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Giuliana Iannaccone
Marco Imperadori
Gabriele Masera

Smart-ECO Buildings Towards 2020/2030

Innovative Technologies for Resource Efficient Buildings

POLITECNICO DI MILANO

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Giuliana Iannaccone
Marco Imperadori
Gabriele Masera
A.B.C. Department
Politecnico di Milano
Milan
Italy

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Foreword

This book intends to contribute reference knowledge on sustainability in building and construction and is designated to any reader interested in the topic. A prime identified group of readers is students in Building Engineering and Architecture, i.e. in short those that will have the most significant impact on the values, attributes and the performance of our future built environment.

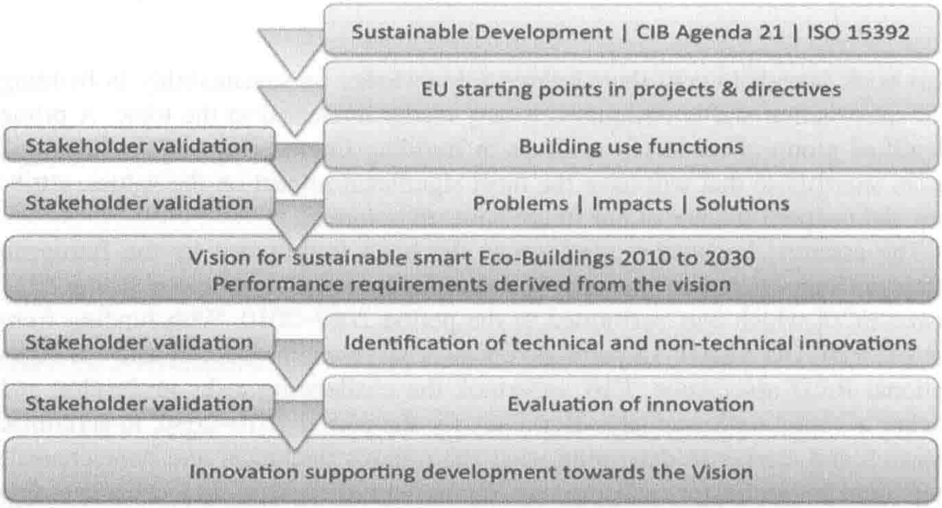
The essential knowledge platform to the book is provided by the European Strategic Support Action project "Sustainable Smart-ECO buildings in the EU," *Smart-ECO*, which was performed in the period 2007–2010. With funding from the EU FP6, DG TREN, 12 partners representing research, industry and the international R&D association, CIB undertook the challenging tasks to develop and anchor a Vision on Sustainable Buildings for the period 2010–2030, to scrutinise research and market to determine what Innovations (technical and nontechnical) that could be useful for realising this Vision, and to identify those elements that have the highest potential impact, all while anchoring the work and all findings with a carefully selected wide-ranging international group of expert stakeholders involved in various aspects of the built sector.

The *Vision* for sustainable Smart-ECO buildings outlines an ambitious direction of development for the time-frame up to 2030. It is based on the state of the art in international standardisation as the situation appeared during the completion of the project, together with findings of other performed R&D activities. With internationally agreed documents such as the CIB Agenda 21 on Sustainable Construction, the ISO General Principles of Sustainability in Building Construction as important background documents, and with evaluation and assessment of the international stakeholders the Vision gained supportive attention of the international standardisation community as well as the UNEP-SUN programme.

The Vision and the resulting requirements were in a defined process condensed to an approach to identify the *Innovations* to support the implementation of the Vision. Also in a foreword, it may be vital to signal the awareness of the project group of the utmost challenge imposed by the task to at a given slot of time identify Innovations that may impact on at least a 20-year period. However, when doing this we did the best possible, also with an awareness that this in fact mirrors the natural effects of the long-lived nature of buildings; what we realise and build today will have due consequences many years to come.

