PHOTOVOLTAICS IN THE URBAN ENVIRONMENT

Lessons Learnt from Large-Scale Projects

Edited by Bruno Gaiddon, Henk Kaan and Donna Munro

Photovoltaics in the Urban Environment

Lessons Learnt from Large-scale Projects

Edited by
Bruno Gaiddon, Henk Kaan and Donna Munro

earthscan
publishing for a sustainable future
London • Sterling, VA

First published by Earthscan in the UK and US in 2009

ISBN: 978-1-84407-771-7

Typeset by Domex e-data Pvt Ltd
Cover design by Rob Watts

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
Web: **www.earthscan.co.uk**

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

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

Photovoltaics in the urban environment : lessons learnt from large scale projects / edited by Bruno Gaiddon, Henk Kaan, and Donna Munro.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-84407-771-7 (hardback)
1. Photovoltaic power systems. 2. City planning. 3. Electrification–Case studies. 4. Energy policy. I. Gaiddon, Bruno. II. Kaan, Henk. III. Munro, Donna.
TK1087.P49 2009
621.31'244091732–dc22

2009014032

At Earthscan we strive to minimize our environmental impacts and carbon footprint through reducing waste, recycling and offsetting our CO_2 emissions, including those created through publication of this book. For more details of our environmental policy, see 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.

Photovoltaics in the Urban Environment

Spain, Barcelona

Estefanía Caamaño-Martín, Technical University of Madrid, Instituto de Energía Solar, Spain

Sweden, Malmö

Anna Cornander, Solar City Malmö, Sweden

UK, London, Croydon

Emily Rudkin, Halcrow, UK

UK, Kirklees

Donna Munro, UK

US, Premier Gardens New Home Development, Rancho Cordova, CA

Christy Herig, Solar Electric Power Association, US

Chapter 3 Case Studies of Urban Areas with Plans for PV in the Future

Denmark, Valby, Sol i Valby

Kenn H. B. Frederiksen, EnergiMidt A/S, Denmark

France, Lyon, Lyon-Confluence

Bruno Gaiddon, Hespul, France

Germany, Solar Urban Planning Berlin

Sigrid Lindner, Ecofys, Germany

Germany, Solar Housing Estate Cologne-Wahn

Sigrid Lindner, Ecofys, Germany

Germany, Solar Quarter Gelsenkirchen-Bismarck

Sigrid Lindner, Ecofys, Germany

Portugal, Lisbon, Bairro do Padre Cruz

Maria João Rodrigues, Wide Endogenous Energy Solution, Portugal
Joana Fernandes, Lisboa E-Nova, Portugal

UK, Port of Barrow Redevelopment

Donna Munro, UK

Chapter 4 Regulatory Framework and Financing

National planning process

Donna Munro, UK

Options to finance PV projects

Sigrid Lindner, Ecofys, Germany

Chapter 5 Design Guidelines

Basics of photovoltaics

Wim Sinke, Energy Research Centre of The Netherlands ECN, The Netherlands

Photovoltaics and aesthetics

Henk Kaan, Energy Research Centre of The Netherlands ECN, The Netherlands
Tjerk Reijenga, KOW X, The Netherlands

Photovoltaics in public spaces

Joana Fernandes, Lisboa E-Nova, Portugal
Bruno Gaiddon, Hespul, France

Photovoltaics and electricity distribution networks

Estefanía Caamaño-Martín, Technical University of Madrid, Instituto de Energía Solar, Spain
Bruno Gaiddon, Hespul, France
Hermann Laukamp, Fraunhofer ISE, Germany

Top tips at various project stages

Donna Munro, UK

List of Contributors

Introduction

Donna Munro, UK
Bruno Gaiddon, Hespul, France
Henk Kaan, Energy Research Centre of The Netherlands ECN, The Netherlands

Chapter 1 Urban Planning with Photovoltaics

Donna Munro, UK

Chapter 2 Case Studies of Existing Urban Areas with Photovoltaics

Australia, Sydney Olympic Village

Mark Snow, University of New South Wales, Australia
Deo Prasad, University of New South Wales, Australia

Austria, Gleisdorf

Demet Suna, Vienna University of Technology, Energy Economics Group, Austria
Christoph Schiener, Vienna University of Technology, Energy Economics Group, Austria

