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

STATE OF THE ART AND NEW DIRECTIONS

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The University of Warwick

1. THREE FUNDAMENTAL QUESTIONS

Our brief is to research solutions for low income housing in hot climate developing countries, with the particular goal of reducing energy use and greenhouse gas emissions. I wish firstly to review briefly the state of the art in sustainable building design, as it has developed in recent years primarily in an OECD – hence temperate climate – context; and then to discuss hot climate solutions and not least, whether temperate climate state of the art may contain lessons for hot climates as well as indicating key issues that should be focused on. However, I wish firstly to note three key points that lie at the basis of the research question we are asked to address. These three are:
---defining low income in the context of this program
---the difference between reducing, and mitigating future growth of, energy use/GHG emissions
---how to define comfort in the low income context

1a. Defining Low Income

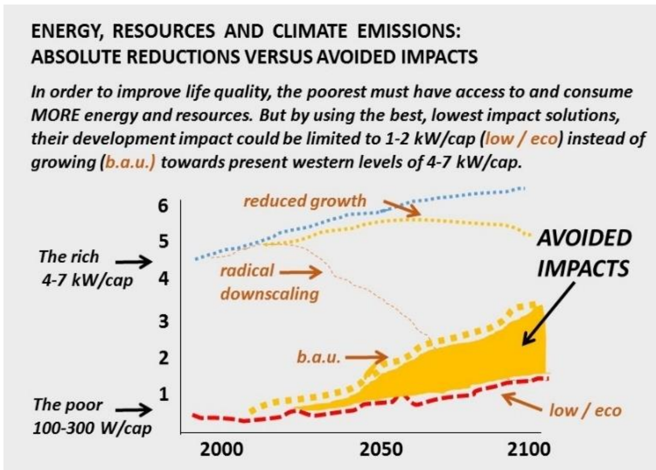
Whereas there are large low income groups in our two African partner countries – many of them in rural areas – there is less absolute poverty in our two Asian partner countries. Thus, the focus of our work has been quite different in Asia and in Africa. There are still poor groups in Asia but neither of these countries has a strong focus on that sector; far more attention is focused on the new, urbanising populations, who are relatively low income but on the upward ladder.

In the context of energy and climate there is very good reason to focus on these groups; it is these new urban millions who are fast acquiring energy amenities, including in particular, air conditioning and cars. This leads us on to the second key question:

1b. Is the task to reduce, or to mitigate future growth of, energy/GHG emissions?

There is an inherent contradiction in our program, which stems largely from it being funded by two different ministries. DECC is concerned with reducing climate emissions whilst DfID is concerned with alleviating poverty. But, clearly, it is not those at the bottom of the pyramid who can, or should be asked to, reduce their energy use or climate footprint. Should they be asked to turn off the one light bulb they have?

Nor do they have the money to buy energy-efficient LEDs or to insulate their homes. No; it is those who over-consume who can downscale. The best we can aspire to do for the poorest groups, is to develop housing that improves their conditions of life, *without increasing* their climate footprint – and in addition, without increasing the cost.



On the other hand, what we can indeed do, and it is a key task, is to promote better housing solutions for the up-and-coming urban millions, to *mitigate the steep rise* in energy use and emissions in that sector. This is about ensuring a *lower growth curve* than is the case at present and will be if we continue to build energy-inefficient and poorly designed housing that entails huge amounts of operational as well as embodied carbon – a huge burden for the future.

As to those at the bottom of the pyramid, surveys by our African partners confirm that the prime concern is cost. Our task there is to propose solutions that cost no more, entail only minimal increases in energy and carbon, and improve living conditions.

Hence, our principal task, more correctly defined, is on the one hand, not to *reduce* the few amenities which the poorest people have, but to improve their living conditions *without increasing* costs or emissions; and on the other, to *mitigate the energy and emissions growth* curve of the urbanising millions. Therefore there is a need not for ideal but for pragmatic approaches – which Ali Cheshmehzangi and I have written about elsewhere. This brings me on to the third basic issue of our research question:

1c. How do we define comfort for the low income context?

The fundamental issue here is that international norms for comfort and indoor environment, such as those of the WHO, are unrealistic in the context of very low income housing. They are simply too expensive. Millions live in slum conditions today. There are many very low cost, simple improvements that could ameliorate living conditions, comfort and health.

The World Bank "Cool Roofs" program in India is a good example. Typical tin roofs in hot climate developing country slums the world over, are like a radiator for those living beneath them. Simply by painting these roofs white, the indoor temperature is lowered by up to five degrees. It is tempting to say that we should cancel half the research programs in the world and buy a paint factory.

What we can do is to provide *significant amelioration* of living conditions – of health – of comfort – very cheaply, but only if we accept that we are not aiming for WHO ideals. The question is, therefore: is this approach acceptable … and if so, which health parameters are most critical?

