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

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

The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that may be made of the information contained therein.

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.

Contents

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

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

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

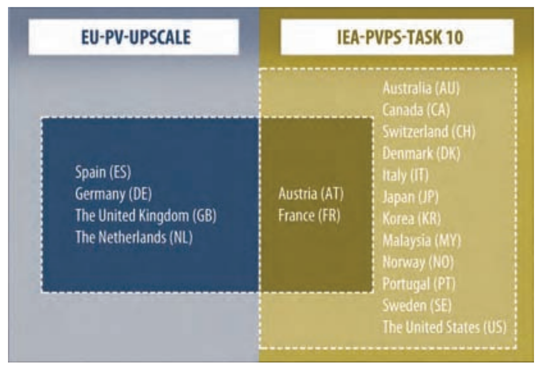
Foreword

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.

Preface

In order to meet the challenges the world is facing we need nothing less than a global revolution in the ways that energy is supplied and used. This was a conclusion from the *Energy Technologies Perspectives* (ETP) publication published in 2008 by the International Energy Agency (IEA). The publication forms the IEA response to the G8 call to provide guidance for decision-makers on how to bridge the gap between what is happening and what needs to be done in order to build a clean, clever and competitive energy future. It is based on analysis of different scenarios of how the energy sector could be transformed over the next decades. According to the most advanced scenario, which corresponds to Intergovernmental Panel on Climate Change (IPCC) emission reduction targets, by 2050 renewable energy should supply 46 per cent of global power. Among the renewable energy technologies, photovoltaics will play a major role.

Solar energy has a unique position in that there is a huge and practically unlimited potential which can be tapped and one which is moreover fairly evenly distributed around the globe. Although geographical variations in the solar resource do exist, they do not in principle prevent the use of solar energy in most regions of the world. In 2001, the IEA's photovoltaic programme IEA PVPS Task 7, Photovoltaic Power Systems in the Built Environment, analysed the potential of building-integrated photovoltaics in a number of countries. It was demonstrated that an important share of the overall power could be produced on the existing building stock using presently available photovoltaic technologies. This work confirmed that photovoltaics is one of the few renewable energy technologies that can supply electrical energy where it is being used, namely on buildings and in the urban environment.

Since then, evidence and experience have grown concerning the ways in which photovoltaics can and should be implemented in the urban environment. This topic has been the subject of the IEA PVPS Task 10, Urban-scale PV Applications in cooperation with the European project PV UP-SCALE. Information and experience from present and future urban-scale photovoltaic projects around the globe have been collected and analysed with respect to urban planning issues, design guidelines and implementation aspects. This book is the result of this broad and interdisciplinary work carried out for the very first time.

The present book is in many ways unique: it is the first systematic collation of existing urban-scale PV projects and experience. It is also the result of an interdisciplinary team of experts who have analysed these projects according to different technical and non-technical aspects. And finally, this book is the result of cooperation between major programmes, namely the International Energy Agency's PVPS Programme and the European Commission's Executive Agency for Competitiveness and Innovation (EACI) PV UP-SCALE project.

I trust that this book will find numerous readers among a broad range of professionals ranging from architects and engineers to urban planners and project developers. The different case studies will provide the interested reader with new insights and lessons learnt about the emerging topic of urban-scale photovoltaic applications. I would like to thank the IEA PVPS Task 10 and PV UP-SCALE experts for their dedicated work to make this valuable information available.

Stefan Nowak
Chairman IEA PVPS
St Ursen, Switzerland
December 2008

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

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

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.

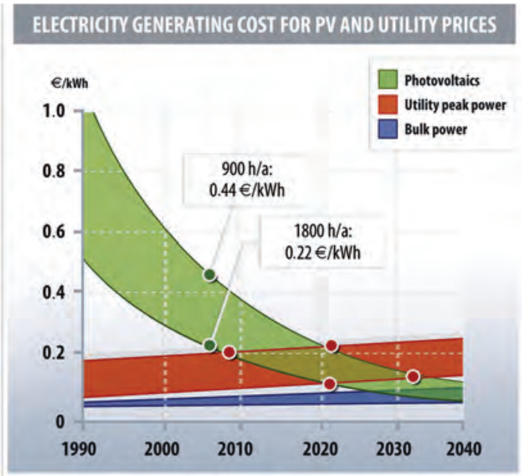
Converting the present fossil fuel economy into a renewable energy-based economy, using all kinds of available renewable energy sources, is part of the solution to both of these problems.

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

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.

PV shading device integrated into the building design

Source: © Hespul

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

Group of PV systems installed in a new urban development

Source: © Sacramento Municipal Utility District

that PV deals with many aspects and interacts with many stakeholders such as the wider urban planning, development, construction and electricity generation sectors which have very limited experience with PV. Also most administrative and regulatory systems are not yet well adapted for groups of small, distributed generators.

Lessons learnt from large-scale projects

This book identifies success factors and potential problems of urban-scale PV systems. It follows on from a wide ranging review of urban areas where the installation of significant amounts of PV has been completed or planned. In all of the areas reviewed the quantity of PV is significant, impacting substantially on the area where it is located. The range of countries, development stages and stakeholders involved is extremely wide and this has led to the collection of a comprehensive set of lessons learnt and successful methods of promoting the implementation of PV within the urban planning process.

Chapter 1 presents the lessons learnt, divided up into the four main stages of developing an urban area: the policy stage, the planning stage, the design and construction stage, and the occupation stage.

Two groups of detailed case studies of urban areas with PV from 13 countries are provided:

- Urban areas that had already installed significant amounts of PV several years ago, for which issues of maintenance and the impact of occupants' behaviour can be assessed, see Chapter 2.
- Urban areas with plans to include PV in the future with a focus on the planning and design stage provided as case studies, see Chapter 3.

The impacts of legal and regulatory structures are then explored in Chapter 4. Chapter 5 provides some technical guidelines on PV basics, site design, PV and aesthetics, grid issues and other aspects. Readers new to the subject of PV may find it helpful to read Chapter 5 first.

References

European Photovoltaic Industry Association and Greenpeace (2008) 'Solar Generation V – Solar electricity for over one billion people and two million jobs by 2020', EPIA and Greenpeace, Brussels

Intergovernmental Panel on Climate Change (2007) *Climate Change 2007 – Synthesis Report*, Geneva

International Energy Agency Photovoltaic (2008) *World Energy Outlook 2008*, IEA, Paris

International Energy Agency Photovoltaic Power Systems Programme (2002) *Potential for Building Integrated Photovoltaics*, Report IEA PVPS T7-4:2002, IEA, Paris

1 Planning for Urban-scale Photovoltaic Systems

Donna Munro

This chapter looks at lessons learnt from urban areas where large numbers of photovoltaic systems have been installed or planned. The lessons learnt come from the experience of many engineers, architects, urban planners and occupants who have been willing to pass on their experiences so that others may learn from their successes and problems.

The lessons learnt are divided up into the four main stages of developing an urban area:

1 National and regional policy formation and strategies. These set the context in which urban planners create plans for specific urban areas and developments.
2 Site layout and initial design. This stage is critical for maximizing the possibilities for installing renewables.
3 Implementation – from design to construction. Good sharing of information and team-working are critical at this stage.
4 Occupation – when the real success or otherwise of a project can be seen. It is all too easy to ignore photovoltaic systems once they are installed but this risks reductions in energy output.

Planning time scales

Source: © Ecofys

Planning for renewables

National policies to promote renewables, such as feed-in tariffs, can provide a positive backdrop and encourage the implementation of individual buildings with renewables. However, when it comes to larger projects such as new developments or concentrations of renewable projects within particular areas, local government has a key role to play.

In the majority of cities that have installed significant amounts of renewable energy infrastructure over the last ten years the local municipal government has had a key role in stimulating projects. When it comes to installation of large amounts of PV, these cities tend to have several important factors in common:

- a strong local political commitment to the environment and sustainability;
- the presence of municipal departments or offices dedicated to the environment, sustainability or renewable energy;
- obligations that some or all buildings include renewable energy;
- information provision about the possibilities of renewable energy;
- challenging development sites that have inspired ambitious renewable energy projects.

Political commitment

In areas where an initial political commitment to renewables has led to successful projects, the positive results and feedback from the projects have strengthened and reinforced the political commitment, and led to further projects. Thus a positive cycle can be set up, with good projects leading to further projects and the continuation of supportive policies. Methods of providing feedback to political bodies that can have a positive impact include winning environmental awards (which can result in positive publicity and in some cases monetary prizes that can be used for further projects in renewables) and ensuring that positive impacts on the local economy and consumers' energy behaviour are identified and fed back to the decision-makers.

Environmental departments make a difference

Having proactive municipal environment/ sustainability departments or officers can make an enormous difference. They can play a key role in defining new development areas with a renewable component; linking up developers and architects of suitable building projects with information on renewables; and providing assistance in obtaining funding. They are also involved with the drafting of supportive local policies and ensuring that the wider results of renewable energy projects, such as the impact on the local economy, are fed back to political bodies and lead to the continuation of supportive policies.

Obligations have a major impact

Obligations to include renewable energy in new developments can have a major impact. In the UK a rule that 10 per cent of the predicted energy demand from new developments must be supplied by renewables (also known as the Merton Rule after the London suburb where it was first applied) is rapidly being taken up by municipal authorities and is a major driver towards the implementation of renewables in the UK.

In The Netherlands entire new cities can be defined in a top-down approach that can include requirements for renewables. This has led to some massive projects such as the Stad van der Zon (City of the Sun in the Heerhugowaard-Alkmaar-Langedijk (HAL) region. These huge projects can be inspirational – but they can also take such a long time to be implemented that they can be unwieldy to steer and vulnerable to changes in government policy.

In France and Germany, municipalities can define new quarters but the development of individual buildings is up to private investors. The role of the municipality is to set targets and to inform and inspire investors. Some municipalities have found methods of setting specific requirements for the implementation of PV. For example, in Gelsenkirchen in Germany, the city is imposing solar requirements in the contract of land purchase.

Money helps but information is vital

Many of the case studies reviewed in this book obtained funding through public programmes. However, capital funding programmes supporting PV have become rare. Some projects, such as the Schlierberg solar estate in Freiburg and the communal PV power plant in Gleisdorf, used innovative financing mechanisms such as shares, and enhanced payments for renewable electricity are becoming more widely available.

When obligations are imposed on developers to include a certain proportion of renewable power generation in new developments, capital funding tends not to be available; instead the provision of information is the crucial factor.

Information can be provided by different actors at different stages. Croydon in London was one of the first municipalities to impose a planning rule of 10 per cent renewables contribution for new major developments. It sees the main barrier as know-how, not cost, so the Croydon Energy Network's Green Energy Centre provides advice and support to developers on accessing grants and deciding what type of renewable technology to use.

In Lyon, France, the local energy agency organized technical visits to renewable energy systems for housing associations. This initiative led to the La Darnaise project with PV on the façades of refurbished apartment buildings. A major redevelopment of the confluence area near the centre of Lyon is now under way and information is being provided by an informal group of local experts.

Challenging development sites lead to innovative projects

The final common factor noted in many of the innovative PV developments was that they were often based on challenging development sites. These more challenging sites seem to have inspired creative approaches and led to the inclusion of renewables in some major developments. Examples include projects to redevelop old industrial areas in Lyon in France, Barrow in the UK and Gelsenkirchen in Germany, as well as the challenging Olympic Village in Sydney, Australia. The inclusion of renewables formed part of a strategy to transform the image of social residential areas such as Alessandria in Italy or La Darnaise near Lyon. The fall of the Berlin Wall led to development opportunities in the centre of Berlin, and also in the centre of Freiburg, where French troops vacated a vast area after the fall of the Wall.

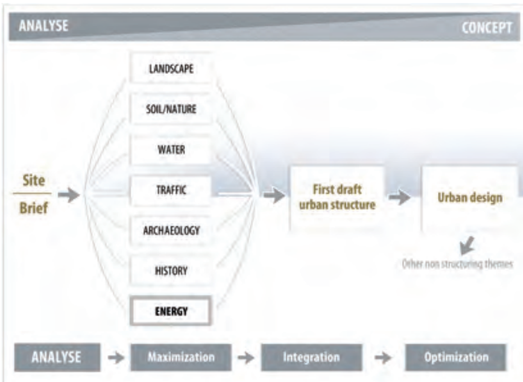
Site layout and solar access

As a solar technology, the effectiveness of PV is highly dependent on solar orientation and shading. This means that many aspects considered early on in the urban planning and site layout process, from the layout of the roads to the building massing and shape of the roofs, will crucially affect the feasibility of installing PV. Most other technologies included in buildings can be considered at the building design stage, rather than the site layout stage. The need to consider PV, and the other solar technologies of solar water heating and passive solar design, from the initial planning of the urban layout challenges the usual way of doing things.

At many of the developments where PV has been installed the decision to include PV was made at a late stage, long after the site layout had been fixed. In many cases developers or builders who had become interested in PV had looked at projects that were already under way and selected areas where PV could be installed on the basis that the development site concerned happened to have a good solar layout. Other sites available were not suitable for PV due to factors that may have been easy to change if they had been considered at an earlier stage. If we do not start taking solar access into account earlier in site planning the proportion of buildings that can make use of solar energy will be a fraction of what it could have been.

In a standard new development, planners may define the site layout without any consideration of solar access, and infrastructure such as roads and electricity supply may be installed before developers and building design teams are appointed. The challenge is to ensure that solar energy is considered during the site layout process. The difficulty today is that many professionals involved in the building industry have very little experience of solar energy. A renewables consultant may not be on board from the beginning and the PV sub-contractor is not likely to be on board until late in the day. As experience is gained across the industry and knowledge of PV and its implications for site layout and planning become a standard part of planners' and developers' repertoire all will become easier. Until then it will take a special effort to ensure that the potential of solar energy is considered during the site layout stage.

If solar access is taken into account at the earliest planning stages, in the same way as car and pedestrian routes or the need for parking, it is usually possible to ensure that the majority of buildings on a site are orientated between



Solar access must be considered in the initial planning of the urban layout to correctly include PV in buildings

Source: © Kees Duijvestein

southeast and southwest to have good solar access. If it is not taken into account there is a risk that many of the buildings will have poor solar access. Not only will this lower the feasibility of installing photovoltaic systems, it will also restrict the use of passive solar design techniques, daylighting and solar water heating.

Example of site design without taking solar access into consideration

Source: © Grand-Lyon

Example of site design with solar access taken into consideration

Source: ©: Grand-Lyon

The resulting urban layout will be in place for hundreds of years, restricting the feasibility of using any of the solar technologies available now and in the foreseeable future.

The sizing and layout of the electricity supply network may also be fixed fairly early on. However, with moves towards sustainable construction there is an increasing trend towards micro-generation of electricity in buildings. These micro-generators can range from micro-CHP (combined heat and power) systems to micro-wind to PV. The Distribution Network Operator (DNO) should be informed of the possible installation of micro-generation in a new development so that it can be taken into account when designing the local electricity network.

Variations in the urban planning process

The approach towards urban planning, who undertakes it, when and at what level of detail varies quite dramatically between different countries; even the term 'town planning' means different things in different places. In some countries it appears to be easier than in other countries to include PV early on in the urban planning process.

In The Netherlands, top-down planning of major new developments is normal. As part of this there is a long consultative process during which PV may be added and urban designs modified. The Nieuwland case study reviews the first large urban PV project, realized in 1999. Here solar optimization was taken into account in the urban planning phase with the land being parcelled out to provide as many roof surfaces as possible suitable for the installation of solar panels. The Stad van der Zon (City of the Sun) case study, again in The Netherlands, also took the sun as one of the starting points in urban planning, although there were some comments that this was more as a philosophical approach than a practical, technical approach as a result of the planners having very limited experience with the technology.

The approach is slightly different in Germany where the case studies demonstrate a willingness on the part of some municipalities to commission detailed analysis and shading simulations of urban renewal or development areas and use the results to inform developers and building designers. At Gelsenkirchen-Bismark, for example, an overall urban plan was developed which included a simulation of shading and solar irradiation on building surfaces. The initial draft of the area plan, with building massing and layout was evaluated and some modifications suggested regarding the height and distance between the buildings in order to provide each building with an ideal sun exposure. To avoid major shading of the building surfaces an advisory committee was formed to assist individual investors.

In the French and UK case studies, PV was added into the plan at a later stage in the urban planning process. This may relate to responsibility for detailed urban planning being more split between municipal planning departments, who tend to set guidelines rather than prepare detailed plans, and commercial developers who are then responsible for a greater part of the detailed urban planning. These breaks in the chain can make it much harder to carry a plan through to completion.

Successful implementation

As sustainability becomes a more mainstream part of the construction and development industries, the installation of PV systems on buildings is moving from isolated examples to being part of the building and development process. This brings new challenges to the PV sector and development industries, which are not yet used to working together. Furthermore, as the implementation of renewables becomes more widespread, it is becoming more and more common that design teams with no previous experience are asked to include PV in a development.

We look here at what lessons we can learn from past projects. The following elements are important for the successful implementation of photovoltaic installations within the urban renewal and development process:

- Enthusiasm. There has to be some enthusiasm for renewable energy or the project will not result in the hoped for emissions reductions. An obligation from above, implemented by a poorly informed design team, will lead to a poor design. If there is no one championing the inclusion of PV it risks being dropped from the design or poorly integrated.
- Technical knowledge. This will be needed by the system designers and by the rest of the project team.
- Inclusion in the work plan for the entire project team. Installation of a PV system will affect other members of the team, not just the PV installer, and they need to allow for it.
- Time. The implementation of renewable energy projects has to fit within the construction timetable or there will be delays and extra costs. If the PV is added to the design late in the day it can result in compromises having to be made.
- Transmission links. A connection to the local electricity network will be needed. The local utility should be informed of the possibility

of any forms of embedded generation at the earliest possible stage.

- Finance. Can the costs come out of the existing budget? If not, can money be raised from external funding sources or innovative financing?

Good communication between the different members of the project team is also important. Architects and engineers can appear to talk different languages at the best of times. The problem can be even worse when dealing with a technology that is new to some members of the project team. Clear communication between the team members on what they hope the PV can offer and the information they need should be discussed at an early stage in the project.

Enthusiasm and a renewables champion

At one time renewable energy projects were few and far between. The ones that were implemented tended to come about as a result of enthusiastic and knowledgeable individual clients, architects or engineers championing the project. The knowledge and the enthusiasm were there, at least in part of the design team. The problem was to raise the money, fit it into the timetable (often complicated by having to wait for results from funding bodies) and get the rest of the team on board.

Today the inclusion of renewable energy in a development may be a requirement imposed by others. There may be little knowledge and less enthusiasm in the design team. However, on the plus side, if the requirement is there from the beginning the timetabling may be easier and implementation of the renewable energy aspects is less likely to be dependent on winning some form of competitive fund-raising procedure. The challenge today is moving from locating funding to providing knowledge and enthusiasm.

Fortunately experience shows that enthusiasm tends to arrive naturally with knowledge. Once a commitment has been made to include PV in a development, results from many projects suggest that developers and architects are often surprised at how easy a technology PV is to design with and install. The key is spotting issues at the right time and providing access to the information needed.

At the earliest stages someone needs to take a lead on including sustainability, renewables and PV into the plans and champion the project to the others involved. In some cases that person is sufficiently expert in PV to provide the technical knowledge needed at this stage. In other cases he or she has commissioned experienced PV consultants and designers to provide advice.

The role of championing the renewable/PV aspects of a new development is a crucial one. If there is no champion these aspects may be shunted aside by others who see them as a risky unknown. Note that the champion has to be directly involved in the development, be aware of progress in all areas and be sufficiently influential that he or she can keep the PV system on the agenda. If the champion is not in the whole loop he or she may not be aware of issues that will affect the PV, such as design modifications, until it is too late.

The design engineers responsible for the detailed design of the solar system are likely to be experienced in the technology. However they may not be in a position to champion the PV project or to provide expert advice to the rest of the design team. The design engineers may not be appointed until quite late in the development process, especially if they are sub-contractors to the main mechanical and electrical sub-contractors. They may also have very limited influence or even contact with other members of the development team.

The renewables lead can come from many different places. In some projects the early lead has come from the municipality. For example, in Kirklees in the UK, the municipal environment unit brought together developers and PV specialists to enable the creation of PV projects. The municipality had the knowledge, confidence in the technology and contacts to provide the initial set of information required. This was crucial in getting the developers started with their first PV projects.

The lead can also come from the building owner such as in the Cologne-Wahn case study where the landowner organized an architectural competition at the beginning to gather options for achieving a solar estate.

In other cases the lead has come from the architect. For example, the Solarsiedlung am Schlierberg project in Freiburg, Germany was led by architect Rolf Disch, who wanted to provide evidence that his idea of an Energy-Surplus-House® could work well for terraced houses and commercial buildings.

Technical knowledge

The design engineers responsible for the detailed design of the PV system are likely to be experienced in the technology. They should understand the available systems and know how to design and install them.

However, the rest of the project team will also need some understanding of the implications of the solar system for their area of responsibility. The solar system will impact on issues ranging from building layout and positioning (and hence road and path layouts), roof shapes and structures, positioning of chimneys and vent pipes to the electrical distribution system. Someone will need to be responsible for making arrangements for the export of electricity and whoever is responsible for sales of buildings will need to be able to explain the system to potential occupants.

Unfortunately, most engineering offices and developers today have very little experience with PV technology. Lack of knowledge by the rest of the project team can lead to a perception of risk, fear of delays and extra costs being imposed to allow for the uncertainty. Having an explicit plan for providing training, advice and visits to completed installations in order to transfer knowledge to the rest of the project team is the best way of ensuring issues are foreseen before they become problems. Many different approaches can be used to transfer knowledge and experience, but the approach used has to fit in with the development process in the country concerned.

The Lyon-Confluence project provides an example of the successful transfer of knowledge. The guidelines for the selection of developers required the team to include an engineering office specializing in energy efficiency and renewable energy systems. However it still appeared that none of its members had any serious experience in PV. To remedy this lack, a team of local specialists was set up to assist engineering offices and developers at all stages of the project, from the preliminary design to the commissioning of PV systems. This local team also organized site visits and training sessions and is helping developers in dealing with a complex financial scheme with multiple sources of funding.

The confluence project learnt from previous smaller projects in the Lyon area, such as the Hauts de Feuilly housing development, where PV was brought in fairly late after developers

Detached houses at Les Hauts de Feuilly showing PV systems with different orientations

Source: © Hespul

had been appointed and the site layout fixed. PV was able to be installed on a group of houses, most of which had a good orientation; however, the orientation varies and is not optimal for all houses. Grid connection was also considered late and additional connection points had to be retrofitted at the utility's cost.

Another example of technical information being passed on effectively is the Stad van der Zon, in The Netherlands. Here a new town area is being developed with PV on houses constructed by different architects, developers and builders. As soon as the detailed urban design and architectural aspects were in sight, a PV workshop was organized for architects and PV system manufacturers, resulting in draft designs and a book. The workshop was repeated four years later. From a technical point of view, there were no problems in the design and realization of this ambitious project. There have, however, been major problems with the funding, as well as incompatibilities between the development timetable and the time scales required under the final funding arrangements.

As more and more PV projects are implemented, so PV will become part of the standard repertoire of architects and engineers. The need for training and information provision by PV specialists will reduce. There may also be a reduced level of uncertainty on the part of clients and other members of the project team, which should lead to further cost reductions.

Inclusion in the work plan

The urban development process tends to be complex, with a lot of issues needing to be taken into account. Everyone involved in a development is likely to be very busy and to have a defined scope of work that may not mention PV. Within the overall development of an area, PV has a very small role and cannot be expected to be high on the priority list of everyone concerned. However, each of the following points needs to be explicitly included in someone's work plan, and this should be backed up by access to expert advice whenever queries arise:

- site layout for solar access;
- building design with suitable surfaces for PV systems considering solar orientation and shading;
- minimizing cable routes and providing a readily accessible location for the inverters;
- negotiating any planning amendments for the PV system;
- roof structure and any extra weight or wind load from PV;
- design and installation of PV system (likely to be a specialist sub-contractor);
- lightning protection;
- scaffolding, secure storage and insurance against theft before installation;
- electric network layout for the site including coordination with the DNO (this may need to be started before an installer is appointed);
- electrical design in the building; needs coordination between PV installer and electrical contractor;
- electricity export may need negotiating and tariff agreeing; this should not be left to individual building owners to deal with once buildings are sold;
- solar training and awareness;
- consideration of arrangements for servicing and maintenance once buildings are handed over;
- funding.

Time

Considering the possibility of solar technology being included in the development site as early as possible will maximize opportunities for designing in good solar access and exploring synergies between PV and other aspects such as shade provision, daylighting and environmental image.

Difficulties in fitting a PV project into a development timetable can cause many problems.

If PV is added late in the timetable it will often lead to less-than-optimal designs. If external funding is required, another level of complexity is added with difficulties matching dates of funding rounds, and restrictions on the dates that money must be claimed by. It may even be necessary to have two versions of the design, with implementation of the PV version being dependent on award of funding. Major developments have many constraints and hurdles to overcome, and PV is only a minor part of the overall picture. Waiting for PV funding cannot drive the timetable, a fact some funding organizations appear to be unaware of.

Grid connection

Photovoltaic systems in buildings are part of the building electricity distribution system and hence are also connected to the local distribution grid. Technically, connection to the grid is straightforward so long as the local grid can absorb the extra power without exceeding voltage limits. However, agreement to connect to the grid must be obtained from the local DNO. In addition, a contract for the sale of electricity, at an agreed tariff, is normally required unless extra electricity is spilt to the grid with no payment obtained. Significant delays and additional costs can arise if discussions with the DNO are left too late.

Large PV systems, or large groups of systems, should be taken into account during the design phase of the distribution grid in order to correctly size the new distribution grid and avoid any additional infrastructure work once buildings are completed. Attention should be paid to the location of medium voltage/low voltage (MV/LV) transformers and the size of transformer feeders to make sure that each PV system can be connected to a suitably robust LV grid. Single systems or small groups of systems can normally be connected to the existing grid without any modifications.

Dedicated connection points may be required for contractual reasons. For instance, in France, in order to benefit from the feed-in tariff for all of the energy produced by a PV system, the utility has to create an additional, dedicated connection point. So for a new development of houses with PV the DNO may need two connection points for each house, rather than the normal one. Unfortunately, the current administrative system officially requires detailed information about power plants before the DNO can take them into account. As the detailed information required is unlikely to be available during the infrastructure design phase, there is a potential problem.

At Les Hauts de Feuilly, France, a group of 19 houses with PV roofs needed dedicated connections to the grid. However, the DNO was not officially informed of this until the houses were complete. The problem delayed the commissioning of all PV systems while dedicated connection points were installed. In this case the extra costs involved were borne by the DNO, rather than the inhabitants, as the power of each PV system was below a certain level.

At the subsequent Confluence project in Lyon the designers were aware of this potential problem so organized a technical meeting with the DNO to find a way, during the design phase of the distribution grid, to take into account the fact that several buildings would be equipped with PV. The objective was to correctly size the new distribution grid to be built and avoid any additional infrastructure work once buildings were completed.

Having individual building owners regarded as generators, with all the associated regulatory requirements, is a very recent phenomenon. Appropriate administrative procedures are not yet in existence for dealing with groups of small identical generators. Standard procedures for export of electricity normally require complicated and time-consuming forms to be filled in. However, if the forms are to be completed by individual householders and this is left until the houses are occupied, problems and delays are likely to result.

Experience at Les Hauts de Feuilly housing development in France led to suggestions that a developer that chooses to install PV systems on its buildings should assist future home owners until the commissioning of the PV system. In particular, developers should make sure that future home owners have signed the contract for the connection of the PV system to the grid with the DNO and the contract for the purchase of the electricity produced at a specific feed-in tariff.

Finance

PV is undoubtedly expensive. Most urban-scale PV projects to date have obtained some level of capital funding subsidy, but subsidies are becoming harder to get. In some countries their role has been replaced by funding paid via premium rate feed-in tariffs for renewable energy. This guaranteed income can allow finance to be obtained through loans.

Sources of funding range from the European Commission (which tends to fund larger projects but not individual buildings) and national or regional renewables programmes (which tend to be more accessible to smaller projects) to local municipal or utility funding. Those municipalities that have created renewables funds, such as Kirklees – which decided to set up the Kirklees Council Renewable Energy Capital Fund in 2000 – have been able to get a range of projects going in their area and encourage the start-up of local supply and installation companies.

Some projects have raised money by selling shares. The financial feasibility of this is improved in countries where a premium feed-in tariff is paid for electricity from PV. In Gleisdorf, Austria, a communal PV power plant on the roof of the offices of the utility company Feistritzwerke-Steweag was the first PV power plant in Austria realized through a shareholder programme that allowed environmentally engaged people to own a share of the PV power plant. In Freiburg, Germany, financial difficulties were encountered during the development of the Solarsiedlung am Schlierberg eco-housing estate. These were solved by starting a fund, called '1. Solar Fond Freiburg', with an invitation for subscription to share certificates of €5000 each. The shareholders were primarily private citizens who wished to make a sustainable long-term investment. The total investment was €1.5 million. The first one was followed by three other investment funds with a total investment of €3 million each. In total, 15 rental houses belong to these four solar funds. The roof-integrated PV systems were marketed separately: either the home owners or other investors purchased them. A return on investment is granted by the 20-year payment of the feed-in tariff under Germany's National Renewable Energy Act.

If no subsidies are available the full costs may be met by developers or builders, and then passed on to the purchasers of the building. If there is an obligation that all new buildings in an area install renewables, then anyone who wishes to own a building in that area has no option but to pay the cost. If there is no obligation then such buildings have to be marketed at a premium price justified by their sustainable design. The viability of that depends on the local market and preferences of purchasers.

In some locations, such as Croydon in London in the UK, there is evidence of higher property values for properties with PV systems. Here, some developers obliged to install renewables have found PV the most cost-effective solution because it does not take up any space in the house, and the cost of the space needed for a hot water tank for solar water heating outweighs the higher outlay for PV.

Long-term operation

PV systems should have a long lifetime successfully producing electricity at, or close to, their original output level for at least 20 years. Maximizing the lifetime and output of a PV system is important because it will take a few years for the PV system to generate the amount of energy used in its construction. Only after this point is reached is the system having a positive impact on climate change or oil depletion.

However, experience has shown that while most PV systems reliably supply power for many years, poor implementation, erratic maintenance or a lack of forward thinking can lead to loss of performance in the longer term.

A photovoltaic system operates silently and without mechanical movement. This makes it ideal to mount unobtrusively in the urban environment and enhances its reliability. Unfortunately, it also means that it is not immediately obvious whether or not a PV system is operating as it should. If a grid-connected system has tripped out, power is still available from the grid. A design that does not make it sufficiently easy for the occupants to check the system performance will allow even minor problems to persist, which may significantly reduce energy production.

Interested and technically minded people responsible for operating PV systems on their own premises often report that they require negligible amounts of time and effort to operate. However, this is not the same as saying that systems left in the hands of the uninitiated and uninterested will operate reliably for 20-plus years.

Experience from around Europe shows that when large numbers of small PV systems are installed on buildings in urban areas and then left for ordinary building occupants to operate with no professional support, there are risks that poor performance may not be picked up. The projects at greatest risk of accumulating problems are those with fairly small PV systems, with occupants who have no particular motivation to keep an eye on things, and where there is no easily accessible person to contact regarding queries or problems.

This situation contrasts with one where an individual decision to purchase and install a PV system has been made. In this case the occupants can be expected to have some understanding of the system, the quantity of electricity expected to be produced, the guarantees available and contact information for the supplier in the event of problems. Nonetheless, issues may still arise in later years if the house is sold on.

Regulatory mechanisms that drive the installation of PV systems as part of the construction of new developments may provide little incentive to consider long-term issues. If PV systems are installed as houses are built there is no direct connection between the eventual occupant and the system supplier. The occupant may have no knowledge and less interest in the energy performance of the house. In addition there is no critical mass of general knowledge about PV in the community if queries arise. In these situations a reliable and effective maintenance and support system is needed. Where these exist, for example with good housing association-led projects where personnel can provide information, answer queries and contact suppliers if repairs are needed, systems can perform very well. Where they do not exist problems may arise.

The alternative approach of promoting the installation of PV systems by offering a high feed-in tariff for PV-generated electricity can encourage individuals to install their own PV systems. This approach avoids many of these issues by ensuring there is a direct connection between occupant and installer and providing an incentive to maintain the system. However, it does mean that PV systems end up dispersed over a wide area with a mix of system types that will bring other maintenance challenges.

The sections below provide best practice guidance on how to ensure urban PV systems are designed, commissioned, handed over and maintained so that they are most likely to be kept in good operating order. This guidance is focused on those potentially difficult PV installations in groups of houses or where they are installed in buildings with no specific connection to renewable energy or electricity generation.

The importance of good design and forward planning

This section looks at factors that should be considered during the planning and project design stage because they will impact on long-term performance. Careful forward thinking should consider the interest and expertise that can be reasonably expected from the occupants of the buildings and the ownership and maintenance arrangements for the building and the PV systems.

It is also beneficial to consider how good design can foster a sense of pride in the sustainable aspects of the area or building. The visibility of PV can be very useful here. For example, in La Darnaise, the first renewables powered district in France, PV is considered the flagship of the project. The social impact of this visible element of urban regeneration is considered to be very valuable.

The question of the size of the systems installed should be considered. Larger systems operated by professional personnel tend to have very few problems. However, in many places the assumption is that we install one system per house. There is experience in Europe of large systems spread over the roofs of groups of houses, but designed as single electrical systems with a centralized inverter room and remote monitoring. The systems can be owned by organizations such as utilities, housing associations or energy service companies (EsCos). House owners can be paid a rental fee for the use of their roof or given a discount on their energy costs or rent. Maintenance of a few larger systems is a much simpler and more cost-effective task than the maintenance of many small systems. Simply gaining access to 20 properties on a housing estate to check something can be a time-consuming and expensive task.

The case studies provide examples of a variety of system sizes and ownership arrangements and highlight some of the pitfalls and benefits of each approach. The case studies of Premier Gardens in the US, the Sydney Olympic Village in Australia, Les Hauts de Feuilly in France and Jyosai Town in Japan are all examples of new housing developments where houses are privately owned each with its own small PV system. Other case studies show housing developments where the PV systems are owned by housing associations or cooperatives: these include Kirklees in the UK, Alessandria's Photovoltaic Village in Italy and La Darnaise in France.

Groups of houses owned by housing associations and occupied by social housing tenants can be very successful, but such developments do require some care and forethought. Factors shared by successful projects include: housing estates with a stable population, involved tenant representatives, system follow-up by someone from the housing association such as an energy officer or an external maintenance service, and provision of information about the PV system to the tenants. The housing association can keep an eye on the condition of the PV systems, act as a central contact in case of queries or problems, and organize maintenance and repairs. However this kind of role fits more easily into some housing associations than others.

At the Nieuw Sloten project in The Netherlands, the PV system is owned by the utility company Nuon who, in 1996, installed PV on approximately 70 houses and apartments. The householders own the property, but not the PV system. The electricity generated is used within the district, but is not linked directly to the house on which it is mounted and the systems are operated as a single 250kWp unit by the utility. The arrangement was chosen in order to minimize the costs of inverters, installation and maintenance, and is monitored online. Nuon sub-contract maintenance to a specialist organization and the system has been trouble free to operate.

Case studies of PV systems on municipal buildings include projects in Barcelona in Spain and Malmö in Sweden. In Gleisdorf in Austria a number of PV systems were installed as part of a municipal programme. The PV power plant installed on the roof of the utility company has been working very reliably and very few problems have been reported. Service activities are carried out by the employees of the utility company. Function control is checked monthly and once a year the modules are cleaned. In the winter the surface of the PV modules is kept free of snow. The expected annual yield of 9000kWh has been exceeded to 9500kWh.

Projects where organizations such as utilities are responsible for operating individual systems on houses have had mixed results. Recent experiences from the Nieuwland project in The Netherlands, set up by the utility REMU (now ENECO), offer a warning that ensuring the successful long-term operation of multiple small PV systems in urban environments takes long-term commitment. This showcase project was set up ten years ago to demonstrate a variety of possibilities for architectural integration of photovoltaics in the urban environment. A mixture of different roof integration technologies and inverter systems was used. Early problems were encountered with leaking roofs and inverters and in the longer term the ownership and maintenance of so many dispersed PV systems, using a mixture of system types and integration methods, proved more difficult than initially expected. During 2003-2007 maintenance was done at a minimum level and the quantity of electricity generated went down.

Relatively large systems may also be placed on buildings such as schools, care homes, health care facilities, libraries and municipal buildings. However, it is important to make sure someone at the building 'takes ownership' of the PV installation, particularly if the normal business carried out in the building is unconnected with energy generation. For example, at one care home there was a fault showing on the display panel because one of the inverters was down but it was not noticed or reported for some time. An operator's handbook was available, but personnel changes since the system was installed and no maintenance personnel residing on site created a situation where no individual held responsibility for monitoring performance. In this type of situation a remote monitoring system is beneficial.

