

Research in Architectural Engineering Series, Volume 10

THE FUTURE ENVELOPE 3



FACADES - THE MAKING OF

edited by Ulrich Knaack and Tillmann Klein

Prof. Brian Cody leads the institute for buildings and energy at the University of Technology in Graz since it was established in 2004. His focus in research, education and practice is aimed at maximising energy efficiency of buildings and cities. Along with his work at the University of Technology he continues to serve as a scientific advisor for Arup. He directs his effort in describing how energy will become a new design parameter for future architecture.

FORM FOLLOWS ENERGY -

ENERGY EFFICIENCY IN ARCHITECTURE AND URBAN DESIGN

Brian Cody

TU Graz / Arup GmbH

Today "energy efficiency" is on everyone's lips. This term is however unfortunately often misused, abused and confused with the terms "energy demand" and "energy consumption". This is especially true in the building sector, where low energy consumption is often falsely equated with high energy efficiency and where a lot of effort in research and practice is directed towards minimising energy demand and too little towards maximising energy efficiency. This misconception of the term "energy efficiency" is fundamental and needs to be corrected in order to avoid future misguided developments. Maximising energy efficiency is more than simply minimising energy consumption. Efficiency implies performance. Efficiency is the relationship between output (benefit) and input (resources). The key issue is the quality of the benefit provided as a result of the energy "consumed".

In the context of the thermal performance of buildings, energy efficiency should be understood as the relationship between the quality of the thermal environment and energy demand. Regulatory devices for the energy efficiency of buildings currently in use, including the new EU "Directive on the Energy Performance of Buildings" unfortunately deal only with energy demand and not with energy efficiency. At my institute we have developed a method, called BEEP (Building Environmental and Energy Performance) which allows the true energy efficiency of a building design to be determined and thus a real comparison of various building design options. Energy efficiency is understood here as the relationship between the quality of the internal thermal environment in a building and the quantity of energy consumption required to maintain this environment.

A second misconception, particularly frequent in central and northern Europe, is the focus on heating energy. This is probably a result of cultural background. Humans are essentially a subtropical species and for those who arrived in regions like central and northern Europe, where the climate is, at least for a large portion of the year relatively cold, the

climatic challenge in the past was to achieve reasonably warm indoor temperatures for living. This line of thought tends to dominate our thinking still today, even though it has little to do with the reality of the buildings we need and use today. Modern buildings do not only need to be heated but also artificially lit, ventilated and increasingly cooled. This has only partially to do with the architectural concepts employed and largely results from the changed requirements due to modern usage of spaces. Heating energy demand in a modern office building for example accounts for only a fraction of the total energy demand of the building.

The third misconception in the current discussion is that there is too much emphasis on quantities and not enough on qualities. It is important to consider not only the quantity of energy "consumed" in a specific process but also the quality. Heat energy at a temperature suitable for space heating is for example a comparably low grade energy form. Electricity is a high grade energy form. When comparing energy efficiency of different options we need to consider the quality of the energy quantities involved. Values for delivered energy or site energy are not suitable for such comparisons. Primary energy consumption or CO₂ emissions are better. The exergy concept can also prove useful to understand better the implications of various solutions and compare their efficiency. In thermodynamics the exergy of a system is defined as the potential of a system to do work during a process that brings the system into equilibrium with a heat reservoir, normally its surroundings. A research project at my institute has shown that mechanical ventilation systems with heat recovery systems in office buildings, as employed in many European countries with the intention of saving heat energy do not in most cases make sense in energy efficiency terms as the heat energy saved is more than compensated for by the electrical energy required to power the ventilation systems.

A fourth misconception is that when various alternative solutions in the building context are compared with each other, too often only the energy efficiency in operation is considered. We need to think more holistically. The total energy efficiency including manufacture, construction and disposal needs to be considered in most cases. Recent research has for example shown that in many built buildings employing double facades to improve energy efficiency, the time taken to recover the embodied energy of the second skin via energy savings in operation can be in the order of 25 years. This amortisation period was calculated purely in terms of primary energy, the economical payback period is substantially longer. The low energy and so-called passive house concepts in the residential building sector so loved by the popular media

at the present time are a classical example of this problem. The resources input (increased building volume and embodied energy due to thermal insulation, triple glazing, mechanical ventilation systems etc.) outweighs by far the benefit of the reduced heating energy demand in operation. The use of electrical energy to power the mechanical ventilation systems in these buildings with the intention of saving heating energy is also problematic (see above). Furthermore, the starting point for energy efficiency is in urban design and not in a solitary building.

The most energy efficient building in the world is absolutely ineffective if not integrated into an energy efficient urban structure. Optimising urban density must be a key component of any future strategy to maximise energy efficiency. This has only partly to do with the reduction of transport energy. The present use of land itself is not sustainable. An aspect which is particularly interesting with regard to energy efficiency in urban design is the possible contribution which tall buildings could make.