Importance of air movement in hot climates: Equivalent temperature at wind speed 1 m/s

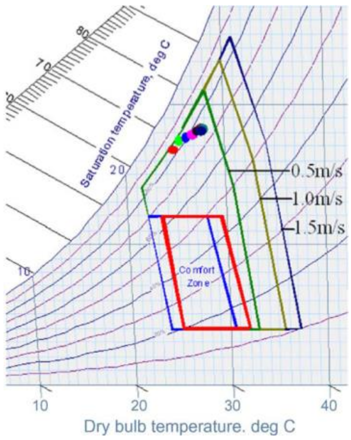
To (°C)	Tn (°C)	Teq (°C)
28	26.3	23
29	26.6	24
30	26.9	25
31	27.2	26
32	27.5	27
33	27.8	28
34	28.1	29

Source - Design Criteria for Low Energy House in a Tropical Climate, Juntakan Taweekun
Dept of Mechanical Engineering, Prince of Songkla University, Hatyai, Songkla, Thailand, paper supported by the Energy Policy Planning Office, Thailand and Prince of Songkla University, Thailand. The author is deeply indebted to Professor Surapong Chirarattananon (Energy Program, Asian Institute of Technology, Thailand)

Comfort temperature, around 28C in the tropics, varies between persons and cultural contexts

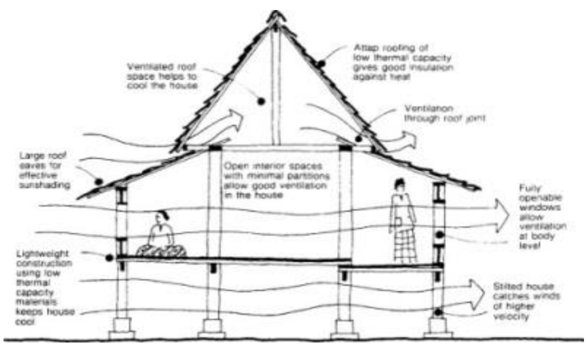
Part of the comfort issue is that of space per person. What is an acceptable "low income" minimum? This varies culturally, but norms (minimum) of around 6 to 8 sq.m per capita can be found in several contexts.

This also reminds us that the fundamental goal is not just energy use and climate emissions, but sustainable development. And we must remember that beyond energy and carbon, this includes fresh air, clean water and sanitation, access to green spaces, avoidance of noise and traffic, social spaces, security, and the other necessities for *sustainable community*. This broader brief must be kept in mind.



The psychrometric chart: how far can we achieve housing comfort using only passive climatisation?

It is recognised that we must cut our climate emissions by 80 or 90% within the coming decades. But – with the well known formula for total **Impact**, I = P.A.T – the maths is simple: if **Population**, as well as **Affluence**, increase that much, it would require **Technology** that is more than ten times more efficient, in order for any overall *reduction* in final energy use or carbon emissions. This is impossible – certainly in a foreseeable future. The millions of buildings going up in countries like China today – in fact in most of our developing countries – is no better than 1960s-style European buildings. Decreasing the *energy intensity* is not enough. The increase in *volume* (of population and affluence) eats up all technical efficiency gains; this is the reality. User-led sustainable consumption is therefore also high on the agenda now.



The Malay House, ill. Lim Jee Yuan: Tropical vernacular climatic solutions

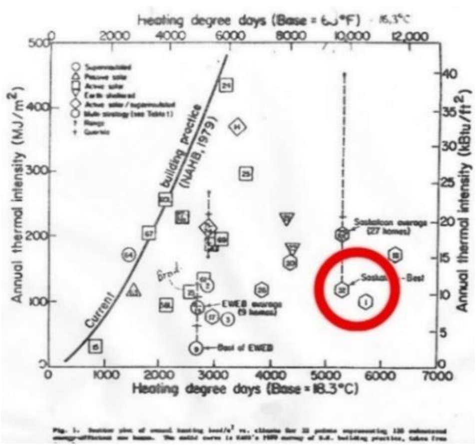
2. SUSTAINABLE DESIGN: STATE OF THE ART

A very brief overview: the first generation of environmental architecture in the 1970s had a holistic agenda that included not only energy but water, wastes, ecological landscaping and much more. The first zero energy house was built in Denmark in 1974. But few people today are aware that the *passivhaus* energy standard (15 kWh/m2.year for heating) was achieved in very cold Saskatchewan, Canada, already in 1979. Yet only now is green building really on the agenda world wide!

The first zero energy house, Denmark, 1974

The first passivhaus level houses, Canada, 1979

Below: the tested houses passivhaus level results, Canada (red circle) Source LBL Berkeley 1979



Thereafter, energy became a main focus; first renewables, such as solar. However, after some years, the focus shifted to the demand side. It was seen that the cheapest options are often to reduce energy needs – not least through better construction. (Unfortunately even today, many politicians tend to focus on the supply side). Energy efficiency is usually the cheapest option; this has led increasingly to a focus on the building envelope and on so-called passive solutions (the term is misleading!). This led to low energy, *passivhaus*, and then recently even *zero energy* and *plus energy* buildings.

This energy focus has been mainly on operational energy – especially for space heating which has been the major energy need in colder climates – and these heating needs are now reduced to less than one quarter in *passivhaus*.