The design also needs to consider access for maintenance. Access to individual properties for maintenance or repairs can be an issue; locating inverters in communal areas is one way around this problem in apartment or flats buildings.

System performance needs to be checkable

During the design stage the designers need to consider how the performance of the system will be checked. There are two levels of checking. The first is to check whether or not the system is operating. The second is to check whether or not the system is producing the amount of electricity it should be producing.

In order to check whether or not the system is operating a simple visual display is needed. The display needs to be in a location where it will be seen by the person responsible for the system, not in the attic.

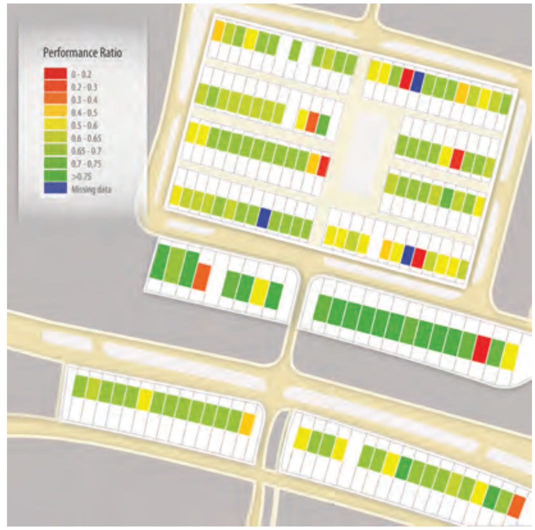
Checking of energy production can be done on site or via remote monitoring. Some systems have complex displays that can provide energy production data. Others may just have an operating light and a fault light on site and more comprehensive data collection and display systems available elsewhere via a remote monitoring system.

The correct solution will vary depending on the type of system and who has responsibility for operating it. The display must give information in a way that can be understood by the operator. A display system that can provide feedback to occupants on energy use and energy provided by the PV system can result in extra energy savings. If displays are not sufficiently clear problems may not be picked up and no incentive to save energy is provided.

It is important that energy production is checked occasionally. Energy production data can tell you if the system is operating as it should; however, this is only effective if you have some idea how much energy should be produced under normal operating conditions. Annual expected energy production data should be provided to occupants along with information on whom to contact if production is lower than expected.

Lower than expected production can be due to poor weather conditions or to a fault. In some instances a fault will be fairly obvious. In other instances, intermittent faults can occur that can reduce energy output but may not be obvious to spot. For instance, vegetation growth can lead to reduced energy output at certain times of day such as winter mornings. Alternatively, voltage issues such as high voltages on the local electricity network can cause the inverter to go over its voltage limit at times and cut out. If the system restarts automatically after a few minutes and the problem is infrequent it is not significant. However, if it is occurring frequently it may be substantially reducing energy outputs and some adjustments will need to be made. Faults may also occur within the inverter that reduce output; for instance, if the maximum power point tracker function in the inverter is not working, output will be reduced but this will be hard to spot without analysis of monitoring data. Diagnosis of any of these problems is possible using monitoring data. Today it is a simple matter to store large amounts of data about system performance. These can be stored by the system controls, which can be interrogated on site or can be accessible via the internet. Remote monitoring and diagnostics services via the internet are now easy to undertake. By making use of advanced information technologies and satellite solar radiation data, a maintenance company can be informed quickly if the PV system malfunctions (Pearsall et al, 2006).

There is a risk that the performance of a PV system is never checked, particularly if nobody feels responsible for the system. In a recent survey of the PV houses in Nieuwland in The Netherlands some occupants were not even aware that their house was connected to a PV installation and the majority did not know how much electricity their PV system produced. Others report that their remote monitoring systems are not working and they are not sure if this means that their system is not working. However, they have had difficulties in locating anyone at the utility to ask. The only telephone number provided was the standard utility helpdesk, which was not able to answer queries about the PV.



Result of a monitoring campaign of the Nieuwland project in The Netherlands with a few systems tripped out; occupants were not sure if it was the monitoring system or the PV system that was not working

Source: © Ecofys and University of Utrecht

Handover

The completed systems should be handed over to the eventual occupants in full working order, commissioned and grid connected.

Before handover it is important to check correct operation and administrative set up including:

- PV system output – ideally this should be compared to expected output although this will require knowledge of irradiance levels. Alternative methods such as comparing the outputs of different strings can also be used. Appropriate monitoring methods are described in an international standard (IEC, 1998).

- Grid connection – ensure the export tariff is agreed and contracts signed if required.
- Ensure electrical commissioning has taken place together with grid connection approval.
- Visual display – check this is working correctly and understood by the operator.
- Monitoring system – check this is working correctly.
- Responsibility for checking performance may need to be specifically allocated.
- Arrange insurance.

Clear operating and maintenance instructions must be provided including:

- operation and maintenance leaflets in a sturdy format;
- information about expected power and yields;
- a point of contact that can reliably answer any queries and organize maintenance.

At some new housing estates developers have been keen to include PV to boost their green image but have not given sufficient thought to explaining the systems to the occupants or completing the paperwork necessary for grid connection. New occupants may have no knowledge of PV before moving into a new house and no particular interest in the system so long as it works. Correct operation needs to be checked and commissioning done by the developer or its representatives. In addition, all the paperwork needs to be complete. This can be very complicated and should not be left for private householders to complete at the same time as moving into a new house.

Maintenance and operation

While PV has much to offer in a low carbon urban environment it is easy to lose sight of the basic issues of long-term maintenance and support networks in a rush to install renewable technologies. Leaving multiple small PV systems with ordinary householders to operate with no support or back-up, people who have not chosen a system, but which just came with the house, is heading for trouble.

In order for a PV system to be properly maintained it is necessary that someone feels responsible for the system and keeps an eye on it. This person needs to know enough about the system to spot any problems. If problems or queries do arise he or she needs to know who to contact for assistance.

In some instances PV systems are being installed and left with building owners to organize maintenance and check operation by themselves. This is not always a success. PV systems are low maintenance and easy to operate but nothing is perfect or lasts forever without some assistance. PV systems differ from other technologies installed in buildings in that they operate so inconspicuously it may be hard to spot if they are not operating.

Good communication and information provision are an important part of setting up a PV project. Most people know very little about PV systems so providing information is important. Specific knowledgeable points of contact will be needed to get any problems resolved. Planning for these should be part of a large-scale PV project.

The ideal solution is a commercially viable method of offering a maintenance and support service. One possibility for ensuring the successful long-term operation of PV systems is to use an EsCo. This has not yet been tried at many locations and there are limited data available, but it is seen as a way forward for some situations, for example, municipal buildings in Barcelona (see case study). The company would have a commercial incentive to maximize energy production and responsibility for holding information on the systems. Checking performance and organizing maintenance would be part of its role.

Another option is maintenance contracts. However, such a service would need to charge an economic cost, which could not be more than a small proportion of the annual income from the system. A feed-in tariff improves the economics of this situation. Maintenance companies also need to be based fairly near by or time spent travelling would cost too much. Another interesting option is lease back schemes. These are available in the US and allow householders to lease systems, with maintenance and support provided by the leasing company.

For any large-scale PV project it is important to look ahead to consider practical and affordable arrangements for maintenance. A maintenance plan should be prepared which includes consideration of the following:

- Is there a centralized monitoring system or is it the responsibility of individual building occupants to keep an eye on system performance? Is it reasonable to expect the occupants to be able to do this? For example, it would not be reasonable for rental houses with a high turnover of occupants.
- Which individual will be responsible for keeping an eye on the system? Does he or she understand how the visual display works? Does he or she know how much energy it is expected will be generated and how to check it?
- Who can the individual responsible contact in the event of problems or queries? Providing the telephone number of the standard utility helpdesk is not sufficient if the person answering the call is not going to be able to answer the query.
- How to transfer information in the event of personnel changes or sale of the house.

References

International Electrotechnical Commission (1998) 'IEC 61724, Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis', Edition 1.0 1998-04, IEC, Geneva

Pearsall, N. M., Scholz, H., Zdanowicz, T., Reise, C. (2006) 'PV system assessment in PERFORMANCE – Towards maximum system output', Proceedings of 21st European Photovoltaic Solar Energy Conference Exhibition, Dresden, Germany, 4–8 September, pp2574–2579

2 Case Studies of Existing Urban Areas with Photovoltaics

Australia, Newington, Sydney Olympic Village[1]

Mark Snow and Deo Prasad

Summary

The Olympics was once referred to as meaning a 'celebration in sport of the excess energy possessed by a civilized people'. Paradoxically, the staging of modern Olympic events typifies the extravagant use of materials and energy. While the responsibility of the host nation to deliver a credible venue for a two-week world contest is vast, the success of the Sydney bid in 1993 stemmed from its commitment to staging the first green games, placing 'environmental responsibility' as 'a key tenet of the Olympics movement'. This case study describes the key elements of PV within the sustainable urban designs constructed for the 2000 Sydney Olympics. These include the Olympic Solar Village (623 kilowatts peak (kWp)), the PV pylon boulevard (124kWp) and the Superdome (70kWp).

1 This section is based on two articles that were written by the same authors: 'Sydney Olympics 2000: A solar power showcase' and published in Refocus, ISES International Solar Energy Society, September/October 2000, pp22–28 and 'The shiny side of gold – Solar power in the Sydney Olympics site', *Renewable Energy World*, August 2000

Introduction

Newington is a low-rise, inner-city suburb of around 90 hectares. It is located some 15 kilometres west of central Sydney, on a site of approximately 262 hectares, which encompasses the Olympic Village. The site originally consisted of salt marshes, wetlands and open grasslands, and had been extensively used for industrial purposes. The brownfield site previously housed salt works, flour and tweed mills, a government asylum and hospital and, most recently, a navy ammunition depot.

The New South Wales (NSW) government Olympic Co-ordination Authority (OCA) requested a sustainable approach, including the promise of delivering a 'green' Olympics. The Olympic Solar Village is part of this, with the ambitious goal of changing the world's view of solar energy and energy efficiency, demonstrating to Olympic viewers and overseas visitors the commercial capacity of renewable energy technologies in providing electrical energy to an entire urban residential development.

The Olympic Solar Village

Project overview

The project is one of the world's largest solar villages. It was a showcase for the Olympics and is part of a sustainable inner-city suburb, exemplifying innovative approaches to energy and sustainable development principles. Its requirements included:

Typical PV roof system with the Sydney Olympic Stadium in the background

Source: © Mirvac LendLease

- Housing for 15,300 athletes and officials and future Newington occupants (2000 homes for approximately 5000 people).
- Strict implementation of energy efficient and demand-side management best practices.
- An environmentally benign community, built on a brownfield site.
- Renewable energy integration as a demonstration for future replication.
- Building-integrated PV (BIPV), which satisfies the architectural requirements for a visually acceptable solution, without compromising the technical performance of the roof and the solar power system.
- Cost-effectiveness in delivering a clean, green suburb.

Sustainable housing design context

New energy efficient, passive and active design guidelines were written to commit the design and development of the Village to conform to best practices. The houses follow exemplar design strategies and energy efficient best practice through passive and active solar application and the maximizing of natural ventilation. The energy smart designs are complemented by gas-boosted solar hot water, gas heating and cooktops and energy efficient lighting and appliances. The National Housing Energy Rating Scheme (NatHERS) software was used to calculate the energy performance of home designs. The Solar Village designs achieved an average four-star NatHERS rating. The overall result is a halving of greenhouse gas emissions when compared to a typical new dwelling in Sydney.

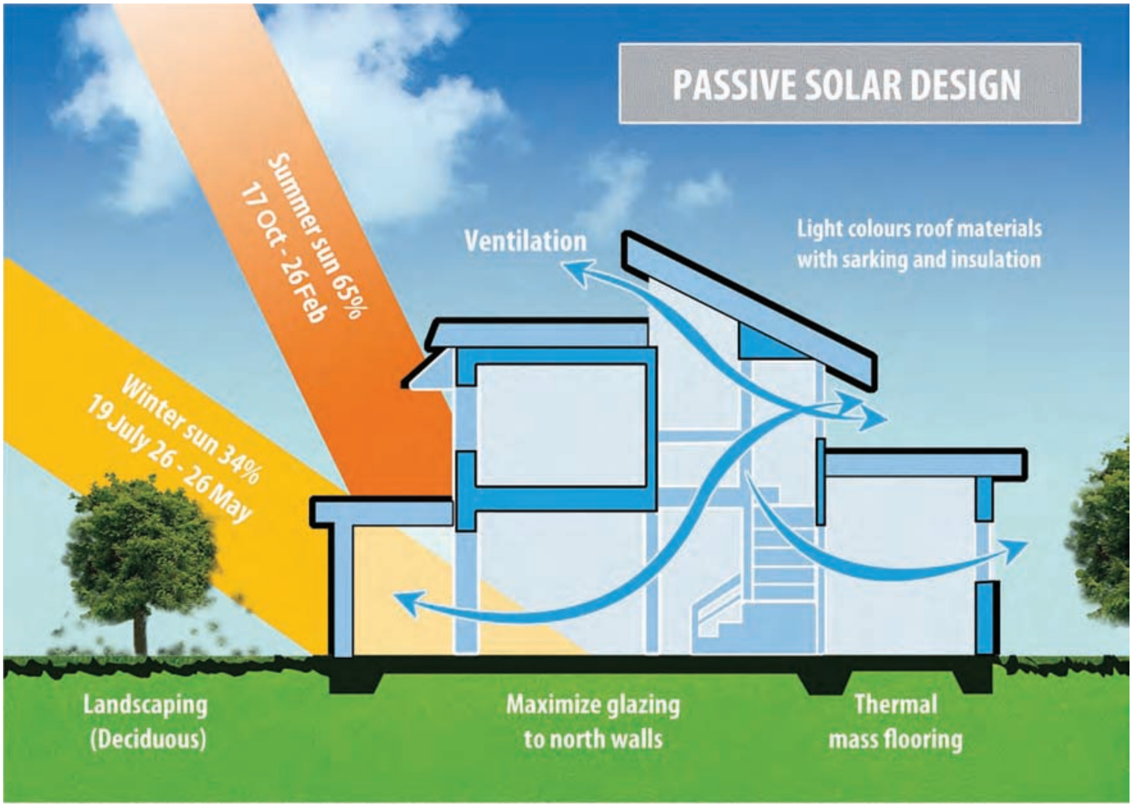
The use of environmentally benign construction methods and materials was also followed. These include minimization of PVC use by choosing alternative cabling materials, low-allergenic paints, wool instead of fibreglass roof insulation, timber and ceramic tile flooring, fibre cement stormwater piping and 90 per cent recycling of hard waste during the construction period.

Water minimization strategies, such as reclaimed water used for toilet cisterns and external taps, reduce the use of potable water by 50 per cent over conventional homes. The energy initiatives have been estimated to reduce non-renewable energy consumption by around 50 per cent compared with standard project housing, which is equivalent to a saving of 7000 tonnes of CO_2 per annum.

Building an integrated PV design process

Architectural design issues that were considered include:

- Balancing the incorporation of photovoltaics with the desire to create a 'low-tech' streetscape. The visibility of the PV is varied over the site depending on the house design concept, orientation and urban design goals.
- Matching the BIPV system to the different architectural styles of each architect.
- Site planning and roof design so that the majority of roofs lie within the range of 20° west of north and 30° east of north.



Passive solar energy model

Source: © Mirvac LendLease

- Provision of about 80 per cent of roofs with a 25° pitch to optimize outputs.
- Positioning of the solar hot water units in relation to the PV laminates.
- Controlling the visual appearance of non-integrated systems where roof orientation was not optimal (minority of houses).
- Various designs from the eight commissioned architects, coordinated by Henry Pollack Architects, have ensured a unique variety of PV building-integrated systems resulting in maximum active and passive solar gain given the constraints imposed by the geometric characteristics of the urban plan.

PV system design

The design was expected to satisfy a number of requirements. These included each system's delivery requirement of 1600kWh per annum, compliance with Australian building load, health and safety specifications and electrical standards, developing and verifying best practices where standards did not exist, and providing a simple product for rapid deployment of the PV systems to avoid compromising the overall construction activities of each dwelling.

A design limitation occurred as the PV performance was compromised by aesthetic

Streetscape of Newington PV residences

Source: © Mirvac LendLease Village Consortium

requirements to use a dark-coloured backing layer rather than an optimal white layer. This change in the laminate resulted in a reduction in efficiency compared with standard test conditions. The darker backing material increases thermal gains and is a less effective internal reflector of incident light. System reliability is not considered to be unduly compromised in meeting the required overall PV performance output of the system.

More highly engineered building-integrated PV approaches from overseas were rejected in favour of a design that could meet market needs and be readily accepted by the housing industry for simplicity and ease of installation. Typically, the tray installation took half an hour and PV wiring a little over two hours. A record number of nine roofs was installed in one day by two skilled labourers. Pacific Power provided third-party indemnity and the systems were covered by a ten-year warranty on deterioration in output due to faulty workmanship or materials. The frameless laminate design and diamond tray mounting clips lower life cycle energy costs and help to achieve a pleasing balance of cost versus thermal performance and energy yield.

Other major PV features of the project

While the athletes' solar village is the major PV initiative, other similarly impressive projects captured centre stage. Huge PV lighting pylons furnish the Olympic plaza and open space in front of the 110,000 capacity Olympic Stadium and the largest indoor 'Superdome' arena in Australia.

The PV pylon boulevard

Nineteen pylons, one for each host city of past Olympics, follow the Olympic Boulevard, stretching 60 metres wide and 1.5 kilometres long. Each pylon is 30 metres high, constructed by using a large concrete leg supporting a counterbalanced steel tower. The arm of the tower supports a 20-metre horizontal steel truss canopy of PV modules, collecting solar energy for night-time lighting use and providing shade during daylight hours. The towers each support a 6.8kWp PV array, generating approximately 23kWh a day and equivalent to the power needs of two houses. All modules face away from the stadium towards true north and provide the necessary electricity to power floodlights directed upwards onto a mirror which spreads

PV pylon boulevard

Source: © Energy Australia

light diffusely below. The PV backing base layer is a blue fluorescent colour illuminating the PVs, producing a stunning effect at night. Each pylon offers services such as telephones, recycling bins and information, including three digital displays that tell visitors how much electricity the 124kWp systems are generating. Expected generating output per year is 160,000kWh and matches the lighting demands of the public boulevard area. This innovative project collected the Olympic Co-ordination Authority Engineering Excellence Award in September 1999. Both PV cell technologies used on the boulevard pylons and residential solar village buildings are based on solar cell technology invented by the PV Special Research Centre at the University of New South Wales in Sydney and commercialized by BP Solar.

The Superdome

Energy Australia has also been directly involved in two other major installations. Using the roofline of the Superdome above the banqueting hall, Energy Australia has installed a 70.5kWp PV system that is the largest of its kind in Australia mounted on a steel frame integrated with the roof structure. Unfortunately, the specification of guaranteeing a 30-year lifetime of the roof skin prevented the adoption of a truly integrated design, despite the likelihood that such products can meet these demands. The installation of a conventional steel sheet roof under the panels could not be avoided and added cost and weight to the overall building.

The Homebush Bay Business Park cafeteria

Another earlier 11.2kWp installation on Energy Australia's Homebush Bay Business Park cafeteria roof was commissioned in January 1997, achieving a total installed cost of €7.64/ Wp (AU$15/Wp). Other PV installations include photovoltaic cells on the finish tower of the Sydney International Regatta Centre, which channel solar power into the local electricity grid and provide power for hot water and timing equipment. The solar power panels save 0.6 tonnes of greenhouse gas emissions each year.

Aerial view of Sydney Superdome and PV pylon boulevard

Source: © Energy Australia

Summary of problems, barriers, solutions and recommendations

A cost-effective and simple solution to install PV on a limited roof surface

The roof areas available were comparatively small for Australia, as the houses were of terrace or semi-detached style in urban configuration. The design strategy and flexible arrangements of the 12 PV laminates provided an effective, yet simple solution to overcome these issues.

The impact of the hot Australian climate on PV modules and inverters

While Sydney insolation levels are favourable, temperature extremes prevail in summer periods and place uncomfortable thermal conditions on PV systems. Standard Test Conditions rate PV panels at 25°C ambient temperature, which is well below typical Australian summer climatic conditions.

A small number of inverter locations, which were sited on the side of the house, due to architectural design and site orientation, suffered from direct sunlight heat gain and consequently shut down frequently. This experience supports the importance of good inverter positioning: placing inverters in the shade, either by using additional shading components or lee-side façades.

Worksite organization

Pacific Power allocated a full-time site manager during the construction phase. This was the building transfer stage once the PV roof was ready to accommodate the installation of the BP laminates. Electricians were sub-contracted to complete the rough wiring and fixing of desirable terminal points. Once the roof and sub-tray system was installed and watertightness approved, the same scaffolding was used, in collaboration with the building construction team (Mirvac LendLease), to complete the PV installation. BP Solar completed this work, in around three man-hours per installation (usually two workers) and supplied the PV laminates, inverters and balance-of-system (BoS) using reusable wooden pallets to transport the parts from factory to site.

Post-installation feedback

While the building-integrated PV project designs may err on the side of simplicity, they remain sensitive to market reality and are clever in that regard. The houses, along with the PV systems, are there to be sold at an affordable price. In pioneering around 840kWp of PV projects around the Olympic site, including the PV Boulevard pylons and the Superdome amorphous

The key aspects of the Newington PV urban site remain the residential solar roofs. Since the completion of the Sydney Olympic Games, Mirvac has commissioned 79 additional 1kWp systems on larger roofscapes under Stage Two of the Newington development.

The Mirvac LendLease Village consortium was responsible for coordinating the development of a three-stage housing project designed, under strict environmental criteria, by eight locally reputed architects. The joint development team consisted of Mirvac and LendLease. Sydney-based electricity generation company Pacific Power owns, manages and maintains the solar electricity component for each house and commissioned BP Solar to supply the grid-connected PV systems.

The NSW government Sustainable Energy Development Authority (SEDA) has supported the sustainable dimensions of the project and checked the quality of work of the consortium delivered to the Olympic Co-ordination Authority as client. Energy Australia, the local electricity retail utility, has been directly involved in grid connection issues and the services of the University of NSW were sought to assist with ensuring compliance to high levels of safety and power quality standards. The Mirvac LendLease Consortium coordinated the integration of the PV systems into the building envelope, producing a schedule of procedures for facilitating the use of PV technology by house builders, including retail of the properties. SEDA offered a one-off €255 (AUS$500) rebate to entice buyers, while the Olympic Co-ordination Authority ensured compliance and meeting of contractual obligations so that the Village was successfully completed.

PV installation, an invaluable knowledge base of building-integrated PV applications under Australian conditions is evolving. Experience has been gained in collaborating with architects, developers, the construction industry and real estate operators throughout the PV project process. PV technologies have been trialled, tested, installed and monitored, allowing comprehensive tracking and recording of data to verify system components and commissioning results.

Work has been carried out with the inverter manufacturer to improve designs as necessary to meet stringent power quality and safety requirements. Important grid connection issues have been resolved in collaboration between the University of New South Wales, Energy Australia and Pacific Power in respect of system safety and power quality. Detailed on-site training and supervision has been organized to enable a large number of builders and tradespersons to achieve a quality result while working with an unfamiliar product and system. Also, appropriate knowledge has filtered to the sales staff and home owners at the commercial end of the stream.

While technical issues of PV projects have to be satisfied, similar importance must be placed on achieving commercial viability through absorbing the higher PV roof component cost per square metre into the overall marketing of the building as a single package. Added values from PV as a distributed generator and in offsetting greenhouse gas emissions will help to facilitate the wider market acceptance of PV products. Achieving successful integration of systems, cost-effective interconnection with external infrastructure and acceptance by all stakeholders is also a challenging task. However, the Solar Village has required pioneering procedures to ensure that security and safety issues are compliant with Australian requirements and also as rigorous as current overseas standards. Australian PV grid integration best practices, that avoid poor distribution network harmonics and islanding effects, have resulted. Knowledge gained from the Solar Village thus far has already facilitated a rapid increase in the number of developments proposing to integrate solar technology.

Austria, Styria, the solar city of Gleisdorf

Demet Suna and Christoph Schiener

Summary

The solar city of Gleisdorf lies in the Austrian province of Styria. Since 1991 many new PV and solar thermal systems have been installed, with over 150 different projects in different locations. A communal PV power plant on the roof of utility Feistritzwerke-Steweag was the first PV power plant in Austria realized through a shareholder programme. The city government takes positive measures to support renewable energy in the city and works closely with the utility Feistritzwerke. The city government has made a decision that in the future PV plants, solar thermal plants and biomass must be installed in all public buildings constructed. For private building owners there is an obligatory free consulting interview with a representative of the utility company for everyone who wants to plan a new building. The actions of the municipality have been recognized by various national and international energy awards and environmental protection awards.

Introduction

The solar city of Gleisdorf lies in the sunny hills of the Austrian province of Styria approximately 25km east of the capital of this province, Graz. The city has 5500 inhabitants and extends for an area of 4.78km^2. The city's geographic situation makes it an important traffic and commercial centre, with attractive business possibilities. A modern meeting centre offers a large number of cultural and athletic events to the region.

Within Austria, Gleisdorf is known for its numerous renewable energy initiatives, projects and measures. Many visible projects like the solar tree, the solar energy road and the multi-functional photovoltaic noise-protection wall along the motorway support the 'solar city' image of Gleisdorf. Approximately 350kWp of PV systems have been installed within over 100 projects.

The major PV programme in Gleisdorf

The first solar thermal initiatives were started in Gleisdorf at the beginning of the 1980s. A group of interested customers built the first solar thermal collectors for single-family houses. Around 1990 the first PV systems were installed in order to generate electricity. Since this time the trend towards renewable energies has been continuous.

Since 1991 many new PV and solar thermal systems have been installed with more than 150 different projects in different locations. The largest projects are:

- 10.4kWp PV power plant on the roof of the utility Feistritzwerke-Steweag GmbH;
- 8.2kWp PV system at the city hall of Gleisdorf;
- 7kWp PV system on the solar tree which is located in the middle of the city;
- 100kWp multifunctional noise-protection PV system wall along the motorway A2;
- 9.9kWp on the roof of Gleisdorf Waves swimming pool;
- 10.2kWp at the medical centre 'Äskulap'.

In addition about 600m^2 of solar thermal collectors were installed. In over 100 households the water is heated by solar energy. There are also two large-scale projects: 230m^2 at the solar low energy house 'Sundays' and 100m^2 on the roof of Gleisdorf Waves swimming pool.

Description of PV projects

Communal PV power plant

This project was the first PV power plant in Austria realized through a shareholder programme. In 1995 a PV system with a capacity of 10.4kWp was installed on the roof of utility Feistritzwerke-Steweag. The system was financed by 68 shareholders and the company Feistritzwerke GmbH, which also coordinated the shareholder programme. This project made it possible for environmentally engaged people to own a share of a PV power plant. The project objectives were:

- to replace fossil energy sources by renewable energies;
- to reduce greenhouse gases: with this project 1.5 tonnes CO_2 a year can be avoided;
- to demonstrate a PV power plant;
- to encourage the general implementation of PV systems.

The costs were kept as low as possible through careful selection of components, appropriate sizing of PV systems and the use of existing infrastructure and know-how. Hence the prices was kept to €7000/kWp, whereas standard system costs at that time were €9500 to €13,000/kWp. This project showed that big systems could be installed at a favourable price if suitable conditions are available.

At the beginning, sales of share certificates were slow. The project manager put a lot of effort into this area with a high advertising effort. This led to greater interest in participation by the local population. About 2500 people obtained information about photovoltaics. In the end 68 people bought shares, which financed 80 per cent of the costs, with the remaining 20 per cent financed by the utility.

Solar street and solar tree

The solar tree – the new symbol of Gleisdorf – was built in 1998 with a capacity of 7kWp and was connected to the public electricity grid. It stands in the 'solar street' which is a 3.5km-long street section, where about 80 objects are powered by photovoltaics, including a public solar clock, advertising boards and street lights. Solar cells have also been used for art and the solar tree is one of these examples. It is 17.3m high and consists of a 12,700kg solid steel sculpture in the form of a tree with five branches holding 140 solar panels.

The tree generates approximately 6650kWh of electricity annually, which can supply about 70 city streetlights in the centre of Gleisdorf. But the solar tree is not only an artistic and technological object that produces electricity. It also underlines the future ideologies in terms of

10.4kWp PV power plant on the roof of the utility Feistritzwerke-Steweag GmbH

Source: © Feistritzwerke-Steweag GmbH

Solar café in Gleisdorf

Source: © Feistritzwerke-Steweag GmbH

Street light in the solar street

Source: © Feistritzwerke-Steweag GmbH

energy of Gleisdorf. Furthermore it promotes energy awareness to the people. In this respect the solar tree connects the elements of art, solar technology, and city organization and planning together in one project.

Most of the PV systems in the solar street have been financed by the utility Feistritzwerke, which partly belongs to the city municipality. Hence the projects of the solar street can also be called a city initiative.

The PV power plant and the solar tree were the first steps towards PV application and renewable energies in Gleisdorf. In the following years more PV plants and solar thermal applications were realized. Most of the PV systems are grid-connected systems. Only a few PV systems like road signs, billboards and other demonstration objects are operated off grid.

The largest photovoltaic system in the solar street is a façade-integrated system with a capacity of 10kWp. The electricity demands of this building can be covered by its PV system.

The headquarters of AEE (working group for renewable energies) is also another interesting example of a passive solar house with a solar thermal system and a photovoltaic system placed on the roof.

Summary of problems, barriers, solutions and recommendations

Positive issues regarding PV power, solar thermal applications and other renewable energies in Gleisdorf

The following may be considered:

- The city has always been very interested in renewable energies and their development. Therefore it has received different national and international energy awards and environmental protection awards.
- A renewable energy exhibition takes place once a year. Many domestic companies based in the region of Gleisdorf/Weiz are specially promoted.
- Every two years an international solar symposium takes place in Gleisdorf. In this meeting about 400 people from 20 different countries participate. This is a general economic incentive for the region, and brings a positive aspect to PV and other renewable energies.
- Within the campaign 'Solar electricity for schools' each school gets a trackable PV power system, if they are customers of the utility. This system looks like a solar wheel and is a triple tracked on-grid PV system. It allows teachers and pupils to operate their own solar power plant and lets the pupils investigate solar power and learn some practical physics.
- The city government of Gleisdorf is also interested in renewable energies in public buildings. In the future, PV plants, solar thermal plants and biomass must be installed in all public buildings constructed. Retrofits at older public buildings have also been made within the renewable energies programme.
- When the shareholders of the PV power plant on the roof of the utility Feistritzwerke-Steweag GmbH were surveyed, half of them indicated that they had positively changed their energy use attitude and nearly 80 per cent of them had taken energy saving measures in order to use energy efficiently.

Trackable solar wheel at a school

Source: © Feistritzwerke-Steweag GmbH

Provision of information about renewable energy in buildings

In Gleisdorf there is a free consulting interview with a representative of the utility company for everyone who wants to plan a new building. In these interviews the options for the application of renewable energies are presented. Furthermore the advantages and possibilities of renewable energies are explored and the size of the requested/needed facility is discussed.

This consulting interview is obligatory for all new building owners. Without this discussion it is not possible to get a subsidy. This service is used yearly by 30–50 house owners.

An energy database: a possibility for energy efficiency measures

Currently there are efforts by the AEE (working group for renewable energies) to create an energy database in which the level of energy consumption of individual buildings would be noted. This will offer different possibilities to the building owners in order to achieve lower energy consumption and the use of renewable energies.

Subsidies for PV or thermal systems

Some limited subsidies are available for PV. PV electricity is publicly supported by the co-financing of 50 per cent of the feed-in tariff by the government of Styria. However, only 200kWp is subsidized per year; this is very low, so only a few people obtain this subsidy. The funds for one year are exhausted within ten minutes of applications opening.

There is also an investment subsidy from the government of the province of Styria which provides a maximum of €2000 per PV system. But this amount is too low to make PV systems attractive. Although PV has no acceptance problem, the high costs and lack of subsidies are still decisive barriers for PV.

Some people apply for the subsidy but when their offer is approved they do not install a PV system. This is a problem because there is a yearly cap of 200kWp for systems to be subsidized so this takes the allocation from others, those who are really keen to install a PV system but cannot obtain a subsidy because the cap has been reached.

Gleisdorf is one of the leading cities in Austria for using solar thermal. Solar thermal systems get the highest level of support within Austria, perhaps even in Europe, in Gleisdorf. The Styrian government also subsidizes the solar thermal systems but the biggest amount comes from the city of Gleisdorf. This means that solar thermal plants are more attractive for a house owner than a PV system.

How to ensure that systems work correctly? Who is responsible for maintenance?

PV systems are known to need no or minimal maintenance. But it is still necessary to ensure that the system works correctly in order to get maximal yield from a PV system:

- The communal system (PV power plant) on the roof of the utility company has been working very reliably and there have been very few problems with this PV system. Service activities are carried out by the employees of the utility company. Function control is checked monthly, and once a year the modules are cleaned. In the winter the surface of the PV modules is kept free of snow. The expected annual yield of 9000kWh has been exceeded and an annual output of 9500kWh is reached.

- Private owners and operators are responsible for their own PV systems. For them the most valuable point is if the system works correctly and effectively. Often private persons cannot tell if there is a problem and they do not check the system regularly. So problems or errors arising are only recognized later and can lead to impaired function for a period of time. If they have questions or problems the private operators can call the energy companies but an annual system check or maintenance service is not offered by the utility.
- Tenants are mostly not interested in where the electricity and the hot water come from, especially if they were not involved in the planning process or they are not intending to stay in the dwelling for a long time. In this case it is only important for them that electricity and hot water are available.
- The latest solar thermal plants have a big advantage in comparison with PV systems because these systems are equipped with a malfunction message system. If an error should arise an error message is sent to the operator.

France, Grand-Lyon, La Darnaise

Bruno Gaiddon

Summary

The conurbation of Grand-Lyon in central France has been active in the area of renewable energy for some years. One of the earliest projects was the installation of PV façades during the refurbishment of high-rise buildings at La Darnaise. This area had a very bad image because of urban riots in the past. PV became part of the strategy to change the image of the area. The reputation and image of the area were successfully transformed to a renewables area where PV provides a visible symbol of the transformation. Initially, renewable energy sources were not part of the refurbishment plan for La Darnaise, which concentrated on the installation of external insulation and low-emissivity (low-E) windows. But in 2001, the local energy agency organized technical visits to renewable energy systems. The technical visit on PV was to an apartment building with a 10kWp PV system. This initiative led to the modification of the project to include renewable energy systems.

Introduction

Vénissieux is a municipality of 60,000 inhabitants located in the Grand-Lyon conurbation, the second largest in France, with a mix of social housing and industry. La Darnaise is a group of multi-storey apartment buildings built in the 1970s and composed of, at that time, 1000 dwellings. The area suffers from a bad image due to urban riots that occurred in this area in the past.

Today, Vénissieux is undergoing significant urban regeneration in order to improve the quality of life of the inhabitants. Between 1989 and 2004, four multi-storey buildings were demolished and replaced by semi-detached housing. The refurbishment of the 11 remaining multi-storey buildings, including improvement of the building insulation and the use of renewable energy sources, began in 1998 and ended in 2006. Today, La Darnaise district is a concrete illustration of the possibility of transforming an old social housing area into an energy efficient and renewable-energy powered district.

Within La Darnaise area, PV was installed on the façade of 11 multi-storey apartment buildings and now supplies renewable electricity to 727 dwellings. This project was funded by the French National Agency for the Environment and Energy Management (ADEME) and the Rhône-Alpes Regional Council.

Site plan of La Darnaise, Vénissieux

Source: © OPAC Grand-Lyon

The refurbishment of La Darnaise buildings, owned by OPAC Grand-Lyon, a public social housing organization, was part of a large urban regeneration scheme (Great City Project) under the leadership of the Grand-Lyon community. Launched in 1998, the objective was to improve the quality of life for inhabitants and to give a positive image to this dilapidated district. Priority was given to improving the thermal comfort of dwellings and reducing service charges for tenants.

Initially, renewable energy sources were not part of the refurbishment plan, which consisted only of the installation of high efficiency external insulation and low-E windows. But in 2001, the local energy agency organized for OPAC Grand-Lyon technical visits to renewable energy systems. The technical visit on PV was to an apartment building near Grenoble owned by another public social housing organization, OPAC 38, which was equipped with a 10kWp PV system installed in 1999 within Green Cities, a European Commission funded project. This initiative was more than successful since it led OPAC Grand-Lyon to modify its project to include renewable energy systems.

Solar hot water systems with a total solar collector area of 730m^2 were installed on the roofs of several buildings in order to reach an optimal size of 1m^2 of solar collector per dwelling. The coal-powered district heating station was also replaced by a 12MW wood chip fired power plant.