The *Evaluation of the Innovations* intended to identify those innovations understood to have the largest potential for a development in line with the Vision. The *Evaluation* was a multi-criteria approach.

In the Evaluation process, the *Anchoring with stakeholders* was essential. Some 230+ technical experts, industrialists, property developers, material experts, architects, builders, demolition companies and educationalists were engaged in following, guiding and scrutinising the work. This was a tedious but rewarding process. The below figure seeks to describe the project framework and the process specially focussing the involvement of stakeholders.



Dear reader, welcome to engage in the great challenge, *Sustainable Construction*. As the Co-ordinator of Smart-ECO, former President of CIB during the period when CIB established the Agenda 21 on Sustainable Construction, and former chairman of the ISO standardisation activities on Service Life Planning in Building Construction I sincerely hope your views and opinions, ambitions and actions will take this important subject area to new levels.

KTH, Sweden

Christer Sjöström
Professor Emeritus

Acknowledgments

This book is an evolution of the work carried out by the research group of Politecnico di Milano coordinated by Marco Imperadori in the framework of the European funded project Smart-ECO. We were privileged to be part of the Smart-ECO consortium, a cluster of researchers and professionals who work internationally in the field of the design and construction of sustainable buildings and built environment. In particular our thanks go to: Christer Sjöstrom of KTH (Project Coordinator), Wolfram Trinius of Buro Trinius (Project Manager) and Stefano Saldini of Mace (WP3 leader). Moreover, we would like to thank: Jean-Luc Chevalier and Alexandra Lebert of CSTB, Amber Stevens of PricewaterhouseCoopers, Hywel Davies of CISBE, Gian Carlo Magnoli Bocchi of Mission Carbon Zero, Gurvinder Singh Virk of KTH, Roode Liias of Tallinn University of Technology, Leo Bakker of Tno, Guri Krigsvoll of Sintef, Santiago Gonzalez Herraiz of European Commission, Bill Porteous and Wim Bakens of CIB.

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We also are grateful to everyone who supported the book with their images: Blauraum Architekten (Hamburg), Atelier2 (Milan), Aiace (Milan).

We could not have started our interest in sustainable building design and the related innovative technologies without the teachings of Ettore Zambelli, passionate designer and professor at Politecnico di Milano, whose work is also reflected in these pages.

Last but not least, the time and effort we dedicated to the writing of this book are the result of the love and support of our families: Gian Piero and Claudia Imperadori, Pietro and Libera Masera, Ciro and Carla Iannaccone, Daniela, Sergio and our beloved little Brayan, Irene and Maia, Irene.

Contents

Chapter 1
Smart-ECO: A Real Vision for Energy Efficient Architecture Towards 2030

Abstract In order to spread a shared vision of sustainable energy efficient buildings in the horizon 2020–2030, the European Commission funded the research project Smart-ECO—Sustainable Smart-ECO-Buildings in the EU. The challenge was to identify the technological and non-technological conditions to design and implement buildings that balance aspects as diverse as aesthetics, cost-effectiveness, accessibility, functionality, history, production, safety, energy efficiency and reduced impact on the environment. This chapter highlights the general approach of the research work that supported the construction of a Smart-ECO vision. The research's results have proved that future buildings already exist and good examples of design and innovative technologies could be easily replied in full respect of the EU roadmap.

Keywords Nearly zero energy buildings · 20-20-20 target · Sustainable buildings · Climate interactive house · Sustainable building technologies

In order to reach the 20–20–20 target in 2020 the European Commission (European Commission 2007) attributes a strategic importance to energy efficiency measures in the construction sector. That is due to the recognized huge impact of buildings on total energy consumption and carbon emissions, estimated respectively at 40 and 20 % of the total (European Commission 2009).

Design strategies and building technologies aiming to reduce significantly the energy efficiency of buildings are already available: for this reason the recast of Directive 2002/91 on Energy Performance of Buildings—Directive EPBD 2010/31/EU—sets the target of Nearly Zero Energy Buildings (NZEB) for all buildings built after 2020 (2018 for public buildings). Therefore, buildings are required minimising their energy needs and producing most of their energy from on-site renewable sources.

Although several cases show the viability of the NZEB standard—in particular in the residential sector—in most of the Member States these practices still need to be brought to the market and to common practice. Exceptions can be found in those countries—such as Germany, Switzerland and Austria—where strategies for

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energy efficient building (with respect to the energy demand for winter heating) are a standard practice.

Regarding to the need to spread a shared vision of sustainable energy efficient buildings, the European Commission funded the research project Smart-ECO—Sustainable Smart-ECO-Buildings in the EU (FP6-2005-TREN4-038699 period 2008–2010) aiming to set a standard of European sustainable buildings in the horizon 2020–2030. The challenge was to find the conditions to design and implement buildings that balance aspects as diverse as aesthetics, cost-effectiveness, accessibility, functionality, history, production, safety, energy efficiency and reduced impact on the environment.

The research group was composed by 14 partners and was coordinated by prof. Christer Sjöström from BMG Gävle (Sweden). Partners of the research project were BMG Gävle (S), CSTB (F), Tallinn University of Technology (EST), Servitec (I), TNO (NL), Sintef (N), Fachhochschule Südwestfalen (D), Endoenergy (UK), Politecnico di Milano (I), Hywel Davies Consultancy (UK), Mace (UK) and CIB (NL).

The Smart-ECO vision relies on a wide group of stakeholders to build a consensus-based framework. Stakeholders were involved in the research project through questionnaires and specific workshops held during the periodic project meetings. The Smart-ECO vision sets demanding future standards for buildings and highlights a wide range of issues that need to be addressed over a building lifetime.

In particular Smart-ECO project:

- defined a vision of European sustainable buildings in 2020–2030;
- identified the innovations (technologies and process) required to implement the vision;
- evaluated the most promising innovations;
- and disseminated the results among the operators of the construction sector in view of the 2020 energy efficiency targets.

So, what will buildings be like in 2020–2030? A very important part of the research project was the definition of a "vision", shared by the research group and the stakeholders alike.

Although sustainability of buildings has been studied for a long time, there is no universally accepted definition of a "sustainable", "ecological", or whatever definition may be used, building. Only recently, ISO finally defined a standard containing a shared definition of "sustainability" applied to buildings (ISO 15392:2008 Sustainability in building construction—General principles). Along with this very important starting point, the research considered other important aspects defining the state of the art about sustainability, such as CIB's Agenda 21 (CIB 2001), the various national legislations, certification and evaluation tools, etc.

According to the resulting vision, a Smart-ECO building in 20 years should:

1. be designed from a lifecycle point of view;
2. be constructed with limited resources and minimised energy consumption and waste production;
3. have minimised operational complexity while allowing easy monitoring of technical and environmental performances;

4. be adaptable to changes in capacity, type of users and performance requirements;
5. include local issues in all aspects of design, construction, use and dismantling;
6. facilitate ease of dismantling—reuse, recycle, restore.

As anticipated, the recast of the Directive on energy performance of buildings, defines pretty clearly the requirements on energy efficiency and carbon emissions from 2018 on. Other aspects are not yet defined by regulations or best practices, but were deemed significant for the evolution of buildings (and architecture) in the next 20 years. While most of these issues may look common sense or obvious, the real challenge for the European Commission is to have these concepts transferred to the market, making them current practice for decision-makers, designers, clients, construction companies, etc.

The approach, as a method, towards sustainability doesn't exclude any material (is steel less natural than glulam wood?) and therefore also polymeric ones have been taken in consideration (Giulio Natta, professor at Politecnico di Milano, was the only Italian Nobel Prize in Chemistry that awarded in 1963).

The projects introduced as case studies in this chapter, which are suitable to show in advance the Smart-ECO roadmap, have in common the building technology: the Structure/Envelope technique that allows easy assembly and disassembly operations, high flexibility and performances. In general, they all have the same DNA, i.e. they're conceived with a "cyclical design" approach: not only they react differently to the cycle of season and to outer climate, but also they are a stage of a life cycle: "from cradle to a new cradle" (Figs. 1.1 and 1.2).

What characterizes a Smart-ECO Building? First of all, the project includes more complex analysis and specific design issues related to the target performances and the context in which the building is located. We can imagine these buildings as *filters* between the macro environment outside and the micro living environment inside. The three dimensional border has to be designed carefully and take into account many factors like thermal resistance, thermal delay, acoustics, seismic, solar radiation, and so on. All these can be easily managed in those climates that are constant during the year or require a more detailed analysis in those climates that have a significant difference between winter, summer and the middle seasons.

As a result, the future is not a P*assiv House* but even beyond it: an *Active House* or a *Climate Interactive House*. This concept opens the way for strategies to design and build *Cyclical Buildings*, i.e. buildings that are able to act/react in harmony with the nature and the seasons and where every part is potentially re-cyclable. Every component can be inserted in a chain of use which is always designed in order to create less enthropy and more efficiency.

Smart-ECO pointed out the necessity to increase density and concentrate building volumes, both in new or retrofitted buildings, in order to improve energy performances (compared to single houses) and also energy distribution/sharing/self production. A desirable scenario would be to move towards smart-grids enhanced by information and communication technology where very efficient buildings are connected into a network producing more energy than they need and this energy can be shared and managed on demand (Lund et al. 2014).

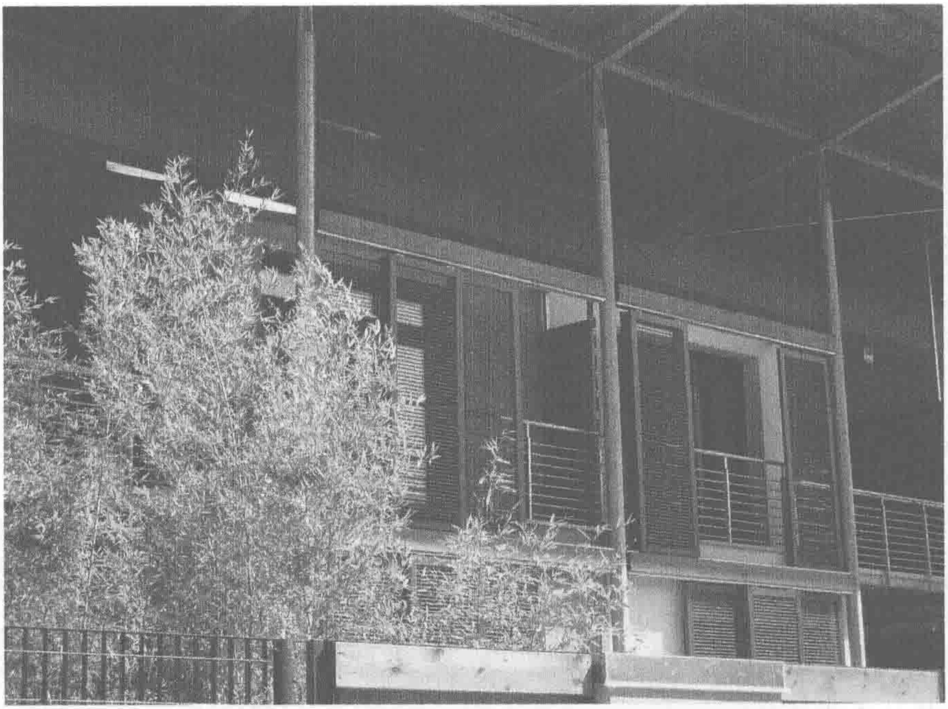

Fig. 1.1 High energy efficient building in Stezzano, Italy (Architect: Atelier2—Gallotti e Imperadori Associati). The energy demand of the house is 22 kWh/m^{2}y

Following the previous consideration, we can finally compare three experimental buildings—three houses of small dimensions, which already embody Smart-ECO concepts: Kingspan Lighthouse in London, Darmstadt team-Solar Decathlon 2007 in Washington and Casa E3—Vanoncini in Bergamo.

They are the result of integrated design approaches merging academic research and professional activity, and they are early examples of very energy-efficient buildings, some of them already compliant with the 2020 requirements of the EU.

They reveal how is possible to deliver Smart-ECO buildings adopting different strategies, different materials and also different shapes and design approaches. They are three different buildings which express three different architectural approaches, although sharing the same principles and performance targets.

Example: Lighthouse. Designer: Sheppard Robson and ARUP The Lighthouse has been built at BRE's Innovation Park in London with the target Level 6 "net zero-carbon for homes in use", the highest level of the government's Code for Sustainable Homes (CSH), mandatory in UK by 2016. The building was designed by Sheppard Robson and ARUP for Kingspan. It is characterized by a mainly blind south façade, a roof facing south accommodating a PV array and solar hot water heating collector for both radiant heating and solar cooling (Fig. 1.3). The building openings face east and west and can are protected in summer by external movable shutters. The

Fig. 1.2 Residential complex in Torre Boldone, Italy, special award for the environmental sustainability and bio-ecological and green building solutions at 9th IQU Prize—Innovation and urban quality (Architect: Atelier2—Gallotti e Imperadori Associati)

building envelope is constructed using high performance SIPS (structurally insulated panel based system), which provides a high level of thermal insulation and performance, and a ventilated façade of lattice wood (Fig. 1.5). The double-height living space enables the natural ventilation through the roof windows on the top level under the wind catcher (Fig. 1.4). In order to absorb the room heat, internal room surfaces are "thermally heavyweight", made of dense cement fibreboards and plasterboard embedding phase change materials (PCM). The building also includes a wastewater management system for re-use: rainwater for the garden and washing machine, shower and bath water for the WC (Figs. 1.3, 1.4 and 1.5).

Example: Solar Decathlon. Design: TU Darmstadt (team leader: prof. Manfred Hegger) Designed by the team of students from TU Darmstadt, leaded by prof. Manfred Hegger, the house has won the prestigious Solar Decathlon 2007 in Washington and then re-built in Germany. It's a compact parallelepiped volume that can be subdivided in 3 volumes. The structure is prefabricated, made by a timber frame with a multi-layer envelope. Vacuum insulation panels (VIP) panels provide super-insulation and plasterboard with embedded PCM create "thermally heavyweight" internal surfaces. Windows opening are limited to the south (triple glazing gas filled window) and north façade. The building has glazing that look south and

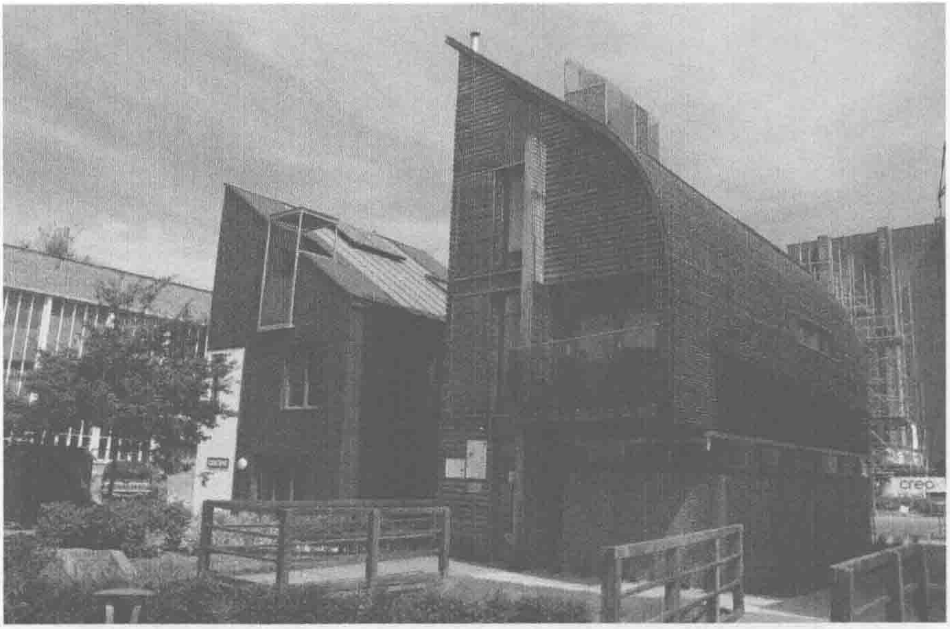

Fig. 1.3 The Lighthouse at BRE's Innovation Park in London

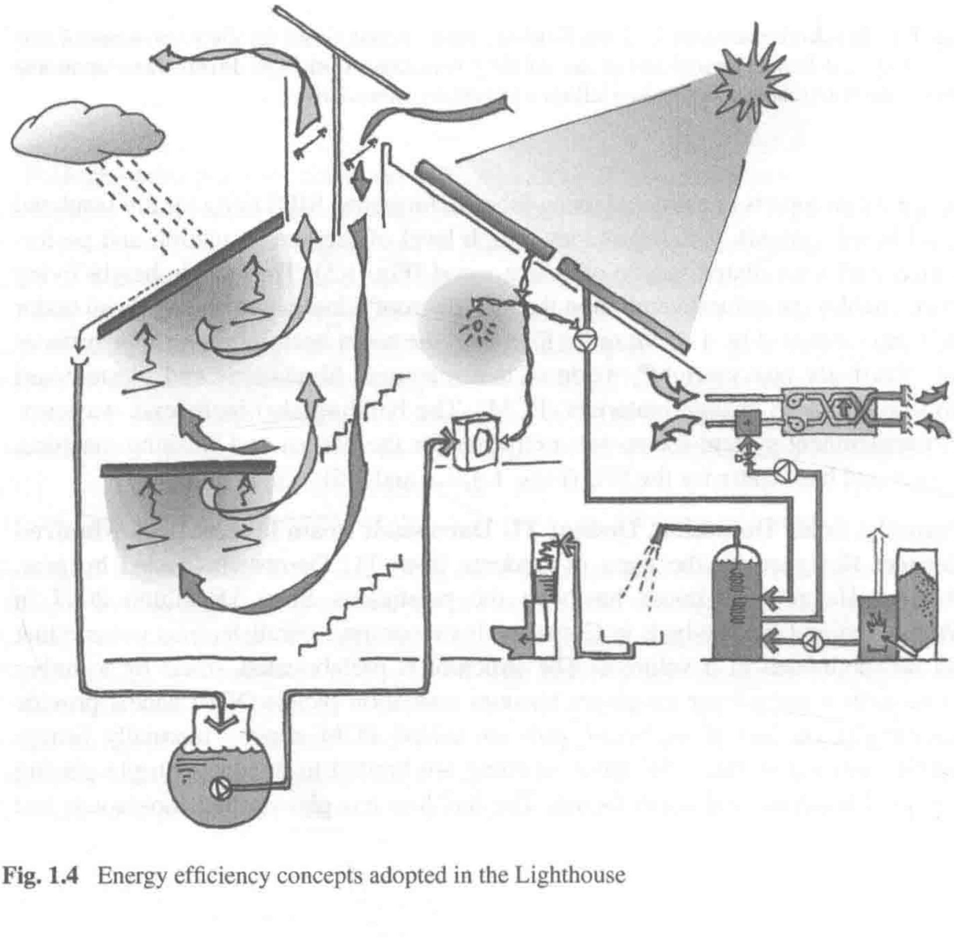

Fig. 1.4 Energy efficiency concepts adopted in the Lighthouse

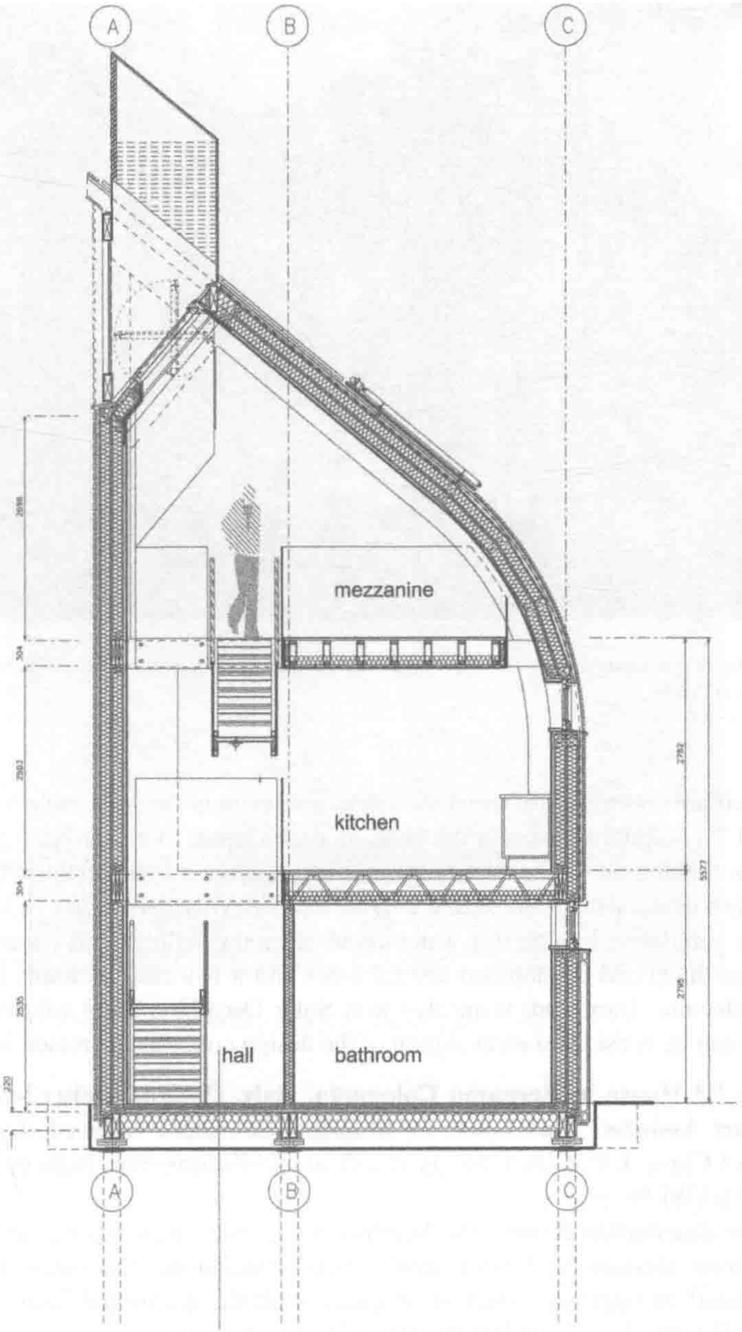

Fig. 1.5 Detailed section of the highly insulated building envelope and the wind catcher

north (quadruple glazing gas filled window) (Fig. 1.6). The timber façade accommodates amorphous photovoltaic modules. On the south façade, a glass covered porch with photovoltaic modules is shaded by louvered panels containing photovoltaic