



# The Handbook of Sustainable Refurbishment

Non-Domestic Buildings



Co-published with  
RIBA  Publishing

Nick V. Baker

# The Handbook of Sustainable Refurbishment Non-Domestic Buildings

**Nick V. Baker**

Earthscan works with RIBA Publishing, part of the Royal Institute of British Architects, to promote best practice and quality professional guidance on sustainable architecture.

**earthscan**  
publishing for a sustainable future

London • Sterling, VA

First published by Earthscan in the UK and USA in 2009

Copyright © Nick V. Baker, 2009

**All rights reserved**

ISBN: 978-1-84407-486-0

Typeset by FiSH Books, London

Cover design by Yvonne Booth

Graphics by Mike J. V. Baker

For a full list of publications please contact:

**Earthscan**

Dunstan House

14a St Cross St

London, EC1N 8XA, UK

Tel: +44 (0)20 7841 1930

Fax: +44 (0)20 7242 1474

Email: [earthinfo@earthscan.co.uk](mailto:earthinfo@earthscan.co.uk)

Web: [www.earthscan.co.uk](http://www.earthscan.co.uk)

22883 Quicksilver Drive, Sterling, VA 20166-2012, USA

Earthscan publishes in association with the International Institute for Environment and Development

A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data

Baker, Nick (Nick Vashon)

The handbook of sustainable refurbishment : non-domestic buildings / Nick V. Baker.  
p. cm.

Includes bibliographical references and index.

ISBN 978-1-84407-486-0 (hardback)

1. Buildings—Repair and reconstruction. 2. Public buildings—Repair and reconstruction.

3. Commercial buildings—Remodeling. 4. Sustainable buildings—Design and construction. I. Title.

TH3401.B35 2009

690'.24—dc22

2009007564

At Earthscan we strive to minimize our environmental impacts and carbon footprint through reducing waste, recycling and offsetting our CO<sub>2</sub> emissions, including those created through publication of this book. For more details of our environmental policy, see [www.earthscan.co.uk](http://www.earthscan.co.uk).

This book was printed in Malta by Gutenberg Press.

The paper used is FSC certified and the inks are vegetable based.



**Mixed Sources**

Product group from well-managed  
forests, and other controlled sources  
[www.fsc.org](http://www.fsc.org) Cert no. TT-COC-002424  
© 1996 Forest Stewardship Council

# Contents

<i>Preface</i> .....	xi
<i>List of Acronyms and Abbreviations</i> .....	xii

## Part One Principles

<b>1</b>	<b>Strategy for Low Emission Refurbishment</b> .....	<b>3</b>
1.1	The case for low emission refurbishment: Energy use in buildings .....	3
1.2	Refurbishment versus rebuild: Economics and environmental impact .....	3
1.3	The building, plant and occupants as a system .....	4
1.4	Implications for change of use .....	5
	Impact on energy consumption .....	6
1.5	Environmental comfort standards .....	7
1.6	Passive environmental strategies .....	8
	Natural ventilation .....	9
	Daylighting .....	10
1.7	Prioritizing refurbishment options .....	13
	Quantifying energy benefits .....	14
1.8	Integration with newbuild .....	18
1.9	Eco-communities and urban renewal .....	19
1.10	Environmental regulation .....	20
	Energy Performance of Buildings Directive .....	20
	Using other legislation in the UK .....	22
	Voluntary schemes and drivers .....	22

## Part Two Practice

<b>2</b>	<b>Floors</b> .....	<b>27</b>
2.1	Solid ground floors .....	27
	Insulation options .....	27
	Underfloor heating or cooling .....	27
2.2	Suspended ground floors .....	28
	Insulation options .....	28
	Underfloor heating or cooling .....	28



2.3	Intermediate floors .....	29
2.4	Thermal response implications of floor insulation.....	29
<b>3</b>	<b>Walls .....</b>	<b>31</b>
3.1	Solid walls .....	31
	External insulation .....	31
	Implications for external insulation .....	32
	Internal insulation.....	33
	Thermal response .....	33
	Cold bridges.....	33
	Interstitial condensation .....	34
3.2	Cavity walls .....	35
	Insulation options .....	35
	Practical considerations .....	36
	Interstitial condensation .....	36
	Thermal implications.....	37
	Retrofit inner or outer leaf .....	37
<b>4</b>	<b>Roofs.....</b>	<b>39</b>
	Roof types .....	39
4.1	Insulating roofs with attic spaces.....	40
	Ventilation of attic space .....	40
4.2	Insulating roofs with voids .....	40
4.3	Insulating solid roofs .....	41
	Insulation above the waterproof membrane.....	41
	Insulation between waterproof membrane and structural deck .....	42
	Insulation below the structural deck.....	43
4.4	Other thermal issues .....	43
	Surface reflectance .....	43
	Low-emissivity membranes in cavities.....	44
	Thermal mass .....	44
	Cold bridges.....	45
4.5	Green roofs and roof ponds.....	45
	Green roofs .....	45
	Roof ponds .....	46
<b>5</b>	<b>Windows .....</b>	<b>47</b>
5.1	Glazing materials .....	47
	Heat transmission through glazing .....	48
	Radiation transmission through glazing.....	50
	High performance glazing .....	50
5.2	Framing and support systems .....	51
	Obstruction of light due to framing .....	52