Preliminary studies found that very little roof surface was available for PV systems, as almost all the roof area was to be occupied by solar thermal systems. The only possibility for installing PV

Aerial view of La Darnaise district

Source: © OPAC Grand-Lyon

View of the southern façades of La Darnaise district early in the morning

Source: © Agence Locale de l'Energie de l'Agglomération Lyonnaise

systems was to integrate them on the southern façade of each building, despite the reduced energy production compared with a roof installation.

In this large-scale urban regeneration, it was of course not possible to adapt the urban plan to optimize the use of PV. The PV systems were therefore sized and positioned on each building to limit shading from neighbouring buildings.

The total cost for the PV was €580,000, of which one-third was paid by the building owner and the remaining cost co-funded by the French National Agency for Environment and Energy Management (ADEME) and the Rhône-Alpes Regional Council. Although this PV system benefits from the national feed-in tariff for the electricity produced, the PV system owner will never get a financial payback for this project. The reason is that the PV system owner chooses to use

Within La Darnaise regeneration programme, 92kWp of PV were installed between 2005 and 2006 on the façade of 11 multi-storey buildings.

The nominal power of each system varies from 4kWp to 12kWp. The size of each system was optimized taking into account the level of shading generated by surrounding buildings:

- three buildings equipped with a 4kWp PV system (12kWp);
- four buildings equipped with an 8kWp PV system (32kWp);
- four buildings equipped with a 12kWp PV system (48kWp).

PV array sizes were optimized in La Darnaise project in order to minimize shading

Source: © Agence Locale de l'Energie de l'Agglomération Lyonnaise

the annual revenue generated by the electricity not to reimburse a loan or its investment, but instead to reduce the service charges of the buildings, in order to increase its social role and reduce the poverty of inhabitants.

PV is just a small part of this large-scale regeneration project that aims to improve the quality of life of the inhabitants and reduce service charges by the improvement of energy efficiency and the use of renewable energy systems. But in contrast to the high efficiency insulation and windows, the wood chip fired district heating and the solar thermal collectors that cannot be easily seen, PV is now fully part of the visible district architecture. This makes the PV systems installed on the building façades the flagship of La Darnaise, the first renewables powered district in France.

Summary of problems, barriers, solutions and recommendations

This large urban renewal did not originally include the use of renewable energy systems

The scheme was aimed at improving the quality of life for inhabitants and giving a positive image to this district. Initially, renewable energy sources were not part of the refurbishment, which consisted only of the installation of high efficiency external insulation and low-E windows. However, the local energy agency organized technical visits to renewable energy systems in order to increase the knowledge and the awareness of renewables within OPAC Grand-Lyon, the building owner. This convinced it to change the project and include renewable energy systems (wood chip boiler, solar thermal and PV).

Where to find a suitable area for PV in the case of apartment buildings?

High-rise buildings generally offer limited roof areas suitable for photovoltaics, especially when the flat roof is also used for solar thermal, which is the case in this project. At La Darnaise the solution found was to integrate PV on the southern façade of each building. This has the consequence of decreasing the annual energy output from the PV systems as the tilt angle of the PV modules is far from the optimal value, which is approximately 30° in Lyon. This loss of yield is, in the case of PV, compensated by additional added values such as visibility.

How to reduce the impact of shading by neighbouring buildings?

High-rise buildings occupy little land surface but generate significant shading on surrounding buildings. When PV is installed on façades, shading can significantly decrease the annual output of PV systems. A detailed study was done to analyse the shading generated by each building in order to size the array area of each PV system and avoid areas of the façade that were regularly shaded by other buildings, thus maximizing the annual energy production. Three different PV systems were designed (4kWp, 8kWp and 12kWp) and are installed on buildings taking shading into account.

Number of PV systems when several buildings are equipped

When several buildings owned by the same entity are equipped with PV, there is the choice to either install one independent PV system on each building or to install subsystems on each building that are then connected together to form a single PV system. Reducing the number of PV systems facilitates monitoring and the administrative procedures for the connection to the grid or the purchase of the electricity produced, but may not be possible if the electrical connection of each subsystem is technically complicated.

Although all the PV at La Darnaise is owned by the same owner, this project is composed of 11 independent PV systems, one for each building. Each system has its own connection point to the grid and its own contract with the utility for the purchase of the energy produced. This solution was preferred because the connection of each subsystem to a single point of the distribution grid would have been very expensive and complicated.

Is it worth spending money on PV that will have a limited impact in reducing the service charges for tenants?

In La Darnaise, PV will produce approximately 59,000kWh per year, an average of 80kWh per dwelling per year. The impact of PV on service charges for tenants will therefore be limited. However, PV modules are installed not on roofs but on façades in order to make PV fully part of the district architecture. This technical choice led to the use of PV, not only for the production of renewable energy, but also for its visibility, as the other energy efficiency measures and renewable energy systems used in the project – solar thermal, building insulation and biomass-based district heating – are not visible to tenants or visitors. PV is the flagship of La Darnaise, the first renewables powered district in France. The social impact of this visible element of urban regeneration is considered to be as valuable as the energy that could have been produced by a more optimally inclined system.

France, Saint-Priest, Les Hauts de Feuilly

Bruno Gaiddon

Summary

Les Hauts de Feuilly housing development in Grand-Lyon was designed as a sustainable development with high levels of energy efficiency and renewable energy systems. It is currently being constructed to meet environmental guidelines proposed by the Grand-Lyon community. The experience gained during this project was used by the Grand-Lyon community to improve the local energy guidelines and to increase energy efficiency in buildings and the use of renewable energy systems above levels required by national regulations.

Introduction

Saint-Priest is a municipality of 40,000 inhabitants located in the Grand-Lyon conurbation, the second largest in France, with a mix of large commercial areas and industry. Les Hauts de Feuilly is a new housing district of 27,700m^2 of useful floor area created by the Grand-Lyon community in 1998 in order to develop a new form of housing based on high quality architecture and urban living. This project includes the construction of 117

Site map of Les Hauts de Feuilly

Source: © SERL

individual homes and 81 dwellings in six apartment buildings.

Les Hauts de Feuilly is now considered in France to be a very innovative and successful project focused on sustainable development. Almost all the developers selected to design buildings used energy efficient building techniques and renewable energy sources in order to reduce the use of conventional energy. For example:

- Les Nouveaux Constructeurs optimized the location and orientation of buildings in order to maximize solar gains, reinforced the insulation and used heat recovery ventilation and solar hot water systems.
- SIER optimized natural lighting, used natural material such as bricks, reinforced the insulation and used solar systems for heating and hot water production.
- France-Terre equipped each building with a roof-integrated photovoltaic system.
- Groupe MCP will build passive houses equipped with solar thermal and photovoltaic systems.

Description of the PV project

At the beginning of the project, environmental issues were not part of the development scheme. This was first discussed when SERL, the company in charge of the city planning, raised the idea of using an environmental management method for the construction of this project. Each developer was given the choice to propose innovative building solutions in order to fulfil an environmental guideline proposed by the Grand-Lyon community.

Within the Les Hauts de Feuilly area, PV was installed as standard equipment by two developers:

- France-Terre equipped 19 detached houses and three apartment buildings with PV.
- Groupe MCP designed passive houses with PV in order to improve their energy balance.

France-Terre, one of the developers selected for the construction of this project, chose to pay special attention to the integration of photovoltaic systems, which was an innovative alternative to solar hot water systems in urban and collective housing projects.

Groupe MCP's passive houses with solar thermal and PV

Source: © hooznext.com pour GRDF

France-Terre's roof-integrated PV system installed on 19 individual homes

Source: © hooznext.com pour GRDF

The initial architectural choice of France-Terre was to equip detached houses with red tiles and apartment buildings with black tiles, both supplied by Imerys TC, France's largest fired-clay tile manufacturer, which was also at that time involved in a European project to develop and install roof-integrated PV systems. Thus, when France-Terre decided to include PV in its commercial offer, it just asked its roof material supplier for a new offer that included PV. Finally, the developer decided to use only dark flat tiles for both types of buildings in order to improve the technical and aesthetic integration of the chosen PV tile.

For this new development, the site planning was completed prior to the decision to equip the site with PV; this explains why the architectural choices, particularly building orientation on streets and the roof type and orientation, are not optimized for PV. In addition, as France-Terre wanted to offer the same quality to each house owner, each house was equipped with the same 1kWp PV system, despite the fact that in reality some of the PV systems have better operating conditions than others.

The price of each PV system was approx. €10,000 including VAT, which represents less than 5 per cent of the total price paid by private owners for each house, approximately €250,000. In order to help the developer sell the houses and help the private owners buy them, each PV system was funded by:

- the European Commission within the PV-STARLET project;
- the French National Agency for Environment and Energy Management, ADEME;
- the Rhone-Alps Regional Council.

The final over-cost for private owners of each PV system was less than 1 per cent of the total price of the delivered house. At the completion of the project, in 2006, the applicable feed-in tariff for PV systems was €0.14/kWh. Fortunately for the house owners, due to a delay in the official connection of each PV system to the grid, none of the PV systems was commissioned before summer 2006, when the new feed-in tariff was announced by the government. Finally, as the PV systems are integrated into the roof, the applicable feed-in tariff for this project was set at €0.55/kWh for a guaranteed period of 20 years.

The PV-STARLET project was a European Commission funded project involving the development of a PV tile and the installation of over 600kWp of this product in Europe. This project was coordinated by Imerys TC, France's largest fired-clay tile manufacturer.

Within PV-STARLET, 25kWp were installed in Les Hauts de Feuilly on France-Terre buildings in 2006:

- 19kWp on 19 detached houses (1kWp each)
- 6kWp on three apartment buildings (2kWp each)

Although the total installed power in this area is relatively small, this project is important as it was the first time in France that a developer decided to include PV as standard equipment on its homes.

All the experience gained during this project was used by the Grand-Lyon community in order to improve the local energy guidelines applicable to all buildings constructed on land owned by the community, and to increase energy efficiency in buildings and use of renewable energy systems above levels required by national regulations.

Summary of problems, barriers, solutions and recommendations

When designing a building shape and layout, developers should know if buildings will be equipped with PV in order to take appropriate measures

In this new development, the site planning was completed prior to the decision to equip the houses with PV. France-Terre, the developer of the project, chose to offer the same quality to each house owner by installing 1kWp of PV on the roof of each house, despite the fact that architectural choices, especially the orientation of buildings on streets and the type and orientation of roofs, were not fully optimized for PV. Consequently, some of the PV systems are installed on roofs that do not face south.

Ideally, in addition to standard urban planning and architectural considerations, developers should take into account basic solar requirements in terms of roof shape and orientation and reduce mutual shadings of buildings. This will allow the installation of a PV system on each home and ensure that each installed PV system operates under acceptable conditions.

France-Terre detached houses each equipped with 1kWp integrated PV system

Source: © hooznext.com pour GRDF

Connecting PV systems on the distribution grid may generate over-costs if not well anticipated with the distribution network operator (DNO)

In France, in order to benefit from the feed-in tariff for the totality of the energy produced by a PV system, the utility has to create an additional connection point to the grid dedicated to the PV system. For this new development, the DNO simply created one connection point to the grid to supply each house with electricity as it does for standard developments. The DNO had not been formally told that each home would be equipped with PV and therefore did not anticipate the fact that an additional connection point to the grid was necessary for each PV system. This was rectified at a later stage in the project, once the inhabitants had moved into their homes, and delayed the commissioning of all PV systems. Fortunately this did not involve extra costs for the inhabitants as the power of each PV system is below a certain level, which meant the costs were borne by the DNO.

Organizations responsible for urban planning and development should inform the DNO as early as possible if new buildings will be equipped with PV systems. This will allow the DNO to modify its usual network planning works in order to include all necessary features for optimal grid operation. It will also avoid additional infrastructure work after the completion of buildings if the DNO requires a direct connection to the transformer, as may be the case for large-scale PV systems.

Selling new homes with PV as standard equipment generates new requirements for developers

A developer who chooses to install PV systems on its buildings will not only have to deal with technical aspects but also with non-technical aspects, such as the administrative procedures for the connection of the PV systems to the grid and the contract for the purchase of the electricity produced at a specific feed-in tariff. Such procedures should normally be carried out by future home owners but, as they are complicated and time-consuming, developers generally choose to initiate them on behalf of future home owners as a commercial service in order to sell the homes.

It is recommended that developers assist future home owners until the PV systems have been commissioned. In particular, developers should ensure that future home owners have signed any contract required for the connection of the PV system to the electricity grid and any contract for the purchase of electricity produced at a specific feed-in tariff. Not assisting them could lead to dissatisfied home owners and damage the developer's reputation.

Germany, Freiburg, 'Solarsiedlung am Schlierberg'

Ingo B. Hagemann

Summary

Freiburg is said to be Germany's ecological capital, with ecological standards for new developments being set nearly 20 years ago. There is a high level of political commitment to renewables, with many people living in the area enthusiastic and knowledgeable about them. The long-standing ecological reputation of Freiburg has led to economic benefits for the city with many institutes based there.

Even for Freiburg the 'Solarsiedlung am Schlierberg' (Schlierberg Solar Estate) has ambitious energy targets. On an annual basis its buildings export energy. They are highly energy efficient buildings with an annual heating demand below 18kWh/m^3 (passive house standard). Additionally, all roofs are covered with PV modules. The whole development was privately funded with an innovative share scheme. It was initiated and championed by the architect Rolf Disch, who took a personal risk to make this privately funded project happen and to provide the proof that today's homes are able to generate more energy than they need.

Introduction

Freiburg is located in the area between the Upper Rhine and the Black Forest. It is one of the warmest and sunniest regions of Germany with approximately 1800 hours of sunshine per year. The city, with 204,000 citizens, is the economic and cultural centre of the region and is the only major city in Baden-Württemberg with a constantly rising number of inhabitants.

It is also the home of one of the most modern housing estates in Europe, the so called 'Solarsiedlung am Schlierberg' (in English: 'Schlierberg Solar Estate'). This solar estate is part of a larger urban redevelopment area in the Vauban district, a former barracks ground of the French army. Over a period of approximately

Site plan of the Schlierberg Solar Estate

Source: © Solarsiedlungs GmbH

ten years, 60 Energy-Surplus-Houses® and a 125m-long service block, called Sonnenschiff, have been built along the main road. The Sonnenschiff provides retail, office and living spaces. The terraced houses are two or three storeys high while the Sonnenschiff is four to five storeys high and thus screens the community from the traffic on the main road Merzhauser Straße.

Within the estate all roofs are covered with standard large area PV modules, which are neatly integrated in a plane above the south facing roofs of the different buildings. The total system size is 445kWp. This large-scale PV application was fostered by the German National Renewable Energy Act (Erneuerbare-Energien-Gesetz, EEG) which was implemented on 1 April 2000.

The project is the result of the 'ecologically sound atmosphere' of Freiburg and the personality and persistence of architect Rolf Disch, who wanted to provide evidence that his idea of an Energy-Surplus-House® could work well for terraced houses and commercial buildings. Finally, he operated as the architect and as the entrepreneur of the Solarsiedlung am Schlierberg. This double function allowed him to ensure that his idea of an Energy-Surplus-House® could be put into practice.

Background

Freiburg is well known for its many efforts to protect and preserve natural resources and the environment.

Bird's-eye view of Solarsiedlung am Schlierberg with the Sonnenschiff in the front

Source: © Solarsiedlungs GmbH

The city has received several environmental prizes, including Ecological Capital of Germany in 1992 and Sustainable City in 2004. Several times it also won the National Solar League.

The roots for this environmental success in Freiburg can be traced back to the 1970s. In this decade plans for a French chemical factory not far from Freiburg, as well as three nuclear plants in German, French and Swiss cities close by, galvanized the population into widespread protest. This raised the environmental awareness of many of Freiburg's citizens, and regional networks of environmentalists came into existence. For years critical and dedicated people have generated political pressure to achieve ecological progress.

After the Chernobyl disaster in 1986, Freiburg was one of the first German cities to adopt a local concept of energy supply in order to protect the climate. The programme included the reduction of consumption of energy, water and resources. Further issues were the use of renewable energy sources and the application of new energy technologies (BUND, 2002; Mayer, 2007).

During the 1990s, Freiburg undertook a study to investigate the economic significance of its commitment to environmental policies. For the region as a whole, the study showed that solar energy and environmental policies have been important economic development assets for Freiburg, which has never had any major industry. It also fits with Freiburg's position in a major tourist area and as the home of a wide network of environmental organizations, businesses and research institutes. Among them are the Freiburger Oeko-Institute (Institute of Ecology), the BUND (Friends of the Earth), the ISES World Headquarters, Fraunhofer ISE and Solarfabrik.

In addition to the economic and environmental benefits, Freiburg's citizens enjoy a pride in their city for showing this kind of leadership. A significant percentage of the population votes Green and many of the residents are happy to pay an extra percentage on building cost, for a payback in lower energy bills as well as social and health benefits.

On a federal level, Germany followed Freiburg's footsteps in trying to save energy, encouraged by the environmentally friendly Green Party that was in former Chancellor Gerhard Schroeder's governing coalition. In 2000, the German government decided to phase out nuclear plants by 2020, and has adopted legislation promoting the development and use of renewable energy sources.

The most important piece of legislation is the German National Renewable Energy Act (EEG), which was approved in spring 2000. According to this law, grid operators have to pay fees for electricity from renewable energy sources. The difference between fees and the market price for electricity from traditional sources is apportioned to consumers via their electricity bills as EEG apportionment. The different types of renewable energy sources receive different fees based on the cost of electricity generation. This way of promoting electricity generation from renewable energy sources has proved to be extremely successful, in particular for wind power and PV.

Project development

The Solarsiedlung am Schlierberg is the result of these national and local framework conditions and in particular of the courage, patience and spirit of innovation of the locally rooted architect and entrepreneur Rolf Disch. He and his team aim

View of the Schlierberg Solar Estate from south

Source: © Ingo B. Hagemann

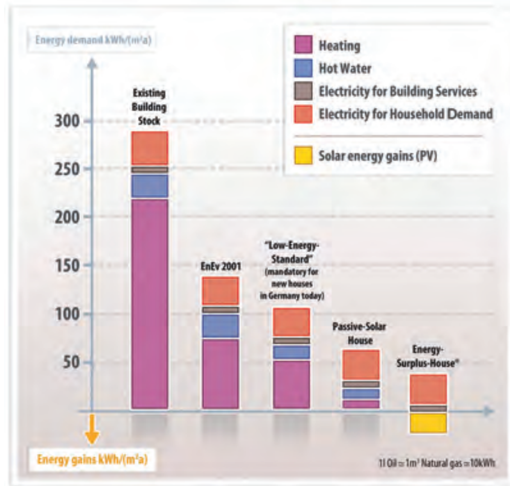
to provide living spaces that have a future in both ecological and economic terms. The Energy-Surplus-Houses® are an example of such spaces. It is calculated that the houses will need less energy than they produce during their lifetime. They utilize, in a smart way, active and passive solar design strategies, such as super insulation of the building shell, triple glazing for windows and door openings, the use of heat pumps, heat recovery systems, solar hot water collectors and PV.

The Solarsiedlung am Schlierberg project demonstrates that a high energy standard, previously tested at the experimental house Heliotop, built by Rolf Disch in 1994 with a 40m PV-tracking system on top, can also work technically and economically for ordinary terraced houses and commercial buildings.

The opportunity arose in 1990 when, after the fall of the Berlin Wall, French troops vacated a vast area south of the centre, now the Vauban district. The city of Freiburg bought the plot from the federal authorities and in 1993 started a challenging urban renewable process for the area, which is located next to one of the arterial roads of the town, the Merzhauser Strasse.

The local city planners were responsible for the planning and development of the plot, located west of the Merzhauser Strasse, focusing on a sustainable development. However, the target set for these buildings was not as ambitious as the plans for the Solarsiedlung am Schlierberg produced by Rolf Disch. The district became a showcase for extended citizen participation that went far beyond the legal requirements and enabled citizens to participate in the planning process.

On the grounds of the former sports facilities of the Vauban barracks, located on the east side of the Merzhauser Strasse, zoning regulations required a due south orientation for new buildings. This, together with the local infrastructure under development for the new Vauban district to the west of the road, seemed to provide ideal conditions to realize the vision of an Energy-Surplus-House® standard at a district level.



Energy demand of different building standards in Germany. An Energy-Surplus-House® needs less energy than it produces during its lifetime

Source: © Ingo B. Hagemann

Rolf Disch succeeded in getting the property developer Rolf Deyhle and his firm Instag AG as a partner for the project. This partnership was very promising since Rolf Deyhle was a well-known property developer and successful businessman, operating on a large scale. He considered the Solarsiedlung am Schlierberg project a starting point for the widespread marketing of such settlements. He also registered the Energy-Surplus-House® as a trademark.

Instag AG concluded an option contract for the plot with the city of Freiburg. This was followed by the submission of plans for the Solarsiedlung am Schlierberg. The local planning authority adopted the existing building regulations according to these plans and provided the building permit. Unfortunately, Instag AG then got into financial difficulties with other projects. By the end of the 1990s it was impossible to continue the project with this team.

In this situation, financial help was urgently needed to rescue the ambitious project. Finally

Sonnenschiff view from southwest/Merzhauser Strasse

Source: © Ingo B. Hagemann

Rolf Disch, with the help of the chocolate manufacturers Alfred Ritter and Marli Hoppe-Ritter, founded Solarsiedlungs GmbH. The new company aimed to take over all existing rights and liabilities of Instag AG for the plot of the Solarsiedlung am Schlierberg.

However, the city of Freiburg rejected this idea and invited new tenders for the plot east of the Merzhauser Strasse. Solarsiedlungs GmbH won this new competition but received only 40 per cent of the original plot to continue the project. The other 60 per cent was allocated to different investors to build conventional houses. The original ecological water concept for the whole plot, making use of the rain and streamlets from the nearby Loretto Mountain, therefore remained uncompleted.

Consequently the plans for the Solarsiedlung am Schlierberg needed to be revised. The number of houses shrank from 219 to 60 and the length of the service centre, shielding the houses from the Merzhauser Strasse, was cut down from 300m to 125m. The targets with regard to the ambitious energy concepts remained untouched.

The construction of the terraced houses was carried out gradually as they were sold. This turned out to be a tough job, since several tasks needed to be done in parallel, including supervision of the ongoing construction site, the selling and marketing of the houses, consulting with building owners and the adaptation of plans according to special requests.

Financing

Teething troubles occurred with the sales of the houses. Rumours of astronomically high house prices circulated. Creditors set a precondition for giving loans to prospective house buyers that the Solarsiedlungs GmbH should prove that at least 60 per cent of all houses in Solarsiedlung am Schlierberg were sold. Therefore it was initially difficult to sell houses.

However, this changed after the project was designated as an external project of the World's Fair EXPO 2000 and the Deutsche Bundesstiftung Umwelt provided some subsidies for communication and monitoring of the project.

Both measures helped in creating greater public awareness for the project. As a result public interest emerged in financial participation in the project. The financial difficulties were solved in 2001 by starting a fund, called 1. Solar Fond Freiburg, with an invitation for subscription to share certificates of €5000 each. The total investment was €1.5 million. This new financing model was the key to success. The first one was followed by three other investment funds with a total investment of €3 million each.

The purchase price for the terraced houses, including property and developer's costs, ranged between €2700/m^2 and €3300/m^2, depending on the individual fittings. In total 15 houses belong to these four solar funds. The houses are rented out for an average rent of €11/m^2. This corresponds to the upper price level in Freiburg. However, one needs to bear in mind that surcharges for heating costs would normally need to be added. In this case they are negligible, since heating bills for each house are between €50 and €100 per year.

The roof-integrated PV systems are marketed separately. Either the home owners or other investors purchased them. A return on investment is granted by the 20 years' payment of the feed-in tariff of the German National Renewable Energy Act.

The results proved that in spite of higher construction costs, the terraced houses allow for higher nominal yields. The reasons for that are the very low operational cost of the buildings (heating costs are negligible) and the revenues from the PV installations. Therefore the Energy-Surplus-House® concept is an attractive investment!

The funds are traditional closed-end real estate funds. Their average interest yield is 5 per cent to 6 per cent, which is about an average interest yield for this type of investment. The shareholders are primarily private persons who are interested in the project and wish to make a sustainable and sound long-term investment. Recently the fifth fund, called 1. Sonnenschiff Fond, started successfully with a total investment of €5.56 million. It owns part of the service centre with total construction costs of €20 million.

One could say that the major challenge of this project was the validation of financing. The funds described provided a successful alternative financing model when conservative creditors had difficulty investing in the innovative concept.

PV system

In contrast to the severe funding difficulties, which resulted in an innovative funding concept, the technical design of the PV system and its architectural integration into the overall design concept were not a problem. For both the architect and the installers PV was not a new topic. For this reason a professional collaboration between the different parties involved could be established, resulting in a simple but elegant solution for the mounting of the PV modules.

Standard, semi-transparent PV laminates were integrated into a plane with an air gap of 16cm above the south facing roofs of the terrace buildings. The PV modules are mounted point-wise on 30mm rectangular hollow section stainless steel profiles which themselves rest on hot-dip galvanized 100mm I-beams. The roofs' water barrier consists of a plastic-sheet sealing layer. Structurally, and therefore also legally, the PV array and roofing are two separate units. However, from the architectural design point of view both parts belong together and are one prominent, pleasant looking design feature of the Solarsiedlung am Schlierberg.

View from southeast showing the PV roofs

Source: © Solarsiedlungs GmbH

The PV system is an essential part of the overall energy and design concept of the Surplus-Energy-Houses®. Due to the cost of PV in the 1990s, early plans for the Solarsiedlung am Schlierberg did not include as much PV as is seen today. However, the German National Renewable Energy Act (Erneuerbare-Energien-Gesetz, EEG), coming into force in spring 2000, made it financially attractive to use PV. 'This new law fits right in with our plans', said the architect.

To increase the roof area and allow additional roof space for PV the flat roofs initially designed were converted into asymmetrical gable roofs. For the service centre and the terraced houses on top of it, mono-pitch roof constructions are used. Both roof styles have large overhangs on the south face and therefore provide shading on these façades in summer.

In total, 445kWp of grid-connected PV is installed. The string inverters are mounted under the roof deck on the buildings' exterior walls. The total annual solar electricity production is 420,000kWh. This, together with the energy efficient building design, allows for 2 million kWh primary energy savings per year. This is the equivalent of 200,000 litres of oil per year.

Occupants' feedback

Occupants report that they enjoy living in the Solarsiedlung am Schlierberg. They experience a variety of benefits compared to occupants of conventional settlements. For example:

- enjoying living in a solar home and contributing to a resource efficient life style;
- benefits from the good inner-city location;
- easy and quick access to public transport facilities nearby;
- an infrastructure appropriate for children (no cars etc.);
- less illness due to a healthy indoor climate/air quality;
- finding the social environment they are looking for (Fesa, 2002).

Italy, Alessandria Photovoltaic Village

Francesca Tilli, Michele Pellegrino, Antonio Berni and Niccolò Aste

Summary

The Alessandria Photovoltaic Village project was initiated by the Alessandria Municipal Council in Italy. It was a comprehensive project with the objective of transforming a low-income suburb into an environmentally friendly and socially integrated urban area. A total of 160kWp of PV is installed in this area on buildings and public spaces. This project won the first prize in the Italian competition, Award for Sustainable Cities.

Introduction

Alessandria's Photovoltaic Village is built in Casermette II, a suburb in the southwest of Alessandria, a town in northern Italy. Originally the area was mainly dedicated to agriculture, although there were some buildings, formerly used as military quarters, from which the name Casermette is derived.

The area was selected as a new residential area by the General Regulatory Plan of Alessandria City Hall in 1973, which identified three large expansion areas. The Casermette II area involved construction of a maximum volume of 743,000m^3, distributed over approximately 39.1 hectares, with an expected population of 7400

In Alessandria, 160kWp of PV is installed on buildings and public spaces

Source: © Comune di Alessandria

inhabitants. Since September 1977 an important transformation and growth process has been on going in the area.

The Public Residential Building intervention within the frame of the Integrated Intervention Programme (PII), endorsed by the 179/92 law, made possible new interventions in the area. The objectives were environmental, building and urban regeneration, and energy saving.

The area was characterized by the following aspects:

- low building density;
- low density of inhabitants;
- large open spaces both private and public;
- height of buildings no higher than three or four floors.

Improving the urban environment

The project was carried out on houses built initially during the 1960s and 1970s when there was an urgent need to provide houses for the large number of people moving from small villages to the urban area. The quality of housing then was very low due to the low income of the families going to live in the apartments and to the obligation to keep the costs low. Since then the slowdown in migratory movements of population and the heightened environmental sensitivity that has developed since the 1980s, have led public authorities to aim at higher quality housing, and this new approach led to the Alessandria Photovoltaic Village.

The Alessandria Municipal Council developed the project aiming to improve sustainability in public and private residential construction and integration within the urban context. It was decided to adopt an approach that was environmentally friendly, with buildings designed to use renewable energy in order to obtain reductions in CO_2 emissions. In addition, the programme aimed to restore a ‘continuum’, with the buildings integrated into the surrounding urban fabric with well-equipped public green areas and provision of public services and roads.

The area is formed by wide squares that are designed as courtyards surrounded by new houses; the two piazzas are connected by an elevated path in order to separate pedestrians from the urban traffic. The open spaces allow people from different social classes to meet each other and also provide space for sporting activities.

The Photovoltaic Village is a good example of urban area regeneration and represents a significant example of how innovative energy technologies can be applied on buildings, resulting in a good integration with the surrounding environment.

Description of the PV project

Alessandria’s Photovoltaic Village was developed over the years 2000–2005 under the coordination of the Residential Building Operators Council of the Province of Alessandria. Photovoltaic technology was installed within a public housing area as part of the urban and environmental regeneration of the area. The occupants of the village mainly belong to the medium and low social classes of the population.

The programme covered two areas and include a total of 192 flats equipped with photovoltaic systems. In the largest area the apartments are structured in five blocks with 40 apartments built by housing associations, 24 by shared ownership cooperatives and 32 are covenanted private building. The smallest area also has 96 apartments but structured in three blocks. These are all public housing built by the agency in charge of housing of the Alessandria province, ATC.

The attempt to find points of reference and architectural meanings in the open spaces was solved by creating different public green spaces for physical activities and for moments of rest and meeting. These new areas are marked by elements such as a shelter, where the photovoltaic modules provide shading for the seats below, a skating rink, a sheet of water and a pedestrian bridge with wooden facing.

A social centre for events and meetings was built with a square plan reinforced in the

The larger area with five blocks with PV on the roofs

Source: © Comune di Alessandria

PV shelter used to provide shade in public spaces

Source: © Comune di Alessandria

The social centre equipped with PV

Source: © Comune di Alessandria

The smaller of the two intervention areas that form the Photovoltaic Village, with PV on the roof of three blocks of apartments

Source: © Comune di Alessandria

corners with steel posts supporting photovoltaic modules, like flowers between earth and sky to catch the light.

The photovoltaic modules installed on the buildings are either fastened to the masonry structure connected to the frame of the roof or fixed to ballasts that simply rest on the roof tops. At the centre of the largest square the photovoltaic modules are integrated both on the roof and in the south façades of the two blocks, hooked to steel structures positioned like a building skin to protect the stairs of the block of flats.

The total photovoltaic power installed is around 160kWp, for an estimated production of 160,000kWh per year and a consequent CO_2 reduction of 100 tonnes per year.

A capacity of 76kWp is installed in the shared ownership cooperatives and covenanted private building; each apartment has its own system of around 1.4kWp producing up to 50 per cent of its power consumption. In housing association cooperatives and ATC public housing, 78kWp are installed to produce energy for the shared parts of the condominium (garage lights, stairs, etc.).

The photovoltaic system on the social centre provides power for the social centre and for the lighting in the square.

The total cost of the photovoltaic plants was €1.2 million of which around 70 per cent was financed with the '10,000 photovoltaic roofs' ministerial programme.

Due to the environmental and sustainability features, the initiative won the first prize in the competition, Award for Sustainable Cities, announced by the Ministry of Environment. The prize revenue (around €125,000) was used for the dissemination of environmental knowledge and initiatives on environmental protection such as electric cars.

Summary of problems, barriers, solutions and recommendations

A complex project

The PV village was a complex urban project, involving different stakeholders, with different levels of integration: firstly, the integration of the various urban functions with a plurality of interventions such as a mixture of public and private housing, and provision of a social centre and open spaces; secondly, private and public actors working together on the integration of financial resources.

In order to define the roles of all the actors and to follow the development of the integrated process, a coordination council was created, the Building Council, which included participants from the public housing sector in the area. This successful concept is now replicated in other towns in Italy.

Financing the PV system

The PV systems in this project were financed by the Italian PV roof programme, which was a financial support scheme in force at the time of construction. PV systems using net metering were provided with a subsidy of 70 per cent of the system cost. No particular problems are reported except for some minor delays in the payment of the incentives from the region. Now, the support scheme for PV in Italy is different: there is a 20-year feed-in tariff for electricity produced by PV. Gestore dei Servizi Elettrici, GSE, is the Italian implementing body in charge of the purchase of electricity produced by PV systems.

Building integration of PV

The Alessandria PV village is a comprehensive urban regeneration project using renewables. As the PV technology was introduced at a late stage of the project, it was not possible to merge the building construction process with the PV design process, which explains why PV is added to buildings and not fully architecturally integrated.

Benefits for the city and inhabitants

The success of this pilot project comes not from the amount of PV installed or the amount of PV electricity produced but from the management method of the whole process and the synergy of all the actors involved in it. Delegations from all around the world now visit the Alessandria PV village. Inhabitants of the village are aware that they are living in an innovative project and feel part of this new, important urban initiative.

Japan, Ota-city, Jyosai Town PV Demonstration Area

Shogo Nishikawa and Tomoki Ehara

Summary

The Jyosai Town PV Demonstration Area in Japan is a research project initiated in 2002 by NEDO, the New Energy and Industry Technology Development Organization, in order to study the effects and impacts of a large number of PV systems on the distribution network. For that purpose, 553 houses have been equipped with PV for a total installed power of 2.13MWp. This project is one of the most ambitious research projects studying the effect of the interconnection of PV systems on the electricity distribution network in the world.

Introduction

Ota-city is an industrial city in the Kanto area with approximately 220,000 inhabitants. Many factories are located in the area including Fuji heavy industry, which is a major automobile company in Japan. Jyosai town, the demonstration site of the PV project, is a new residential area in the central part of Ota-city.

In 2002, NEDO initiated a new R&D programme for PV grid interconnection. The objective of this programme was to demonstrate that a power system of several hundred residences, where each residence has a PV system, can be controlled by the technologies developed in the programme without any technical problems.

Stakeholders from various fields joined this research project. The leader of the project was Kandenko Company Ltd, an electrical

Site map of the Jyosai town demonstration area

Source: © NEDO

engineering and construction company. The other members who joined this project from the beginning were Meidensha Corporation (electronic manufacturer), Electric Power Engineering Systems Company Ltd (power consultant), Shin-Kobe Electric Machinery Company Ltd (battery manufacturer), Matsushita Ecology Systems Company Ltd (electronic manufacturer), Tokyo University of Agriculture and Technology and Ota-city. Later on Omron Corporation (electronic manufacturer), Nihon University, and JET, Japan Electrical Safety & Environment Technology Laboratories (official testing organization of electronic devices) joined the project.

The demonstration site was selected as having the following two factors:

- Adequate possibilities of certain levels of voltage rise in which output control function of the power conditioner will operate.
- Reasonable schedules for the construction and installation of the test devices possible.

Description of the PV programme

All the PV systems were installed on the roofs of residential houses. The number of houses equipped with PV is 553. Most of the houses were newly built but there are also a few cases where PV systems were installed on existing houses. The capacity of the PV systems is 2.13MWp in total. The first PV system in the project started operation in December 2003, and the installation of the PV systems was completed in May 2006.

The development of the demonstration site, Jyosai town, was originally planned as a normal housing area development. In order to shift the concept of the R&D project to a solar development and align it with the needs for research on the PV grid connection the local government was also included in the project team. In addition, the concept of this R&D project was explained to the potential owners of the houses. The development plan was modified so that it matched with the research project.

Summary of problems, barriers, solutions and recommendations

Negotiation with the utility company

In order to implement this research, a number of PV systems needed to be connected to the normal grid (without special protective devices); therefore, various questions were raised by the

Overview of the Jyosai town demonstration site

Source: © NEDO – unauthorized use or reproduction of this picture is strongly prohibited utility company from the security perspective. Examples of the questions are shown below:

- Is the system designed to regulate the output when excessive voltage rises occur by the electricity reverse flow, so that the voltage can be controlled within a certain range?
- Is the system designed to disconnect from the grid within a given length of time if an accident happens on the distribution line?
- Can the system be disconnected promptly along with the utility's instruction in the case of intentional blackout for distribution line maintenance?
- How will the system respond if an accident happens on the system side?