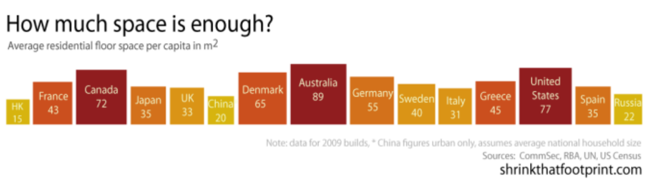
From there, the focus has progressed again, more recently, to include embodied energy (or carbon). As operational energy decreases, the energy to produce the buildings becomes much more significant. LCA studies show that embodied energy/carbon now approaches or even exceeds 50% of the total lifetime building footprint in modern sustainable buildings (slide). This aspect however is not yet equally in focus in the hot climate developing countries.

Beyond this lies the area of *plus-energy* or *carbon positive* buildings. These concepts, currently still defined in slightly different ways, indicate where the future lies; in buildings with almost no negative eco- impacts. So-called *regenerative design* is an extension of this.

In developing countries, there has been less activity in these fields, although there is a huge amount of research in countries like China now - but there are also good examples to be found. To simplify, one may say that the focus in many of these countries in recent years has been twofold; on the one hand, a revalorisation of traditional climate-adapted designs and materials, maximising passive climatisation and vernacular solutions, in both hot-dry and hot-humid climates; but this is still only a minority interest amongst eco-designers. On the other hand there is a strong typically Asian technology focus: more efficient lighting, air conditioning, solar photovoltaics, smart controls and advanced building components.

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

As with our Thai partners, there has also been a lot of focus on improving efficiency codes and green building standards. Hence, in the historical development in this field of sustainable buildings, some clear trends and patterns emerge. Below are shown two recent hot climate "low impact" projects. But where does the future lie? I then highlight briefly, **five key areas** which are receiving increased attention in the OECD countries now. These are cutting edge areas where our developing countries should almost certainly devote more attention.

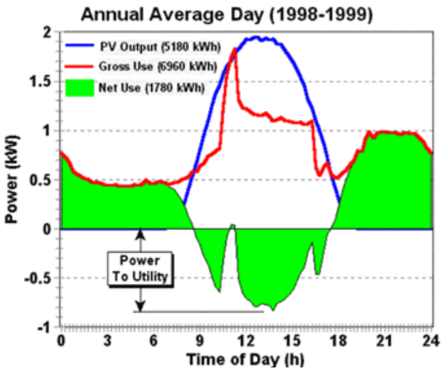


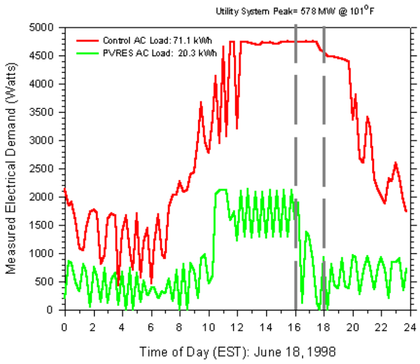
TWO CURRENT EXAMPLES OF SUSTAINABLE DESIGN IN HOT CLIMATES: FLORIDA (HOT SUBTROPICAL) AND SRI LANKA (HOT HUMID)

Both of these examples show the current «technological» approach; we see a few passive climatisation features, but the main focus is on building envelope and services technology, plus adding renewable energy with photovoltaics to reduce the energy/carbon impact. No attention is paid to embodied energy/carbon.

A. ZEB (zero energy) house, Florida, USA.

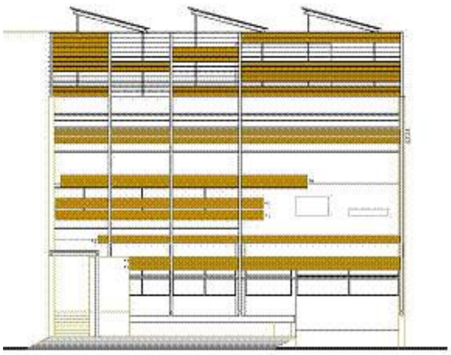
Energy reductions over 70% + 20% supplied from PV
Typical technological focus, high-tech materials
Wasteful space use
Some passive features: reflective roof, large roof overhangs.
But embodied energy/carbon is NOT addressed at all





Isocyanurate foam insulation - not healthy or ecological !

B. Nikini building, Sri Lanka



Annual energy use: 89 kWh/m2, of which 60 from PV
Embodied energy/carbon is NOT addressed
Roof mounted PVs are added on NOT integrated as the roof material
There a range of technological features (see below)
Rainwater harvesting and daylighting are however addressed too

http://www.mrt.ac.lk/archi/staff_upra.html

Shading on immediate microclimates 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
Rain water harvesting
Building energy management system

3. FIVE CUTTING EDGE AREAS

3a.Natural climatisation

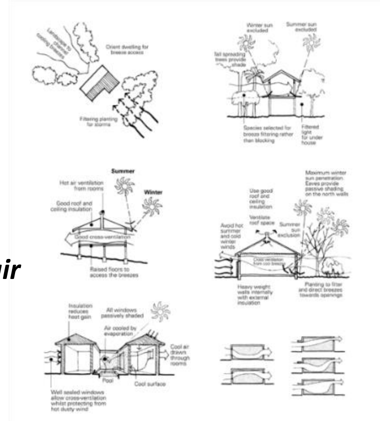
Principles for passive cooling have long been known, going back centuries, as well as in research going back to pioneers such as McHarg, Olgyay and Givoni 30-40 years ago. But they are still very seldom applied. In our cold climates, natural ventilation was widely seen as “idealistic dreaming” only 20 years ago. I have been working on this on Norway; and there have been big advances, so it is better accepted and significantly, natural and hybrid ventilation solutions have been shown to be much more widely applicable than was thought. This is a big change.

