ARCHITECTURE AND ENVIRONMENT ECOLOGICAL BUILDING DESIGN RECOMMANDATIONS FOR ONE FAMILY PASSIVE HOUSE DESIGN

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ABSTRACT

Ecological issues had begun to command a higher profile on the international agenda at early nineties. Ecological architecture deals with different scopes in different studies. This study examines the ecological architecture and the *passive house concept*. Four main physical design components have been classified for study's structure; site selection and planning, ecological design, energy and resources and waste. The social design components left out of the scope because of variability of them according to specific cases. Basic design principals of a passive house are defined at the end of the study. In this context, the recommendations of this study can determine a new architecture which tries to balance the emotional institutional design and the analytical design components and this knowledge can be used in any design studies.

Keywords: Passive House Concept, Ecological Design, Energy Efficient Building

INTRODUCTION

The buildings of the twentieth century were built on the basis of function, aesthetic and/or technology. With the technological developments, designs can be made independent of climatic conditions, buildings can be constructed which heat, cool and ventilate mechanically and have high comfort levels. However, energy usage increased in these buildings which don't consider physical and social environmental systems.

The result of this attempt to use resources which are the products of billions of years of solar energy within what is relatively a mere instant has been, conversely, to spew more substances and energy into the environment than the planet is capable of digesting, throwing the entire global ecosystem out of balance. All over the world we are finally beginning to recognize the threats to civilization like abnormal weather, pollution in the air, water and ground etc.

In this context by the early nineties *ecological issues* had began to command a higher profile on the international agenda. The basic terms of ecological architecture are the careful husbandry of energy and resources and their more effective use in ecologically sustainable forms. Changes are taking place on many levels - on an urban scale, in individual developments and in building components - as well as in planning methods and procedures.

METHODS AND MATERIALS

The new environmental consequences create a new architecture. This new architecture will be highly rational a highly functional, but it will look extremely different from the usual images of modern architecture. The underlying principal of any energy optimizing design strategies must relate to: *natural existents and needs* and also *social existents* and *needs*. In this case, it must: firstly reduce the social and physical high demands and secondly provide the energy required, if possible, from a renewable source, thus creating a self sustainable/ecological system.

The questions to answer should be: What are ecological architecture and passive house concept?

In the architectural history there are also many architectural styles, modernism, post-modernism, deconstructivism or any other 'ism' of architectural aesthetic styles. But environmental-ecological design is more a philosophy and a manifest in building design ideology rather than a building style.

Ecology is defined in this paper as the study of the interactions between organisms and their physical and social environment. Under all organisms only people have the ability to control the movement of energy and material between their internal and external environments. The architect can adapt the buildings in order to use the water, energy, heat, light and resources available in different environments and climates to sustain life in the multiplicity of ecosystems. Ecological architecture sees the buildings as a part of the earth and the passive house as a segment of the living habitat.

In this context the second question is: How is this to be done?

Three principles which all ecological building and/or passive house concept should be based on are:

- Design for climate
- Design for the physical and social environment

- Design for time, the using of contemporary technologies

The physical design components which constitute the ecological architecture and passive house concept are categorized in different times, in different researches from different researchers with different classifications. In this paper, four main design components have been classified for study's structure;

- Site selection and planning
- Ecological design (Building form, Building orientation, Space organization, Building Envelope)
- Energy & Resource
- Waste

Because of the social design components are governed by the different life styles and roots of peoples, they must be taken into consideration for each design work.

THE PASSIVE HOUSE CONCEPT

Sue Roof defines the passive house concept as follows:

> "The passive houses are not ordinary houses. They express, in their varied forms, the local climates, resources, culture and the tastes of their designers, as well as the design ethos of the times in which they were built. The temptation to 'innovate' can often lead us unwittingly into problems, but from them we learn. For example, the early solar houses often overheated because, in the rush to utilize free, clean solar energy, the dangers of the sun were underestimated. The best modern buildings do have excellent solar control and yet it is astounding to see how many still employ glass roofs and walls that not only can cause severe discomfort to people inside but also can result in huge bills for compensatory cooling systems" (Roaf, 2003:10)

The *passive house* uses the available energy from solar radiation through the windows and the heat emissions of appliances and inhabitants suffice to keep the building at pleasant temperatures during the heating period. The technical use of solar energy for heating systems in a passive house should occur in collectors and conversion surfaces (e.g. thermal collectors and photovoltaic installations) from where the energy is transported to storage units or the actual place of use. This is an indirect (or active) use of solar energy, and the technical installation will be positioned on the skin of the building where it is not subject to shade (Herzog, 1996, 27). The term *passive house* defines a building standard that can be achieved with different construction techniques, forms and materials. In a passive house the comfortable climate conditions are attained without any or with minimum use of a conventional active heating system (Tönük, 2005,31).