In order to assure the security of the system, a site office was set up and monitoring staff were stationed at the office on a full-time basis. In addition, an integrated control system was developed so that the staff could monitor and control the system.

Although most of the questions raised by the utility company were solved through those measures, there were still some technical questions remaining on the second issue. The issue was addressed throughout the project and a new inverter technology was developed. Based on this technology and the experience obtained in the project, utility companies are now starting discussions on new technical requirements to support community scale PV installations.

Cooperation with the house owners

As this project is focused on research, cooperation with the house owners was essential. Conflict with residents in the area could lead to a serious risk for the project.

Explanatory meetings for the house owners were held many times to ask for cooperation of the residents. In addition, official contracts were made to avoid trouble.

It should be noted that this project was aimed at research and the costs were paid from the research budget, therefore, it might be quite different from a general development project. In addition, the organization, structure and mindset of the utility companies in Japan are quite different from those in Europe or the US. In Japan, it is very important to understand the utility's intention through prior consultation. This six-year demonstration project has successfully finished. A new two-year project has started to disseminate the fruitful outcome of the demonstration project.

Overview of the demonstration site

Source: © NEDO – unauthorized use or reproduction of this picture is strongly prohibited

Overview of the demonstration site

Source: © NEDO – unauthorized use or reproduction of this picture is strongly prohibited

The Netherlands, Amsterdam, Nieuw Sloten PV houses

Jadranka Cace and Emil ter Horst

Summary

The Nieuw Sloten PV houses project was the first truly large-scale PV housing project ever realized. In this project PV was installed on houses in a new housing area. The project was led by the local electricity utility, the Energy Company of Amsterdam (now Nuon). It was an important demonstration of PV in urban areas and helped to pave the way for later projects. A number of technical issues had to be worked out for the first time. In addition, the project involved many professionals with no previous experience with PV and very little knowledge of PV. These professionals were assisted by the manager of the PV project.

The houses were completed in 1996 so there are now 12 years of experience from the project. This case study looks at the lessons learnt since the project was started.

Introduction

The Nieuw Sloten PV project is located in the southwest of the city of Amsterdam in The Netherlands. The goal of the project was to realize a fully integrated PV system in a newbuild residential area with approximately 100 dwellings. The PV system was integrated physically (solar modules instead of roofing tiles), electrically (connected to the public grid) and organizationally (the project was embedded into the area development process). A total of 250kWp of PV was installed.

The PV system is owned and operated by the utility. There is a legal separation of the house and the roof marked by the waterproof layer installed under the PV modules. The electricity generated is used within the district but is not linked directly to the house on which it is mounted.

In a densely populated area such as Amsterdam it is not always possible in urban planning to orient houses towards the south, so some of the PV roofs are oriented to the east and west. The east and west facing roofs have low roof inclinations for better insolation.

Amsterdam Nieuw Sloten. Architect: Duinker van der Torre samenwerkende architecten, Amsterdam

Source: © Norbert van Onna and Jan Derwig

Stakeholders and added values

From the beginning until completion, the PV project was led by the policy department of the Energy Company Amsterdam (EBA) as an environmental initiative. Work started in 1991 when a dedicated project manager was appointed with the objective of implementing a PV project on the scale of 100 houses in the area. The first task of the project manager was to locate a development where the PV project could be implemented. The project manager of the PV solar project saw the development in the Nieuw Sloten district as an ideal opportunity to realize the solar project of the energy company and successfully took the initiative to join efforts with the Nieuw Sloten area development project team.

In a standard development process the utility company only gets involved during the last phase of the development of a new district. In this project the utility began collaboration with municipal organizations at a very early stage of the development. This made it possible to create better conditions for the realization of the PV system. An important success factor turned out to be positioning the PV project manager within the area development team. As a spin-off from this project the municipality of Amsterdam now invites the utility company to participate every time they start a new, innovative building project.

The PV project was subsidized by the European Commission under the THERMIE programme. Other members of the PV project team were: Ecofys, the Newcastle PV Centre, and the environmental organizations Miljøkontrollen from Copenhagen, Sermasa from Madrid and ICIE from Genoa. The environmental organizations aimed to learn from the project and use the knowledge when implementing similar projects in their countries.

Three PV companies bid to supply and install the PV systems. After a thorough analysis and negotiations, it was agreed that two companies, instead of one, would be contracted. BP Solar supplied half of the PV modules; R&S Systems (Shell Solar) supplied the other half of the modules and the rest of the components. R&S was also responsible for the system engineering and the delivery of the system on a turnkey basis. The building company UBA from Uithoorn was the property developer. Architectural office Duinker van der Torre designed the PV houses.

With this project, the EBA achieved a number of goals that have played an important role in later urban PV projects. It is important to remember that at the beginning of the 1990s very few parties really believed that PV had a future. This project showed that:

- PV 'works', even in a northern country like The Netherlands.
- PV can also be applied in 'standard' architecture.
- Important lessons were learnt regarding the physical integration of PV, project organization and market development.
- Market parties worldwide were encouraged in applying PV as a promising technology.

The project also had positive impacts on the stakeholders involved:

- The architects involved in the project learnt how to use PV modules and applied the knowledge gained in later projects.
- The utility gained experience with PV in residential areas and confidence that the PV would not cause complications for the public electricity grid. This experience was used in the development of the plug-in PV products for individual houses and in later large-scale projects in The Netherlands.
- Buyers of the PV houses liked the visual appearance of their houses and were proud to be an 'ambassador' of PV energy and learn about solar electricity.
- The real estate developer learnt that while PV solar energy is certainly not the most important benefit people take into account when they buy a house, it is also not a barrier. The houses with PV were easy to sell, if the primary needs of buyers were met.

Amsterdam Nieuw Sloten. Architect: Duinker van der Torre samenwerkende architecten, Amsterdam

Source: © Norbert van Onna and Jan Derwig

- The municipality learnt that it was possible to fulfil energy and environmental policy goals together with an energy company. From this project on, Amsterdam municipal project teams have included the energy company in the project teams for all large projects with energy and environmental ambitions.

Costs and financing

The total cost of the PV system in Nieuw Sloten was €2.5 million. Forty per cent of the costs were subsidized by the THERMIE programme of the European Commission and 9 per cent by the Dutch national energy agency Novem.The remaining costs were covered by the municipality of Amsterdam, the project participants from Copenhagen, Madrid and Genoa, and by contributions from the module suppliers Shell Solar and BP Solar. It is important to mention that at the time, EBA was owned by the municipality. That is why the municipality invested and not the utility.

System concept

Before starting this project EBA investigated a number of alternative options regarding the implementation of a 250kWp PV system within its area, including using a PV system for the tramway grid. Aspects considered included: utilization of the PV electricity, electrical configuration of the system, mechanical construction of PV roof covers and costs.

After thorough investigations it was concluded that the most appropriate use of PV electricity was in a newly developed housing project. A feasibility study was conducted in which three different system concepts were analysed:

- one system per house: 100 individual systems;
- one system per block of houses: six systems;
- one system per district: a single 250kWp system.

The analysis showed that the last option, one single installation on the district level, would be financially the most attractive one.

Experience at Nieuw Sloten showed that private householders are concerned about maintenance costs of PV systems over the long term. It seemed that they would be prepared to have a PV roof as their own responsibility only if the cost of maintaining the system was clear and maintenance contracts were available with certified installers.

Integration into the architecture and construction of the houses

The Nieuw Sloten housing development consists of around 100 dwellings. Photovoltaics is installed on the roofs of 34 of the terraced houses (orientations west, south and east) arranged in a U shape around some further flat roofed houses (without PV). To the north is an apartment building with 37 dwellings. PV is mounted on the south façade, the main roof and two penthouse roofs on the apartment building.

As the implementation of the PV system was embedded into the development process, the architect was able to take into account all measures necessary for the good functioning of the PV systems while providing visually attractive houses:

Amsterdam Nieuw Sloten. Architect: Duinker van der Torre, samenwerkende architecten, Amsterdam

Source: © Norbert van Onna and Jan Derwig

- The family houses were provided with extra windows along the roofs as dormers (roof extensions which are very usual in The Netherlands are not an option in a PV roof).
- The colour of the cladding material was chosen to match the colour of the PV modules.
- All chimneys were shorter than standard chimneys to avoid shading the PV arrays.
- The roof construction was adapted to carry the profiles for mounting the PV modules and to allow ventilation under the PV modules.

The PV array area fully covers the roof surface of the PV dwellings with a mono-pitch roof.

In this project, solar modules replace the traditional roofing. As a consequence, the utility company, being the owner of the PV system, must guarantee the watertightness of the roof. For this, it was necessary that the utility provide a guarantee for the PV roofing. This requirement was integrated within the turnkey delivery of the PV installation.

On the wooden construction of the roof, in place of the roof tiles, standard aluminium profiles were fastened in a vertical position. Also, string cables were positioned to connect groups (strings) of modules. Hereafter, the modules were mounted between the profiles and connected to the string cables.

Chimneys are integrated within a plate with the same dimensions as the solar modules. The chimneys were specially shortened to reduce shading on the modules.

Modules

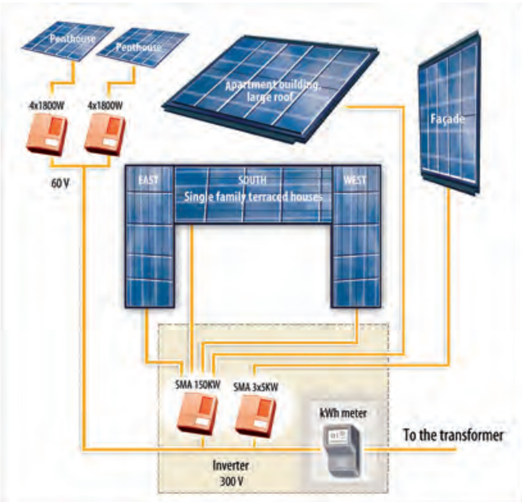
Two types of solar modules were used in this project: 1586 BP modules with a total peak power of 113.6kWp and 2821 Shell modules with a total peak power of 136.8kWp. For both types of modules a guaranteed minimum power was provided and checked. Module test results provided by the suppliers were used to group the PV modules into strings of similarly performing modules in order to optimize the system yield.

Amsterdam Nieuw Sloten. Architect: Duinker van der Torre, samenwerkende architecten, Amsterdam

Source: © Norbert van Onna and Jan Derwig

Electric design and grid connection

The PV system in Nieuw Sloten consists of four subsystems. The family houses and the large roof of the apartment building are connected to one large inverter of 150kW manufactured by SMA. The cladding of the apartment building is connected to a block of three SMA inverters of 5kW each in master slave configuration. Each penthouse roof is connected to a series of four independent Sunmasters of 1800W (on the roof). The SMA inverters are situated



Electrical scheme of the PV system in Nieuw Sloten, Amsterdam

Source: © Energiebedrijf Amsterdam

within the inverter room on the central square in the district. The AC sides of all inverters are connected on the low voltage bus bar leading to the transformer room from where the current is distributed to the district.

The PV system is connected to the public grid at one point. Solar electricity is used within the district. The quality of the electricity matches the requirements regarding decentralized electricity production as defined by the Dutch energy federation Energiened.

The electricity generated is fed into the public grid at low voltage level. The fluctuation in the ratio between the PV system output and the demand in the local grid was considered before the system was installed. The worst case, maximum yield from the PV system and no demand from the district, was expected in the summer when the majority of tenants are on vacation. In that case, the public grid is able to distribute the solar electricity to consumers outside the PV district.

The voltage housekeeping in the area of Nieuw Sloten has been thoroughly analysed in order to find out the relation between solar electricity generation and electricity demand in the district. The conclusion is that the demand in the district is much higher than the PV electricity generated. On a very few occasions, the demand was lower than the PV electricity generation. In that case, solar electricity was distributed to the neighbouring district. There were no distortions in the public grid caused by the PV system. This knowledge was later used while developing the Stad van de Zon (City of the Sun) in Heerhugowaard.

Monitoring

The average energy production of the PV system in Nieuw Sloten was calculated to be in the range of 160–180MWh per year. The actual energy performance, monitored from August 1997 to July 1998, proved to be higher than predicted (76.5 per cent performance ratio rather than the 72.5 per cent performance ratio predicted). The calculations were based on the results of the flash tests of the modules.

The energy monitoring showed that:

- The performance of the east and west oriented PV arrays is significantly (about 20 per cent) lower than for the south arrays. The total electricity generation is therefore lowered by about 4 per cent.
- The mismatch because of the coupling of areas with different orientations to one inverter is about 1 per cent. This corresponds with the computer simulations made during the preparation of the project.
- There was no difference in performance between the Shell and BP modules.
- Combining differently oriented PV arrays with different kinds of modules to one central inverter led to lowering of electricity production by 1 per cent to 5 per cent. These losses are compensated by lower costs of this configuration.
- Energy losses due to high temperature of the PV array are between 3 per cent and 5 per cent.

- Shadowing due to the chimneys in the PV roofs led to energy losses of 3 per cent to 4 per cent.

Maintenance

The maintenance of the PV system in Nieuw Sloten is in the hands of the owner of the system: the energy company NUON, previously EBA. The system is monitored online. In order to ensure the safe operation of the installation and be able to follow it at a distance, three indicators are placed in all switchboards (DC-over voltage protection (varistors), DC-isolation control of the inverters and a smoke alarm). There is one switchboard in the district for each PV array.

The only repairs up to now took place in the first two years of operation:

- The SMA 5000 inverter had to be replaced due to serious malfunctioning. This was covered by the inverter guarantee. Except for a few exchanged fuses, there were no other electrical problems in the PV system up to May 2008.
- There was a leakage problem with the roofs of the houses. The original concept was that the PV modules would form the watertight layer for the roofs. However this proved not to be reliable for shallow roof angles. This problem was solved quite rigorously: all modules were removed in order to place a watertight sheet on the wooden roof construction. After this, the modules were put back in the same way. The costs for this repair were paid equally by the energy company, Shell Solar and Novem.

Lessons learnt

Architecture and urban design

The architects learnt that working with PV is not so difficult if detailed data of the solar building elements are available. But they also learnt that PV has to be taken into account from the very beginning, as the location of PV in the roof or on the façade of the building can conflict with other functions such as ventilation, chimneys, etc., as well as with future functions such as space for windows, dormers, etc.

The urban planners learnt that orientation of streets (though a bit difficult) and height and sloping angles of roofs can still be optimized during the urban planning process, as long as PV is taken into account early enough. In fact in Nieuw Sloten the PV project development and the urban planning processes were integrated a bit late.

The landscape architect, who entered the project with suspicions regarding the visual effects of PV roofs, admitted that the PV district now has an attractive visual appearance.

Construction

The installer of PV roof systems must be skilled in both PV installation and in roofing. The PV company learnt that installing PV in a roof is completely different from realizing a PV system in a field. The skills for this were not developed in time. The PV company also learnt that it was not able to do a turnkey PV roof delivery in the complicated market of real estate development and housing.

It turned out that some of the PV roofs in Nieuw Sloten were not watertight, even under non-extreme weather conditions. This was despite previous laboratory testing of the design. It appeared that the real conditions were more extreme than the laboratory conditions under which a test roof was studied. In reality, there are roof lengths of 8m at a slope of 25°, whereas the test roof measured 2m^2 and under a slope of 45°. In addition, the roof construction consists of two parts, which means that there is a horizontal seam in the middle of the roof; water entered the house through this seam.

Roofs in Nieuw Sloten which have a slope of 36° and a maximum length of 6m stayed watertight, although on these roofs the same construction of the PV roofing was used as on the leaking roofs.

This problem led to the recommendation that watertight layers be installed under PV roofs. This has been applied to all PV roofs built in The Netherlands since then. Publicity around the problem led to greater caution by developers and a perception of risk. It is important to keep in mind that the watertight layer must be of very good quality because people walk across it during the mounting of the modules.

Project management and coordination

The PV project manager learnt that it is crucial that he or she is part of the overall urban development team with sufficient power. On the other hand it also became clear that all other stakeholders had to be sufficiently involved and committed to the PV project. Having a central manager of the PV project who had a complete overview of all agreements helped to prevent misunderstandings and to keep up speed. It also helped prevent problems when members of the project team left the organization.

At various stages in the development of the project there were issues, sometimes only minor details, in which the PV project formed a hurdle for the property developer, the architect or the spatial planner to develop their ideas in the 'usual way'. It was one of the success factors of the project that these kinds of problems were often discussed (and solved) during informal meetings between the project manager of the PV solar project and the 'owner of the problem'.

Ownership

The PV system belongs to the utility Nuon, not to the house owners. This means that there is one system to operate and one body responsible for operation and maintenance rather than hundreds of individual householders each responsible for a small system. This has proved to be a success. Private owners are concerned about taking responsibility for installations they know little about.

Getting the details right

Because PV is a new technology for the construction industry to deal with people will not have experience of how to deal with all the minor issues and special efforts must be made to get the details right. For example:

- Contractually it must be specified how possible technical risks in the form of leakage and/or disruptions in the electrical supply will be dealt with.
- More attention must be paid to training and information of the involved parties with respect to electricity generation from solar energy.
- Since insurance companies in The Netherlands had no special insurance scheme for PV, the insurance construction is rather complex. For future projects the insurance company should be contacted at an early stage.
- Measuring and fuse equipment should be positioned close to the PV strings, in order to avoid long and numerous cables and wiring.

PV is not yet part of standard planning procedures

At one time, the project in Nieuw Sloten was almost brought down because changes in the original design due to the PV were not passed on to the planning authority. In order to avoid similar situations it is a good idea to integrate PV in the standard procedures in the development process of new city areas.

Goodwill is good, commitment is better

The system in Nieuw Sloten was realized based on goodwill of the municipality, the property developer and the residents of the PV houses. This goodwill made it possible for the utility company to realize this project. From the point of view of common interest, it is desirable that the commitment and costs are shared among all the parties involved: government, council, utility company and the house owner.

The Netherlands, Amersfoort, Nieuwland 1MW PV project

Jadranka Cace and Emil ter Horst

Summary

In the Waterkwartier district of the Nieuwland expansion area of the city of Amersfoort, the world's largest complete urban PV project was realized in

1999. The municipality of Amersfoort initiated the project together with the local electricity utility company REMU. The project has been widely quoted and visited as a demonstration of urban-scale PV. However, policies to support renewables in The Netherlands were dropped by the national government after the project was implemented so the experience obtained by developers and architects in the implementation of PV has seldom been called on.

The project consists of over 500 houses, schools and sports facilities with 1.35MWp of PV modules integrated into façades and the roofs, about 12,300m^2 of PV. Solar optimization was taken into account in the urban planning phase with the land being parcelled out to provide as many roof surfaces as possible suitable for the installation of solar panels. All the urban planners, architects and developers involved were required to cooperate in the implementation of the solar power project. An information centre was established in the city district with PV buildings. This centre was a cooperation by the electricity company REMU and the municipality and a coalition of real estate developers active in the district. Studies of consumers' energy awareness and behaviour were carried out.

Introduction

The energy company REMU initiated the project with the objectives of:

- illustrating the impact of using solar power at district level;
- reducing costs by applying solar power on a large scale;
- learning about various forms of ownership and management;
- acquiring experience regarding architectural aspects;
- learning about other aspects connected to the urban scale of the project.

REMU also cooperated with the municipal Energy Company Amsterdam, which was preparing a 250kWp project in the Nieuw Sloten district.

The district was divided into 12 development areas and each developer had its own architect.

Quarter Waterwoningen in Nieuwland

Source: © H. F. Kaan

Only a few of the architects had previous experience with PV. For each subproject, a separate contract was made for turnkey delivery of the PV system.

As one of the goals of the project was to investigate the effects of various forms of ownership and management the solar systems were installed on various different types of houses including single-family houses, apartment buildings, schools and sports halls.

The houses are in private ownership or rented from a housing corporation. The PV solar energy system on the roof can be owned by the energy company or owned by the house owner. The tenants of the houses who have made their roof available for the energy company get, as compensation, 20 per cent of the generated solar electricity (based on calculation) for free. The house owners who have bought the PV solar roof installed on their house, have bought the PV system for 25 per cent of the system costs and get all the solar electricity generated.

REMU later merged into the larger Eneco. The energy company is responsible for maintenance of the systems for a period of ten years. After the summer of 2008, Eneco and the residents made new arrangements for the next ten years.

Project organization

In 1992, when the development of the Waterkwartier district started, the municipality of Amersfoort had ambitious environmental targets. This ambition was communicated to the property developers of the district. In order to facilitate further action, the municipality engaged the environmental research and consulting firm BOOM as environment supervisor. Additionally, the municipality provided a budget of €1.8 million to support achievement of the environmental targets.

The energy company REMU wanted to gain experience with a large-scale application of PV and was especially interested in the effects of a high concentration of PV sources on the public grid. REMU also believed that PV houses, although having a non-standard roof and being more expensive than conventional houses, could be sold on the market. Another reason for REMU to start this project was a commitment to support the development of solar technology. At that time, the Dutch government required the energy companies to develop their own energy and environmental saving programmes. Other energy companies had chosen to focus on wind energy or energy production from waste. REMU focused on solar energy. The costs of the 1MW project were estimated to be €8.6 million. REMU was the main investor in the project and carried full responsibility for the project.

For this project, REMU applied for and received a subsidy under the EU THERMIE programme and cooperated with the Italian utility ENEL, which had experience with large-scale solar projects.

Novem (now SenterNovem, the Dutch renewable energy agency in the Ministry of Economic Affairs) also supported the project. The main goal for Novem was to learn about technical and social implications, possible barriers, problems and solutions in urban planning, architecture and grid integration for such a large-scale application of solar systems.

Urban planning and architectural integration

The environmental supervisor, the consultancy firm BOOM, was responsible for creating the ground conditions for the implementation of solar energy on such a large scale. The most significant contribution was a change in the spatial orientation of the houses from that which had already been defined in the Urban Plan. Originally, the houses were to be oriented in an east–west direction, which would limit the solar energy yield. After intervention from BOOM the urban plan of the Waterkwartier was changed to have more houses oriented in the north–south direction.

BOOM also developed a methodology that structured the effort of achieving the environmental and sustainability goals defined by the municipality. The method enabled the involved parties, who had no experience with solar energy, to understand the necessity of specific architectural solutions.

Taking the 'solar factor' into account from an early stage allowed the urban development of the district to be structured in line with a target of 20m^2 of PV per household. The land was parcelled out in such a way as to render as many roof surfaces as possible suitable for the installation of solar panels, with a minimum of 500 to reach the level of 1MWp.

The requirements regarding the PV houses were developed by REMU in cooperation with the consultancy firm Ecofys. The idea was to use well-proven concepts for the integration of solar modules in the buildings. Guidelines were developed regarding orientation, inclination and ventilation. The resulting architectural designs show a great variety of PV buildings, oriented between southeast and southwest, with PV integrated in a variety of ways.

On some buildings solar modules were used instead of roofing tiles, on others they were used for cladding or as shading devices. The tilt angles for the solar modules varied between 20° and 90°. Where PV modules were mounted above

Jersey Quarter in Nieuwland

Source: © H. F. Kaan

Prefab PV roofs in Nieuwland

Source: © H. F. Kaan

roofs standard roof construction was used and the watertightness of the PV roofs was guaranteed by a watertight layer under the solar modules.

The project includes over 550 houses, an elementary school, a kindergarten and a sports complex. Also, there is one application with solar portals connecting two rows of single-family houses.

The PV arrays

The solar modules used in Nieuwland were supplied by Shell Solar, BP Solarex and RBB.

School houses with PV modules each replacing four standard roofing tiles

Source: © H. F. Kaan

For special purposes, like the sunshade systems on the apartment buildings, the Shadovoltaics system was used. Translucent modules for the solar portals and the sports complex were supplied by Pilkington Solar.

The modules were supplied in batches, according to the results of the manufacturer's flash tests. Modules with similar performance in the flash tests were grouped together when forming the strings. The system price was based on the flash-test power. The average turnkey price was €6.9/Wp.

Most solar modules were integrated in a simple aluminium profile construction. In the horizontal direction an asymmetric H-profile with a water gutter on the far side was used. This profile was fastened on one long side of the module. The following module was pushed into the lower part of the H-profile. On this side, there was an expansion gap for the panels, in order to allow for any movement in the roof construction. In the vertical direction, modules were fastened within the two parts of a standard profile.

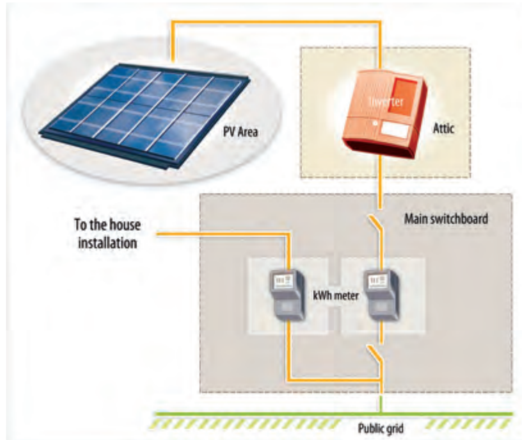
On ten 'school houses' and 23 other terraced houses the RBB PV700 mounting system was used in combination with the RBB modules. These modules have the same dimensions as four standard roofing tiles together.

Electric design and grid connection

The Nieuwland project was designed on the basis of each house having an individual PV system. The sizes of individual systems vary between 0.8kWp and 4.4kWp. Each house has its own inverter and a feed-in kWh-meter. The main suppliers of inverters were Mastervolt and ASP.

The illustration below illustrates the electric configuration of individual systems. The inverters are normally placed in the attic. There are two separate kWh-meters, one for PV generation and one for electricity consumption.

The electricity generated by the solar systems is supplied into the public grid. During the preparation of the project, REMU analysed the potential capacity problems in the PV district. In order to avoid potential capacity problems,



Electric design of individual PV systems

Source: © Horisun/Rencom

especially during the summer months when most of the tenants are on vacation, REMU provided some adaptations in the local public grid. These were: heavier distribution cables and transformers with enhanced power (one 630 kilovolt-Amp (kVA) and two 400kVA instead of one 400kVA and two 250kVA) in the low voltage grid.

Up to 2008, no serious problems have occurred with regard to the grid connection.

Maintenance

REMU (now Eneco) has been fully responsible for the maintenance of the PV systems for a period of ten years.

Initially an experimental performance guarantee and maintenance system was set up. For the first two or three years this worked well, with a consultancy company responsible for monitoring the performance of all PV houses. During the first years of operation, there were many problems with water leakages through roofs. Also, some inverters malfunctioned. All of the problems that occurred in this period were solved.

However, after some years this guarantee and maintenance system did not work any more.

There were too many possible causes for lower performance or malfunctioning, such as shading by trees or leakage of roofs. Also some of the companies who had provided equipment did not exist any more and it would have been difficult to claim under the guarantees initially provided.

In general the maintenance system is no longer ensuring good performance of all the PV systems. The energy company Eneco is now responsible for most of the maintenance. However when REMU merged into Eneco, the company got less involved in PV. Eneco logged the problems but only performed maintenance activities once a year. Maintenance had to be done both regarding the roof integration, where there were a few problems, and regarding the technical quality and performance of the PV. Between 2003 and 2007 maintenance was done at a minimum level, and the performance of the PV systems went down significantly.

Lessons learnt

Technical monitoring was provided by the consultancy firm Ecofys and by the University of Utrecht. The experiences of the participants in the project were studied and reported by the University of Rotterdam. Within the PV UP-SCALE project, there were interviews with the architects and the tenants of Nieuwland. In this chapter the lessons learnt are reviewed.

Architectural and constructional

The general impression is that Nieuwland is a very successful project with attractive and varied PV architecture.

The architects have drawn the following conclusions from this project:

- The application of solar energy puts pressure on the spatial design of the district. It means that the streets must be oriented from east to west, except in the case of flat-roofed buildings.
- PV roofing puts significant requirements on the architectural design of the PV houses. The architect involved must take all these requirements into consideration when designing PV houses.
- A simple replacement of roofing tiles by PV modules is not possible. Extra measures are necessary (watertight layer or watertight profiles, adapted roofing construction).
- The introduction of a watertight layer has consequences for the logistics of the building process. After the layer was put in place, building workers walked across the layer, damaging it in many places.
- Each new project means that (some) new parties will be involved. It is very likely that these parties will have no knowledge and/or no experience with PV. It is important to inform these people about PV, especially about the aspects important for their part of the project.
- Some of the project developers wanted a traditional appearance for the PV houses. The architects found it very difficult to combine the high-tech appearance of solar modules with traditional housing.
- Architects seek more colours, varied dimensions and structures for solar modules. Also matching accessories are needed such as fastening constructions and edge and corner pieces. They expect that more choice will stimulate creativity and increase the number of applications.
- There was too much pressure to realize the target PV capacity and no space for other measures that were potentially more financially attractive and environmentally effective.

The major lessons learnt were, firstly, that there was no problem integrating PV in the urban process. Even at a rather late stage the urban plan could be modified, though of course it is better to take the solar factor into account from the very beginning. Secondly, architects had no problem in designing and working with PV. The only important condition was that sufficient information was available to them. In this project this was achieved by a helpdesk the architects and developers could call during the housing development.

The PV company Shell Solar learnt especially in this project not to embrace the idea of combining the necessary watertightness of a house roof with the integration of a PV solar roof. As in the previous Nieuw Sloten project in Amsterdam, too many problems arose with water leakage.

Operation and maintenance

Except for the malfunctioning of some inverters at the very beginning of the project and cable connection failures, no major electrical problems have occurred. In particular there was no negative impact on the quality of the grid.

The major lessons for Eneco concern the ownership and maintenance of so many dispersed and varied PV systems. This was much more difficult than initially expected. Though a final conclusion cannot be drawn here, it is apparent that these problems must be solved, as sub-optimal or unclear ownership and poor maintenance have caused major problems during the lifetime of the project.

The Nieuwland 1MW PV project was the first of its kind in the world: never before had a PV project been implemented on such a scale. From an architectural point of view, the project was a big success with a variety of system designs and integration methods demonstrated. However, the after-care of the PV systems has been more time-consuming than anticipated and it looks like the growing pains are not over yet.

It turns out that yearly monitoring and inspection rounds (the current practice for this project) have not been sufficient to keep system outages down to an acceptable level. Between 2003 and 2007 maintenance was done at a minimum level, and performance went down.

Tenants

The tenants were asked to summarize the strengths and weaknesses of their PV houses. They named the following strengths: lower electricity costs, higher value of the house, contribution to green energy generation and environmental savings. On the other side, they named the following weaknesses:

- Long period at the beginning of the project where repairs were needed (leakages and inverter problems).
- Uncertainties regarding the costs and responsibilities in the long term. If Eneco offers to take over the PV system, what will be my responsibilities? What are the maintenance costs and what are the benefits?
- There are no possibilities for roof extensions on PV roofs.
- On some roofs there is no clear border in ownership between the neighbours and/or between the house owner and Eneco.
- Some monitoring units are not working. The tenants are not sure if that also means that their system is not working. They did not get a handbook for the monitoring system. Also, they could not ask Eneco about these issues since there was no contact person available at Eneco.

Communication

The original tenants had a basic understanding of PV due to excellent communication by REMU and the municipality between 1997 and 2000. However subsequent owners often were not aware of existing contracts and not well informed about PV. Now, ten years after the opening of this impressive urban PV project, breakdowns or poor performance of the PV systems are often not noticed, except for roof leakages.

Eneco offered the inhabitants tools to check the performance of their PV system, either through a display in their homes (a data logger) or through an internet service which can keep track of the performance of their system. So now most PV houses do have a monitoring system. However, this has not resulted in any significant error reporting by inhabitants. This may be partly due to 'lack of ownership' and not feeling responsible (they did not make the investment) and lack of substantial financial repercussion (no high feed-in tariffs). However, simple problems like not knowing who to call or simply not being called back when they did make enquiries were in fact the main reasons reported.

In the coming year it is expected that Eneco will try to interest the tenants in a continuation of the project, when they will offer to improve the maintenance and service. It is unclear if they will be successful as confidence by tenants in Eneco might be too low.

Conclusions

Nieuwland has been a very successful demonstration of urban-scale photovoltaics. The project was well set up and managed by a team committed to its success. Integration into the urban planning process and architectural design was successful. The systems continue to deliver electricity to the grid without causing any problems for the grid. However, problems have accumulated over time and now the future of this project is unclear, with occupiers unhappy with the service they have been receiving.

After the project was started government support for PV dropped away in The Netherlands and REMU was taken over by Eneco who did not have the same interest in the project. Operation and maintenance turned out to be more difficult and expensive than predicted, partly due to the ground-breaking nature of this project, the numerous small systems and the variety of designs and integration methods used. Communication between the energy company and the building occupiers reduced, with occupants reporting that there was no contact person available at the company. Improving communication, monitoring and maintenance will be vital to the future of this world-famous project.

The Netherlands, HAL location 'City of the Sun'

Marcel Elswijk, Henk Kaan and Lucas Bleijendaal

Summary

An ambitious project is under way to install a total of 5MWp of PV in new urban districts currently being built in the location Heerhugowaard, Alkmaar and Langedijk region of The Netherlands, the so-called HAL location, approximately 40km north of Amsterdam.

The City of the Sun (Stad van de Zon), where 3.6MWp of PV are being installed, is one part of this HAL location that, after completion, will have 5MWp of PV. It is a new town of about 2500 dwellings in the municipality of Heerhugowaard. This is one of the largest urban-scale PV projects in the world. It is inspirational but is also proving very challenging to complete. Projects on such a large scale take such a long time to be implemented; they can be unwieldy to steer and vulnerable to changes in government policy. Despite changes in government policy and the loss of expected funding the project continues. The continuation of the project is partly down to the involvement of all stakeholders in the HAL consultative body: municipalities, province, energy supplier, the Energy Research Centre of The Netherlands and consultants.

Introduction

The dense population of The Netherlands means that the design and construction of complete new urban districts is a standard part of urban development. The design of new urban areas allows for careful spatial planning. This spatial planning is a complicated process that is initiated by the national government. The government assigns areas for future urban development in White Papers. The provinces, in this case the province of North Holland, have a role in coordination and further development of assigned urban areas.

The area between the North Holland municipalities of Heerhugowaard, Alkmaar and Langedijk, abbreviated HAL lokatie (HAL location), was identified in one of the White Papers as a future urban development for housing.

Both the province and the three municipalities involved in the HAL location have high ambitions with regard to quality of building, quality of living, and above all energy and CO_2 reductions.

Heerhugowaard, City of the Sun

Source: © Gemeente Heerhugowaard, Harry Donker

When the development of the HAL location started early in the 1990s, the application of PV was strongly supported by a national research programme on solar energy, financed by the Ministry of Economic Affairs and coordinated by the national energy agency Novem. With strong support for PV available, a low energy housing area with a focus on PV, combined with low energy demand, passive solar energy and solar thermal energy, was an obvious choice. In addition, the project developer involved, who owned a large part of the HAL location area, also had similar ambitions as far as quality, energy and reduction of CO_2 were concerned.

The PV installations are split between the three municipalities involved with 0.4MWp in Langedijk (largely completed in 2004), 1MWp in Alkmaar (completed in 2003) and 3.6MWp in Heerhugowaard City of the Sun (completed in 2009).

Development of the solar city

1989: Solar House 'Zonnehuis' in Castricum

The idea of making a solar city first arose in 1989, when the first off-grid solar powered house in The Netherlands was built in the city of Castricum, about 20km from Heerhugowaard. The owner of the house was working with the province of North Holland in the field of renewable energy. The province wanted to stimulate replication of the project. Heerhugowaard was one of the few municipalities with an energy coordinator whose primary task was to improve the energy efficiency of municipal buildings, and who also had close contact with the provincial renewable energy department. So, informal contacts were established in order to discuss the possibilities for a solar project on a larger scale.

1991: Scaling up to ten terraced houses

The first multi-house PV project in The Netherlands was built in Heerhugowaard. The main motivation was the need to decrease the living costs in social rental houses. The municipal department of housing in Heerhugowaard had set a goal of decreasing the living costs for tenants. Energy was an important component of total living costs at the time, so reduction of energy consumption contributed substantially to reduction of living costs as well as providing environmental benefits. Furthermore, a local project developer and building contractor wished to develop low energy houses as much as possible. In cooperation with the project developer, the municipality, the provincial energy department and the future tenants, ten terraced solar houses were designed and built for the social rental sector (Butterhuizen project).

Community involvement was achieved by the involvement of the future tenants in the design process. They were selected as being willing to live in a solar powered house. The project was officially commissioned in December 1991.

Butterhuizen project realized in 1992 in Heerhugowaard consisted of ten houses with a total output of 24kWp

Source: © H. F. Kaan

1991–1993: Cooperation of Heerhugowaard, Alkmaar and Langedijk in developing the HAL location

In 1992, upon the request of the province, the municipalities of Heerhugowaard, Alkmaar and Langedijk started cooperation in the development of the HAL location. In an early meeting concerning the way the three independent municipalities could cooperate, the internationally known planner Ashok Bhalotra, who was invited by the city of Heerhugowaard, introduced sketches for a city largely based on passive solar techniques (1993). Based on these sketches a structural sketch was made for the HAL location (in the Dutch planning procedure the structural sketch is the first visualization of the points of departure). The Stad van de Zon (City of the Sun; the name was introduced by Bhalotra) saw its first light.

