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

THE URBAN SCALE

The University of Warwick

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

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1. **THE URBAN DIMENSION**
2. **MITIGATION OR REDUCTION ?**
3. **THE URBAN SCALE**
4. **URBAN ENERGY AND CARBON**
5. **DISTRICT ENERGY SOLUTIONS**
6. **INTEGRATION OF 3 LEVELS**
7. **5CONCLUDING REMARKS**

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1. THE URBAN DIMENSION

Chris Butters, Warwick University, UK

--MORE THAN HALF GLOBAL POPULATION IS NOW URBAN

--THE MAIN GROWTH IS IN HOT CLIMATES IN DEVELOPING COUNTRY CITIES

--THIS IS WHERE THERE IS BIGGEST GROWTH IN ENERGY AMENITIES AND EMISSIONS (esp. cooling and transports)

--LIVING CONDITIONS ARE OFTEN VERY POOR

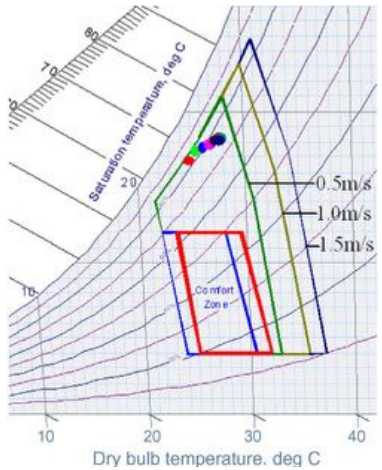
DEFINING COMFORT : STANDARDS FOR LOW INCOME?

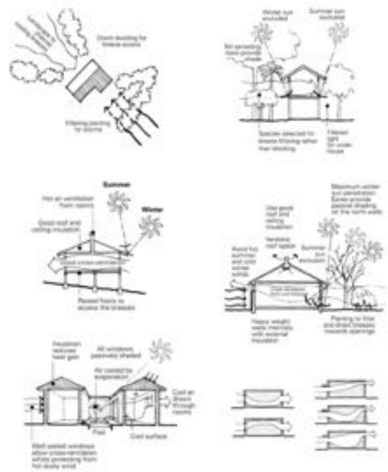
Our main focus is indoor environment, but outdoor urban environment is also a major factor in health and comfort.

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?





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THE URBAN SCALE: TRANSITIONS

…high quality high-rise is OK,but low quality high-rise is vertical slums !

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THE URBAN SCALE: TRANSITIONS

From living in a field to living in a cupboard? – Hong Kong

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THE URBAN SCALE: TRANSITIONS

… from growing crops to growing zombies ??