The same, I am in no doubt, will prove to be the case for natural ventilation in hot climates. In hot climate contexts, what do we have to work with at present? There are dozens of papers reviewing traditional vernacular solutions, but often without sufficient scientific and systematic conclusions as to which techniques worked or how. There are also many research papers that are still too theoretical, or else narrowly specialised on one parameter only – for example evaporative cooling or wind scoops seen in isolation from all other factors. And thirdly, there is a whole genre of attractive design manuals, of a not very rigorous kind, where any and all natural climatisation techniques are recommended, without distinguishing which ones are best applicable where, and whether there is any point in using three or four of them all at the same time. There is a need for more empirical, practical research and more evaluation of results.

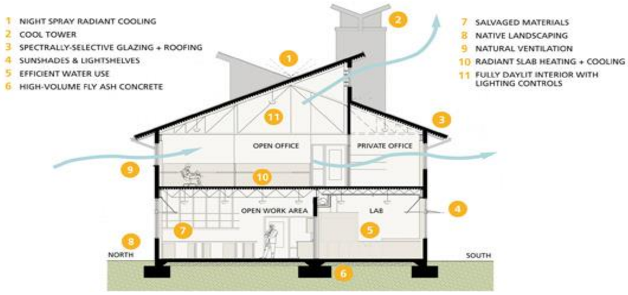
There are connections between aspects of building performance. The role of hygroscopic building materials in regulating indoor humidity is a new field that deserves far more attention;; and this is related to ventilation strategies The materials themselves can reduce the need for mechanical ventilation. This has potentially a big role to play for indoor environment and health. This applies particularly in the hot-dry and moderately humid climates. Hygroscopic materials is as yet a relatively unexplored aspect of natural climatisation.

The use of passive climatisation is somewhat easier in hot-dry than in hot-humid climates. Optimal use of climatically adapted design and natural climatisation can reduce energy needs for cooling by approximately 50% in typical hot climate contexts.

Principles for maximising air movement

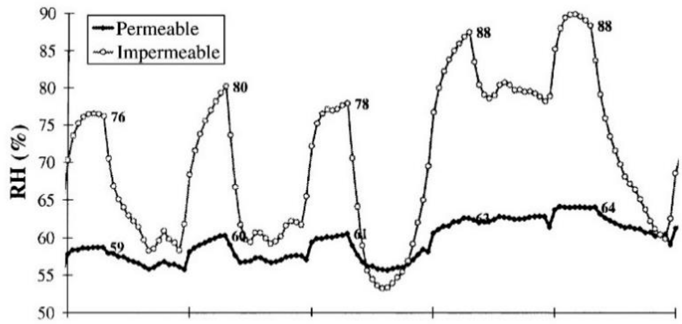


Vanse School, Norway: natural ventilation (Bernouilli effect roof), GAIA architects



Enhanced stack effect ventilation, the Global Ecology Center, Washington

Wind cowls, Jubilee Campus University of Nottingham, UK



Hygroscopic materials: regulating indoor humidity

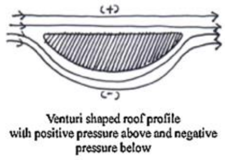
Natural Climatisation (contd).

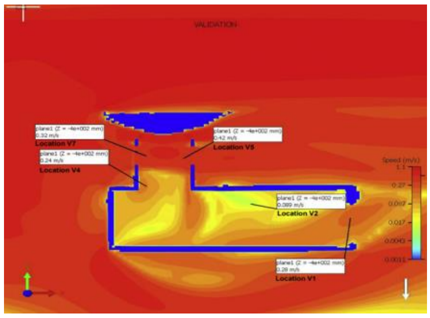
Climate responsive design in cold and hot climates follows the same principles, but with opposite intent: for example maximising solar gain in cold climates versus maximising solar protection in hot climates: and minimising unnecessary air infiltration in cold climates, versus maximising air movement in hot climates.

With advanced natural ventilation design, high air change rates can indeed be achieved, even with low incident wind speeds (see example with CFD modelling from Malaysia).

A main difference is in the building envelopes, where there are three types: thick, thermally insulated envelopes in cold climates; thick, heavy envelopes in hot-dry climates; thin and preferably permeable ones in tropical climates. (This is a general but not absolute rule). This difference in envelope thickness and complexity has a big effect both on the costs and the embodied carbon of buildings.

In general, there are more techniques available for passive cooling in hot-dry climates, as illustrated below. The most difficult challenge to indoor comfort is the near constant high humidity in the hot-humid tropical climates.





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

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).