1997: Schedule of requirements for the City of the Sun

The ideas for the solar city were further developed in 1997, when the schedule of requirements for the area which is now Stad van de Zon was defined. Environmental aspects had a high priority in this schedule of requirements. With the help of Cees Duijvestein, professor of Environmental Urban Design at Delft University of Technology, a plan for the environmental quality of the area was prepared. Furthermore, national policy was becoming more and more focused on reduction of CO_2 emissions and the government was providing financial support for initiatives in this field.

A study on how to define the optimal energy infrastructure, subsidized by the Dutch energy agency Novem, led to the idea to make a fully CO_2 neutral quarter, where the energy demand was much reduced (the energy performance of the buildings had to be twice as good as required by the Building Code) while energy was generated by PV and, if necessary, a wind turbine.

The schedule of requirements was prepared by about 30 parties involved in the process of urban planning. It was important to have the future partners involved in the process in a very early stage, as their involvement and participation in the design and development process would reduce future objections. The high level of ambition, expressed in the name of the project, contributed to the enthusiasm of politicians, the involved parties and the citizens. During the political decision-making process there was hardly any opposition. Two aldermen had political responsibility for the project with support from a steering committee including managers of the departments involved and the project developer (who was also the owner of the land where Stad van de Zon was going to be built).

1998: PV in urban design: development and financing

As soon as the detailed urban design and architectural aspects were in sight, a PV workshop was organized for architects and PV system manufacturers, resulting in draft designs and a book. Financial models and alternatives were developed, resulting in the conclusion that subsidies were required in order to get the project realized. Subsidies were obtained from the European Commission (under the SunCities project), the utility Nuon (a public body at the time), the province of North Holland and the Dutch government.

Final realization of the City of the Sun

The 5MW project involves the municipalities of Alkmaar (1MW), Langedijk (400kW) and Heerhugowaard (3.6MW). In each municipal area the developments are split into a number of phases that have been developed at different dates. In all projects and in all stages the province of North Holland and the utility Nuon were involved.

Steady progress has been made in finishing the project and the Heerhugowaard part of the project was completed at the end of 2008. The Alkmaar part of the project was finished in 2003. The decision about financing the last phase of the Langedijk part of the project was only taken in March 2008; consequently this part of the project has not finished yet.

So far, five project developers have been involved in the 5MWp project and have gained experience with photovoltaic systems.

As well as being the urban developer of the Solar City, Ashok Bhalotra from Kuiper Compagnons is also the architectural supervisor in the HAL area. In addition, nine architects' offices have been involved in the 5MWp project.

In recent years the 5MWp project received numerous national awards for the level of innovation of the project and the example it set other municipalities.

Heerhugowaard, City of the Sun

Source: © Gemeente Heerhugowaard

Buildings with PV in the City of the Sun

Source: © Gemeente Heerhugowaard

The information centre set up to present the City of the Sun by the municipality of Heerhugowaard

Source: © Hespul

Overview of problems, barriers and solutions

Earlier experiences in Amersfoort-Nieuwland, another urban area in The Netherlands where 1MW of building-integrated PV was installed in 1996, were very useful for the development of the City of the Sun. Urban designs for both areas were made by the same architect (Bhalotra). However, compared to the Nieuwland project, there are a number of differences. In Nieuwland and in Langedijk – the first phase of Stad van de Zon – the utilities are the owners of the PV systems. However, in Alkmaar and Heerhugowaard the owner-occupiers of the houses are the owners of the PV systems. Initially, the occupiers were not very interested, but back-counting electricity meters increased their interest. In Amersfoort-Nieuwland the utility (REMU) was the leading party. In the Heerhugowaard project the municipality had the lead. Initially the utility (Nuon) was rather reluctant, although it became more and more enthusiastic and cooperative during the process.

From a purely technical point of view, there were no problems in the design and realization of the project.

Looking back to the process several things can be noticed:

- The initiative was highly dependent on the enthusiasm of persons working with public bodies and able to convince political decision-makers.
- As PV cannot compete with other forms of energy generation (both conventional and renewable) subsidy is a prerequisite. As the policy of the Dutch government is very unreliable as far as subsidies for renewable energy are concerned, the government was the uncertain factor in the process. In addition bureaucratic procedures caused numerous problems.
- The project developer, although very cooperative and wishing for low energy buildings, was very demanding. The developer wanted to avoid future claims caused by uncertain and unproven construction methods. In some of the previous large-scale Dutch PV projects, the PV modules were used as the waterproof layer in the roof construction, causing problems of leakage and condensation. In Heerhugowaard, the project developer insisted on a watertight construction, fully separated from the PV system. This requirement raised the price of the project. Furthermore, the project developer had to guarantee the functioning of the PV systems to the future owners. The EU, as subsidizer of the project, requires six years of guarantee as a minimum. Before purchasing the house, the owner had to sign a contract to maintain the PV system for at least ten years. This was a product guarantee, not a power guarantee.
- Many of the architects had no experience with PV, and some had no knowledge of PV at all. A few of the architects went on designing other PV projects after having designed a housing complex for the City of the Sun. It should be noted, however, that shortly after the design process of the City of the Sun, the Dutch government stopped financial

and political support of PV. Consequently, architects were seldom asked to design a building with integrated PV again.

- One of the barriers in the process was lack of knowledge of PV by the urban designers. The total concept of the City of the Sun was created by Ashok Bhalotra. Urban designers then produced the more detailed designs. Their lack of knowledge about PV resulted several times in designs that were unsuitable for PV (orientation, structure and shading). Furthermore, some architects considered PV as a design limitation rather than a challenge. Consequently, PV was not always high on the agenda of the design team. It was the task of the energy coordinator of Heerhugowaard to keep the design team focused on the targets with regard to PV.
- The largest challenge in the process was to get the project financed. The major concern was the instability of the Dutch subsidy policy. There are three major subsidizing bodies: the Dutch government, the province of North Holland and the European Commission. When the project started, the Dutch government provided a subsidy to the project within the framework of the National Research programme for Solar Energy. This subsidy scheme stopped and was replaced by another subsidy scheme, which was subsidizing the buyer of the PV system, rather than the project as a whole. This was not a firm project foundation as the new scheme could be stopped by the Dutch government, which eventually happened. The European Commission, who contributed substantially to the financing of the project, required a more solid basis for the financing of the project. In response the energy company Nuon, the province of North Holland and the municipality of Heerhugowaard founded a guarantee fund, guaranteeing €3.50/Wp for a total of 1.5MWp, which was considered by the Commission as sufficiently solid.
- The strict requirements of the European Commission with regard to the time frame and planning of the project form another concern. Initially, the Commission required four years as a maximum for the project realization, which proved to be impossible for a dynamic process like the development of a new town, with numerous parties and interests. Eventually a two-year extension was allowed by the Commission, but it is still difficult to have the project finished within this new scheme.
- Contrary to expectations when the project started, the price of PV in The Netherlands has risen tremendously, due to huge demand in Germany. The parties involved in the City of the Sun expected that the fact that the City of the Sun requires 3.4MW of PV would attract suppliers and help to reduce the price. According to the project leader of City of the Sun this project has had little influence on the price of PV. In his opinion attention became focused on innovative financing during the project, which distracted from technical inventiveness.
- All parties that had anything to do with the 5MW project were represented in the HAL consultative body: municipalities, province, energy supplier, the Energy Research Centre of The Netherlands, consultants, etc. The province took care of continuity in the project; the requirements of the EU could be used to speed up decisions. All parties in the financial constructions had a function in stimulating each other. All parties had their own reason to find a solution for the problems arising, and nobody dared to step out of the consultative body. Thanks to the complexity of the project, the project became a success.

Spain, Catalonia, Barcelona

Estefanía Caamaño-Martín

Summary

Barcelona City Council has been pioneering municipal actions in support of energy sustainability in Spain since 1998 when a political decision was made to promote energy sustainability and the use of renewable

energies. In 2000, the first integration of PV in buildings was realized on a Barcelona City Council building, and in 2002 a Plan for Energy Improvement was developed and a new Energy Agency created. These actions have led to the integration of PV on highly visible public buildings across all city districts. The knowledge gained by the professionals involved and dissemination of the results have increased acceptance of PV technology in Barcelona.

Introduction

Barcelona is the capital and most populous city of Catalonia and the second largest city in Spain. A major economic centre with one of Europe's principal Mediterranean ports, Barcelona is today an important cultural centre and a major tourist destination with a rich cultural heritage, particularly renowned for its architecture.

Barcelona City Council is a pioneer municipality supporting energy sustainability. In 1998, a political decision was made to promote energy sustainability through the use, amongst others, of renewable energies. It was the first European city to develop a Solar Thermal Ordinance (1999) making it compulsory to use solar energy to supply at least 60 per cent of hot water demand in all new buildings, renovated buildings or buildings changing their use. In 2000, the first integration of PV in buildings was realized (Barcelona City Council building); since then an increasing number of projects have been carried out, both in public and private buildings.

PV in Barcelona City Council, Novissim building

Source: © Barcelona Energy Agency

In order to meet Barcelona City Council's international environmental protection commitments a Plan for Energy Improvement 2002–2010 (Plan de Mejora Energética de Barcelona, PMEB), was developed by Barcelona City Council in 2002. Specific goals of the plan are to increase the use of renewable energy (especially solar energy), to reduce the use of non-renewable energy sources and to lower the emissions produced by energy consumption. The PMEB foresees the realization of 55 projects for local action, where information and citizens' participation are essential factors to achieve a change in the present energy consumption patterns.

In 2002 a new energy agency was created. The Barcelona Energy Agency (Agència d'Energia de Barcelona) is a public consortium comprising the Barcelona City Council, public institutions related to energy and the environment, and universities. It has the following objectives:

- to guarantee the application of the PMEB;
- to foster energy saving and energy efficiency;
- to promote the use of local renewable energy sources;
- to continue to improve the quality of energy services.

The Agency has assessed the potential of different renewable energy technologies to provide renewable energy in the city. The assessment considered solutions that were technically feasible, economically cost-effective, environmentally acceptable and socially desirable. The results indicated that the potential resources available were:

- 7–14MW of PV technology;
- 6–12MW of wind;
- 2–5MW of biomass;
- 0.2–0.5MW of hydroelectric.

PV in Masia de Can Cadena, a traditional Catalan house used for environmental education and urban orchards

Source: © Barcelona Energy Agency

PV Pergola at the Forum of Cultures 2004

Source: © Isofoton S.A./Barcelona Energy Agency

The maximum PV potential refers to the roof surfaces of existing (in year 2000) commercial, services, office and public buildings, together with new buildings expected by 2010. For all these buildings an electricity coverage of 10–12 per cent from PV technology was proposed within the PMEB (see section 'The Solar Photovoltaic Ordinance of Barcelona'), so the figures can be considered highly realistic. This analysis has found PV to be the technology with the highest potential in a city like Barcelona, characterized by a compact urban layout and a good solar resource (1500kWh/m^2 annually on a horizontal surface).

Several strategies are being developed by the Barcelona City Council to promote the integration of PV at urban scale. These are described below.

Demonstration PV projects in municipal buildings

In 2002 the Barcelona Energy Agency (AEB) was entrusted by the Barcelona City Council to integrate PV in highly visible public buildings. Three different objectives were established:

- Energy objective: to support the use of renewable resources.
- Educational objective: to bring knowledge of renewables to the users of highly visible public buildings (such as social centres, schools, libraries, etc.), which are spread throughout the city and have different technical and architectural possibilities.
- Stimulating objective: through the promotion of PV by the municipal administration, to develop projects that can be used as a model for the private sector, thus creating confidence and stimulating the market.

As a first step, meetings were held with the technical services departments of the municipal districts, in order to explain the initiative and ask for suggestions for buildings suitable for PV integration. (Note: the technical services of the City Council are decentralized in the ten municipal districts). Once the list of initially selected buildings was received by the AEB, the basic projects for the technically suitable buildings were designed and sent to the districts' technical services for approval. Existing building structures were assessed in all cases for support of the PV modules, although in many cases new structures were necessary.

The execution of the tenders for the different projects was approved, according to the type of PV system and the state of the buildings (finished, under construction or renovation). The districts' technical services participated in the assessment of proposals received and awarding of the finally selected contractors. The construction of the PV systems was carried out in collaboration with the districts' technical services. Finally, public presentation of the projects occurred in collaboration with the municipal districts.

Financing of the PV installations was shared between the AEB and the municipal districts, the districts covering the cost of the supporting structure in the case of new buildings and the AEB the remaining costs. All PV projects include an automated monitoring system that supervises general operation variables and sends an alarm (via Information and Communication Technologies) if a malfunction occurs to the General Services of Barcelona City Council, responsible for the PV plants' monitoring and maintenance. Real-time monitoring data can also be publicly accessed via the internet.

PV in Casal de Gent Gran Navas, a social centre for elderly people

Source: © Barcelona Energy Agency

By the end of 2008, 39 projects had been carried out in public buildings across all city districts, with a total installed PV power of 1.65MWp:

- Barcelona City Council and districts buildings: five projects, 99kWp;
- social and cultural centres: ten projects, 106kWp;
- primary and secondary schools: 12 projects, 90kWp;
- public libraries: six projects, 65kWp;
- pergolas in public areas: three projects, 1198kWp;
- others (parks, markets, urban waste disposal plant): three projects, 90kWp

In the second implementation phase of the PV development strategy for municipal buildings (2008–2012), new criteria will be taken into account for the selection of proposals, including:

- Energy audits: to what extent PV can provide additional benefits in terms of the buildings' energy performance.
- Innovative financing mechanisms, for example, private investors that could finance and manage PV systems installed on public buildings.
- Intelligent electricity consumption, demand-side management within the buildings, etc.

Economic measures

All PV installations can benefit from the Spanish feed-in tariffs which in 2007 were €0.4404/kWh for installations up to 100kW, and

Interview with Cristina Castells Guia

Photovoltaics offer great integration possibilities in buildings and are therefore more attractive than other renewable technologies (e.g. solar thermal). However, large-scale integration of PV in cities with a compact urban development structure like Barcelona is a difficult task and requires a big effort to systematize building integration. It should be also taken into account that PV technology must coexist with other renewable technologies in buildings such as solar thermal, which in some cases (e.g. apartment blocks) can be difficult due to available space limitations. In this sense, it is important to identify a realistic potential for PV technology in urban areas.

For PV to be systematically employed in cities, the following aspects should be improved:

- PV technology should increase in efficiency considerably and continue developing (as has been the case in recent years) a wide diversity of options for architectural integration in buildings and other urban sites.
- Although PV is increasingly known about by architects, it is still very little known by society in general.
- PV costs should decrease significantly, although the increasing costs of electricity can bring forward the cost-effectiveness threshold and therefore help to remove the perception of high cost that is nowadays associated with PV.
- Finally, simple administrative procedures should exist to connect PV installations to the grid, as well as management and maintenance procedures comparable to those existing for other energy technologies used in buildings (for example, conventional heating systems).
- The role that can be played by local energy services companies is also important. They should have the capability to carry out the design, commissioning, management and maintenance of high quality PV installations. At present there are still very few of these companies, but this is a promising sector.

Cristina Castells Guiu is Director of the Barcelona Energy Agency and Director of Energy Services and Environmental Quality in the Environmental Department of Barcelona City Council

Source: © Barcelona Energy Agency

€0.4175/kWh for bigger installations (up to 10MW). Besides these incentives, the Institute of Urban Landscape and Quality of Life (Institut Municipal del Paisatge Urbá) provides subsidies of up to 25 per cent of the installation costs for private buildings.

The Solar Photovoltaic Ordinance of Barcelona

Since 2006, all new buildings and renovated buildings over 1000m^2 in Spain must comply with a new regulation, called the Technical Building Code, the aim of which is to improve safety and habitability by means of a rational use of energy (energy demand limits), improvements of thermal and lighting systems efficiency, and the use of active solar technologies (solar thermal and photovoltaics). PV technology is compulsory in the following types of buildings if they are over the minimum application limit:

- commercial buildings: large supermarkets, 5000m^2 surface; multi-stores, 3000m^2 surface; big stores: 10,000m^2 surface;
- show grounds (for trade fairs): 10,000m^2;
- office buildings: 4000m^2 surface;
- hotels and guesthouses: 100 beds;
- hospitals and clinics: 100 beds.

Within the European project Comprehensive Energy Planning in European Cities, the Barcelona Energy Agency and Barcelona Regional carried out in 2003–2004 a study to promote PV in buildings, with the aim of complementing the requirements stated by the Technical Building Code. First of all a detailed assessment of building integration possibilities and the legal framework for PV in Spain was conducted, from which it was concluded that PV installations in the range 40–120kW achieved the required profitability conditions (these included: internal rate of return higher than the market interest rate and payback time of investments shorter than the PV system's lifetime). After a series of meetings and contacts with the key stakeholders of the PV and building sectors (complemented with several studies on legal and administrative issues in order to identify the right framework), a Solar PV Ordinance for the Municipality of Barcelona was developed, with the aim of increasing PV penetration at the urban scale. It has specific energy targets for the following building types:

- Commercial and tertiary (services) buildings (new or renovated) with a minimum roof surface of 3500m^2: the objective is to produce 10 per cent of electricity consumption with PV.
- Office buildings (new or renovated) with a minimum surface of 1500m^2: the objective is to produce 12 per cent of electricity consumption with PV.

In all cases a minimum of 7Wp/m^2 of PV power must be installed per square metre of constructed surface. Special emphasis is placed on architectural integration, quality of the projects and simplification of the administrative procedures necessary for compliance with the Ordinance and other legal requirements.

It is expected that the Solar Photovoltaic Ordinance will come into effect in 2009. Wide acceptance between municipal, economic, industrial and social stakeholders has been guaranteed through permanent consultations and discussions with the 'Solar Board', created in 2003 after the initiative of the Barcelona City Council to debate and revise the existing Solar Thermal Ordinance. This Board is a public–private partnership with representatives of the local government (Barcelona Energy Agency, Barcelona City Council), regional government (Directorate General for Energy and Mining of Autonomous Government of Catalonia), several public companies (Municipal Housing Council, Institute of Urban Landscape and Quality of Life, Catalan Energy Institute), Association of Developers and Construction companies of Barcelona, several professional associations (architects, engineers, installers, renewable energies industry, buildings administrators), power utilities and the Organization of Consumers and Users representing citizens.

Summary of problems, barriers, solutions and recommendations

Increasing knowledge and acceptance of building-integrated PV solutions

At the beginning of the PV development strategy for public buildings (2003), PV technology was unknown by the majority of the staff in the municipal districts' technical services, and some prejudice against this technology could be noticed amongst architects. For example, PV pergolas with a minimum tilt angle of 5° (recommended for the PV modules to be cleaned by rain water) were not accepted for aesthetic reasons.

Close collaboration between the districts' technical services and the Barcelona Energy Agency was found to be essential to increase knowledge and acceptance. Besides regular meetings, visits to PV installations were organized, so that the district's technical services could see for themselves the aesthetics of PV modules in different integration solutions (for the example mentioned above, no substantial difference exists between horizontal and 5° tilted surfaces). Not all districts were equally enthusiastic about PV at the beginning, but the positive attitude shown by some of them proved to be very motivating for others.

Public presentation of a PV installation in a municipal building

Source: © Barcelona Energy Agency

A positive result of this collaboration is the fact that, nowadays, for many public buildings (new and renovated) the districts' technical services are already designing structures that can easily integrate PV modules in the future. PV technology is also being considered for buildings that will be the object of Municipal Plans in the 2008–2012 period. Technical assistance by the Barcelona Energy Agency experts is also being continued.

Disseminating existing information about building-integrated PV solutions was also very important in increasing acceptance of PV technology. In Barcelona a growing interest has been experienced amongst architects from the public and private sectors since the first PV projects were developed, as this professional group has become increasingly aware of integration solutions being used worldwide.

Maintenance of PV systems in public buildings

Maintenance of energy installations in public buildings is done by the general services departments at the district level. The existing work load of these services, together with the special characteristics of PV installations compared to conventional electrical ones (they are noiseless and feed electricity to the grid independently from the building's electrical installation, so that malfunctions are not always easily identified) has not yet allowed the creation of a successful model for maintenance.

For solar thermal systems (a more developed market than PV in Barcelona), the Barcelona City Council is nowadays working to introduce energy services companies for management and maintenance activities. These companies, which could be of public-private ownership, could also provide other services such as project finance, energy consultancy and the development of guidelines and regulations leading to a sustainable market of renewable energy projects, including photovoltaics.

Sweden, Malmö

Anna Cornander

Summary

Since 2001 the city of Malmö has taken a number of concrete measures in order to reduce CO_2 emissions by 25 per cent in 2012 compared to the level in 1990. The municipality has been involved in several projects related to the energy, transport and building sectors. Malmö has installed 15 PV plants on official buildings including schools, a museum and the hospital. The PV plants are installed on existing buildings and have a total area of 3400m^2 and a peak power of 500kW. Malmö is now the city with the largest amount of PV in Sweden and work has been undertaken to raise awareness, experience and professional knowledge of PV in the city and in the rest of Sweden.

Introduction

Malmö is a municipality of 280,000 inhabitants located in southern Sweden. The city of Malmö is the third largest city in the country. It has developed from a garrison town in the late Middle Ages, into a shipping and transportation town, into an industrial city and today into an expansive big city with higher education. Even today some of the blocks are still characterized by the Middle Ages appearance of the city. Malmö has many parks and other recreational areas around the canals, beaches and harbour.

The city of Malmö has a target to reduce CO_2 emissions by 25 per cent as an average for the period 2008–2012, compared to the level in 1990. To achieve this goal, a number of larger measures have been taken in the energy, transport and building sectors in recent years.

The creation of the district of Western Harbour is based on a fundamentally ecological approach to planning, building and construction. The aim is for the district to be an internationally leading example of environmental adaptation of a densely built urban setting. It will also be a driving force in Malmö's development towards environmental sustainability. The district is provided exclusively with locally produced energy from renewable sources. Sun, wind and water are the basis for energy production together with biogas produced from organic waste from the district in biogas digesters. Buildings are designed to have a low energy demand and the area is planned to minimize future transport needs and car dependency. Cycle traffic is the most important element in the area's transport system. The district is built with the aim of containing a diverse range of natural life using plant beds, foliage on walls, green roofs, water surfaces in ponds, and large trees and bushes.

A similar concept has been, and is still being, used in restoration of existing districts in the city of Malmö, for example the districts of Augustenborg and Sege Park.

Another important task is to promote sustainable travel, with the intention of increasing the use of public transportation, car pooling, eco driving and environmentally friendly cars and buses. Malmö has also made investments to make it a cycle friendly city. The city has more than 400km of cycle ways and was awarded Bicycle City of the Year in Sweden in 2004. Some

Museum of Science and Technology equipped with PV

Source: © City of Malmö, Martin Norlund

40 per cent of commuter travel and 30 per cent of total journeys are made by bike.

Parallel to the physical investments, a number of information campaigns have been carried out to increase the citizens' consciousness of the greenhouse effect and of what can be done to reduce emissions of greenhouse gases. The local climate work has also engaged a great number of actors from industry, who cooperate with the city of Malmö to find common solutions to decrease energy and fuel consumption, and reduce emissions of greenhouse gases.

Description of the PV project

Malmö is the city with the largest area of PV installations in Sweden. The work of the municipality has been ongoing since 2001 and includes installation of several large PV plants on public buildings. A total of 15 PV plants have been installed on official buildings like schools, the museum and hospital. The PV plants are installed on existing buildings and have a total area of 3400m^2 and a peak power of 500kW.

The city of Malmö is making investments in solar energy to strengthen and market the environmental profile of the city. It is also likely that rising energy prices can make PV profitable in the future. An investment in solar energy is one step on the way to reducing CO_2 emissions and future energy costs, and to becoming more self-sufficient in energy.

In Sweden there is 70 per cent government funding for installation of PV systems on public buildings, approximately €15 million for the years 2005–2008. This is the reason why the majority of PV installations in Sweden are placed on public buildings. Since all electricity producers in Sweden must pay a fee in order

PV façade of the Museum of Science and Technology

Source: © City of Malmö, Martin Norlund

The Sege Park PV system

Source: © City of Malmö, Martin Norlund

PV shading devices on the façade of the Mellanhed School in Malmö

Source: © City of Malmö, Martin Norlund

to deliver electricity to the grid, the majority of PV installations in Sweden are sized so that production never exceeds the consumption in the building.

Solar City Malmö, the first Solar City Association in Sweden, was established in 2007. The main objective is to promote the implementation and development of solar energy systems and strengthen the solar energy market in southern Sweden. This will be achieved by spreading information and knowledge about solar energy by arranging seminars, guided tours, educational courses, conferences etc.

The largest and most spectacular PV plant in Sweden was completed in July 2007 in the city of Malmö in the old hospital area of Sege Park. The plant has a unique architectural and technical solution and it rests on a 20m high steel frame. The total area equipped with PV is 1250m^2 for a peak power of 166kW. The area of Sege Park is going through major restoration and there are plans for an expansion with new buildings in the area, for example student apartments. The area will be self sufficient in energy from renewable energy sources like PV, solar thermal plants, bio fuel and wind energy.

The PV plant on the Museum of Science and Technology was installed in September 2006. Some 335m^2 of PV is installed on the flat roof, and 180m^2 on the façade. The total peak power is 67kW. The plant was awarded Solar Plant of the Year by the Swedish Solar Electricity Programme 2006, for its architectural integration in the building.

PV was also installed in 2007 on the Mellanhed School as solar shading. The plant has a peak power of 34kW. Since installation of some kind of solar shading system was necessary to reduce cooling costs in the building, the cost of a regular solar shading system can be deducted from the investment cost of the PV system, which gives good economy to the installation. The plant was awarded Solar Plant of the Year 2007 by the Swedish Solar Energy Association for its educational purpose.

The solar shading had also been used at the Student Union House in Malmö. The surface of PV is 180m^2 and the peak power is 25kW.

PV shading devices on the façade of the Student Union House in Malmö

Source: © City of Malmö, Anna Cornander

One of the first PV installations in Malmö was the one at Augustenborg. Augustenborg is an area built in the 1950s that has gone through an ecological change over the past ten years. Solar thermal plants and PV plants have been installed, and the number of green spaces in the area has been increased. The area is famous for its green roofs. PV has been installed on two buildings and in three different types of applications. On one of the buildings PV is installed as solar shading. On the other building, PV is installed as a demonstration plant with different types of PV cells available for visitors to see on the roof and on the façade. The third installation is a PV cell hybrid, with reflectors and PV system functioning as solar shading. The reflectors concentrate sunlight to the PV cells to produce more electricity, and the PV cells are cooled with water producing solar thermal energy. The PV plant in Augustenborg has a total area of 100m^2 and a peak power of 11kW.

Summary of problems, barriers, solutions and recommendations

Lack of long-term subsidies for PV in Sweden

The governmental funding for PV installations that was available in 2005–2008 was not enough to create a stable market for PV companies in Sweden or to provide an incentive for investments in staff training and education. Because of this there is a lack of competence in the PV area.

It has been difficult to find consultants who know the technology well enough to write a good procurement document. Most of the tendering documents have therefore been written by the project manager at the Department of Internal Services in the city of Malmö. It was also difficult to find qualified inspectors to do the final inspection after installation of the PV plants.

To address this issue Solar City Malmö has been working at a national level to reduce the fees and promote the implementation of a more beneficial and long-term system for selling electricity from small-scale production from PV to the grid in Sweden. This is necessary in order to enable private and larger investments in PV plants. When the market grows, knowledge will increase, and it will be easier to find qualified and experienced consultants and inspectors. Solar City Malmö will also arrange training to increase the knowledge of PV.

Building permits for PV installations

The project manager at the Department of Internal Services in the city of Malmö has experienced difficulty getting building permits for PV installations, due to lack of knowledge in the town planning department. The opinion of the planning department was that PV systems are ugly and that it was hard to find good examples and reference objects.

It is important to have good reference objects to show what the installation and the PV modules will look like. It is also important to arrange training for the parties concerned. It is an advantage if the PV plant can be integrated in the building in an attractive and simple way.

Security of public buildings

PV is a new technology, and there have been very few reference objects built in Sweden to show as good examples. Some of the managers of public buildings refused to install PV systems when the municipality made a proposal because they were afraid that the systems would cause problems.

However, the experience gained by the city over the past few years means there are now several successful reference objects to show. Public awareness of the city's investments in solar energy has grown. The interest among the managers of different public buildings has increased, and they have now started to come up with initiatives of their own to install PV systems.

UK, London, Croydon

Emily Rudkin

Summary

The London Borough of Croydon was one of the first municipalities in the UK to implement the 'Merton Rule'. The Merton Rule is a new planning policy, pioneered by the London Borough of Merton, which requires the use of renewable energy on site to reduce annual CO_2 emissions in the built environment. Croydon Council adopted the rule, which requires all proposals for non-residential developments exceeding 1000m^2 gross floor space, and new residential developments comprising ten or more units, to incorporate renewable energy production to offset at least 10 per cent of predicted carbon emissions. This rule applies to both newbuild and conversion for residential developments, and is in addition to meeting requirements for use of energy efficiency under the Building Regulations.

The first project designed to reach the 10 per cent target was completed in July 2005, and since then a further 11 projects have been completed. Out of these projects, seven have incorporated PV, with the most notable example being the integration of 39.4kWp of PV on three new residential blocks at the Queen's Hospital site. The main barrier for developers is seen as know-how not cost. Croydon Energy Network's Green Energy Centre provides advice and support to developers including accessing grants and suitable renewable technologies to use.

Introduction

The London Borough of Croydon is located 10 miles (15km) to the south of London, England. The area is 34 square miles (87km^2) and houses a population of 342,700. The borough is based around the historic town of Croydon. Today central Croydon houses one of the largest office and retail spaces outside of central London. Croydon has a very diverse urban heritage, which is of high quality and unique in nature.

The diversity is also apparent in the mix of housing that Croydon offers. This ranges from some areas and sections of the community that experience significant disadvantages compared to others that are quite affluent. To steer the future planning, regeneration and development of this borough, Croydon Council was one of the first councils in the UK to implement the Merton Rule.

Description of PV project

Summary of PV projects installed in Croydon

Within the Croydon Council area, PV has been installed on a number of public and private developments including schools, shopping centres and residential developments. Most recent PV systems have been installed as a direct result of the Merton Rule. The first project designed to reach the 10 per cent target was completed in July 2005. A year later Croydon Council had approved more than 100 new developments with on-site renewable energy generation.

In total, more than 250kWp of PV have been installed in Croydon, including:

- 108kWp of PV integrated into the BedZED housing development of 82 flats and houses in 2002 (not installed under the Merton Rule);
- 50.4kWp PV system on multipurpose commercial units at the Spitfire Business Park;
- 39.4kWp PV solar tiles installed on residential blocks at the Queensgate development;
- 3.6kWp PV façade integrated into the top floor roof of the Croydon Centrale shopping centre;
- 3.5kWp of solar roof tiles installed on the entrance roof to a nursery;
- 2.2kWp PV system installed onto the roof of St James the Great School;
- 0.99kWp PV system mounted on the roof of St Joseph's Infant School;
- Numerous PV systems (bolt-on and integrated) on individual residential roofs. Examples are Croydon Mills (1.44kWp), Croydon Mickelburgh (0.96kWp), Croydon Card (1.14kWp). These are not a requirement under the Merton Rule.

108kWp of PV integrated into the BedZED housing development in Croydon, not installed under the Merton Rule

Source: © telex4, creativecommons.org

Queensgate Housing Development

Queensgate Housing Development is a large-scale, low carbon development in Croydon, comprising 365 new residential dwellings. The developers, Fairview Homes, have met the 10 per cent renewables requirement on this 3.7ha site, through a combination of integrated solar PV, solar thermal roof tiles and micro wind turbines. The PV systems comprise:

- integration of 39.4kWp of PV on five new residential blocks at the south end of Queen's Hospital site;

- over 1000 solar PV tiles provide 44,243kWh of electricity per year for communal lighting.

The solar PV provides annual carbon reductions of over 15 tonnes of CO_2.

Spitfire Business Park

Hillview Developers have developed multipurpose commercial units at the Spitfire Business Park in Croydon. The business park is designed to accommodate full height warehouses with office space, and comprises 30 units. Natural ventilation and lighting were designed into the units, in addition to incorporating low energy light bulbs and recycled insulation. To meet the requirements under the planning policy, the developers chose to install PV on six of the units. The PV system comprises:

- a total of 316m^2 of PV panelling installed on the roof of six of the units;
- a total installed capacity of 50.4kW of Sanyo 200 hybrid silicon PV modules.

The estimated annual energy generation is 45,360kWh, resulting in emission reductions of 25.8 tonnes of CO_2.

A shot of part of the Fairview New Homes development in Croydon, which incorporates over 1800 of Solarcentury's C21e and C21t solar roof tiles

Source: © solarcentury.com

Hillview's multipurpose business units were required to reduce carbon emissions by 10 per cent under the Merton Rule, with significant reduction achieved from a photovoltaic energy roof

Source: © solarcentury.com

The Merton Rule

The Merton Rule is a planning policy that was first introduced by the London Borough of Merton in October 2003, requiring non-residential developments to generate at least 10 per cent of their electricity needs from on-site renewables to reduce carbon emissions in the built environment. This pioneering policy has since been revised so that residential developments also are required to cut their carbon emissions by 10 per cent.

Other local authorities were quick to follow and adopt similar policies. To date, 34 local authorities throughout the UK have fully adopted policies requiring 10 per cent+ on-site renewable energy. Many other authorities are either assessing the feasibility, actively progressing or have incorporated similar draft policies.

Croydon's policy is regarded as the best practice model for the 10 per cent renewables requirement. The policy states:

> *The Council will expect all development (either new build or conversion) with a floor-space of 1000m^2 or ten or more residential units to incorporate renewable energy production*

equipment to provide at least 10 per cent of the predicted energy requirements.

This is a prescriptive policy which requires the use of on-site renewables, encompasses change of use in regeneration areas and precludes the purchase of green energy to meet the requirement. As such, it has been effective in lowering CO_2 emissions, stimulating the micro-renewables industry, addressing fuel poverty and lowering energy bills.

Both Merton and Croydon have collaborated to enforce the application of the Merton Rule, requiring the approval by the Local Planning Authority of a report provided by the applicant, detailing how the requirement will be met. The required carbon savings are above and beyond what is required to comply with Part L of the UK Building Regulations (which covers fuel and energy conservation and sets maximum CO_2 emissions for whole buildings). As such the Merton Rule was specifically designed to act as an incentive to design and build beyond the Building Regulations requirements.

The only instance when a developer is not required to comply with the Merton Rule is if it can be proved conclusively that the policy is either 'unfeasible' or 'unviable' within a particular development. However, in practice there are few developments with valid reasons why implementation of the policy is not feasible or viable. In these cases, the developer and local authority may negotiate on the percentage target.

The Council is encouraging developers to install as many energy efficient measures as possible and then to look at renewable energy alternatives. The most common renewable energy solution is solar water heating. PV is recommended to be taken up where it is the best possible option. For example, PV is being installed in instances where hot water tanks are not preferred due to spatial requirements, i.e. if the cost of losing space outweighs the cost of PV, then PV is the better option.

The most popular on-site technologies used to date are solar water heating, biomass, solar PV and ground source heat pumps, in that order. Compared to solar water heating, the main barrier to further uptake of PV under the Merton Rule is cost.

View of the Croydon Centrale shopping centre with newly installed solar cladding

Source: © solarcentury.com

Eligible technologies under the Merton Rule as implemented in Croydon include: photovoltaics, solar water heating, wind, combined heat, power and cooling, communal heating, cooling and power, biomass fuelled heating, cooling and electricity generating plant, renewable energy from waste (subject to air quality standards being addressed, which is unlikely for units below 400kW), hydrogen fuel cells, and ground-coupled heating and cooling.

Summary of problems, barriers, solutions and recommendations

Impact of the renewable energy requirement on obtaining planning permission and subsequent delays

The Council advise that the renewable energy requirements are part of the planning process. The developers are naturally resistant to change, but usually report that it is relatively easy when they have done it once. The intention is that incorporating renewables into a development becomes 'just part of the process'.

PV integrated into façade at Ashburton School, Croydon

Source: © Halcrow

As with any new planning conditions and regulations, it takes time to become familiar, to comply and meet the standards required. This is why Croydon Council have set up a help line, called Croydon Energy Network's Green Energy Centre, that provides advice and support with identifying the type of renewable energy that can be used for a particular development and where developers can access grants to contribute to the costs of a renewable energy installation.

