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SUSTAINABLE URBAN DESIGN:
CONCEPT STUDY FOR A RESIDENTIAL BLOCK IN NINGBO, CHINA

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ENERGY AND URBAN FORM

The energy and climate impacts of urban development in the fast expanding cities of countries such as China is a major concern. In many countries development is not subject to energy efficiency or other environmental requirements and is being planned and constructed following outdated and very energy-intensive models. This implies a huge energy and emission burden for such cities in the future. In addition to environmental factors, typical housing developments often pose problems of poor quality including fragmentation, gated communities and social segregation. Sustainable urban layout and design can provide far better solutions without necessarily increasing the costs. A goal of our ELITH research program (1) is to spread awareness of such alternatives. By applying recognised green principles, both outdoor and indoor environments can be designed to provide an improved microclimate, increased comfort, and much lower energy needs. Selecting simpler types of construction and materials lowers the embodied energy as well. Why are more sustainable solutions seldom being applied?

Energy needs in hot climate buildings are increasing rapidly. With well designed, bioclimatic site layouts and architecture, as well as efficient appliances for lighting, cooking and so on, one can greatly reduce these needs. The main energy challenge is that of space cooling. The rapid spread of air conditioning (AC) represents the largest increase in energy use. But every individual AC unit rejects more heat into the city air, thus increasing needs for cooling, as well as the urban heat island effect (UHI) which is already a major health and comfort issue in many cities. Developing more efficient AC technology does not reduce this problem. This concept proposal illustrates what is almost the only solution to combat UHI in hot climates: district cooling (DC), which in addition to being far more efficient, can offer savings in primary energy of up to 80%. The crucial difference is to address the problem of energy for cooling, not with *individual solutions* of small AC units but *at the urban scale*.

This study is an outline only and does not illustrate energy efficient, bioclimatic design in detail. Our basis is pragmatic, taking as our starting point typical current trends of large, high-rise residential city blocks. Whilst we question that approach, they could be greatly improved with eco-design. Such solutions can reduce the lifetime energy and carbon footprint of typical urban developments by over half; using not advanced or experimental solutions but well-known technology. Adding renewable energy in the form of building-integrated solar photovoltaics can further reduce the energy needs.

PLANNING AND LAYOUT

Many recent city blocks are planned without consideration as to improving urban microclimate, maximising local breezes or enhancing outdoor conditions with the help of the layout, landscaping and vegetation. The high-rise buildings themselves are often poorly oriented with regard to sun and wind and have one-sided apartments with inadequate daylighting and little or no cross-ventilation. In addition, most high-rise structures are extremely carbon intensive (mainly concrete, steel and glass) and lack even simple energy measures. Some greener options are directly cost saving, and others are inexpensive. These are missed opportunities where the only major requirement is better awareness and planning amongst investors, property developers and designers.

Whilst we do not address the issue of urban transports here, it is well known that the overall urban layout and location of work/residential/service zones also has a major impact on energy use in cities. Core principles as to mixed use zoning and sustainable mobility are well established in recent ecocity experience, although difficult to implement as long as the private car remains such a high priority.

DO WE NEED HIGH-RISE?

Chinese and other developing cities often aim for a very high density. Following an analysis of various urban typologies and of cities elsewhere, including successful recent European ecocity districts (2), we posit a density or floor area ratio (FAR) of around 2.5 in this study. This is somewhat lower than some recent Chinese high-rise neighbourhoods, but we consider that residential densities above FAR 3,0 can imply a range of environmental as well as social disadvantages. It is notable, however, that traditional low-rise European cities often achieve this density or even higher – up to FAR 4,0 in parts of Paris for example (3). There is thus *no inherent need to go high-rise* in order to house large populations.

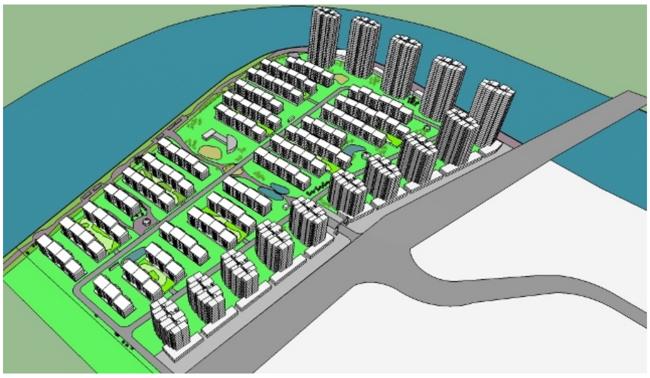
We have therefore chosen to illustrate an urban block layout which has elements of high-rise as well as low-rise solutions. This offers comparisons, and illustrates significant climatic and energetic – as well as economic and social – advantages of low-rise options.