Results of a research project at my institute indicate a potential for increasing the energy efficiency of cities by the use of tall buildings in urban developments. We showed that the urban density can be increased by the use of vertical structures by a factor of nearly two compared to traditional European city configurations while avoiding the usual technical problems associated with high rise buildings; daylight access, reduced area efficiency due to enlarged cores, discomfort at pedestrian level due to environmental winds etc. After proving that high rise buildings can increase density and thus potentially reduce energy consumed by transportation, the next question is whether they can really increase total energy efficiency. On first sight, high rise buildings appear to have inherently low energy efficiency in their operation. This is mainly due to wind related issues. On account of the increased wind pressures due to height, external solar shading and natural ventilation with operable windows become difficult and thus all tall buildings to date employ mechanical ventilation and air conditioning. Therefore, strategies allowing natural ventilation of tall buildings offer significant potential to improve energy efficiency.

For the new headquarter building of the European Central Bank in Frankfurt we developed a concept which would enable the building to be exclusively naturally ventilated and allow us to dispense with mechanical systems completely. We have since developed these concepts further in a research project where we have demonstrated the feasibility of concepts to avoid mechanical ventilation completely in very tall buildings. The benefits of these concepts are: increased energy efficiency in operation, reduced

embodied energy (ventilation system, plant rooms, shafts), lesser risk of Sick Building Syndrome, savings in running costs (energy costs, maintenance and operation) and savings in capital costs (system, plant rooms, shafts). We have just started to work on a research project concerned with the nature of the relationship between different forms of teleworking and total energy efficiency in society.

In recent years the use of new forms of working has unquestionably increased energy consumption. There is a potential however to use these new parameters to generate radically new forms of building and transport systems with the aim of increasing total energy efficiency. To study this we are not modelling the energy performance of building or city structures but of typical corporation and company structures. There is a huge potential for increasing energy efficiency by architectural means by developing concepts for usage neutral spatial structures which enable adaptation for varied uses during the lifetime of a building. The days where a new build residential apartment block is by design condemned to remain a residential apartment block, on account of its floor to floor height and its structural, facade and circulation systems, must soon come to an end. Another issue is the degree of utilisation of our building stock. One look at a typical city in the western world quickly reveals that the percentage of time that any particular building is in use, is very very low. If we begin to think about buildings in this way, building design parameters will also radically change. One small example of this is the fact that the 24/7 use of buildings means that concepts employing thermal mass may no longer make much sense. While we are naturally primarily concerned with the issue of increasing energy efficiency with the aim of stopping global warming, an interesting question poses itself with regard to the seemingly inevitable climate change which will occur and how this will effect the design of our buildings; in other words, how must we design our buildings to cope with the effects of impending climate change?

In a recent research project we examined the influence of the expected climate change on the heating and cooling demand for buildings in Austria. In the future we will need to look more closely at possibilities for integrated building and transport systems. In a project on the coast of the Adriatic sea we have developed a total energy concept for a carbon neutral development on an peninsula with an area of approx. 100 hectares. In our proposed solution the energy demand of the entire development including all buildings and vehicles is supplied by on-site renewable energy sources. The use of solar and wind energy, rain water, even waste water and garbage are integrated into the more or less closed system. We are

proposing an integrated building and vehicle network; an Energy Grid. An interchange building provides the transformation from the primary conventional system outside the site to a secondary transportation system on the peninsula comprising electrical taxis, in which the batteries are recharged by renewable energy. A combination of centralized plant and decentral building integrated systems supply the Energy Grid with renewable energy. Buildings and vehicles are connected together via the Energy Grid. Both buildings and cars can extract and supply energy to the grid. When using renewable energy sources, energy storage systems are a vital component of the total system in order to match supply and demand and the cars thus partly fulfil this important function by providing storage capacity. We are also using the topography of the site to store energy by using excess energy produced by solar and wind sources to pump water to the highest point of the peninsula and store it in a large reservoir. This potential energy in the form of water mass can be used, when required, to drive turbines and generate electrical power. This system is also combined with a system for collecting and using rainwater. Sea water is used for cooling purposes. Solar cooling systems employ solar energy to drive absorption chillers.

Concentrating the urban development in densely built villages means that a large part of the peninsula can be left in its natural condition, the biodiversity can be preserved to a large extent and the transportation demand can be minimized. Solar geometry and wind analysis are used to generate urban morphologies which provide pleasant microclimatic conditions in the external urban spaces.

A central issue in my work in research and practice is the relationship between built form and energy efficiency; summed up in the phrase Form follows Energy. When aspects relating to energy efficiency are considered right from the start of a design process, new and interesting possibilities for form language and form result. Many built examples show this already. In any case, there is always a relationship between architecture and energy. Whether Form follows Energy or energy follows form; the energy efficiency of a building is influenced to a large extent by its architectural design. All of these aspects will have huge implications for the design of future facade systems. Using case studies and based on the results of recent research work these themes will be explored in my talk.