The council require planning applications to include an Environmental Performance Statement for any new development. This details how it will meet the high sustainable construction standards in accordance with local planning policies including the siting, size and location of renewable technologies. Guidance is provided to ensure that what the council recommend is completed.

With maturity of the policy, improved enforcement and developer understanding, there has been a steady increase in the uptake of on-site renewables. As stated in a report issued in September 2007 by London South Bank University, throughout the Greater London Authority there has been a gradual reduction in the length of the application process from 700 days in 2004 to around 100 days from the end of 2005 onwards.

Added cost of installing on-site renewables

The main objection to implementing the Merton Rule is the added cost to developers, and that it may undermine the feasibility of otherwise viable projects. While there is an added capital cost to a project, Croydon Borough Council has observed that the real obstacle appears to be know-how rather than cost. This is backed up by research undertaken in 2006 for the Office of the Deputy Prime Minister's Part L Building Regulations review that demonstrated that carbon reductions of at least 20 per cent in newbuild housing could be achieved with small renewable energy systems typically adding 1 per cent to the sale price of the average newbuild house in the southeast of England.

More evidence is emerging to suggest that houses and developments that are environmentally sustainable will also add value to a property, a bonus to any property developer. Eddy Taylor, former Environment and Sustainability manager at Croydon Borough Council stated, 'Evidence is increasing that renewable energy can increase sales values. There is also recognition among developers that this is the direction the industry is moving, and it is in their interests to stay ahead of the game.'

It is also interesting to note that some purchasers are prepared to pay a premium for homes built with PV. A development in the Peak District of the UK by Gleeson Homes sold homes with integrated solar PV tiles at €148,650 (£140,000) compared to €135,915 (£128,000) for otherwise identical non-solar homes on the same estate. As Tom Whatling of Gleeson Homes commented, this 'allowed the homes with photovoltaics installed to be sold at a premium thereby offsetting the additional cost involved.'

Merton Rule seen as acting as a barrier to affordable house building

This argument is due to the added cost of installing renewable energy technologies. However, the experience from Croydon does not support this argument. The Merton Rule was introduced into Croydon Borough Council's Unitary Development

Plan in 2004, and there has subsequently been a significant increase in housing completions. Furthermore, in 2006–2007, Croydon exceeded the London Mayor's target of 50 per cent of all new homes being affordable. The Mayor congratulated Croydon Council saying, 'It is very noteworthy that, unlike many councils, you have delivered – in fact exceeded – the levels of social rented housing recommended in the London Plan.'

Some grudging acceptance of the planning conditions placed on developers

Soon after the introduction of the new rule, enforcement action was required in some instances. However developers have now generally accepted the requirements. Some developers continue to see the difficulty and cost implications of adding renewable technologies, but most are finding it less difficult to comply than originally anticipated. As Eddy Taylor stated, 'developers are working with us to deliver the 10 per cent requirement and are often surprised at how easy it is to achieve. On a new housing estate for example, it is often unnecessary to install a micro-renewable system on every dwelling in order to achieve the estate's overall 10 per cent target.'

Some developers are now starting to see the PR benefits. One such developer is Barratt Homes, with David Pretty reporting, 'We're doing this not just because it makes commercial sense, but because we believe it makes sense for the future. New homes buyers are pleased with the aesthetics and particularly impressed that solar tiles can save them money.' Fairview New Homes Director, Terry Rood commented about their development at Queens Gate, 'The Merton Rule encouraged us to add value to our buildings, which we believe have set a blueprint for the future. Fairview New Homes is delighted to be involved in a nationwide first.' The development, which was completed in July 2007, has since sold out.

Energy output from renewable installations not maximized

In one of the earlier projects under the Merton Rule, the maximum energy potential from a PV installation was not realized due to the poor location of the PV systems. They were placed in the shade on a garage roof.

Guidance is available to developers to ensure that the energy output is maximized. The London Renewables Toolkit provides guidance on renewable energy technologies and how to calculate the 10 per cent figure, based on off-setting 10 per cent carbon emissions above and beyond compliance with Building Regulations.

The toolkit can also be used as guidance for developers and installers to ensure that PV systems are correctly located and oriented to maximize performance. This advice is also available for other renewable energy installations.

Restriction on renewables in some areas

A barrier to the uptake of on-site renewables has been obtaining planning permission, in part due to the time, cost and also lack of clarity about the need for planning permission for some technologies.

To overcome this barrier, Croydon Council has been lobbying for permitted rights across all boroughs in England. Permitted development rights have now been introduced throughout England, as of 6 April 2008. Planning permission for roof-mounted PV is now not required unless:

- panels when installed protrude more than 200mm;
- they would be placed on the principal elevation facing onto or visible from the highway, in buildings in Conservation Areas and World Heritage Sites.

Stand-alone PV does not require planning permission unless it is:

- more than 4m in height;
- installed less than 5m away from any boundary;
- above a maximum area of array of $9m^2$;
- situated within any part of the curtilage of the dwelling house or would be visible from the highway in Conservation Areas and World Heritage Sites.

The Welsh Assembly government, Scottish government and Northern Ireland government are currently all considering changes to their legislation to provide permitted development rights for micro-generation installations.

Not the most effective means of reducing carbon emissions

One of the criticisms of the Merton Rule is that it is not the most cost-effective means of reducing carbon emissions. However it was implemented specifically to incentivize renewables.

The renewable energy industry views the Merton Rule as an extremely important policy instrument to stimulate jobs and investment in these new technologies. It creates guaranteed demand opportunities that companies can safely invest into. Seb Berry, Head of External Affairs at Solar Century, the company that has installed the majority of PV systems in Croydon, stated that 'the Merton Rule is absolutely critical to development of the fledgling UK micro-renewables industries. It is driving the demand for these technologies.' In 2007, Merton Rule projects delivered 30 per cent of Solar Century's UK turnover.

Energy efficiency measures are generally more cost-effective than renewables, and this has been an argument against the Merton Rule. However, energy efficiency is covered within the Building Regulations, Part L, whereas renewables are now viewed as a planning issue. (The latest revisions to Part L set maximum carbon dioxide emissions for whole buildings, but the building designers have an element of flexibility that could include renewable micro-generation.) It is also worth noting that the Merton Rule encourages developers to reduce the carbon footprint of a building before the contribution from on-site renewables. In addition, the recent national policy PPS1: Planning & Climate Change promotes the use of energy supply from local renewable and local low carbon sources (i.e. on site and near site, but not remote off site) on a relatively small scale.

There has also been some argument for off-site generation to be an option. However offsetting carbon emissions by purchasing electricity generated from remote renewables generation will not promote development of the UK's renewable energy industry or result in any additional generation capacity.

UK, Kirklees Council solar PV projects

Donna Munro

Summary

Kirklees Metropolitan Council, in the northwest of England, was one of the first municipal authorities in the UK to promote the widespread use of PV on buildings within its urban area. The first projects undertaken were within the European Commission funded SunCities project. This led to the installation of 400kWp of PV, mainly on housing, within Kirklees. The SunCities project was followed by other renewable projects within the area including installing PV on council buildings and schools, and projects designed to promote renewables to local residents.

There has been a strong commitment to renewables in the local council backed up by a dedicated Environment Unit able to advise and assist with implementation of renewables projects. Targets have been set for the implementation of renewables in the area and obligations may be imposed on developers to include renewables in major new developments. The economic benefits of the renewables policies have been assessed and quantified and the impact on residents' energy consumption studied.

Introduction

Kirklees Council is the local governing body for an area of 253km^2 in northern England consisting of the towns of Huddersfield, Batley and Dewsbury and surrounding areas, with a population of over 380,000 people. The Council has a dedicated Environment Unit covering areas of work such as biodiversity, energy management and renewable energy,

PV and solar thermal retrofit to houses in Primrose Hill

Source: © Donna Munro

environmental management systems, planning and policy development.

Kirklees Council was one of the first municipal authorities in the UK to promote the widespread use of PV on buildings within the urban area. The Council participated in the European funded project SunCities, which led to the installation of 350kWp of PV, mainly on social housing. The Council has also installed PV on council buildings and schools. The Environment Unit is the central point for coordinating renewable energy projects and initiatives.

SunCities Solar PV project

Within the Kirklees district, PV supplies renewable electricity to over 390 houses, apartments, schools, care homes and public buildings. The majority of the PV was installed under the SunCities project.

The initial decision which eventually led to these successful PV projects was the decision in 2000 to set up the Kirklees Council Renewable Energy Capital Fund. The fund was set up using savings from reduced National Insurance contributions under the climate change levy.

The political decision to promote renewables was made reality by the Kirklees Council Environment Unit, which has a broad remit and enthusiastic renewable energy officers. The Environment Unit coordinates activities that promote and support the development of renewable energy both within and outside the Council, including policy advice, technical and financial advice, developing demonstration schemes, and securing and administering financial support for renewable energy.

Success in the early projects led to continuing political support, strengthening of policies to support renewables and further successful projects. Local enthusiasm and commitment to renewables were also strengthened when the Kirklees PV projects won an Ashden Award for Sustainable Energy, a British Renewable Energy Association Award and a Green Apple Award. Again these public measures of approval led to further political support for policies to promote renewables.

Like many success stories, success has led to further success but would not have occurred without the presence of a number of individuals who were committed to renewables and persevered despite occasional set-backs.

Council policies continue to develop in a manner that encourages renewables. The recently adopted 2025 Kirklees Environment Vision includes commitments to reduce greenhouse gases, work with partners to become carbon neutral, and continue to raise awareness of climate change and its impacts and to raise the environmental standards of buildings.

To meet these policies the council has set ambitious targets for the use of renewable energy in the district. Targets have been set in four areas:

1. Reducing the council's own CO_2 emissions by more than 30 per cent by 2020 from a 2005 baseline. This follows on from a successfully achieved target of a 30 per cent reduction by 2005 from a 1990 baseline.
2. By 2010/11 all new council buildings will meet 30 per cent of their energy demand from on-site renewable energy sources.
3. New developments across the district will be required, through the Local Development Framework, to reduce CO_2 emissions through increased efficiencies and incorporating renewable energy sources. Non-residential developments above a threshold of $500m^2$, along with all residential developments (newbuild, renovation or conversion), will aim to provide energy

SunCities was a large European Commission funded project involving the installation of over 3MWp of PV in The Netherlands, the UK and Germany. Kirklees was the location for the 351kWp installed in the UK between 2000 and 2006.

The PV was installed in a number of locations:

- 40kWp retrofit to 31 houses on Sackville Street, a Kirklees Community Association social housing complex in Ravensthorpe.
- 50kWp on the roof of Titanic Mill, the conversion of a historic textile mill into 130 luxury apartments by a commercial developer as part of the CO_2 neutral development of the mill.
- 110kWp in Fernside retrofit to 100 social housing properties, mainly occupied by elderly and disabled people, as well as two local schools.
- 113kWp Primrose Hill – a solar village with 121 new and existing houses and flats.
- 40kWp on six newbuild care homes for the elderly and people with disabilities.

Other projects:

- ZEN Civic Centre III: PV (17.6Wp), solar thermal and two 6kW wind turbines were installed on one of the main council buildings in the centre of Huddersfield as part of the Zero Emissions Neighbourhoods project;
- Moldgreen Primary School: 15.4kWp with funding from the Major PV Demonstration Programme and the Councils Renewable Energy Fund;
- Scolar Programme: Cliffe House 0.8kWp.

through incorporation of renewable energy sources to reduce predicted CO_2 emissions from the development by at least 10 per cent by 2010, 15 per cent up until 2015 and 20 per cent up until 2020.

4 Increasing the proportion of the district's energy consumption coming from renewable resources to 10 per cent by 2010. This follows on from a target to meet 5 per cent of the district's energy consumption from renewable sources by 2005. Despite the considerable progress the Council has made in installing renewable energy across the district these targets are still a long way from being achieved. It is recognized that much larger scale projects are needed if these targets are to be reached.

Measures taken included:

- analysis of renewable resources;
- promoting and part funding domestic solar thermal systems through the Simply Solar Programme;
- working in partnership for the development of exemplar projects such as the SunCities and ZEN projects;
- administering the Renewable Energy Fund – a €212,365 (£200,000) Capital Grant Scheme for Council projects.

SunCities received funding from the Renewable Energy Fund as well as grants from the European Commission and the UK Department of Trade and Industry major PV demonstration programme. The housing associations and the developers Lowry Renaissance also contributed to the costs. There was no charge to social housing tenants.

Retrofits also involved a programme of general refurbishment, increase in energy efficiency and insulation, and solar water heating in some properties.

Housing associations have set up maintenance contracts with installers or Kirklees Council Building Services.

Summary of problems, barriers, solutions and recommendations

Building up positive political and popular commitment to PV to get substantial numbers of PV buildings installed

Good projects lead to more good projects! Kirklees Council continues to develop policies and development plans that are positive to renewables. The success of the early PV projects led to confidence in renewable technologies and a willingness to push for more renewables in the area.

Since the early 1990s, Kirklees Council sought to take a lead on issues relating to the environment and energy. In 1992 the Council signed the Friends of the Earth Climate Resolution which included a commitment to making a 30 per cent cut in greenhouse gas emissions by the end of 2005. This target was met and a further target for emissions reductions set. In 1998 the Energy and Water Conservation Fund was established to encourage energy and water conservation in Council services. The Council is the only local authority to participate in the UK Emissions Trading Scheme.

PV on new housing at Primrose Hill

Source: © Donna Munro

Recently the Council undertook a rebranding exercise that included redesign of its logo, which now has a wind turbine as its inspiration. Council activities were refocused into four cornerstone 'Ambitions', one of them being 'Kirklees will be a beacon for green living'.

In Kirklees support from local Councillors was a key point right from the beginning when Councillors voted to set up the Renewable Energy Fund.

Achieving good value and low cost was critical in demonstrating the effectiveness of PV as a technology and also assisted in securing external support. Value can be achieved in particular through innovation, increasing the scale of projects and achieving added value from effective integration, for example, displacing normal roofing costs and selling Renewable Obligation Certificates as well as power.

Successful projects were built on by researching and publicizing the benefits obtained by early projects. For example, in Kirklees the impact on the local economy was checked and the results publicized:

- local jobs were created and local skills increased;
- more than €424,730 (£400,000) in external funds was brought into the Kirklees community;
- the project attracted national attention.

In parallel consultation exercises residents in other areas of Kirklees expressed their support for more renewables to be installed in Kirklees.

Management of a complex project with multiple funding streams

Funding is available from various sources to contribute to the costs of renewable energy systems such as PV systems. However, the funding bodies normally have specific requirements, rules for eligible costs and time constraints. Obtaining and managing this funding has to be done within the constraints of a building programme which will have its own motivating forces, aims and timetable.

Solutions to this issue include:

- Keeping all partners engaged and committed throughout the project is crucial. Someone needs to take a lead on that. Note: it may not be picked up by the person you think will do it.
- Projects often have multiple funding sources. Commitment is needed from all partners to meet the requirements of all funding streams. It may not be worthwhile to obtain small additions to the funding if it complicates the project management too much.

Getting projects started and finding the right buildings to put PV on

Council policies aim to encourage the installation of renewable energy in the Kirklees area on buildings built or owned by a variety of different organizations:

- Good links between developers and the local council at the early stages of project development can lead to interesting projects.
- Individual developers may be interested enough to pursue renewable energy projects on their own.

PV on housing association properties in Fernside

Source: © Donna Munro

- Encouraging developers or householders to take advice from other users/clients of PV systems allows them to obtain an objective view of the technology.
- For housing associations in particular, having tenant representatives involved in the project can be a key to success. They can help with acceptance and security. As informed local residents, they can be a focal point for enquiries and feedback, even taking part in workshops and talking to the media.

What to do with excess electricity?

Electricity that is not used within the building will 'spill out' on to the local electricity grid. In some countries a premium is paid for the export of this renewable energy but getting any payment at all for exported electricity proved very difficult for the Kirklees projects, and obtaining a premium for producing renewable electricity has not so far proved possible.

Until recently only large renewable generators could realistically obtain Renewable Obligation Certificates (ROCs) for the export of renewable electricity. ROCs are worth around €0.048/kWh (£0.045/kWh). Recent changes to legislation simplified the process for small-scale generators; however, a considerable amount of paperwork and effort is still required from householders to obtain and sell ROCs.

Kirklees Council Environment Unit wished to enable people to sell excess electricity and to group together to receive payment for ROCs. Kirklees Council conducted research on behalf of householders involved in the SunCities solar PV project to explore the options for selling back electricity. It was apparent that it can be very difficult for a householder to sell back electricity: it is a complex process and may involve switching to a more expensive electricity tariff. Since the research conducted in August 2005, the situation has improved. There are a number of suppliers who will offer to buy back energy from householders. The council suggest that householders talk to their electricity company first to investigate whether it is necessary to switch tariffs and how this will impact on the cost per unit paid for energy consumed versus how much is paid per unit generated. However, the majority of householders have not obtained agreements to sell excess electricity. Nor has it so far proved possible for householders to group together and aggregate ROCs to sell. These problems led to Kirklees Council lobbying for better payment for export of electricity and easier access to ROCs for small generators.

Actions suggested to maximize the benefits obtained from the electricity generated include:

- Starting with buildings with a good match between supply and consumption. Many of the PV-powered buildings in Kirklees have a substantial demand for electricity in the daytime, which maximizes the use of the PV-generated electricity by the occupants. Examples include care homes and houses for young families and the elderly. The Titanic Mill building houses 130 apartments, many of which will be empty during the day. However, the PV system is owned by Mill Energy Services, an energy service company that provides energy services to the building

PV on the roof of Titanic Mill

Source: © Kirklees Environment Unit

users. The PV-generated electricity is used alongside a biomass fuelled CHP system to deliver energy to the ground floor spa and leisure centre, which has a substantial daytime demand, as well as to the apartments. The aim is to make the apartments CO_2 neutral.

- Ensuring that the connection of the system to the local electricity grid is considered at an early stage in the design and discussed with the electricity distribution network operator, as this can introduce a significant time delay within a project.

Someone must take responsibility for keeping an eye on PV systems

PV systems are often described as needing minimal maintenance and in Kirklees there have been very few problems with the PV systems. However, it is still necessary to ensure that there is an effective plan for operation, maintenance and repair of systems. PV systems need to last to achieve their potential and elements of the systems, especially inverter devices, will require replacement and/or repair eventually; some inverters trip out and some tenants accidentally switch off their PV system. Access to individual properties for maintenance or repairs can be an issue; locating inverters in communal areas is one way around this problem in apartment or flats buildings.

Fernside solar village housing

Source: © Donna Munro

With buildings such as schools or care homes it is important to make sure someone at the building 'takes ownership' of the PV. For example, at one site there was a fault showing on the display panel because one of the inverters was down, but it was not noticed or reported for some time. An operator's handbook was available but there had been personnel changes since the system was installed and no maintenance personnel reside on site. Kirklees Council Building Services staff received training in maintenance through the projects and the Council is now looking at providing recognized training courses (City & Guilds) for maintenance staff.

Private house owners who have chosen to install and pay for a PV system have a strong incentive to keep it working well, but if the house is sold the new owners will need to get to know the system and how to get the best from it. Creating an energy service company to own and run the PV system is an alternative to private ownership of the system by householders that particularly suits apartment buildings such as Titanic Mill.

Housing association tenants need to know something about their PV systems. In Kirklees the housing associations prepared leaflets and the installers explained the systems when they were installed. The systems have been particularly successful on estates with a stable population and involved tenant representatives. Follow-up can be done during a monitoring programme. For example, at the Fernside solar village monitoring is done manually with a project officer visiting the houses on a monthly basis and noting meter readings. At the same time the officer can answer questions or concerns. At the first estate where PV systems were installed the tenants have changed fairly frequently leading to a poor understanding of energy issues with those tenants who were not there when the system was first installed. A tenant information sheet is now included in all new tenant packs.

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

Christy Herig

Summary

This new home development in Rancho Cordova, California, consists of 95 homes, Premier Gardens, on the west side of the property, and 98 high energy efficiency homes, Cresleigh Rosewood, on the east. The Premier Gardens houses have PV and energy efficiency measures and are termed near zero energy homes (near-ZEH). The focus of this case study is a comparison of the energy performance of the high efficiency homes compared to the near-ZEH homes. The similar designs and occupancy provide a unique opportunity to fully analyse the near-ZEH performance and this was the foundation for the new California Energy Commission (CEC), New Solar Homes Partnership programme which aims at incorporating solar power into 50 per cent of all new homes built in California by 2020. The programme will change the way solar incentives are allocated in all Independent Service Operator areas including Pacific Gas and Electric (PG&E), Southern California Edison (SCE) and San Diego Gas and Electric (SDG&E) and serve as a model for the rest of the country.

Introduction

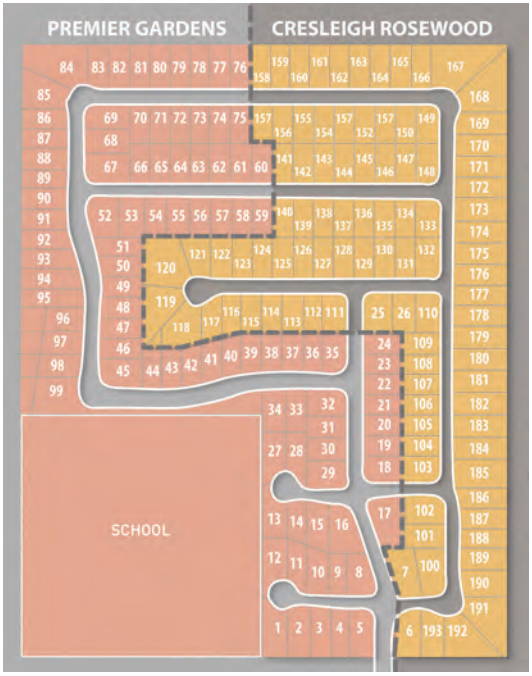
Rancho Cordova is a municipality of approximately 60,000 citizens. This suburban community, located on the east side of Sacramento, California established cityhood in 2003. The area around Sacramento is well known for its citizens' decision on early decommissioning of the Rancho Seco nuclear power plant, replacing the nuclear plant's energy generation with renewables and energy efficiency. In fact the Sacramento Municipal Utility District, SMUD, built 2MW of utility-scale PV generation at the site of the nuclear plant in the mid-1980s.

SMUD's 2MW utility-scale PV generation at the Rancho Seco nuclear plant

Source: © DEO/NREL, Warren Gretz

In 1993 SMUD's PV Pioneer I programme was one of the earliest PV rooftop programmes where customers paid a 'green fee' of €3.8/month (US$5/month) for the privilege of having a 2–4kWp, utility owned, PV system installed on their home's roof. The energy from the PV Pioneer I systems went directly to the utility grid and did not decrease the customer's energy bill, demonstrating a market of customers willing to pay to be green.

The energy crisis that occurred in 2000 and 2001 in the western region of the United States led to customers experiencing both a tripling of energy bills and rolling blackouts. Unfortunately, it often takes a catastrophic event to cause change. The State of California has had PV financial incentives in place since 1998, but it took the rolling blackouts during the crisis for inhabitants and builders/developers to jump on the bandwagon. Shea Homes, a builder in San Diego, California responding by changing plans mid-stream on its San Angelo, 300+ home development to include PV on 100 of the new homes. The San Angelo PV homes, marketed as zero energy homes (ZEH), not only sold first in the development, they later proved to have



Site map with near zero energy homes on the west side of the property and high energy efficiency homes on the east

Source: © Premier Homes and Cresleigh Homes

a nearly 17 per cent higher resale value (Farhar et al, 2004).

The Premier Gardens development was part of a new home builder / ZEH programme backed by SMUD, which continues to promote PV. Its solar activities have evolved to a focus of working with new home builders. Premier Gardens was the first near-ZEH full scale development for both SMUD and the builder. The project is also involved in one of the six US Department of Energy, Building America programme teams titled Building Industry Research Alliance (BIRA). The BIRA team consists of 28 partners from the building, solar, energy efficiency, utility and research/analyst sectors. Additional BIRA team participants in the project include Consol and GE Solar. Pacific Gas and Electric also provided residential gas usage for the analysis.

Development of a low energy community

Premier Homes and Cresleigh Homes undertook a business agreement to divide the development of a plot of land in Rancho Cordova, CA. The resulting community consists of 95 near zero energy homes, Premier Gardens, on the west side of the property, and 98 high efficiency homes, Cresleigh Rosewood, on the east.

The plot plan shows many of the homes are adjacent. This side-by-side community provided the opportunity to fully analyse the near-ZEH performance above a well-built high efficiency home, which had previously only been modelled. The result was the foundation for the California Energy Commission, New Solar Homes Partnership programme, which aims to incorporate solar power into 50 per cent of all new homes built in California by 2020.

Premier Homes is a medium size home builder in the Sacramento region, building 70–90 homes per year. Prior to the Premier Gardens development, Premier Homes had only built two homes with PV. With little in-house expertise, Premier relied on the assistance of the BIRA team to design, build and market the Premier Gardens development. They were one of the first builders to standardize PV rather than provide it as an option. The resulting PV system design was a 2.2kWp, GE Solar roof tile on an inclined roof. The inverter was a Sunnyboy SMA2500.

SMUD provided about €5270 (US$7000) towards the PV and €377 (US$500) towards the energy efficiency measures. The added cost to the construction for the PV and efficiency combined was €11,723 (US$15,000). Additionally, SMUD has tiered residential electric rates. The first 700kWh per month use are charged €0.06/kWh (8US¢/kWh) and any use above this pays €0.113/kWh (15US¢/kWh). At the homes in Premier Gardens electricity use fell well under the first rate tier while the comparable homes at Cresleigh Gardens went over to the second rate tier.

All the homes in this Premier Homes entry-level home development feature a 2.2kW building-integrated photovoltaic system manufactured by GE Energy

Source: © DEO/NREL, Premier Homes

The planning for this development had an energy focus and traditionally this would mean a southern orientation for PV to achieve maximum energy output. However, the utility peak loads are late in the day because of residential air conditioning loads. West oriented PV arrays that provide maximum generation at peak load time can therefore help to reduce the peak load significantly. Having a variety of roof orientations also fits in with a desire for aesthetically broken rooflines and efficient land use layout. The utility benefits if some PV systems face east or west as the generating profile of the PV then more closely matches the grid load profile. In this development an east or west facing orientation means that energy production is decreased by only 5 per cent compared to a south facing orientation. At higher latitudes the losses could be more significant. For this development about 60 per cent of the houses faced south, 24 per cent west and 16 per cent east.

The home owners

In addition to the energy analysis, occupant demographic and attitude analysis was also preformed on this development (Hanson and Bernstein, 2006). The results showed increased occupancy comfort and home owner satisfaction.

Research funded by and in support of the Department of Energy's Building America programme was conducted by RAND Corporation, a non-profit think tank focused on policy-changing research. The results provide some insight into the attributes of home owners preferring energy performance housing. Focus group discussions with home owners in Premier Gardens and Cresleigh Rosewood were conducted in October of 2005. RAND cautions that due to "… limitations of our qualitative research approach and the small sample size in our study, our results should be considered as preliminary, and our conclusions as tentative …. This report is a "working paper" intended to share preliminary findings, invite comment, and continue progress made on better understanding the issues surrounding home buying decisions.'

The following was learnt of the near-ZEH homebuyers relative to the non-ZEH homebuyers:

- near-ZEH homebuyers are younger;
- near-ZEH homebuyers have a lower household income;
- near-ZEH homebuyers are more educated (twice as many hold advanced degrees);
- near-ZEH homebuyers viewed more homes before purchasing (more than twice as many).

Builder benefits

When the project was first considered, Premier Homes was asked to list its goals. When these goals were revisited in October 2006, John Ralston, Premier Homes Director of Sales, stated that each goal was met and many were exceeded. The initial goals are listed below with explanations on how they were met:

- To differentiate themselves from all other builders. As the first near-ZEH development in the area, Premier Gardens was of course differentiated. However, in the Sacramento

Aerial view of near zero energy homes of Premier Gardens New Home Development

Source: © Sacramento Municipal Utility District

region, many entry-level homes look similar and the PV on the roof actually acted as a visual curbside attention getter to drive-by customers.

- To promote innovative construction and energy efficiency and be energy conscious and doing good to the community. Both the Premier and Cresleigh homes were similarly priced. The different features were the standard granite countertops in the Cresleigh homes and the near-ZEH features in the Premier homes. The Premier sales persons learnt how to market the social responsibility of the energy features. Additionally, the analysis results influenced state policy to provide incremental incentives to promote energy performance housing based on levels of performance rather than carte blanche.
- To attract attention, and hopefully provide faster sales. The Premier homes sold out long before the Cresleigh, even though the Premier construction started later.
- To continue to build with photovoltaic systems. Since 2006, Premier has built 250 PV homes.
- To be competitive and have an advantage over Cresleigh Homes in the same development as well as other Sacramento builders. Again the PV homes sold before the standard homes.
- To take advantage of incentives from SMUD for building ZEH. SMUD provided approximately half the cost of the near-ZEH features or €5647 (US$7500).
- To sell the ZEH homes with higher resale values. Market research on the Shea homes in San Diego showed a 17 per cent premium in resale value (Farhar et al, 2004).
- To offer ZEH homes as a standard package and make it affordable for entry-level homebuyers while other builders only offer ZEH as a move up option.

Additionally, Premier Homes have found many benefits from the local and national media attention reducing advertising costs. Their reputation among buyers was evident in the RAND study, by a 4:1 turnout in favour of Premier Homes over Cresleigh.

Premier Homes has also gained the respect of the homebuilding industry for its innovative designs and marketing success, winning an Energy Value Housing Award, administered by the National Association of Home Builders Research Corporation and funded by the US Department of Energy.

Premier estimates that when PV is sold as an option it costs 40 per cent more to install than if built as standard. Though overall this is only about 10 per cent of the PV system cost, these homes are mainly first time home owner, lower cost homes and the builder has a minimal profit margin. Premier has also learnt and crafted its marketing message based on what resonates with homebuyers. Both Ralston and his sales personnel work to communicate the benefits of a ZEH to potential homebuyers. This mission is difficult and takes a clear and concise message. Premier Homes is now confident that it can sell cost savings through reduced energy bills as Premier Gardens has offered verifiable evidence.

Most Premier Homes' employees are proud of what they have accomplished and believe that their homes enhance people's lives. Some Premier employees even own Premier ZEHs. This benefit is difficult to measure but none the less important for the people who work for Premier.

Energy savings

Both the Cresleigh and Premier homes are approximately the same size, but the energy features differ in many ways. The Cresleigh built homes participated in the SMUD Advantage Program anticipated to reduce summer cooling by 30 per cent and meeting the California Title 24 requirements. The Premier Gardens' homes have a PV system and additional energy efficiency features, such as high efficiency air conditioning, fluorescent as opposed to incandescent lighting, and buried ducts for air conditioning reducing coolth losses.

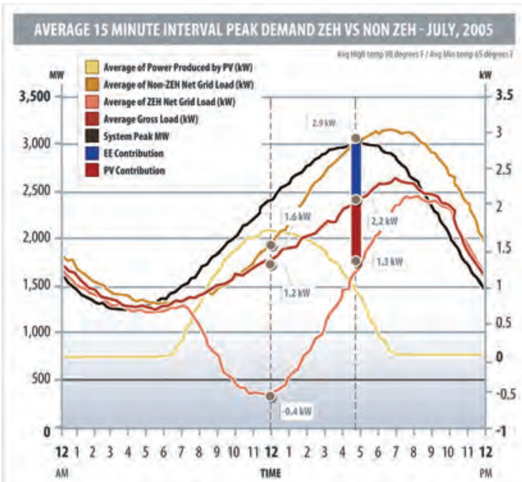
The analysis of energy savings used 12 months of continual data from March 2005 to February 2006. The average monthly electricity use before PV for Premier Gardens is 9.3 per cent less than Cresleigh, and 53.5 per cent less with PV.

A common theme among Premier owners is their happiness when they open their summer electric bills. While their highest summer near-ZEH bill may be €45.2/month (60US$/month), their old smaller home's bill was over €150.6/month (US$200/month). The average bill for Premier Gardens is €30.1/month (US$40/month), for Cresleigh Gardens the bill is €42.2/month (US$56/month); the average for SMUD residential bills is €55.0/month (US$73/month). The near-ZEH is 45 per cent less than an average home and 25 per cent less than the energy efficiency home.

Gas savings for the Premier Gardens' homes come from buried ducts, higher efficiency furnaces, improved ceiling insulation and a tankless water heater. The non-ZEH Cresleigh development was designed to surpass California's strict energy code by 30 per cent. The Premier Gardens near-ZEH homes saved an additional 44 per cent over the Cresleigh homes.

System peak demand is a serious concern for SMUD, and utilities across the country. The heat storm experienced in July 2005 in Sacramento is the best opportunity to evaluate peak performance between communities. During July 2005, the average daily high was 36.7°C (98°F), and low was 18.3°C (65°F), the highest on record. SMUD set a new system peak demand 15 July 2005 at 5pm that was 5 per cent above the previous system high.

On average, the demand savings for the Premier Gardens' homes were 60–70 per cent during peaks. However, the demand saving for individual houses varied because of the different PV orientations. As the peak load is in the late afternoon due to air conditioning loads, the west orientation provided an additional 42 per cent demand reduction for a resulting overall load reduction of nearly 80 per cent or 1.3kW peak



Significant savings at peak for the utility due to energy efficiency measures and PV

Source: © Sacramento Municipal Utility District

per house on average. If all the orientations were to the west the peak on average would have reduced to 0.75kW. The reduction in annual energy production from the PV due to the different orientations was not more than 5 per cent (decrease from latitude tilt – south).

Summary of problems, barriers, solutions and recommendations

Builder had insufficient PV expertise

As a medium size home builder, Premier Homes did not have the in-house expertise to design the integrated PV systems. The expertise was provided through the local utility, SMUD and the US Department of Energy, Building America programme.

Fear that broken rooflines would cause problems

Early on there was a belief that the current trend in housing design for broken rooflines would cause problems for PV systems design and reduce energy production. However, broken rooflines are no longer seen as an obstacle in the SMUD service area. Utility involvement with the builder places a value on PV oriented to the west as peak energy production will then more closely match the network load profile of an afternoon peak. The exception to this would be extremely northern latitudes.

References

BUND Regionalverband Südlicher Oberrhein (2002), ‘Veröffentlicht Regionale Umweltgeschichte (Südbaden, Elsass, Nordschweiz)’, http://vorort.bund.net/suedlicher-oberrhein/tag-der-regionen-2002.html, accessed 2 October 2002

Farhar, B. C., Coburn, T. C. and Murphy, M. (2004) *Comparative Analysis of Homebuyer Response to New Zero-Energy Homes*, NREL Report No. CP-550-35912, NREL, Golden, CO

Fesa, e.V. (2002) ‘Die Bewohner machen die Solarsiedlung zu dem, was sie ist: Ein liebenswertes Wohnviertel für groß und klein’, *Die Solarregion*, March, p9

Hanson, M. and Bernstein, M. (2006) ‘The role of energy efficiency in homebuying decisions: Results of initial focus group discussions’, RAND Working Paper, RAND, Santa Monica, CA

Kerr, R. and Baccei, B. (2006) *Occupied Home Evaluation Results*, US Department of Energy Building America Report 12.E.2, November, Washington, DC

Kerr, R. and Baccei, B. (2007) *Building America Research Highlights Report*, US Department of Energy Building America Report 16.A.1, February, Washington, DC

Mayer, A. (2007) *Freiburg und Umwelt: Alles Öko in der Umweltstadt?*, www.frsw.de/oekohauptstadt.htm, accessed 7 August 2007

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

Denmark, Valby, Sol i Valby

Kenn H. B. Frederiksen

Summary

Valby is a suburban area of Copenhagen in Denmark with ambitious environmental targets defined in an environmental agenda. One objective is to have, by 2025, 10 per cent of the annual electricity consumption of the area generated by PV, for which approximately 300,000m^2 of PV modules are necessary.

In order to make the Valby Solcelleværk project successful, several preliminary actions are planned such as:

- a study to assess the potential amount of PV to be installed in the city;
- an educational outreach targeted to local actors and inhabitants;
- the installation of demonstration PV projects financed by different means.

Introduction

Valby is situated a few kilometres west of central Copenhagen and has almost 50,000 inhabitants. The area is, among other things, known for Valby Hill where the zoo is located, as well as a large part of Carlsberg Breweries and Nordisk Film.

The built area of Valby has a residential zone with an equal amount of flats and residential houses. Part of the area has residential houses, shops and offices. In the western part of the area, there is a small industrial zone.

The Valby area is marking its place on the environmental agenda with one of the most ambitious ecological projects in Denmark ever. The goal of this project, coordinated by Copenhagen Energy and Urban Renewal, is to generate 10 per cent of the electricity consumption in Valby on a yearly basis using PV. To reach this goal, there are plans to install a total of 300,000m^2 of PV by 2025. To get things started, it is planned that 5000m^2 of PV be installed before 2012.

The proposed strategy will allow the installation of PV in Valby to provide a model showing how to integrate large PV areas into a whole city in a well-ordered way.