Passive houses are buildings in which the comfort desired by consumers is achieved cost-effectively with max.80% less energy consumption. A recent study of CEPHEUS (www.cepheus.at) explained that the passive houses attained on the category energy reduction the minimum values of the valid buildings laws (room heat, warm water and electricity). Total savings of 57% were achieved on the level of active energy. The room heat requirement alone dropped by 80%. A 52% saving was achieved in terms of final energy and a 57% reduction of primary energy in relation to the construction standards permitted by building laws (Krappmeier & Drössler, 2001, 15-16).

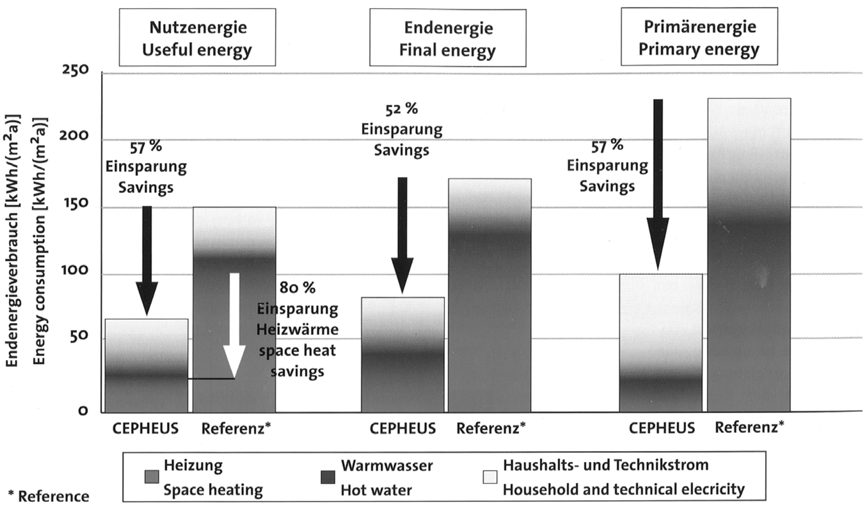

Figure 1. The Energy Reduction of Passive Houses - (Krappmeier and Drössler, 2001:14)

For achieving these values, they must be controlled with the technical knowledge requirements as follows, during the design, construction and using phases.

- Minimize the amount of primary energy, in addition for room heat and also the energy of electricity for household appliances, etc.
- Reduce the energy consumption for warm water - (water-saving fixtures reduced water) - , plan lines as short as possible, insulate lines and storage tanks thoroughly, etc.
- Test building envelope for air-tightness
- Supply the house with fresh air with a ventilation system. The air supply is necessary for a good room air quality
  etc…

Buildings are part of a complex interaction between people, the buildings themselves, the climate and the environment. The view that buildings are fixed also fits well with certain types of scientific analysis, of daylight factors, energy flows, U-values, mechanical ventilation and soon. But this mechanistic view finds the more dynamic parts of the system (temperature, natural ventilation, passive cooling and all the multitude of human interaction) very difficult to model, therefore, to understand. But passive houses are built on the principle of simplicity and only optimize the components required for a building: the walls, floors, roofs, windows and the comfort ventilation employed for hygienic reasons. Passive house concept involves a design work with knowledge of the physical environment (natural and built environment). The architect first must analyses the physical environment and than he designs the building on the basis of this knowledge of the physical environment. The design process has two basic steps, and these are the analysis phase and the design phase. All physical and social design components of passive house concept must relate to environmental system. The social design components must be specializing for each land, region, life styles, etc. and for all design work. The physical design components of a one family passive house will be explained as follows;

Site Selection and Planning

Ken Yeang, who applies ecological and bioclimatic design approaches in his designs successfully, is explaining criteria concerned with site selection and analysis which must be considered as follows; "... Site isn't a plane that the building will sit on only, site is a living and working ecosystem. Minimum effect to the site and pre-existing ecosystem must be aimed acting on the light of this reality. It is impossible to construct a building which has no effect on ecosystem in no way, however it is probable to minimize of building's effects" (Yeang, 1995, 22)