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

There are more options available to designers for passive cooling in hot-dry climatic zones than in the hot-humid tropics *(ill.: Butters)*

The Souk (market): passive cooling strategies in Madinat Jumeirah – using shading devices, natural stack ventilation, courtyards, wind-towers, thermal mass, landscaping

Source - Mahmoud A. Haggag, UAE University mhaggag@uaeu.ac.ae

3b. Embodied energy/carbon

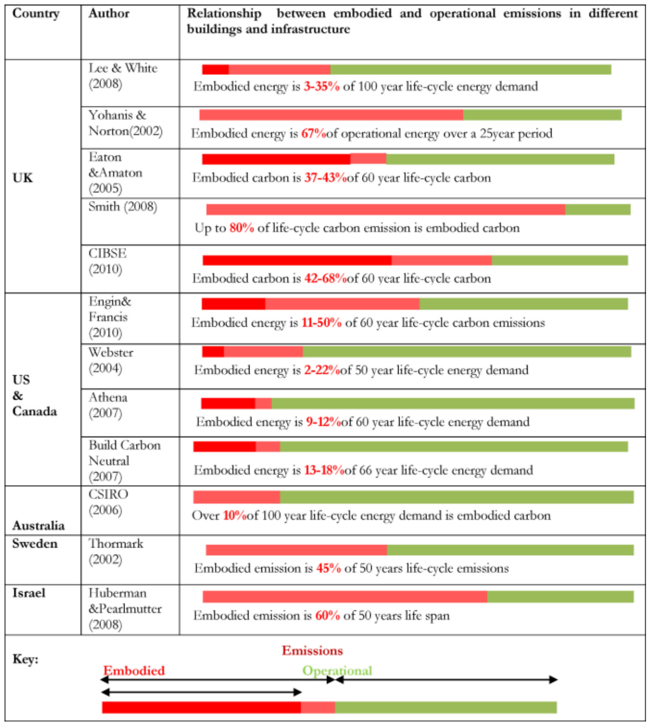
In today's low energy buildings, the operational energy needs are reduced to a fraction, often less than a quarter, of conventional buildings. This means that the energy/carbon required to produce the building itself, mainly the materials, becomes far more important. The embodied carbon (EC) is an increasing part of the overall life cycle picture. For example in a new sustainable office in Norway, the EC is very nearly equal to the total operational carbon: 69 versus 75 tons CO_2e/year respectively.

The largest carbon items in a building life cycle analysis (LCA) are often cement products and steel – often over 70% of the total lifetime EC. And the *embodied* part will increase as operational energy decreases drastically in future low energy buildings.

The other, minor components of the embodied impacts of buildings are the energy for *transport* of materials, and *on-site* energy use. The *post-use* impacts of dismantling and disposing of or recycling buildings has been less studied. This phase requires more attention. Recycling aluminum saves roughly 85% of the energy needed for virgin aluminum; and recycling steel saves over 50%. However, recycling concrete requires 5% *more* energy than new concrete, and recycling plasterboard is *48% more energy intensive* than using virgin material.

Further, LCA should include the *recurrent embodied* energy/carbon inputs over a building's lifetime, for maintenance, repair and replacement of parts. This may for some components even be as much as the initial embodied fraction.

Hence the growing importance of moving away from carbon-intensive materials. Below we note the potential of new biomaterials in particular.



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

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)

TYPICAL FIGURES -- EMBODIED CARBON

Below: examples of embodied carbon (EC) in some building LCA studies. from: Butters/Cheshmehzangi

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).

3c. District/urban scale

Our task extends beyond the scale of individual buildings. Design and layout at the urban scale is a major factor in determining energy needs – as well as human comfort. Together with Chinese partner UNNC we have therefore also addressed issues of housing at the larger, urban scale.

There is still often no coordination between the areas of individual building design, urban planning, and energy planning. This means that decisions are not always taken at optimal level. In many cases, energy solutions will be advantageous at urban scale rather than at the scale of individual building. In addition, creating a favourable microclimate for housing (with resultant lower cooling needs and emissions) is very much a task at the urban scale.

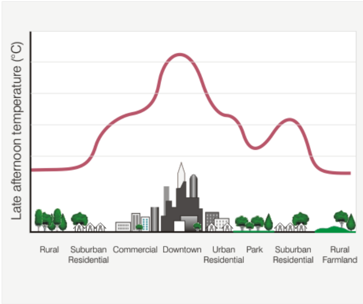
Cooling apartments with individual air conditioning (AC) units is extremely inefficient; and each unit just heats up its neighbours even more, adding to the urban heat island effect (UHIE). In cities like Ningbo, AC usage is increasing at rates of 10% annually. The only way to mitigate UHIE is thinking at a larger scale: to apply district cooling systems.

We need to consider not only the buildings but also the site works associated with different types of housing development. In dense and high-rise urban projects with extensive engineering works such as underground parking, culverts and other infrastructural services, the carbon footprint of the site works may be up to one-third of the total carbon footprint.

Energy designers, urbanists and energy planners seldom communicate. We have focused our research in Ningbo City, China, on whether the common high-rise model of residential development, typical of China and elsewhere, is appropriate; it is also very carbon-intensive.