	Thermal performance of framing.....	53
	Framing material.....	54
5.3	Modifying apertures.....	55
5.4	Shading systems.....	56
	Daylight redistribution.....	56
	Shading options for refurbishment.....	57
	External shading.....	57
	Internal shading.....	59
5.5	High performance daylighting.....	60
<b>6</b>	<b>Atria and Double Skins.....</b>	<b>63</b>
6.1	Atria and energy: Principles.....	65
	Thermal performance.....	65
	Winter performance.....	65
	Summer performance.....	67
6.2	Effect on daylighting.....	67
6.3	Planting and vegetation.....	68
6.4	Double skins and energy.....	68
6.5	Other environmental factors.....	68
6.6	Atria and double skins as part of sustainable refurbishment.....	69
<b>7</b>	<b>Mechanical Services and Controls.....</b>	<b>71</b>
7.1	Boilers.....	71
7.2	Heat distribution.....	72
	Water.....	72
	Air.....	72
7.3	Heat emitters.....	73
	Positioning emitters.....	75
	Sizing emitters.....	75
	Coolth emitters.....	76
7.4	Fans and pumps.....	76
7.5	Refrigeration.....	77
7.6	Lighting installations.....	77
	Luminous efficacy.....	77
	Illuminance level and distribution.....	79
7.7	Controls.....	79
	Local control.....	79
	Central control.....	80
	Zoning.....	80
7.8	Lighting controls.....	81
	Occupancy detection.....	81

	Daylight detection .....	82
	Zoning .....	83
	Energy savings .....	83
7.9	Building energy management systems .....	83
7.10	Adaptive controls .....	84
	Feedback .....	85
	Caretaker controls .....	86
7.11	Hybrid and mixed mode systems .....	86
<b>8</b>	<b>Renewable Energy Options .....</b>	<b>89</b>
8.1	Other renewable energy technologies .....	89

## Part Three Case Studies

<b>9</b>	<b>The Albatros, Den Helder, The Netherlands .....</b>	<b>93</b>
	Objectives .....	93
	Refurbishment strategy .....	93
	The double skin .....	94
	Performance of double skin .....	96
	Ventilation and heating .....	96
	Performance .....	97
	Daylighting .....	98
	Overall energy performance .....	98
	Comfort .....	100
	Conclusions .....	100
<b>10</b>	<b>Lycée Chevroliier, Angers, France .....</b>	<b>101</b>
	Strategy for sustainable refurbishment .....	101
	Main low energy measures .....	102
	A. Thermal .....	102
	B. Lighting .....	102
	C. Comfort: Shading and ventilation .....	102
	D. Other features .....	102
	Insulation .....	102
	Daylight and artificial lighting .....	103
	Artificial lighting .....	103
	Performance .....	104
	Ventilation .....	104
	Performance .....	104
	The atrium .....	105
	Photovoltaic panels .....	106



Waste management and other environmental issues .....	106
Overall energy performance.....	107
Gas consumption .....	107
Electricity consumption .....	107
CO <sub>2</sub> emissions.....	107
Comfort .....	108
Conclusions .....	109
<b>11 Daneshill House, Stevenage, UK .....</b>	<b>111</b>
Strategy for refurbishment.....	111
Main innovative energy-saving features .....	112
The CoolDeck system.....	112
Performance .....	113
Energy efficient air-conditioning controls .....	114
Performance .....	114
Energy-efficient lighting controls .....	114
Performance .....	115
Light emitting diode (LED) lighting in Customer Service Centre .....	116
Solar water heating array.....	118
Performance .....	118
Increased space use efficiency .....	119
Post occupancy evaluation.....	120
Overall energy performance.....	121
<b>12 Ministry of Finance Offices, Athens .....</b>	<b>123</b>
Refurbishment strategy .....	123
Main energy saving features .....	124
Fabric improvements .....	124
Night ventilation techniques.....	124
Ceiling fans .....	124
Daylighting and artificial lighting.....	124
Heating .....	124
Cooling.....	124
Ventilation.....	124
Energy management, control and monitoring .....	125
Performance .....	125
Thermal comfort and air quality.....	125
Daylighting and artificial lighting.....	127
Daylighting performance .....	127
The photovoltaic array .....	127
Overall energy performance.....	127
Heating.....	128



	Cooling.....	128
	Comfort surveys .....	128
<b>13</b>	<b>The Meyer Hospital, Florence .....</b>	<b>131</b>
	Refurbishment strategy .....	131
	The greenhouse .....	132
	Daylighting .....	134
	Overall energy performance.....	134
	Comfort .....	134
	<i>Appendices</i> .....	<i>135</i>
	<i>Index</i> .....	<i>165</i>

# Preface

In most European cities there is a vast stock of existing buildings, many of which are getting to the end of their useful life. To replace the stock would take several decades and incur an unrealistic financial burden. It would also create a large contribution to CO<sub>2</sub> emissions, as a result of the energy associated with the production of materials and the construction of replacement buildings.

It is therefore essential that we develop strategies and techniques to improve the energy performance of our existing stock. It is commonly understood that the heating, cooling, lighting and ventilation of buildings accounts for nearly half of global energy consumption, with the consequent CO<sub>2</sub> emissions having an effect on global warming. The reduction of day-to-day consumption of fossil fuels for heating, cooling, lighting and ventilation must be the main objective in any attempt to refurbish a building sustainably.

This guide is a product of the European Union (EU) funded REVIVAL project, which set out to demonstrate some of these principles by incorporating them in five refurbishment projects of large non-domestic buildings. Wherever possible it draws from the experience of the REVIVAL project, but includes other examples and illustrations when necessary.

This guide is aimed at the architect, engineer, surveyor and project manager. It sets out the case for sustainable refurbishment and the principle measures that can be adopted. It presents principles in a concise technical language, but follows with an explanation of practical implications. It does not attempt to be a source book of manufacturer's information and technical data, or to deal with construction detail.

REVIVAL Team  
July 2009

# 13

## The Meyer Hospital, Florence

### Refurbishment and addition of large greenhouse to historic building in warm climate

The building dates from the 1930s when it was a hospital for tuberculosis patients. It consists of a long three-storey terrace running east-west, of traditional construction with very thick walls and a tiled roof. A central corridor serves rooms on the north and south side (Figures 13.1 and 13.2). The total area is 10,480m<sup>2</sup>. The building had been semi-derelict for some years. A new paediatric hospital has been built on the site adjacent and the refurbished building forms the administrative and reception centre.

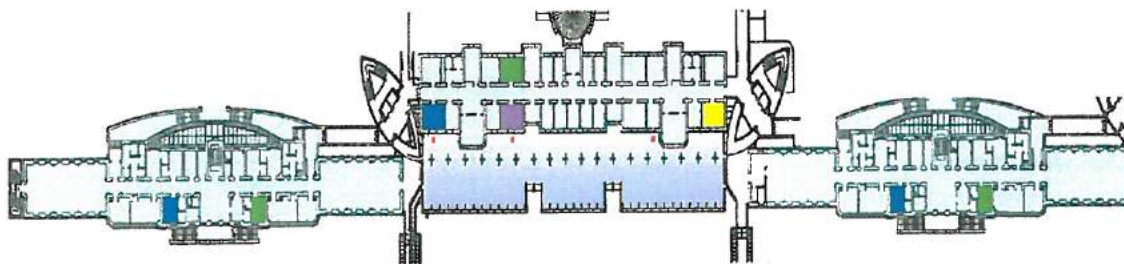
#### Refurbishment strategy

Being of traditional construction the building was non-insulated and single glazed. The first consideration was how to insulate the envelope. The roof presented no problem, since during reconstruction insulation material was included, in this case mineral fibre quilt. The windows were also replaced giving the opportunity to incorporate low-e double glazing in timber frames, giving a U-value of 2.85W/°Cm<sup>2</sup>. This also reduced uncontrolled infiltration.



**Figure 13.1** South elevation of the Villa Ognissanti, the original Meyer Hospital

The solid walls presented some problems. External insulation would have disturbed traditional detailing of this historic building, whilst internal insulation would have reduced thermal inertia.



**Figure 13.2** Plan of the east-west running terrace showing the additional greenhouse (centre)





**Figure 13.3** Replacement timber windows with low-e glazing

In the end, bearing in mind the nature of the climate (mild Mediterranean) it was decided to leave the walls non-insulated other than a small improvement brought by new external render containing a natural lightweight volcanic aggregate. The resultant U-value is calculated to be  $2.0\text{W}/^\circ\text{Cm}^2$ .

