

Green Intelligent Buildings to Meet Sustainability Agenda & Challenges and Opportunities for Intelligent Buildings in the 21st Century

Professor Derek Clements-Croome

The University of Reading

Intelligent Buildings Research Group

www.ibrg.rdg.ac.uk

Taiwan STAG/XCUAT 2006¹

Preview

- Contradictions
- Changes in Living, Innovation and Globalisation
- Global Warming
- Pollution in China
- World Energy Patterns
- Airconditioning: For Betterment of Mankind?
- Environmental Design Affects Well-Being of People
- Ideas for Progress
- Embedded Sensors in Buildings, Equipment and Clothing
- Meeting the Challenges
- Delivering Sustainability

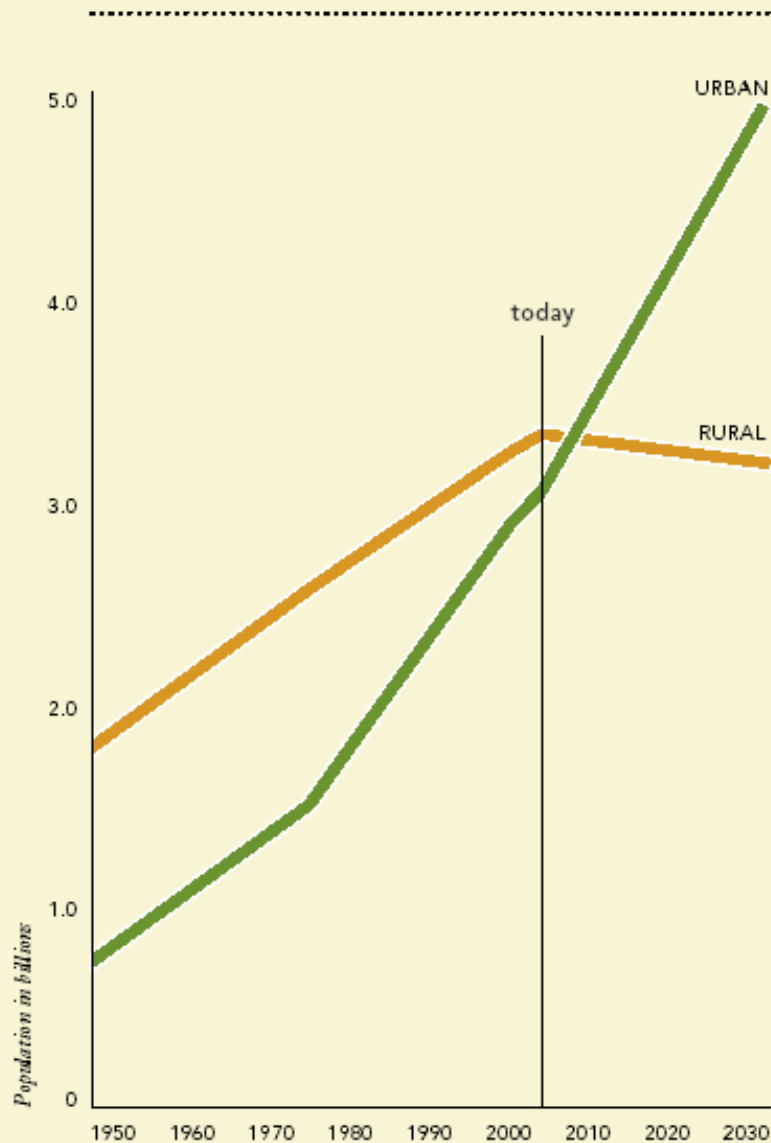
Contradictions

Fact	Consequence	Question
Warmer weather	More airconditioning	Is this sustainable?
Tighter construction	Less infiltration	Is this healthy?
More technology	Increasing complexity	Less reliability?
Rising user expectations	More demands	Client participative design?
Capital cost outlook	Cheap ineffective solutions	Mindset cultural change?

Changes in Living, Innovation and Globalisation

WORLD URBAN & RURAL POPULATIONS

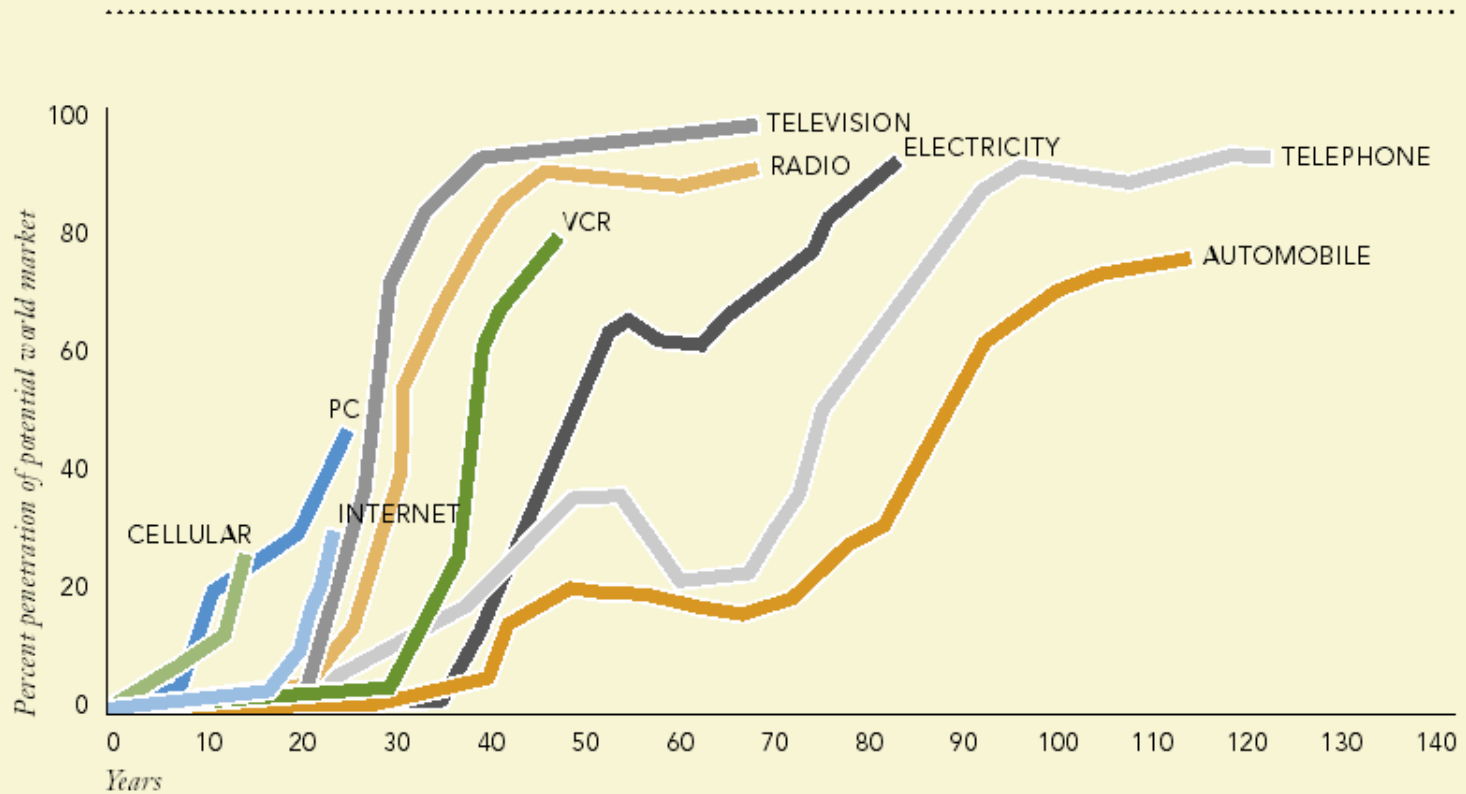
1950 - 2030



Source: Economic Division, Department of Economic and Social Affairs, United Nations, Outlook 2004, IBM₅

PACE OF INNOVATION ACCELERATING

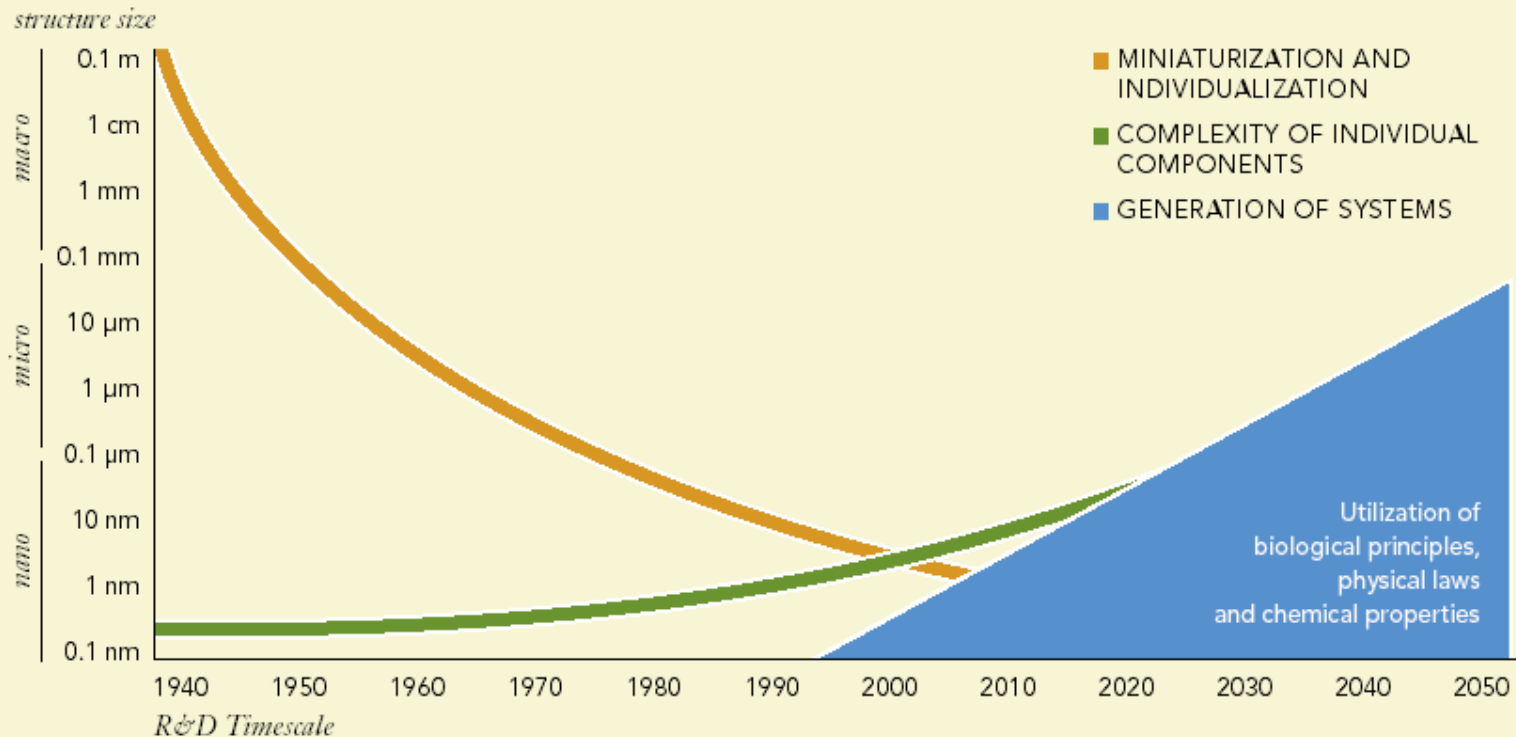
Newer technologies taking hold at double or triple previous rates



Source: Joseph Jacobsen, *Organizational and Individual Innovation Diffusion*
Global Innovation Outlook 2004, IBM, p.6

INNOVATION WILL REQUIRE MULTIDISCIPLINARY APPROACHES

Example: Nanotechnology

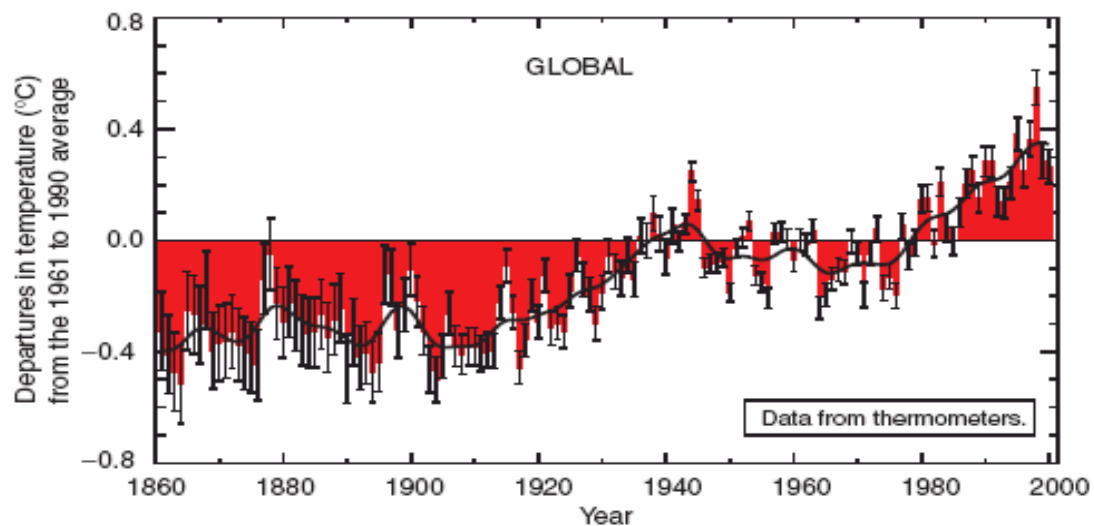


Wider cross sector collaboration is essential to innovation in many fields.

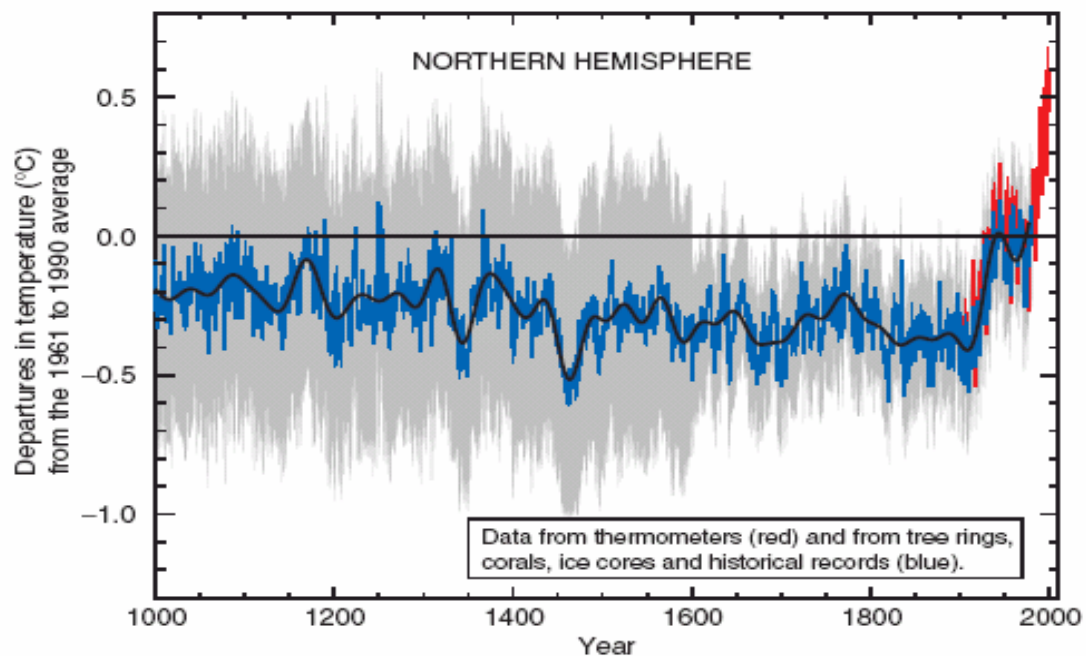
Global Warming

Variations of the Earth's surface temperature for:

