LOW INCOME HOUSING IN HOT CLIMATES: REDUCING ENERGY USE AND CLIMATE EMISSIONS

STATE OF THE ART AND NEW DIRECTIONS

The University of Warwick

Chris Butters, Warwick University, UK
Kampala, 27-28.2016

1. **THREE UNDERLYING QUESTIONS**
2. **SUSTAINABLE DESIGN - STATE OF THE ART**
3. **FIVE EMERGING AREAS**
4. **DYNAMICS OF CHANGE**
5. **CONCLUDING REMARKS**

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1. THREE FUNDAMENTAL QUESTIONS UNDERLYING THIS RESEARCH PROGRAM:

- 1a. DEFINING LOW INCOME / POVERTY
- 1b. ABSOLUTE REDUCTIONS OR AVOIDED IMPACTS
- 1c. DEFINING COMFORT / STANDARDS

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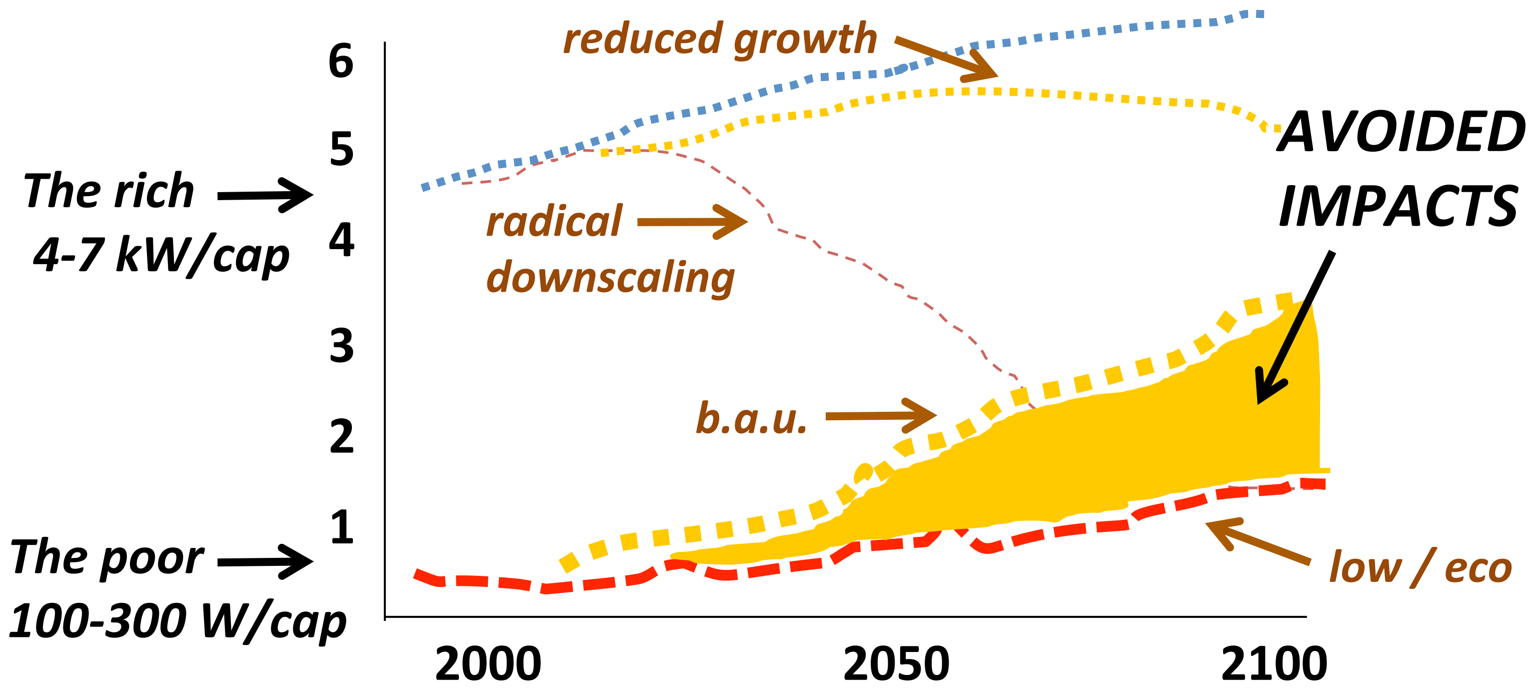
1a. DEFINING POVERTY - ?

GNP or GNH ?

1b. ABSOLUTE REDUCTIONS VERSUS AVOIDED IMPACTS

In order to improve life quality, the poorest must have access to and consume MORE energy and resources.
But by using the best, lowest impact solutions, their development impact could be limited to 1-2 kW/cap (low / eco) instead of growing (b.a.u.) towards present western levels of 4-7 kW/cap.1b.



1b. ABSOLUTE REDUCTIONS OR AVOIDED IMPACTS ?

Improved low cost, low environmental impact housing solutions :

-will *increase* land use (more space per person) (but e.g. double storey may help)

-can *possibly* enhance biodiversity (given green site planning)

-will *increase* energy and climate impacts (more amenities) (unless all renewable)

-will generally *increase* costs at the lowest levels (more space and amenities)

-will *improve* health and wellbeing at all levels

-at slightly higher income levels, they *may* reduce energy use and climate impacts whilst not increasing costs

The key for our program is therefore *avoided impacts* compared to a "normal" development and growth trends. The poorest need *more* resources; *absolute* reductions are relevant mainly in developed economies.

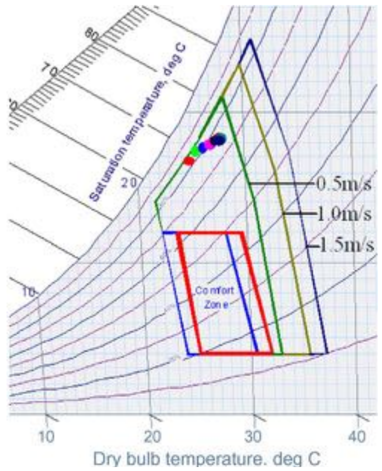
1c. DEFINING COMFORT : STANDARDS FOR LOW INCOME?

