KEEPING WARM IN A COOLER HOUSE

http://www.historic-scotland.gov.uk/technicalpaper14.pdf

Historic Scotland Technical Paper 14

COTAC Conference
Improving Thermal Comfort in Traditional Buildings
Old Royal Navel College, Greenwich
15th - 16th November 2011

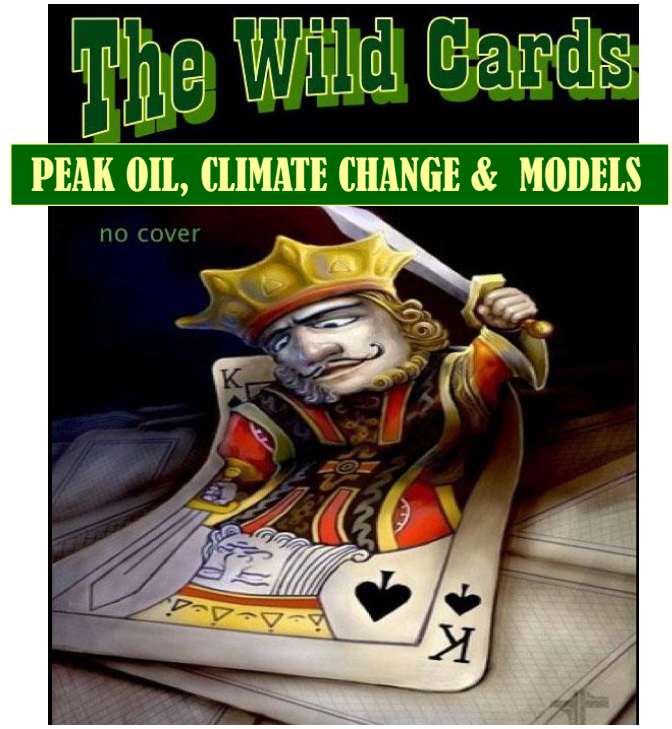
With thanks to Fergus Nicol, Michael Humphreys, Roger Curtis and Carsten Hermann

2011 Challenges for Historic Buildings:

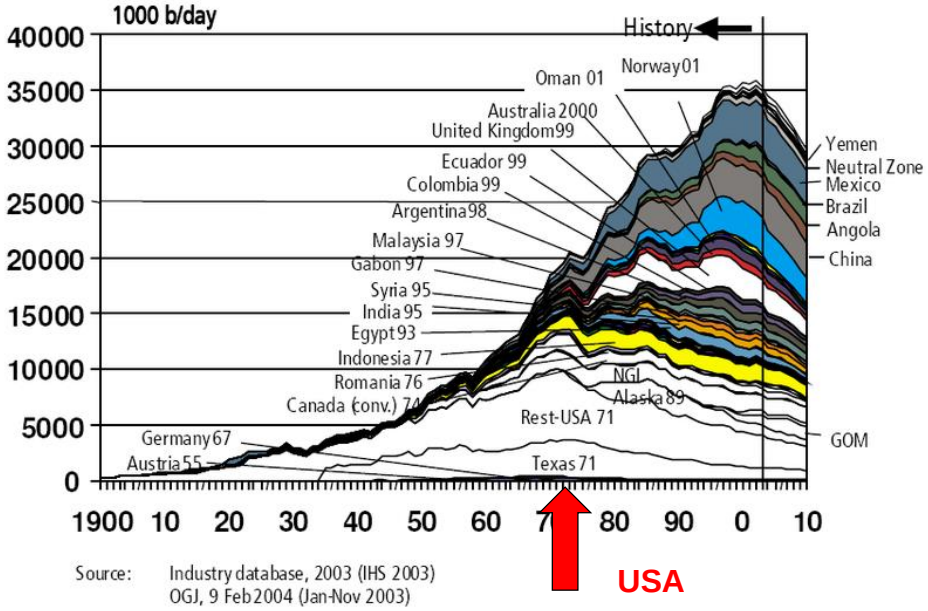
1. Rising costs of materials, labour, energy, products, professional services, transport, credit, etc.

2. More stringent / inappropriate regulations

So How Do You upgrade older houses and still make them more energy and cost efficient ?


The Wild Cards
PEAK OIL, CLIMATE CHANGE & MODELS
no cover

PEAK OIL


1000 b/day
40000
35000
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25000
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10000
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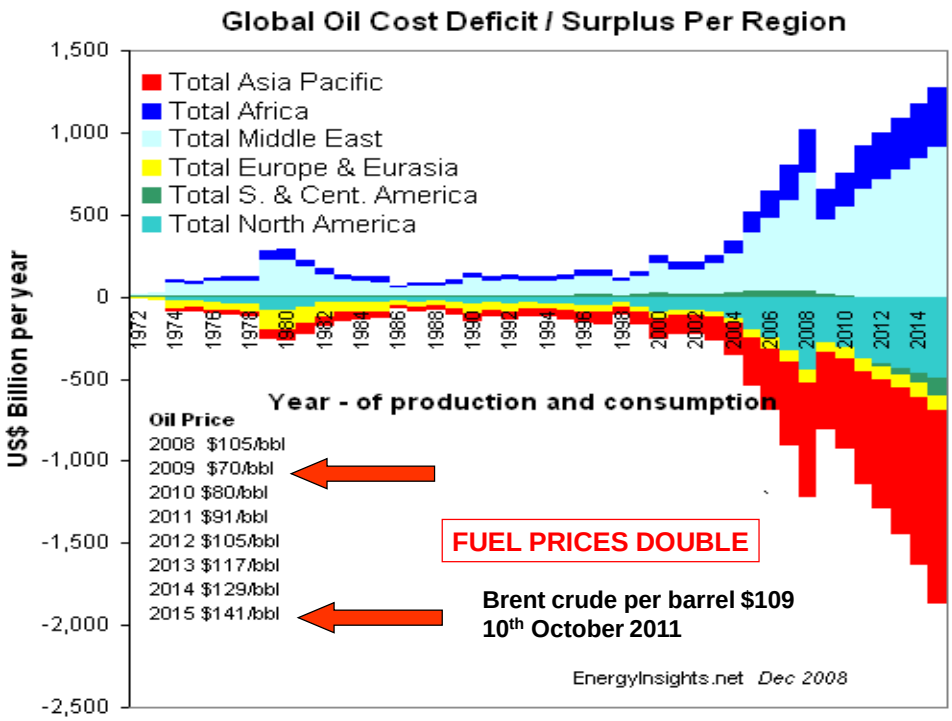
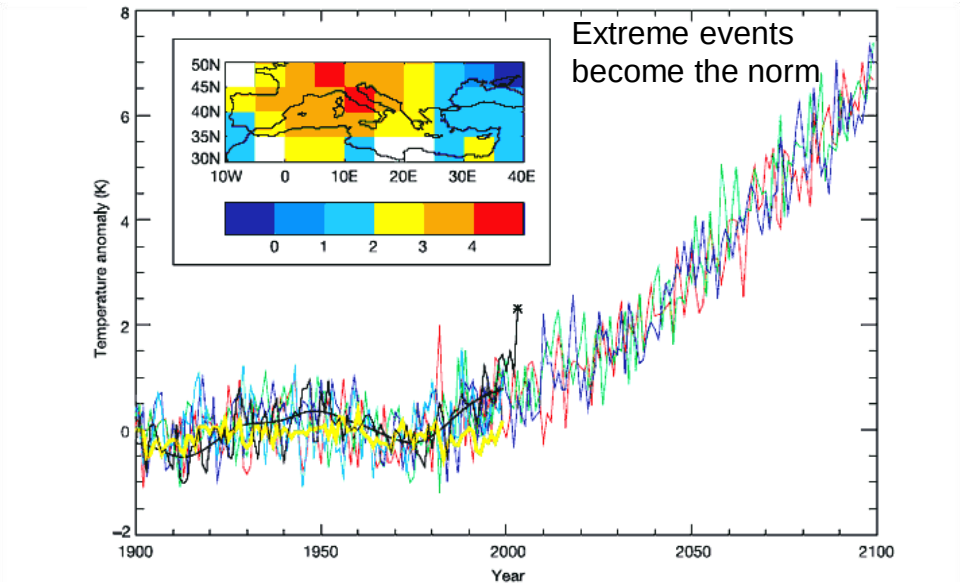
0
History
Oman 01
Norway 01
Australia 2000
United Kingdom 99
Ecuador 99
Colombia 99
Argentina 98
Malaysia 97
Gabon 97
Syria 95
India 95
Egypt 93
Indonesia 77
Romania 76
Canada (conv.) 74
Germany 67
Austria 55
Rest-USA 71
Texas 71
NGL
Alaska 89
GOM
Yemen
Neutral Zone
Mexico
Brazil
Angola
China
1900 10 20 30 40 50 60 70 80 90 0 10
USA
Source: Industry database, 2003 (IHS 2003)
OGJ, 9 Feb 2004 (Jan-Nov 2003)





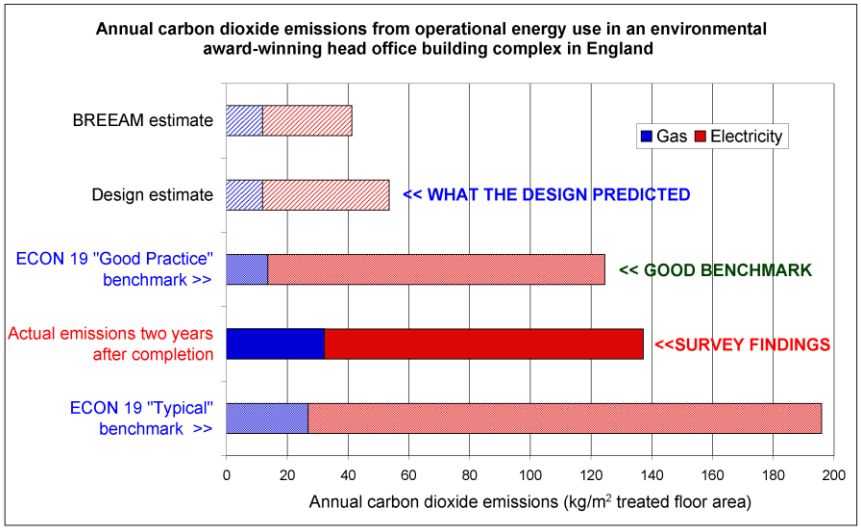
EXTREME TEMPERATURES AN INCREASINGLY COMMON OCCURANCE

Figure 5. June-August anomalies (relative to 1961-90 mean in K) over the region shown inset. Shown are observed temperatures (black line, with low-pass-filtered temperatures as the heavy black line), modelled temperatures for four HadCM3 simulations including both anthropogenic and natural forcings to 2000 (red, green blue and turquoise lines), and estimated HadCM3 response to purely natural forcings (yellow line). The observed 2003 temperature is shown as a star. Also shown (red, green and blue lines) aqree three simulations (initialized in 1989) including changes in greenhouse gas and sulphur emissions according to the SRES A2 scenario to 210022. The inset showsn the observed summer 2003 temperature anomalies in K.
(Source: Nakicenovic, N. and R. Swart (2010). Special Report on Emission Scenarios, Cambridge University Press, Cambridge, UK.)