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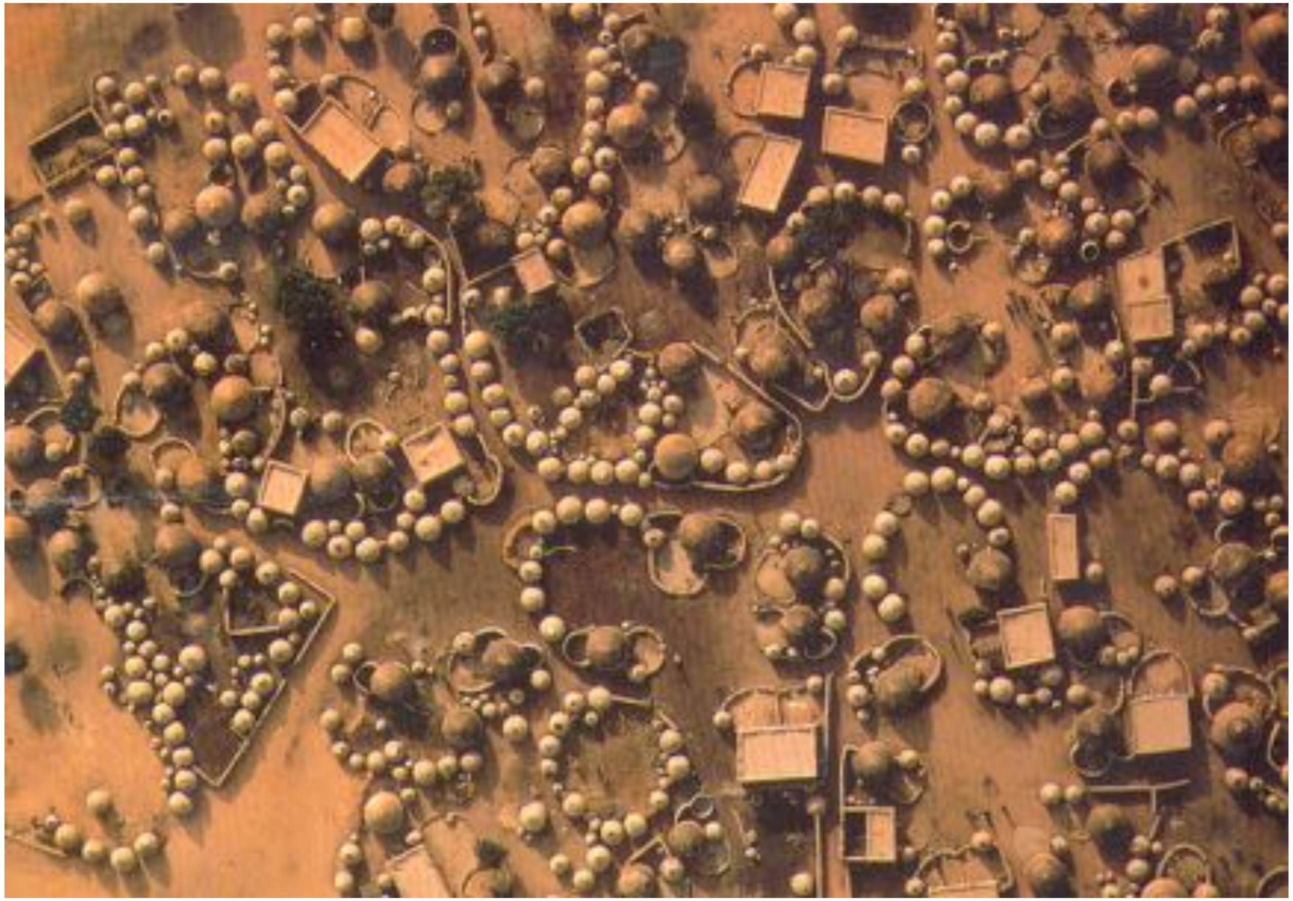
THE URBAN SCALE: TRANSITIONS