France, Grand-Lyon, La Darnaise

Bruno Gaiddon, Hespul, France

France, Saint-Priest, Les Hauts de Feuilly

Bruno Gaiddon, Hespul, France

Germany, Freiburg, Schlierberg Solar Estate

Ingo B. Hagemann, www.architekturbuero-hagemann.de, Germany

Italy, Alessandria

Francesca Tilli, Gestore dei Servizi Elettrici, GSE, Italy
Michele Pellegrino, ENEA, Italy
Antonio Berni, Eta Florence, Italy
Niccolò Aste, Politecnico di Milano, Italy

Japan, Jyosai Town

Shogo Nishikawa, Nihon University, Japan
Tomoki Ehara, Mizuho Information Research Institute, Japan

The Netherlands, Amsterdam, Nieuw Sloten

Jadranka Cace, Rencom, The Netherlands
Emil ter Horst, Horisun, The Netherlands

The Netherlands, Amersfoort, Nieuwland

Jadranka Cace, Rencom, The Netherlands
Emil ter Horst, Horisun, The Netherlands

The Netherlands, Heerhugowaard Alkmaar Langedijk (HAL) location, 'City of the Sun'

Marcel Elswijk, Energy Research Centre of The Netherlands ECN, The Netherlands
Henk Kaan, Energy Research Centre of The Netherlands ECN, The Netherlands
Lucas Bleijendaal, Energy Research Centre of The Netherlands ECN, The Netherlands

Acknowledgements

The editors would like to thank:

- all the contributors for their work;
- International Energy Agency PVPS experts for their technical support;
- the European Commission (Intelligent Energy Europe programme) for its financial support;
- the French National Agency for Environment and Energy Management (ADEME) for its financial support.

The editors would also like to thank the following organizations for having provided information and technical support in the preparation of the case studies in this book:

Australia, Sydney Olympic Village

Mirvac LendLease Village Consortium
BP Solar Australia
Energy Australia
Sustainable Energy Development Authority (SEDA)

Austria, Gleisdorf

The City of Gleisdorf
Feistritzwerke

France, Grand-Lyon, La Darnaise

OPAC Grand-Lyon
Tenesol
The French National Agency for Environment and Energy Management (ADEME)
Grand-Lyon Energy Agency

France, Saint-Priest, Les Hauts de Feuilly

SERL
France-Terre
GRDF

Germany, Freiburg, Schlierberg Solar Estate

Fraunhofer-Institut für Solare Energiesysteme ISE
Rolf Disch
Solarsiedlung GmbH
The City of Freiburg

Italy, Alessandria

The City of Alessandria

Japan, Jyosai Town

The New Energy and Industry Technology Development Organization (NEDO)
The City of Ota

The Netherlands, Amsterdam, Nieuw Sloten

Energiebedrijf Amsterdam
SenterNovem
NUON

The Netherlands, Amersfoort, Nieuwland

ENECO
BOOM
SenterNovem

The Netherlands, Heerhugowaard Alkmaar Langedijk (HAL) location, 'City of the Sun'

The City of Heerhugowaard

Spain, Barcelona

Barcelona Energy Agency
The City of Barcelona

Sweden, Malmö

The City of Malmö

UK, London, Croydon

Croydon Council
Solarcentury

UK, Kirklees

Kirklees Council Environment Unit
Yorkshire Housing

US, Premier Gardens New Home Development, Rancho Cordova, CA

Premier Homes
Sacramento Municipal Utility District (SMUD)
US Department of Energy
NREL

Denmark, Valby, Sol i Valby

Copenhagen Energy and Urban Renewal
Cenergia
Hasløv & Kjærsgaard

France, Lyon, Lyon-Confluence

SPLA Lyon-Confluence

Germany, Solar Urban Planning Berlin

Senatsverwaltung für Stadtentwicklung Berlin

Germany, Solar Housing Estate Cologne-Wahn

Energy Agency North-Rhine-Westphalia
The City of Cologne

Germany, Solar Quarter Gelsenkirchen-Bismarck

The City of Gelsenkirchen

Portugal, Lisbon, Bairro do Padre Cruz

The City of Lisbon
Empresa Pública de Urbanização de Lisboa (EPUL)
National Energy Agency (ADENE)
Lisbon Municipal Energy-Environment Agency (Lisboa E-Nova)

