PhD, DIC, on the Johnsen-Rahbek Effect, in 1974. He then worked at the GEC Hirst Research Centre and then the Jules Thorn Lighting Laboratory. In 1980, whilst heading the Wandsworth Energy Conservation Section he founded the London Boroughs Energy Management Group. He joined UMIST in 1991 from South Bank University. Currently he is Chair of the CIBSE Weather Panel and Co-ordinator of the CIB Task Group21; Climatic Data for Building Services and a Lead Author on the IPCC (WG3).

**Research interests**

- \* Weather data: for design of buildings, plant and natural ventilation, climate change
- \* Control and modelling: intelligent buildings, low-energy buildings, natural and mixed mode air conditionbs
- \* Occupant feedback: the interior environment with Overall Liking Score and fingerprint
- \* Lighting perception: related to coloured light sources and daylight in buildings



# IPCC

IPCC (Intergovernmental Panel on Climate Change)

Established in 1988

by WMO (World Meteorological Organization)

UNEP (United Nations Environment Programme)

Endorsed by the United Nations General Assembly

Established to “**assess** scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation.”



## IPCC Fourth Assessment Report - Climate Change 2007 to be published

## IPCC Third Assessment Report - Climate Change 2001



**Climate Change 2001: The Scientific Basis**  
[SPM](#) | [TS](#) | [Full report](#)

**Climate Change 2001: Impacts, Adaptation  
and Vulnerability**  
[SPM](#) | [TS](#) | [Full report](#)

**Climate Change 2001: Mitigation**  
[SPM](#) | [TS](#) | [Full report](#)

**Climate Change 2001: Synthesis Report**  
SPM



## UNFCCC

- IPCC provides scientific, technical and socio-economic advice on climate change to **UN Framework Convention on Climate Change (UNFCCC)**
- It is an international environmental treaty to stabilise GHGs in the atmosphere to prevent "dangerous" human interference with the climate system.
  - originated at a UN Conference (Earth Summit) in Rio de Janeiro in 1992.
  - 154 nations signed up.
  - UNFCCC requires them to develop, update periodically, publish and make available their national inventories (GHG inventories) of anthropogenic emissions by sources and removals by sinks.



# UNFCCC

- UNFCCC has no enforcement provisions.
- it allows for protocols, e.g. Kyoto Protocol, with **mandatory** GHG emission limits to signatory countries.
- Annual meetings of politicians, Conferences of the Parties, COP, to the UNFCCC,
- COP-1 in 1995 in Berlin.



# IPCC

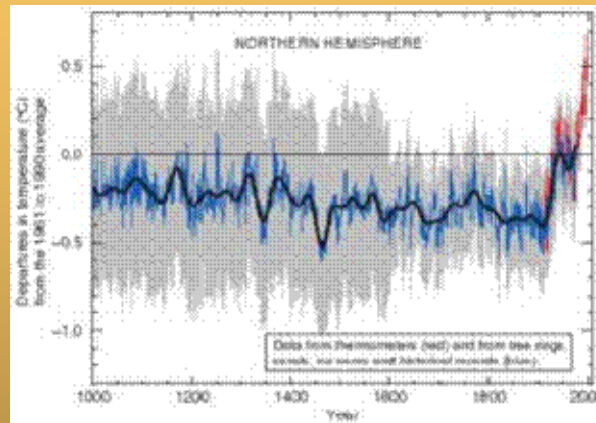
Role is to assess:

- technical and socio-economic information on *risk of human-induced* climate change,
- its potential impacts
- options for adaptation and mitigation.

IPCC is not to research or monitor climate data.  
*Assessment on peer reviewed and published literature.*



# IPCC criticism



The so-called Hockey-stick graph as shown in the 2001 IPCC report. This chart shows the data from Mann *et al.* 1999. The colored lines are the reconstructed temperatures, and the gray shaded region represents estimated error bars.





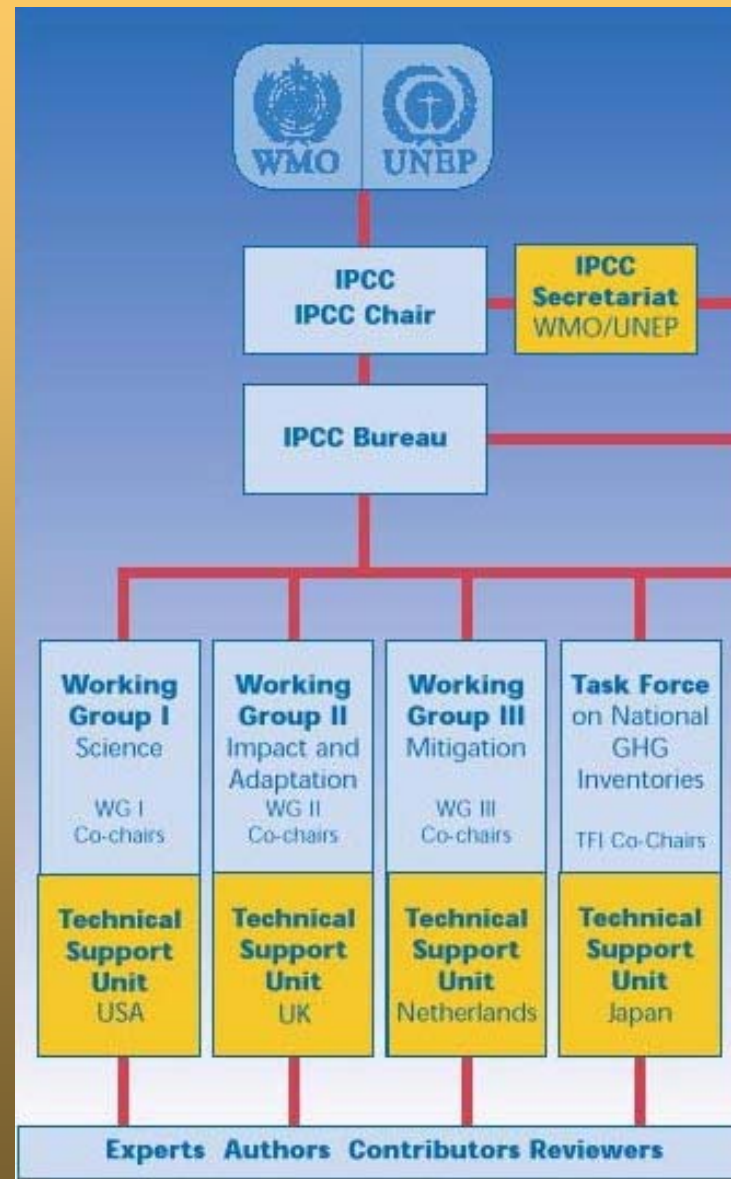
# IPCC Structure

## IPCC Panel

Representatives appointed by governments and organisations.

Meets about once a year, controls the organization's structure and procedures.

It elects the IPCC Chair, Bureau members and approves IPCC reports.