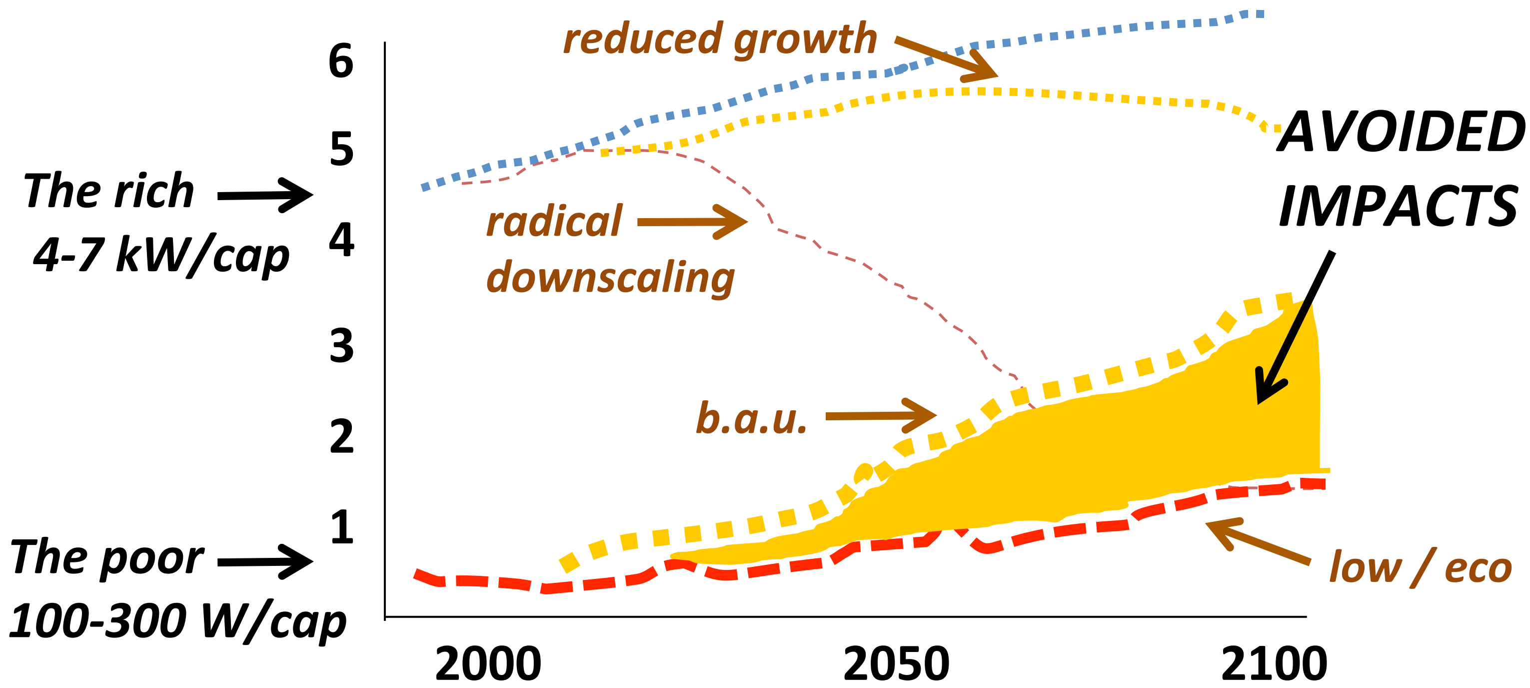
… breaking down long cultural patterns?



Mali village

2. 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.**



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3. THE URBAN SCALE: microclimate / energy / comfort