UK, Port of Barrow Redevelopment

Barrow Borough Council
West Lakes Renaissance

Foreword

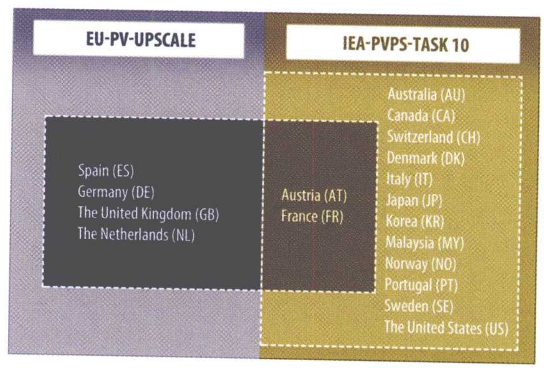
This book is the collective work of international experts from 18 countries with experience of large-scale implementation of photovoltaics in Europe, North America, Asia and Oceania.

This work was carried out within two different international groups:

- PV UP-SCALE, a European funded project under the Intelligent Energy for Europe programme related to the large-scale implementation of photovoltaics in European cities – www.pvupscale.org.

- TASK 10, an international collaborative project on Urban-scale Photovoltaic Applications of the International Energy Agency Photovoltaic Power Systems Programme (IEA PVPS) – www.iea-pvps.org.

PV UP-SCALE (Photovoltaics in Urban Policies – Strategic and Comprehensive Approach for Long-term Expansion) aims at bringing to the attention of the stakeholders in the urban planning process the economic drivers, bottlenecks such as grid issues, and do's and don'ts within the photovoltaic process. The project complements the activities that are being executed in TASK 10 of the IEA PVPS Implementing Agreement.



List of participating countries

TASK 10 has the objective of enhancing the opportunities for wide-scale, solution-oriented applications of photovoltaics in the urban environment as part of an integrated approach that maximizes building energy efficiency and solar thermal and photovoltaics usage. The Task's long-term goal is for urban-scale photovoltaics to be a desirable and commonplace feature of the urban environment in IEA PVPS member countries. It builds on the results of TASK 5 (Grid issues), which ended in 2003 and TASK 7 (Building Integrated Photovoltaics), which ended in 2001.

List of Acronyms and Abbreviations

Acronyms

ACs	Autonomous Communities (Spanish regional governments)
ADEME	French National Agency for the Environment and Energy Savings
AEB	Barcelona Energy Agency
BIRA	Building Industry Research Alliance
BREEAM	Building Research Establishment's Environmental Assessment Method (UK)
CEC	California Energy Commission
DNO	Distribution Network Operator
EACI	Executive Agency for Competitiveness and Innovation
EBA	Energy Company Amsterdam
EsCos	energy service companies
ETP	Energy Technologies Perspectives
EU	European Union
FP	framework programme
HAL	Heerhugowaard, Alkmaar and Langedijk
IEA	International Energy Agency
IEA PVPS	International Energy Agency – Photovoltaic Power Systems Programme
IEC	International Electrotechnical Commission
IEE	Intelligent Energy – Europe
IPCC	Intergovernmental Panel on Climate Change
LEG	State Development Association (Germany)
NatHERS	National Housing Energy Rating Scheme
NEDO	New Energy and Industry Technology Development Organization
NSW	New South Wales
OCA	Olympic Co-ordination Authority
OECD	Organisation for Economic Co-operation and Development
PMEB	Plan de Mejora Energética de Barcelona
PV UP-SCALE	Photovoltaics in Urban Policies – Strategic and Comprehensive Approach for Long-term Expansion
ROC	Renewable Obligation Certificate (UK)
SCC	Solar City Copenhagen

SEDA	Sustainable Energy Development Authority
SET	Strategic Energy Technology
SMUD	Sacramento Municipal Utility District

Technical abbreviations

AC	alternating current
BIPV	building-integrated PV (BIPV)
BoS	balance-of-system
CHP	combined heat and power
DC	direct current
kWp	kilowatts peak
LV	low voltage
MV	medium voltage
MWp	megawatts, peak
near-ZEH	near zero energy homes
PV	photovoltaics
R&D	research and development
RE	renewable energy

In response to growing concerns about global warming, the high volatility of fossil fuel prices and the need to improve the security of energy supplies, the European Union (EU) is giving increasingly high priority to integrated policies for addressing climate change and energy. The EU has agreed to set an example to the rest of the world by cutting its greenhouse gas emissions by at least 20 per cent by 2020, and to do that has set ambitious 2020 targets: reducing energy consumption by 20 per cent through improved energy efficiency and introducing 20 per cent of renewable energy sources, including PV, into the EU final energy demand.