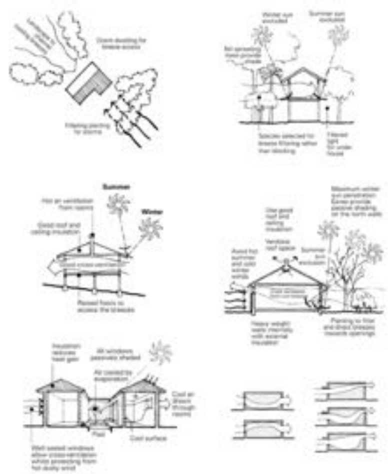
Our main focus is indoor environment, but outdoor urban environment is also a major factor in health and comfort.

It is recognised that there are no absolute or universal norms for comfort. *Adaptive comfort* is important. Non-automated, user controlled systems can lead to satisfaction with lower energy use.

High requirements such as WHO norms are expensive and unlikely to be provided for the lowest income groups. To have a realistic chance of being applied, what *very low cost* solutions are available? Solutions for the poor could be seen in *relative* terms of "major improvements" to current living conditions, rather than aiming for *absolute* levels. '

Are slightly lower IAQ and comfort standards acceptable for the poorest sectors, and if so, how to define this?





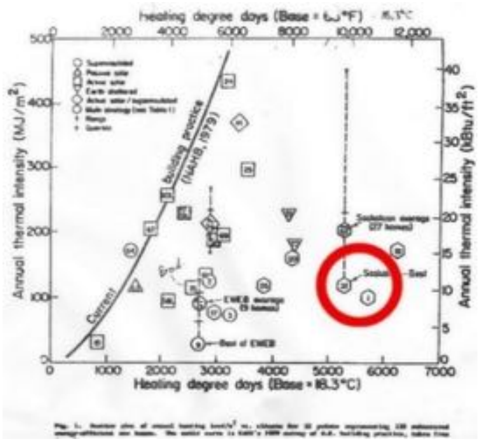
2. SUSTAINABLE DESIGN: STATE OF THE ART

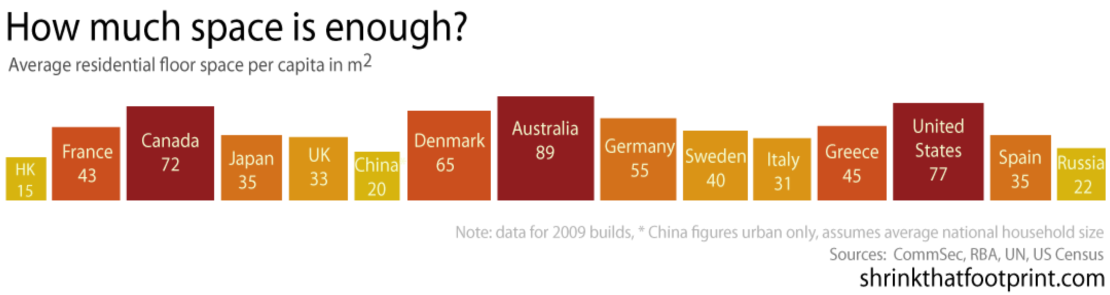
From the 1970s until today

The first zero energy house, Denmark, 1974

The first passivhaus level houses, Canada, 1979

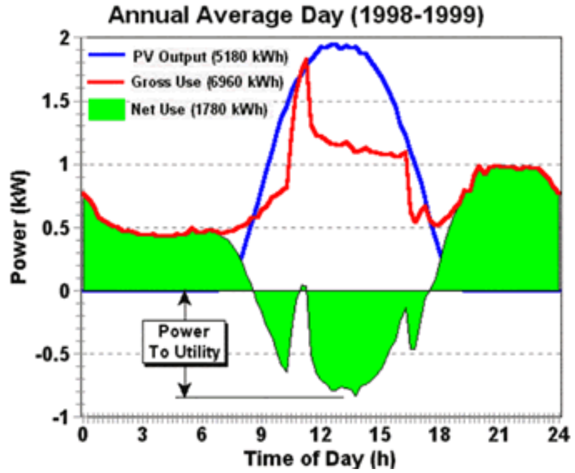
Plus energy houses, Freiburg Germany 2004 www.rolfdisch.de





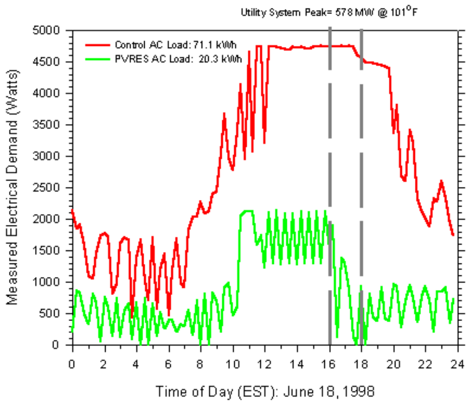
EXAMPLES OF SUSTAINABLE DESIGN IN HOT CLIMATES: 1. FLORIDA

Main focus: building envelope and services technology
Adding photovoltaics to reduce the energy/carbon impact.
Only a few «passive» features
No attention is paid to embodied energy/carbon.



ZEB (zero energy) house, Florida, USA.

Energy reductions over 70% + 20% supplied from PV
Typical technological focus, high-tech materials
Wasteful space use. Reflective roof, big roof overhangs.
Embodied energy/carbon is NOT addressed at all

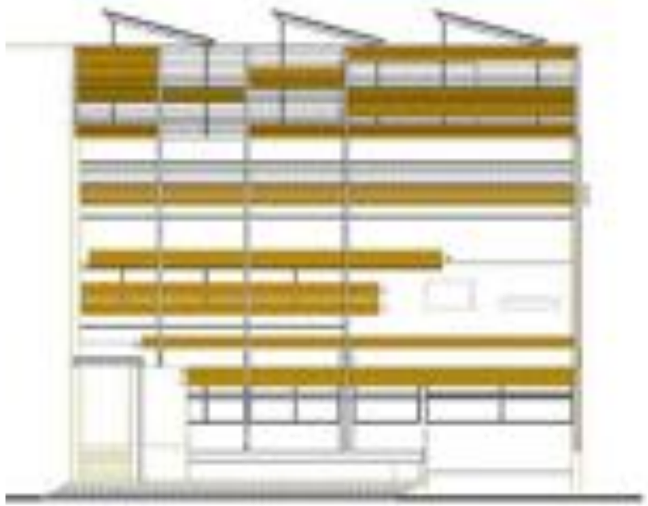


Isocyanurate …NOT low energy or healthy materials!