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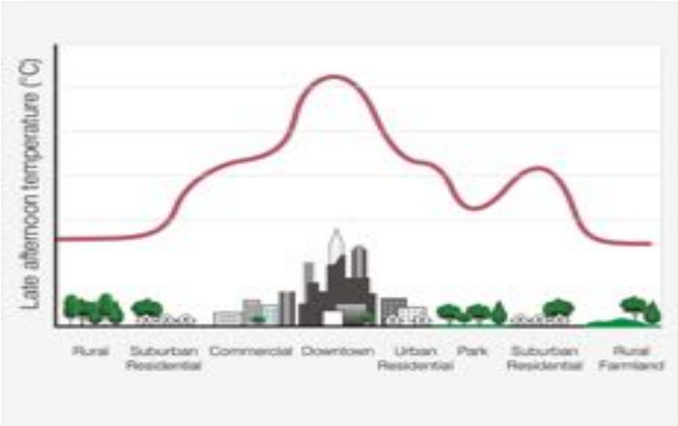
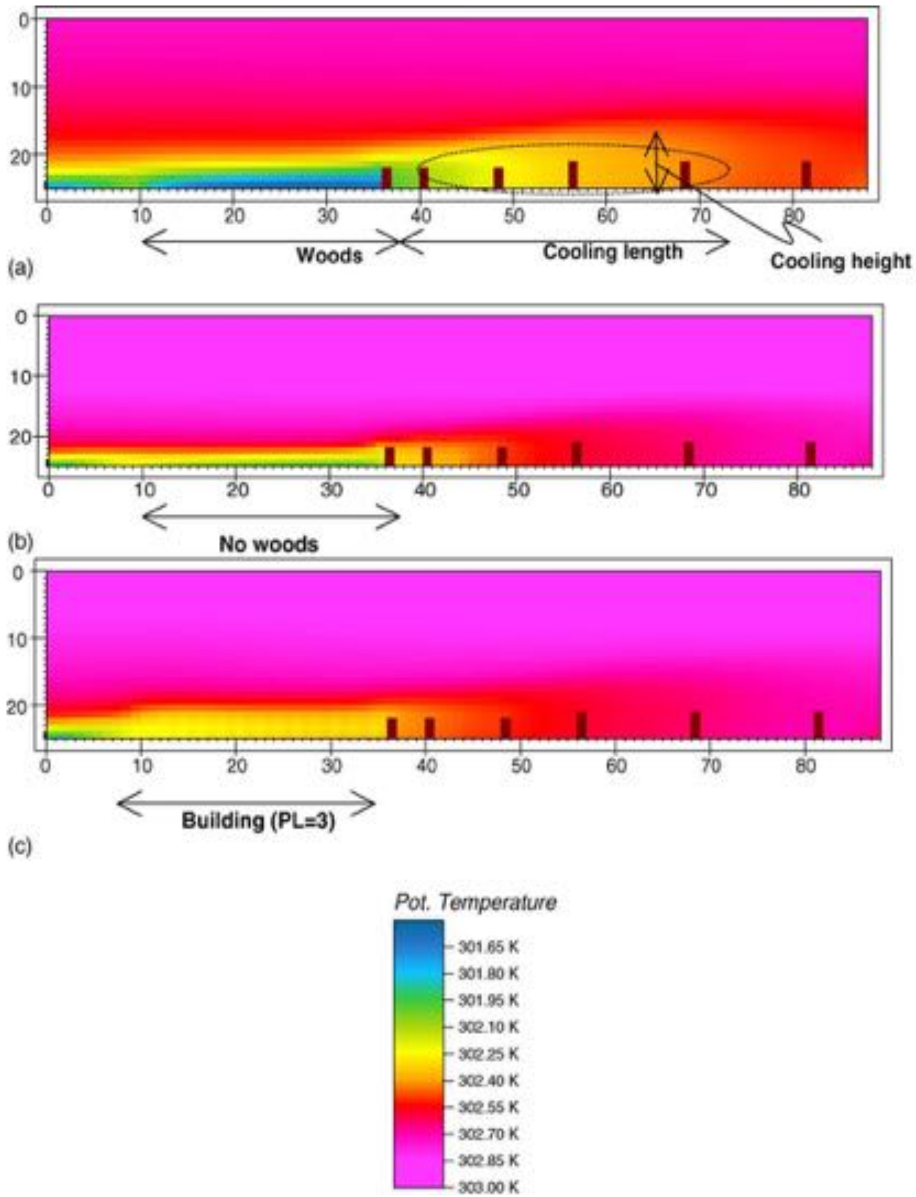
URBAN MICROCLIMATE



Urban Heat Island Effect: +2-5 DEGREES



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*

Integrated sustainable design **ECOCITY TAINAN**

Integration of 3 levels: Building design -- Urban design - Energy systems design

Master design by:
Archilife / EDS /
GAIA International

台灣
生態城市

永續城鄉模型

- ecology
- economy
- society

4.URBAN = HIGH 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).

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

Post-use impacts of recycling composite materials (RC)

4.Urban Embodied Energy / Carbon

Urban residential block, Ningbo, China:
--extremely high embodied carbon
--almost no energy efficiency measures
--poor social qualities, gated «islands»
Source: Butters/Cheshmehzangi, ELITH

4. Embodied Energy / Carbon

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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).

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4.THE URBAN SCALE: ENERGY / CARBON

From slum to low-rise urban to high-rise: 3 urban generations

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5. 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