# IPCC Outputs

- Special Report on Emissions Scenarios (SRES) in 2000
- Future emissions data (for climate change models).
- Emissions depend on projections of:
  - world population,
  - technological and economic development
  - governance.
- No scenario has future policies that explicitly address climate change.
- Four different “storylines” were developed.
- Scenarios based on an extensive assessment of the literature, and an “open process” that solicited wide participation and feedback

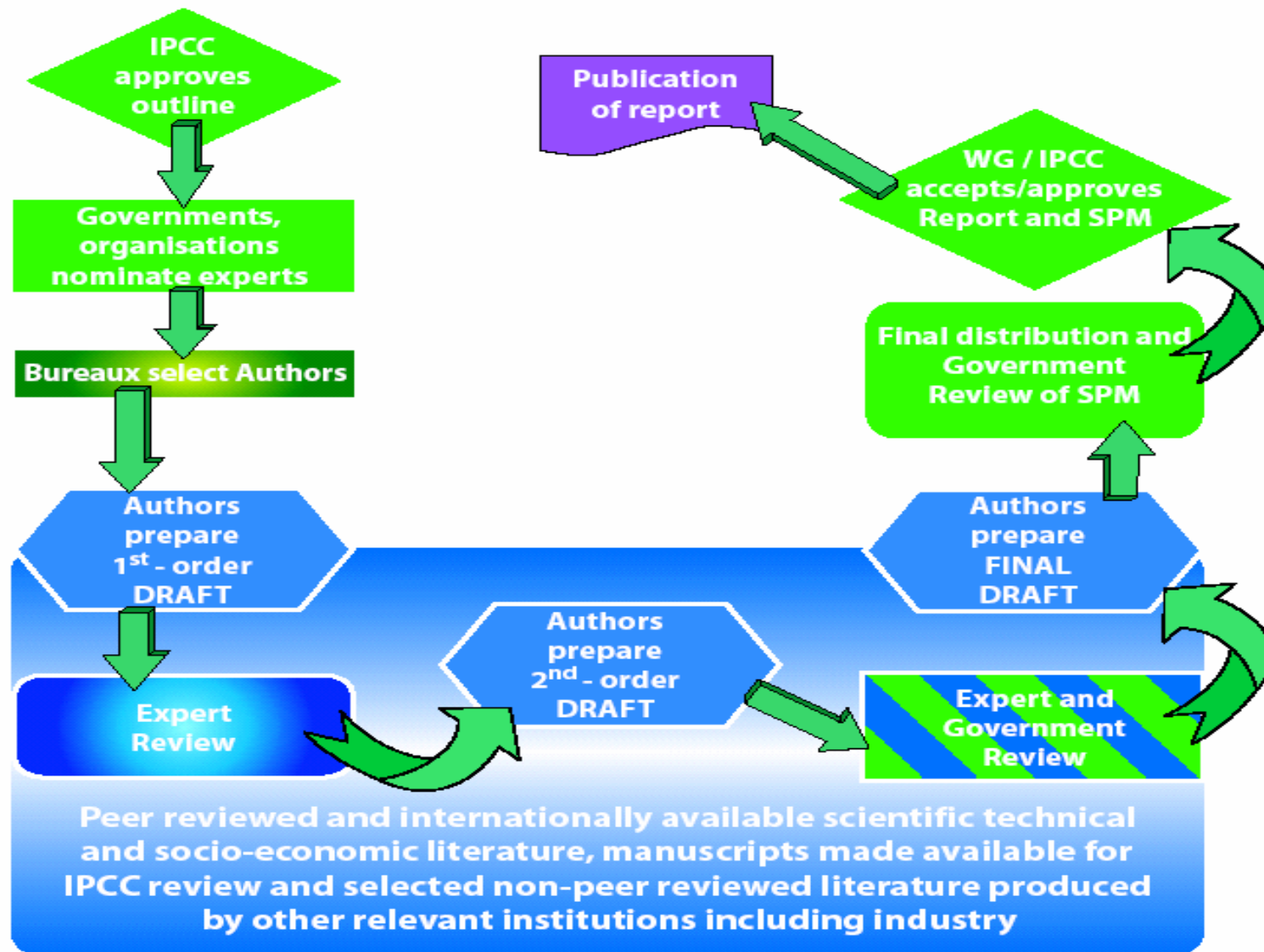


# The Fourth Assessment Report (AR4)

- 2002 Panel elected Dr. Pachauri (India) as Chair of the IPCC.
- To be published in the latter part of 2007 although it is now available on the web.
- It has cross-cutting themes including uncertainty and risk to avoid the hockey stick controversy.



## The IPCC writing process





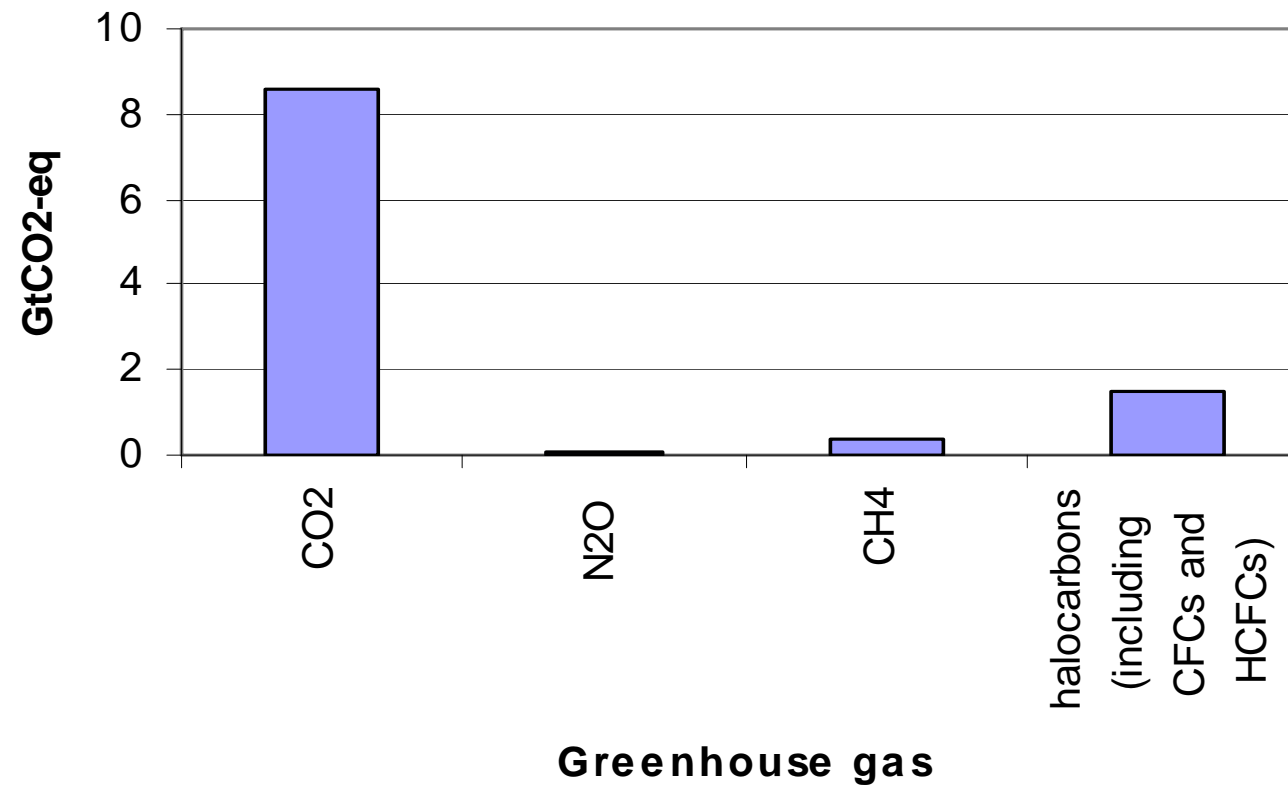
# AR4, Working Group III

- **Authors of Chapter 6, Mitigation options for residential/commercial buildings**
- 2 Coordinating Lead Authors:
  - Mark Levine (USA), Diana Ürge-Vorsatz (Hungary)
- 9 LeadAuthors
- 7 Contributing Authors
- 2 Reviewing Experts