Source: http://www.fsec.ucf.edu/en/publications/html/FSEC-CR-1044-98/pvres4.htm

EXAMPLES OF SUSTAINABLE DESIGN IN HOT CLIMATES: 2. SRI LANKA

Main focus: building envelope and services technology
Adding photovoltaics to reduce the energy/carbon impact.
Only a few «passive» features
No attention is paid to embodied energy/carbon.



Nikini building, Sri Lanka

Annual energy use: 89 kWh/m2, of which 60 PV
Embodied energy/carbon is NOT addressed
Roof mounted PVs are added on, NOT integrated
A range of technological features (see below)
Rainwater harvesting and daylighting also
http://www.mrt.ac.lk/archi/staff_upra.html

Shading to minimise incidence of solar radiation
Cantilevered floor plates for shading on windows
Automated solar sensitive double skin envelope
Envelope dependant day lighting potential
High thermal mass for walls and ceilings
Motion sensitive active and task lighting system
VAV air conditioning systems
Building energy management system

3. FIVE CUTTING EDGE AREAS

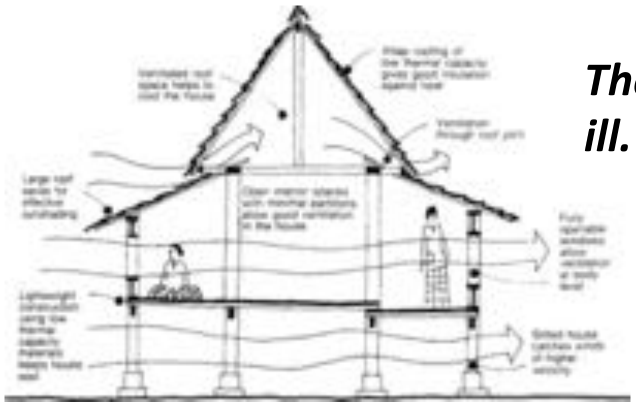
3a.Natural climatisation

In our cold climates, **natural ventilation** was widely seen as “idealistic dreaming” 20 years ago. Natural / hybrid ventilation solutions are now seen to be much more widely applicable than was thought. .

The use of passive climatisation is generally somewhat easier in hot-dry than in hot-humid climates.

Vanse School, Norway: natural ventilation, GAIA architects

Enhanced stack effect ventilation, Global Ecology Center, Washington

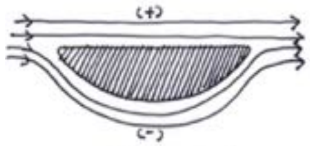


The Malay House, ill. Lim Jee Yuan

Advanced natural ventilation – African termite mounds

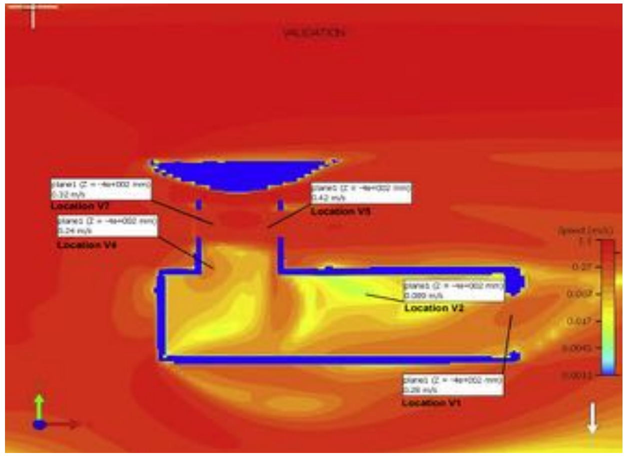
3a. Natural climatisation (continued)

With advanced natural ventilation design, high air change rates can be achieved, even with low incident wind speeds. Case study with CFD modelling from Malaysia.



Venturi shaped roof profile with positive pressure above and negative pressure below

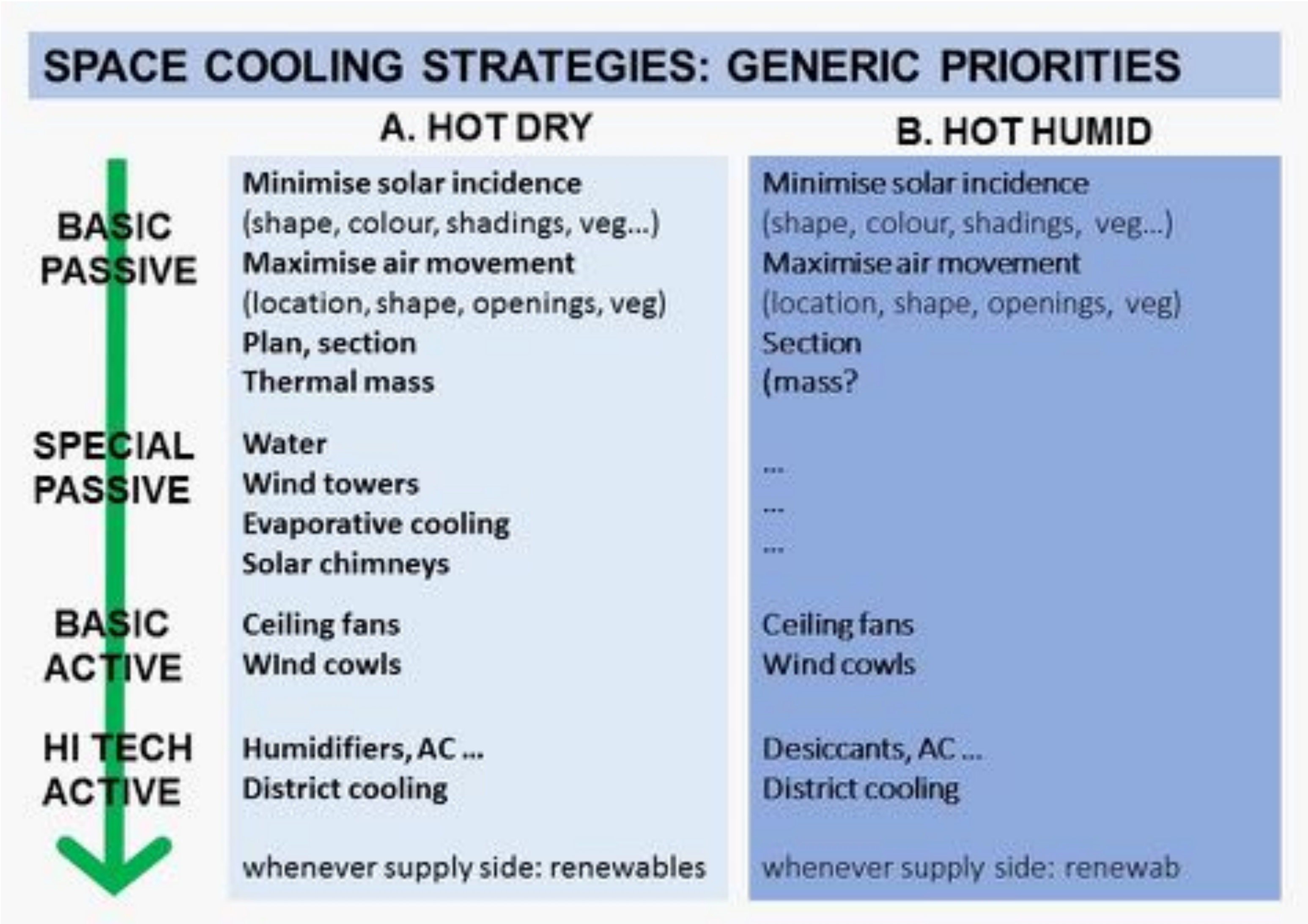
The wind-induced ventilation tower's extraction flow rate is 10,000 m3/h at external wind velocity of 0.1 m/s. With the same external wind velocity, it produces average of 57 ACH (air changes / hour).