Site selection and planning stage constitute the first step of design and also construction activity. Adoption of environmental/sustainable criteria in site selection is proportional with success of other stages directly. Sites that are close to or in areas where there are asbestos or other heavy metallic waste, polluted air emissions, power line easements, oil/gas lines and also earthquake/volcanic active areas should be avoided. The site should not be a farmland, green field or providing habitat for any species. Careful site assessment can enable developers to capitalize on the land's potential views, solar access, natural drainage opportunities, natural shading through vegetation, cooling from prevailing wind- while minimizing or avoiding damage or disturbance to the site and surrounding areas (ERG, UCD and etc, 1999, 54).

Ecological Design

Planning is a process which utilizes scientific and technical information for considering and reaching consensus on a range of choices. Ecology is the study of the relationship of all living things, including people, to their biological and physical environments. Ecological planning may be defined as the use of physical and social knowledge in each design work. Adaptation to climatic conditions on building design, configuration of building envelope in context with minimum energy consumption, making the construction robust, resistance, long-lasting and integration of outdoor spaces with the building must be considered. Main issues of ecological design and/or passive house design process are as follows;

Building Form

Functional, technical and aesthetic considerations contribute to determination of building plan and form. Making the building the right shape and with the correct orientation can reduce the energy consumption by 30-40% at no extra cost (ERG UCD and etc, 1999, 60). Saving energy is an important criterion in ecological or/and passive house designs. Heat losses which occur with natural and/or artificial climatization are unwanted conditions. According to studies, building form affects the heat losses and/or gains at an important rate. Krusche, Althaus and Gabriel (1982) indicate different combinations of the buildings change the heat loss ratios. It is necessary to examine especially the mass housing settlements by considering the following factors;

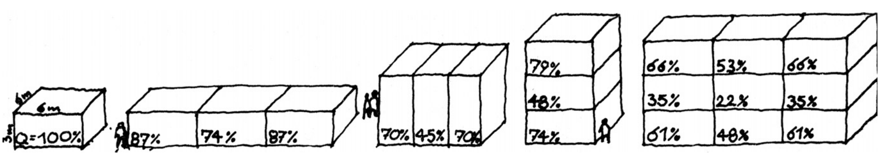

Figure 2. Heat Losses of Different Combination of the Buildings (Krusche, Althaus and Gabriel, 1982:116)

Building Orientation

Solar radiation, wind, topographical data, site cover etc., act as factors that affect the orientation. The affect of solar radiation on building orientation will be dwelled upon. In Olgyay's study, the best orientation had been explained like as follows; "...At European latitudes the south facade of a building receives at least three times the solar radiation in winter as the east and west. In summer the situation is reversed. In both in summer and winter, the north side receives very little radiation" (Olgyay, 1973, 32).

In tropical zones, the closed or protected primary mass, the core, should be located on the east and west sides of a building to ensure that it is shaded in daytime against the low sun. In arid zones, the mass should also be located on the east and west side; shading is primarily needed in summer. In temperate zones, it is best

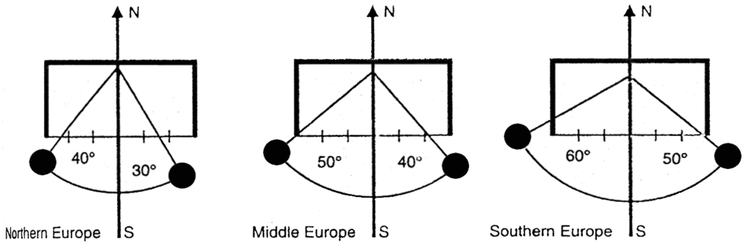

Figure 3. Best Orientation for Solar Gain Varies with Latitude (ERG, UCD and etc, 1999:55).

to place the primary mass on the north side, in order to leave south-facing sides available for solar gain in winter time. Buildings in cold zones should ideally have open perimeters, to maximize heat penetration and solar heat gain (Daniels, 1997, 33). These principles should be generally applied in each local region, to decide the bioclimatically correct orientation of buildings.