5.DISTRICT ENERGY SOLUTIONS

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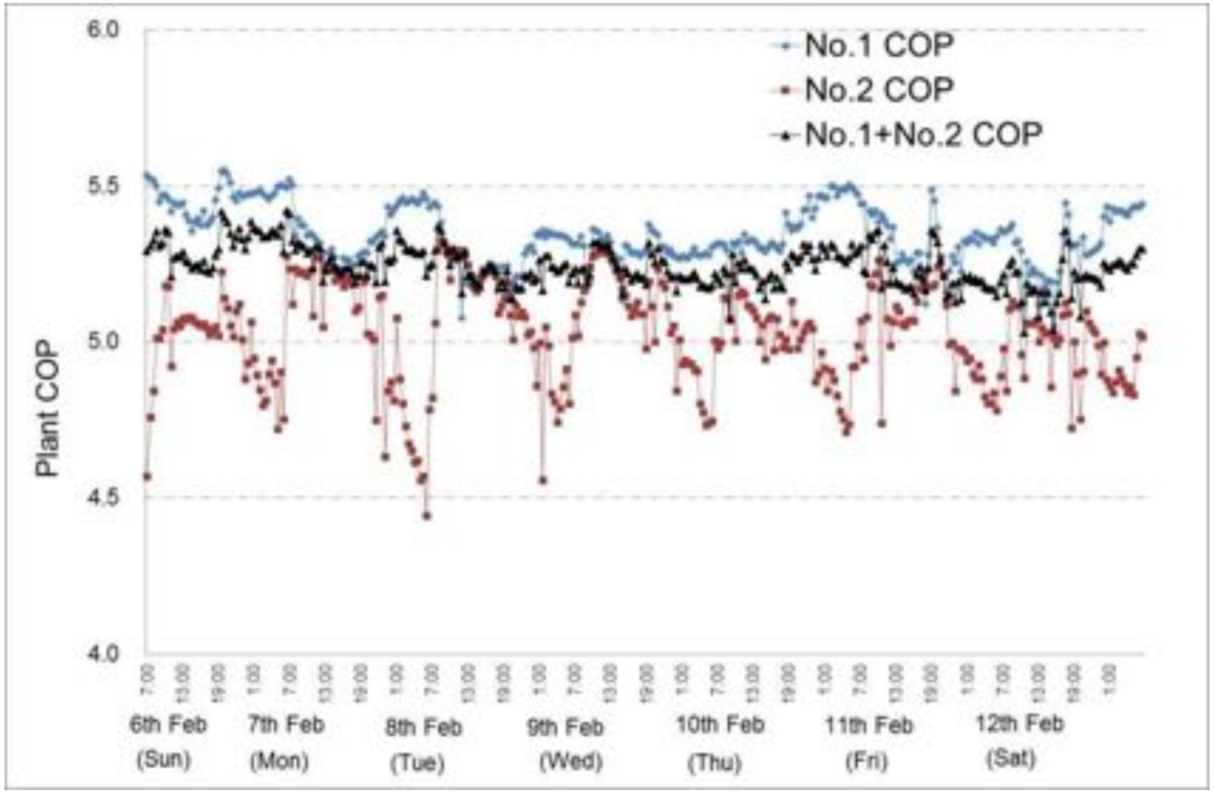
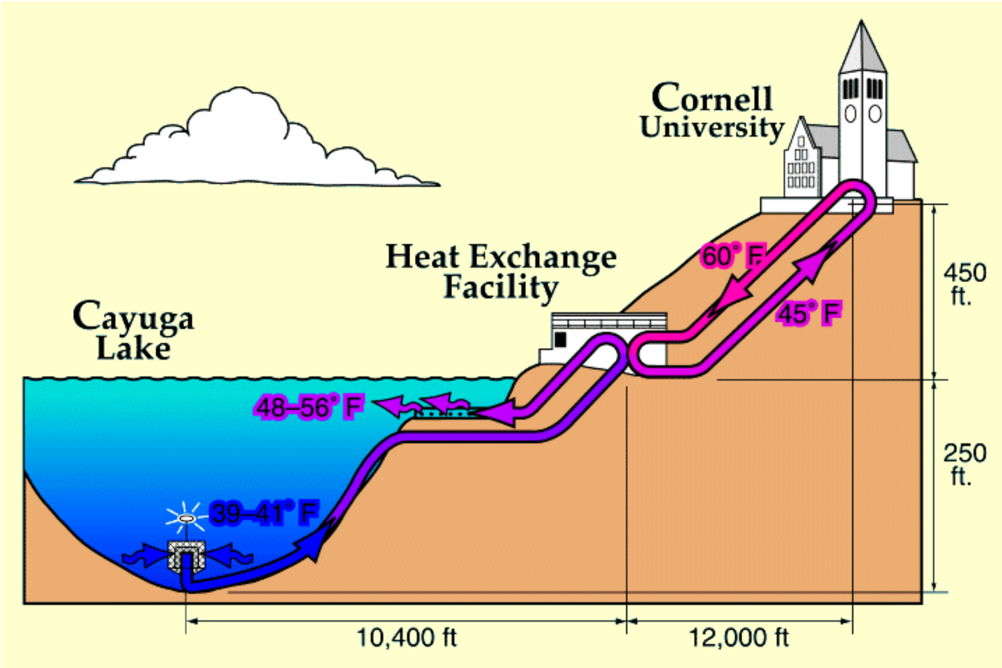
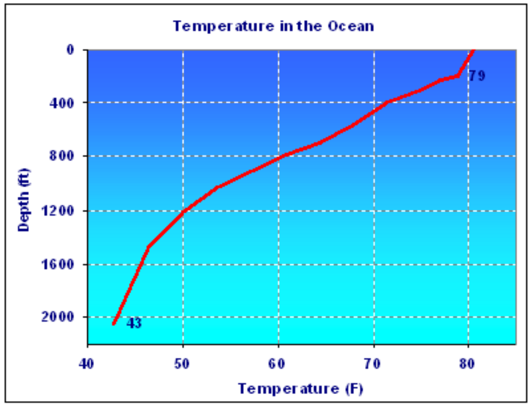
Singapore Marina Bay District Cooling System