(a) the past 140 years



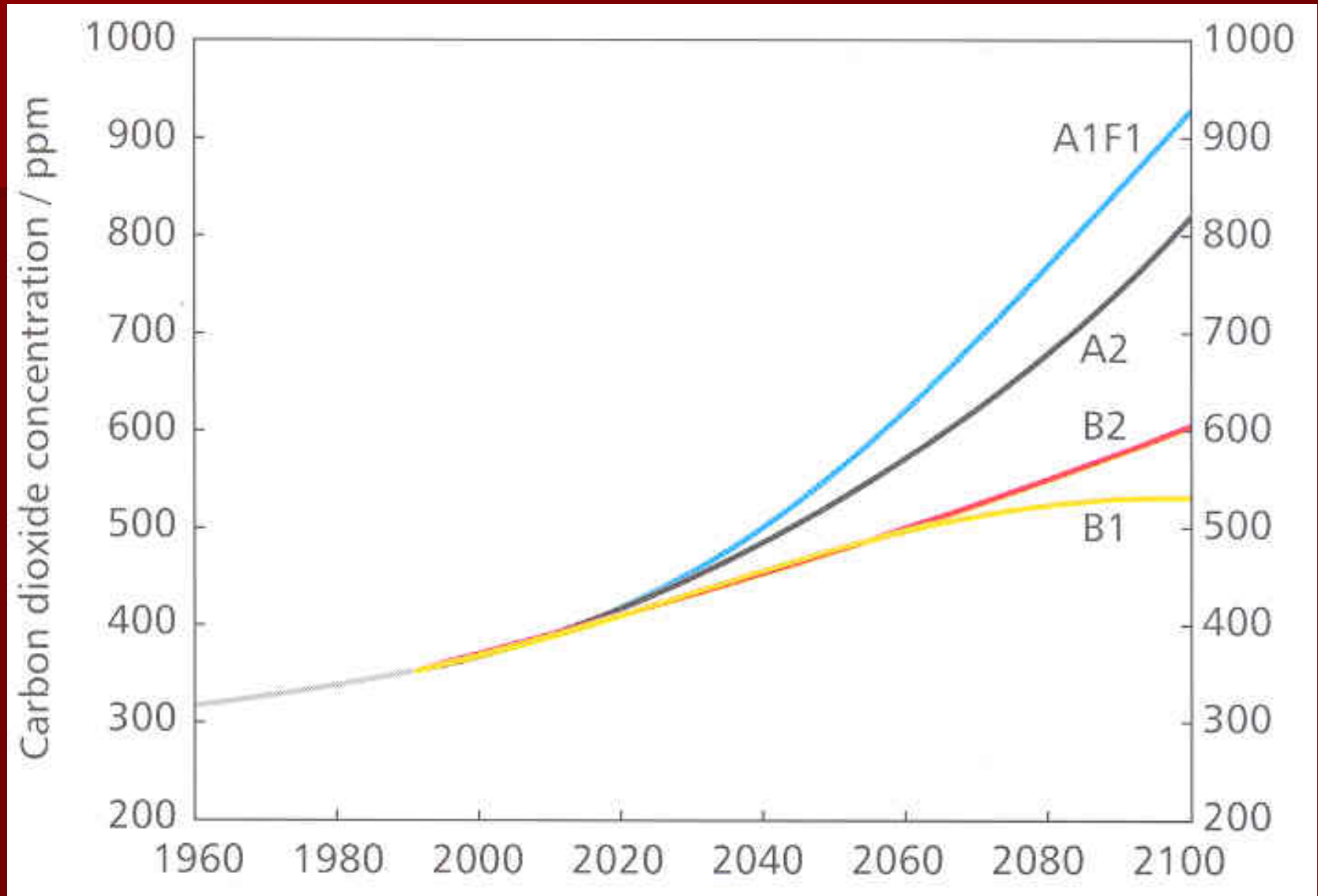
(b) the past 1,000 years



Climate Change

Intergovernmental
Panel on Climate
Change 2001

Global Carbon Dioxide Increases



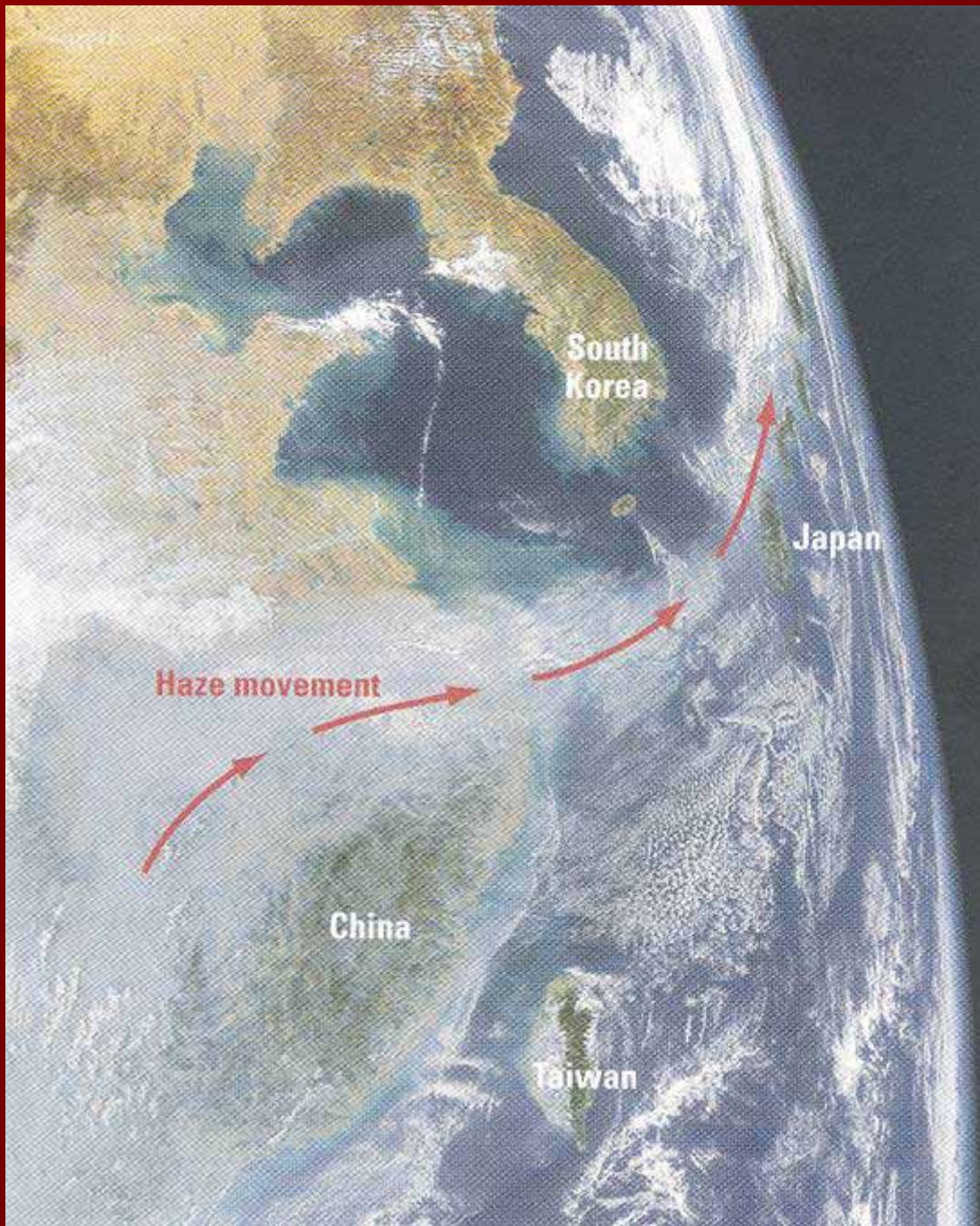
World Carbon Dioxide Emissions 2001-2025

Region	Carbon Dioxide emissions (million tonnes)		
	2001	2010	2025
Industrialised Countries	3179	3572	4346
East Europe/Russian Federation	856	1038	1267
Developing Countries	2487	3075	4749
Total	6522	7685	10361

Relative Carbon Emissions Life Cycle Energy

System Basis	Annual Carbon Emission (kg/m ²)
CIBSE (2002)	13
Natural Ventilation - good	12
- typical	20
Airconditioning - good	20
- typical	37

Pollution in China



Air pollution spreads out over eastern China, across the East China Sea towards Japan in October 2004.

The haze accumulates in the atmosphere from the burning of carbon-based fuels.

Pollution (dark grey) is easy to distinguish from clouds (bright white).

Image courtesy of the SeaWiFS Project,
Nasa/Goddard Space Flight Centre and Orbimage

Air Pollution in Beijing

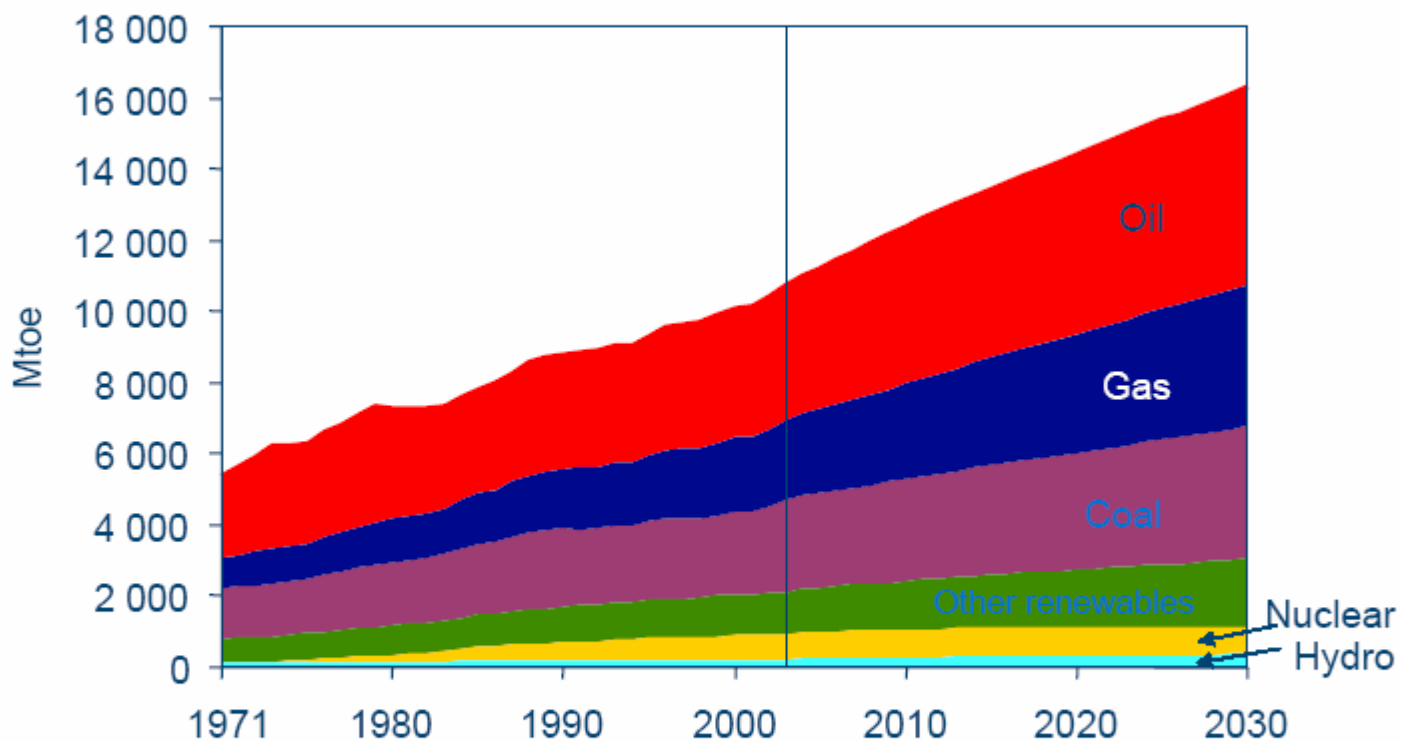


Two photos of the same Beijing skyline taken less than 24 hours apart

World Energy Patterns



World Primary Energy Demand

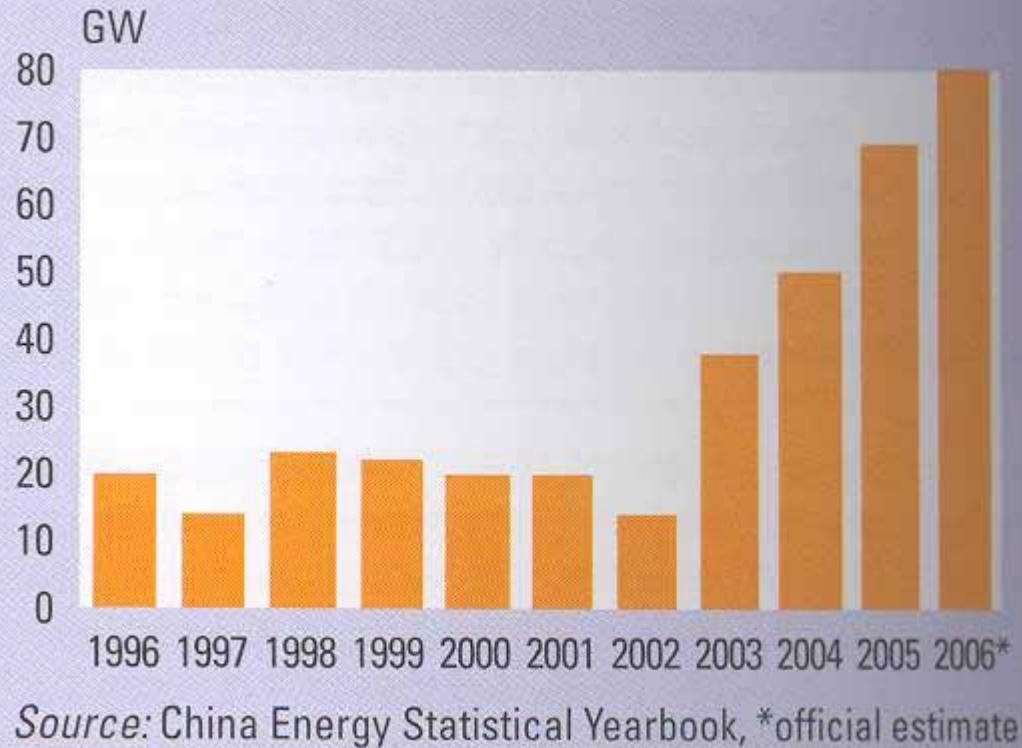


World Energy Demand rises by 52 % between now and 2030 in the Reference Scenario

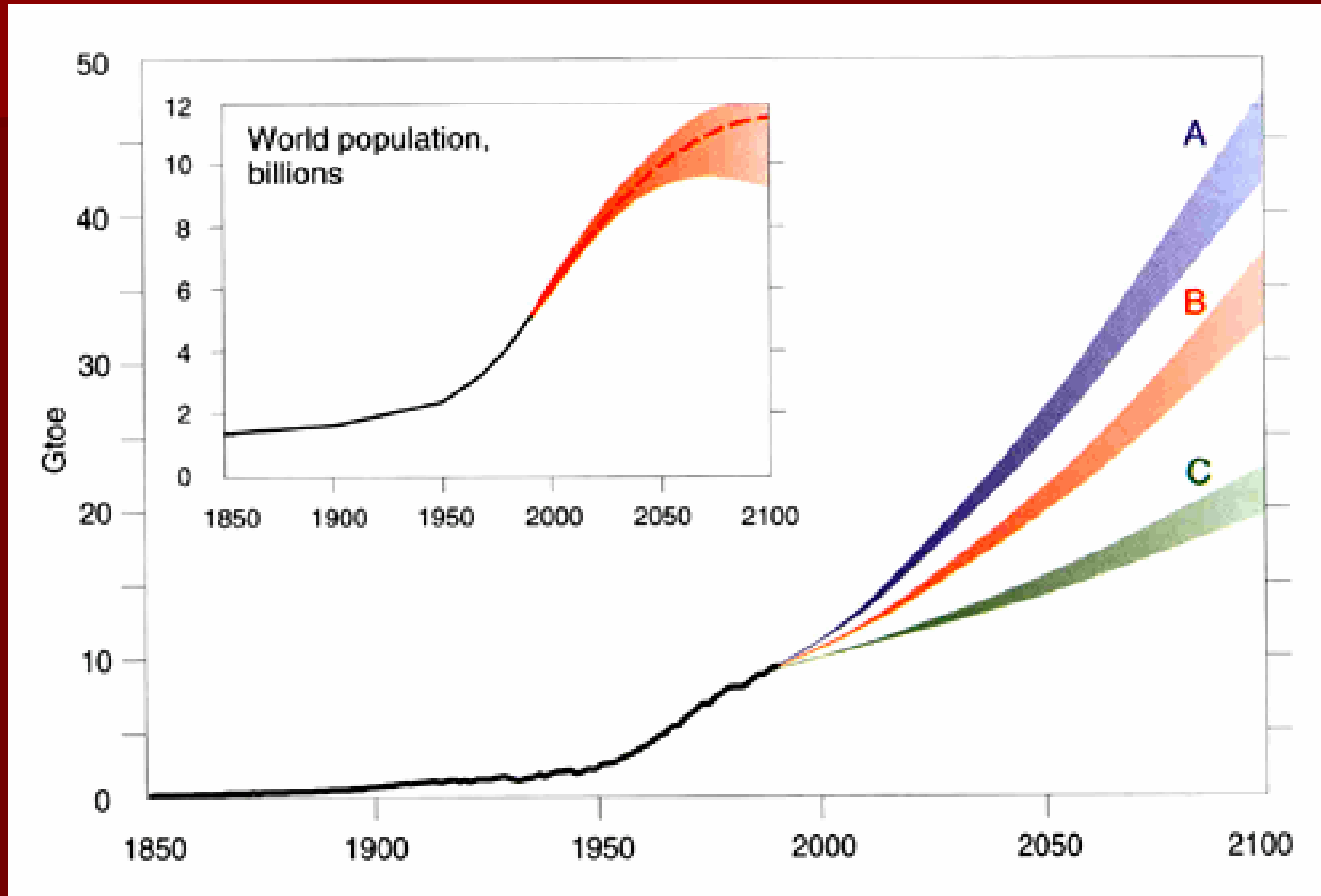
INTERNATIONAL ENERGY AGENCY

AGENCE INTERNATIONALE DE L'ENERGIE

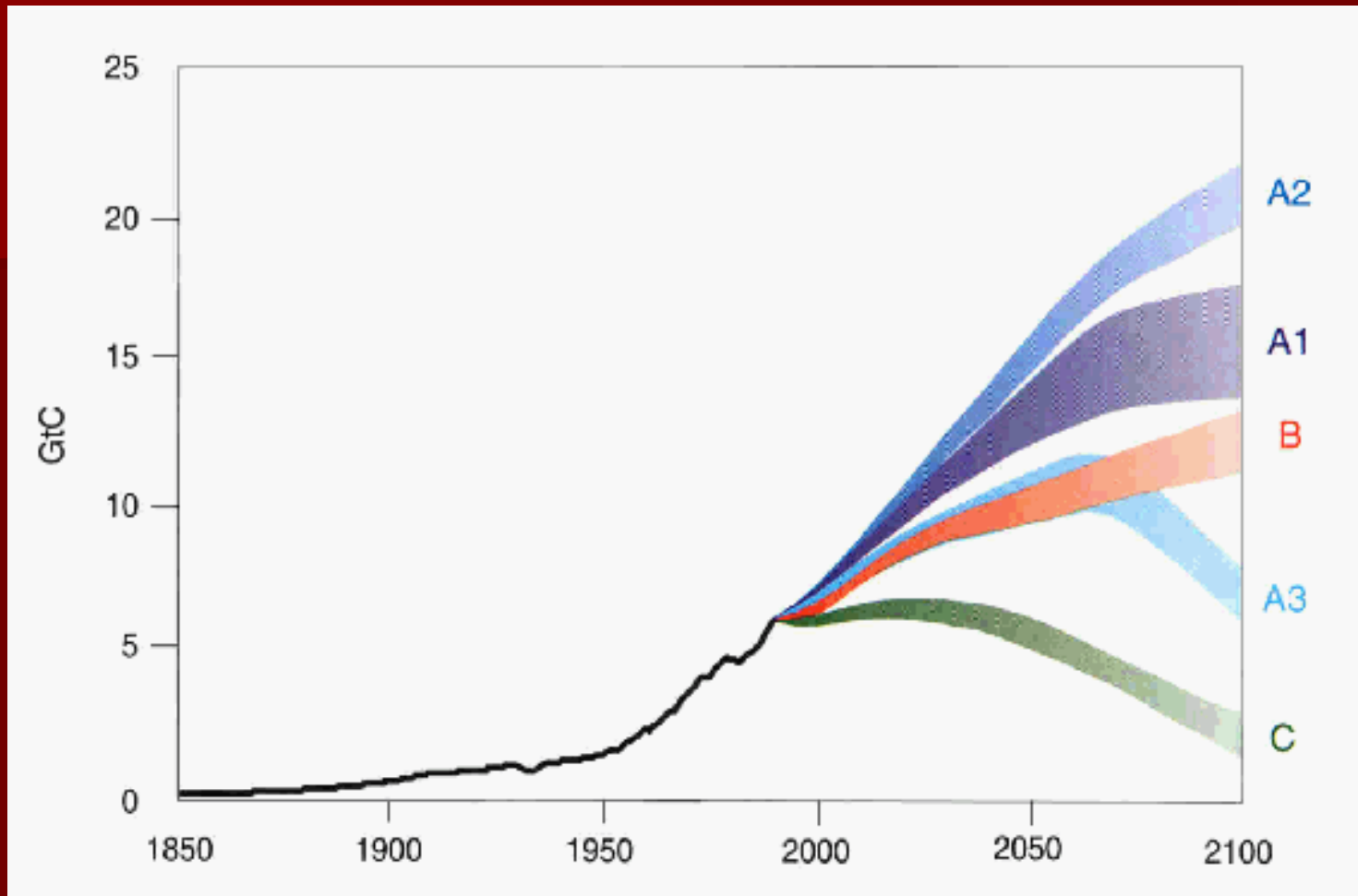
China Generating-Capacity Additions



Population Growth, 1850 to 1990 and projections to 2100, in billion people



Global Primary Energy Use, Historical Development from 1850 to 1990 in the three cases to 2100, in Gto.



Global Carbon emissions from Fossil Fuel Use, 1850 to 1990, and for scenarios to 2100, in GtC. For each scenario, the range shows the difference between gross and net emissions.

Global Consumption of Energy in 1998

Energy Source	Consumption (Mtoe*)	Consumption (%)
Oil	3500	41.1
Natural gas	1900	22.4
Coal	2100	24.7
Nuclear	800	9.4
Hydro-electric	200	2.4
Total	8500	100

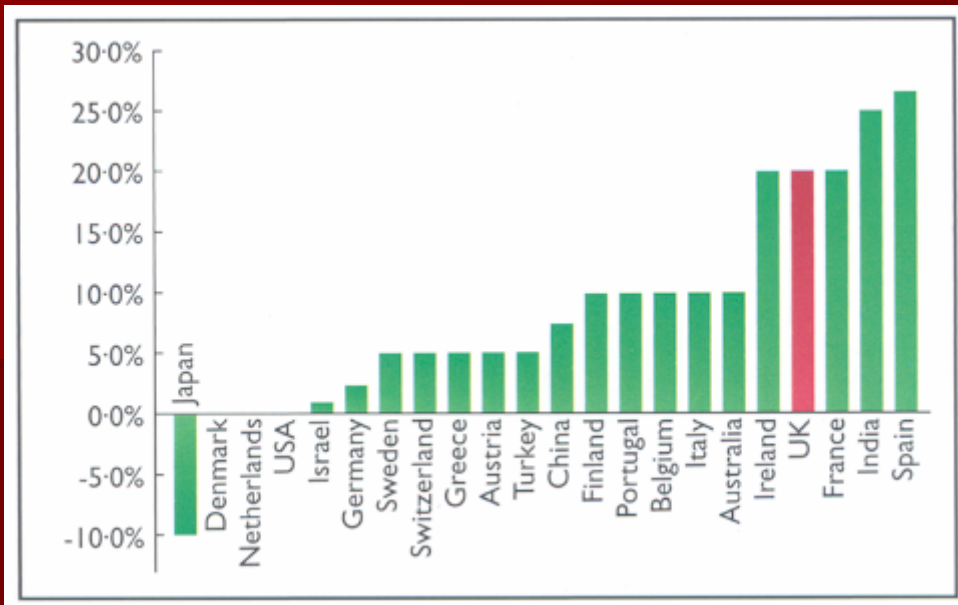
*Mtoe = Million tonnes oil equivalent = 42 GJ.

Colls (2002)₂₁

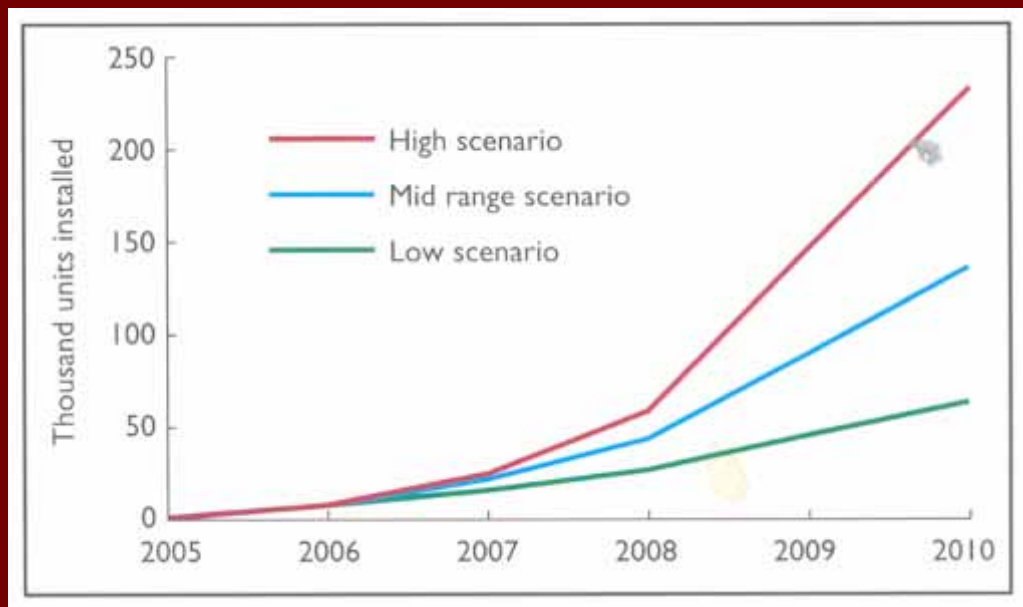
Global Renewable Energy Potentials

EJ thermal equivalent annual contributions (1 Exa Joule = 10^{18} J)			
Energy Source	1990	2025	Long term
Hydro-electricity*	21	35-55	>130
Geothermal	<1	4	>20
Wind	-	7-10	>130
Ocean	-	2	>20
Solar	-	16-22	>2,600
Biomass	55	72-137	>1.300
Total	76	130-230	>4,200

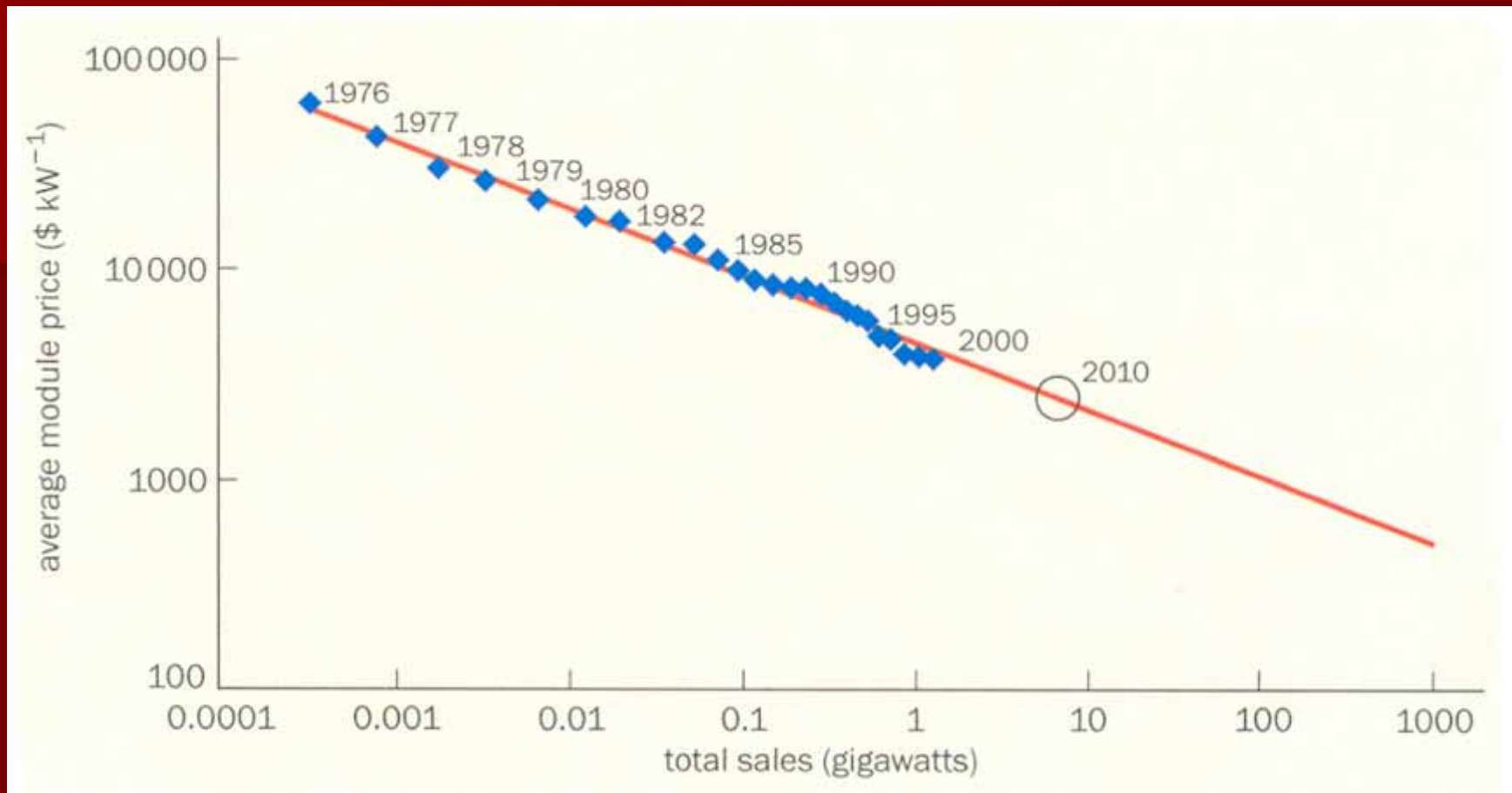
* Hydropower accounts for about 19% of the world electricity supply; largest producers are Canada, US and Brazil.



Forecast growth rates in world solar-thermal markets. 2005-2010.



Three different scenarios for the near-term growth of micro-chp in the UK.



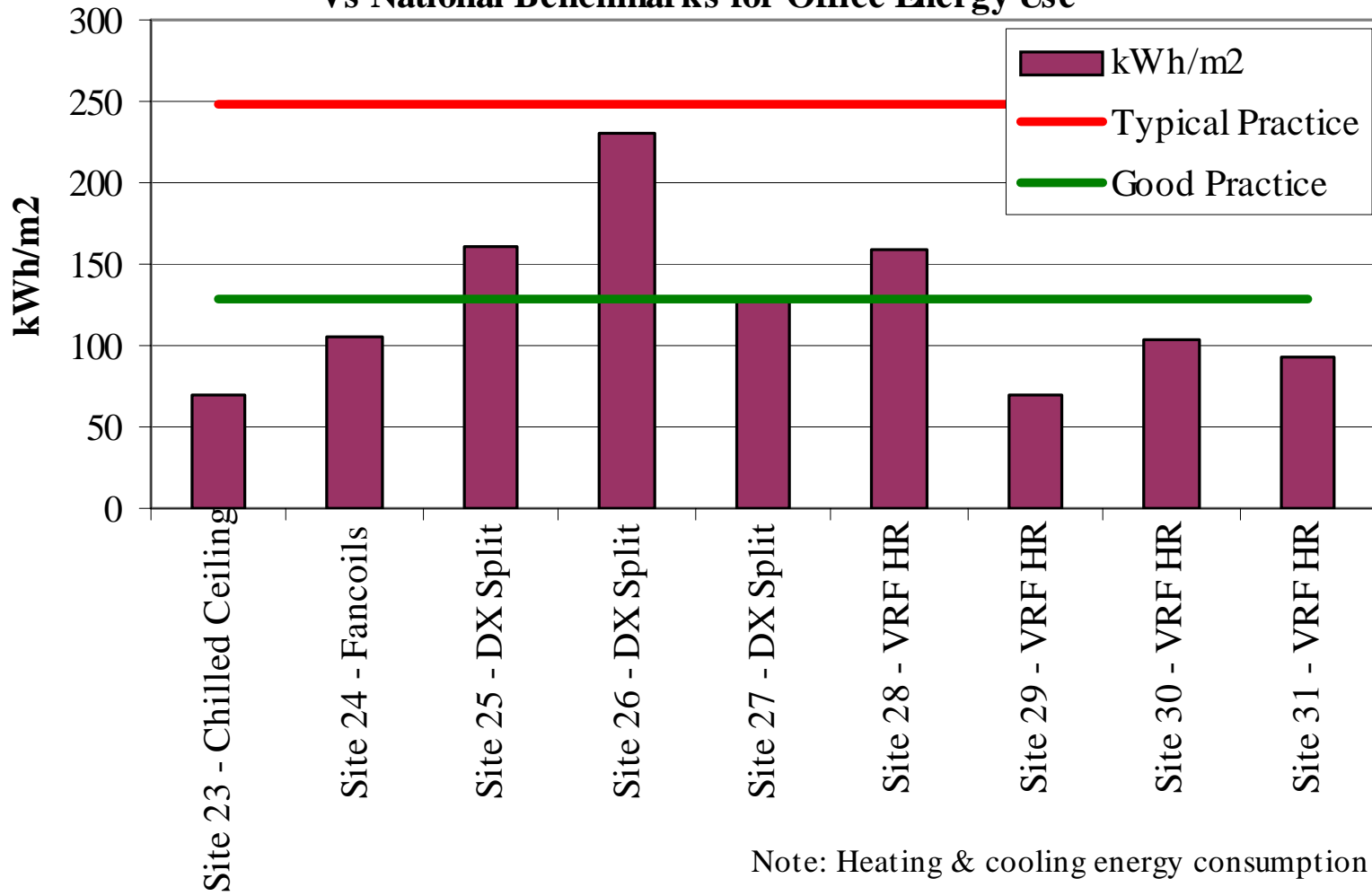
The average price of a photovoltaic module divided by its peak power versus the total power generated by all the modules ever sold. The trend shows the cost of modules falling by about 20% each time that sales double. (Data from Strategies Unlimited.)

Rules of Thumb for Solar Design

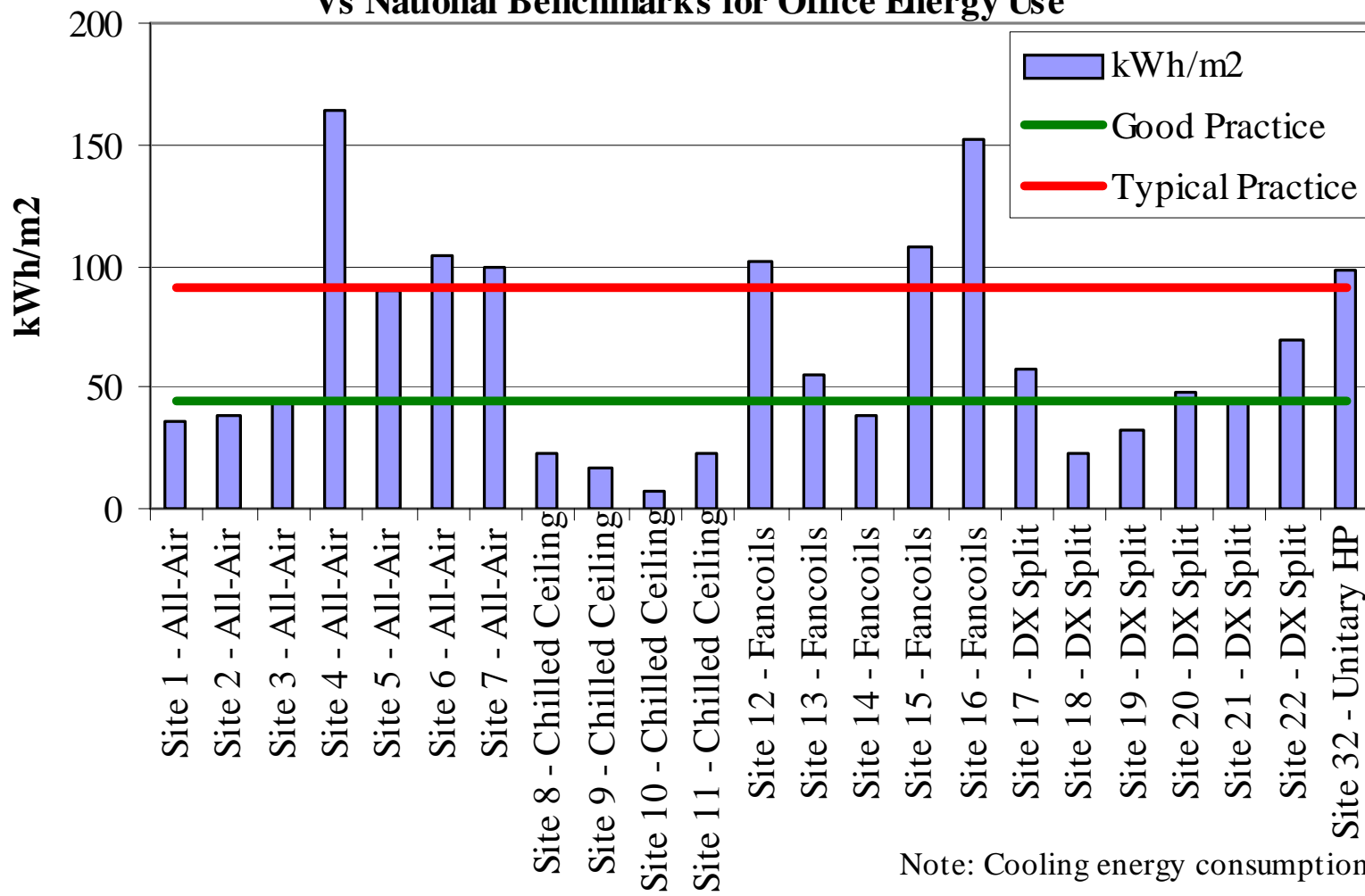
Form	<ul style="list-style-type: none">• create sun spaces, lighting ducts, light shelves
Orientation:	<ul style="list-style-type: none">• main glazing to face 30 degrees either side of due south• reduce north glazing• minimise tree over-shadowing• on housing estates build to a density of ≤ 40 properties/ha• design atriums/roof lighting in accordance with the position of the sun in both summer and winter
Fabric:	<ul style="list-style-type: none">• fabric transmission losses may be reduced by improving insulation or by reducing the mean inside air temperature.

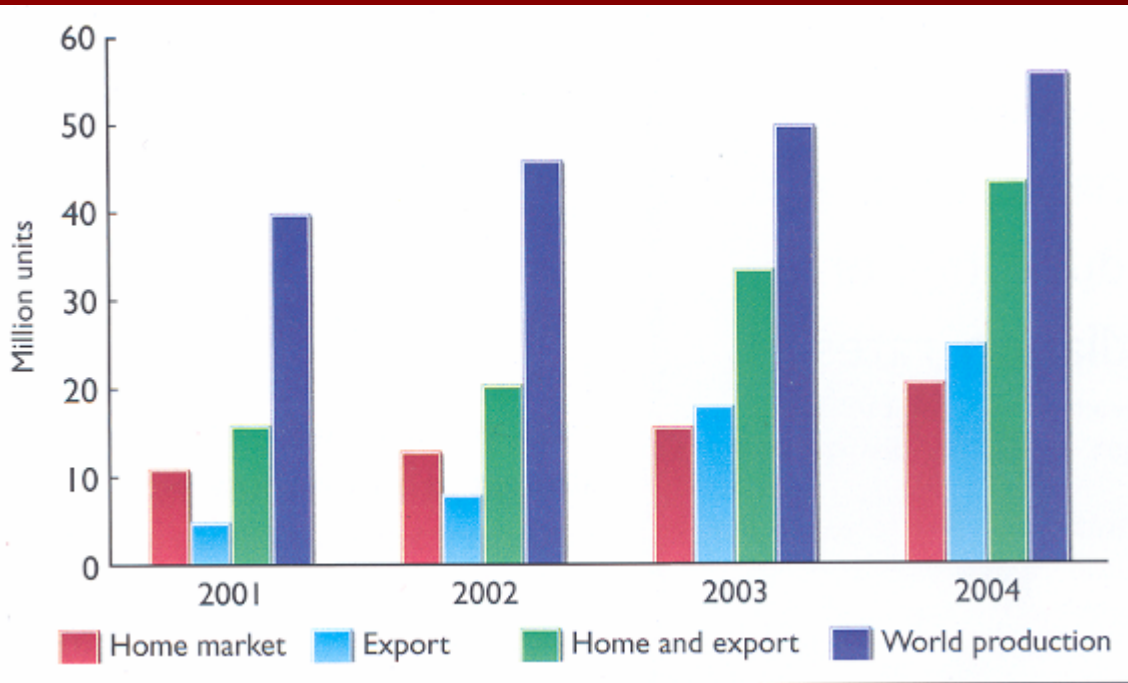
Airconditioning for the Betterment of Mankind?

Reverse Cycle Systems Annual Energy Consumption Vs National Benchmarks for Office Energy Use



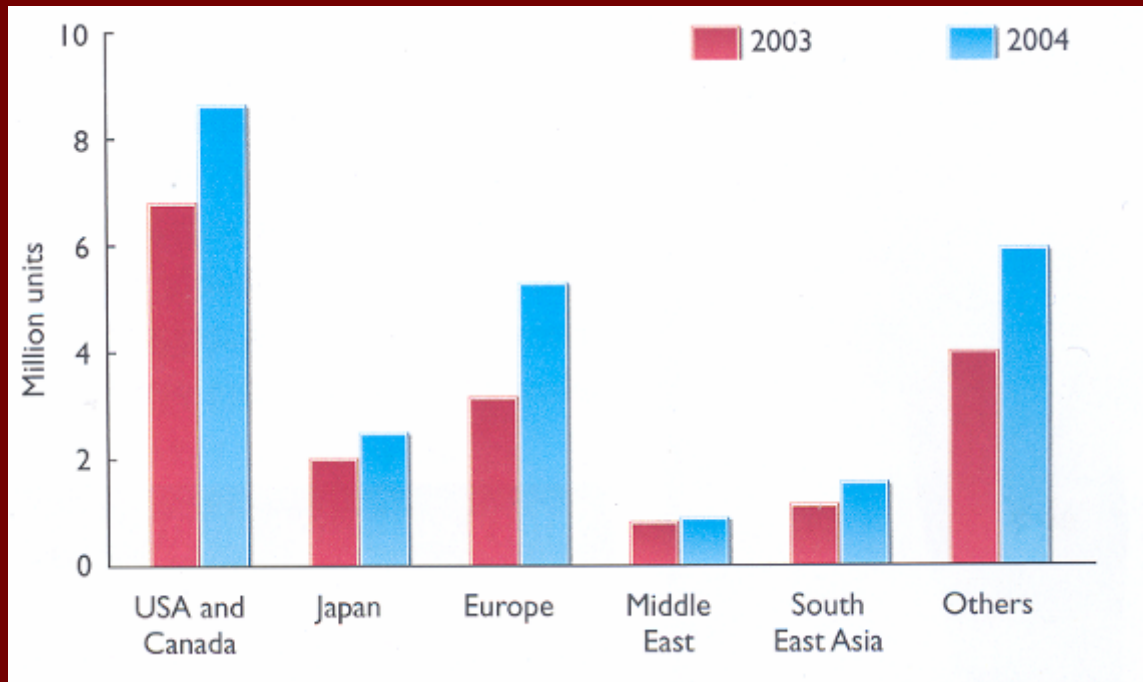
Cooling Only Systems Annual Energy Consumption Vs National Benchmarks for Office Energy Use



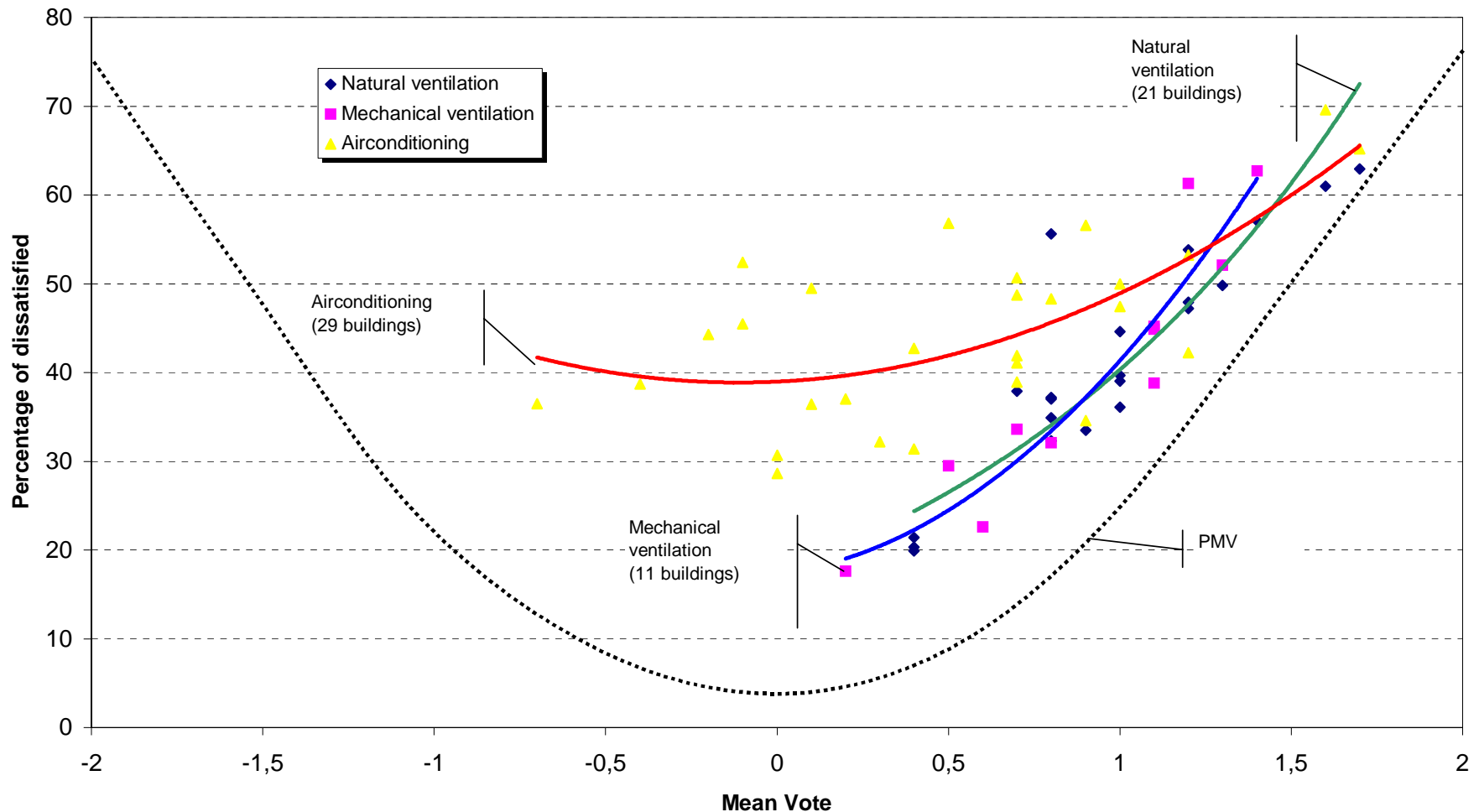


China supplied 75% of the world air-conditioning market by 2004.

Comparison of exports from China to all regions in 2003 and 2004.



Relation between MV and PD in summer for 29 air-conditioned buildings and for 32 buildings with individual temperature control and natural or mechanical ventilation.



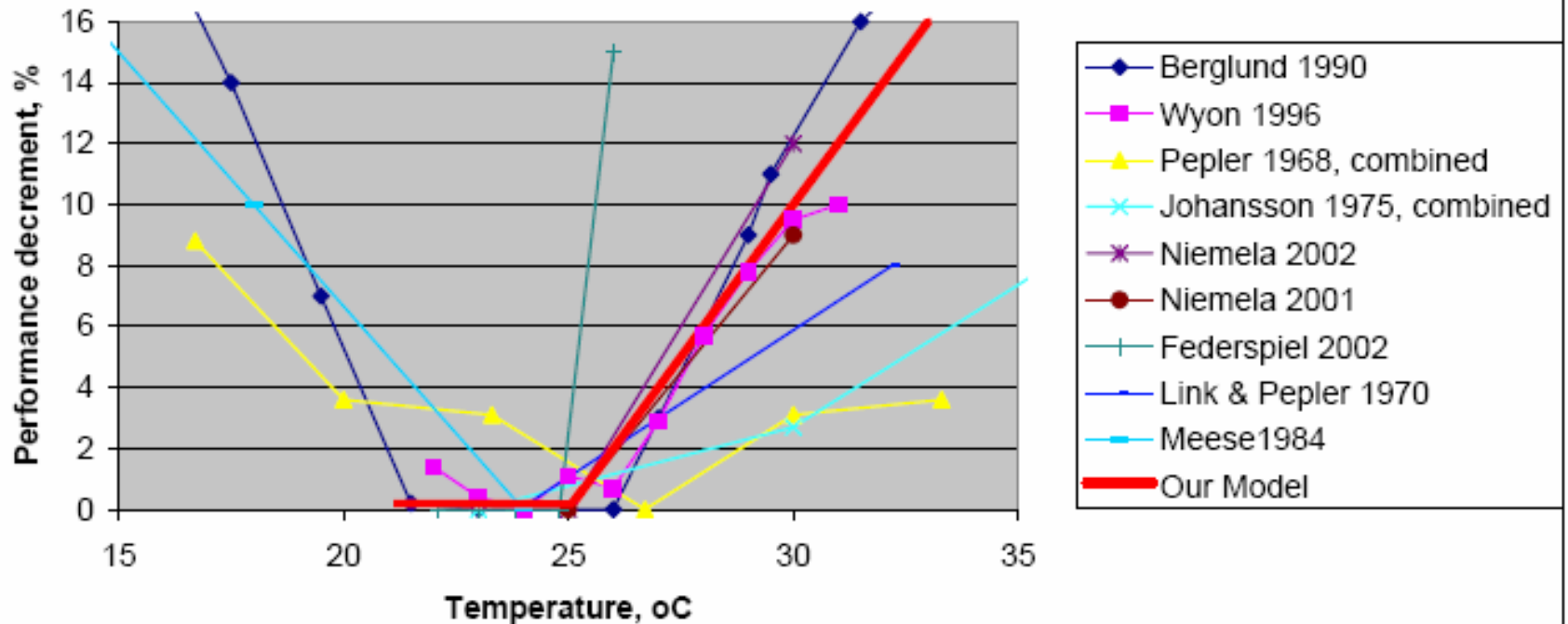
Environmental Design Affects Well-Being of People

Deficiencies in these Factors can Rapidly Fatigue Office Workers

- Aural/acoustic quality
- Visual illumination quality
- Thermal quality
- Air quality
- Building amenities
- Functional ergonomics
- Organisation
- Social milieu
- Personal Life

Decrease of Performance and Productivity with Temperature

2,5% decrease per deg C above 25°C and below 20°C



Stata Building at MIT by Frank Gehry

University officials sought an unconventional building to inspire creativity

exterior



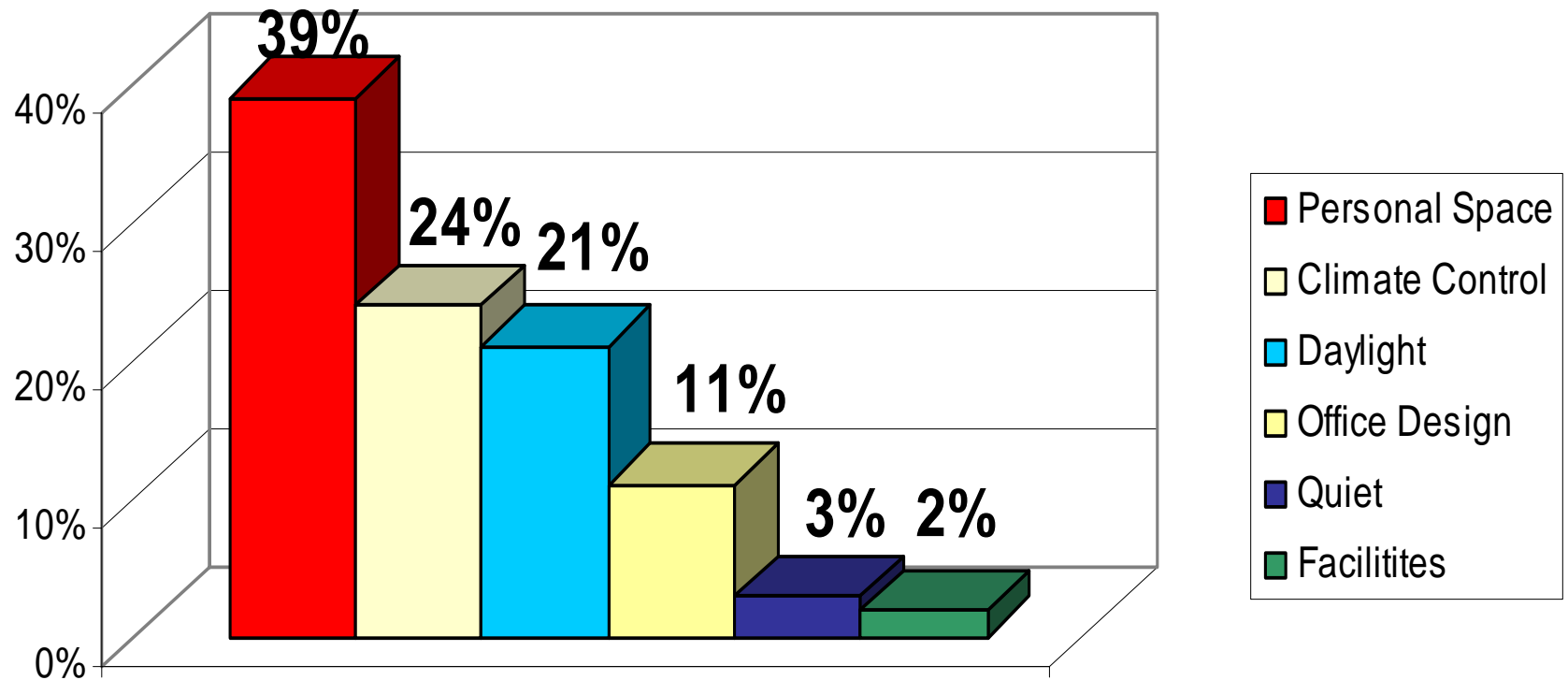
Stata Building at MIT Interior

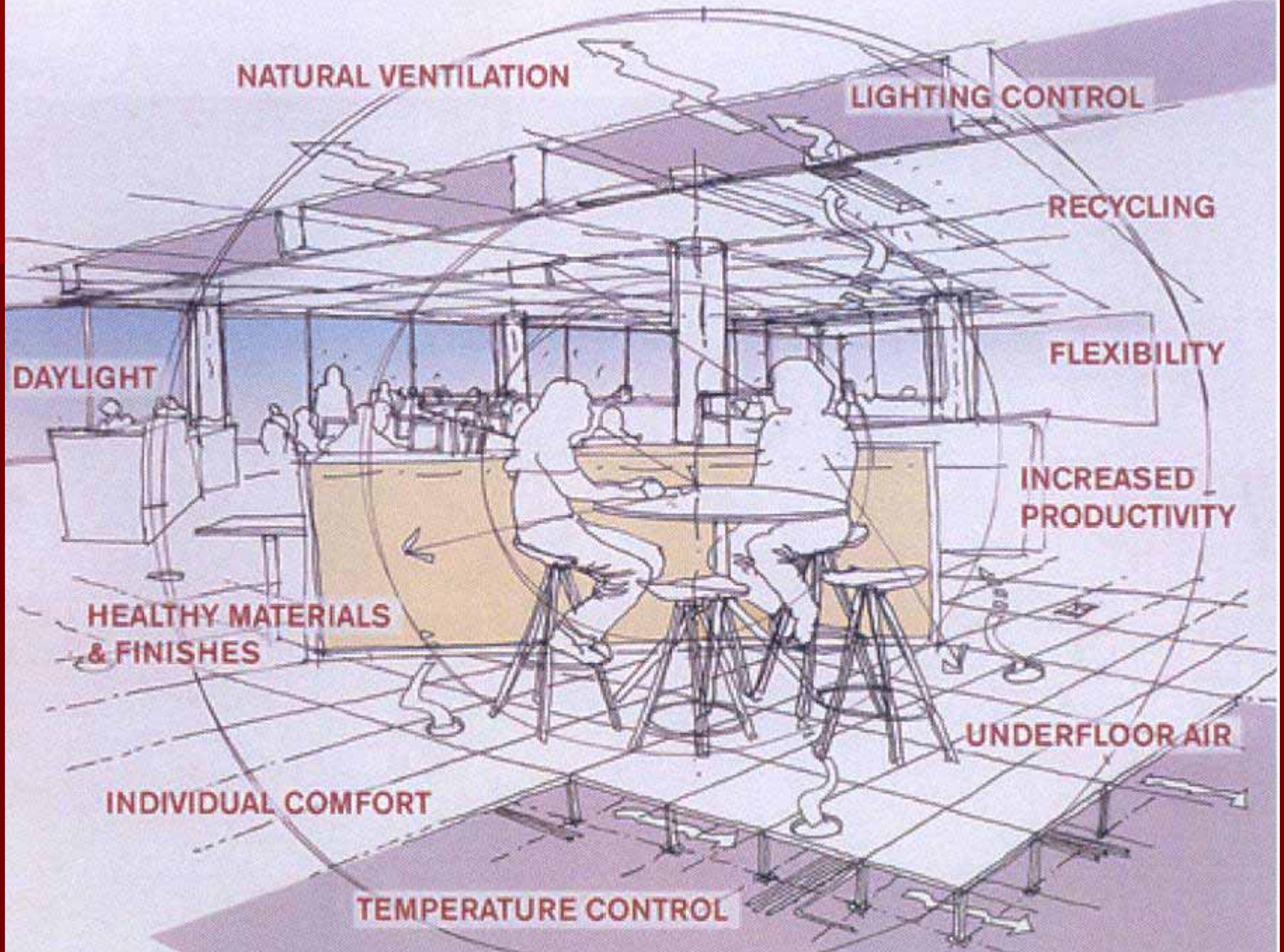


Joyce N, 2004



Key Factors in a Good Working Environment





Life Costs and Value Ratios

Design & Construction (X)

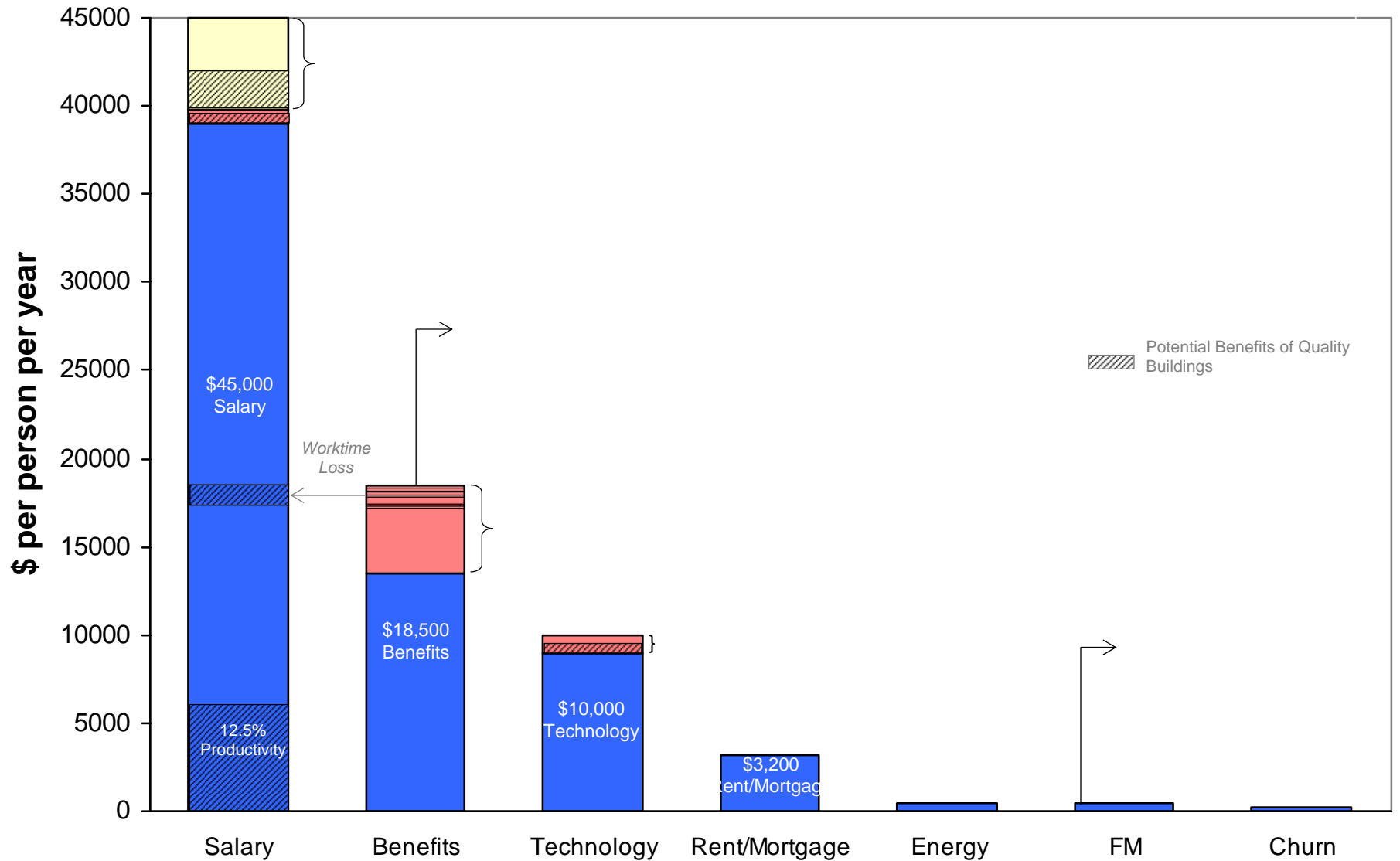
Facilities Management (Y)

Utilisation (Z)

Z >>> Y > X

e.g. 80 : 8 : 1

Improving the Quality of the Built Environment will Reduce the Life Cycle Costs of Business

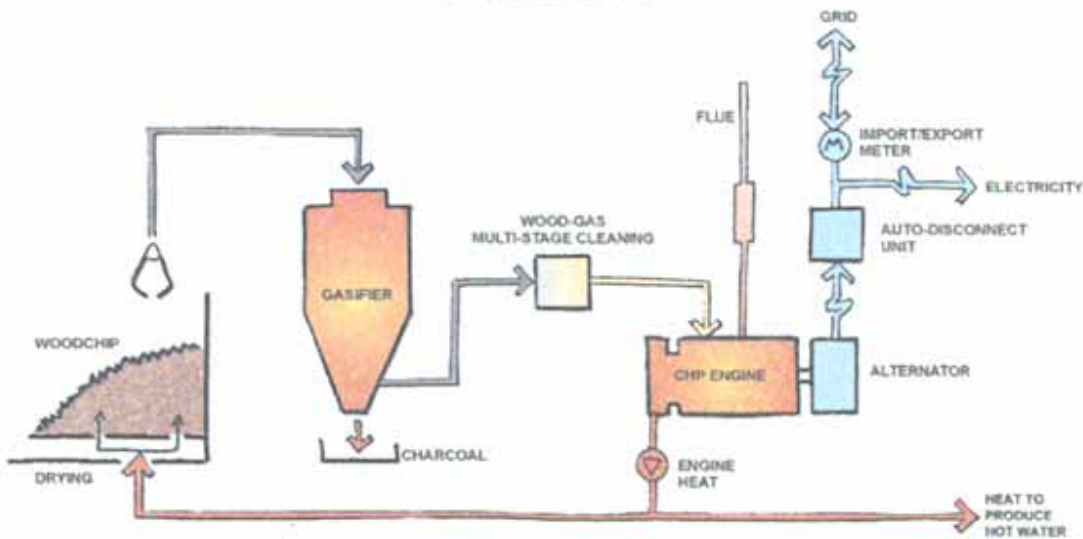


Ideas for Progress

Bedzed Energy Development

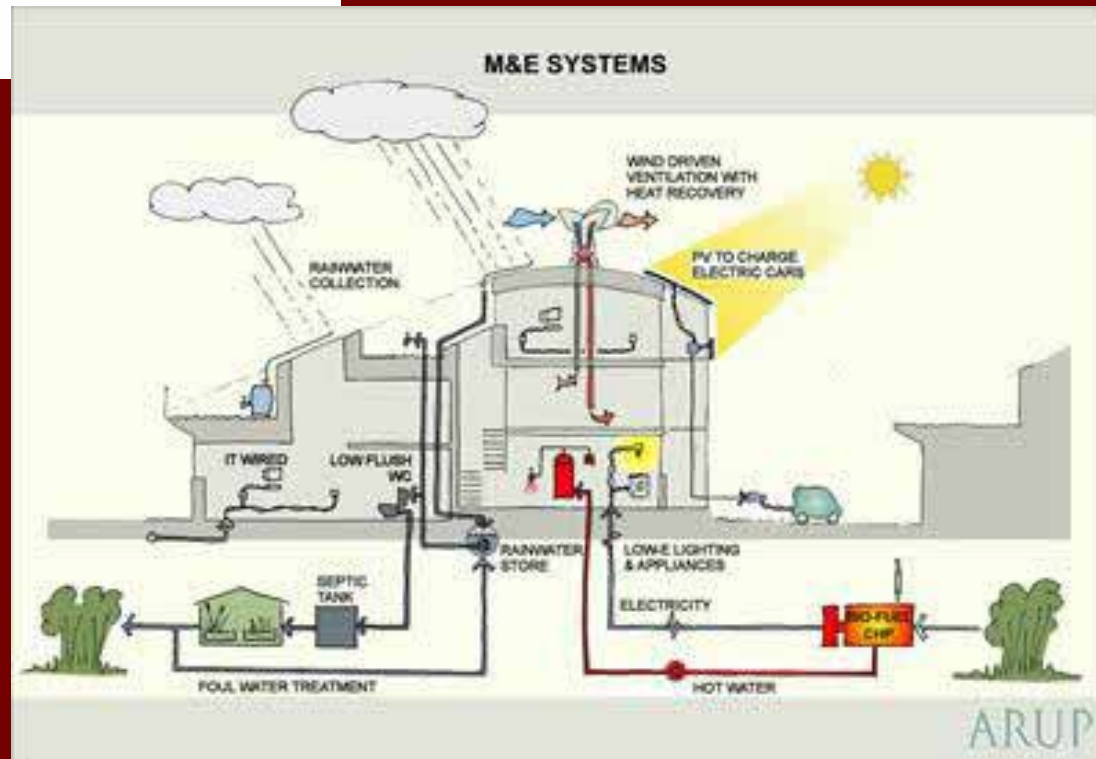


BIO-FUELLED CHP

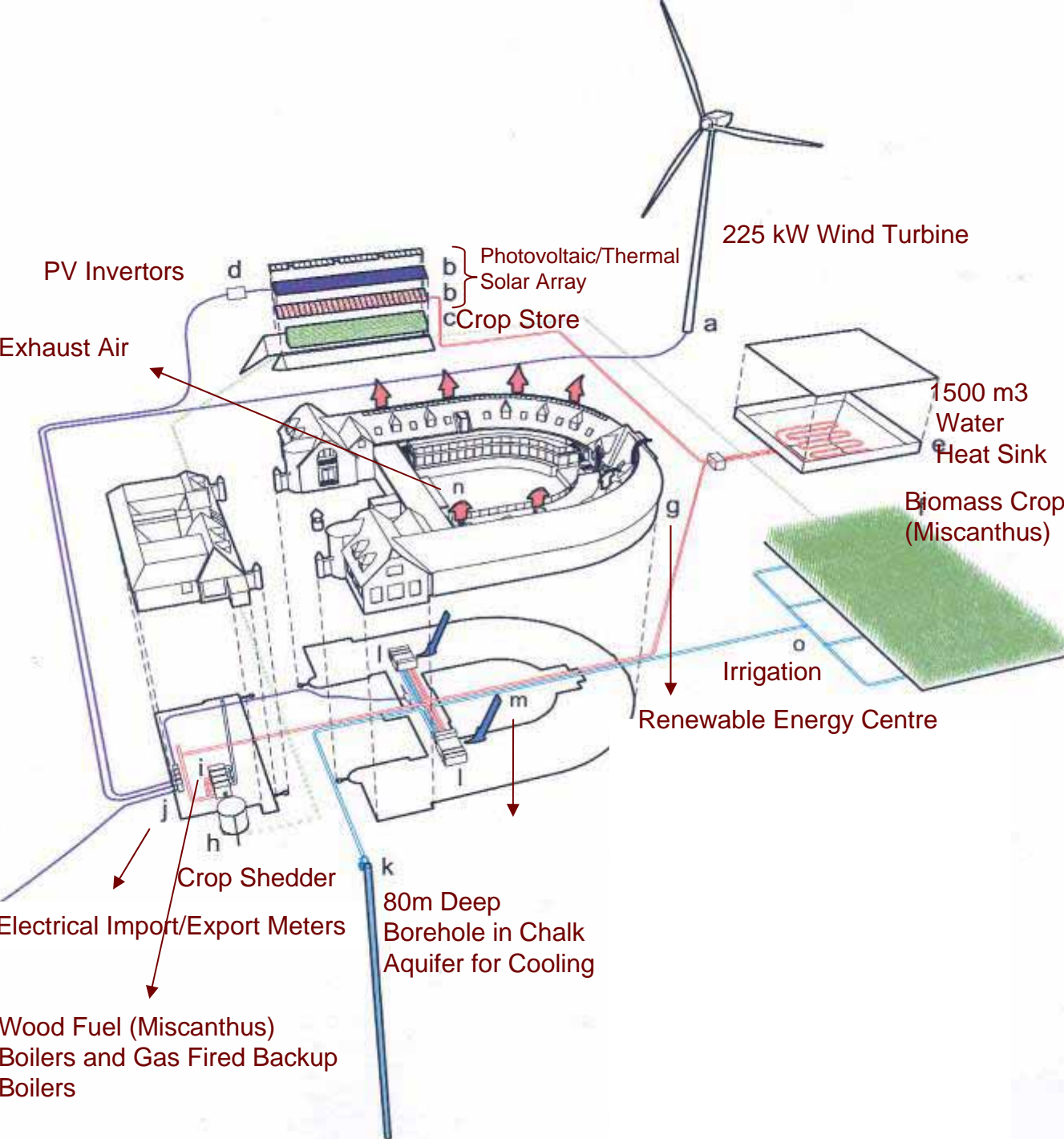


Gasified wood technology provides heat and electricity to the entire site with zero net CO₂ emissions

How the Zed system Works



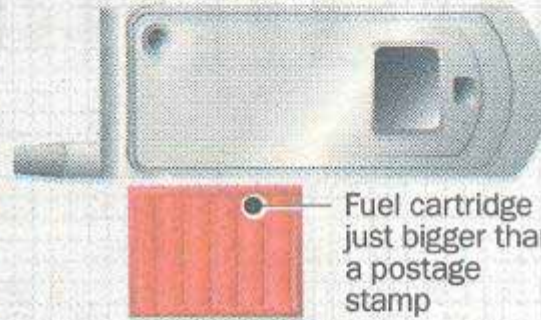
Integrated Renewable Energy at Beaufort Court



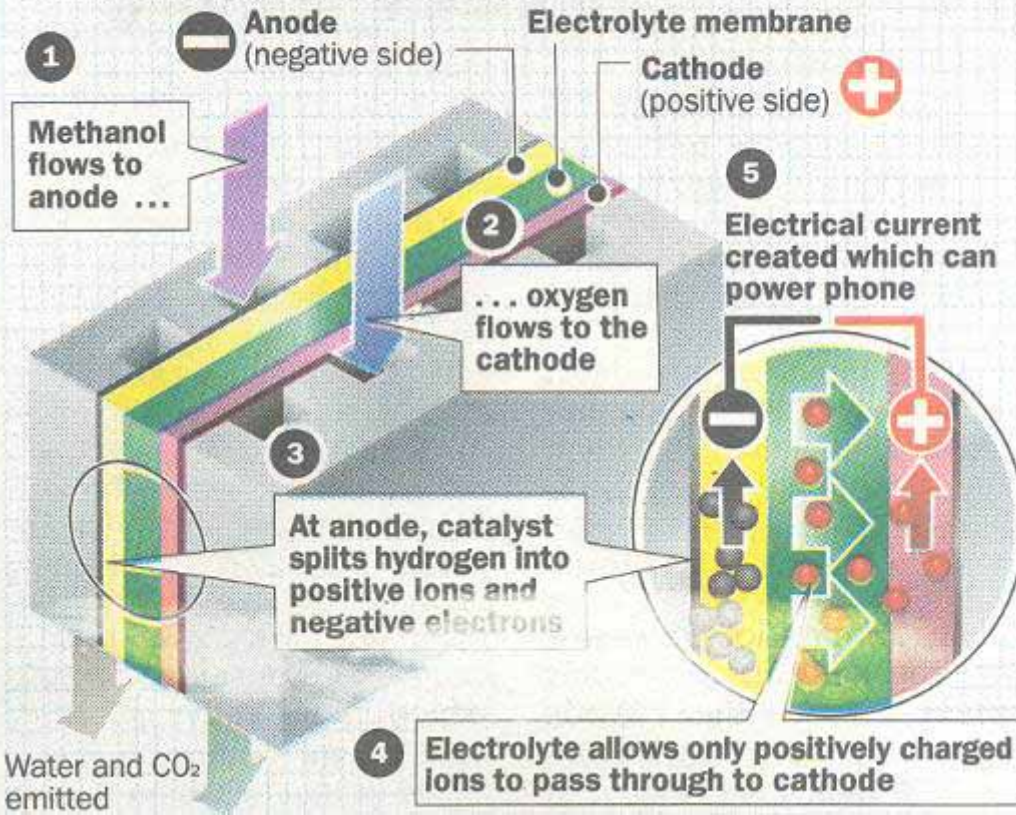


FUEL CELL THAT POWERS A MOBILE PHONE

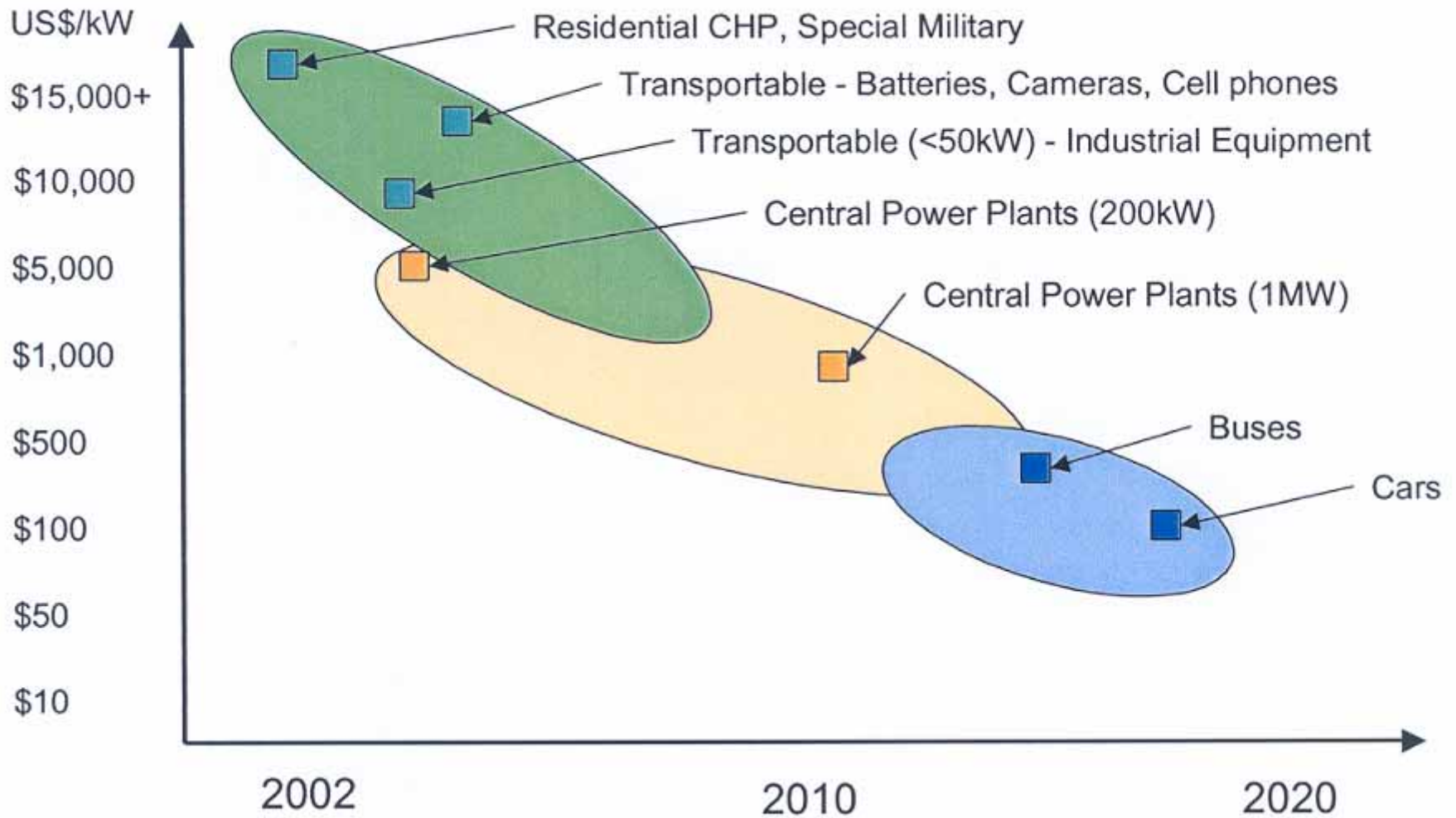
Solid-state methanol (in left-hand bottle) is easy to store and transport



HOW THE CELL WORKS

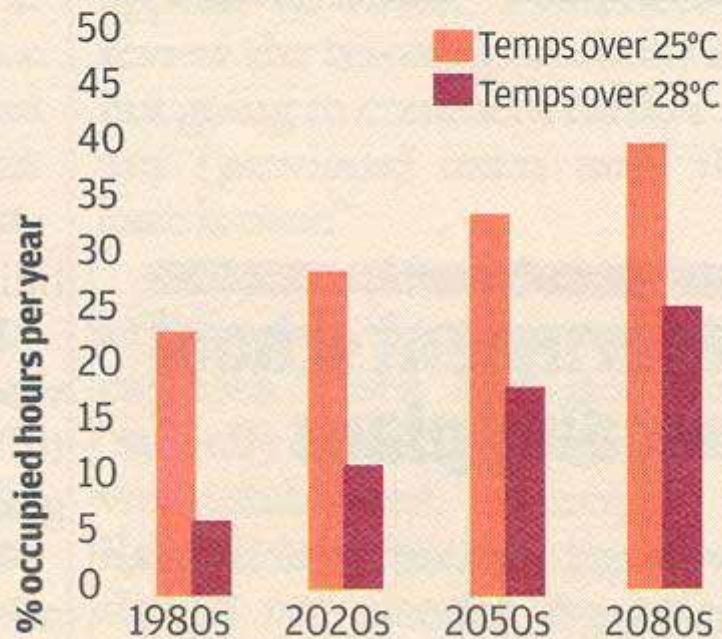


Projected Commercialization of Fuel Cells



How to adapt a 1960s office block to the UK's changing climate?

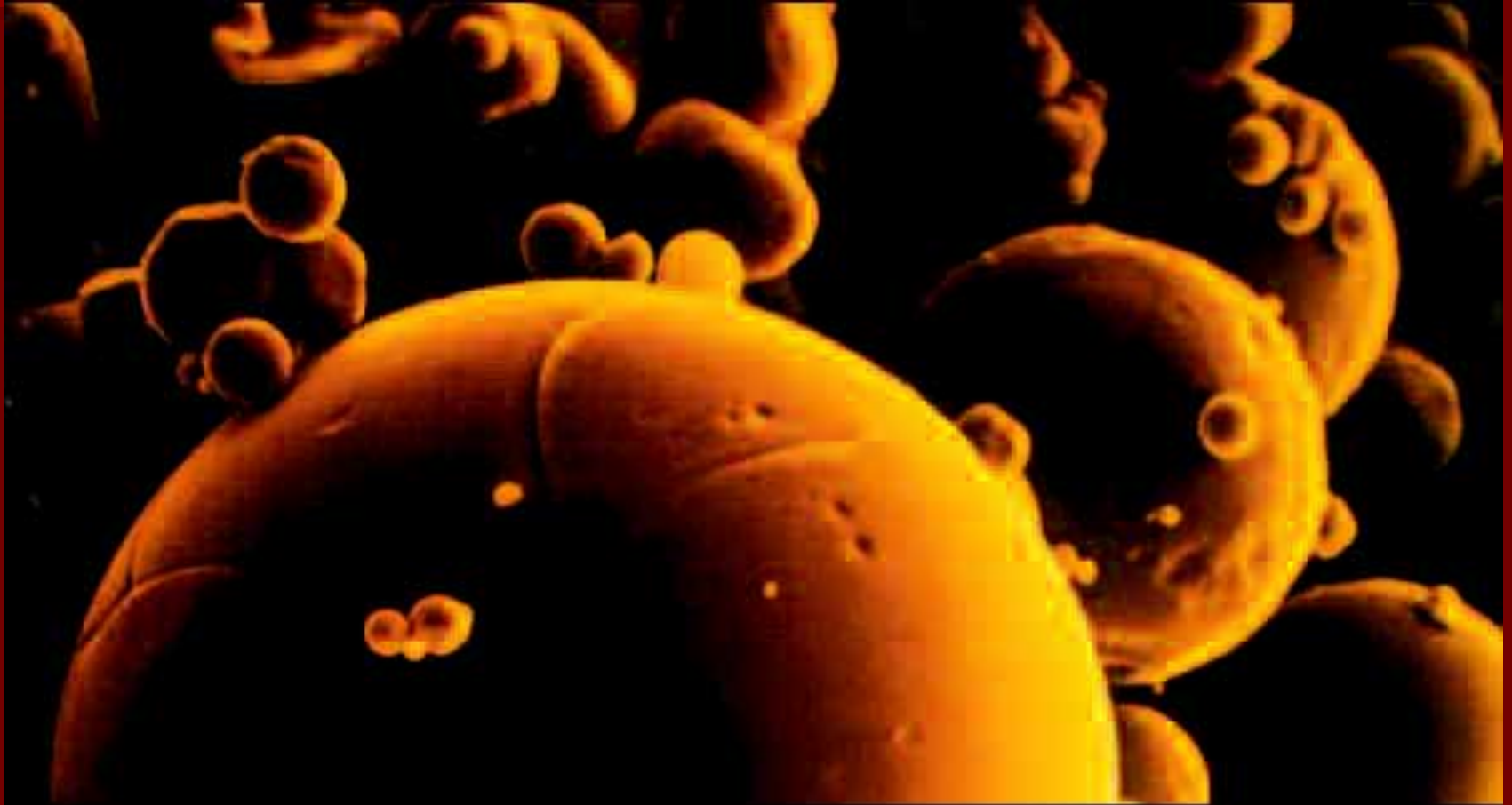
Hours per year building temperatures will exceed the comfort level

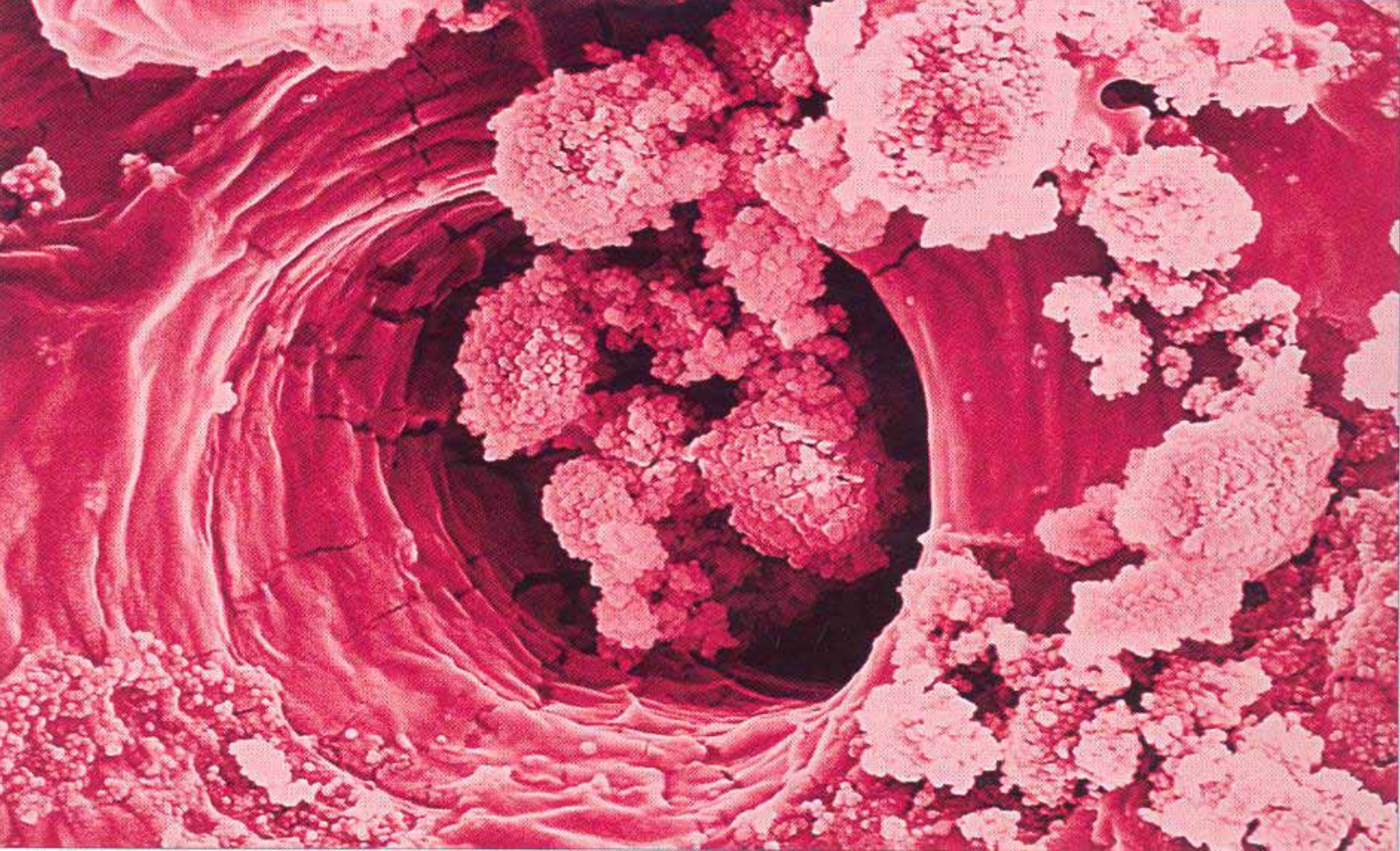


- Use double glazing
- Increase fabric insulation and air tightness
- Use solar shading
- Expose the thermal mass in concrete floor slabs
- Use automatically controllable mechanical ventilation via an underfloor air supply system
- Use nighttime cooling in summer
- Reclaim heat from the exhaust air in winter
- Use water-chilled beams when temperatures go above 25°C

Nanotechnology

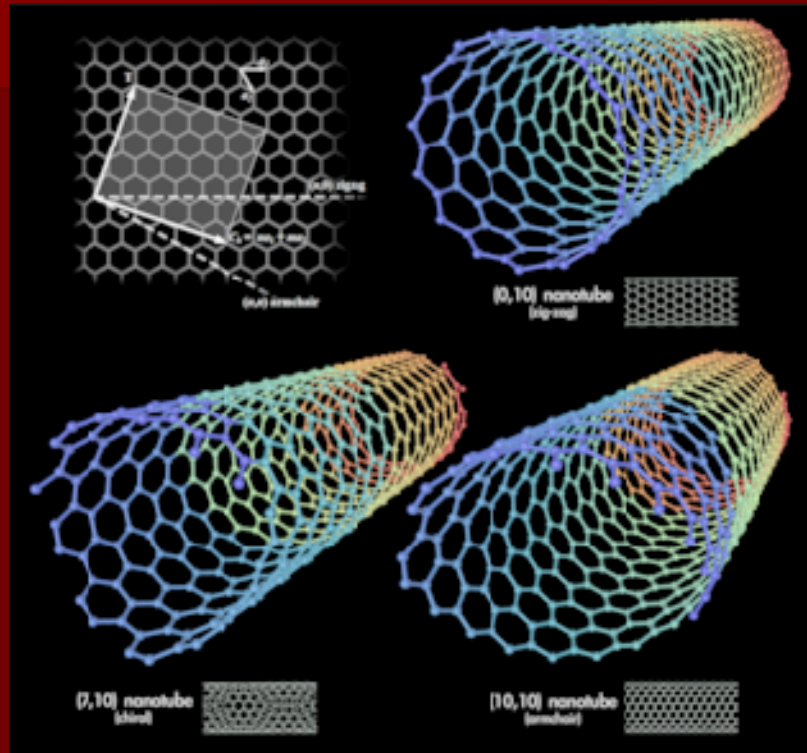
Titanium dioxide nanoparticles with a smooth surface may be used as an anti-adhesive coating for windows or spectacle lenses





Scanning electron micrograph of nanospheres filling one of the tiny holes that cause sensitive teeth (Leeds University)

Carbon Nanotubes



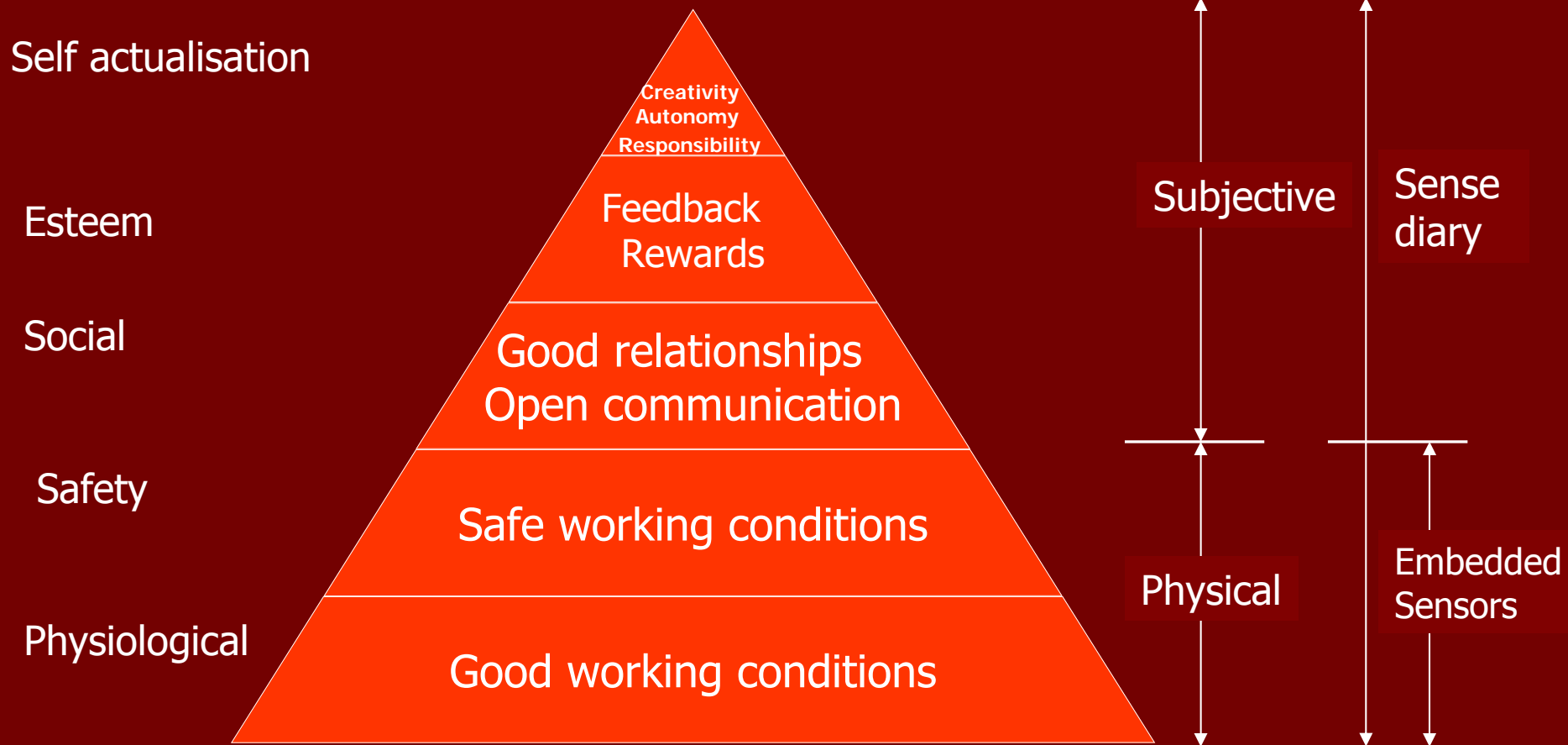
Carbon nanotubes are cylindrical carbon molecules with novel properties that make them potentially useful in a wide variety of applications. They exhibit extraordinary strength and unique electrical properties, and are efficient conductors of heat.

Embedded Sensors in Buildings, Equipment and Clothing

Occupants lifestyle affect energy consumption

Embedded sensors help occupants to save money and society save energy

Maslow's Hierarchy of Needs



Systems Performance and Human Reaction

Building and Environmental Systems

People

Objective Data

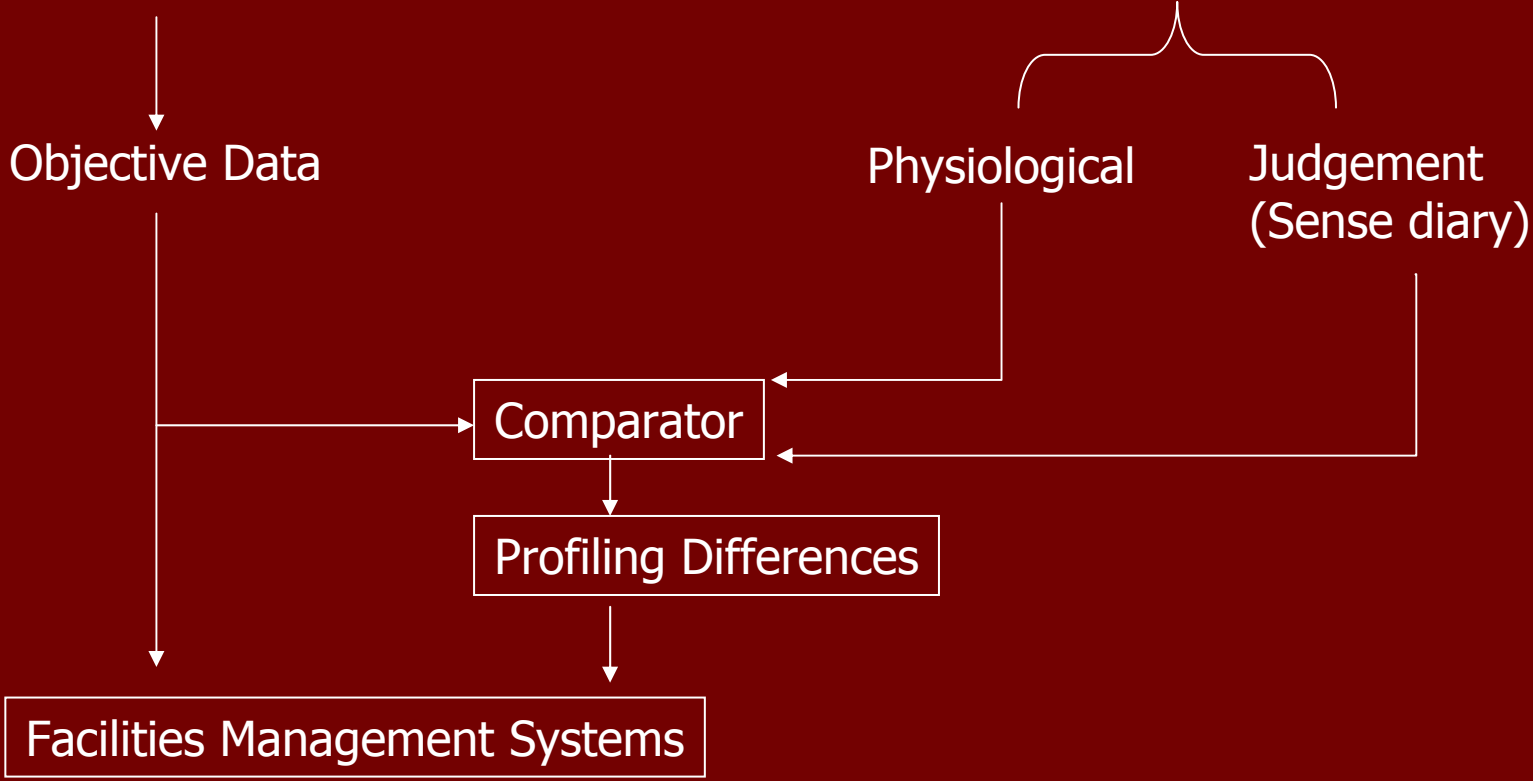
Physiological

Judgement
(Sense diary)

Comparator

Profiling Differences

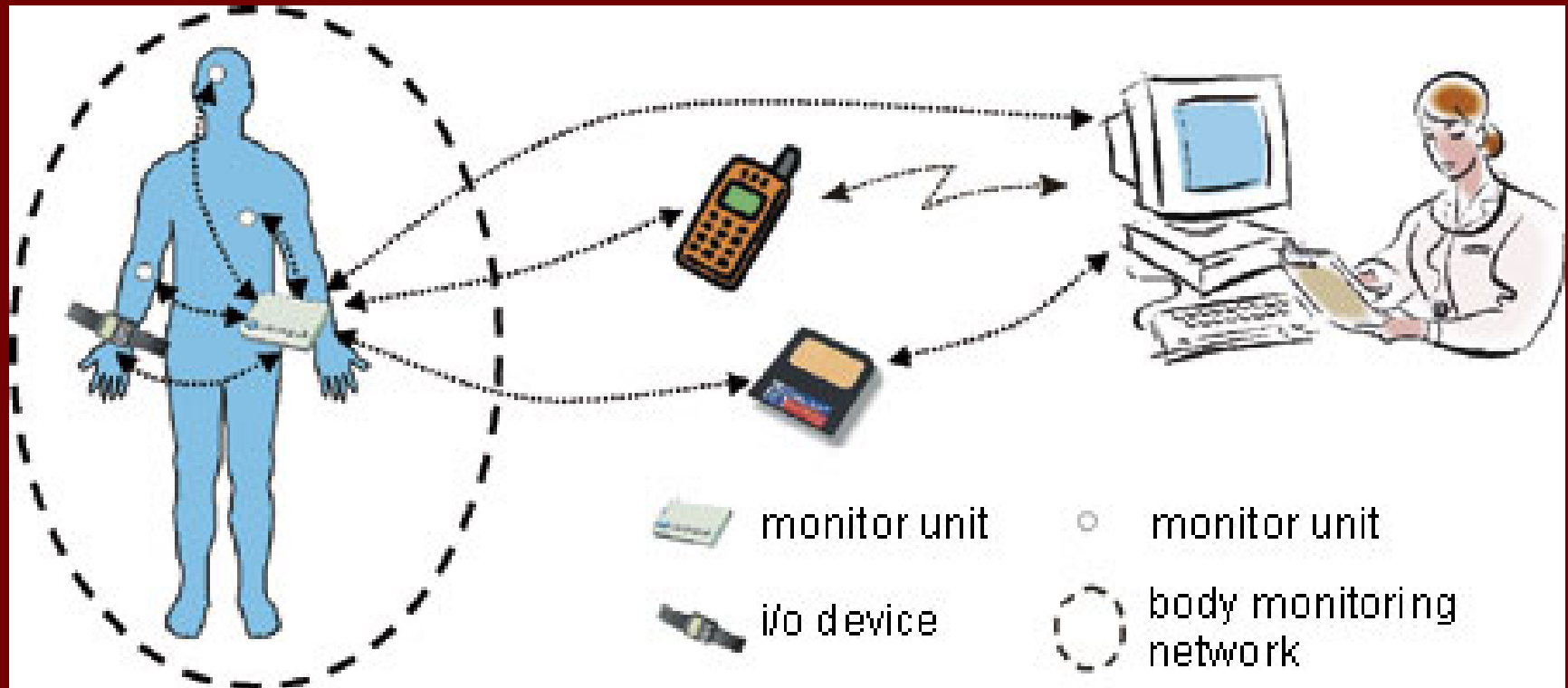
Facilities Management Systems



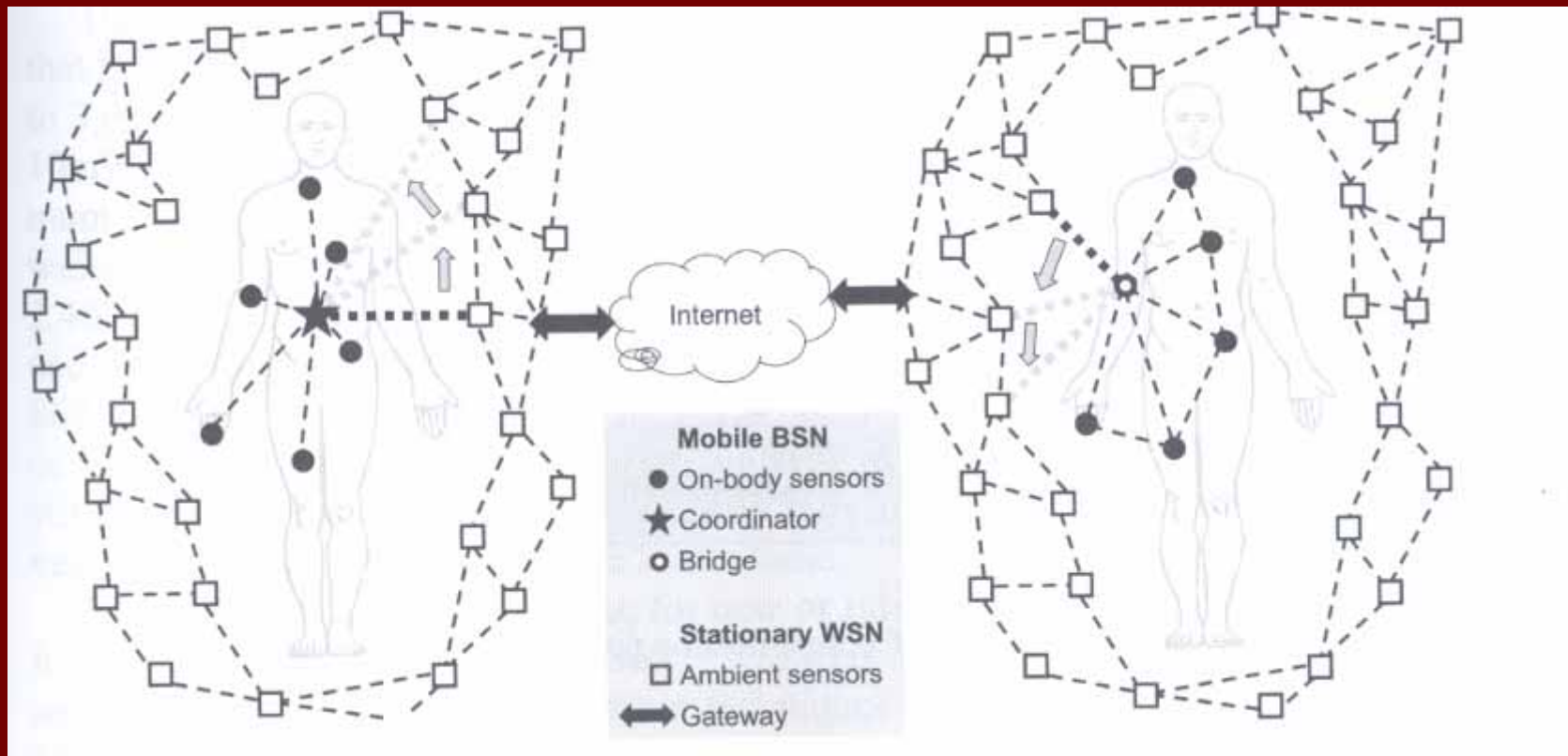


BSN architecture with wirelessly linked context-aware “on body” (external) sensors and integration with home, working, and hospital environments.

Body Sensor Network Connected to Hospital Network



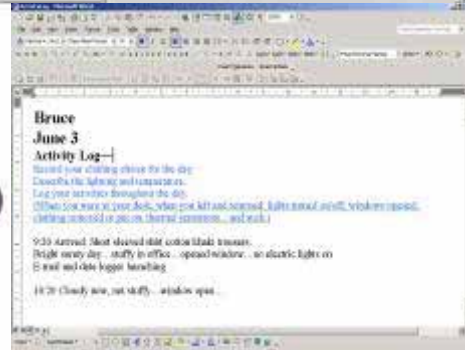
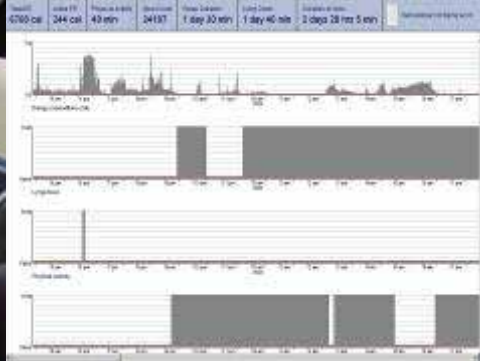
Mobile Body Sensor Network Connected to Ambient Sensor Network



Design

Data Sources:

1. Data Loggers (measure environmental conditions and equipment status)
2. Body Media Sensors (measure physiological status of people)
3. Activity Logs (record of interactions with environmental controls and workstations)
4. People Counter (count people entering and leaving the space)



Sensing physiological response may provide a link between physical and emotional data

Body Media software allows you to examine a wide variety of measured and derived data. Data can be exported in Excel format.

Accelerometer: 2-axis micro-electro-mechanical sensor (MEMS) device that measures motion.

The **heat flux sensor** in the armband measures the amount of heat being dissipated by the body.

Skin temperature is measured using a thermistor-based sensor located on the backside of the armband near its edges and in contact with the skin.

The **near-body ambient temperature** sensor is thermistor-based and directly reflects the change in environmental conditions around the armband; for example, walking out of an air-conditioned building on a hot day.

Galvanic skin response (GSR) represents electrical conductivity between two points on the wearer's arm. Skin conductivity is affected by the sweat and emotional stimuli. GSR can also be an indicator of evaporative heat loss.



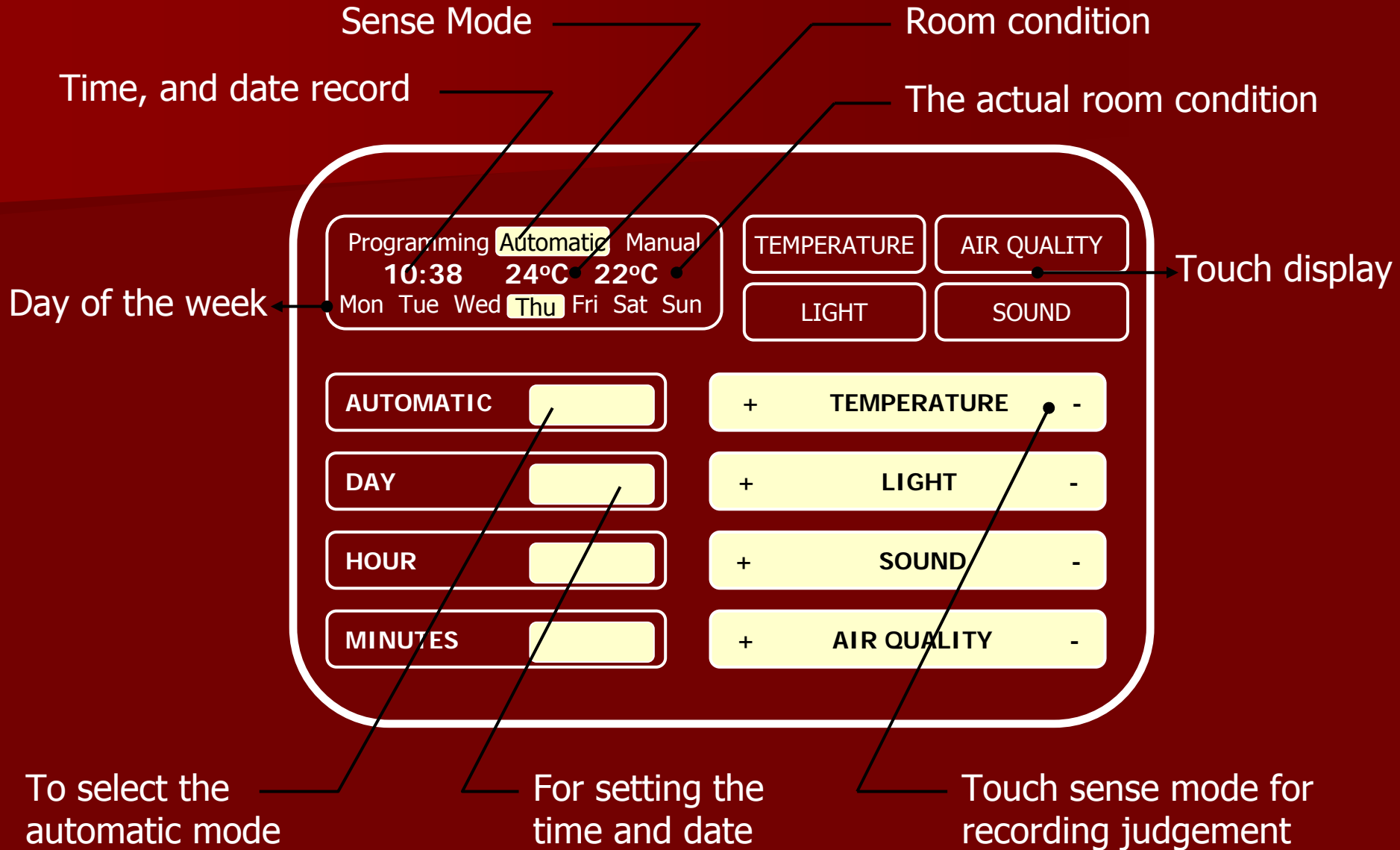
- Accelerometer
- Heartbeat receiver
- Heat flux sensor
- Near body ambient temp (on side)
- GSR sensor
- Skin temp sensor



Objectives

- To identify the behaviour patterns associated with the use of the building fabric
- To establish a relationship between the behaviour patterns and the consumption of energy
- To develop an intelligent sensor system

Evaluation of Environmental Conditions by Occupants



Sense Diary

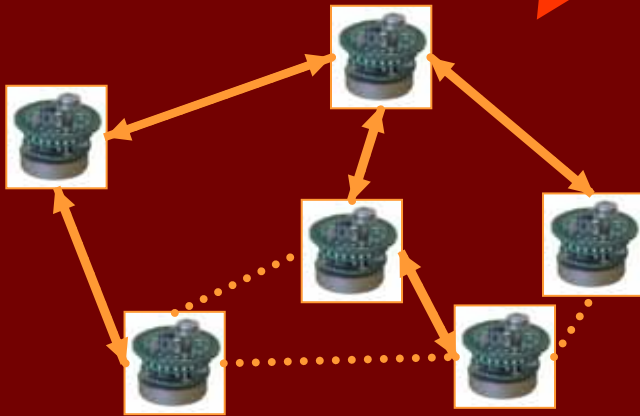
Goal



Sense Diary

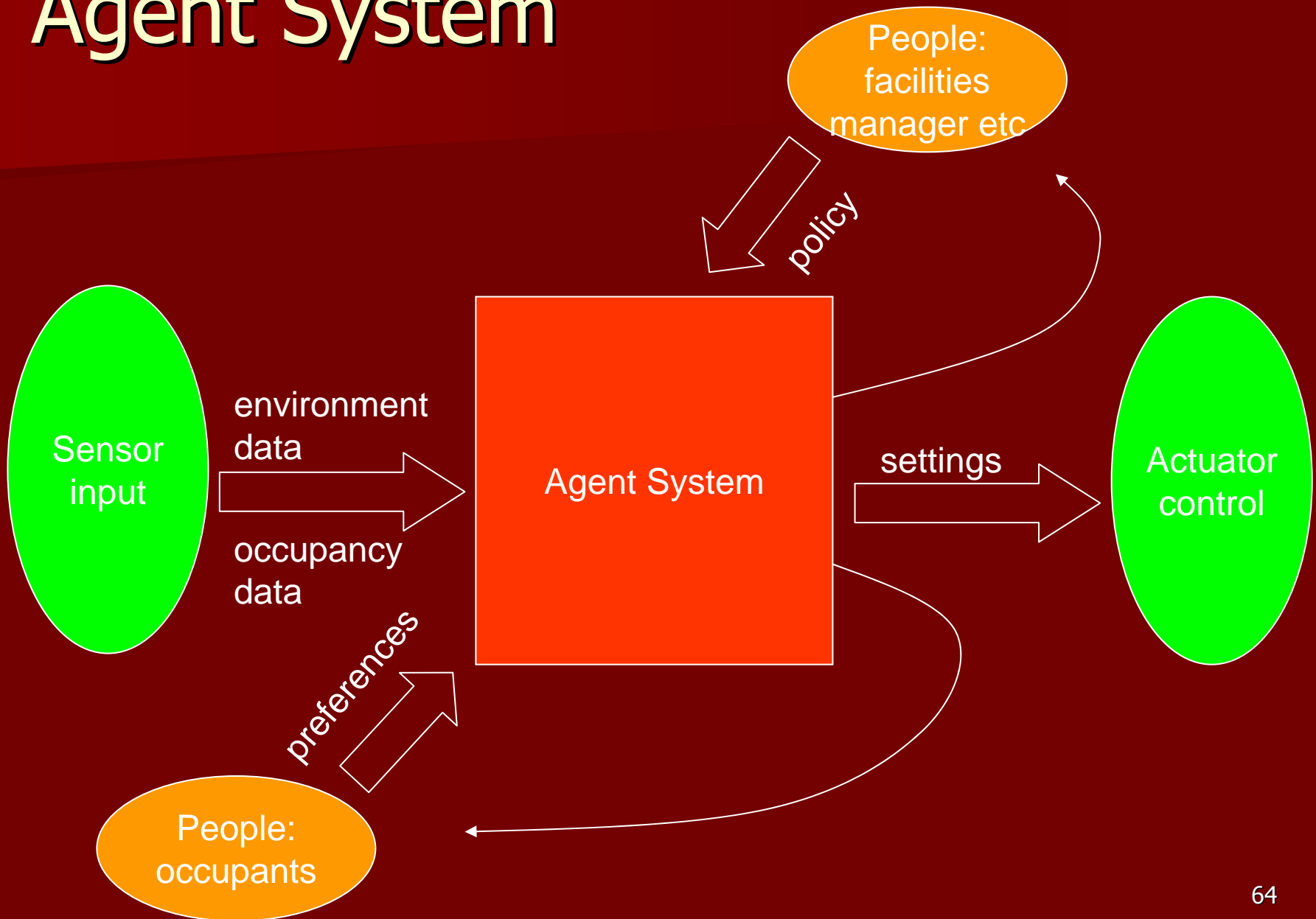


HVAC, power meters



Sensor Network

Agent System



Intelligent Homes



powered controls
for curtains and
blinds

built-in soft controls
within interior
surfaces

soft remote controls
for technology

soft controls for
powered chairs

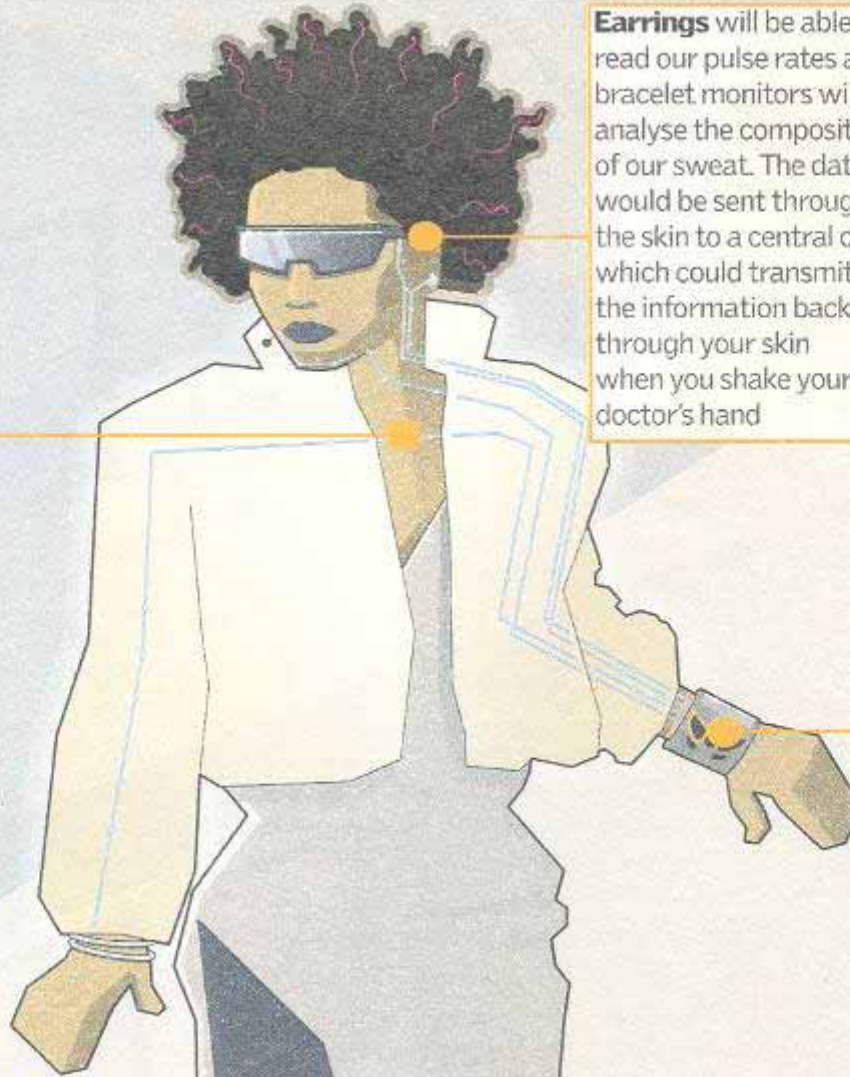
heated carpets

CLOTHING IN 2020?

- Embedded computing within textiles
- Clothes that read-out body processes
- Clothes that 'talk'
- The end of washing and ironing?

LIVING IN THE WIRELESS WORLD

Skin has conductive properties that will be used to link a host of electronic devices around the body, from pagers and personal data assistants to mobile phones and microphones



Earrings will be able to read our pulse rates and bracelet monitors will analyse the composition of our sweat. The data would be sent through the skin to a central chip, which could transmit the information back through your skin when you shake your doctor's hand

Gadget lovers will carry a single keypad, which could control your phone, PDA and MP3 music player, or combine the output of your watch, pager and radio in one speaker

Guardian 18.9.2004

Smart sneakers



Adidas has teamed up with Vectrasense, a tech company attached to the Massachusetts Institute of Technology, to develop the world's first **intelligent trainers**. The trainer uses an electronics system developed by Motorola to sense the wearer's activity level and automatically inflate and deflate air Bladders to support and cushion feet accordingly. A small in-shoe computer controls a battery-operated sensor that decides whether the cushioning is too soft or firm. A motor-driven cable system makes the adjustments to adapt the shoe to the runner's style and to the conditions, for instance adapting between running on grass and on concrete.

Using Electrical Energy of Human Body

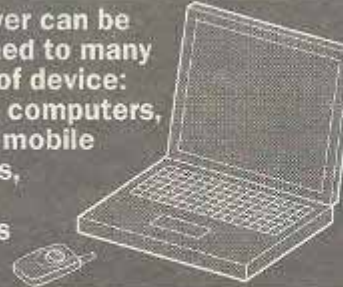
HOW RED TACTON WORKS

Red Tacton uses the human body as a path for the electrical signals which let computerised equipment communicate



Transmitter worn on the body uses the body's electrical field to transmit digital messages

Receiver can be attached to many types of device: laptop computers, PDAs, mobile phones, mpeg players

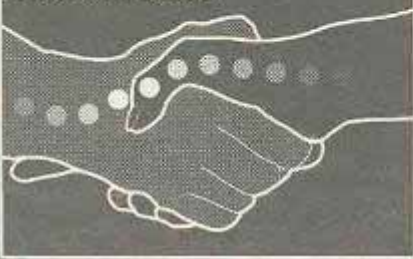


Optical crystal and laser technology converts the changes in electric field back into a signal



HOW IT COULD CHANGE OUR LIVES

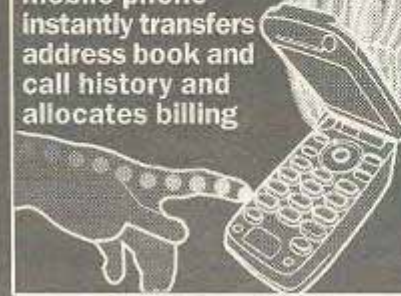
In the simple act of shaking hands, two people (or more) can exchange electronic business cards



As the handle of door is touched, Tacton security systems recognise user and allow access if permitted



Touching a Tacton mobile phone instantly transfers address book and call history and allocates billing



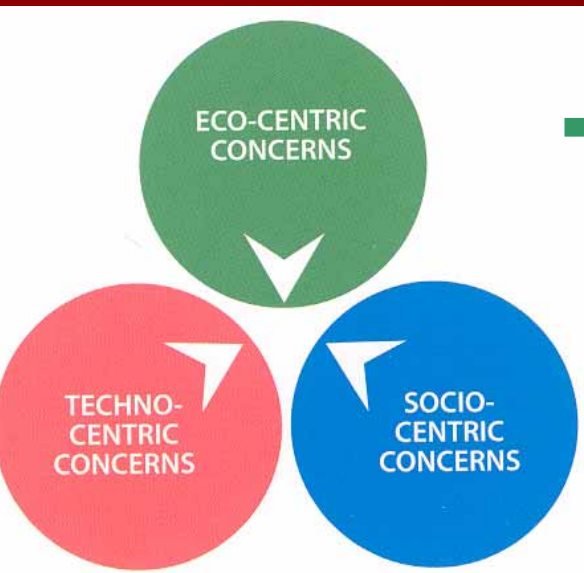
Print from a digital camera by holding it and touching a printer



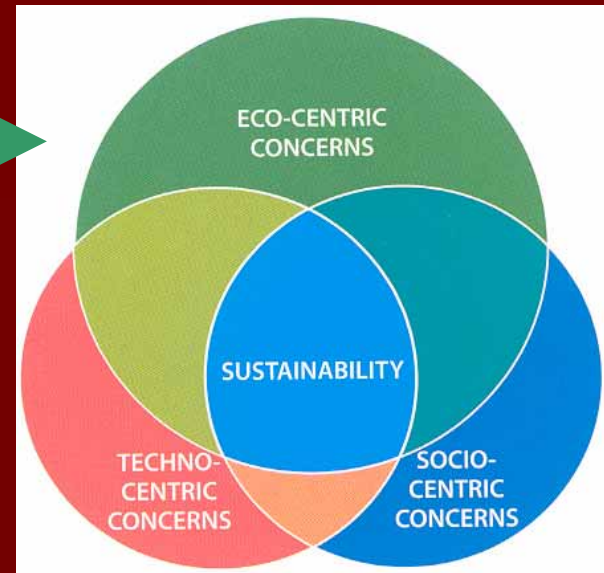
Meeting the Challenges

- Processes, Products (Systems), People Integration
- Whole Life Value
- Cross-Sectoral Learning
- Design for Sustainable Healthy Environments
- Consider Environmental, Economic and Social Values
- Use Innovation as an Enabler
- Use of Embedded Sensor Technology
- Building Services Engineers become Architect-Engineers

DELIVERING SUSTAINABILITY



- Keep all energy options open
- Ensure the necessary investment in energy infrastructure
- Adopt a pragmatic approach to market reform
- Place priority on the measures needed to ensure reliability of supply
- Promote regional integration of energy supply systems
- Exploit the "win-win" opportunities of emerging climate change responses
- Ensure technical innovation
- Foster and sustain public understanding and trust



**INTELLIGENT
HEALTHY
SUSTAINABLE
BUILDINGS**



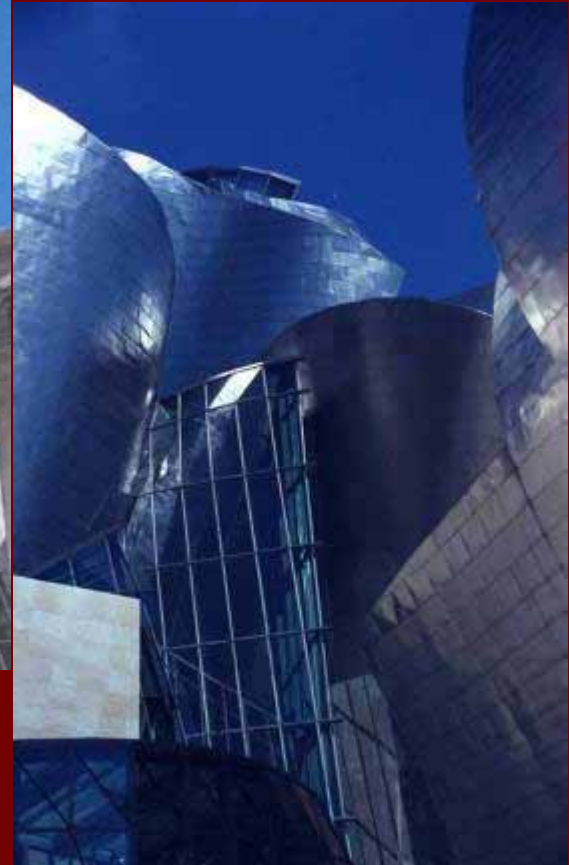
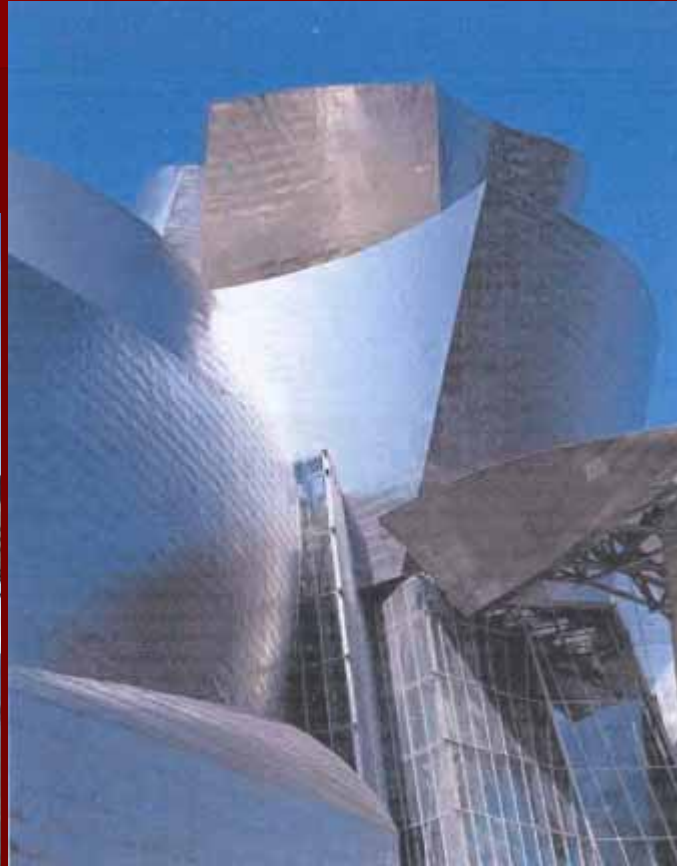
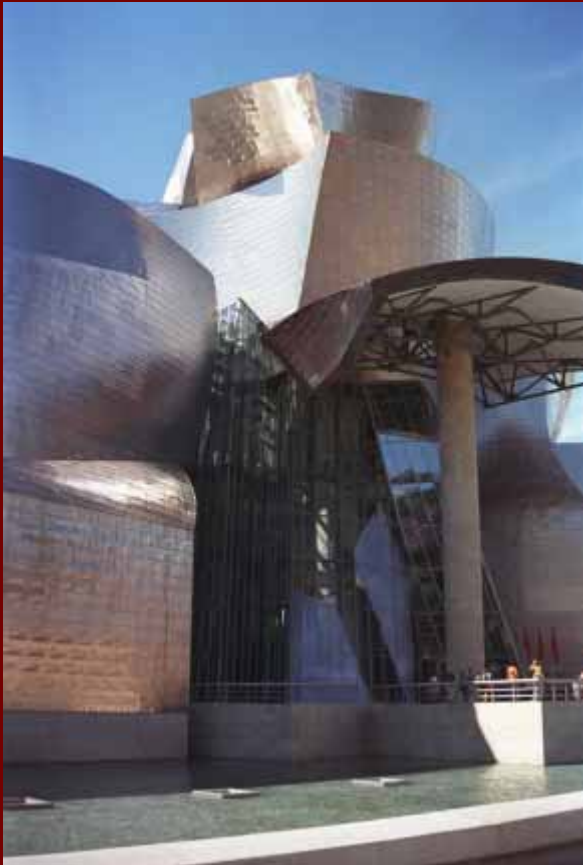
Swiss Ré Headquarters London



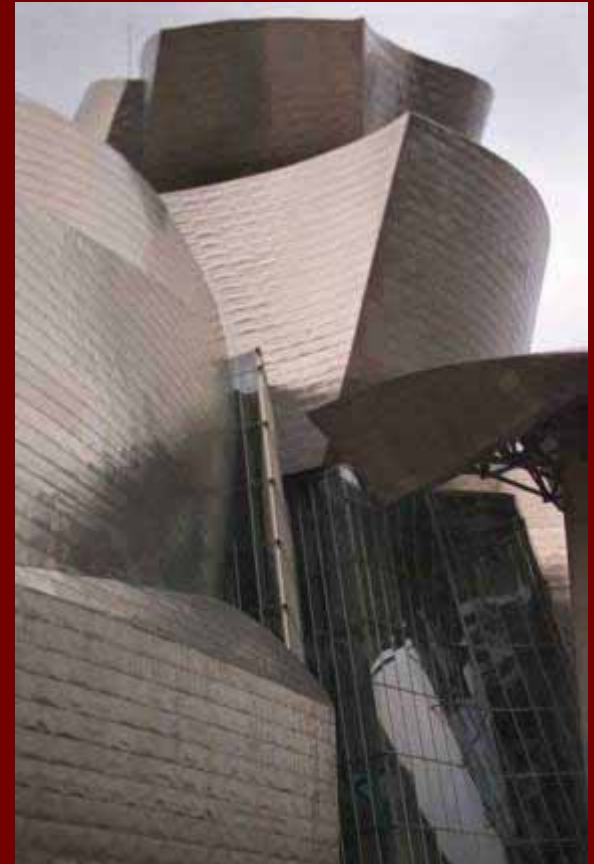
Frank Gehry Walt Disney Concert Hall LA



Frank Gehry Guggenheim Museum Bilbao



GUGGENHEIM MUSEUM BILBAO



Hong Kong



Europe

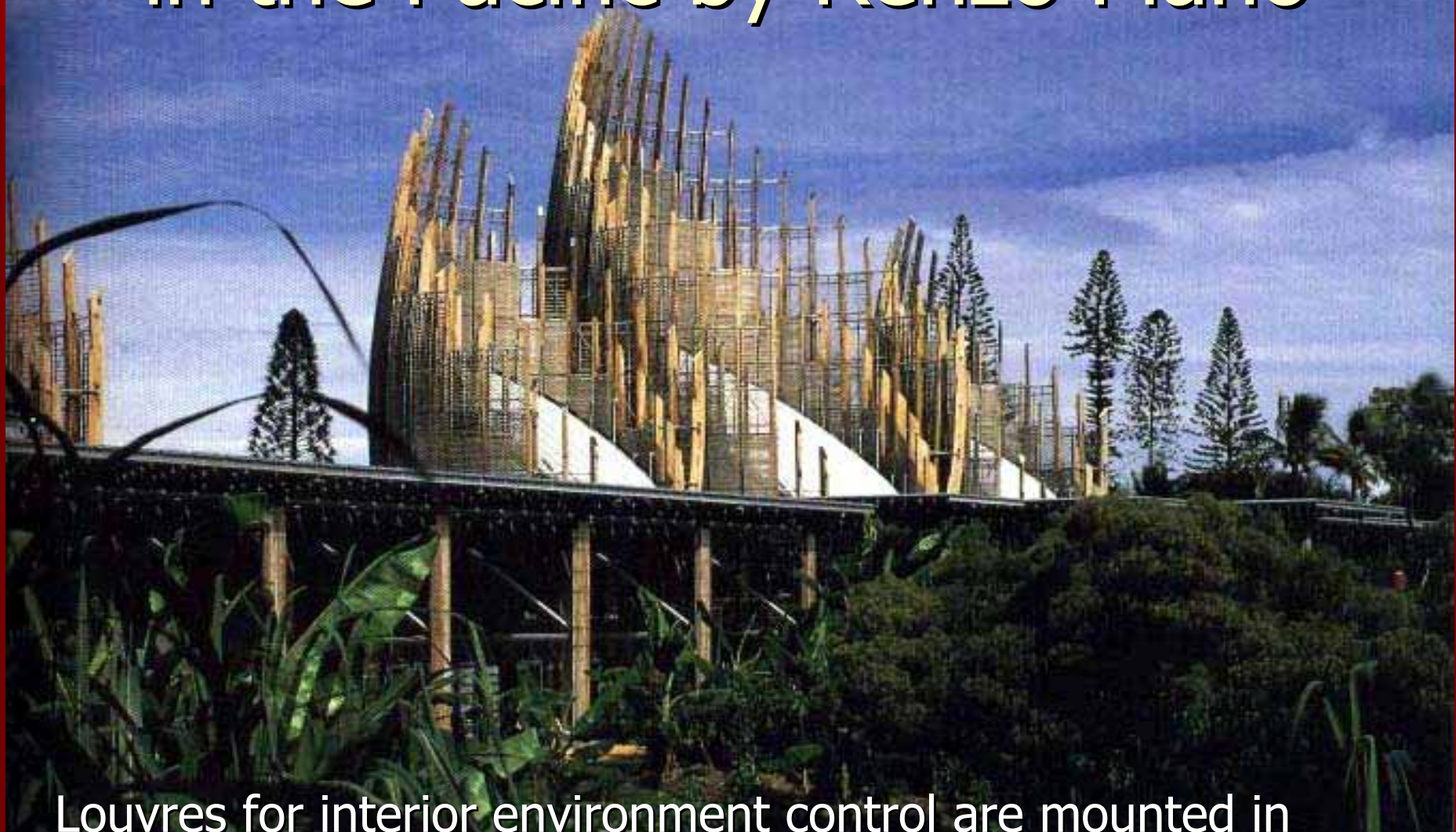


China/ Singapore



U
S
A

Cultural Centre in New Caledonia in the Pacific by Renzo Piano



Louvres for interior environment control are mounted in the glass facade of the low-rise volume.



Urban Form and Sustainability

Urban forms (e.g. urban villages, urban renaissance & regeneration, intensification, compact city etc.) **are claimed to be:**

- spatially sustainable
- environmentally sound
- efficient for transport
- socially beneficial
- economically viable



Making a Difference

Reusing urban land



Reclaiming the streets



Shift to public transport,
cycling & walking



Participation




Social vitality



Human scale development

Economic viability



China is to build the world's first eco city

– and it's designed in Britain

Dongtan's main features

- **Ecological Management**
(wetlands/ Wildlife) - only 30% will be built
- **Sustainability**- Self supporting food, energy from renewables,
- **Energy** –wind turbines, bio cells recycling organic materials
- **Recycling** – NO landfill of waste, human sewage will be processed
- **Buildings** –Labour will be sourced locally, good public transport, green roofs, compacts city
- **Transport** –cycle paths, pedestrian routes –solar powered water taxis

"Good design may initially cost a little more in time and thought, although not necessarily in money. But the end result is more pleasing to the eye and more efficient, costs less to maintain and is kinder to the environment."