Today the peak load in the Valby area is approximately 25MW. It is planned to reduce the peak load consumption to 20MW by implementing energy saving measures. After that, a PV capacity of 10MW will reduce the load on the public grid by 50 per cent, covering around half of the electricity consumption in Valby on a sunny day.

Description of the PV project

The idea of the Valby Solcelleværk project is to establish one system with several smaller PV systems installed on buildings and urban furniture in suitable areas of Valby. In total, the PV plants will supply a significant amount of energy and cover a large amount of the electricity consumption in Valby.

This project includes the following actions:

- analysis of the city areas to define suitable areas for PV;
- contact with building associations, public institutions and companies, where PV is an option;
- installation of demonstration PV projects;
- creation of computer-generated images of buildings with PV;
- setting up of campaigns and marketing of the different financing possibilities for PV;
- installation of 5000m^2 of PV before 2012.

Potential for PV in Valby

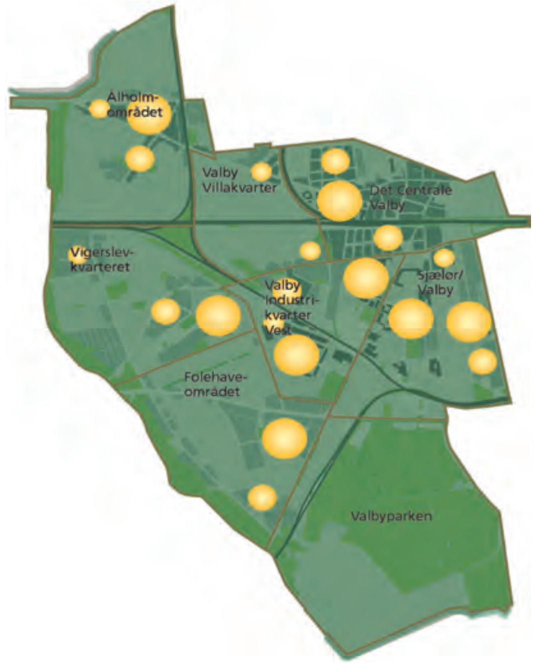
The conclusion of the PV potential study done for Valby was that the city offers about 285,000m^2 of existing roof surface on which 115,000m^2 of PV could be installed, taking into account the existing architecture, roof materials, and the orientation of roofs and façades. A map was designed to show the amount of PV that could be installed in each of Valby's areas. This potential study does not include new reconstructed areas where PV could be installed on walls, façades, small urban furniture etc.

The central part of Valby is dominated by a block of buildings from the 1920s built in red brick with red tiled roofs. In the Ålholm area, located in the northern part of Valby, houses dominate with a few apartment blocks.

The southern Vigerselv area has three-storey terraced houses built around the streets Vigerslevvej and Valby Langgade. The large roofs are very visible from the surrounding areas and not suitable for PV, except for the block 'Valbyholm' and two areas with terraced houses facing south at Handstedvej and Maribovej. Individual PV solutions will have to be implemented in this area e.g. on car shelters and greenhouses and installed with due consideration of the local architecture.

Dialogue with the inhabitants

Early in the beginning of the Sol i Valby project it was recognized that it was necessary to have



Map of Valby with best locations for the installation of PV

Source: © Hasløv & Kjærsgaard

Southern Vigerselv area with large roofs of which only a little will be equipped with PV because of architectural considerations

Source: © Hasløv & Kjærsgaard

the people living in Valby participating in the project. In acknowledgement of this, from the beginning of the project, there has been a focus on dialogue with the citizens, industry and public institutions in the area.

To install 300,000m^2 of PV in an existing urban city area is something of a task – and some buildings are not suitable for PV. Roofs and façades need to have the right orientation in relation to the sun and some of the buildings' appearance and architecture will change dramatically. To meet the challenge and to have the PV plan harmonized with the architecture in the city area, the Valby PV Group made contact with some of the best architects in Denmark, even before the start of the project.

Demonstration PV projects

The Valby PV Group has been working on the project since 1999. One of the first steps in the project was to install PV on existing buildings in Valby. In this way, PV was demonstrated and the plants were used as ice breakers for the larger project plans that followed. At the same time, Valby PV Group wanted to show models of buildings with PV at exhibitions and at discussion evenings with the public.

As part of a previous EU funded THERMIE project, Cenergia has installed approximately 9kWp of PV modules in Valby. Another three small pilot projects with building-integrated PV modules that are cooled by and preheat incoming ventilation air were implemented in Valby in 2002.

The Valby school was equipped with 43kWp of PV on the roof. The system is not visible from the ground and the plant is used as part of the teaching curriculum at the school.

To raise public interest in PV and energy optimization, a CO_2 neutral house was developed and built. This house was equipped with a combined air solar collector/PV roof and was exhibited at Toftegårds Square in Valby.

Due to the high prices for apartments in Copenhagen, many building owners are now using previously unused attics for new apartments. Buildings with flat roofs are also being rebuilt and equipped with an extra storey. In response to this a CO_2 neutral rooftop apartment with PV was developed. The rooftop apartment is a prefabricated building that can be attached onto an existing building with low costs. The apartment is equipped with thin film PV modules used for shading and integrated in the roof windows.

Computer-generated images of buildings with PV have also been created in order to

Valby school with 43kWp of PV on the roof

Source: © Cenergia

CO_2 neutral rooftop apartment with PV developed for the city of Copenhagen

Source: © Cenergia

Computer-generated image of an industrial building with 1500m^2 of PV

Source: © Hasløv & Kjærsgaar)

help building owners to install PV on their buildings. Such a computer-generated image was created for an industrial building equipped with 1500m^2 of PV modules. Combined with electricity and heat savings, a completely CO_2 neutral building design can be obtained. The project is financially balanced over 30 years taking operation, maintenance and the costs of investments (including 50 per cent funding of the PV installation) into consideration. The project idea is now under development.

Financial and sustainable plans

From the start, the Valby PV Group has worked on securing a reasonable economy in each project planned in Valby. During the first years, Valby PV Group will rely on public support for the project and will seek to find alternative finance schemes so that PV plants will be cheaper for private citizens to buy and so that businesses and public institutions will be willing to install some plants.

Nevertheless, the Valby PV Group expects falling prices for equipment on the PV market and rising electricity prices to ensure that in a few years PV could be sustainable in itself. In the long term, the Sol i Valby could be financed by private investments.

Status of the Valby PV project and plans for the future

The current focus is on planning issues to obtain an optimized result for the implementation plan for PV systems in Valby. Actions may include an architectural competition on how PV modules can best be integrated on a number of different building types. For this reason, visualization of where PV modules can be installed in Valby is necessary and the Danish architects Hasløv and Kjærgård have made such a visualization.

In connection with the expected demonstration projects with building-integrated PV, subjects such as ownership of the PV systems have to be clarified. For example, ownership could be shared between the utility company, building owner and maybe the local authorities, possibly organized in some kind of PV association.

One idea that seems very interesting is to establish sales of green PV electricity for environmentally concerned consumers, e.g. as in the PV stock exchange in Switzerland.

It has been suggested that the work on PV implementation should be combined with an effort on energy and electricity savings in general.

At the moment, promotion work is being done, which includes a website (www.solivalby.dk). Funding has been obtained from the EU for the first part of the project, which is linked to the EU energy demonstration project 'Resurgence' with five countries involved (UK, Denmark, The Netherlands, Switzerland and Germany). Some supplementary funding will also be provided from the Danish SOLAR 1000 programme.

It has been decided by the Valby PV implementation council that the use of PV should be part of an overall energy saving and a 'solar city' policy where existing buildings as well as refurbishment projects should be optimized for maximum energy savings.

Summary of some of the problems, barriers, solutions and recommendations

Economic

The major barrier in the project is the cost. With the high initial investment in PV, the systems need some kind of support. There is no feed-in tariff in Denmark and therefore the building owners interested in the projects have to use net metering, and this is not economically attractive enough to provide an incentive to invest in PV.

The Sol i Valby project has applied for support from national and EU support schemes. With the support raised, it has been possible to install PV systems at a lower price. Another approach has been to offer PV systems as a BIPV product with multiple functions. The house owner is often willing to invest extra, if the system can also be used, for example, as shading. Another way to optimize the financing for the PV system is to combine it with a package of energy saving measures, which can reduce the financial payback time for the PV system itself.

Lack of knowledge about PV

There is a lack of knowledge about PV and how it can be used on buildings. There is no normal

Interview with Holger Blok

Photovoltaics is one of the most significant sources of energy for the future. This technology offers unique possibilities to implement renewable energy in buildings due to its clean nature and the fact that power production takes place without noise, harmful emissions or waste products. Furthermore, PV offers other benefits, as it can fulfil useful functions besides energy production, for instance solar shading in building-integrated applications.

In my opinion, PV will have a major influence on energy companies such as EnergiMidt, as an increasing proportion of domestic electricity consumption will be produced by individual building owners. This will reduce turnover at the primary business of the branch, which is delivery of electricity. This change in market conditions will be a great challenge for the electricity sector. I firmly believe that PV will create new business opportunities that will more than compensate for the losses caused by reduced turnover on electricity delivery.

Given that the consumer price of electricity is expected to further increase and that the cost of PV will definitely drop further, grid parity will eventually occur. I expect that the interest in PV among our customers, and therefore our business opportunities, will grow significantly. For this reason, energy companies should turn from being electricity providers to being total suppliers of energy services.

Holger Blok is President CEO of EnergiMidt A/S, the local energy and broadband company of the mid Jutland region of Denmark with 172,000 customers

Source: © EnergiMidt A/S

market supply situation, so it is a challenge for a potential customer to get professional advice if they want to have a PV system. The lack of knowledge can be seen among all stakeholders.

The Valby neighbourhood council was one of the organizations that founded Solar City Copenhagen (SCC). SCC has the objective of establishing Copenhagen, including Valby, as a demonstration and development centre for solar energy systems and energy optimization. Stakeholders with questions about PV can contact SCC and get professional assistance. SCC can also help with support for architectural and technical consultancy in the planning stage of a PV system. Public information meetings have also been held outside working hours to give people the opportunity to get more information and to ask questions about PV.

Municipal urban plan

The municipal urban plan does not allow PV on the most visible places on buildings due to the aesthetics. To solve this issue new solutions for flat roof PV systems and integration methods have to be developed and tested.

France, Lyon, Lyon-Confluence

Bruno Gaiddon

Summary

Following on from the successful earlier projects of Les Hauts de Feuilly and La Darnaise in the Grand-Lyon area, PV is now being included in a major development site at the heart of Lyon on the peninsula formed by the Rhône and Saône, Lyon's two rivers. Lyon-Confluence is the name of the southern part of this peninsula. For a long time it was given over to industry and transport logistics, but it is now undergoing a radical change. Major development projects here over the next 30 years will double the area of Lyon's city centre. Renewable energy and sustainable development are now important elements in the development but this was not originally the case. PV initially had a poor image; it was not considered relevant to high-density urban areas or adapted to the high architectural quality of the project. Now opinions have changed and PV is acknowledged as an easy technology to deal with, well suited to large-scale urban projects.

Introduction

Grand-Lyon is a conurbation of 1.4 million inhabitants, the second largest in France, and is located close to the Swiss and Italian borders. At the heart of Lyon is the peninsula formed by the Rhône and Saône, Lyon's two rivers. Lyon-Confluence is the name of the southern part of this peninsula. Reclaimed in the past from both rivers, the site is now returning to its riverbanks and natural setting, with ongoing development highlighting a remarkable space and a unique landscape. Ultimately, the project will double the area of Lyon's city centre: a rare achievement in Europe, a real challenge for the metropolis and a great opportunity for residents.

With Lyon-Confluence, Grand-Lyon has opted for attracting to its centre the jobs, services, institutions and major events that characterize capital cities, contributing to the city's international future.

The project aims to:

- create a new central-city neighbourhood to enhance Grand-Lyon's prestige and influence;
- reclaim industrial and logistics wastelands;
- open up the south of the peninsula, notably via the use of public transport;
- highlight the two rivers and the site's landscape;
- provide innovative, attractive forms of urban leisure.

Since its creation in 1999, SPLA Lyon-Confluence, the semi-public company in charge of city planning, has been pursuing a concrete, balanced sustainable development programme.

Description of the urban plan developed and its evolution

Within the Lyon-Confluence area, PV will be first installed in three sections of the development estate composed of 620 dwellings, offices and shops. Up to five emblematic buildings will also be equipped with PV and probably more in the future.

Supported by a study carried out in late 2000 by a team of planners and architects, the challenge is to establish a new city centre through a 30-year plan including more than 1,200,000m^2 of new buildings (housing, commercial, services and cultural infrastructure), plus the refurbishment of roughly 60,000m^2 of an existing residential area.

Political impetus towards sustainability as a major axis of the project was given by the new municipality elected in 2001. There is now a comprehensive approach to sustainability including ground de-pollution, transport reorganization, waste management, water conservation and sustainable energy.

Overview of the Lyon-Confluence area at the beginning of the project

Source: © Desvigne Conseil pour Lyon Confluence

Site plan of the Lyon-Confluence area at project completion

Source: © Asylum-Axyz pour Lyon Confluence

In 2003, an environmental study was carried out by a specialist engineering office in order to analyse environmental options of this development. The study concluded that the main weaknesses of the project were a lack of consideration of energy efficiency and renewable energy sources.

In order to correct this, SPLA Lyon-Confluence set up an informal group composed of local experts to submit ideas and help it define the energy strategy of the project. Discussions focused on the energy performance of buildings and the relevance of renewable energy sources. It became apparent to participants of this group that the development should be emblematic in terms of energy efficiency, but there was no consensus on the level of performance. A fear of over-costs and innovation preventing the commercialization of buildings led some participants to propose designing buildings just slightly more efficient than the regulations and equipped only with solar thermal collectors for domestic hot water.

Hespul, a consultancy organization and a participant in the group, highlighted the opportunity provided by a call for proposals launched by the European Commission, the CONCERTO initiative, set up to support innovative urban projects and define ambitious goals in terms of energy efficiency and renewable energy sources. In December 2003, a proposal was submitted to the European Commission relating to the first housing to be constructed in the area. The objectives set out in this proposal were:

- a maximum energy consumption for heating of 60kWh/m^2/year (40 per cent less than the then French regulation);
- 80 per cent of heat and domestic hot water demand from renewable energy;
- 50 per cent of electricity demand for communal areas from renewable energy.

When, in March 2004, the European Commission evaluated this proposal and ranked it in first position, SPLA Lyon-Confluence immediately upgraded its guidelines for the selection of developers that provided architectural and environmental requirements with the technical details of the proposal.

In January 2005, three developers were selected to each build one section of the estate, following the architectural, environmental and energy guidelines provided. Buildings designed by each developer included wood chip fired boilers, solar thermal systems and PV in order to comply with the renewable energy requirements of this guideline.

The RENAISSANCE project is a European Commission funded project under the CONCERTO initiative that involves the construction in Lyon of 75,000m^2 of energy efficient eco-buildings equipped with renewable energy systems.

As part of the RENAISSANCE project, three sections of estate are under construction and will be equipped with PV:

- 80kWp on the A section developed by Nexity Apollonia;
- 100kWp on the B section developed by Manignan Bouwfonds;
- 50kWp on the C section developed by ING Real Estate.

The experience gained within RENAISSANCE led SPLA Lyon-Confluence, the semi-public entity in charge of city planning, to upgrade its guidelines for the construction of other buildings to include requirements to install PV. Thus PV will also be installed on other emblematic buildings in this area:

- Le Progrès headquarters, the local newspaper;
- Eiffage headquarters, a large building company;
- the Regional Council building;
- the Natural History Museum.

Over a two-year period, meetings and workshops were organized to assist architects, engineering offices and developers of this project to finalize building design. Discussions focused first on building envelopes in order to reach the energy consumption targets without affecting the architectural appearance of buildings. In the second stage, discussions focused on wood chip fired boilers and on PV systems. These were at first seen by developers as irrelevant and impractical for this kind of urban project.

A series of site visits, training courses and technical analysis finally convinced the developers that PV was not a difficult technology to deal with, although some questions about price were still pending. The success of the commercialization of the first dwellings in 2006 definitely ended the discussions about the price of PV and showed developers that energy efficient buildings have a market, with no negative feedback received during the sale of dwellings.

At the time of writing, most infrastructure works for this development, such as the harbour inlet, parks, roads, networks and the tramway were completed. The first sections of the estate were still under construction but the success of the project has already had several significant impacts at local and national levels.

At a local level, SPLA Lyon-Confluence adopted the energy guidelines used for the first buildings in other buildings in the Lyon-Confluence area. Consequently, PV will also be installed on several other emblematic buildings in this area such as the headquarters of private companies, the Regional Council building and the Natural History Museum.

Office building of the Lyon-Confluence area with PV shading devices

Source: © Bremond/Lipsky-Rollet, Asylum pour Lyon Confluence

Model of energy efficient buildings equipped with PV and other renewable energy systems to be constructed in the Lyon-Confluence area within the CONCERTO EU funded project

Source: © Depaule/PAD/Asylum pour Lyon Confluence

PV on the roof of Le Progrès headquarters, the local newspaper in the Lyon-Confluence area

Source: © SPLA Lyon-Confluence

At a national level, other semi-public companies in charge of city planning included energy requirements in their guidelines for the selection of developers as successfully done by SPLA Lyon-Confluence.

Summary of problems, barriers, solutions and recommendations

Lack of RE systems in global project focused on sustainable development

In 2003, an environmental study carried out by a specialized engineering office to analyse environmental options for this development concluded that the main weaknesses of the project were the lack of energy efficiency and renewable energy measures.

In response, an informal group of local experts was set up by the semi-public company in charge of urban planning to help define an energy strategy for the project. The CONCERTO call for projects launched in 2003 by the European Commission was of great help in setting energy consumption and renewable energy supply targets.

How to make developers design energy efficient buildings including PV?

Lyon-Confluence aims to showcase best practice in terms of design and construction of energy efficient buildings. The objective is not to install PV on buildings that are not energy efficient but to design and construct architecturally pleasant and energy efficient buildings powered by renewable energy sources.

Instead of requesting a defined power to be installed per building, the guidelines state the share of the total electricity consumption to be provided by renewable energy sources. This has the effect of making rational use of energy measures more cost-effective since any additional investment in energy efficiency will reduce the investment in PV. The more efficient buildings are the less PV will be installed!

Lack of knowledge of engineering offices and developers

Although the guidelines for the selection of developers gave some requirements on the need to have in the team an engineering office specializing in energy efficiency and renewable energy systems, it appeared that none of its members had any serious experience in PV.

As part of the CONCERTO project, a team of local specialists was set up to assist engineering offices and developers at all stages of the project, from the preliminary design to the commissioning of PV systems. This local team also organized site visits and training sessions and will help developers in dealing with a complex financial scheme with multiple sources of funding.

Is PV a technology suited to buildings of high architectural quality?

The architectural quality of the Lyon-Confluence project is high with each architect's team in charge of a section of the estate under the leadership of a world-recognized architect. Prestigious names such as Tania Concko, Massimilliano Fouksas and MVRDV are associated with the project. In addition, Lyon has two world heritage listed districts next to which the installation of PV on roofs may be complicated or impossible. This was why, at the beginning of the project, the semi-public entity in charge of urban planning wondered if PV was a technology really suited to buildings of high architectural quality.

PV is of course a technology suited to high architectural quality buildings. But in order for PV to be integrated in buildings in a pleasing manner, whether the choice is to make it highly visible or invisible, the architect has to take it into account at the beginning of the building design process, otherwise PV will give the feeling of being added to the building at the last minute. In most cases, architects will find good opportunities to integrate PV into the building design but it is always necessary to make sure that PV will operate under acceptable technical conditions. In Lyon-Confluence, although most of the PV modules will not be easily visible, PV increases in some cases the global aesthetic of the development since it is used to build homogeneous surfaces that cover and therefore hide technical systems generally installed on roofs, such as ventilation. In addition, as standard PV modules are generally less expensive than custom-made PV products, architects and engineering offices of this project choose to use standard PV modules and find a way to install them in an architecturally pleasing way.

Present distribution network design guidelines not adapted to new urban plans with PV

During the design stage of the project, it appeared that the distribution network operator's usual way of designing distribution networks is not adapted to new urban plans with PV. Presently, the DNO can design new distribution networks according to the type of buildings to be supplied with electricity and their distance from transformers, but cannot take into account distributed electricity generation during the design phase, since the DNO requires detailed information about the power plants that cannot generally be provided at this stage. The main risk is that due to a lack of anticipation by the DNO, additional infrastructure work will be necessary in order to connect PV systems to the newly built grid, leading to high grid connection costs.

As soon as the semi-public entity in charge of urban planning was alerted to this specific problem, it organized a technical meeting with the DNO to find a way to take into account the fact that several buildings would be equipped with PV. The objective was to correctly size the new distribution grid to avoid any additional infrastructure work once buildings were completed and PV systems ready to be commissioned. Particular attention is now paid to the location of medium voltage/low voltage transformers and the size of transformer feeders to make sure that each PV system can be connected to a strong enough low voltage grid.

Germany, Berlin, solar urban planning

Sigrid Lindner

Summary

The fall of the Berlin Wall led to development opportunities in the centre of Berlin. The municipality commissioned a solar urban master plan for the city in order to determine the solar potentials of the different city quarters. An analytical solar planning process was performed where 20 types of city quarters were identified, each with a solar potential determined by their history, structure and utilization. Specific areas were selected as high priority areas for solar development. This assessment was combined with an urban renewal programme and a PV campaign was planned to inform building owners of the possibilities of PV and motivate them to invest in PV. The municipality's role is limited to the provision of information and encouragement. No obligations are imposed and the municipality is not responsible for the design of new developments, which are the responsibility of owners and developers. However, robust analytical data, with information on shading and potential outputs, are provided to potential investors.

Introduction

Berlin is a city with a unique history of urban development due to the division of the eastern and western parts. Areas situated in the very centre of the city have not been developed because they were close to the borderline. Now those areas have a huge potential for urban renewal. Situated in the middle of a capital and surrounded by a strong infrastructure, many areas have been reactivated. However, there are still many areas in need of new development. Urban renewal in Berlin represents an opportunity for the implementation of building-integrated

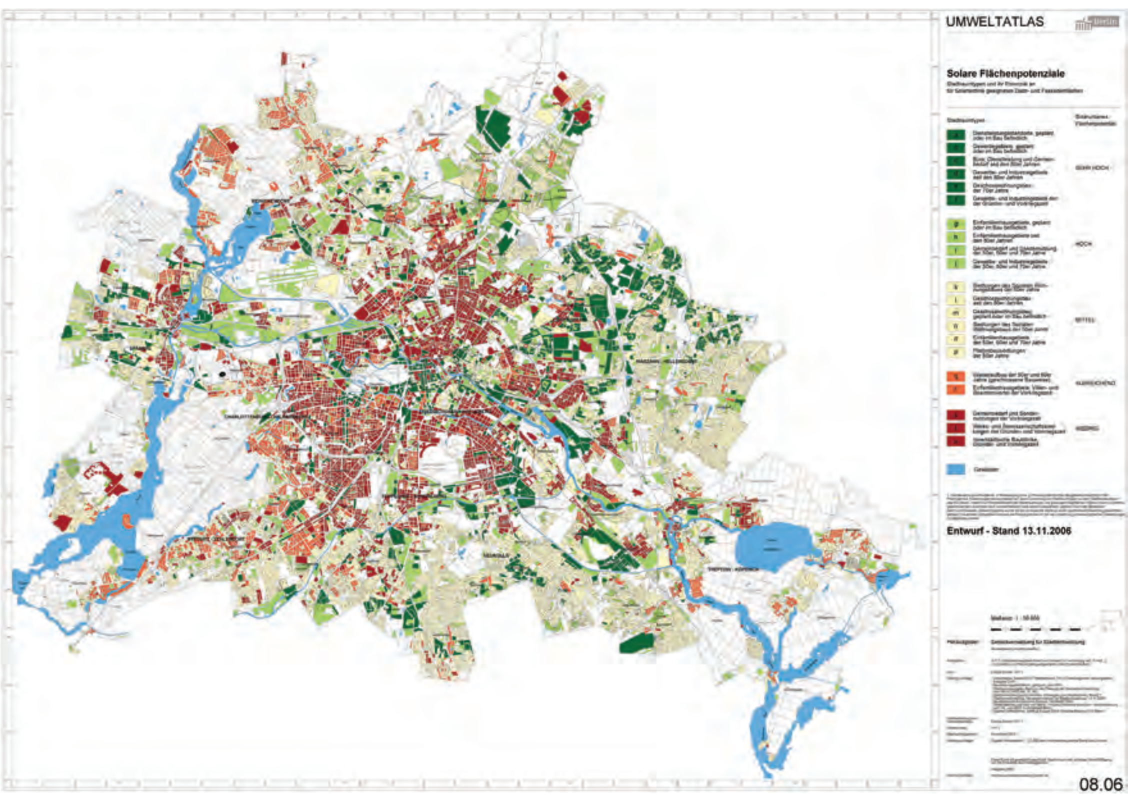
Berlin skyline

Source: © extranoise, Creative Commons

PV systems. The building stock was assessed and areas with high solar potential on building surfaces identified to allow the integration of PV in the urban area.

Project development

The solar urban master plan for the city of Berlin was created by Ecofys in 2004 at the request of the City Council in order to determine the solar potentials of the different city quarters. During the solar planning process, 20 types of city quarters were identified each with a solar potential determined by its history, structure and utilization. The solar grading factor, an instrument that relates the solar potential of



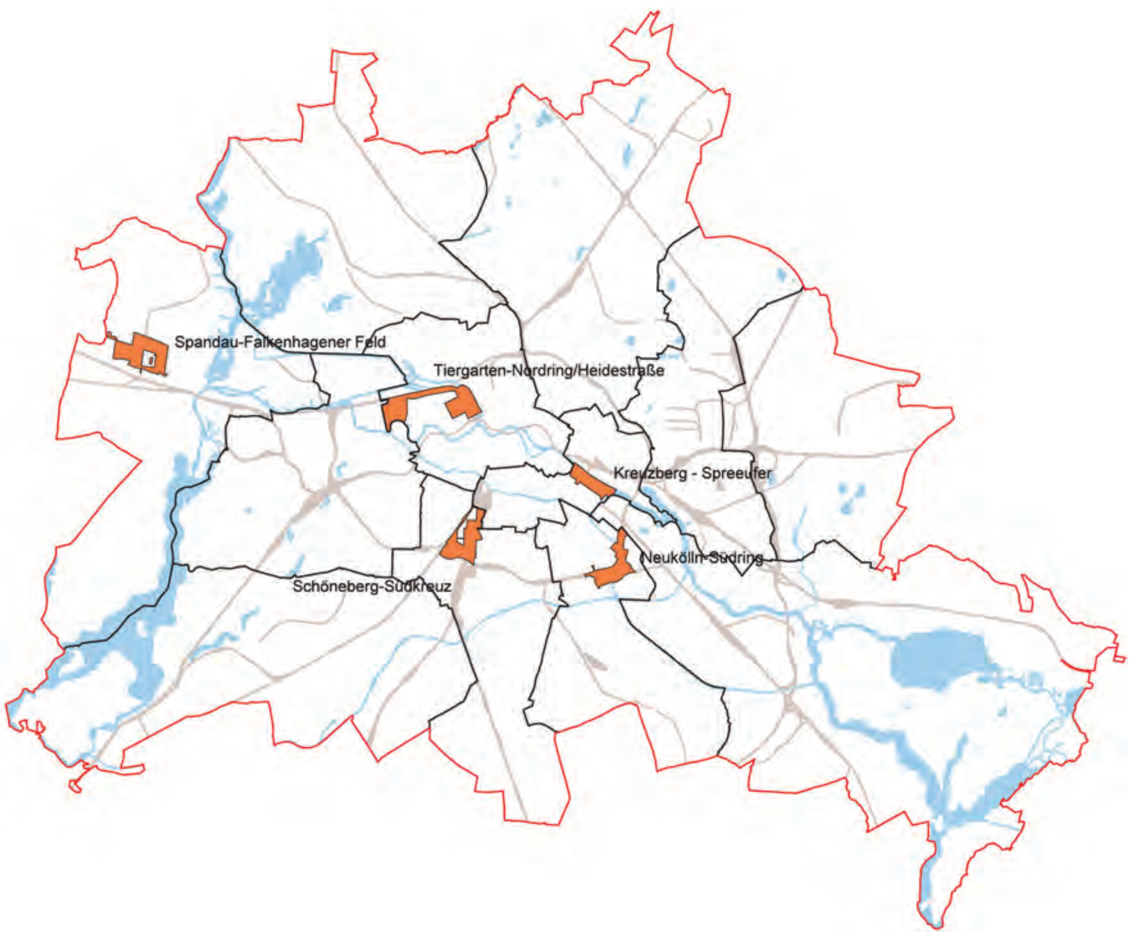
Map of solar urban potential

Source: © Senatsverwaltung für Stadtentwicklung Berlin buildings to the net building land of an area, was used to present the solar quality of certain areas in a simplified way. Based on the solar grading factor specific areas were selected as high priority areas for solar development.

This assessment has now been combined with additional information such as the demand for solar heat or the possibilities of new planning or urban renewal. Architectural conditions related to the buildings such as conservation of historic structures were considered as important as the technical feasibility and the urban situation.

The Urban Renewal West programme of the German Ministry of Building and Regional Development targets urban planning. This programme aims to formulate strategies for urban areas with declining construction activity because of structural change. The areas are affected by rebuilding, wasteland and a lack of urban structure. By rearranging the urban situation and investing in infrastructural measures, the programme aims at initiating private actions.

The solar urban master plan had identified the solar urban potential of the different city



Map of renewal areas

Source: © Senatsverwaltung für Stadtentwicklung Berlin quarters of Berlin. A planning workshop was held to combine the urban renewal programme with solar targets by identifying specific areas with a high solar and developmental potential.

Planning

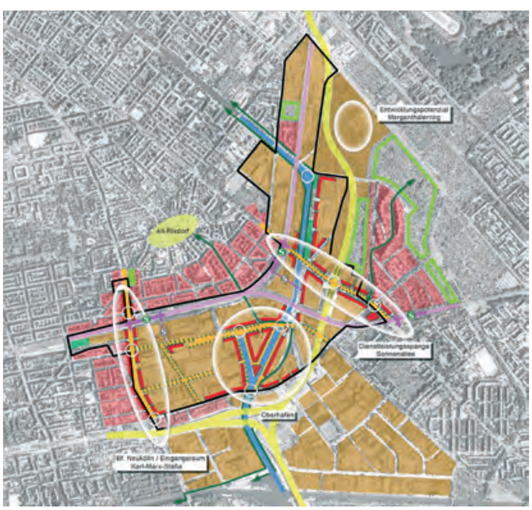
The planning workshop was held in Berlin in July 2007 and brought together the planning team for the urban renewal programme, in this case the Berlin urban planning office and representatives of the urban development department commissioned with renewal planning, and people involved in the solar planning process. The key question was how to transform the knowledge and the proposed measures of the solar urban master plan and the activities of the renewal process into actual projects.

It was hoped that ongoing actions within the urban renewal process could be used to hook solar topics and implement solar requirements in the different city areas.

A list of measures was proposed connecting renewal activities with possibilities for the integration of solar systems. The industrial area of Neukölln-Südring situated in the inner city and already included in the renewal programme was chosen to establish a project because of this strategic planning. Within the area of Neukölln-Südring trade and industrial areas from the period 1950–1970 and trade and industrial areas from the 1980s are predominant.

Roofs of Berlin with Neukölln in the distance

Source: © Secret Pilgrim, Creative Commons



Urban plan renewal area

Source: © Senatsverwaltung für Stadtentwicklung Berlin

The large buildings in industrial areas from the post war period have one of the highest solar potentials. However, most of these industrial buildings have little or no demand for space heating and no demand for water. Therefore, this type of city area is well suited to the application of PV systems. The overall potential of the complete quarter regarding solar power generation was calculated as 33,500MWh/year.

The renewal programme for this area included the establishment of a business network with the companies involved in the industrial park Neukölln-Südring. The city council planners of Berlin and the urban planners commissioned for that project created a platform in order to improve communication between the companies and to motivate new investors to decide on this location because of the high potential for new development.

As result of the workshop, it was agreed to use this local network as a platform to spread information on the possibilities and potential of solar systems by creating a solar roof campaign.

Implementation

The implementation of the solar roof campaign within the urban renewal programme was planned as a pilot project with the objective of combining urban renewal and the mobilization of solar urban potential. The business network will be used in order to get access to the owners of the roofs and façades of this area, to motivate them to invest in PV and to inform them about the possibilities of financing or contracting.

The PV campaign may consist of:

- realization of information events;
- generation of a roof register;
- technical and economic assessment of the roofs.

The urban planning office arranged a PV campaign for 2008.

Barriers and solutions

Regarding the implementation of solar targets within existing building structures the main barrier identified has been the unwillingness of private companies to invest. The mobilization of solar potential depends on the willingness of private investors and mostly their interests are very different. To mobilize the potential of a complete city quarter, strong incentives are needed to get people involved. Awareness of the possibilities of PV systems within urban space, and particularly in combination with urban renewal, is not very high. Many chances to install PV in public spaces, for instance, are missed. Town planning should focus on solar potential and consider it in the planning process from the beginning. Another barrier is located within the structure of municipalities and their internal communication. Gaps in communication between departments and diverse allocation of responsibilities can lead to delays of the implementation process.

Recommendation

This example shows how the solar potential of the existing building stock can be mobilized in connection with the urban renewal of city quarters. The methodology can be used for regions with a similar structure and similar problems. Another possibility for more residential areas is the creation of shareholding PV systems. These are initiatives in which a cooperative of neighbours or citizens owns a PV system. A solar campaign can detect potential roofs and bring the different stakeholders together.

Germany, Cologne-Wahn, solar housing estate

Sigrid Lindner

Summary

Close to the centre of Cologne but in a rural area a new solar housing estate is planned. Cologne-Wahn is a formerly independent village around the castle of Wahn. Now it is part of the city of Cologne. The landowner of an estate close to the castle plans to build a solar housing estate with around 120 dwellings.

This project is not so much due to policies of the local municipality as to a subsidy programme of the state of North-Rhine-Westphalia for solar housing estates. The programme has specific requirements for active and passive solar energy including either 1kWp of photovoltaics per dwelling or a share of 60 per cent of domestic hot water generation by solar thermal systems.

The landowner decided he was willing to invest in the development of a solar housing estate and invited eight well-known architects to realize an urban plan consistent with solar requirements and building types fitting the concept of solar housing. The work was embedded in the scope of an official architectural competition.

Introduction

This project concerns the realization of a solar housing estate on the outskirts of Cologne.

Visualization of competition contribution

Source: © LINK Architekten + RMP Stephan Lenzen Landschafts-architekten

The project provided a chance to create a solar estate starting from the earliest stages of urban development. Solar planning aspects like the distance between buildings, shading and orientation of the main façades and roofs were included; the result should be an optimized structure of the area.

It is planned to establish a new solar housing estate close to the centre of Cologne but in a rather rural area. The area is situated between a train station and rail tracks on one side and the castle of Wahn on the other side. The landowner of the area plans to create a solar housing estate with around 120 dwellings. A new quarter with its own character will be established. The creation of the solar housing estate is connected to the overall target of the project, which aims to bring together families, single people and older people in a village way of life.

Stakeholders involved in the development

In order to get a variety of ideas on the creation of a solar housing estate of this size, the landowner invited eight well-known architects to prepare an urban plan consistent with solar requirements and including building types fitting the concept of solar housing. The project is part of a special programme of the energy agency of North-Rhine-Westphalia stimulating the development of solar estates with a subsidy programme.

The work was carried out in an official architectural competition. The solar qualifications of the designs were presented to a professional jury after pre-judging by the consultancy firm Ecofys. The jury, composed of urban planners, architects and local politicians, chose the winner of the competition. The winning design should now be implemented through a private investor.