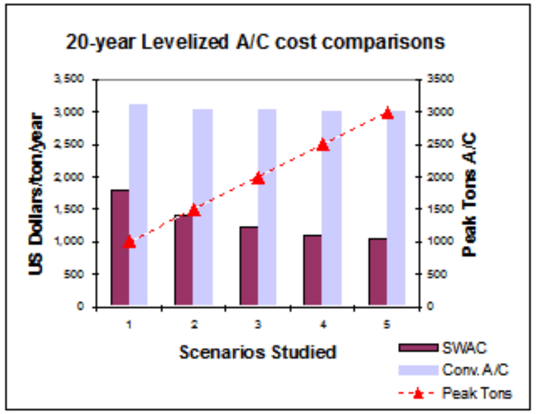
Plant overall COP (efficiency), measured data: Average 5.24
(small individual air conditioning units are seldom over 2.0



5.District Cooling - Cornell University, USA
(deep lake water system)



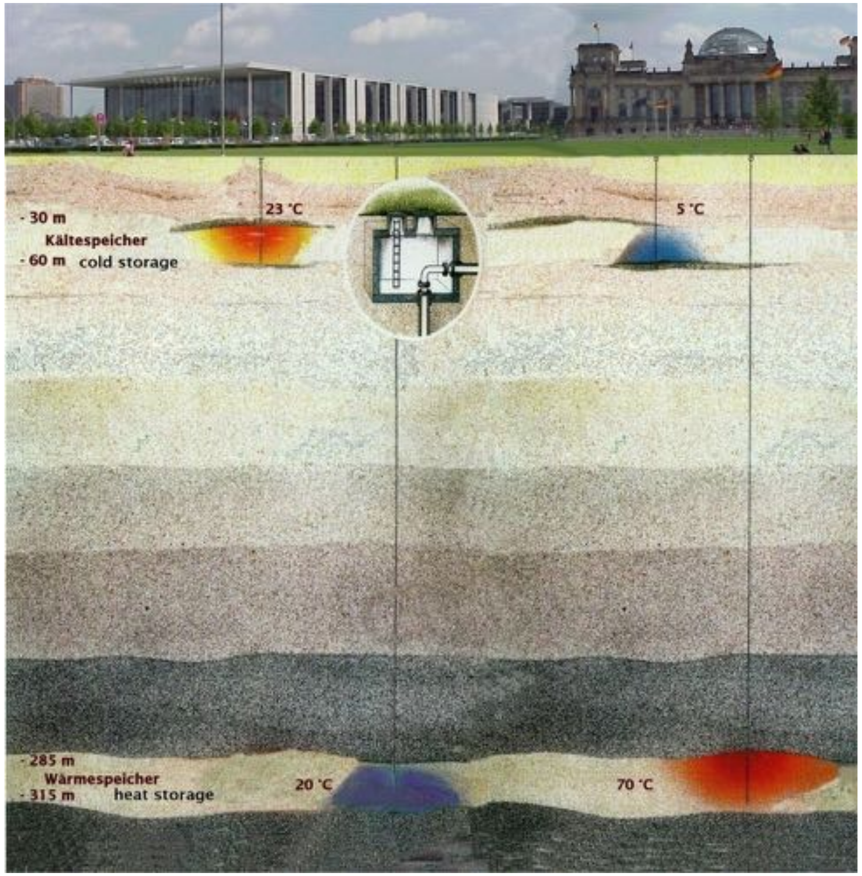




Over 85% primary energy savings
Much lower costs
Also provides fresh water supply
Very few environmental impacts

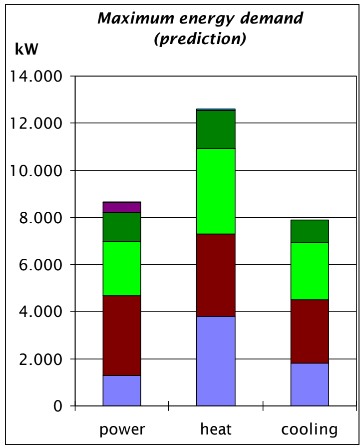
5. ENERGY SOLUTIONS

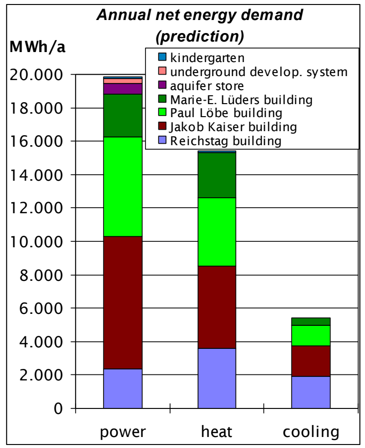
Spree River District, central Berlin
Seasonal Energy Supply System



Aquifer storage

District heating and cooling
with seasonal storage
of cold and heat





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District / Urban Scale

5.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), rivers OR underground
Large scale infrastructure planning

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6. THREE LEVELS OF PLANNING:

BUILDING – URBAN – ENERGY PLANNING

On which level are the best sustainable solutions? Why solve a problem as architect for an individual building, if it could be solved better and more cheaply at the level of the urban plan? Or by the energy systems plan?

Planning must be integrated between these three levels

Future cities: density / land use choices

start

WARWICK
SCHOOL OF ENGINEERING

Very high FAR in typical European city blocks.

Requires large public spaces fairly nearby

"Big, compact city" has no particular advantage for dph