Space Organization

A rational and ecological space organization has the benefit of reduction of the energy consumption at occupation phase of the building. After determination of the heating requirements of the spaces according to their function, the location of these spaces on the plans must to be determined. South sides play a part as a *natural heating resource* in temperate climatic zones. It's well known that if the general living spaces which need to be heated more are located on south facades, the heating requirements can be reduced up to 30%. Surrounding of living spaces which are used by people more with the spaces which heat for short times and constitution of buffer transition zones with servicing spaces which heat less in horizontal and vertical plane on outer parts is used as a method to reduce heat losses.

Space organization must be made for both winter and summer months with planning that facilitate the cooling. The location and direction of spaces must to be determined in a manner which takes advantage of the prevailing winds. Space organization which creates a natural ventilation -(cross ventilation)- between north and south facades must be considered. It is not to be forgotten that spaces which gain sun in winter will heat excessive in summer. In this respect, precautions protecting spaces from summer sun on south side must be taken (i.e. leaf shading tree species, operable windows, sunshades, ventilation of winter gardens etc).

Building Envelope

As a part of the design process, architects and engineers create a shape, defined by an envelope, that respond to functional, structural and aesthetic considerations. The envelope encloses distinct spaces and provides controlled access to them. The building envelope is viewed not simply as protection from, but as connection to the environment. Within the envelope itself, the concept of integration is often applied to increase construction efficiency while reducing energy use. Envelope subsystems integrate several envelope functions (e.g., thermal protection, structural support or water and weather protection) into a single cost-effective component. In a study of The European Commission take part a series of criteria about maintaining a comfortable thermal environment. One of them is; "An average ratio of window to wall of 30% for the building as a whole makes a good starting point for design. Then adjust to account for climate, orientation and building use. In warm climates consider limiting window area to about one tenth of floor area" (ERG, UCD and etc, 1999, 31).

Wind, solar availability and direction, shelter and exposure, natural ventilation, day lighting and noise conditions will inform the relationship of the building to its external environment and affect the form and the design of the envelope.

Energy & Resource

Through out the world and especially in developing countries, production, consumption and saving of energy is a general problem. Economical balances of developing countries; whose energy saving policies and laws are not constituted yet are disturbed and the environment is more polluted due to unconscious energy consumption. Developed countries behave more sensible than developing countries concerning energy saving issues. It is possible to say that this is an indicator of evolution. The most important duty is given to architects regarding protection of environmental systems and reduction of environmental pollution. In this context non-renewable energies are not seen as future's energy resources because of their limited reserves and hazardous effects on environment. In this context, on a passive house minimizing or eliminating consumption of total energy resources should be considered. An energy-efficient passive house aims to reduce consumption especially in these areas (Jones, 1998, 36);

- In the manufacturing of building materials; components and systems (embodied energy);
- In the distribution and transportation of building materials and components to the construction site (grey energy);
- In the construction of the building (induced energy);
- In running the building and its occupants' equipment and appliances (operating energy).
- In maintenance, alteration and final disposal of the building

Waste

The natural world knows no waste, but only continuous cycles of decay and regeneration, with the same elements passing through these cycles in many different forms (Vale & Vale, 1991, 56). But because of the built environment, many sorts of wastes are entering the natural environment in a number of ways. The World Commission on Environment and Development reported in 1987 the following: "In many cases the practices used at present to dispose of toxic wastes, such as those from the chemical industries, involve unacceptable risks". The EU Waste Management Strategy lists a four-step waste management system (World Commission on Environment and Development, 1987, 8):

- Reduce waste at source
- Sort wastes
- Re-use or re-cycle
- dispose of waste safely

In this context the passive house concept is governed by guiding design principles. By means of the mentioned knowledge some of the basic design principles and/or the *How to* design key issues of a passive house are defined on following examples;

EXAMPLES

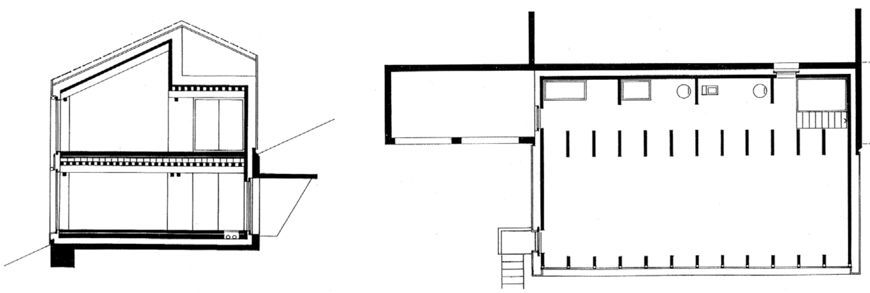

Figure 4. House with Zero Energy Heating, Trin / Andrea- Gustav Rüedi (1994) (Herzog, 1996:72)