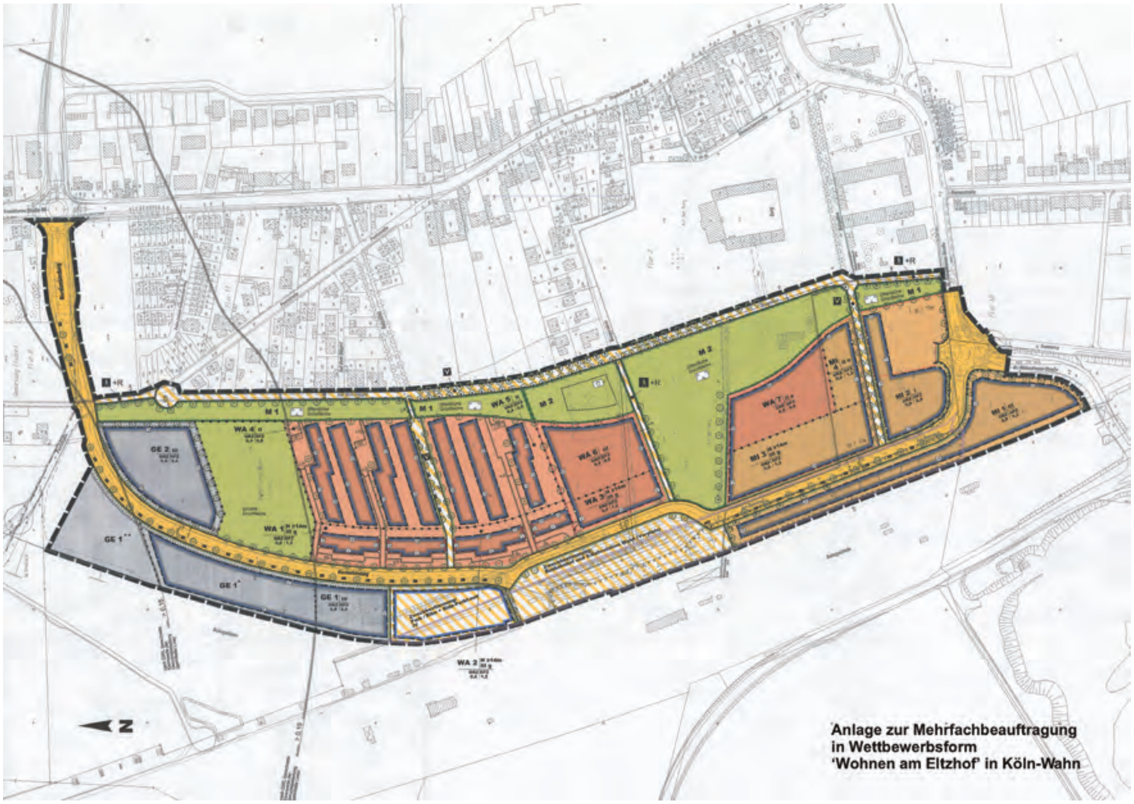
Development of an urban plan

A local plan for the area already existed but there was still scope for detailed solar planning. The western part of the area is close to the train tracks so the plans needed to include an acoustic barrier to protect the area from train noise. To provide this acoustic shelter, the buildings had to be 14m in height, which could have led to shading problems. A sufficient distance between the north–south oriented buildings was important to avoid shading adjacent buildings.

To satisfy all the demands of a solar estate, specifications for the urban planning were developed covering solarization, solar area potential and solar systems per building type. Eight urban plans, including design proposals for the building types, were prepared. The feasibility of all the plans was assessed using a point system with different categories of evaluation for urban planning and architecture.

The targets for the area covered issues including energy, housing density, probable costs, design and atmosphere, and feasibility of implementation. All the submitted designs were judged feasible solar estates. The plans are considered as preliminary drafts with possible further adaptation in the implementation phase.

Because of the variety of requirements, other issues as well as the solar aspects were crucial for the final decision of the jury. The design awarded the most points for solar requirements was judged too expensive and not realizable. The proportion of glazing in the walls within this plan was very high and the necessary shading devices would increase the price significantly. Some other plans were disqualified due to the



Site plan of the Cologne-Wahn project

Source: © Stadt Köln

specific style of the building designs or the lack of an integrated concept for the entire area.

Finally, the jury selected a winning plan that will be the basis for later implementation, shown below. The structure of the urban plan provides distance between the buildings. The different types of buildings are clearly arranged according to the orientation needs. For the north–south oriented buildings, the entrance is on the northern side with the main façade oriented towards the south. The row buildings on the west border open up towards the west with entrance terraces. On the top levels the orientation changes towards the east.

The roofs of the buildings are inclined to the south or east at 5°–10°and are designed for the installation of PV systems. The installation of 9m^2 of PV modules per dwelling (1kWp) is a challenging target for the multi-family buildings. Additional solutions like integration of PV modules in the façade or the balustrade of the terraces are possible. For the one-family buildings, the required area of PV can easily be integrated into the southerly oriented roofs.

Implementation

The project is currently in the first implementation phase with negotiations with possible future investors being carried out.

Additionally an energy supply concept for the complete area has been commissioned by the owner of the land in order to achieve the best solution. The strategy of assessing possible

Competition contributions

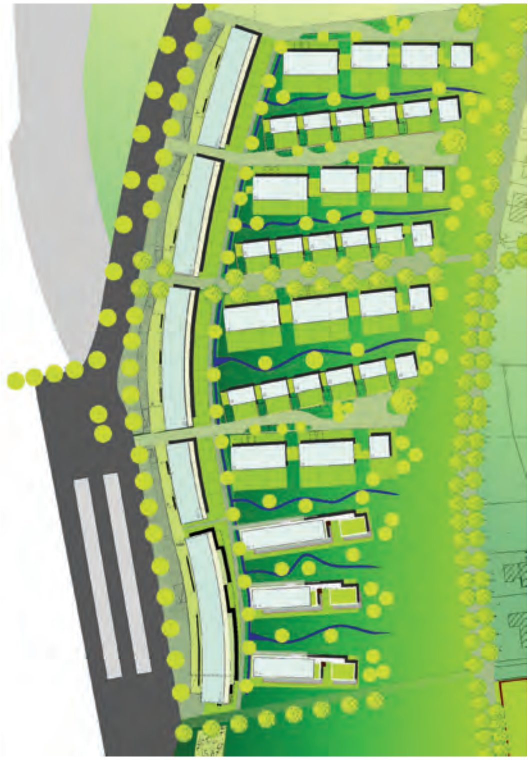
Source: © LINK Pässler, Sundermann und Partner Architekten; Schmitz-Helbig Architektur; Hahn Helten + Assoziierte Architekten GmbH; Eller + Eller Architekten GmbH; Hellriegel Architekten BDA; LINK Architekten + RMP Stephan Lenzen Landschaftsarchitekten; Architekturbüro Schönborn; Architekturbüro Kölsch

options before detailed work starts on the project will provide a firmer basis for planning for future investors. Solar thermal systems will contribute to the overall energy performance of the buildings and decisions to include them will hopefully be taken even if the buildings were initially designed for the application of PV systems.

Barriers and solutions

The main barrier expected in the implementation of the project is the acceptance of the solar concept by future investors and a willingness to pay for the extra costs involved. A very precise calculation regarding density, price and additional solar targets will answer the question concerning economic efficiency. The promotion of 'green buildings' with solar applications such as PV systems can serve as a marketing tool, but only if future owners are willing to invest more than they would need for a standard building.

A particular barrier for PV is that solar power does not contribute to the energy performance of a building according to the calculation method applied under the current German energy saving directive (EnEV 07). This directive focuses on the thermal performance of a building so only solar heat is assessed as contributing to the energy performance of buildings. The installation of solar thermal systems would be an option to reduce the primary energy demand of the buildings.



Urban plan selected by the jury

Source: © Pässler, Sundermann und Partner Architekten

The implementation of solar targets is still considered as an additional optional extra. The different stakeholders in the development and planning process each have their own specific priorities in building projects. An integrated holistic approach can only work if the persons involved are familiar with solar urban planning or they are willing to accept the needs of solar architecture.

If preliminary development of the local plan follows solar requirements then subsequent planning is made easier. Changing a local plan later to allow for solar requirements is difficult to accomplish. It is important to inform people involved in the urban planning process about the effect they can have on later maintenance and energy supply costs. Otherwise, the focus is only on the direct investment costs and does not support long-term sustainability.

Computer generated image of buildings

Source: © Pässler, Sundermann und Partner Architekten

Recommendation

The development of a solar housing estate fitting in with an existing local plan and the associated risks concerning finance and sale of the houses are relevant to newbuild solar architecture. In this particular project, the landowner took this risk and invested at the beginning in the creation of options for achieving a solar estate in the best possible way. The willingness to push a development in this direction is a prerequisite for the successful formation of this kind of project.

Germany, Gelsenkirchen-Bismarck, solar quarter

Sigrid Lindner

Summary

Gelsenkirchen is a former industrial city in Germany going through a structural change. Known as the city of 1000 fires (coal mining), a new sustainable mission (city of 1000 suns) was

Interview with Andreas Gries

In my opinion, the topic of energy in the building sector includes both heat and electrical power supply. In this context, the potential of all renewable energies should be used. Surely the emerging reduction in costs for PV will contribute to a strong increase in its attractiveness. For myself I wish that by 2020 it will be possible to build settlements which cover their demand for electrical power and heat completely from renewable energies. By then I hope that we will have developed appropriate solutions, e.g. for the necessary energy storage within the building sector.

With our project for 50 solar settlements in North-Rhine-Westphalia we have already realized a whole range of projects in the new building and redevelopment sectors. One of the most important experiences gained from these projects, apart from the energy inputs, is the contribution to an identity and the visibility of solar technology. A solar settlement in Cologne Bocklemünd, started by the local housing company, has upgraded the quarter. These solar settlements lead to reduced additional expenses, which improve the renting situation in the existing building stock and provide security against rising energy prices for the occupants.

Regarding the economic aspects, the solar label on its own cannot justify the incremental costs. The solar settlement leads to reduced additional expenses, which improve the renting situation in the existing building stock and represent a security against rising energy prices for the resident families within the new building sector.

Taking the sharp increase of energy prices into account, I do not see any alternative to energy efficient building and renovation with an added integration of renewable energies. With the renewable energy heat law in Germany, the first step to codify it legally has been achieved.

Andreas Gries is responsible for the programme 50 Solar Housing Estates at the North-Rhine-Westphalia Energy Agency in Germany

Source: © North-Rhine-Westphalia Energy Agency

created to support the structural change. As part of this mission the city provides and supports:

- local agenda network (energy and environment);
- climate protection in schools (information and implementation);
- solar urban planning;
- energy consultancy;
- installation of solar systems on communal buildings;
- solar round table;
- website.

The mission has led to economic and education benefits for the city. Now a solar quarter is planned on derelict land from a former power station, close to a waterway. The area will include residential and office buildings, trade, commerce and recreation, with high requirements for energy efficiency, solar urban planning and applications of solar systems. The quarter is predicted to include 2000 work places and 700 dwellings. In an innovative approach the city is imposing solar requirements in the contract of land purchase.

Introduction

A solar quarter is planned in Gelsenkirchen on derelict land from a former power station, close to a waterway. The area will include: residential and office buildings, trade, commerce and recreation with high requirements for energy efficiency, solar urban planning and applications of solar systems. The quarter is predicted to include 2000 work places and 700 dwellings. In an innovative approach the city is imposing solar requirements in the contract of land purchase. This approach was possible because the State Development Association (LEG) is the owner of the land.

Area in the 1970s

Source: © City of Gelsenkirchen

Area today

Source: © City of Gelsenkirchen

The sustainable mission – city of 1000 suns

In 2001, the City Council of Gelsenkirchen, together with the Ministry of Urban Development, decided to create the mission of a solar city. The overall targets to reach this goal were expressed in the concept 'Solar City Gelsenkirchen', developed by the University of Wuppertal and Aachen in cooperation with the consultancy Ecofys. The objective of this study was to identify future fields of activity and benchmark basic objectives.

Based on the structural change the city was undergoing, a marketing strategy was created, which includes a voluntary commitment to sustainable and solar development. An overall emission target has been set of 3.3 tonnes CO_2 annual emissions per inhabitant by 2050. Partners from industry, trade, science and solar associations are cooperating to enhance the research, development and appliance of solar technologies.

The city of Gelsenkirchen is the driver towards this development. As part of this mission the city provides and supports:

- local agenda network (energy and environmental);
- climate protection in schools (information and implementation);
- solar urban planning;
- energy consultancy;
- installation of solar systems on communal buildings;
- solar round table;
- website.

The mission has led to economic and educational benefits for the city including:

- new research institutes targeting solar development;

- production plants of solar cells and modules;
- establishment of various solar systems on trade, industrial and residential buildings;
- education options with a focus on solar technologies.

Development of an urban plan for the solar quarter

The structural change the city was going through provided a useful background and reasons to create something new. A former industrial area was chosen to be converted into a solar quarter, in line with the commitment to become a solar city.

The LEG was asked by the city of Gelsenkirchen to develop the complete quarter in accordance with an urban master plan designed by Scheuvens+Wachten, an urban planning office. In addition, an energy concept was prepared by the Gertec engineers in cooperation with Ecofys. As a result an investor manual was published, which includes commitments to solar architecture and technical needs for the application of solar systems. The City Council is involved in the decision-making process and is responsible for ensuring compliance with the primary targets of the project.

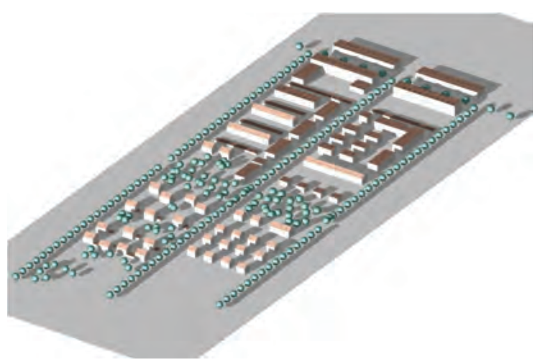
A review workshop was held with participants from the City Council, the LEG and the engineering office to gather information on the planning process, from the early stage of development and urban planning to the implementation of the project. This workshop focused on the identification of potentials and barriers for solar urban planning. To create an overview of the results of the different parts and phases of the project a questionnaire was generated and presented to the participants.

Solar requirements

The long-term climate protection target of 12.5 kgCO_2 annual emission per square metre floor area can be reached through low energy buildings and efficient and renewable energy supply. The main target in planning the solar quarter was to increase the proportion of building surfaces suitable for the use of passive and active solar energy. A holistic approach to solar architecture is then possible using the optimized surfaces for the application of PV and solar thermal systems and opening the buildings towards the sun.

A preliminary evaluation of the solar potential of the quarter led to requirements for PV being specified in the investor manual. The solar potential was calculated for the different areas of the quarter. To simplify the specifications in the investor manual a fixed size of 1–2kWp for residential buildings was established. Non-residential buildings are required to install PV on surfaces visible to the public. A size of 1–2kWp guarantees a cost-effective PV system. The investment required for 1–2kWp PV systems is considered reasonable even for private investors. The decision to install a solar thermal system depends on the investor. There are no requirements for solar thermal systems at this stage.

The other main task related to solar energy during the preparation of the investor manual was the development of an urban plan that includes a simulation of shading and solar irradiation on building surfaces. The initial draft of the area plan, with building massing and



Shading visualization

Source: © City of Gelsenkirchen

Urban plan

Source: © City of Gelsenkirchen

layout, was evaluated and some modifications suggested regarding the height and distance between the buildings in order to provide each building with an ideal sun exposure.

The resulting urban plan specifies the layout of the buildings in the area. Defining the orientation and spacing of buildings in this manner ensures the prescribed solar commitments can operate as intended. In addition, requirements for heat protection and heat supply are set in order to reach a certain primary energy factor.

Because of this study, the urban structure was adapted to suit the requirements of solar urban planning. Some suggested optimizations could not be implemented since they contradicted the overall structure of the area. In general, the height of the buildings increases to the north, which guarantees high density and at the same time high solar suitability.

Sketches of the waterfront

Source: © City of Gelsenkirchen

Implementation

Legal conditions to prescribe solar requirements in local plans are theoretically possible but have not so far been tried out in Germany. Instead, for this development, the contract of land purchase is used as an instrument under private law, to set the requirements of the solar quarter. Because the land is owned by the State Development Association (the LEG), the prohibition to install private heating systems (except solar thermal systems) and the requirement to connect to the local heating net can be accomplished by an easement on real estate. The commitments for PV systems and for low energy buildings are prescribed in the contract of purchase. There are no size requirements set for PV systems for non-residential buildings but the systems must be installed on surfaces visible to the public with the aim of contributing to the sustainable appearance of the quarter. Together with solar applications in public spaces they will work as marketing instruments for the resident companies.

To avoid major shading of the building surfaces and to realize the concept of a solar quarter an advisory committee (experts from town planning, energy consultants, etc.) was established. Its function is to adapt the solar requirements to the plans of each investor and to include plans for individual buildings into the overall plan. Investors in individual buildings have to include an external energy consultant in their design teams in order to assure the quality of their detailed plans.

The current stage of development is primary negotiations with possible investors. The local heating net is also being designed with specific requirements concerning the primary energy factor.

Barriers and solutions

The acceptance of the solar concept by future investors is the main barrier expected. This barrier is exacerbated by the fact that the installation of a PV system on a building does not contribute to the overall energy performance of the building according to the calculation method applied under the current German energy saving directive (EnEV 07). This directive focuses on the thermal performance of a building so only solar heat contributes to the energy performance of buildings. As a result PV is not often installed on newly built low energy houses.

Given this background, some of the solar requirements have been kept flexible in order to leave space for individual planning of buildings. For instance, the requirements for large non-residential buildings to install visible PV systems do not define a size of PV system. The flexibility in the urban plan leads also to very general commitments regarding active and passive solar energy.

It is hoped that the advanced objectives of a quarter realized with solar architecture will be reached by working with investors convinced of the potential of sustainable development and the growing public demand for corresponding living conditions. Within the framework of the sustainable mission of the city of Gelsenkirchen this outstanding project will become well known as a regional pilot project showing possibilities for future developments.

Recommendations

Currently there are several cities in Germany working with commitments under private law, such as requirements imposed in the contract of purchase if the city is the owner of the land. In this case, commitments for PV systems can be implemented in many ways depending on the designated objectives. The economic effectiveness of PV plants is commonly accepted in Germany. To convince investors to approve a solar concept, which means primarily more planning complexity and higher investment costs, an incentive to invest could be the growing demand for sustainable buildings with low maintenance costs.

Portugal, Lisbon, Bairro do Padre Cruz

Maria João Rodrigues and
Joana Fernandes

Summary

Bairro do Padre Cruz in Lisbon is the largest low-income residential area in Portugal. The Municipality of Lisbon is coordinating the rehabilitation of this area, aiming to eliminate its current negative image. An international design competition initiated by PV Portuguese, the 2nd Lisbon Ideas Challenge, was set up to gather ideas for transforming this low-income residential neighbourhood into a solar neighbourhood. Competitors were asked to present intervention ideas for urban renovation and rehabilitation plans for one commercial building, a kindergarten and a social housing apartment block with the use of photovoltaics.

Introduction

Bairro do Padre Cruz is a neighbourhood located on the northeast side of Lisbon, in the parish of Carnide. It is the largest low-income residential neighbourhood in Portugal and one of the biggest of the Iberian Peninsula. This neighbourhood has its roots in the late 1950s, when the first construction phase was carried out to provide a quick response to rehousing needs. The newly constructed neighbourhood had a temporary nature and as such relied on simple construction methods and rustic materials seldom used in vernacular residential architecture. The social housing provided was expected to be short lived; however, this did not turn out to be the case and the neighbourhood continued to expand after this initial urbanization phase, with three subsequent phases of urbanization.

Actual state of urban structures in Bairro do Padre Cruz

Source: © Relatório Social do Bairro do Padre Cruz

The rehabilitation plan of the Bairro do Padre Cruz neighbourhood, coordinated by the Municipality of Lisbon, follows a priority action plan being undertaken due to the state of the area. The plan considers the need:

- to eliminate the negative image of rehousing neighbourhoods and revitalize the urban tissue;
- to create reallocation and youth-oriented housing with urban coherence and high construction quality;
- to create endogenous living spaces in the neighbourhood.

The plan also considers use of the blocks' courtyards as leisure spaces and the introduction of equipment and commercial spaces. Mobility and accessibility in the neighbourhood are also taken into account, with traffic access to the neighbourhood and pedestrian mobility being carefully considered. The area of intervention is 112,000m^2. Within this area 1619 homes are to be constructed in 18 lots with a total area of 50,000m^2. Some 10 per cent of this area is allocated for commercial purposes.

The Lisbon Ideas Challenge

The Lisbon Ideas Challenge is an international design competition initiated by Portuguese PV experts from the Centre for Innovation, Technology and Policy Research, IN+, at

Instituto Superior Técnico, Technical University of Lisbon, that aims to foster and promote PV deployment in urban areas. The first Lisbon Ideas Challenge called for ideas for urban structures incorporating PV. Following on from this the organizers decided to run a second competition focused on Lisbon and promoting the integration of PV in one of the most significant low-income neighbourhoods in Portugal. The motivation was to ally PV dissemination with the possibility of creating the first solar neighbourhood in Lisbon.

The 2nd Lisbon Ideas Challenge aimed at promoting the presentation of ideas for well-integrated and well-designed urban renovation and rehabilitation to transform a low-income residential neighbourhood of Lisbon into a solar neighbourhood.

The solar neighbourhood should serve the triple purposes of technological demonstration site, proactive dissemination and education; and targeting stakeholders ranging from the local community to public authorities and energy services companies.

As Portugal has one of the lowest installed PV capacities in Europe, mainly due to a lack of government incentives and complex administration procedures, the most important issue was to obtain the attention and cooperation of the Lisbon Municipality. For this, the first step was to involve the National Energy Agency, ADENE, who supported the project from the very beginning, as well as the Lisbon Municipal Energy-Environment Agency, Lisboa E-Nova, which is the direct link to the Lisbon Municipality.

Site plan of the rehabilitation of Bairro do Padre Cruz and 2nd Lisbon Ideas Challenge intervention area

Source: © Relatório Social do Bairro do Padre Cruz

Finally, from the already existing plan developed by the Empresa Pública de Urbanização de Lisboa (EPUL), the Municipality of Lisbon, assisted by several organizations, decided to back this initiative. In cooperation with IN+ they invited the international community of architects, designers and engineers to present proposals for integrated renovation and rehabilitation programmes of urban intervention to transform the Bairro do Padre Cruz neighbourhood into a 1MWp solar neighbourhood.

Competitors were requested to present intervention ideas for urban renovation and rehabilitation plans for one commercial building, a kindergarten and a social housing apartment block. They were asked to take into account the three following factors:

1 Integration. PV materials should be adequately integrated in the urban-scale design concept, both physically and aesthetically. The level of integration should be explicitly stated in the design description, as well as the identification of functional added values of the PV materials.

2 New applications or technological concepts. Entries should attempt to make use of PV materials in innovative ways, regarding both conventional and new technological concepts.

3 Communication. The use of well-integrated PV materials should be explicit and therefore easily communicable with the public.

The objective of the 2nd Lisbon Ideas Challenge was to promote the presentation of ideas for renovation / rehabilitation plans for the transformation of a low-income residential neighbourhood of Lisbon into a 1MWp solar neighbourhood.

Competitors were requested to present intervention ideas for urban renovation and rehabilitation plans for:

- one commercial building;
- a kindergarten;
- a social housing apartment block.

The Lisbon Municipality was involved in the project and hopes to implement the winning entries, provided that the relevant stakeholders join the initiative.

Commercial building

The commercial building is a shopping centre with a rectangular shape and an open space in the middle. It offers possibilities for integrating PV materials in the south, east and west façades and in a flat roof cover. Solutions combining the properties of PV with shadowing effects and natural lighting functions were presented for both the roof and the façades.

The proposal that won the first prize for the commercial building category was Shopping Delight. The concept follows an orthogonal grid plan similar to downtown Lisbon where blocks become shops and streets circulation space. A glass façade fronts the shops allowing natural light in and views out. PV materials constitute the commercial building rooftops; a non-innovative approach that allies natural light with shadowing effects, forming shopping galleries. The north façade is covered with vegetation in hanging gardens, allying the PV integration strategy with other methods of expressing sustainability issues and possibilities.

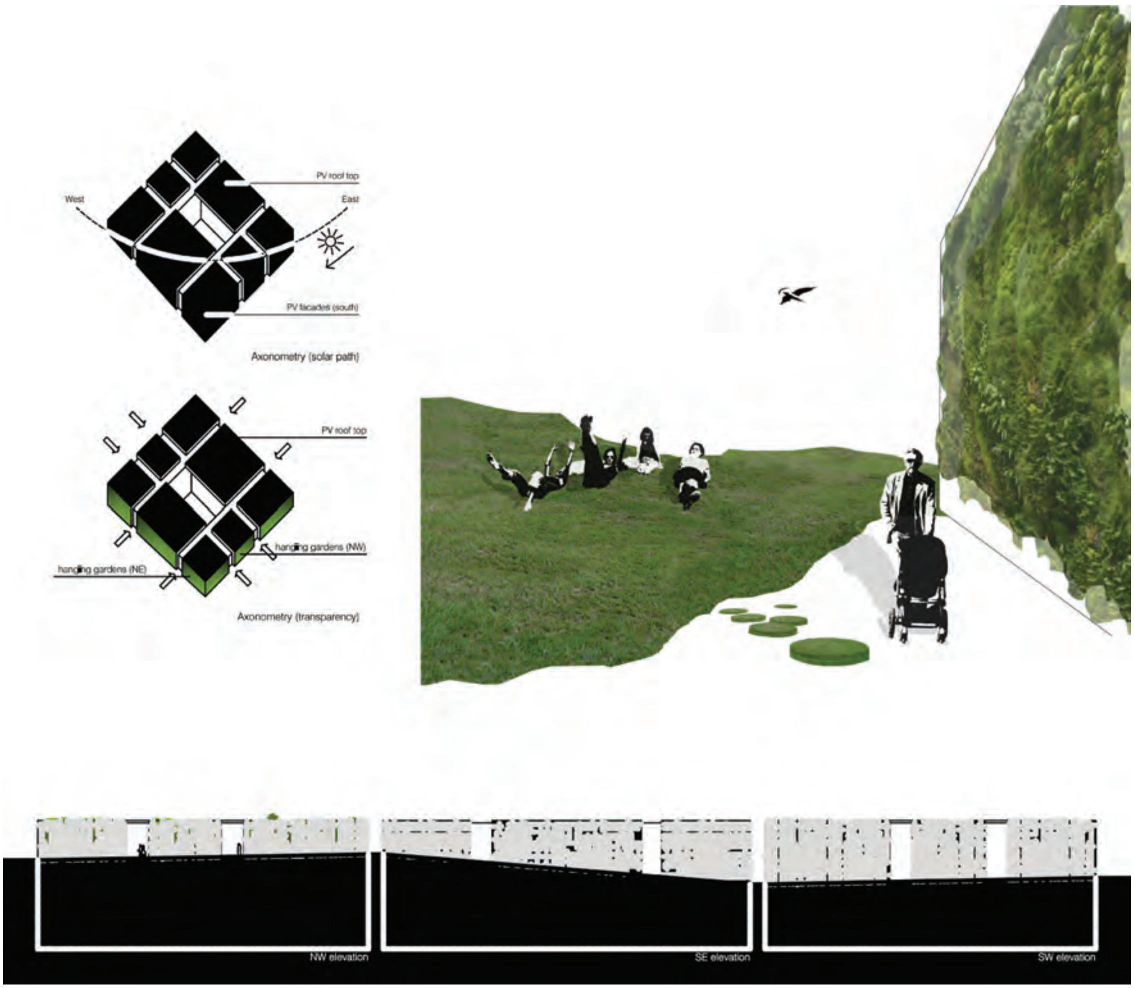
Public spaces: kindergarten

The kindergarten is the most important public outdoor space in this block. It is intended to be a leisure area with special attention given to the possibility of integrating urban art to increase awareness of PV technology among the community. In this public space, the solutions presented covered a wide variety of structures from esplanades that ally PV panels with shadowing panels, to kiosks and lamps, and innovative playgrounds integrating PV materials.

The winning entry was for a public space with PV flowers (PV systems designed as giant flowers); this was a strategy to catch the maximum amount of the sun's energy while consuming a minimum of materials. Being a moving structure, adapting to the sun's position, it communicates a relationship with the sun and an energy dependency. Besides the electricity generation, the PV flowers offer more functions for this urban space, working like parasols. The PV panels' green colour might be achievable using semi-transparent, thin film technology that would offer both energy production and shadowing effects. Being a self-standing structure, possible vandalism issues would have to be considered, as well as the connection to the electricity network. Even so, the structures are designed to close themselves in conditions of darkness or bad weather. Taking into account all the kindergarten area, 78m^2 of PV surface would be installed.

Social housing

The social housing apartment blocks under consideration were to be sustainable mass-production houses, including PV as part of a wider strategy. The block facing south is the best-oriented building in the whole intervention area. The building front faces one of the neighbourhood's main streets, while the rear faces the kindergarten. The blocks will be six storeys high, providing 10 or 28 apartments. Being the best south oriented building in the competition this housing block presented the possibility of integrating PV in



Solution for the commercial building

Source: © Chotima Ag-Ukrikul, Karin Pereira, Sofia Chinita for the 2nd Lisbon Ideas Challenge

façades, balconies or shadowing devices to cover whole façades or roof areas with semi-transparent PV modules to provide natural light.

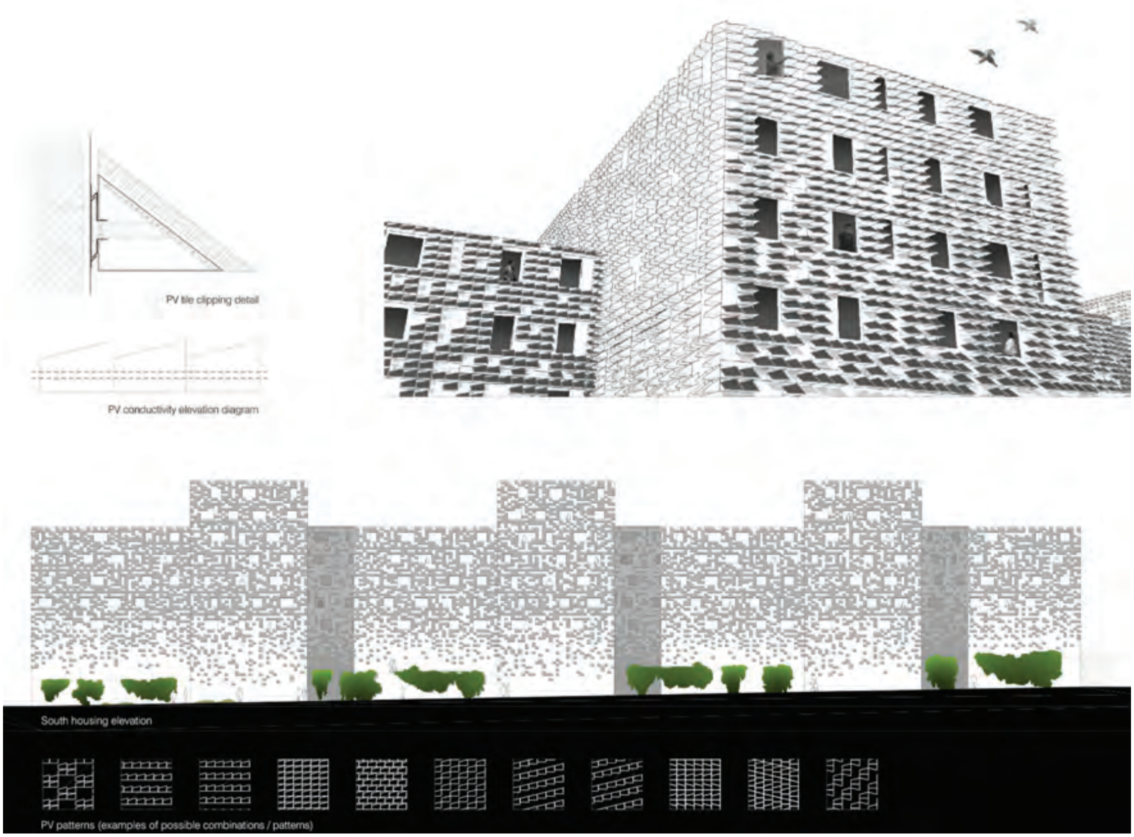
The winning project for the social housing was PV tile. The main idea is to create an object that can be applied to existing buildings and renovations, or to new constructions. The Urban Tile is a photovoltaic object inspired by Portuguese tiles where a three dimensional component has been added. Designed to be facing the best solar orientation, optimizing solar gains and electricity production, the Urban Tile is designed to be 0.2m^2, a smaller PV surface breaking down the scale of standard PV panels, therefore becoming more versatile to integrate in buildings. The social housing building under competition is to integrate 26,500 PV tiles, 540m^2 of Urban Tile, in the building's south façade.

This project effectively responds to the purpose of the competition. Aimed at new

Solution for the kindergarten

Source: © Wolfgang Krakau Architekt for the 2nd Lisbon Ideas Challenge

housing concepts and refurbished buildings, the design presented is an innovative and feasible product, considering the built environment which it is aimed at. Technically some issues have to be dealt with, namely the wiring system might be complex, involving electrical losses and high installation costs. In addition, the overall maintenance cost of the building, the insulation of the building envelope and vandalism constraints must be analysed when considering development of the product. Regarding the building conception, and not the PV tile, the achieved result shows good integration, despite the fact that the tile density on the top of the building is high and could cause shadowing effects between tiles.



Solution for the residential block

Source: © Chotima Ag-Ukrikul, Karin Pereira, Sofia Chinita for the 2nd Lisbon Ideas Challenge

Summary of problems, barriers, solutions and recommendations

How to get local decision-makers to consider the possibility of building a solar district?

Portugal is one of the European countries with the lowest PV capacity installed, mainly due to a lack of government incentives and complex administrative procedures. Thus, PV is generally not seen as an energy option for buildings or cities. Asking international teams to design a solar district in Portugal with the support of the Lisbon Municipality was therefore seen as hardly possible!

In order to get the attention and cooperation of the Lisbon Municipality, Portuguese PV experts benefited from the technical support of the Photovoltaic Power Systems Programme, a programme of the International Energy Agency, to initiate an international competition to design a 1MWp solar district in Lisbon, the 2nd Lisbon Ideas Challenge. This initiative was so successful that the Lisbon Municipality claimed to be willing to adopt and effectively implement the winning entries of this competition, providing that the relevant stakeholders join the initiative.

How to finance the construction of a 1MWp solar district without any national incentives?

The project's overall costs and business models have still not been developed. Despite that, several options are open and available for discussion, namely the ownership and maintenance responsibility of the systems and the legal framework to apply.

One of the possibilities is that the over-cost caused by the integration of the PV panels in the neighbourhood is supported by the municipality in partnership with the utilities and regional and local energy agencies. This clear action would set an example and foster the new energy market that is beginning to rise. Being the owner of the system the municipality would also be the entity benefiting from the feed-in tariff incentive scheme offered by Portuguese legislation; this would provide the municipality with the possibility of becoming an early investor in the green electricity market.

One other option is for the construction company to provide the investment and own the system. They would then be responsible for its production and maintenance. An energy service company (EsCo) concept might also provide an attractive solution.

The development of this project can thus provide benefits to the PV sector through the possibility of entering the independent power producer market and to the city by strengthening the image of the municipality regarding sustainability and innovation.

UK, Barrow, Port of Barrow redevelopment

Donna Munro

Summary

Barrow is a city on the northwest coast of the UK in the region of Cumbria. The city was a major shipbuilding centre; however, shipbuilding has been in decline in the UK for a number of years, leading to a decline in the prosperity of the city. Major redevelopments are now ongoing including a plan to develop a large part of the waterfront adjacent to the docks, the developments to include a marina, housing village, water sports leisure area, wetland wildlife area, business park and cruise terminal. The transformation of the underused and partially derelict dock locations into a modern, sustainable development has the potential to transform the city. A development brief for the site has been developed by the local regeneration organization with the consultancy firm Halcrow providing information on renewables. This includes obligations to achieve sustainable building standards and to install sufficient renewables on site to provide a minimum of 10 per cent of the expected energy demand. This will be the first major sustainable building development in the area. Priorities in the area tend to be focused

on economic regeneration, and environmental concerns have not been high on the political agenda.

Introduction

Barrow is the main urban centre for southwest Cumbria with a catchment of over 130,000 people. Barrow is known throughout the world as a centre of excellence for marine engineering and shipbuilding with major companies such as BAE Systems based in the city. The city came into being when rich seams of iron ore were discovered in the area in the 1850s and it became a centre for mining and heavy industries. In the 20th century it was a major shipbuilding centre. However, shipbuilding has been in decline in the UK for a number of

Victorian housing close to the docks, now a declining area

Source: © Donna Munro

Development master plan for the waterfront

Source: © West Lakes Renaissance

years, leading to a decline in the prosperity of the city with significant job losses and severe economic difficulties. There is now a need to stem the decline and regenerate the local area and the local economy in a sustainable manner.

Major redevelopments are under way, including a plan to develop a large part of the waterfront adjacent to the docks. The new mixed-use development will include a marina, a housing village, water sports leisure area, wetland wildlife area, business park and cruise terminal. The development is seen as a driver for the regeneration of the whole dock area. A principal objective is to create a major employment opportunity through the development of a 23ha Innovation Park.

Renewable energy in the development

Early site layouts had no particular provision for sustainable or eco-areas. The final call for proposals as eventually released includes an eco-area and set requirements for renewables and sustainable design for the entire site. