

ROBERTO GONZALO KARL J. HABERMANN

ENERGY-EFFICIENT ARCHITECTURE

BASICS FOR PLANNING AND
CONSTRUCTION

BIRKHÄUSER

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FOREWORD

Utopias and experiments are important forces that drive the development of our technologies. In the course of time, Jules Verne's visions of space travel became reality, as did Eugène Hénard's on urban design. The idea of energy-autonomous buildings has resurfaced in recent years. Buckminster Fuller, Norman Foster and Richard Rogers are but a few names that come to mind.

Experimentation is followed by applying the positive experiences to construction and everyday building practices. The authors' goal in this work is to build a bridge between the available knowledge and expertise of the specialists in building sciences and technologies on the one hand and the great majority of those working in the sector on the other.

"There is no energy-saving style. Building of that kind does not call for a uniform aesthetic or universally binding rules, unless it be those rules of common sense to preserve (or at least avoid polluting) the environment." (Robert Kaltenbrunner in *Bauwelt*, 1993)

Original material from the architects has been included in the project documentation and the theoretical chapters for good reason. This alone preserves the individual aesthetic imprint as a whole. CAD programs have long since been mastered to such a degree that drawings can once again be rendered with greater individuality. In this book, we have therefore deliberately abstained from visually coordinating the detail information. It also seems important to note here that in the area of innovation there is some risk associated with borrowing details all too readily and perhaps rashly. Only direct contact with a colleague in the field can offer safety through an exchange of valuable experiences and set into motion the technology transfer that is as vital as it is desirable. To this end, the appendix contains a list of all major planning partners and a selection of interesting manufacturers. The book is organized in familiar fashion: starting off with an analytical overview of the history of building up to the current state in architecture, the theme is explored step by step, beginning with urban design through to energy-efficient building planning and innovative detail solutions. The featured projects from Germany,

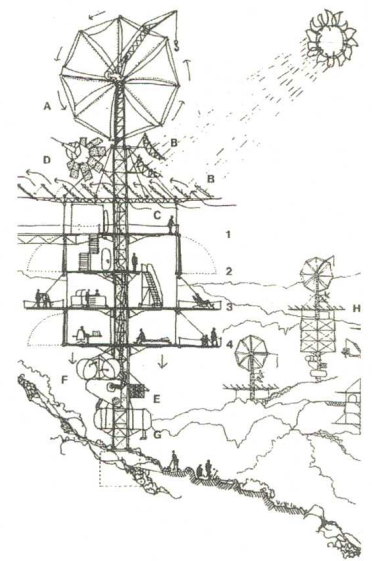
Austria, Switzerland, Spain and Great Britain were selected with great care and form an important component of this work. A particularly beautiful example of sustainable architecture in the context of development aid is given with the school in Ladakh, where the elements from the pioneering stage of solar architecture were sensibly applied. Consideration of local building traditions, in this example shaped by the extraordinary climate, and of local resources, is a key element in energy-efficient building.

No effort was spared to introduce as broad a palette of different categories as possible. Without claiming to be complete, this volume presents a multitude of possible solutions for a wide variety of different requirements.

The authors are indebted first and foremost to all those colleagues who made their material available and patiently answered all their questions. As experts in technical completion and building physics, the engineers offered additional data that were invaluable for the purpose of achieving the density and depth of information we had set out to present. We would like to extend our special thanks to John Berry, Klaus Eggert, Helmut Krapmeier, Andreas Lackenbauer, Clemens Pollok, Wolfgang Schölkopf, Peter Schossig, Matthias Schuler, Michael Weese and Jan Wienold. Finally, this book could not have been completed without the advice, practical support and patience of our wives, Susana Gonzalo and Ulla Fulde-Habermann.

Munich, January 2006

Roberto Gonzalo
Karl J. Habermann



left:

Facade section of student residence in Wuppertal, first stage of construction; architects: PPP Architekten in partnership with Christian Schlüter and Michael Müller

top:

"Autonomous House," Aspen, Colorado, Richard Rogers, 1978. An idea of autonomous buildings operated solely by renewable energy sources.



RESOURCE-CONSERVING AND ENERGY-EFFICIENT BUILDING: ORIGINS

Christian Lenz, Hermann
Kaufmann: Office and
residential building in
Schwarzach, Vorarlberg.
Solar panels
are integrated
for warm-water processing
in the balcony balustrade.
See also p. 122

RESOURCE-CONSERVING AND ENERGY-EFFICIENT BUILDING: ORIGINS

"In setting out the walls of a city the choice of a healthy situation is of the first importance: it should be on high ground, neither subject to fogs nor rains; its aspects should be neither violently hot nor intensely cold, but temperate in both respects ..." (1) With his famous treatise *Ten Books on Architecture*, Vitruvius created an early cornerstone for a tradition of architecture and urban design. In it, he refers to the architecture and urban design of the Greeks, which had come before his time and plays particular attention to the influence of the sun on the various functions of the city, elaborating on this topic in great detail. For both the Romans and Greeks had long been aware of the link between building orientation and building use.

When we look at the selection of appropriate building materials described by Vitruvius, we can discern early ecological approaches. The differences in the local availability of such materials – be they natural stone, timber, lime or clay – led to an entire spectrum of different types of wall construction until the advent of *Opus cementitium*, an early version of concrete. The Romans were less successful in handing down their discoveries in building technology to future generations: their elaborate floor and wall heating systems were largely forgotten until they were rediscovered by archaeologists in the modern age.

As we search for traces of other useful basic principles of resource-conserving and hence early attempts at energy-efficient construction, the broad field of so-called autochthon, traditional or vernacular building is particularly fruitful. In addition to revealing the prototypes of basic constructional forms, this field also allows us to study the beginnings of house technology. However, it is important to understand the comfort conditions of these early low- or zero-energy habitations in clear relation to the specific climate zone, the achieved living comfort and the average life expectancy of people at that time.

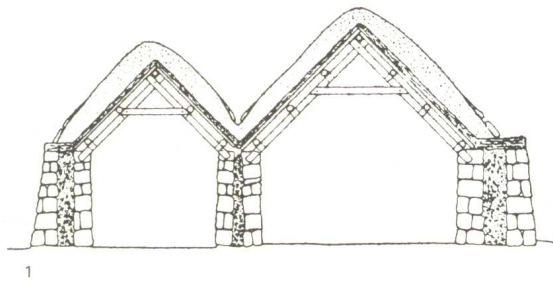
The Blackhouse, an archaic dwelling on the Outer Hebrides, a group of islands off the coast of Scotland, seems to merge with the sparse,

treeless landscape because of the rubble masonry and sod-covered roof. Local materials were utilized in a sensible and natural manner. Two parallel narrow rectangles accommodate humans and livestock, and also provide space for a barn. Living room and bedroom lie across from the stable on the other side of a central hallway. Aside from an open fireplace, in which peat was burned, the livestock served as an additional source of heat in winter: according to current knowledge, a 600 kg cow generates a thermal output of roughly 1,200 watt. In those days, people rarely left their homes during the cold season. There was no chimney; the smoke escaped through narrow hatches in the roof and the permeable roof covering. The interior was blackened by smoke. The only technical item in the home consisted of a fire hook, suspended from the ceiling on an iron chain. Every component of the building was reusable or recyclable, as we would say today. Nevertheless, given the harsh climate, life in this primitive "ecological" house could hardly be described as healthy. The average life expectancy was thirty years. A brief description provides some insight into the living conditions and the few romantic moments of life in the archaic Blackhouse of Lewis: "During winter, many neighbours come in each night. We form a circle round the fire and we discuss many subjects. The fire can be built as high as you like because there is no risk of a chimney catching fire." (2) The house was erected circa 1875 and inhabited until 1964. It was refurbished and has been open to the public as a museum since 1988.

The cave dwellings found in the temperate Mediterranean climate represent another form of habitation in harmony with the natural environment, albeit in a completely different manner than the one described above. The cave settlement in Guadix, featured as an example here, has been a tourist destination for some time and therefore includes a perfectly adequate hotel. Nevertheless, this settlement deserves closer study. The whitewashed entrances as well as the chimneys that project above the ground here and there are the only visible manifestations of the development in the landscape. The habitation as such is hidden

(1) Vitruvius: *Ten Books on Architecture*, http://penelope.uchicago.edu/E/Roman/Texts/Vitruvius/chapter_4/paragraph_1 (original: "In ipsis vero moenibus ea erunt principia. Primum electio loci saluberrimi. Is autem erit excelsus et non nebulosus, non pruniosus regionesque caeli spectans neque aestuosas neque frigidas sed temperatas...")

(2) Alexander Fenton: *The Island Blackhouse*, Edinburgh 1978, p. 6



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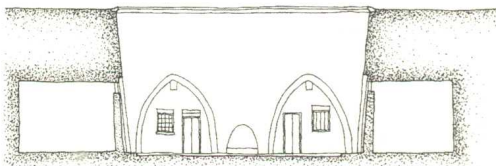


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- 1 Cross section of Blackhouse with barn and living quarters. A narrow strip of grass on a thin layer of earth forms the upper completion of the enclosure wall built of rubble masonry.
- 2 Blackhouse in Arnol on the Island of Lewis, today a museum
- 3 Historic photograph of an interior: Family in Ballallan 1934, by S.T. Kjellberg, with kind permission from the Museum of History, Göteborg



4

4 Section and plan of a cave dwelling cut into the loess ground in the Province of Henan, China

5 Cave dwellings cut into rock in Guadix, Spain

6 Sun-dried brick housing settlement in Humanuaca, Argentina

7 Ventilation chimneys in the Baris development in the oasis town of Al-Kharga, Egypt, Hassan Fathy, 1967



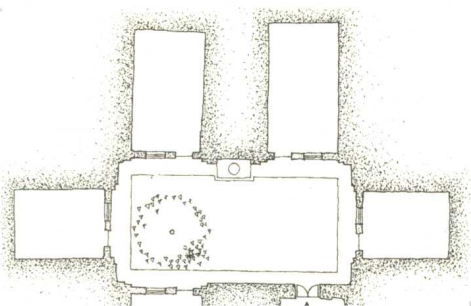
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from view. Constant year-round temperatures of roughly 18 to 20°C ensure natural comfort in the interiors, which have in the meantime been outfitted with the standard home equipment. In winter, the internal climate is perceived as adequately warm, while the same temperatures are experienced as comfortably cool in summer.

The cave dwellings and their courtyards in the loess belt on the Yellow River (Huang He) in China are dug into a layer of clay. The ground above this layer and its natural vegetation remain intact for cultivation. Here we find another, roughly 6,000 year old building method that is impressive for its resource-conserving use of the site. In a climate zone known for extreme temperature fluctuations, indoor temperatures are equalized by up to 10°C in summer and in winter. Due to extreme damp during heavy rainfalls and the resulting condensation caused by poor ventilation, the living quality leaves much to be desired. Housing density is also limited in this case.

In hot and arid zones, clay is often the building material of choice for non-nomadic peoples, if the top layer of the earth consists of clay or the clay-sand-mix known as loam. The excellent mouldability of this clay (weathered feldspar) when water is added and the many variations in its application are chiefly responsible for the popularity of various building methods with clay around the world. The simplest methods employ rammed earth and sun-dried clay bricks. Depending on bulk density, this building material can be utilized for heat storage; the insulating properties are further improved when straw is added to the mix. The moisture-balancing character of this building material can have a positive influence on the interior climate.

Hassan Fathy, the renowned Egyptian architect, revived the traditional clay building technique in his housing projects, most of which were constructed for the socially disadvantaged. He achieved remarkable results in New Gourma (1946) and in the oasis town of Kharga (1967). The minimal use of windows prevents any direct sunlight from entering the building. Fathy employed ventilation chimneys to ensure air circulation throughout the interior by utilizing

the ascending convection currents that occur naturally. The buildings are not only oriented toward the sun but also toward the principal wind direction. The constant flow of air offers comfort in the interior despite sweltering temperatures outside. Fathy documented the practical experiences he gained throughout his career in his seminal work *Natural Energy and Vernacular Architecture, Principles and Examples with Reference to Hot Arid Climates*. (3)

In Central Europe, traditional building methods have also been influenced by local climate, on the one hand, and resource availability on the other. The half-timbered house is a natural construction method in timber-rich regions. Depending on the subsoil, such houses are either erected on piles, on level ground or on a solid plinth story. The infilling is executed in a variety of ways with straw, clay, brick or natural stone. In plan, these homes adapt to a variety of needs. The only common element in all structures of this type is the solidly constructed core with fireplace and chimney. It occupies the center of the house and acts as a storage mass. Roof covering, incline and overhang are chosen in response to local precipitation patterns. The window orientation is still very much geared toward minimizing heat loss in winter.

When we look at the use of natural resources, we invariably encounter sophisticated mill technology powered by water or wind energy. We would benefit greatly from not only admiring these models – most of which survive only as exhibits in open-air museums – with a sense of nostalgia, but from carefully analyzing the remarkable sustainability they achieve.

New technologies and devices were developed for house and home during the Industrial Revolution. Traditions handed down through the generations were no longer considered appropriate for the time and replaced, giving rise to new visions for housing.

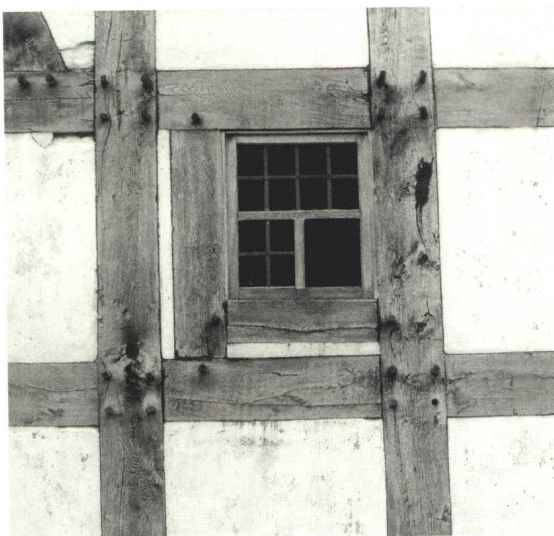
In 1910, the French urban planner Eugène Hénard (1849–1923) formulated a preliminary conclusion in his essay “Les villes de l’avenir”: two sketches illustrate the rapid advances in



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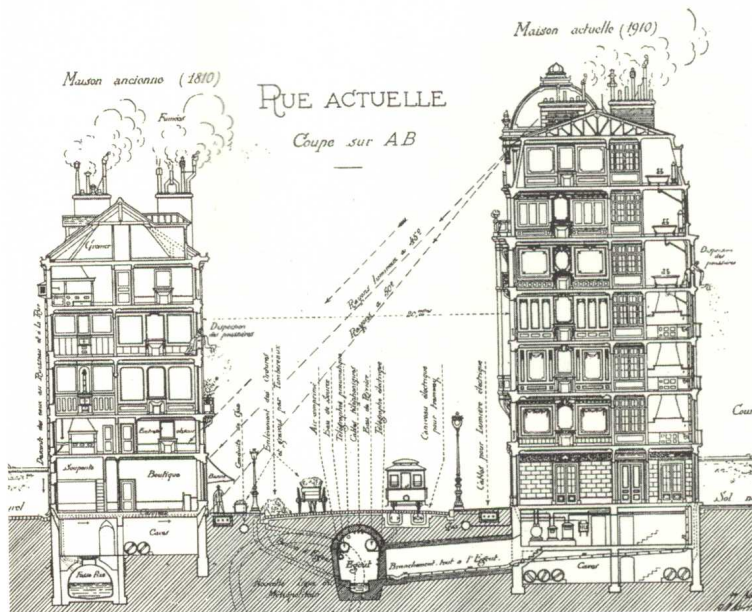


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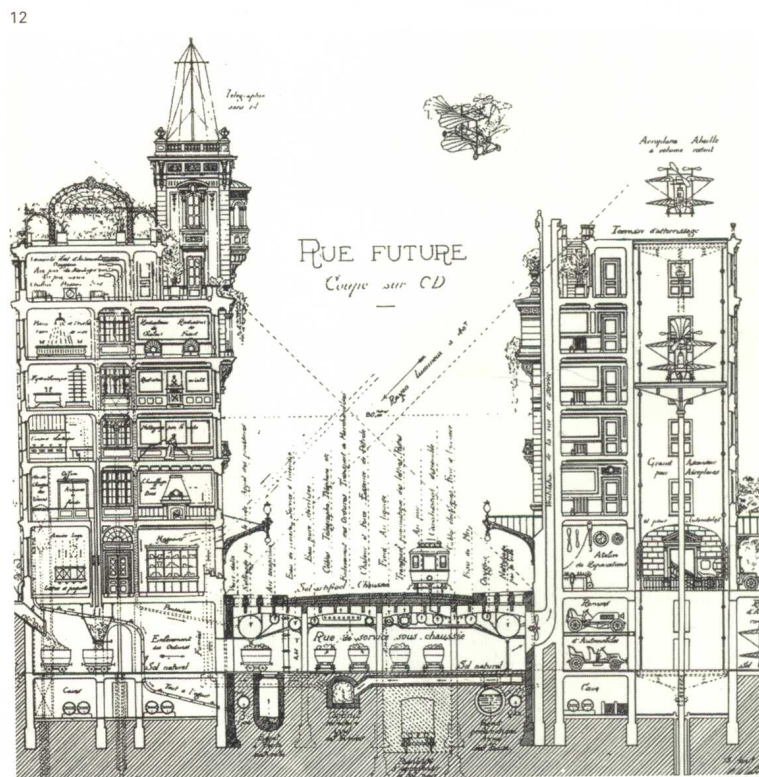