The guiding design criteria and/or the *How to* design key issues of the passive House in Trin- Switzerland;

- South orientation on the site plan
- Compact form of the building

- Thermal zone on the northern façade
- Enclosed northern façade
- Living rooms on the southern façade
- Open - glazed envelope on the southern façade
- Natural ventilation – cross ventilation
- Sustainable materials use
- Active usage of solar energy
- Heat insulation for thermal comfort
  etc.

Figure 5. House with Zero Energy Heating, Trin / Andrea- Gustav Rüedi (1994) (Herzog, 1996:73)

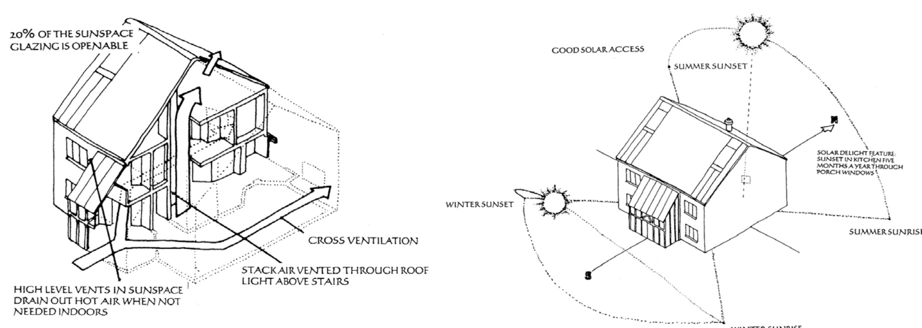

Figure 6. Oxford Ecohouse with Zero Energy Heating, Oxford / Sue Roaf & David Woods (1994) (Roaf, 2003:166)

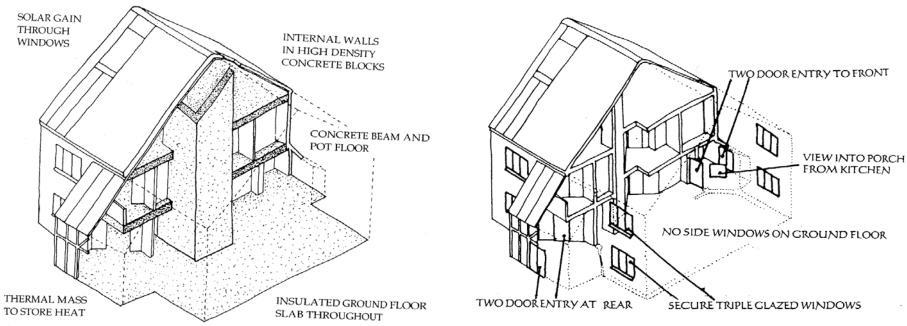

Figure 7. Oxford Ecohouse with Zero Energy Heating, Oxford / Sue Roaf & David Woods (1994) (Roaf,, 2003:166-167)

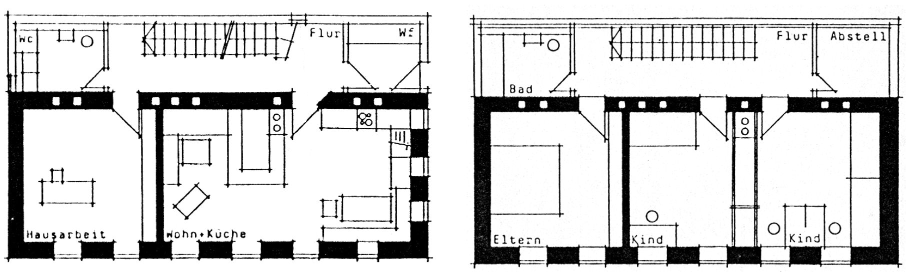

Figure 8. Ground Floor and Upper Floor Plans of a Passive House, Germany, Architect: Johannes Brucker (Kleiner (ed.), 1995: 82-83)

The guiding design criteria and/or the *How to* design key issues on section-isometrics of the passive House in Oxford, England

- South orientation on the site plan
- Compact form of the building
- Thermal zone on the northern facade
- Enclosed northern, eastern and western facade
- Living rooms on the southern facade
- Open - glazed southern facade
- Cross ventilation
- Sustainable materials use
- Active use of solar energy
- Heat insulation for thermal comfort etc.