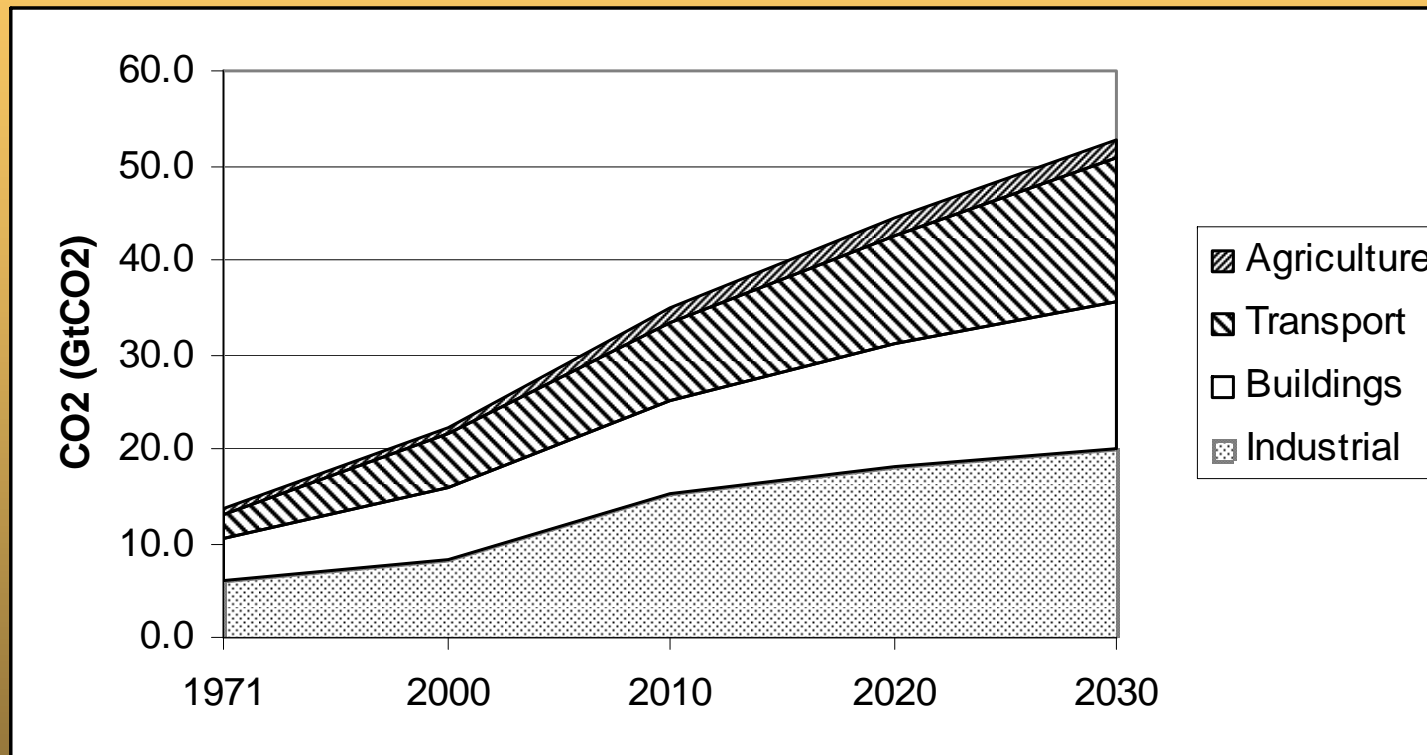
# Emissions from buildings

World GHG emissions in 2004





# Trends in emissions



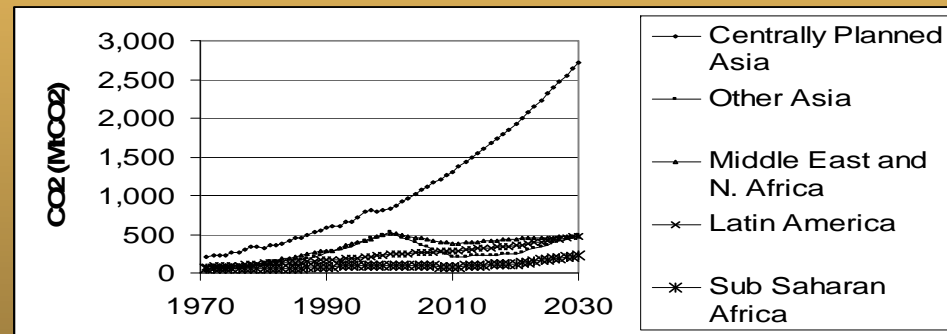
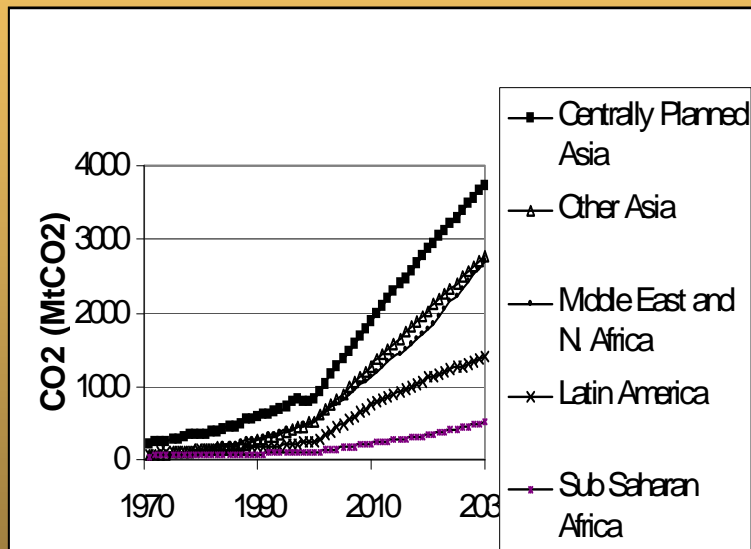
Global Energy-Related CO<sub>2</sub> Emissions by End-Use Sector, Historical to 2000 and Projected by the SRES A1 Scenario to 2030.

Based on Price, L., S. De la Rue du Can, S. Sinton, E., Worrell, N. Zhou, J. Sathaye, and M. Levine, 2006. Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions. Lawrence Berkeley National Laboratory, Berkeley, CA. LBNL-56144





# Trends in emissions



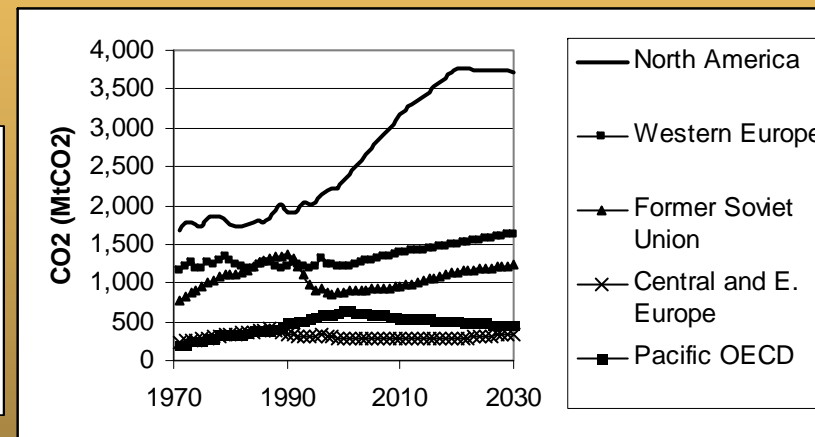
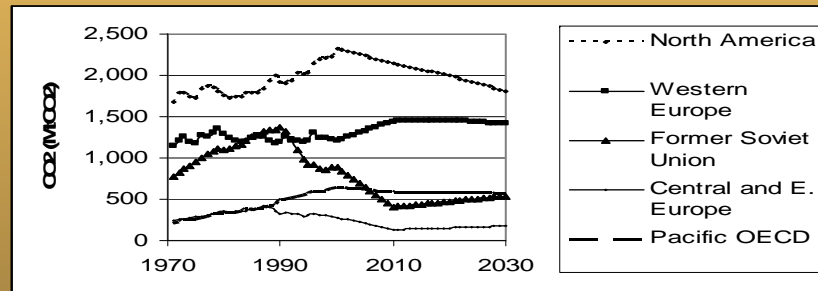
Emissions by End-Use Buildings Sector, 5 higher growth regions. Historical to 2000 and Projected by the SRES A1(left) B2 (right) Scenario to 2030.

Based on Price, L., S. De la Rue du Can, S. Sinton, E., Worrell, N. Zhou, J. Sathaye, and M. Levine, 2006. Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions. Lawrence Berkeley National Laboratory, Berkeley, CA. LBNL-56144





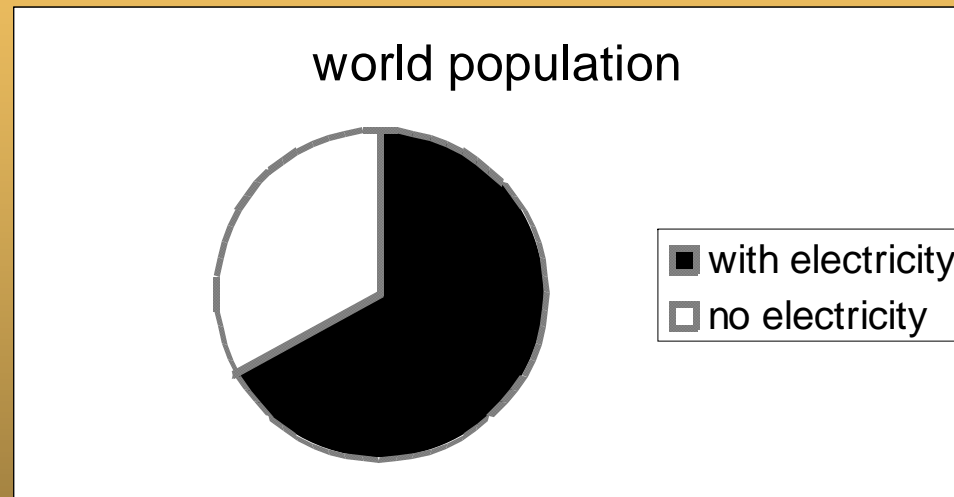
# Trends in emissions



Emissions by End-Use Buildings Sector, 5 lower growth regions.  
Historical to 2000 and Projected by the SRES A1(left) and B2 (right)  
Scenario to 2030.



# World view

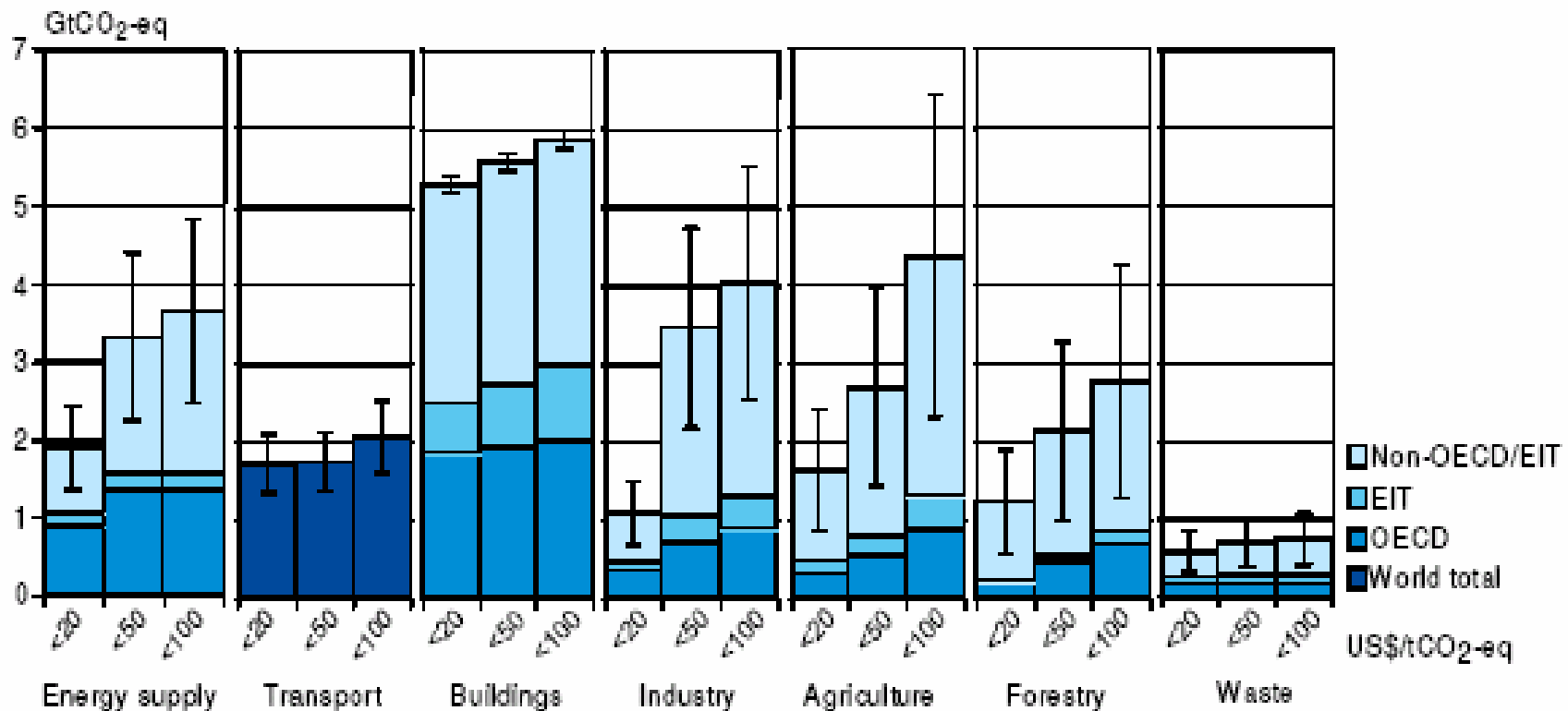


6.6 billion population

Photovoltaic panels, batteries, LEDs can replace kerosene lamps. "Tunnelling" through inefficient tungsten lamps.



# Potential savings



*Figure SPM 6: Estimated mitigation potential at sectoral level in 2030 from bottom-up studies, compared to the respective baselines assumed in the sector assessments (see notes)*



# Potential GHG reducers

- lighting technologies, daylight use, good in most regions of the world,
- solar water heating systems,
- efficient appliances, (washing machines etc)
- building energy management systems.



# Good savings from

- Cooler regions
  - Improved insulation
  - District heating
- Warmer regions
  - Efficient space conditioning
  - Efficient cooking stoves in developing countries.



# Good design to reduce GHG emissions

- integrated design process (IDP)
- reduce peak thermal loads
- need for good commissioning, operation and maintenance.



# Technical fixes

- Improvements to the thermal envelope of houses; use 10% of the heating of a house built to the local regulations. Passive houses.
- Condensing boilers and ground source heat pumps.
- thermal performance of windows has improved; they can reduce summer solar heat gain by up to 75%.



# Technical fixes

- Summer heat gain reduction, minimising the glazing facing east or west, utilising thermal mass.
- Reflective roofs and trees for shade are reported as being successful in some USA cities.
- Use low energy ac (displacement, chilled ceilings)
- Natural ventilation with night ventilation; adaptive comfort.





# Refurbishment

- One of biggest challenges; buildings last a long time and therefore vast majority is old inefficient stock.
- In the scenario projections to 2030 the largest portion of carbon savings will be from refurbishment.
- UK study showed that reducing air leakage and improved insulation reduced heating energy by about 35% and that a 50% reduction could be achieved using well-proven technologies.



# Policies

- AR4 Chapter 6 says for GHG mitigation:
- The technology is there,
- The costs are reasonable
- But there are many barriers, e.g.:
  - Fragmentation of building and design industry
  - First cost accounting
  - Tenant–landlord costs
  - Behaviour

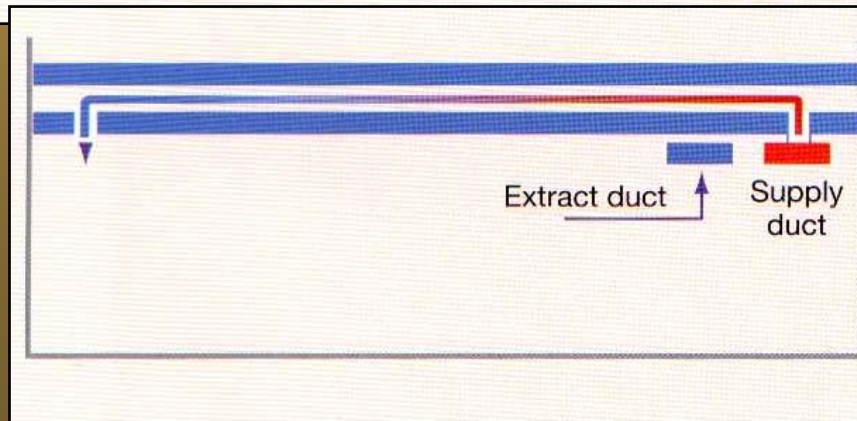
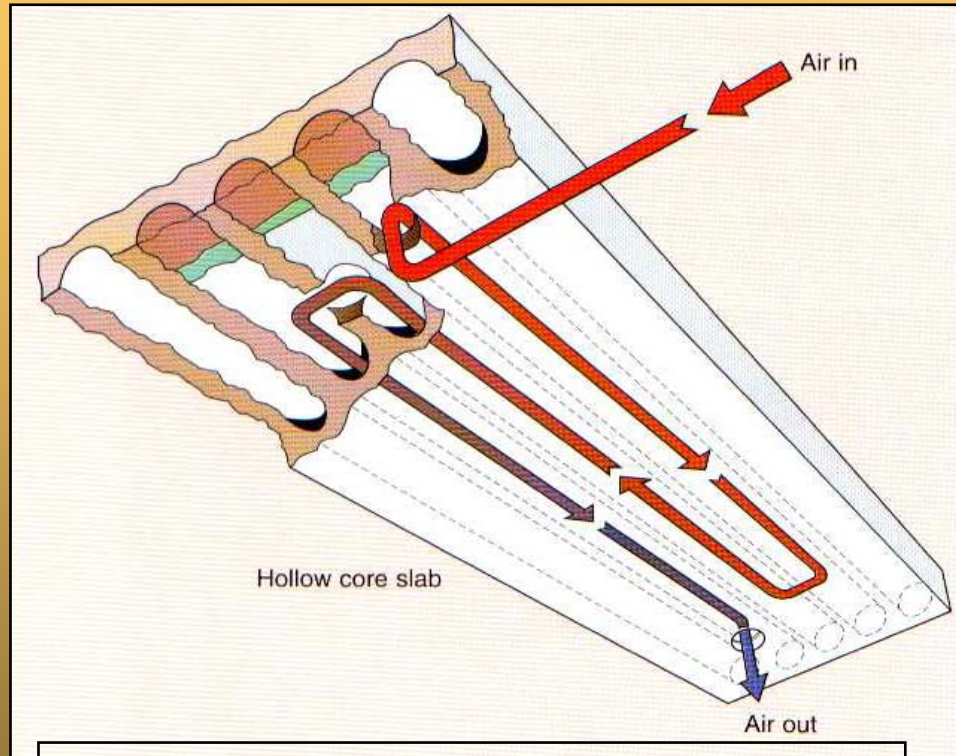


# Example Policies

- Performance building codes (carbon based).
- Demand-side management, ESCOs promoted
- Energy Star Labeling, Leadership in Energy & Environmental Design (LEED) rating.
- Carbon trading, renewables obligation
- Financial incentives for the design process (Canada, Commercial Building Incentive; California, Savings By Design program)



## Hollow Core Slab Cooling Using Air



- **Hollow core systems**  
**Termodeck**
- **Performance**  
**typically 30-50**  
**W/m<sup>2</sup> cooling**





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MANCHESTER

## TermoDeck Installation – Elizabeth Fry Building UEA, Norwich





## A windcatcher ventilation device

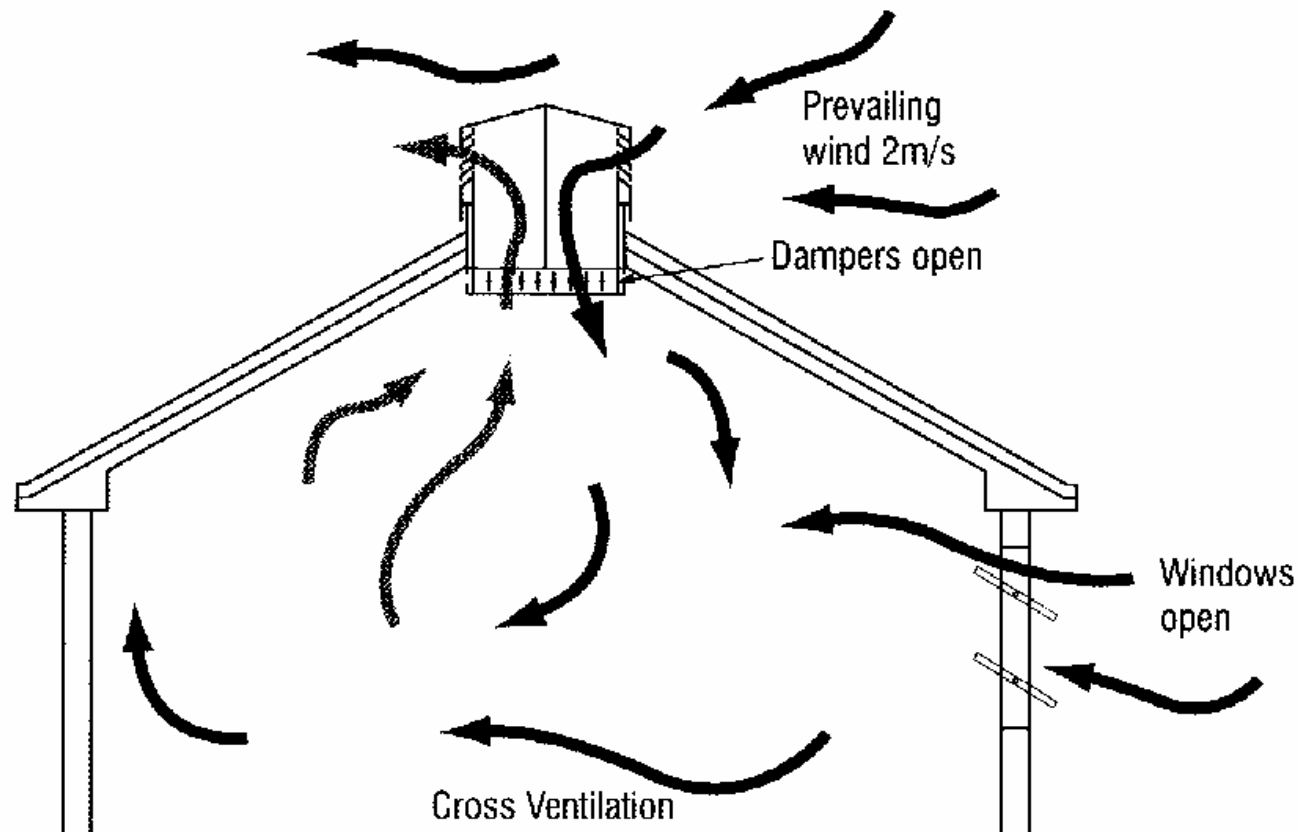


Fig nv.5 A windcatcher (courtesy of Monodraught Ltd)



# Ventilation funnels

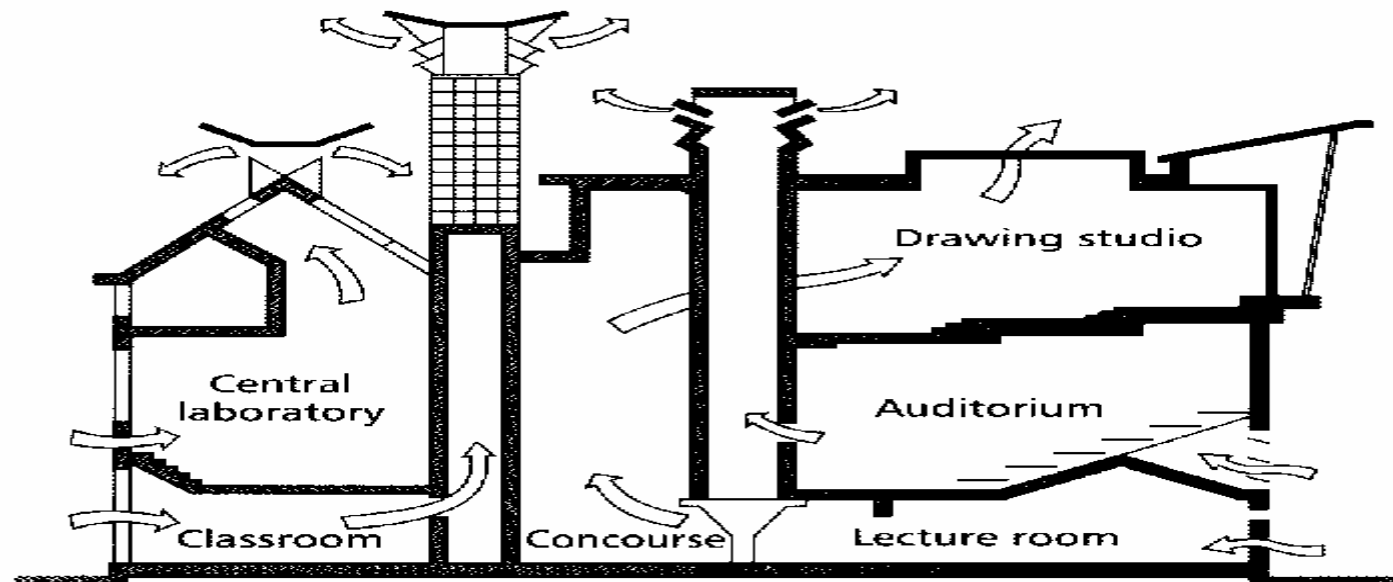
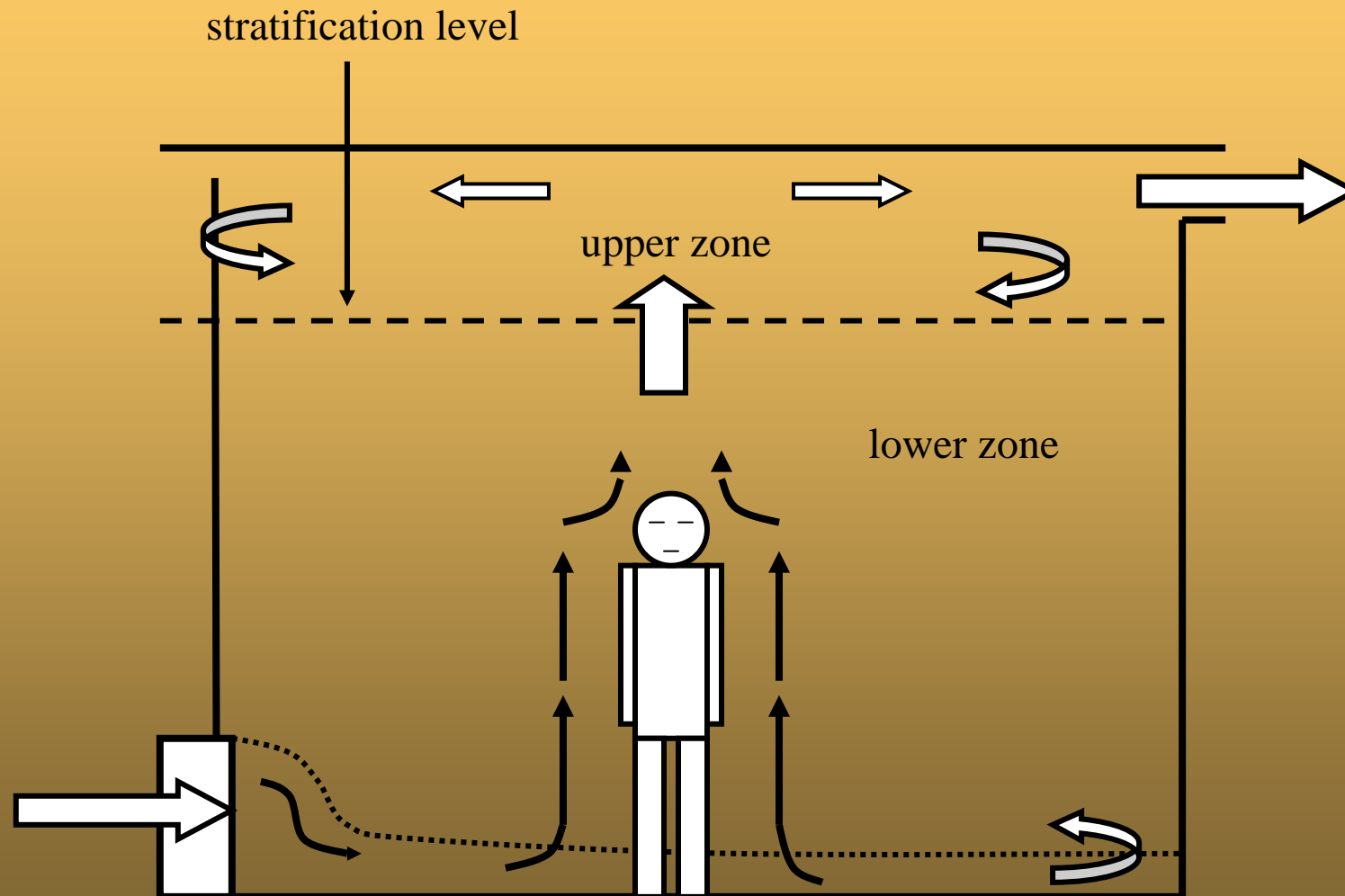


Fig.nv.4 Ventilation funnels or chimneys at the De Montfort Queen's Building,  
(from references 6 and 10)



Displacement ventilation





# Chilled ceiling

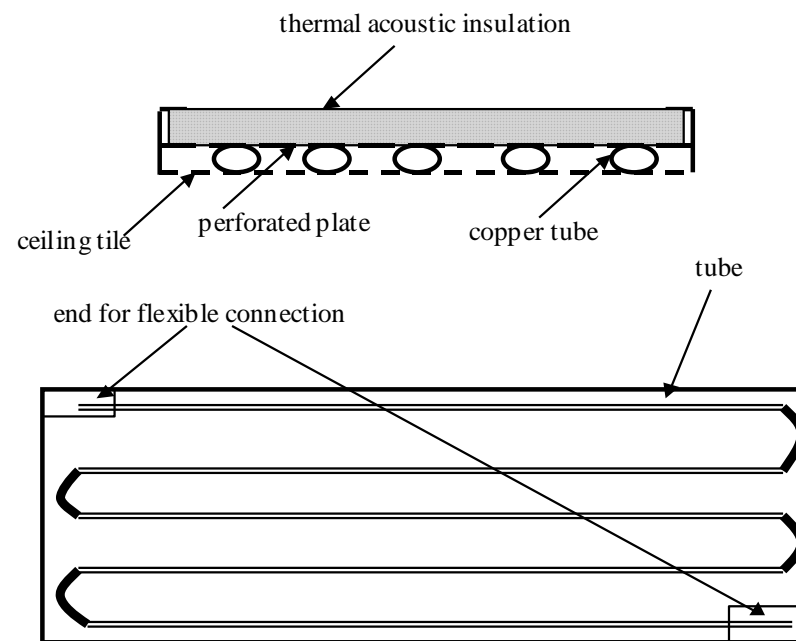


Fig.12.4 A chilled ceiling section



# Chilled beam

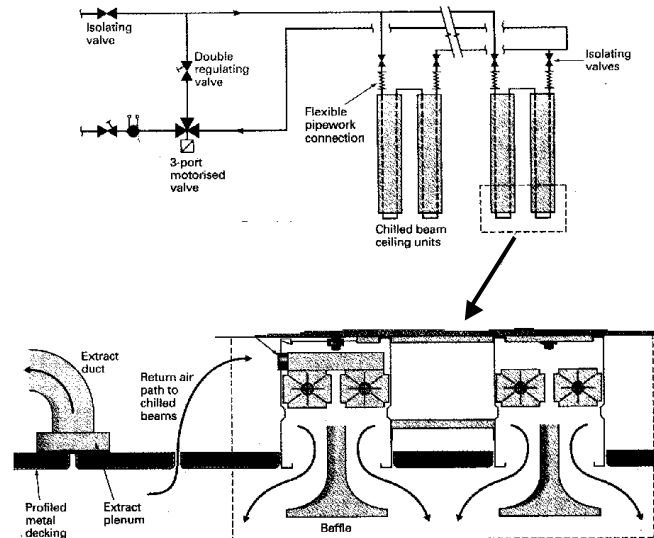


Fig.p.6 A chilled beam (from ref 27)



# Developed double-Likert Overall Liking Questionnaire

Do you like the...

**noise level**

How important is this in the

design of your ideal office?

**dislike**

**like**

**unimportant**

**important**

-3 -2 -1 0 1 2 3

1 2 3 4 5 6 7

Comments: \_\_\_\_\_

## Questionnaire To Assess How Much You Like Your Building



We would like you to tell us how much or how little you like the room you work in and how comfortable you find it. This is part of a UMIST project to determine what people think of their buildings. The information gained will help engineers and architects to design buildings in which people like to work. Your answers will be treated in confidence: we do not need to know who you are, but just what you like and dislike. Please complete this questionnaire

### SECTION A: Background information

1. How would you describe the work you do? (Please circle a number)
 

1 Clerical / Secretarial	3 Managerial
2 Professional	4 Other
2. What is your age? (Please circle a number)
 

1 20 years or under	4 41 - 50 years
2 21 - 30 years	5 51 - 60 years
3 31 - 40 years	6 over 60 years
3. What is your sex? (Please circle a number)
 

1 Female	2 Male
----------	--------
4. Number of hours spent using a VDU on a typical day. (Please circle a number)
 

1 0 - 1 hour	4 3 - 4 hours
2 1 - 2 hours	5 4 - 5 hours
3 2 - 3 hours	6 more than 5 hours
5. Number of hours per day you normally spend at your desk:
6. Number of hours per day you normally spend in the building:
7. Number of years you have worked for this organisation:
8. How long you have been in this office at your current desk position:  yrs  mths
9. How many people do you share your office with, not including yourself? (Please circle a number)
 

1 none	4 three to five
2 one	5 six to ten
3 two	6 more than ten



This questionnaire concerns the effect of the office environment upon your performance at work.

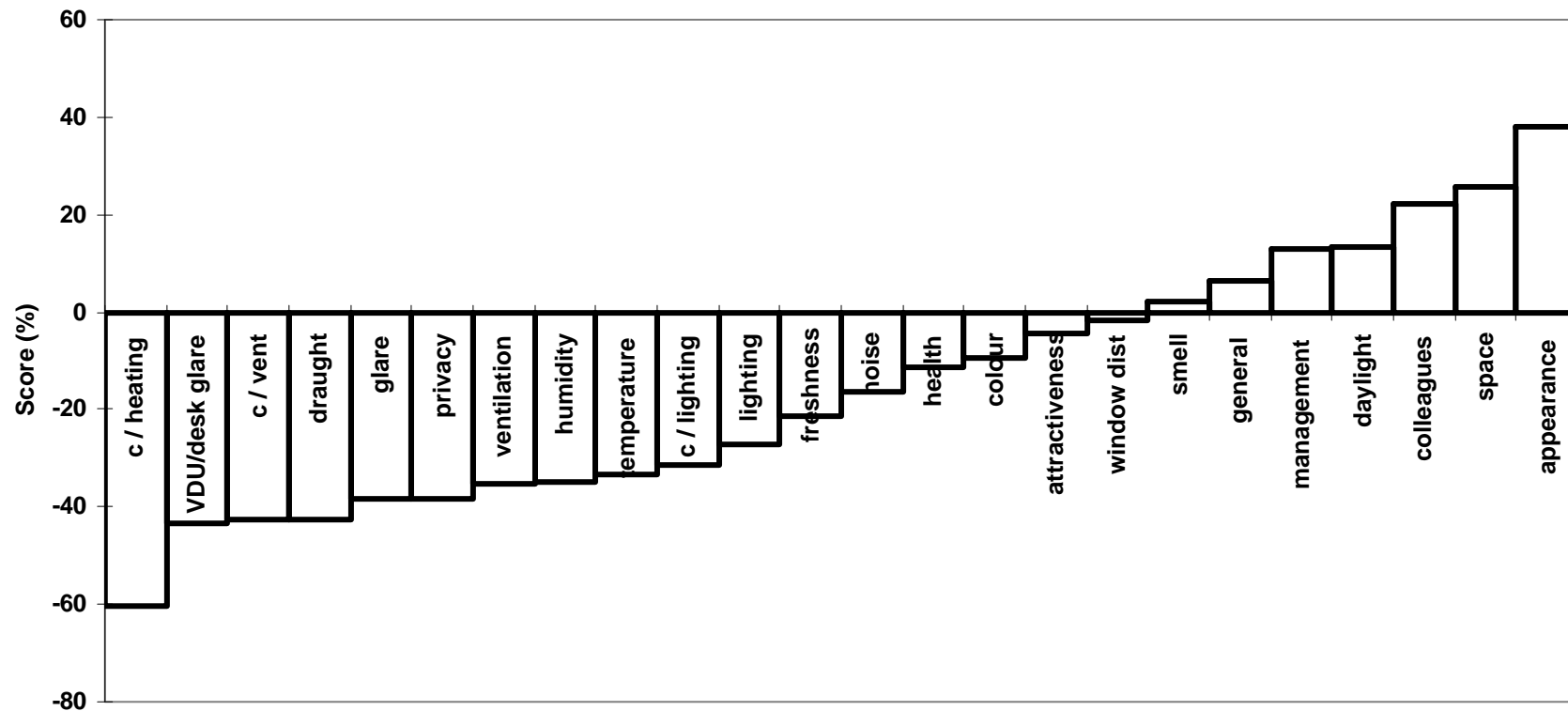
Considering the effect on your productivity at work, how satisfied are you with the facilities in your office? Please also indicate the importance of each factor in affecting your overall productivity.

	very important (4)	(3)	(2)	(1)	unimportant (0)	very satisfied (+2)	satisfied (+1)	neutral (0)	dissatisfied (-1)	very dissatisfied (-2)
Desk space (work surface)										
Storage space										
Layout										



# The fingerprint

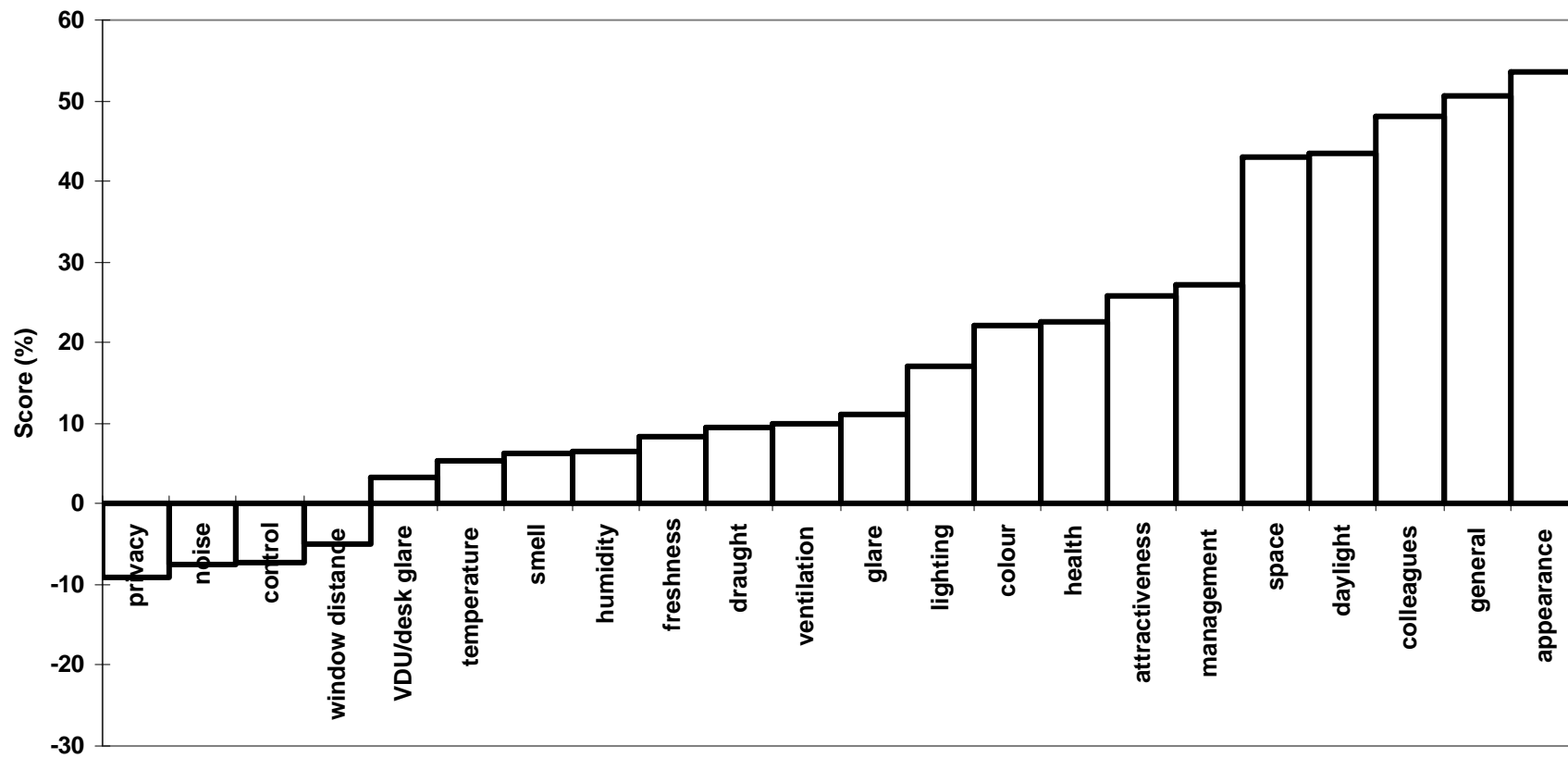
Deep plan, modern, naturally ventilated building.  
Fingerprint of ranked liking scores (overall score = -15%)





## Deep plan office, OLS +17%

Deep plan office with atrium and underfloor ac. Fingerprint of ranked scores (overall score = +17%)





# Conclusion

- Buildings are responsible for about 33% of global GHG emissions
- Buildings show largest potential reduction in future emissions
- The technology exists
- It can be applied cost effectively
- Many barriers but policies need to be implemented