A new EU Directive on renewable energy (RE) is being prepared to achieve the 2020 RE target, and this will contain several elements that are important for the PV sector:

- streamlining administrative procedures for authorizing the construction of RE projects;
- obligatory consideration of RE use in local and regional planning;
- minimum RE requirements in building codes;
- improved training and certification of installers;
- easier access to the electricity grid.

The new RE Directive will require each Member State to adopt in 2010 a National Action Plan, in which they must define concrete strategies to reach their 2020 national target for RE and the contribution of each sector (electricity, transport, and heating and cooling). Here, there is an important opportunity for promoting the use of PV at Member State level.

Complementary to the EU policy initiatives, the Strategic Energy Technology (SET) Plan and the European Solar Industrial Initiative aim at reducing PV technology costs and turning technology opportunities into business realities. *The Strategic Energy Technology (SET) Plan: Towards a low carbon future*, which was published by the European Commission in November 2007, has identified solar technology as particularly relevant to the European climate-energy policy objectives. In response, the leaders of the European Solar Industrial Initiative have recently updated their targets for the market penetration of PV technology to levels that are considerably more ambitious, reflecting the rapid growth of PV markets and the increasing confidence of the PV industry in the future role of its technology.

The European Commission has maintained long-term support for research, development and demonstration in the PV sector through a series of Research and Technological Department framework programmes (FPs), providing a framework within which researchers and industrialists can work together to develop PV technology and applications. The current FP7 (2007–2013) has an increased budget for RE compared with earlier FPs.

The current Intelligent Energy – Europe (IEE) programme (2007–2013) also has a substantially increased budget (€730 million for seven years) compared with earlier programmes. Its annual work programmes aim to tackle the 'softer' factors that influence the growth of RE markets, including the removal of market barriers, changing behaviour, raising awareness, promoting education and certified training schemes, product standards and labelling. The current IEE programme is supporting multinational teams that are working together to create more favourable market conditions and a more favourable business environment in the different Member States for energy efficiency and renewable energy sources, including PV. Whilst EU policies set the targets and legal framework, the IEE programme supports market actors who work together to 'make it happen' on the ground.

PV UP-SCALE was one the first PV projects to be funded by IEE, and benefited from a fruitful cooperation with the IEA PVPS Task 10 'Urban-scale Photovoltaic Applications'. In line with the market-oriented approach of IEE, PV UP-SCALE addressed important issues related to the large-scale implementation of dispersed grid-connected PV in the urban environment. The following areas have been covered by the project: the introduction of solar technologies in the urban planning process; working collaboration with architects, engineers and policy-makers; the connection of a large number of PV systems to the low-voltage grid, involving utilities and energy companies; raising awareness of relevant market stakeholders, for instance by means of the PV World Database, which contains information on hundreds of building-integrated PV (BIPV) projects and several examples of urban-scale PV projects.

This book is one of the outcomes of the PV UP-SCALE project, and provides up-to-date information and examples of planning for PV systems in urban areas. It will be found particularly useful by architects, engineers, project developers and urban planners wishing to include this innovative, clean and attractive technology in new urban developments.

William Gillett
Head of Unit Renewable Energy
European Commission EACI
Brussels, Belgium
December 2008

Contents

Introduction

Donna Munro, Henk Kaan and Bruno Gaiddon

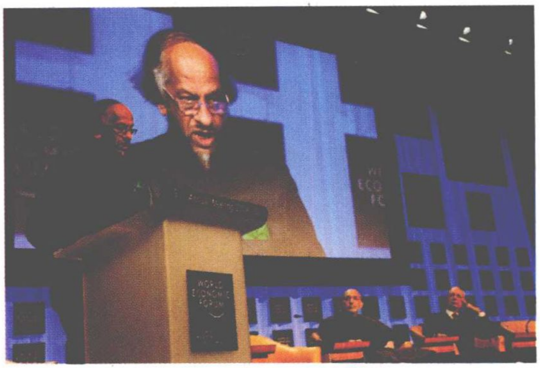
Why do we need renewable energy?

The world currently faces two major interrelated energy problems. The world economy is based on fossil fuels, mainly oil. However oil reserves are finite and the *World Energy Outlook 2008* report by the International Energy Agency highlighted the fact that output from the world's oil fields is declining (IEA, 2008). At the same time demand for oil is expected to grow in countries such as China and India. Concern is rising in the industrialized countries that these issues could lead to a major economic crisis.