A new building energy management system (BEMS) was also installed. This not only managed the conventional heating and cooling, but also the night cooling.

Originally, the renewed south-facing windows were to have included an interpane shading system, magnetically controlled from outside the sealed unit. These were finally rejected on the grounds that since the external louvred casement shutters (Figure 13.4) had to be kept for historic reasons, the expense of the additional integral shading was not justified.

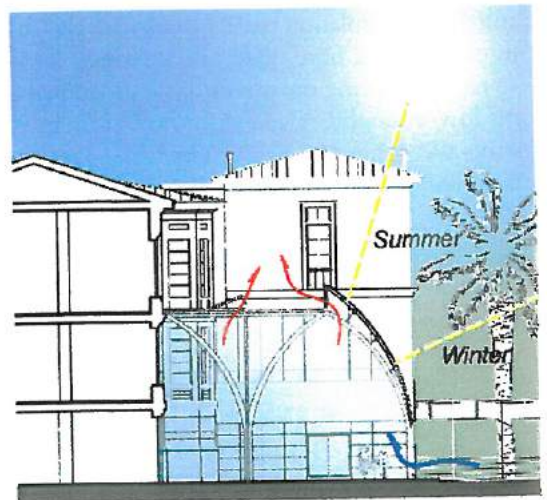
### The greenhouse

The boldest intervention is the installation of a large greenhouse on the south side of the central pavilion abutting the lower two of the three storeys (Figures 13.5, 13.6 and 13.7). As an



**Figure 13.4** Refurbished traditional louvre shutters on south elevation

energy conserving measure, this strategy may be a little surprising for a warm climate. However, there were two mitigating circumstances – firstly much of the lower glazing is shaded by vegetation, and being in contact with the massive non-insulated wall provides stabilizing thermal mass. However, considerable interest has been



**Figure 13.5** Section of greenhouse showing shading and ventilation openings



focused on the risk of overheating in the greenhouse itself, and in the adjacent offices.

The structure is made from laminated timber columns and is a striking addition to the architecture. Its spatial function is as the arrivals foyer and reception area for the whole hospital complex.

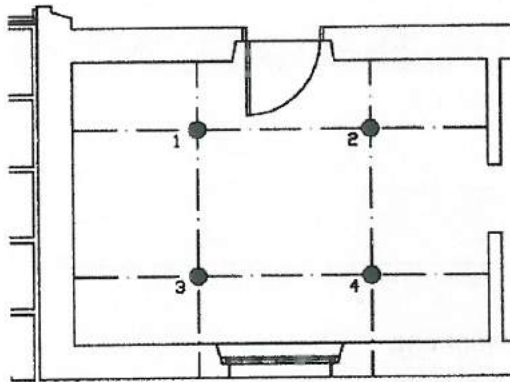


**Figure 13.6** Interior view of greenhouse showing semi-transparent PV shading



**Figure 13.7** Exterior view of greenhouse during construction

Recognizing the potential risk of overheating, the design demonstrates the sound principle of shading and ventilation. In this case, the shading



Position	Daylight Factor %
1	1.71
2	1.37
3	2.57
4	2.02
Average	1.91

**Figure 13.8** Simulated daylight results for office facing greenhouse

is provided by semi-transparent photovoltaic panels. This, and the ventilation provision, are shown in Figure 13.5. The ventilation openings at the top and bottom of the greenhouse are controlled by the BEMS. A further open area can be obtained by leaving the main doors open.

**Table 13.1** CO<sub>2</sub> emissions for corrected measured Meyer 2007 data compared with reference case

	kWh	kWh/m <sup>2</sup>	CO <sub>2</sub> factor	CO <sub>2</sub>
Gas reference	1,257,600	120	0.19	238,944
Meyer	876,652	83.7	0.19	166,563
Electricity reference	1,194,720	114	0.44	525,676
Meyer	880,320	84	0.44	387,340

Note: Total CO<sub>2</sub> kg – Reference 764,620; Meyer 553,903.

## Daylighting

The impact of the greenhouse on the daylighting of the adjacent office rooms had been tested by simulation (Figure 13.8). The result shows a mean value of 1.91 per cent.

Occupants report a high level of satisfaction with the lighting, 4.0 on a 1–5 scale in the end pavilions, but slightly less, 3.5 in the central pavilion adjacent to the greenhouse (Figure 13.9).

## Overall energy performance

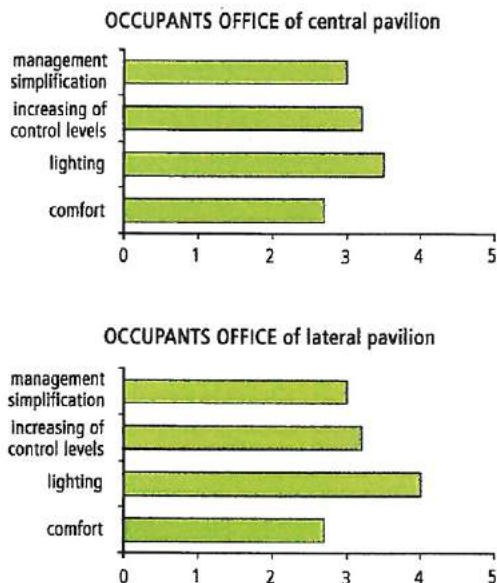
The Meyer project is one of those where there has been major change in the function of the building, so there is no comparable data available for energy consumption before the refurbishment. Thus a reference office has been defined.

This shows a 28 per cent reduction in emissions, although it has to be said that the reference values for gas and electricity per m<sup>2</sup> are very high for a building in the climate of Florence.

## Comfort

Questionnaires were issued to occupants in the central wing adjacent to the greenhouse, and in the two lateral wings. The results are shown in Figure 13.10. These are consistent, with the exception of a slightly lower satisfaction for lighting reported in the central wing, which could be due to the presence of the greenhouse. Unfortunately the question does not distinguish between artificial lighting and daylighting.

Comfort, which is probably strongly weighted towards thermal comfort, is a little on the posi-



**Figure 13.9** Results of user survey for office facing greenhouse (central pavilion) and office facing open air (lateral pavilion). Scale ranges from 0 – very dissatisfied to 5 – very satisfied.

tive side of neutral, which is typical where discomfort is not present, and should therefore be regarded as successful, although since all values are averaged, it is not possible to see if discomfort was reported by some respondents.

It is interesting to note that a positive response is recorded for the level of user control. This indicates that the temperature controllers in each room, providing a simple user-friendly adaptive opportunity, are appreciated.



*'An incisive book that provides practical strategies and tactics for sustainable refurbishment, literally from the ground up. Richly illustrated with informative diagrams, supported by accessible quantitative analysis and reinforced by detailed case study examples, this book is a triumph.'*

Koen Steemers PhD RIBA/ARB, Professor of Sustainable Design and Head of the Department of Architecture, University of Cambridge

*'Nick Baker tackles head on what many eminent scientists in Cambridge regard as most pressing contemporary problems, the sustainable refurbishment of the existing building stock, much of which is going to be with us still in 2050. Dr Baker delivers his profound understanding of these difficult issues in a wholly intelligible and compelling way. I cannot commend this book to my profession and its patrons highly enough.'*

Professor Alan Short, University of Cambridge and Short and Associates Architects

The refurbishment of existing buildings is a crucial yet often neglected subject within sustainable architecture – attention is usually focused on new buildings. Many old buildings waste large amounts of energy and provide poor internal conditions for occupants through poor lighting, poor ventilation, solar penetration and glare, and poor control of heating and cooling. Demolition is an option but the refurbishment alternative is increasingly seen as more sustainable in terms of architectural value, materials use, neighbourhood disruption and waste disposal. In addition, the potential impact of low energy refurbishment is much greater than that for new build since there are many more buildings already in existence than will be built in the next 10–20 years, the period over which many CO2 targets apply.

*The Handbook of Sustainable Refurbishment: Non-Domestic Buildings* offers architects, engineers and a wide range of building professionals practical advice, illustrated by real examples. It moves from principles of sustainable refurbishment to specific design and engineering guidance for a variety of circumstances. It emphasizes the need for an integrated approach by showing how refurbishment measures interact with one and other, and with the occupants, and how performance is ultimately influenced by this interaction.

**Nick V. Baker** is an independent consultant and technical expert on the energy efficient refurbishment and the development of LT software. He is affiliated to The Martin Centre, Department of Architecture, University of Cambridge.

AECOM

Architecture/Engineering

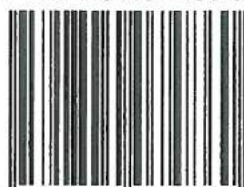
earthscan

publishing for a sustainable future

[www.earthscan.co.uk](http://www.earthscan.co.uk)

Earthscan strives to minimize its impact on the environment

ISBN 978-1-84407-486-0



9 781844 074860