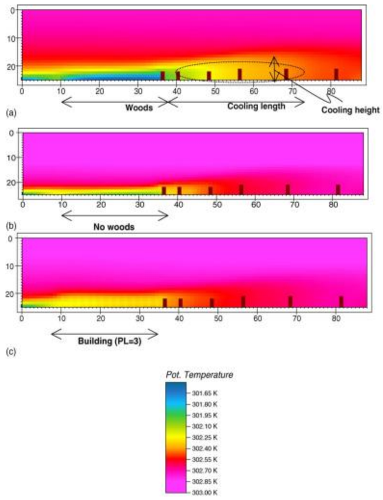
Urban Heat Island:

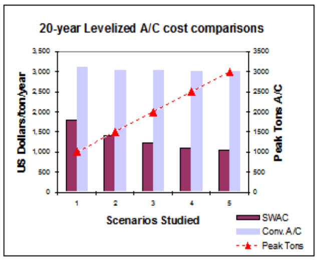
growing energy use, climate emissions, discomfort and rising heat stress mortality

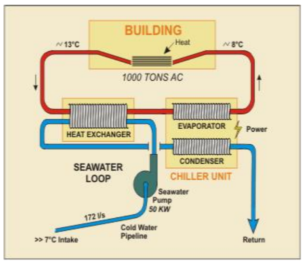


Urban Heat Island and Green Spaces:

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*







District cooling systems can achieve over 85% reduction in air conditioning and primary energy

Technology applied:

- Heat pump used for space heating and cooling.
- Heat storage in bedrock with water circulating in boreholes

Performance:

- Environmental benefit: 60-70 % reduction in electricity use.
- The annual cost is reduced by 0,5 mill. EUR, or 55 %.
- Efficiency/saving achieved by the project: 8,9 GWh energy, representing a 75 % reduction in energy use.

NYDALEN URBAN DISTRICT HEATING AND COOLING SYSTEM

Winter heating and summer cooling
Heat storage in bedrock
Oslo, Norway, 2001-2003

This was implemented not by the city authorities, but by the developer as a new and profitable line of ESCO business

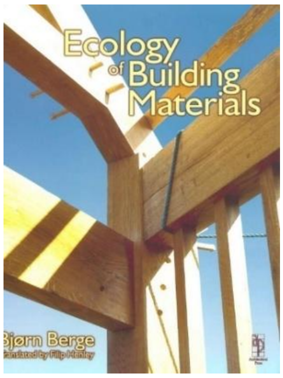
3d.Biomaterials

Synthetic materials are often carbon intensive, as well as polluting, and some present health hazards in buildings. This includes the polymers (plastics) which are normally based on fossil fuels. These are an environmental burden and, in the longer term, are to be phased out.

Some of the very first plastics, such as Bakelite, were made from maize. Plant materials can be refined into all sorts of plastic-type materials, insulation, building panels and more. There is a huge potential in the field of biomaterials – which can replace most polymers. The European Union, is devoting considerable attention to this new field. Cellulose-based industries and biomaterials are a fast growing new industrial sector.

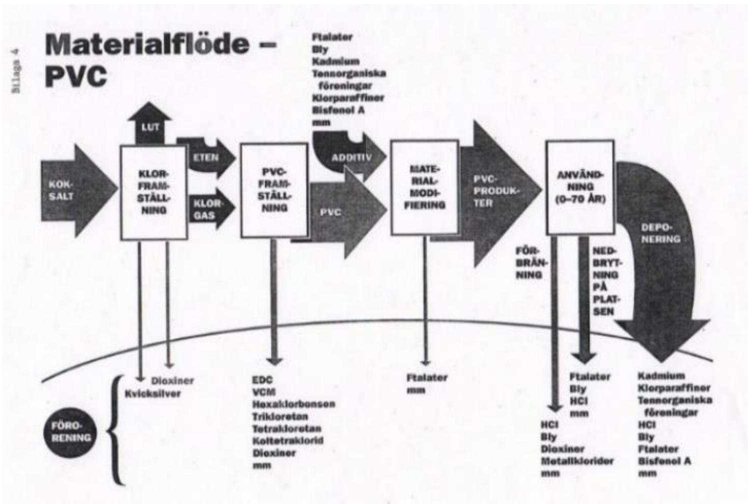
In tropical and hot climate developing countries one finds a wide range of natural fibres and other plant materials that can be processed to alternative building materials. Many of them have in fact been researched, but for other purposes, such as textiles. Sisal, kenaf, hemp, cotton, straw and cellulose derivatives are amongst these. Developing country building science should focus major efforts in this field.