High-rise is not cheap. It necessitates complex structures and is particularly expensive in relation to factors such as fire safety, ventilation, façade maintenance and, ultimately, demolition. Typical high-rise residential blocks are virtually gated communities, and even where they are provided with a few common facilities these are often underused. It should be remembered that the additional green space offered by high-rise layouts is not a "natural" environment, but usually only a thin green layer on top of heavy concrete underground parking garages. The open landscaped areas are often attractive but of very limited functionality, designed for aesthetics rather than to improve the microclimate. By contrast, the classic European city has equal – or higher – population densities, but green open spaces are provided mainly in the form of large (and fully public) urban parks, within a short distance, which provide more functions and social meeting places as well as being genuinely green and large enough to ameliorate the city microclimate.

THIS STUDY: PRAGMATIC CONSIDERATIONS AND RELEVANCE ELSEWHERE

The present study illustrates one large city block in Ningbo, China. The choice is again pragmatic due to our base being in Ningbo. Whilst our key concern is hot climate cities, Ningbo is hot in summer but has some winter heating need; the principles embodied in our study have *even more* relevance in hotter climatic contexts. Similarly, the cooling system shown is in the Ningbo case based on river water, but such DC systems will be *much more advantageous* in other, hotter locations especially with a large heat sink such as near the ocean. Large DC systems can already be found in a few Asian locations such as Singapore, and in the Middle East.

Similarly, we do not question here the basic model of high-rise. We have discussed elsewhere (5) how that model has problematic implications for sustainability, not least for embodied energy/carbon, both due to their technical complexity and the necessity for vast underground parking structures.



DESCRIPTION

On a riverside site of about 15 hectares in Ningbo, presently vacant, we illustrate a layout comprising around 370,000 sq. metres of residential building, containing some 4,600 apartments, with a few common facilities and, as is the custom, some commercial premises along the edge. This equates to a FAR density of 2.5. There are extensive areas of green space between the buildings and along the river shore. The layout is designed to maximise prevailing local breezes, as well as to ensure access to sun in winter and solar protection in the hot seasons.

It is stressed that the proposal is an outline only. Detailed site layout and design depend on specific local studies and simulations of seasonal insolation, wind and air movement, maximising site ventilation, selection of appropriate vegetation, permeable and reflective surfaces, optimising stack effect, noise reduction and other parameters.

About half of the apartments are in fairly high-rise towers; but in contrast to common practice, these are designed so that nearly all units have light and ventilation from at least two sides. Overhangs and balconies provide summer shading as well as enhancing air flow. There are almost no units with exclusively north facing exposure, which commonly fetch considerably lower prices. It is notable that many current high-rise developments do not even adopt such basic measures that would not only improve the living qualities and energy picture but give higher profits.

The high-rise part of the site requires large underground parking areas. Facilities such as common rooms, gym etc., are located in the bottom floors of these towers, and a kindergarten is provided on the site with access to playground, gardens and riverside. The low-rise (4-6 floors) part of the layout illustrates a simple and cost-effective building typology. Here, parking is only partly underground and is inexpensive since most of it forms the necessary foundations and base walls of the *buildings themselves*: whereas in the high-rise case the underground structures extend far beyond the buildings. In the low-rise solution, ground floor apartments are raised one metre above ground level, providing privacy but equally to enable cross-ventilation through the garages. With this typology, the area required for parking corresponds to no more than the floor area of the buildings themselves.

Note that in this low-rise layout, *all apartments* have access to sunlight and there are *almost no facades* that receive troublesome east or west sun. Similarly, these low-rise buildings can be shaded (for free) by moderately tall trees, whereas this is impossible for high-rises. Crucially, all apartments are cross-ventilated. The solution provides apartments of various sizes and flexibility for different tenants. For the elderly and wheelchair users, access with lifts is provided in a fairly small percentage of the buildings. The spaces between the low-rise rows form semi-private "courtyards" with social functions.