The second major problem is climate change. The Intergovernmental Panel on Climate Change (IPCC) released a synthesis report in November 2007 based on several decades of international scientific research that confirmed the warming of the climate on Earth (IPCC, 2007). This report also clearly demonstrates for the first time that human activity is the origin of the rapid climate change.

In December 2007 the Nobel Peace Prize was awarded to the IPCC and Al Gore, the former Vice President of the United States, for efforts to build up and disseminate greater knowledge about manmade climate change, and to lay the foundations for measures that are needed to counteract such change. This again demonstrates the need for urgent international actions to mitigate the negative consequences of climate change due to the increase of greenhouse gas emissions, following the tremendous consumption of fossil fuels.

Converting the present fossil fuel economy into a renewable energy-based economy, using all kinds of available renewable energy sources, is part of the solution to both of these problems.

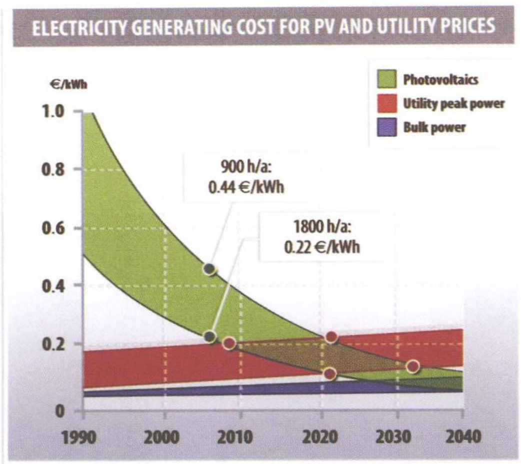


R. K. Pachauri, Chairman of the Intergovernmental Panel on Climate Change, co-winner of 2007 Nobel Peace Prize

Source: © World Economic Forum, swiss-image.ch, photo by Remy Steinegger, Creative Commons

Today, according to the United Nations, half of the world population lives in cities where a significant share of the total world annual energy is consumed either for the heating or cooling of living spaces, for the transport of goods and people, or for electrical appliances. Around 40 per cent of the energy consumption in Organisation for Economic Co-operation and Development (OECD) countries is used by the built environment, in some form or another, with electricity taking an increasingly larger role. Energy savings in cities as well as the generalized use of all renewable energy sources are therefore necessary to mitigate global warming. Solar photovoltaics (PV) is a renewable energy technology that is ideal for use in cities where it can be placed on buildings' roofs and façades to generate electricity.

Photovoltaic electricity is still generally more expensive to produce than conventional electricity,



Cost for PV electricity compared to utility prices

Source: © European Photovoltaic Industry Association, EPIA, W. Hoffman

PV shading device integrated into the building design

Source: © Hespul

but increases in production capacities and research and development (R&D) achievements are leading to major cost reductions in PV. Among the renewable energies, PV is the one with the highest long-term potential, and some experts predict it will be the cheapest option for electricity generation in the mid and long term. In the coming decades, solar electricity from the roof may be more attractive in terms of price than electricity from the wall socket offered by utilities (EPIA, 2008).

Solar photovoltaics in the urban environment

Among present energy systems, PV is the most widely applicable energy solution for the production of electricity in urban areas. As with all renewable energy systems, PV produces electricity in a CO_2 neutral way.

Roofs and façades offer a huge amount of unexploited surface that can be used to install PV. The possible contribution of PV electricity to the demand of IEA cities with the present PV technology was evaluated as being from 15 per cent up to 60 per cent depending on the city structure (IEA, 2002).

But PV is not just an efficient energy system that produces electricity close to the place of consumption. In contrast to all other energy solutions, it can also be used for other technical or aesthetic functions of buildings, such as shading devices or as a visible element of the building envelope.

From single PV projects to urban-scale PV systems

Historically most of the PV systems installed have been single projects rather than groups of systems in urban areas. Today PV systems are generally installed when building owners voluntarily decide to install PV on their buildings, whatever the type of building considered: private house, apartment building or public building. However, if PV systems are to make a significant contribution to reducing CO_2 emissions from buildings they will need to be installed on a larger scale than at present.

Compared to one-off buildings, the installation of large groups of PV systems presents new challenges. This is not due to the PV technology, which causes very few problems, but to the fact