source: Empirical study of a wind-induced natural ventilation tower under hot and humid climatic conditions
Haw et al, Malaysia, Energy and Buildings 52 (2012)

3a.Natural climatisation (continued)

More options in hot-dry climatic zones than in the hot-humid tropics *(ill.: Butters)*



SPACE COOLING STRATEGIES: GENERIC PRIORITIES

	A. HOT DRY	B. HOT HUMID
BASIC PASSIVE	Minimise solar incidence (shape, colour, shadings, veg...) Maximise air movement (location, shape, openings, veg) Plan, section Thermal mass	Minimise solar incidence (shape, colour, shadings, veg...) Maximise air movement (location, shape, openings, veg) Section (mass?
SPECIAL PASSIVE	Water Wind towers Evaporative cooling Solar chimneys	... ...
BASIC ACTIVE	Ceiling fans Wind cowls	Ceiling fans Wind cowls
HI TECH ACTIVE	Humidifiers, AC ... District cooling	Desiccants, AC ... District cooling
	whenever supply side: renewables	whenever supply side: renewab

3b. Embodied Energy / Carbon

Operational versus embodied energy: The part of embodied energy is growing and can be over 50% of total lifetime energy on advanced sustainable buildings

(source. Sartori/Hestnes, Energy and Buildings 39).

Post-use impacts of recycling composite materials (RC)

Country	Author	Relationship between embodied and operational emissions in different buildings and infrastructure
UK	Lee & White (2008)	Embodied energy is 3-35% of 100 year life-cycle energy demand
	Yohanis & Norton(2002)	Embodied energy is 67%of operational energy over a 25year period
	Eaton &Amaton (2005)	Embodied carbon is 37-43%of 60 year life-cycle carbon
	Smith (2008)	Up to 80% of life-cycle carbon emission is embodied carbon
	CIBSE (2010)	Embodied carbon is 42-68%of 60 year life-cycle carbon
US & Canada	Engin& Francis (2010)	Embodied energy is 11-50% of 60 year life-cycle carbon emissions
	Webster (2004)	Embodied energy is 2-22%of 50 year life-cycle energy demand
	Athena (2007)	Embodied energy is 9-12%of 60 year life-cycle energy demand
	Build Carbon Neutral (2007)	Embodied energy is 13-18%of 66 year life-cycle energy demand
Australia	CSIRO (2006)	Over 10%of 100 year life-cycle energy demand is embodied carbon
Sweden	Thormark (2002)	Embodied emission is 45% of 50 years life-cycle emissions
Israel	Huberman &Pearlmutter (2008)	Embodied emission is 60% of 50 years life span
Key:		Emissions: Embodied / Operational

3b. Embodied Energy / Carbon

TYPICAL FIGURES -- EMBODIED CARBON

Examples of embodied carbon (EC) in some building LCA studies.
from: Butters/Cheshmehzangi, Applied Energy 2016

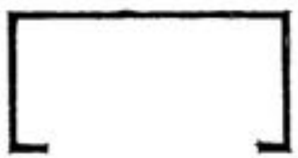
No.	Building type	Main materials	EC $kgCO_2e/m^2$	% of which concrete+steel
A	Large buildings, UK	concrete, steel, glass	700-1200	60-80
B	Large buildings, China	concrete, steel, masonry	ca. 600	ca. 70
C	Typical low rise housing UK	concrete base, masonry	450-550	ca. 75
D	4 storey block, low energy, Sweden	concrete, blocks, timber	274	58
E	House, passivhaus, UK 2003	mix, low carbon	230	ca. 60
F	nZEB-eco house, Norway 2013	timber products, RC slab	140	40
G	Traditional houses, Thailand	lightweight on slab	70-100	ca 60

Sources: A, C, E, (RICS QS & Construction Standards, 2012); B, (Xiaocun Zhang and Fenglai Wang, 2015); D, (Dodoo, Gustavsson and Sathre, 2009); F, (xx4 authors, 2016); G, (Chiarakorn et al., 2015).

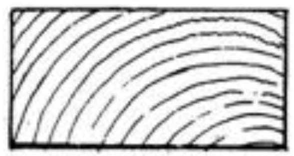
3b. Embodied Energy / Carbon

**Emissions of CO2e for two standard solutions for the same building function and at similar cost:
internal wall framing using steel or timber.**

Source: GAIA architects, Norway



galvanisert stål 0,6 kg



trevirke 5,6 kg

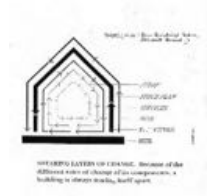
Steel: six times more embodied carbon than timber

Utslipp:
1,32 kg CO2-ekv.

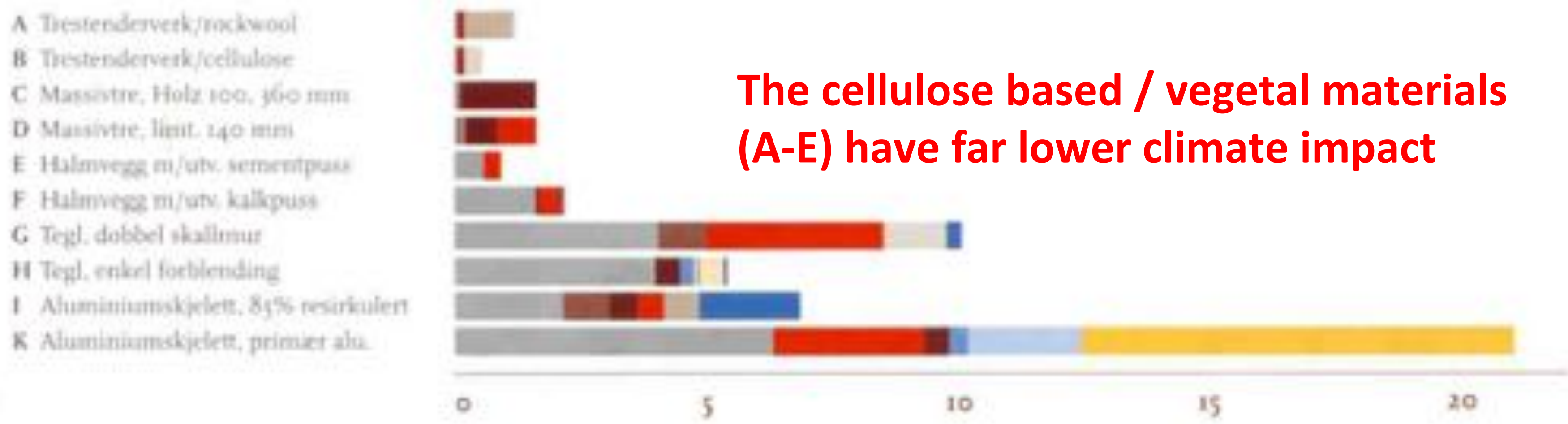
Utslipp:
0,22 kg CO2-ekv.
binding -10,08 kg CO2-ekv.
netto utslipp -9,86 kg CO2-ekv.

kilde: GAIA Lista

3b. Embodied Energy / Carbon



BURDEN ON CLIMATE PER SQ.M of DIFFERENT CONSTRUCTIONS



The cellulose based / vegetal materials (A-E) have far lower climate impact

New materials: an example from Asia:

Art gallery, Singapore Botanical Gardens

Zero net energy (mostly PVs), and with Hempcrete insulation for hot humid climates -natural, healthy, low embodied energy

3b. Embodied Energy / Carbon

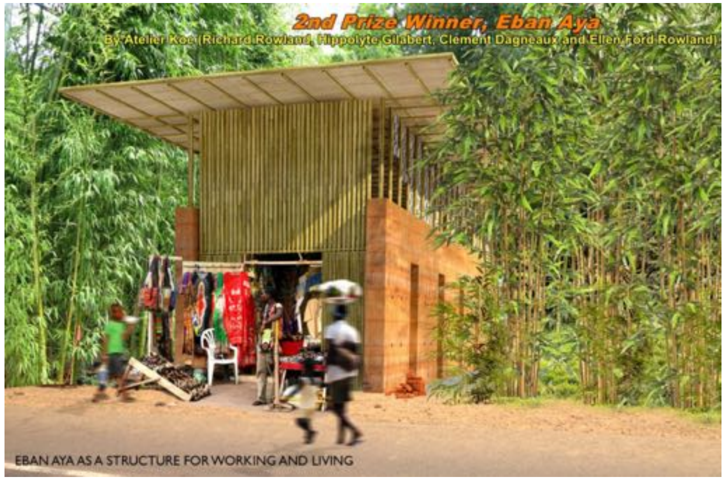
Lilac Cohousing, England –-clay, straw
Earth house, Chiang Mai, Thailand

Modern earth house, CLC Thailand
Modern earth house, Austria

3b. Housing and Embodied Energy / Carbon

Modern earth and thatch, West Africa
Modern earth house, USA

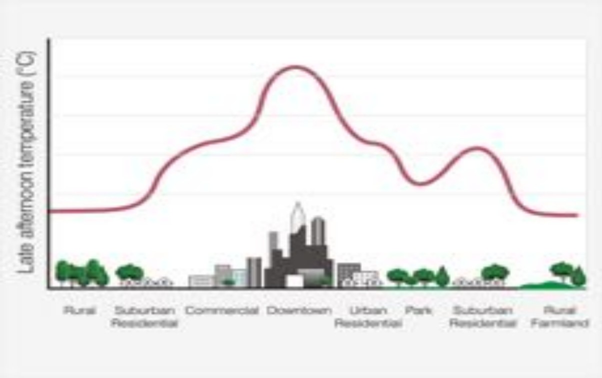
India, naturally cooled microclimate
Modern earth and reed house, Africa



3b. Embodied Energy / Carbon

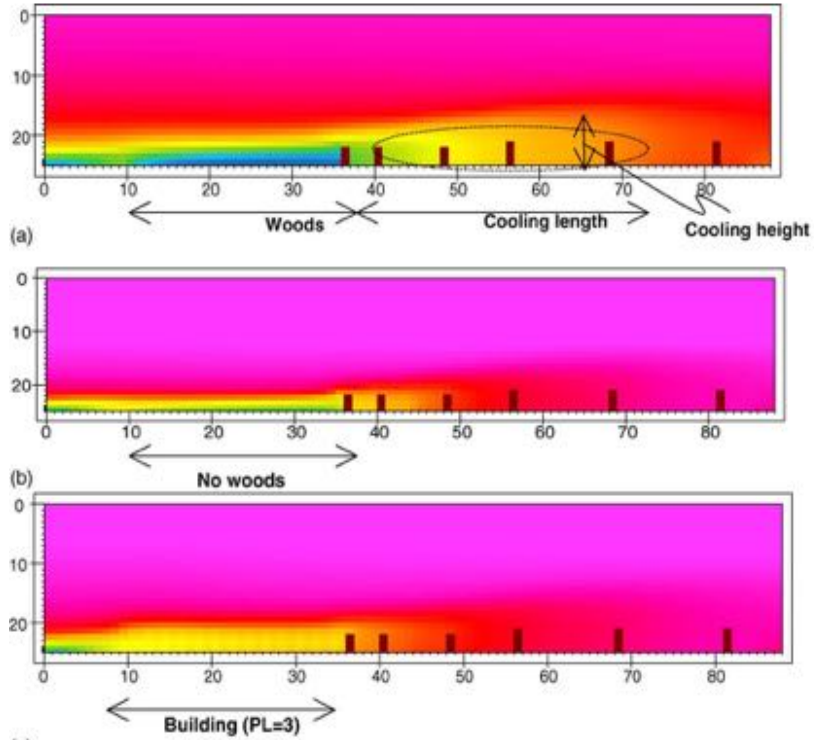
Urban residential block, Ningbo, China:
extremely high embodied carbon
NB - including for the urban site works
almost no energy efficiency measures
Poor social qualities, gated «islands»
Source: Butters/Cheshmehzangi, ELITH

3c. District / Urban Scale



Urban Heat Island Effect - UHIE

Green Infrastructures for an improved urban microclimate



Urban Heat Island and Green Spaces:

Cooling effect of parks: *a comparison of section views of scenarios with woods (top), without woods (middle), and with buildings replacing woods (bottom).*
Source: Chen Yu, Wong Nyuk Hien, Thermal benefits of city parks, Energy and Buildings 38

3c. DISTRICT ENERGY SOLUTIONS

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Urban district cooling (and heating) solutions

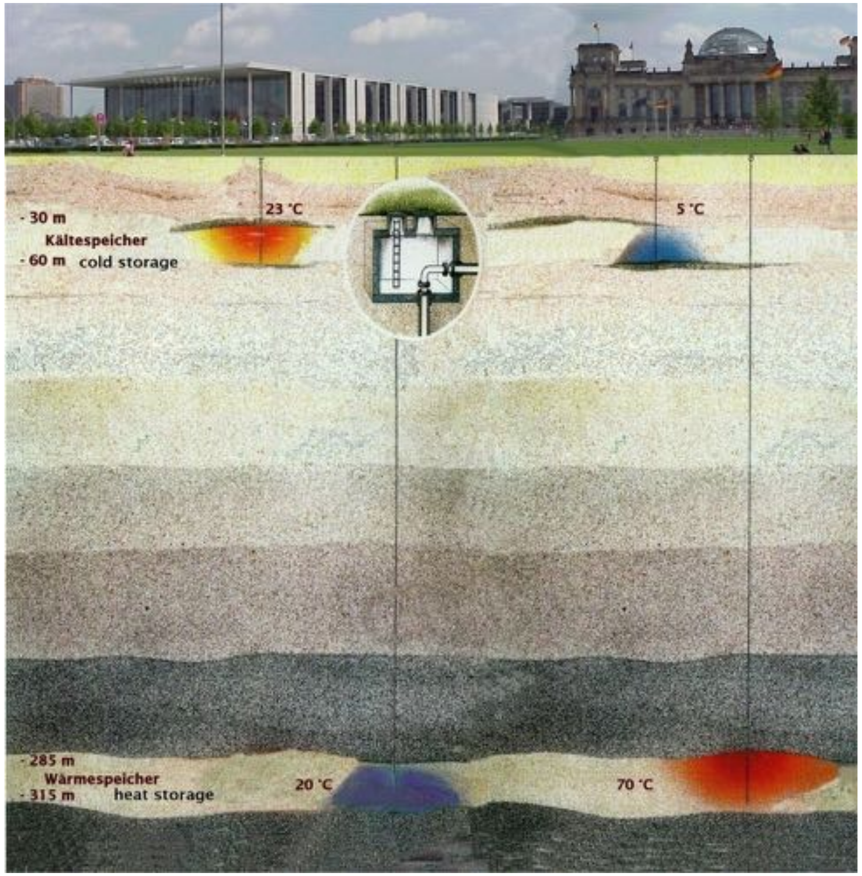
Also in hot-humid climates
Primary energy can be reduced by 50-80%

Singapore Marina Bay DCS

Palm Jumeirah DCS

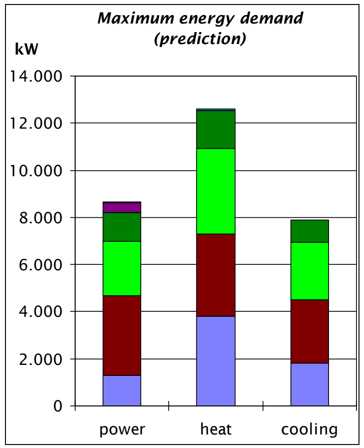
3c. District / Urban Scale

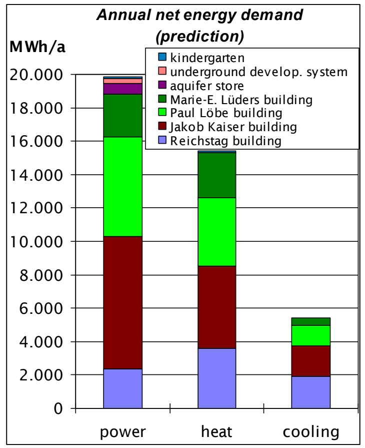
Spree River District, central Berlin
Seasonal Energy Supply System



Aquifer storage

District heating and cooling with seasonal storage of cold and heat





3c. District / Urban Scale

DISTRICT COOLING for hot climate cities:

Compare recent major shift to DHS (district heating) in cold climates

Economies of scale
Avoids retrofitting
Avoids (counteracts) the urban heat island effect
Standard, simple technology: pumps, heat exchangers
Up to 85-90% reduced elecricity
Can provide heat source as well where cold winters
Very economical where feasible
Greatly reduces climate emissions

Requirements:
Deep water source (oceans, deep lakes) OR underground
Large scale infrastructure planning

3d.Biomaterials

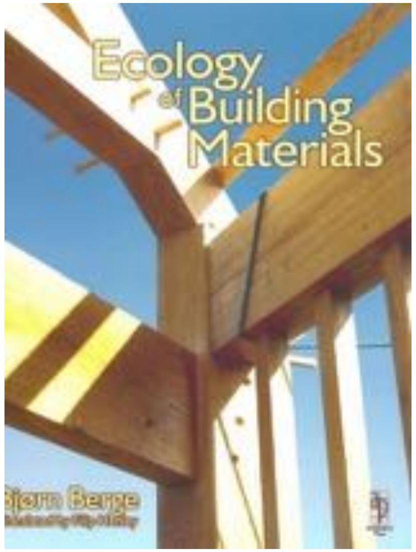
Synthetic materials are often carbon intensive as well as polluting, and some present health hazards. Most polymers (plastics) are based on fossil fuels.

Very early plastics, such as Bakelite, were made from maize. Plant materials can be refined into insulation, building panels and more. The EU is devoting considerable attention to this field. Cellulose-based industries and biomaterials are a fast growing new industrial sector.

Tropical countries have a wide range of natural fibres and plant materials that can be processed into eco building materials. Many have been researched, but for other purposes, such as textiles. Sisal, kenaf, hemp, cotton, straw and other cellulose derivatives are amongst these. Developing countries should focus major efforts to this.

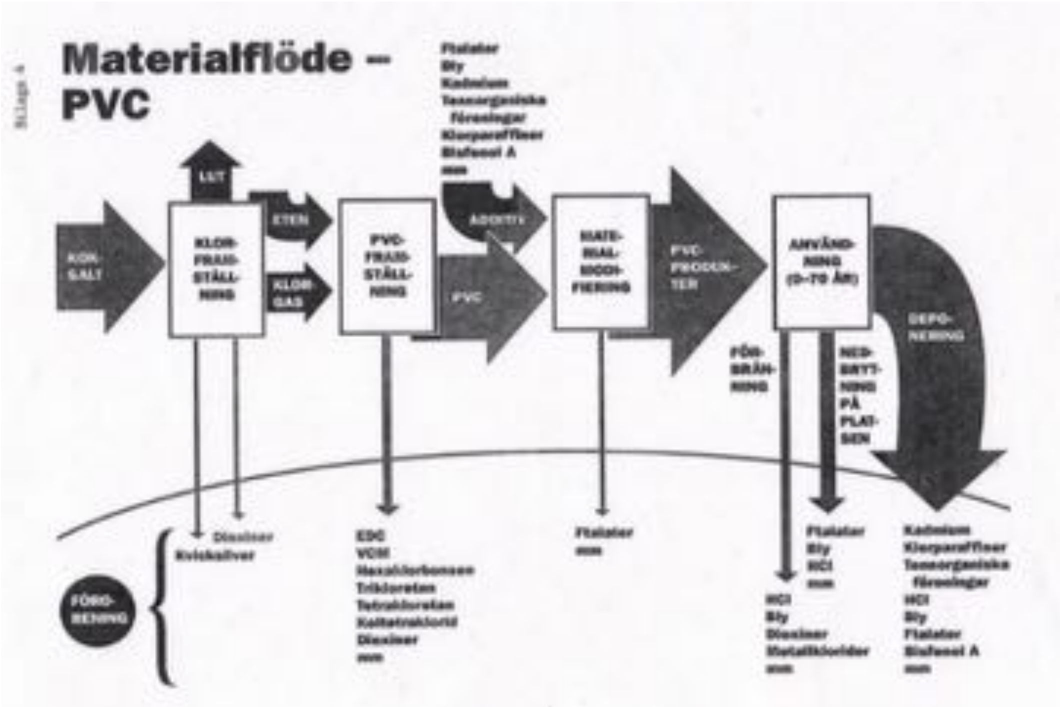
Cellulose, paper, recycled textiles, (wool + cotton, no glues)

Ecology of Building Materials - Bjorn Berge
transl. Chris Butters GAIA Norway. 2nd ed., Elsevier / Architectural Press , UK 2009



3d.Biomaterials

Replacing synthetic polymers with bioplastics



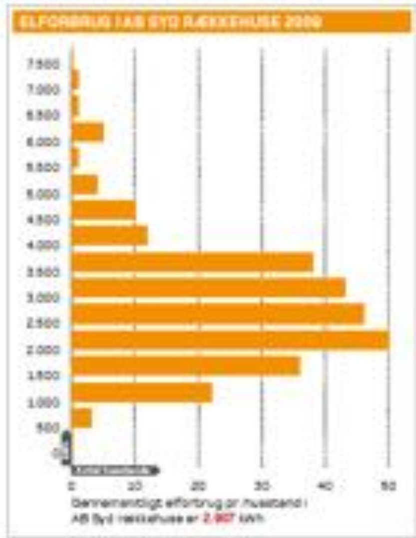
Production and life cycle of PVC – very energy intensive and hazardous components and by-products, including dioxins

«Natural», low carbon building products are becoming available (examples: Germany, UK)

3e.Sustainable consumption – the human factor

More and more post-occupancy (POE) surveys and analyses are showing that low energy buildings are often failing by a long way to achieve the expected results. There is now more focus in design as well as in policy, on the behavioural aspects of energy use and climate emissions.

Electricity use: huge variations in identical houses, Albertslund, Denmark, show the importance of behavioural issues



Minna Sunikka-Blank & Ray Galvin : *Introducing the prebound effect: the gap between performance and actual energy consumption* BRI 40:3 (2012):

Post occupancy experience from thousands of buildings in European countries shows that the result of a narrow technical focus may be far less energy savings than expected, and a far longer payback times for consumers than promised

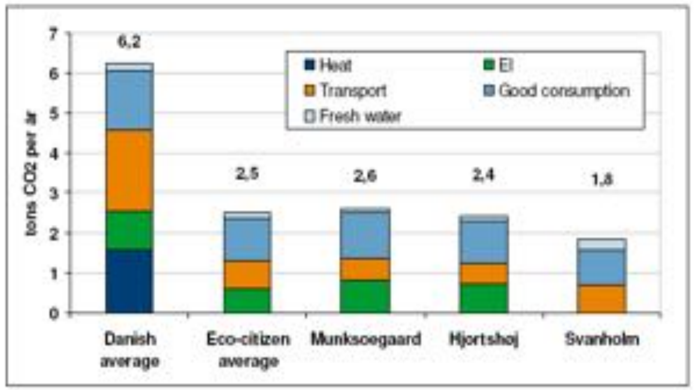
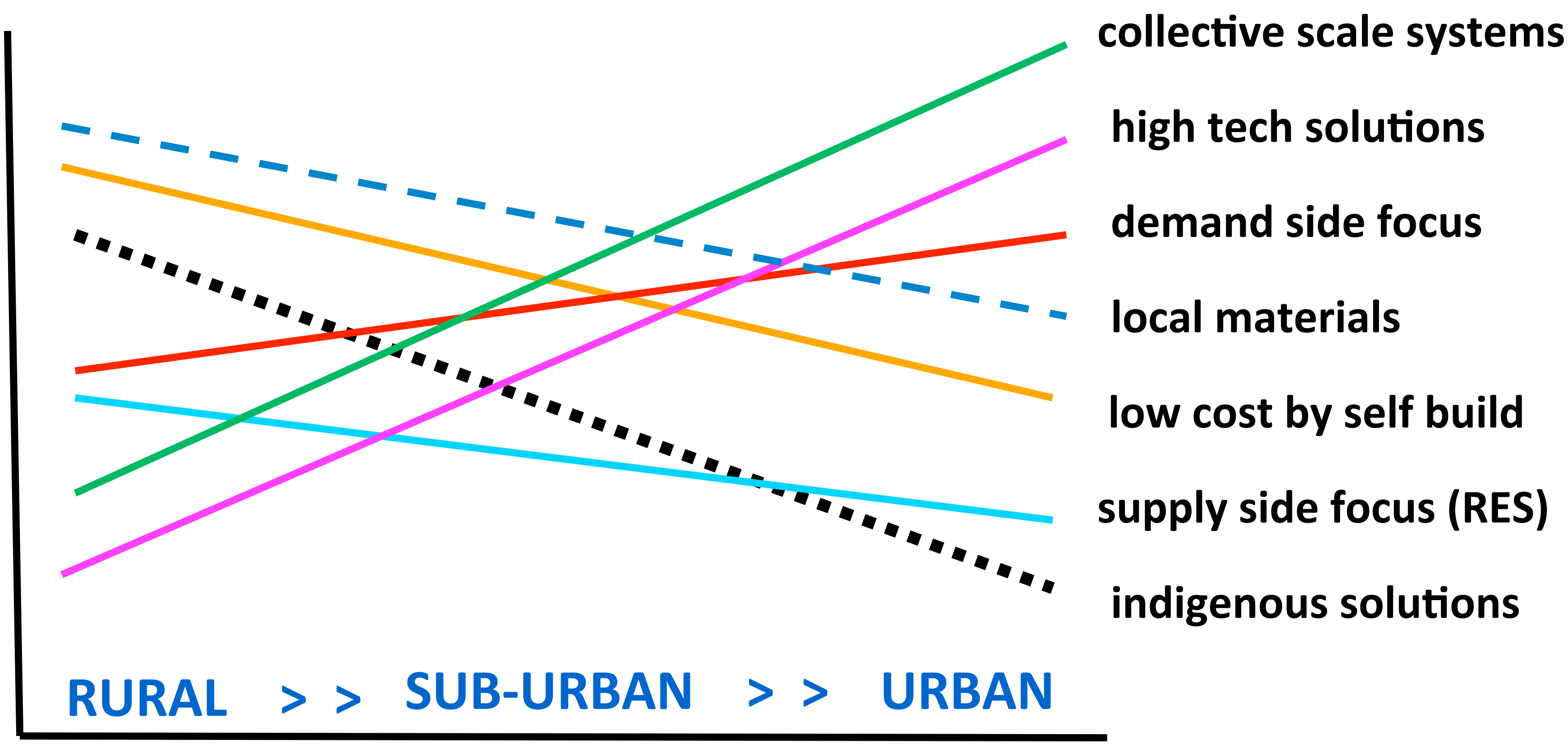


Figure 2: Average CO_2 emissions for a Danish citizen compared with citizens from the different eco societies

Sustainable living: ecocommunities have 1/3 of the resource footprint

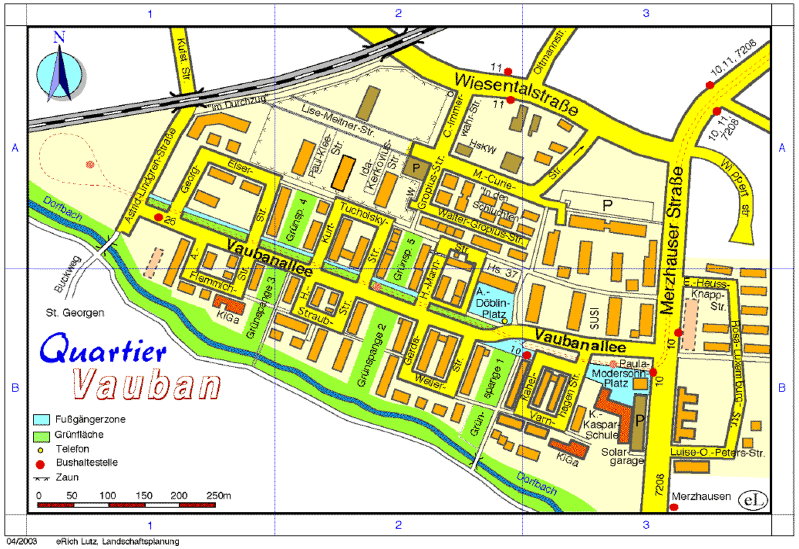
Low Impact, Low Cost Sustainable Housing:
Hypotheses for most appropriate solution paths
(nb: for new build)

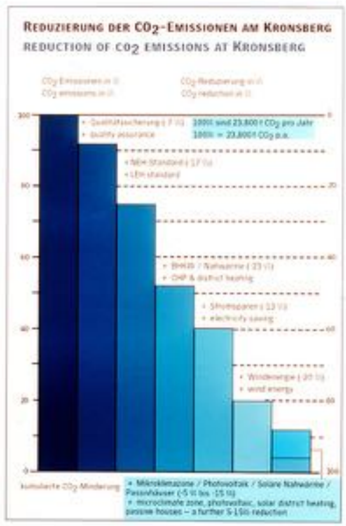


Urban residential choices - ?

European Eco Housing districts: low-dense, with integrated energy, water, waste, transport solutions





4. Processes of change

Looking at the dynamics and processes of change, sustainable building and urban development almost everywhere has identified and pursued four difficult but essential processes - summed up as follows:

>> from segregated spatial zoning of cities to mixed use districts

>> from specialisation to integrated design and planning - also a key to lower costs

>> from uncontrolled construction to *voluntary* energy efficiency guidelines to *mandatory* standards and codes for environmental quality

>> from private-public contradictions to a win-win modus with better cooperation.

All of the above have been the subject of very major efforts and important shifts in policy, planning and practice in industrialised countries.

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Chris Butters, Warwick University, UK - Bangkok, 24.03.2016

The University of Warwick

SUSTAINABLE HOUSING: FIVE IMPORTANT FOCUS AREAS FOR PLANNING AND POLICY:

---NATURAL CLIMATISATION
---EMBODIED ENERGY / CARBON
---DISTRICT and URBAN SCALE ENERGY SOLUTIONS
---BIOMATERIALS
---BEHAVIOURAL ASPECTS

Thank you