Recycled textiles insulation batts (wool + cotton, no glues)



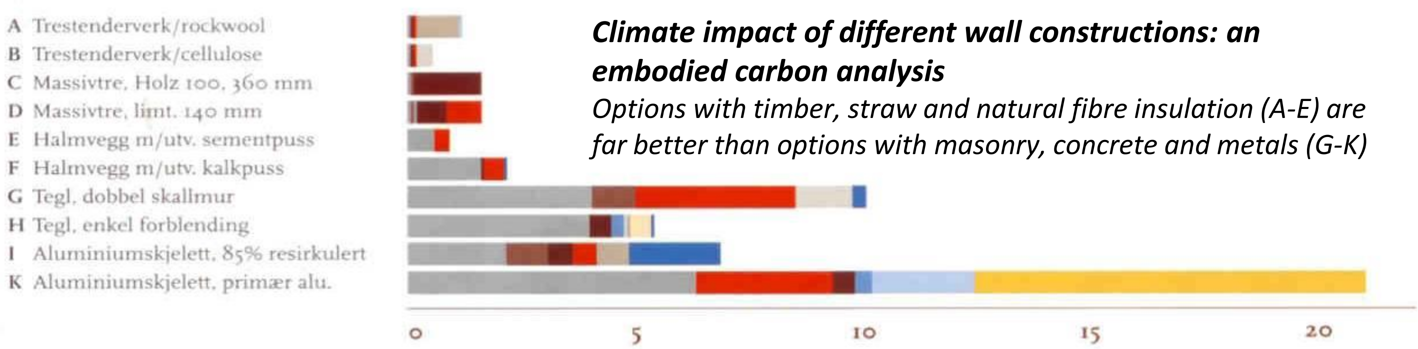
Ecology of Building Materials
Bjorn Berge
transl. Chris Butters, 2009
GAIA Norway. 2nd ed., UK
Elsevier / Architectural Press,

Low carbon construction products



Flow chart for synthretic polymer PVC: very high energy content, and very high eco-impact factor

Climate impact of different wall constructions: an embodied carbon analysis
Options with timber, straw and natural fibre insulation (A-E) are far better than options with masonry, concrete and metals (G-K)



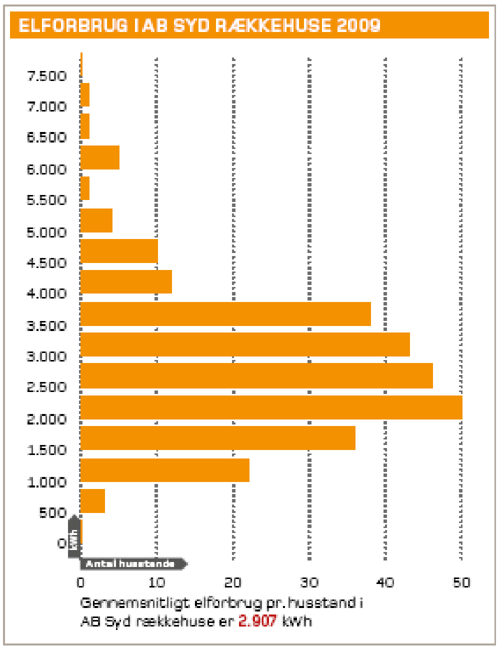
3e.Sustainable consumption – the human factor

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 awareness that technical solutions are not sufficient. This argues in favour of new, user-oriented technologies, and of simplicity in general; above all, for more focus in design as well as in policy, on the behavioural aspects of energy use and climate emissions.

Poor comfort, poor housing conditions and inappropriate technology can result in high energy use and climate emissions. For example, a study of poor communities in Peru found that "social fragmentation, material poverty and marginalization were working against people's wellbeing and making in difficult for them to live sustainably. The latter was exemplified by increased waste, extensive use of chemical fertilizers and growing deforestation".

One of many recent post-occupancy evaluation studies (POE) showing similar poor results was a large Cambridge study of several thousand low-energy houses in six European countries. It showed that the expected energy efficiency gains are far below what was calculated, due largely to cultural and behavioural factors [see box below].

Hence, sustainable consumption is a field that needs much higher priority in regard to energy policy and housing research.



Electricity use variations in identical apartments, Albertslund, Denmark: the importance of behavioural issues

One ton of CO2 …

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

•Building Research & Information, 40:3, 260-273. *(the "Cambridge study")*

•*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*

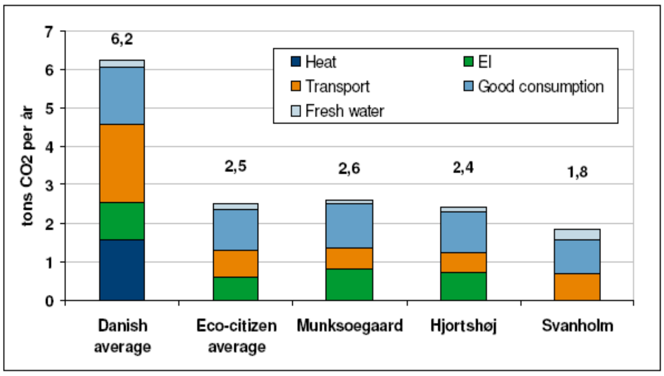


Figure 2: Average CO_2 emissions for a Danish citizen compared with citizens from the different eco societies

Sustainable living: ecocommunities have 1/3 of the resouorce footprint of the national average

4. Processes of change

Sustainable development and good planning are difficult anywhere; in many developing countries, planning and governance capacity are weak or absent. How then can good quality low impact and low cost housing be promoted?