The guiding design criteria and/or the *How to* design key issues on section-isometrics of the passive House in Oxford, England

Figure 9. External View of the Passive House (Kleiner (ed.), 1995:82-83)

- South orientation on the site plan
- Compact form of the building
- Thermal zone on the northern facade
- Enclosed northern, eastern and western facade
- Living rooms on the southern facade
- Open - glazed southern facade
- Cross ventilation
- Sustainable materials use
- Only passive use of solar energy
- Heat insulation for thermal comfort

etc.

CONCLUSION

Buildings are intimately linked to the local, regional and global environments that are all part of our habitat. It is the responsibility of our generation to begin to adapt our buildings to ensure that we can stabilize climate change, that we can live without fossil fuels and that we do not pollute the environment unsustainably. Only by so doing, we can ensure the survival of our own habitats.

By means of the mentioned knowledge and examples of the passive house concept some guiding design criteria and/or the *How to* design key issues, as results of this study will be tried to explain.

Some of the basic design principles of a passive house are defined below:

- compact form of the building (for the continental climate zone, the climate conditions of central European or similar climate conditions)
- south orientation on the site plan; large glazed surfaces on the southern facade and minimum opening on the northern facade,
- thermal zone on the northern facade, includes all sanitary facilities , storage and the stairs, etc. (Because these spaces are used at certain times of a day)
- open southern facade; south-orientated living room and the bedrooms
- natural lighting and ventilation
- sustainable material use
- the indirect - or active - use of solar energy (at min.)
- loss minimizing before profit maximizing of energy

This list could certainly extend and/or changed.

As can be seen from the examples, the design criteria of the contemporary passive house caused monotony on plans and create same sort of plan types. If these design criteria are necessary for the sustainability of our environment, we have to decide which one we choose; livable environment or design freedom? We need a new architecture which tries to balance the emotional or institutional design with the sustainability of environmental systems.

Sue Roaf says, “The world needs a new profession of eco-tects, or arci-neers or engi-tects, who can design -(passive)- buildings that use minimal energy and what energy they do use comes from renewable sources if possible. It is the only way forward.” (Roaf, 2003)

REFERENCES

DANIELS, K. (1997), *The Technology of Ecological Buildings*, Birkhauser Verlag, Boston.

European Commission, Directorate General Xvii for Energy and the Architect’s Council of Europe (1999), *A Green Vitrivius - Principle and Practice of Sustainable Architectural Design*, James & James (Science Publishers) Ltd., London.

HERZOG, T. (eds.) (1996), *Solar Energy in Architecture and Urban Planning*, Prestel Verlag, Münich.

JONES, D. L. (1998), *Architecture and The Environment*, Overlook Press, New York.

KRAPMEIER, H., DRÖSSLER, E. (2001), *Cepheus-Wohnkomfort ohne Heizung-Living Comfort without Heating*, Springer, Wien.

KRUSCHE, P., ALTHAUS, D., GABRIEL, I., (1982), *Ökologischen Bauen*, Bauverlag, Wiesbaden.

OLGYAY, V. (1973), *Design with Climate*, Princeton University Press, Princeton.

ROAF, S. (2003), *Ecohouse 2- A Design Guide*, Architectural Press, Oxford.

TÖNÜK, S. (2005), The Design Principals of The Passive House in *Proceedings of International Seminar on Environmental Planning and Architecture*, Yıldız Technical Publication Center, İstanbul, pp. 31-36.

VALE, B. and VALE, R. (1991), *Green Architecture: Design for a Sustainable Future*, Thames and Hudson, London.

World Commission on Environment and Development (1987), *Our Common Future*, Oxford University Press, London.

YEANG, K. (1995), *Designing with Nature*, McGraw Hill, USA.

KLEINER, H. (eds.) (1995), *Ökologische Architektur - Ein Wettbewerb - 40 Ausgewaehlte Beispiele Für Umweltbewusstes Bauen-Wohnen-Leben*, Callwey Verlag, München.

http://www.cepheus.at; CEPHEUS (Cost Efficient Passive Houses as European Standards) Project within the THERMIE Program of the European Commission.