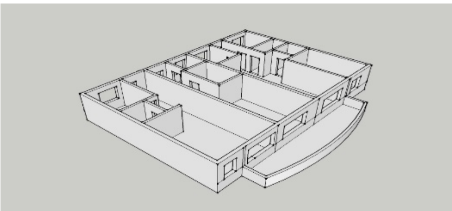
ENERGY AND CARBON

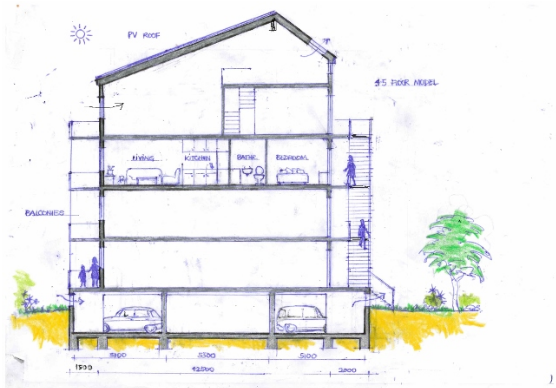
The buildings themselves are designed using passive strategies to reduce energy needs. The low-rise option also means one can use simpler construction materials with considerably reduced embodied energy/carbon. Given a low-rise typology, photovoltaic solar systems on the south facing roofs could provide most or all of the remaining low energy requirements. Solar roofs on high-rises by contrast would only provide a fraction of the energy needs. All units are cross-ventilated. Ceiling fans, which consume very little energy, can further provide a cooling effect of about 3 degrees. In both the high-rises and the low-rise blocks, all stairwells are, further, designed to enhance stack effect ventilation and contribute to passive cooling of the buildings.

Undesirable internal heat gain in the apartments, especially from cooking and lighting, are also minimised. This is achieved partly by selecting the most energy efficient electrical appliances and LED lighting, plus ensuring better natural daylighting than in typical high-rises. In the low-rise blocks, provision is also made for balconies where some semi-outdoor cooking can be done during the hot seasons.

As regards embodied energy (or carbon), materials choices can greatly reduce this part of the resource footprint of buildings. But it is much easier to use low carbon materials *in low-rise* structures. In high-rises it is difficult to avoid reinforced concrete and steel. These two materials alone often constitute more than 75% of the total embodied carbon in large buildings. Even so, the embodied footprint of the high-rises is also significantly reduced in this proposal compared to current models. Note also that high-rise necessitates large areas of underground parking. These structures, and the thick concrete decks above them, are both very expensive and extremely carbon intensive, and may contribute nearly as much carbon as the structures above ground. This little noticed issue – the carbon footprint of site infrastructures - has been explored by us elsewhere (4).

Hence, a range of design features contribute to low energy needs. The site landscaping, vegetation, water features and overall layout also provide cooling, maximise site ventilation, and there are a minimum of hard paved surfaces which increase temperatures. The site as a whole has a minimum of internal roads and no surface parking except for services and deliveries, plus along the main street shopping zone – outside the residential zone itself. The low commercial podium along the street also serves as an acoustic buffer for the residential zone. The energy plant with the river-based cooling system is located on the bend in the river.





Top left: concept layout, typical high-rise floor.
Bottom left: concept layout, low-rise floor.
Above: section sketch for low-rise, showing cross ventilated basement garage and solar PV roof.

DISTRICT COOLING

As described in a separate paper (5), district energy systems can be extremely favourable. District heating systems (DHS) are becoming more common now in temperate climates: in some cities there are district energy systems that provide both summer cooling and winter heating. However, district cooling systems are as yet little known. The source of cooling may be sea, river or lake water or the underground; they use standard heat exchange and distribution technology. It should be noted that rejecting the waste heat to the sea or a large river normally has negligible ecological effects at this scale.

In regard to energy and climate emissions, DC has three main advantages. Firstly, the larger scale offers efficiencies double that of small AC units. Secondly, the cooling source, such as river water, is at a lower temperature than the ambient air in the hot season, and this difference ("delta-T") again provides a large energy saving. Thirdly, not least, the waste heat is rejected outside the city itself – in this case via the river – so that there is *no heat island effect* as with thousands of individual AC units; on the contrary, the system contributes to cooling the whole local environment.

CONCLUSIONS

The expanding cities of hot climate developing countries are the fastest growing source of energy consumption and climate emissions. Much of what is being built today is of an outdated and very inefficient standard. One might say that these buildings already need energy efficiency retrofitting on the day they open. This represents a huge missed opportunity; cities are locking themselves into huge future energy and climate burdens. Whilst only illustrated briefly here, the study suggests that these can be avoided by better planning; and that this *does not require* new knowledge, nor vast added costs, nor advanced technical solutions.