Alongside gradual capacity building, only quite pragmatic approaches, attuned to local context, can succeed. Sustainable solutions are available, but success is a question of quite long processes. Where strong governance is unfeasible and public demand is low, authorities must gradually raise awareness and build dialogue with developers, backed with examples locally and from abroad.

European experience in pioneering eco-housing has shown that there are win-win opportunities where environmental and social ambitions can be raised whilst maintaining the "bottom line" of profitability. Green building is often hardly more expensive once established – though incentives are needed to achieve initial market penetration. Low energy solutions are good for everyone's pockets, both individual and public finances.

Many ecological solutions now have fairly short payback times. Developers can benefit from a greener image; and there is opportunity to become market leaders in view of future stricter environmental requirements.

There is a great dynamic in "community" processes. Involvement and participation of housing users has been a key feature of eco-housing successes.

Sustainable design requires holistic approaches to achieve all three essential facets of ecological, economic and social sustainability: This can be assisted by tools such as the Sustainability Value Map, illustrated below.

State of art eco-housing developments as well as large scale eco-city projects have often managed to achieve good, positive cooperation between planning authorities and business. This serves, equally, to promote interdisciplinary and inter-sectoral dialogue and planning. 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:

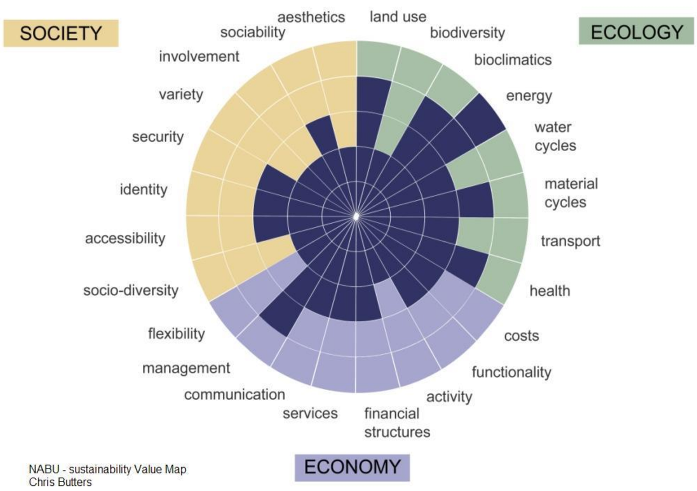
>> from segregated spatial zoning of cities to mixed use districts,

>> 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.



The Sustainability Value Map visualises the goal that all architecture and city planning should fulfil the three conditions of sustainability

Example: the Lindås passive houses, Sweden:

Energy: outstanding
Materials: very good
Cost: reasonable - good
Aesthetics: average
Management: excellent
Health: very good

5. Concluding remarks

Whilst the focus of our work has been different in the Asian and African contexts, there are still important comparative planning and policy conclusions to be drawn. This especially the case for less developed regions such as Africa, which in many ways is heading towards the same kind of development and similar kinds of urban housing and energy solutions as those we see in Thailand or China.

Should African housing and cities follow Thai or Chinese models? There are lessons to learn, both positive sides of current Asian policies, serious pitfalls to avoid, and encouraging design examples for hot climates.

South Africa (bottom picture): apartheid is gone, but much of the planning is still apartheid type planning!

As noted the aim of such a research program as ELITH cannot primarily be to *reduce* the very small energy use and climate impact of those at the bottom of the pyramid; we can at best aim to improve their poor living conditions without significantly *increasing* their housing costs and emissions.

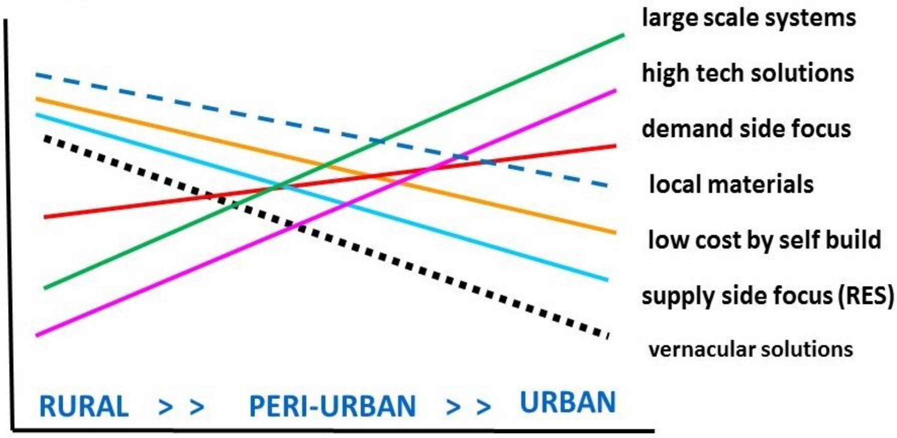
The other goal, however, equally important, is to *mitigate* the growth of energy use and emissions, the steeply rising energy consumption and climate footprint of the rapidly urbanising millions., in the hot climate developing countries.

Warwick / Low Impact, Low Cost Sustainable Housing in Developing Countries: Policy and planning priorities

-which solutions and priorities are most appropriate in rural, peri-urban and urban contexts respectively?

GAIA

Chris Butters



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