Courcelles, Paris: SC 57, FAR 4.88
S/V 0.11 SC 57. Source: LSE/Eifer

Zafer, Istanbul: SC 55; FAR 3.14
Source: LSE/Eifer

WHAT KIND OF CITIES DO WE WANT, AND WHICH ARE MOST SUSTAINABLE?

FAR = floor area ration, SC = surface coverage, dph = dwellings per hwectare

6. For and against the ”compact city”

CSBSJU 1

Seen in terms of sustainability, compactness has some advantages. This is often used by politicians / developers to argue in favor of dense, high rise (and more profitable)

Some of the main arguments cited in favor of concentration are:

-It allows minimum land use	*(not correct)*
-High density of activities is dynamic, varied, productive	*(yes, but mega?)*
-Efficient and fully utilized public transport systems	*(in theory!)*
-Compact technical infrastructures, including DHS energy	*(but very costly)*
-Compact therefore energy efficient building volumes	*(not correct)*
-It facilitates walking distances and ”walkable cities”	*(not if full of cars)*

But taking sustainability in a holistic way, such as with the Sustainability Value Map, one sees downsides in compactness:
-Urban heat island effect
-Higher concentrations of negatives such as traffic, air pollution, noise
-Specialized urban space requires more in/out flows, imports and transports
-Land prices become very high
-Far more complicated technical solutions are needed
-Unfavorable environment for children (high rise living, stress, little nature)

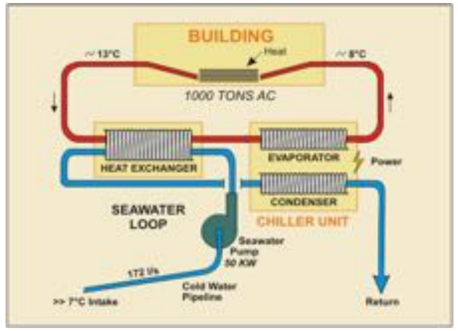
6. SUSTAINABILITY: ADVANTAGES OF LOW-DENSE

Environmental Impact Area:	Low-dense opportunities:
1. Inhabitant Density / Land Use	equal / some advantages
2. Microclimate and Green Space	advantages
3.Infrastructures and transport	both sides; some advantages
4. Energy Supply	both sides; advantages for RES
5. Buildings Typology	equal
6. Operational Energy	equal
7. Embodied Energy	advantages
8. Recurrent EE/EC	advantages
9. Post Use	advantages
10.Resilience	advantages

NB with obvious simplifications

THREE LEVELS: CLIMATE ADAPTED DESIGN AND LAYOUT, MEDIUM DENSITY + DISTRICT ENERGY SOLUTIONS

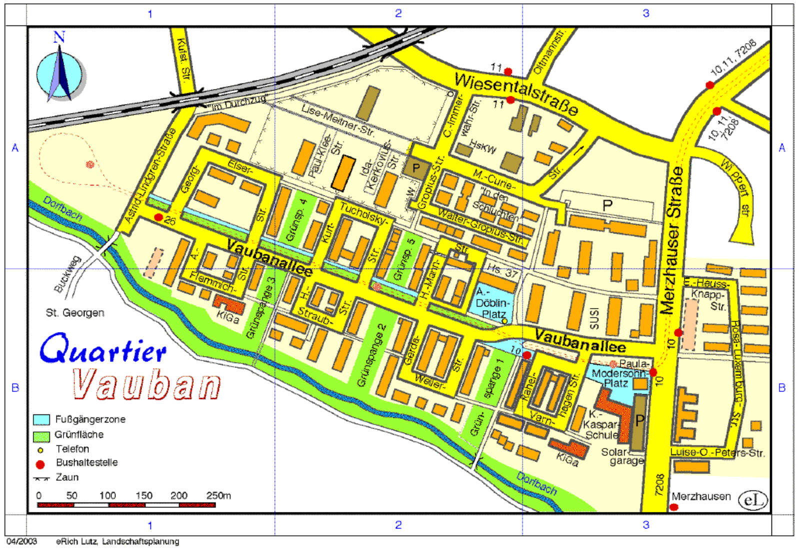
Proposal for Ningbo urban block, with District Cooling System

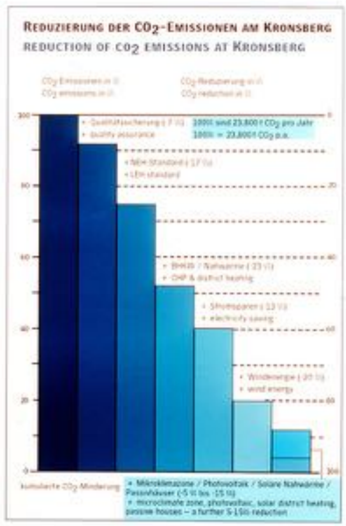


Central cooling from river water:
COP efficiencies increased from ca 2 to over 4
15ha, 5000 apartments, FAR=2.5
Source: Cheshmehzangi and Butters, ELITH 2016

6. Urban residential choices - ?

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





7. Concluding remarks

Asia / Africa: important comparative planning and policy conclusions can be drawn. Many developing countries are following similar urban housing and energy solutions as those in Thailand or China. Should they follow such models?

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

The goal cannot be to ***reduce*** the very small energy and climate impact of those at the bottom of the pyramid; we can at best aim to improve poor living conditions without significantly ***increasing*** housing costs or emissions.

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