High-rise city ideas are still popular. This may be desirable for central business districts, but for residential areas there are a number of serious potential disadvantages, both social, economic and environmental. Further, one may achieve equally high population densities with low-rise typologies. It is not difficult to plan and build much more sustainable housing. Such solutions can be equally profitable for developers. The potential energetic and climatic savings to the cities, to consumers and to society as a whole are very large indeed. Given growing political commitment to energy and emission reductions, it is imperative that solutions of this kind be better understood and widely applied.

Chris Butters and Ali Cheshmehzangi
Warwick University / UNNC Ningbo, ELITH, 2016

References:
(only a very brief selection of sources are provided here)

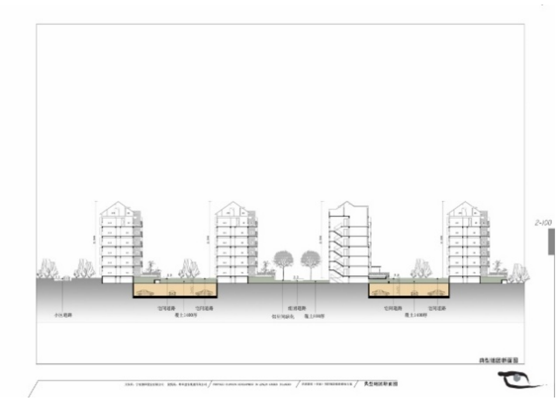
1.ELITH: *This document is an output from a project co-funded by UK aid from the UK Department for International Development (DFID), the Engineering & Physical Science Research Council (EPSRC) and the Department for Energy & Climate Change (DECC), for the benefit of developing countries. The views expressed are not necessarily those of DFID, EPSRC or DECC. Grant number: EPSRC EP/L002604/1.*

2.See several papers/articles on the ELITH website under UNNC China, WEB ADDRESS

3. LSE Cities/EIFER (2014). Cities and Energy: Urban Morphology and Heat Energy Demand, Final Report, London.

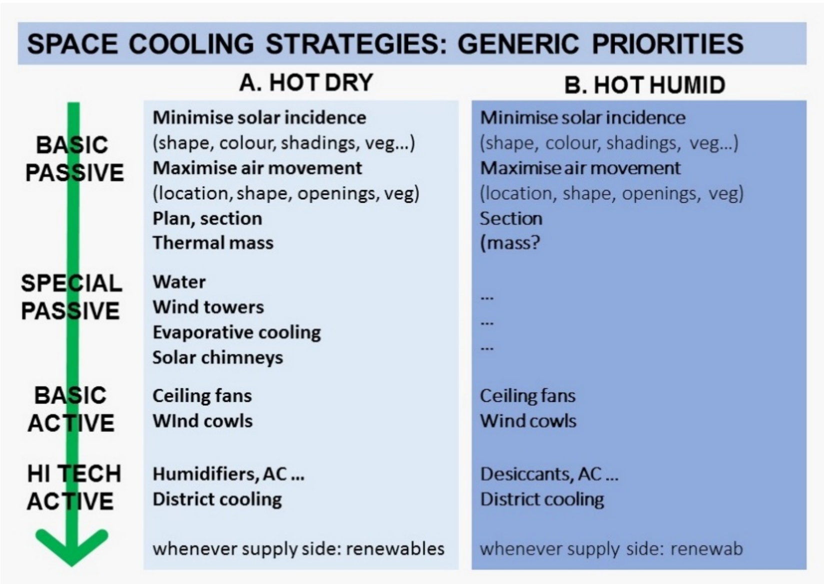
4. *The Carbon Impact of Site Works and Infrastructures.*Butters (BRI submitted).ELITH, 2016. C.Butters, T.H.Thomas, Warwick/ELITH, 2016. See ELITH publications W07.

5. *District Cooling.* C.Butters, Warwick/ELITH, forthcoming, ELITH W05.



A similar China low-rise typology (but note the parking here is not combined with the building basement, and is not cross ventilated)

Typical residential high-rises, Ningbo, China



Chris Butters: Design Principles for Cooling. ELITH 2015.
Passive cooling solutions should always be the priority.
Note that there are fewer options in hot humid climates