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- 8 Windmill in Spiel, Düren district, 1782
 - 9 Half-timbered house in Altenburg, Neuwied district, circa 1700
 - 10 Half-timbered house with hemp infilling near Hennef, Rheinisches Freilichtmuseum Kommern, 1688; Window detail: the opening is reduced to the smallest necessary size in order to minimize heat losses during the cold season.
- (3) Hassan Fathy: *Natural Energy and Vernacular Architecture*, Chicago 1986



11



12

technology in the years leading up to his work and Hénard's vision for the future. (4)

The changes in technology and hygiene over the course of the nineteenth century are documented in the sketch of the "rue actuelle" or contemporary street. While the left side of the street is still equipped with gas lamps for illumination, the right side has already been provided with electric street lighting. In this sketch, the large sewer is already designed to accommodate supply pipes for compressed air, potable water, pneumatic mail, telephone cables and similar services along the ceiling. Every floor in the homes features bathrooms with hot and cold running water, while the homes on the opposite side still dump their waste in the street. The emissions from the dense forest of chimney heads are clearly depicted on both sides. This problem seems to have been solved with the help of district heating in the image of the "rue future" or the street of the future. In addition to a lushly verdant roof patio and a crowning antenna for "telegraphy," the only remaining task seems to be a provision for private air traffic with sufficient space for take-off and landing on the roof. A second street level, the "rue de service" or service road, represents a great improvement in urban comfort unlike anything we experience even today. Some reservations aside, Hénard's vision is therefore still current today.

Today, the "ensanche" (Catalan: *eixample* means expansion) is Barcelona's central urban quarter. Its attractiveness lies mainly in the many surviving structures in the Catalan version of Art Nouveau. Antonio Gaudí crowned his cleverly ventilated buildings with fancifully designed ventilation stacks. The uniform nineteenth-century block structure is somewhat monotonous. Still, despite the criticism sparked by the project upon its opening in 1867, it remains an important testimony to the beginnings of modern urban planning and design, shortcomings in the execution notwithstanding.

The expansion of Barcelona began in 1854 with the demolition of the city's Gothic fortifications. The road engineer and theoretician Ildefonso

Cerdà, who was committed to social reform, undertook a series of studies on the living conditions in the industrial society. His principal work, the *General Theory on Urbanization and the Application of its Principals and Theses to the Renewal and Expansion of Barcelona* (1867), contains the technical solutions he had developed. Cerdà was not only familiar with the theories of British and French utopians, hygienists and economists, he also had an open mind toward progress in technology. He developed technical solutions for political and social problems, the origin of which he identified as lying in urban concentration, the catastrophic hygienic conditions, land speculation and the lack of urban design in the interest of public needs. The urban grid adopts the axial lines of the old city and reflects Cerdà's requirements for space and light. The original plan consisted of two block edge developments on opposite sides. The courtyard was to be kept open as a green space and for the cooling breeze from the sea. The pressure of development nowadays makes hardly any allowance for this type of consideration. The glass verandas that run across the entire height of the buildings on the courtyard side characterize the development to this day and continue to serve as climate buffers. Glazed loggias and glazed oriels are not exclusive to Barcelona. They also dominate the streetscape in southern Spain and in La Valetta on the island of Malta. During the day, the glazed areas are covered by mats and awnings, and the recessed doors are closed. At night, cool air is allowed to flow through the buildings. In winter, the warming sun can penetrate into the interior. These early double-skin facades also act as an effective barrier against street noise.

In the *Well Tempered Architecture* (5), Reyner Banham explored the origins of modern house technology and discovered one source in Catherine Beecher's concept for the "American Woman's Home" (6) from 1869, which offered an interesting evolution of traditional housing models: Beecher organized life in the home around a central service core. In addition to other functions, the entire house was supplied from this core with "healthy" air at comfortable temperatures by means of a cleverly designed forced-air heating system.



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- 11 "Rue actuelle" from "Les villes de l'avenir," Eugène Hénard, 1910
- 12 "Rue future" from "Les villes de l'avenir," Eugène Hénard, 1910
- 13 Palacio Güell, Antonio Gaudí, 1889, ventilation stacks
- 14 Large glazed veranda in Barcelona
- 15 Street front with balconies and glazed oriels, La Valetta, Malta
- (4) Jean-Louis Cohen: Eugène Hénard. *Etudes sur les transformations de Paris et autres écrits sur l'urbanisme*, Paris 1982, pp. 345ff.