The Credibility Gap

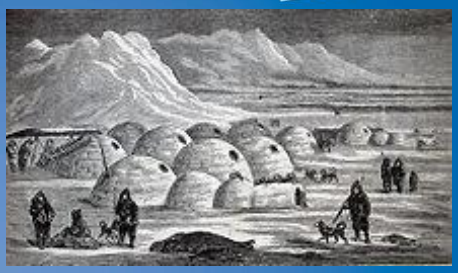
for a green building award winner

MODELS THAT ARE GIVING WRONG ANSWERS



PROPOSED SOLUTION:

HERIOT WATT UNIVERSITY



Why not save energy and costs by reducing the expected heating levels ? Living in a cool house (cooler than generally expected today) was not only commonplace until relatively recently, but is comfortable if human behaviour is adjusted accordingly

We are not advocating that buildings are not heated, but that it is possible to provide comfortable conditions while significantly lowering energy costs and related CO_2 emissions, providing comfort by using lower background temperature heating and local warmth from supplementary heaters.

If a normal central heating system (with boiler and radiators) is installed and run at 20 to 22 degrees Celsius (°C), a large amount of energy is required to heat a traditional house.

Because of the rapid rise in electricity, gas and particularly oil prices, the cost of heating older houses is increasingly a concern.

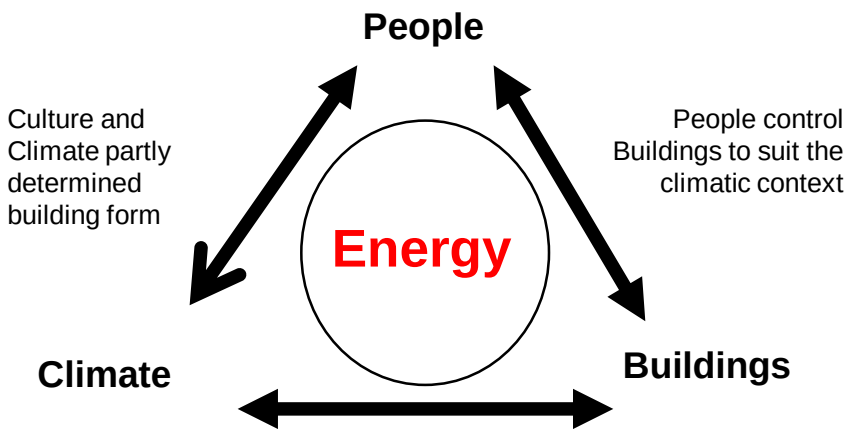
You can improved the thermal performance of the building envelope (walls, roof etc.) but solutions need to:

•Be carefully considered to ensure that they do not harm the historic fabric

•Respect architectural or historic significance

Authentic heating and Cooling systems are part of the design of a good building, old or new.

COMFORT IS A DYNAMIC PROCESS RESULTING FROM INTERACTION BETWEEN :



SOLUTION: EMBRACE THE COMPLEXITY

1. COMFORT

2. ENERGY

3. BUILDINGS

4. ADDRESS THE SKILLS DEFICIT

What is Thermal Comfort?

"that state of mind which expresses satisfaction with the thermal environment" (ASHRAE)

How do you feel ?

+3 Hot
+2 Warm
+1 Slightly warm
0 Neutral
-1 Slightly cool
-2 Cool
-3 Cold

"Comfort"

Thermal comfort in PEOPLE is a self-regulating system

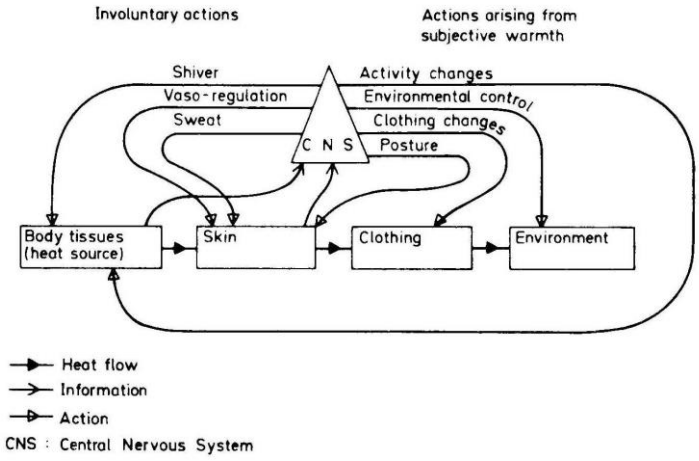


Figure 2. *The thermal regulatory system.*

1) The physics

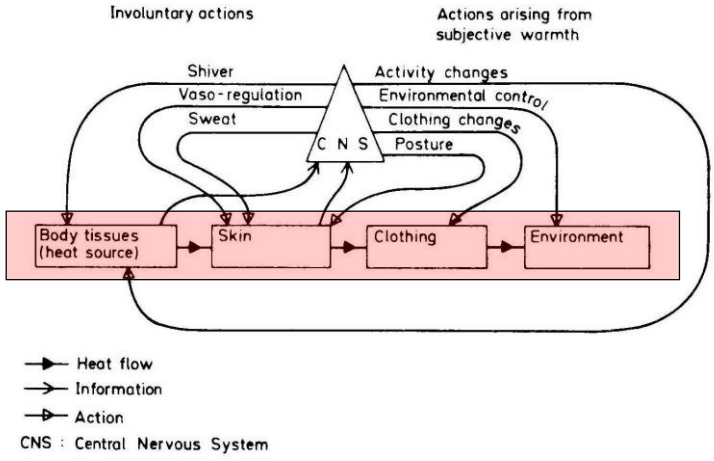
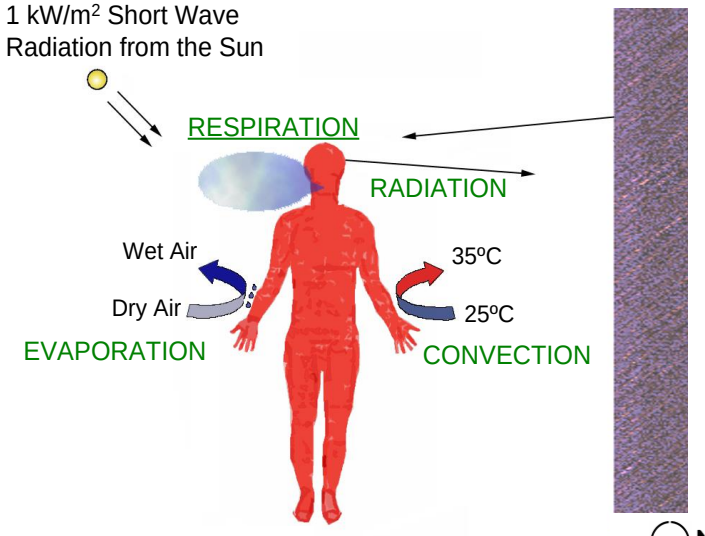


Figure 2. *The thermal regulatory system.*

Heat Exchange of the Body with the Environment

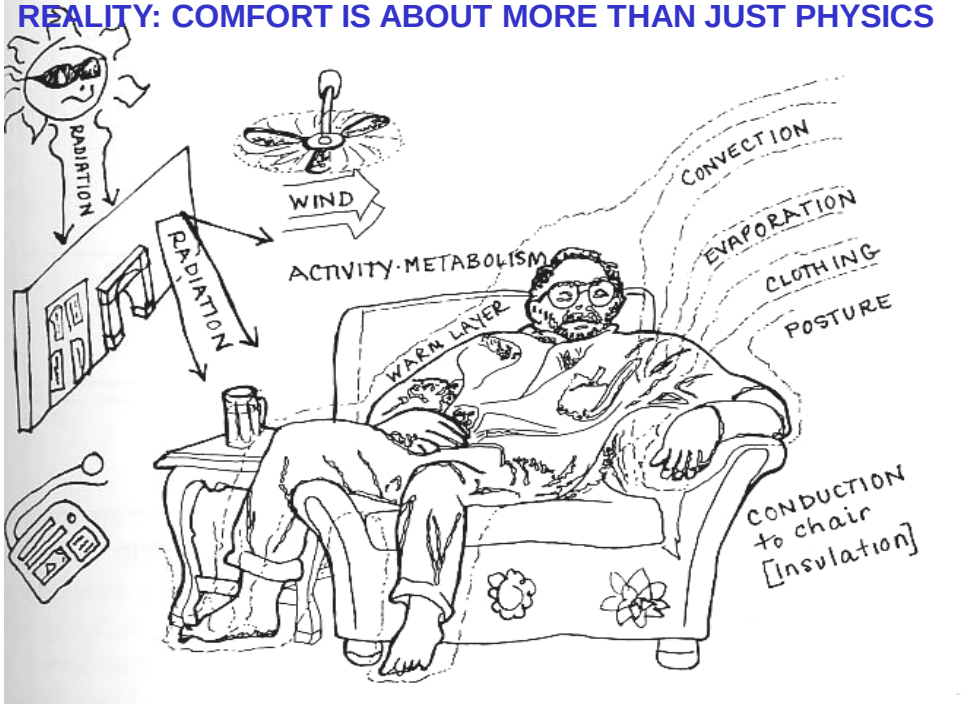
THEORY



The PHYSICS approach

MFP

REALITY: COMFORT IS ABOUT MORE THAN JUST PHYSICS



2) The physiology

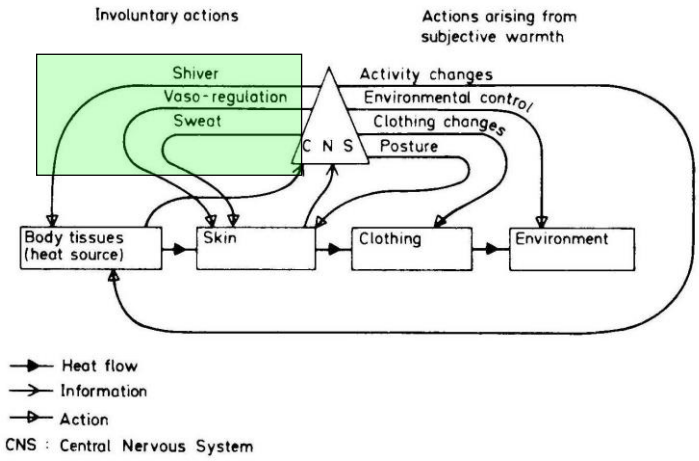
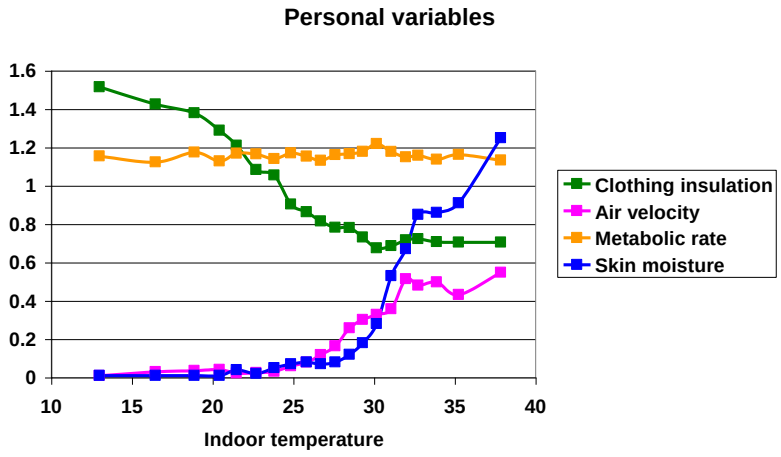
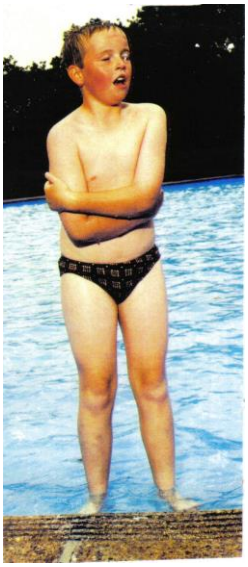


Figure 2. *The thermal regulatory system.*

Different controls are used in different circumstances



Shivering to reduce heat loss



Adaptation need not be a conscious act……

3) Behaviour is also an essential component

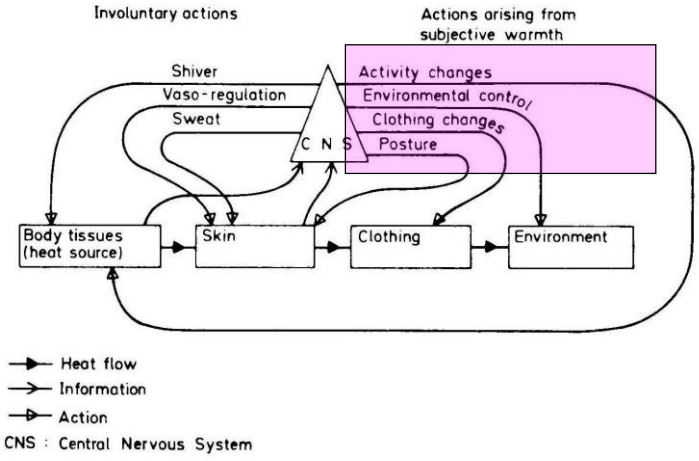
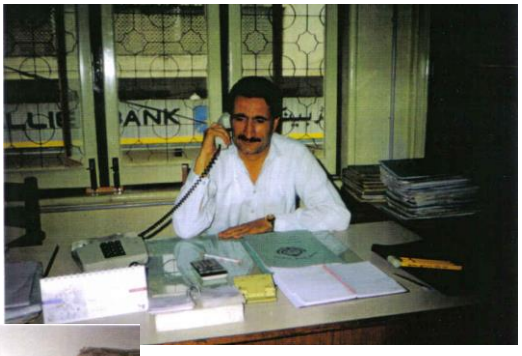


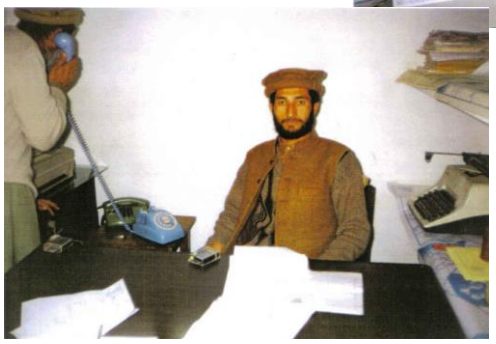
Figure 2. *The thermal regulatory system.*

Wearing appropriate clothing

Adapting appropriate clothing for local conditions: High altitude, cold sky, bright sun, warm wall, wind sheltering

Summer

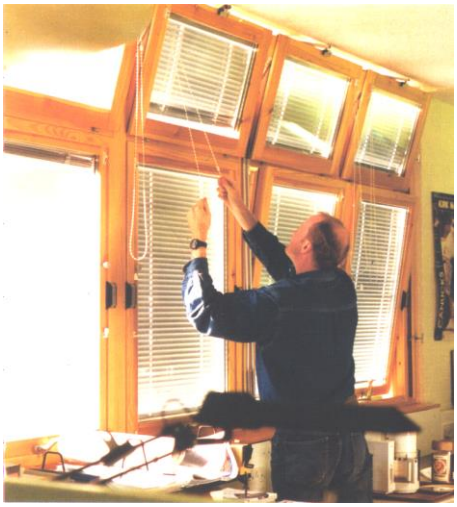




Winter

Note posture as well as clothing

Open the windows – shut the blinds



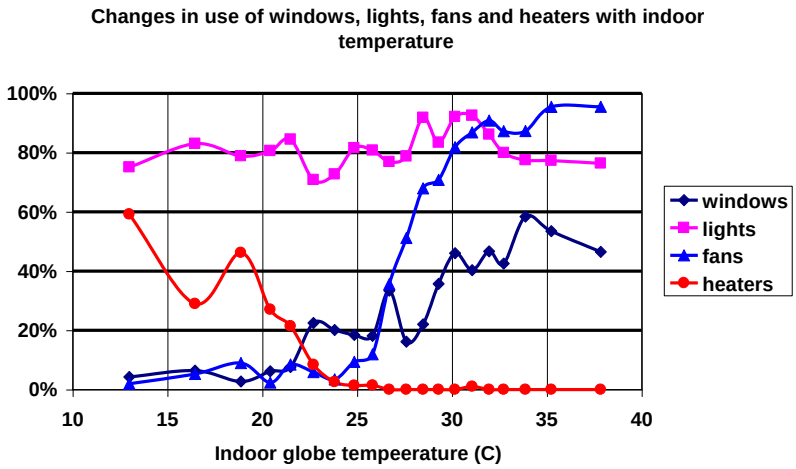
The profound importance of personal control
Over sun, glare, daylight, breeze, draft, shade etc.

Adaptive opportunity

Nick Baker and Mark Standeven, working in Cambridge, UK, linked comfort to the available means of thermal adaptation – the 'Adaptive Opportunity'.

'If there was little Adaptive Opportunity, discomfort was likely to occur'

Different controls are used in different circumstances



The Forgiveness Factor

Bordass & Leaman (working in the UK) developed protocols for the Post-Occupancy evaluation of buildings. Their results showed that people who had control over their environment were more tolerant of it. They called this the 'Forgiveness Factor'

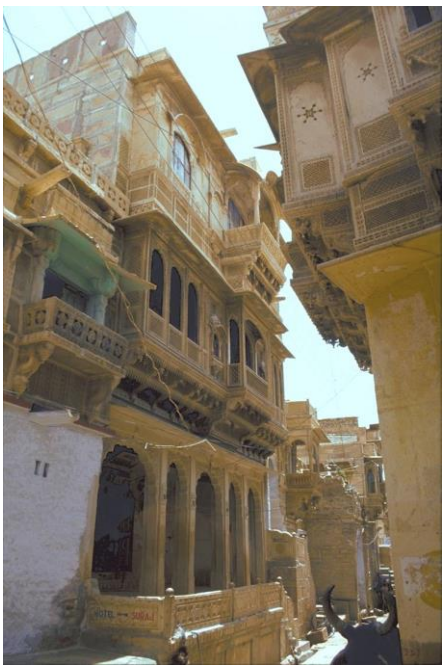
'If the occupants could not control their environment discomfort was likely to occur'

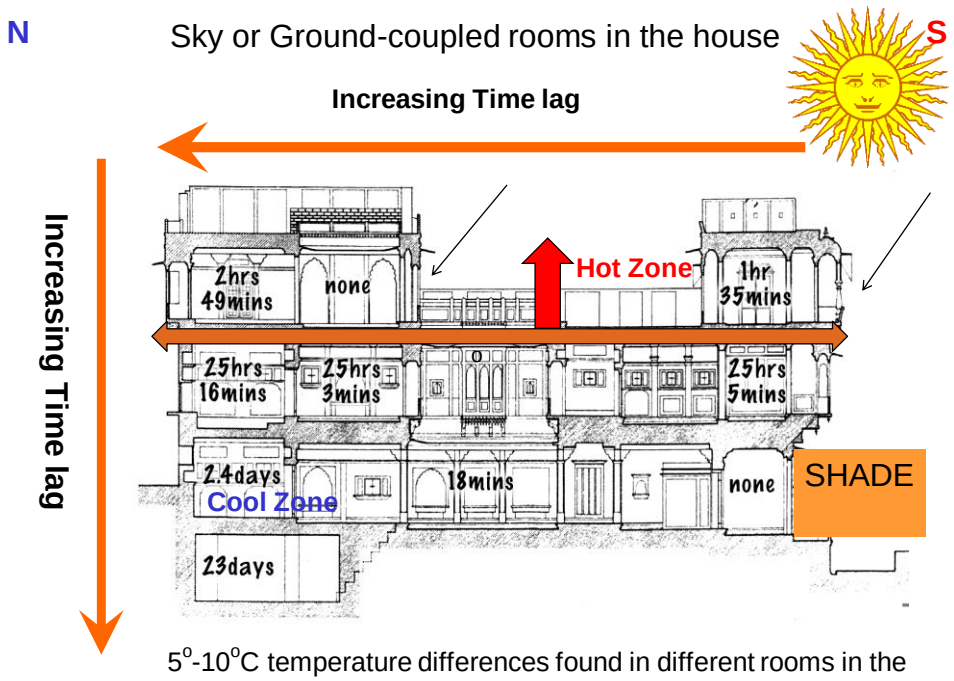
Micro-climates **around** a house vary enormously:

Courtyard house, N. India.

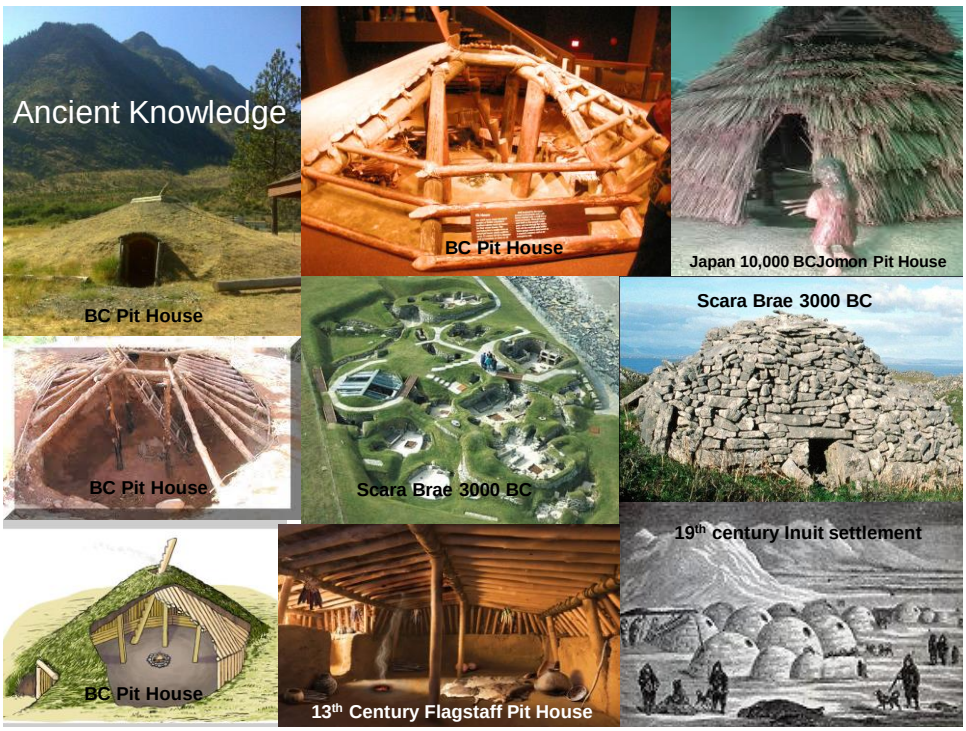
There are spaces for winter and summer, spaces with massive construction, spaces with light construction, sunny spaces and shady spaces, etc.

The result is that there is always a space that is comfortable, whatever the season and at any time of day





5^{o}-10^{o}C temperature differences found in different rooms in the same house here



Diurnal and Seasonal Migration around rooms in the home

The snug

The Veranda

The breakfast room

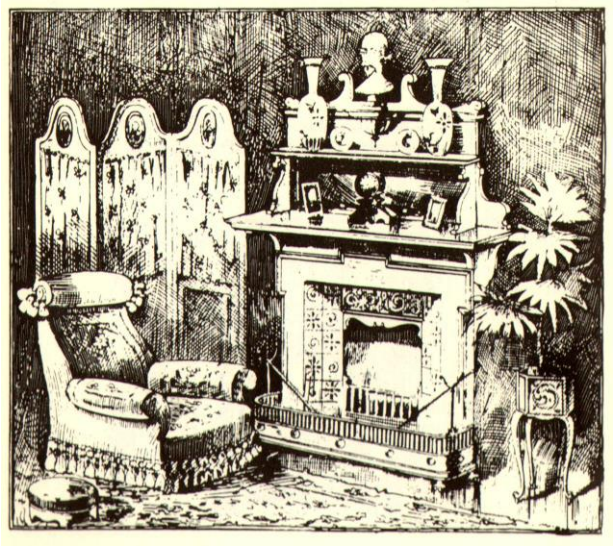
The winter garden

Lower background temperature adequate with Radiant heat source

Lower background
Comfort temperature
Required because of:

Warm high backed chair

Drafts below and behind
stopped by the screen
And the chair skirt



Lower background temperature adequate

If you sit in a high backed chair in front of the fire

Lower background temperature adequate with local heat sources

Thermal hospitality!

"it's a little chilly, so I've put an extra dog on your bed."

Hot water bottles and electric blankets also work !

"It's a little chilly, so I've put an extra dog on your bed"

Thermal Histories: The upstairs / downstairs divide

Thermal Histories: Downstairs staff worked from early morning till night keeping Active and warm

Thermal Histories: Upstairs they had a fire

Men's clothing was also much heavier

(mens' club, London, 1906)


PUNCH, OR THE LONDON CHARIVARI. 379

"Yesterday I was looking up my ancestral tree—"
"Did they throw any nuts?"

Changing comfort temperatures over time

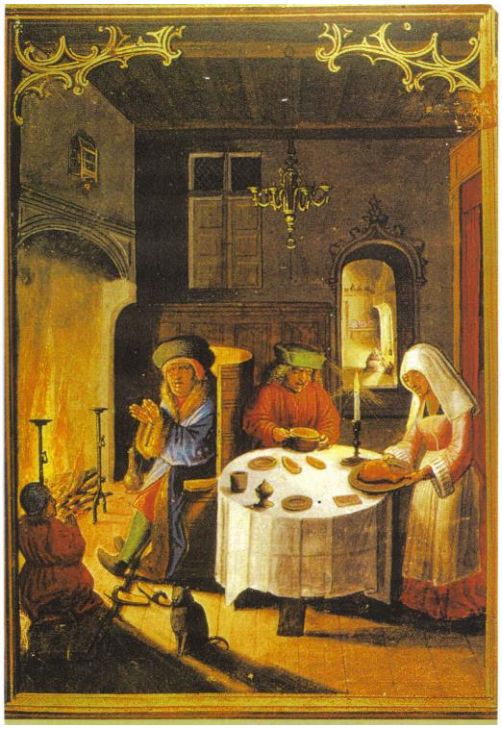
Comfort in the UK winter at about 15°C (1906)

Notice the heavy indoor clothing that can reduce required background heating temperatures by 2°C or more.


NOVEMBER 21, 1906.] PUNCH, OR THE LONDON CHARIVARI. 365

"THE SPIRIT IS WILLING—"

Governess. "You're a naughty little girl, Christabel, to kick your cousin like that!"
Christabel. "I didn't kick her."
Governess. "Oh, hush, dear! I saw you kick her several times."
Christabel. "I didn't. I missed every time!"



Upstairs / Downstairs

Master is comfortably seated in front of the fire

His minions are comfortably active away from its heat

In their daily life most people will have a 'normal' thermal experience which reflects their own personal circumstances and the culture and climate in which they live.

Within that experience they are safe – until factors such as the climate change around them.

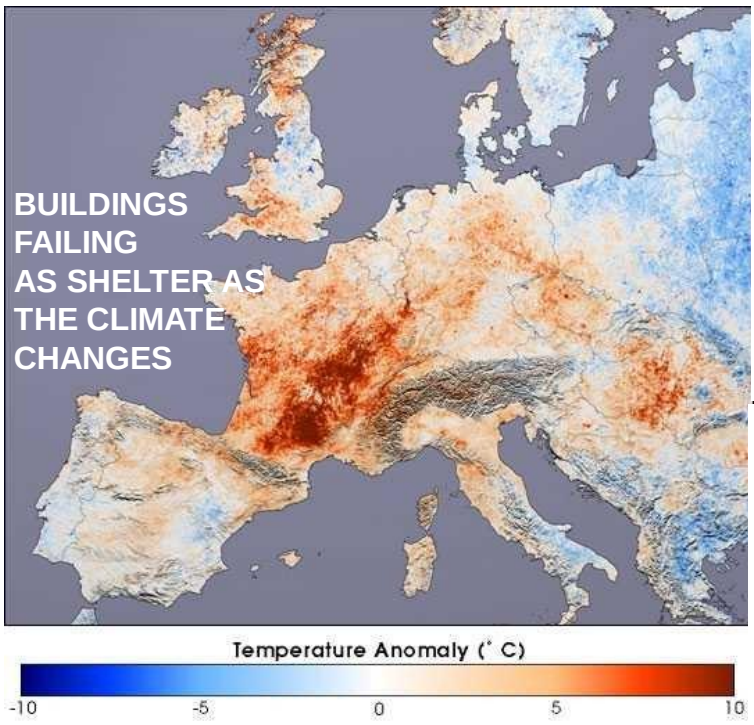


Image showing the differences in daytime land surface temperatures between July 2001 and July 2003 compiled by data collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. (Source: Reto Stockli and Robert Simmon, NASA Earth Observatory Team, based upon data provided by the MODIS Land Science team).

35,000 PEOPLE DIED IN EUROPE

IN JULY 2003

BECAUSE OF THE HEAT

Constraints

There may be insufficient opportunity for adaptive action to be fully effective. It may be *constrained* by (for example)

Climate

Culture and fashion

Work requirements

Personality

Insufficient adaptive opportunity leads to discomfort:

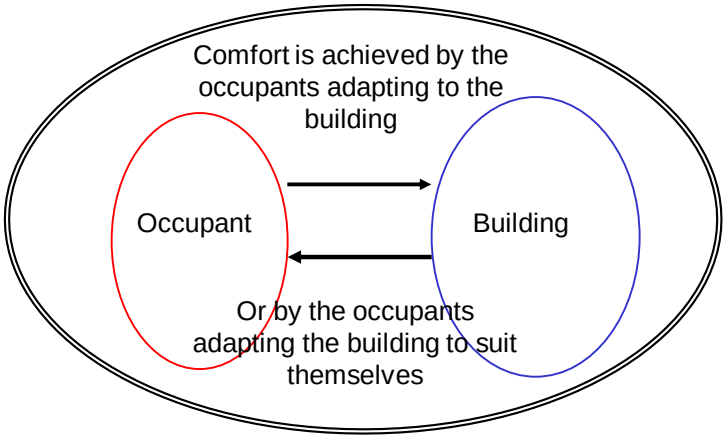
COOLBIZ : Overcoming the Constraints

Junichiro Koizumi is a Prime Minister of Japan from 2001 to 2006 who recommended the COOLBIZ.

On May 31, 2009, the Japanese Ministry of the Environment (MOE) publicity event for the "Cool Biz 2009" campaign in Kyoto, first since the campaign kicked off in 2005.
Workers must limit the use of air conditioning and wear casual clothes such as short-sleeved shirts without jackets or ties. T
MOE expanded the movement from the business scene to everyday lifestyles, using various means, to encourage all to stay comfortable in 28C (82F) rooms.

http://www.runway-ch.com/news/detail/381/2011-05/

To reiterate ……



There are two kinds of Thermal Comfort research:

Climate chamber:

- Controlled conditions
- Full measurements

Accurate but can be artificial and not locally relevant data

Eg. PMV, PPD etc.

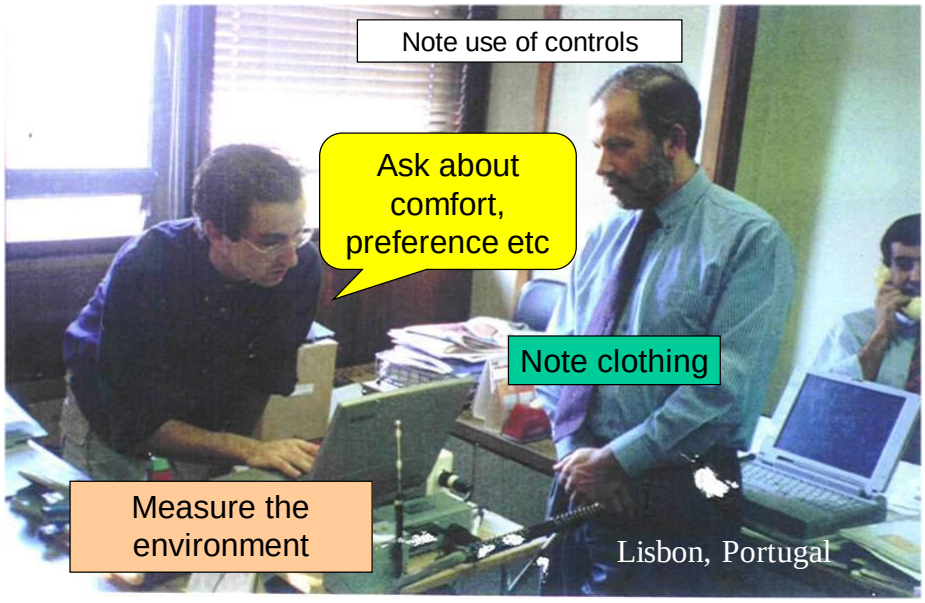
Field study:

- Real conditions
- Real buildings
- Normal behaviour

Relevant but can lack precision but can provide local data

Adaptive T C Method

Field Study - The comfort survey – how do we know what is acceptable ? We ask people – BPE / POE



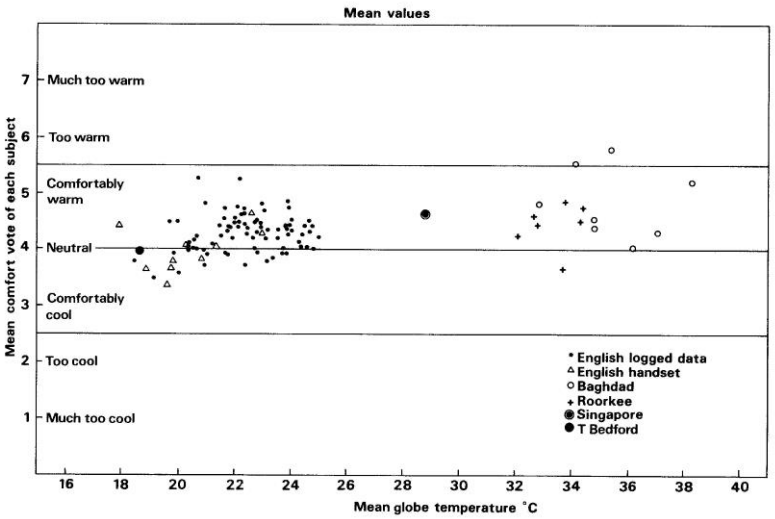
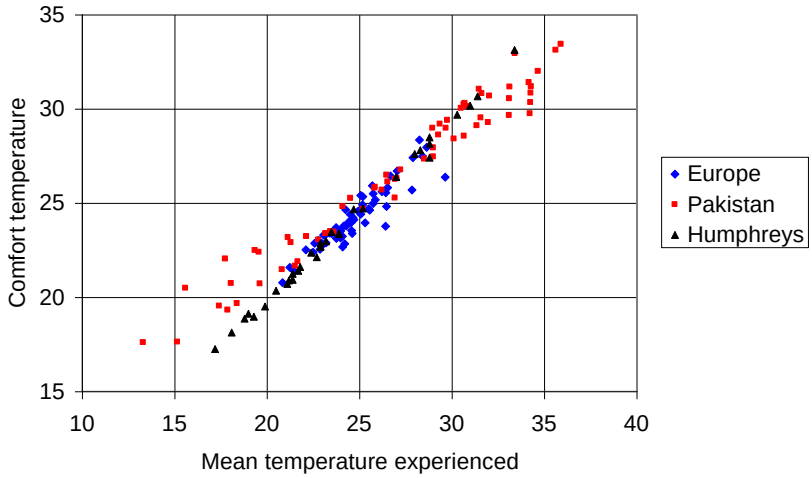


Fig. 8. Monthly mean comfort votes including data from various sources

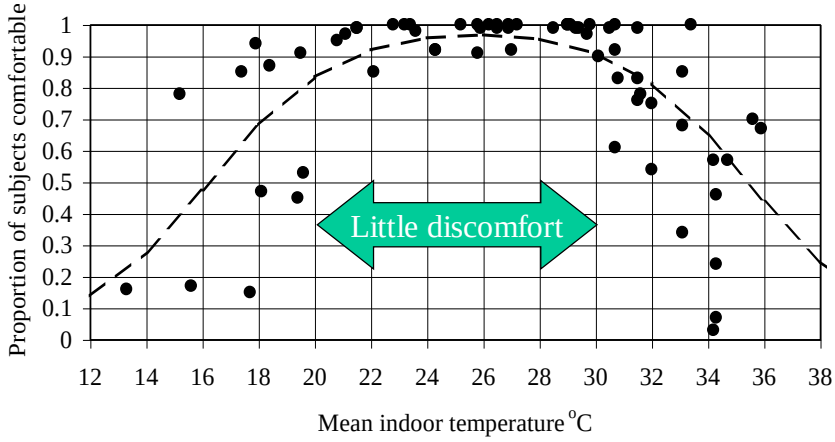
Findings: People are comfortable over wide range of temperatures

Each point is the average for a whole survey

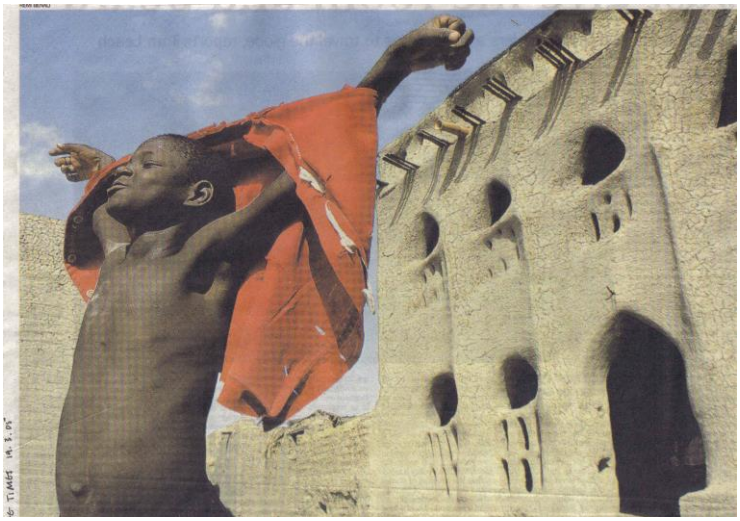
Survey results: A direct correlation between mean outdoor and comfort temperatures



The result of these actions is shown in this graph of the level of discomfort at different indoor temperatures among office workers in Pakistan

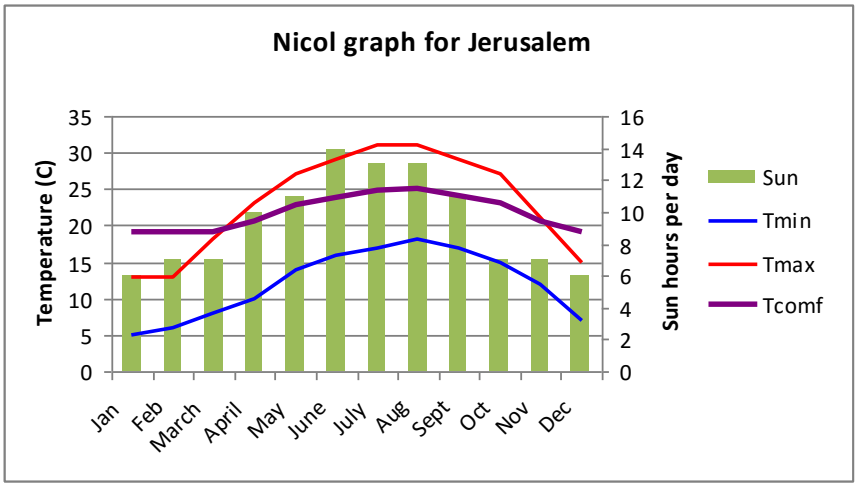


The Adaptive Principle:
If a change occurs that produces discomfort
People will tend to act to restore their comfort



(The return towards comfort is pleasurable)

Understanding the Climate Challenge



Each unique climate has a comfort temperature for locally adapted populations

Comfort Conclusions (1)

There is no temperature at which everyone will feel comfortable

comfort is a psychological state of mind defined by climate, culture and economics

A comfortable building will provide:

1. Appropriate indoor conditions
2. Possibilities for adjustment
3. Freedom to adapt

Another approach to thermal comfort
THE MECHANICAL APPROACH

"Creating thermal comfort for man is a primary purpose of the heating and air conditioning industry, and this has had a radical influence ... on the whole building industry"

"…thermal comfort is the **'product'** which is produced and sold to the customer…"

PO Fanger, *Thermal Comfort,* 1970 pp14,15

The 'High quality' standard here is NOT compatible with low-energy and low-carbon buildings

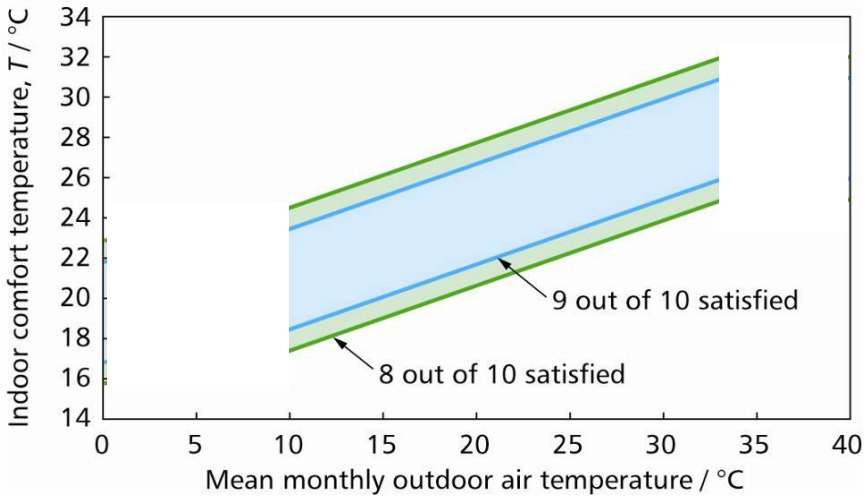
PMV related thermal comfort standards

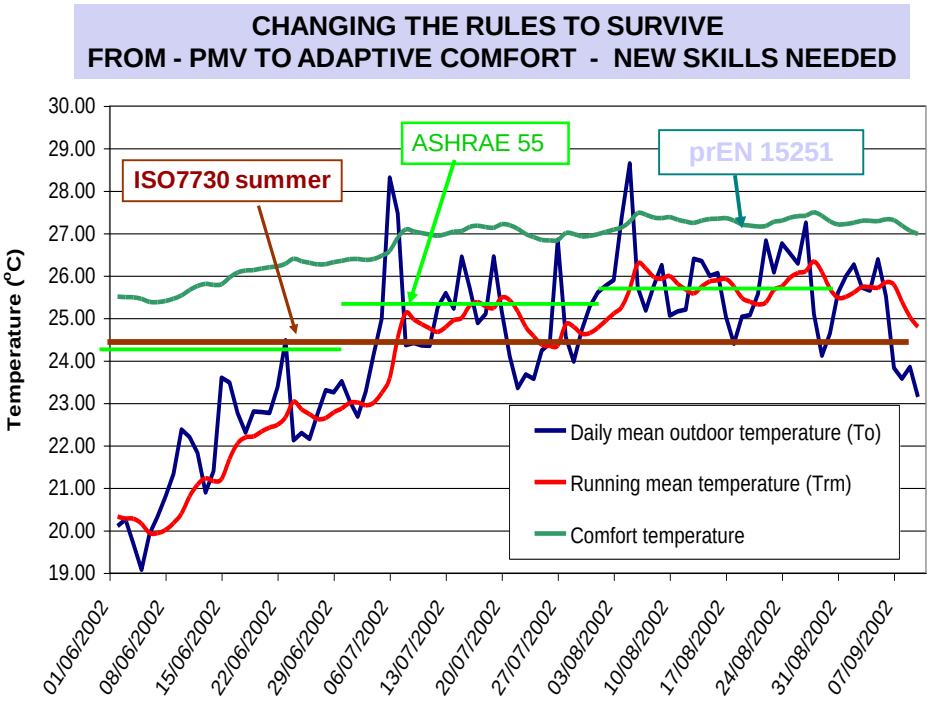
Type of Building/ Space	Clothing Cooling Season (summer) Clo	Clothing Heating Season (winter) Clo	Activity met	Category	Operative Temperature Cooling season (summer) °C	Operative Temperature Heating Season (winter) °C	Mean Air Velocity Cooling season (summer) ms^{-1}	Mean Air Velocity Heating season (winter) ms^{-1}
Office	0.5	1.0	1.2	A	24.5 ± 0.5	22.0 ± 1.0	0.18	0.15
				B	24.5 ± 1.5	22.0 ± 2.0	0.22	0.18
				C	24.5 ± 2.5	22.0 ± 3.0	0.25	0.21
Cafeteria/ Restaurant	0.5	1.0	1.4	A	23.5 ± 1.0	20.0 ± 1.0	0.16	0.13
				B	23.5 ± 2.0	20.0 ± 2.5	0.20	0.16
				C	23.5 ± 2.5	20.0 ± 3.5	0.24	0.19
Department Store	0.5	1.0	1.6	A	23.0 ± 1.0	19.0 ± 1.5	0.16	0.13
				B	23.0 ± 2.0	19.0 ± 3.0	0.20	0.15
				C	23.0 ± 3.0	19.0 ± 4.0	0.23	0.18

The standard is designed to ensure that it can only be met using expensive machines and HVAC engineerswho wrote it

The Adaptive field study based Standards

ASHRAE 55-2004 (NV limits)





Rethinking comfort standards

Up until now comfort standards have been concerned with accurate measurement and definition of indoor conditions on the basis that this equates with accurate measurement of ‘comfort’

In the process it has become accepted that tightly controlled conditions equate with better comfort

Redefining comfort standards

Analysis of field surveys and adaptive comfort theory have made it clear that whilst close control is **one** way of achieving comfort it is not the **only** way

At the same time **close control is an expensive** strategy in terms of energy

New standards already exist that reflect the need for low energy, low cost and low carbon futures

Redefining comfort standards

Standards must now encourage **NOT** high energy buildings but **LOW** energy buildings

They must be **comfortable** or they are not sustainable

How can standards drive change ?

Low energy categories

Category	Possible description
A	Buildings which are comfortable with no use of energy
B	Buildings which are comfortable but only use energy part of the year
C	Buildings which are comfortable but use energy all year

Comfort Conclusions (2)

Any building will be comfortable which:

Provides an indoor environment which is familiar and acceptable to occupants and varies little within any day or from day to day

Can be changed to suit the occupants if they want and allows them to dress to suit the conditions or move to a better place

Such buildings should be classified according to energy use rather than closeness of control

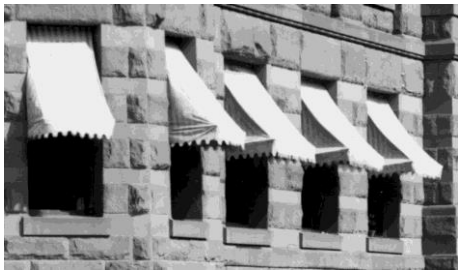
Comfort in low energy buildings

1. Environment should be within usual comfort limits by use of shading, thermal mass (to control range of temperature) etc
2. Building should allow occupants to control their environment by having opening windows, adjustable shades to keep sun out, fans for increased air movement.
3. Where possible occupants should feel free to adjust clothing, move to more comfortable places etc (management need to be aware of the 'cost' of a 'dress code')



Buildings with shading and opening windows for ventilation and cooling for most of the warm months


PODUNK

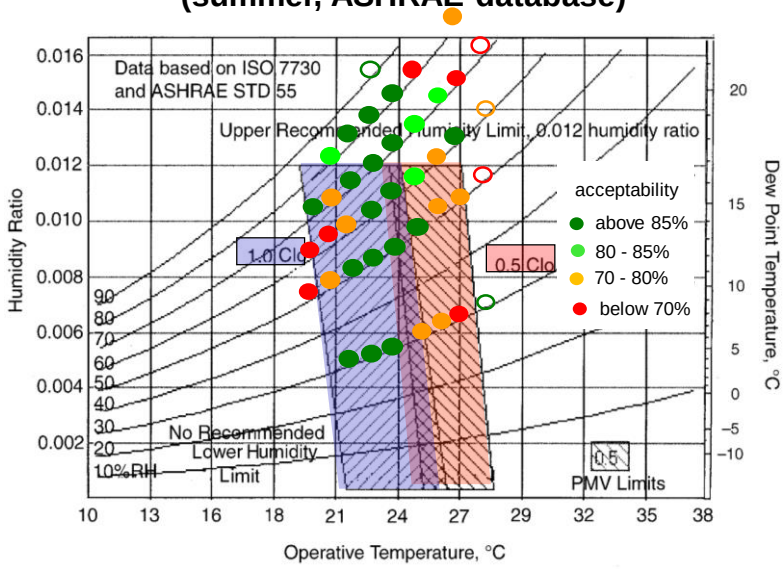



WWW.SPAGHETTIHOUSE.CO.UK

Comfort in low energy buildings

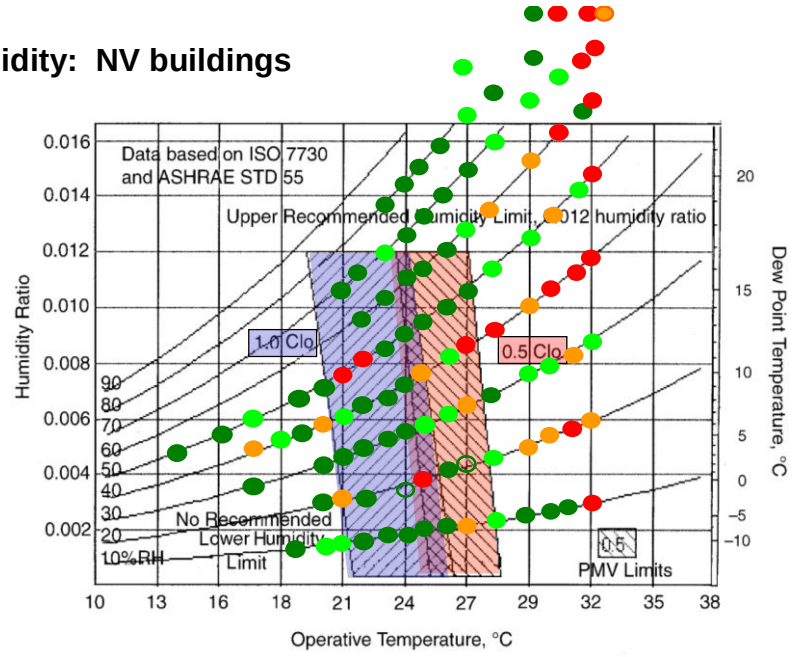
1. Environment should be within the comfort limits by use of shading, thermal mass (to control range of temperature) etc
2. Building should allow occupants to control their environment by having opening windows, adjustable shades to keep sun out, fans for increased air movement.
3. Where possible occupants should feel free to adjust clothing, move to more comfortable places etc (management need to be aware of the 'cost' of a 'dress code')

Humidity: HVAC buildings (summer, ASHRAE database)



Source: Ed Ahrens, Berkeley

Humidity: NV buildings

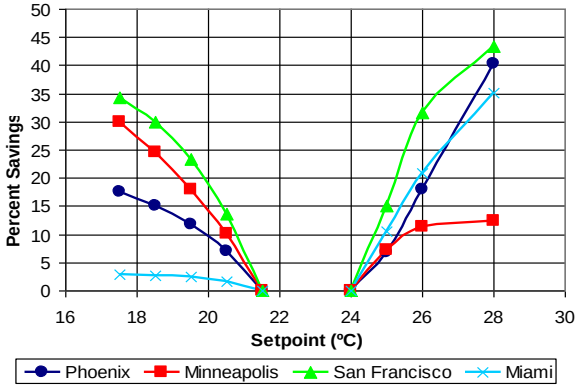


Source: Ed Ahrens, Berkeley

Energy savings from expanding the interior temperature range

Substantial energy savings in HVAC

May enable the use of more efficient cooling systems



(71F to 75F)

Hoyt, T., H.L. Kwang, H. Zhang, E. Arens, T. Webster, 2009, "Energy savings from extended air temperature setpoints and reductions in room air mixing." *International Conference on Environmental Ergonomics* 2009. Source: Arens

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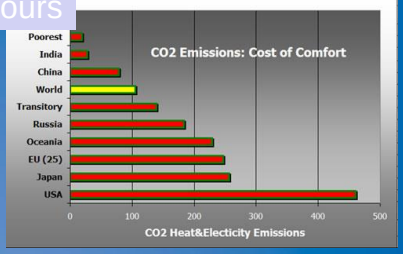
Adapting Behaviours



2005 Cool Biz introduced Japanese Government Offices AC only goes on above 28 C

SOLUTION: EMBRACE THE COMPLEXITY

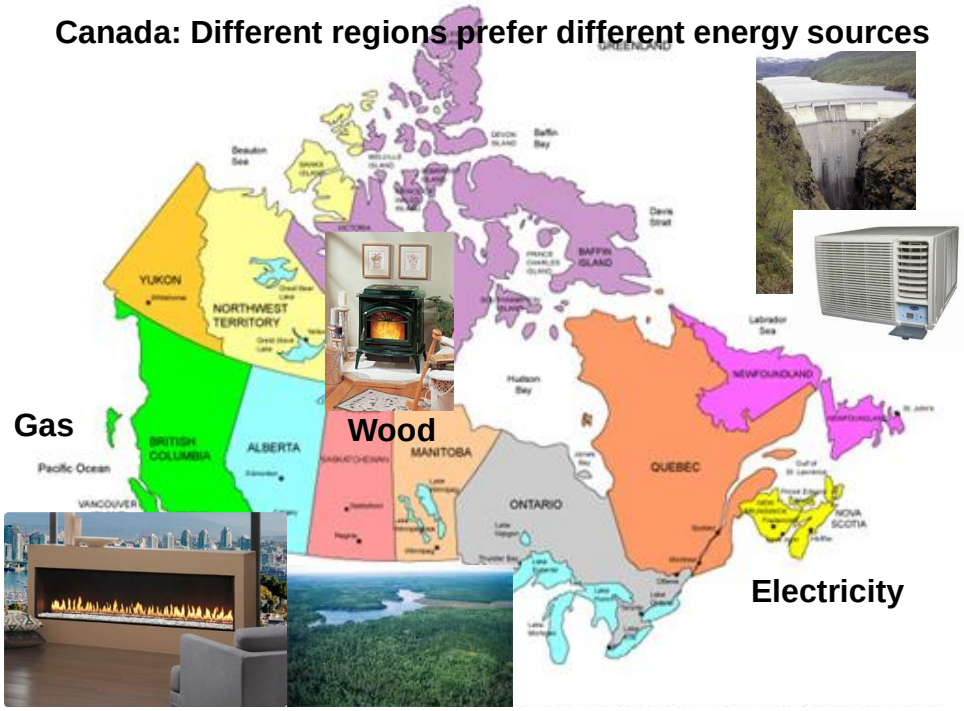
1. COMFORT

2. ENERGY

3. BUILDINGS

4. ADDRESS THE SKILLS DEFICIT

Canada: Different regions prefer different energy sources



Historic buildings run on solar energy
See: Lister Housing project – Changeworks Report
http://www.changeworks.org.uk/publications.php

SOLUTION: EMBRACE THE COMPLEXITY

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2. ENERGY

3. BUILDINGS – BIG ENERGY SOLUTIONS INAPPROPRIATE IN TRADITIONAL BUILDINGS

4. ADDRESS THE SKILLS DEFICIT

WARNING: PROBLEMS - FABRIC ISSUES:

Traditional houses in Scotland (heated by open fires):

- Ceilings are often high

- Solid walls are mainly of lime bonded brick or stone

External insulation + Internal insulation + draught stripping cost - condensation - poor indoor air quality - disruptive to install

Glazing Changes and External Renewable Energy systems: Backlash from reactionary Planners.

Etc.

21ST Comfort Approach: Its about the Architecture Stupid

1. Thermally landscape the micro-climates around the buildings with planting and shade structures
2. Thermally landscape the building itself externally with temporary or permanent shades with appropriate and authentic period solutions

Sydney – Australia with verandas

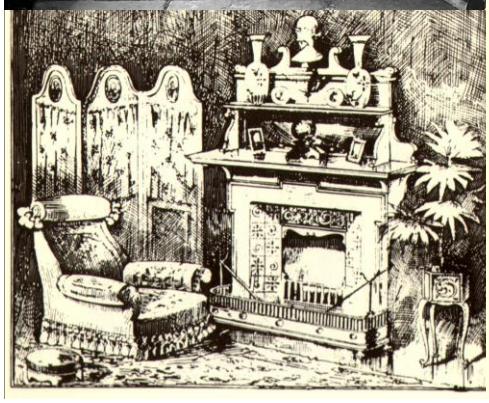
Canada – without verandas

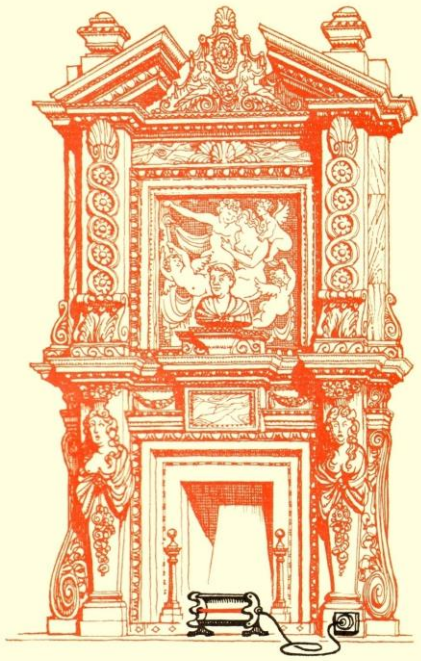
Authentic climate-proofing of buildings in period solutions

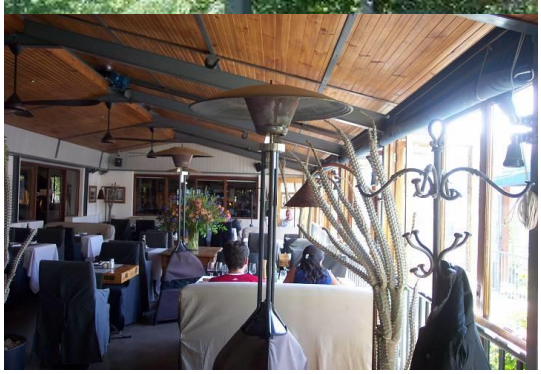



21ST Comfort Approach: Its about the Architecture Stupid

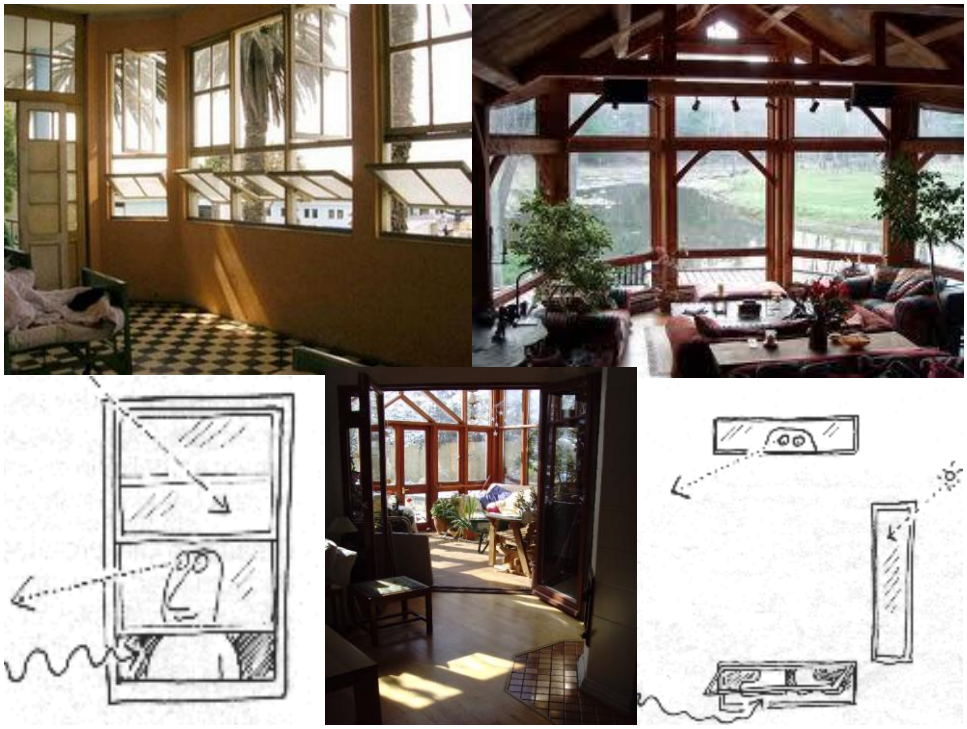
1. Thermally landscape the micro-climates around the buildings with planting and shade structures
2. Thermally landscape the building itself externally with temporary or permanent shades with appropriate and authentic period solutions
3. Lower (or higher) background temperatures with local supplementary heating (or cooling)



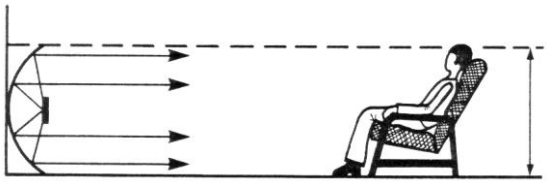


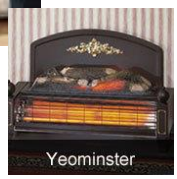


An opening roof, windows, heaters, fans, punkas give lots of adaptive opportunities



New Design Philosophy of Lower or Higher Background Temperatures with local supplementary heating / cooling

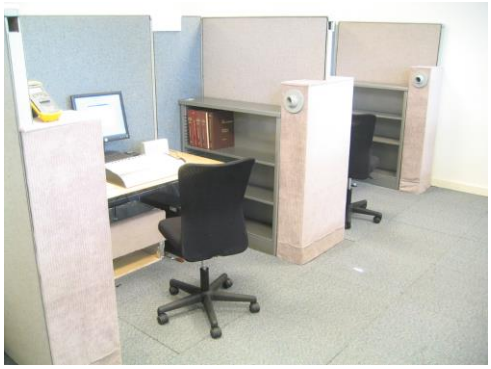




Royal Botanic Gardens Edinburgh,John Hope Gateway, radiant down-heaters suspended from the high mass ceiling http://www.rbge.org.uk/the-gardens/edinburgh/the-gateway

Radiant foot warmer

120 W max power
26W continuous @ 65F
Occupancy sensor



SOLUTION: EMBRACE THE COMPLEXITY

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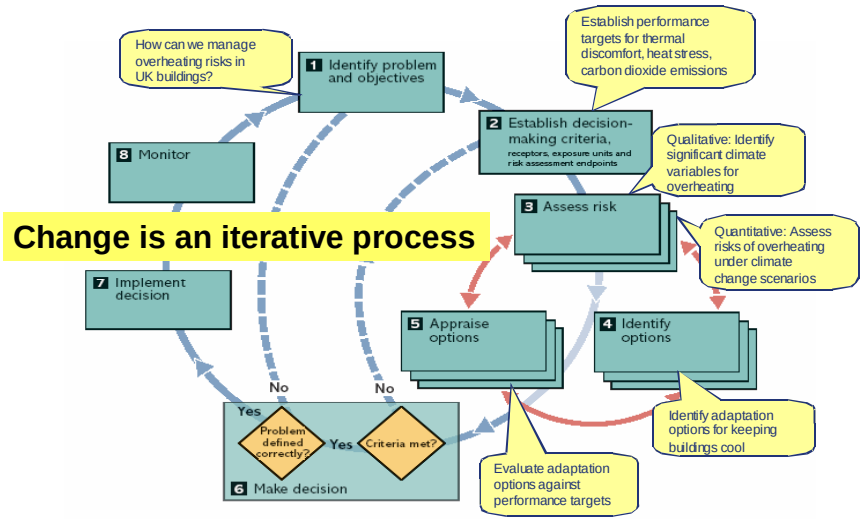
Adaptation Planning: Evolutionary Process
New Understanding and Skills needed



See: www.UsableBuildings.co.uk for POE and BPE information

Build the Evidence: Understand the underlying physiology of the buildings and it climate risks and energy requirements

SEASONS	SPACES	1	2	3	4	ETC.
Sum – am						
Sum - noon						
Sum – pm						
Sum - night						
Aut – am						
Aut - noon						
Aut – pm						
Aut - night						
Wint– am						
Wint - noon						
Wint– pm						
Wint - night						
Spr – am						
Spr - noon						
Spr – pm						
Supr - night						

TAKE YOUR TIME - TEST SOLUTIONS

In order:

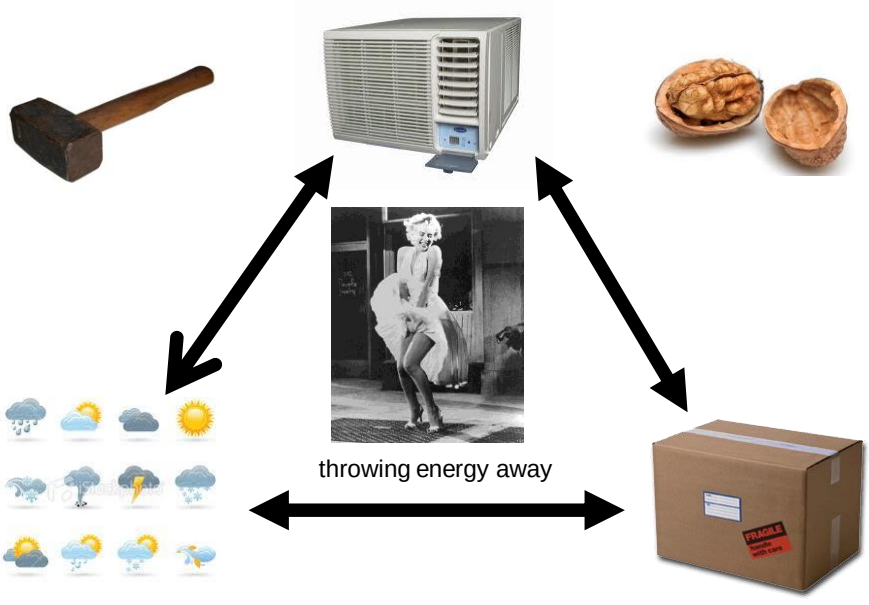
1. Reduce demand
- Passive improvements to fabric – and form
- Change usage patterns to avoid climate extremes
- Change clothing and work patterns of staff
- Shift the work to appropriate micro-climates - offices to cool spots

2. Provide minimal- cost efficient heating cooling solutions first
- Avoid big systemic solutions that will be unaffordable in a few years when energy prices double again
- Do not increase building failure risks by fixing windows etc – blackouts will happen

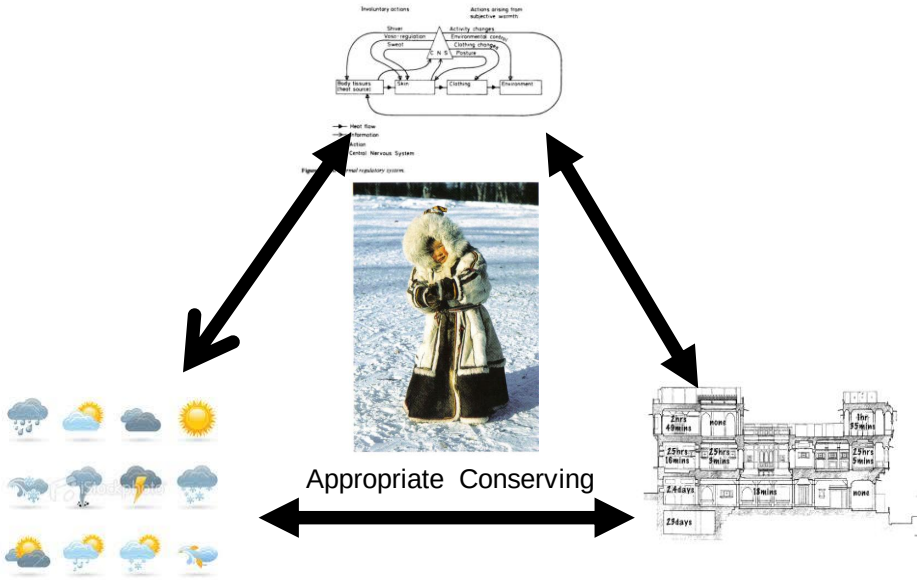
3. Use as much on site renewable energy as possible (esp. solar) because this is the only free energy source in perpetuity once paid for

4. In extremis have climate refuge plans for the building and Plan B in place to close areas of it (top floor – west rooms) or the whole building in very extreme events.

20th CENTURY – UNDEVELOPED - SIMPLISTIC – INFLEXIBLE – UNEVOLVING – INCREASINGLY OBSOLETE RESPONSE

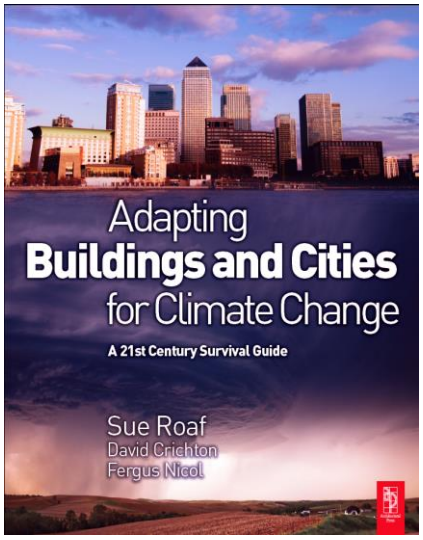


MATURE UNDERSTANDING: COMFORT IS A DYNAMIC PROCESS
AN ADAPTIVE INTERACTION BETWEEN COMPLEX SYSTEMS

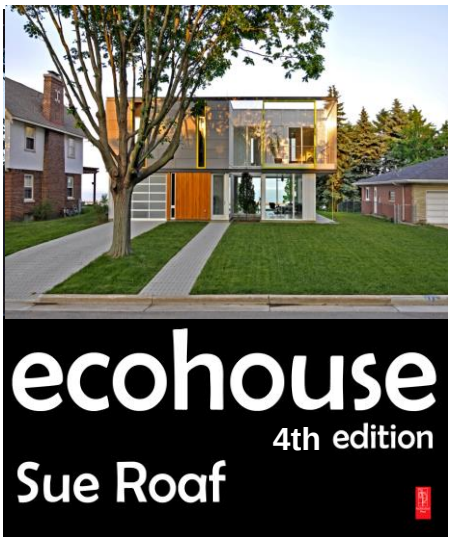



U.S. COAST GUARD
Run buildings ships in the wind - on clean free ambient energy

2009


Adapting
Buildings and Cities
for Climate Change
A 21st Century Survival Guide
Sue Roaf
David Crichton
Fergus Nicol

2012


ecohouse
4th edition
Sue Roaf

Adaptive Thermal Comfort Principles and practice

Fergus Nicol
Michael Humphreys and Susan Roaf

s.roaf@hw.ac.uk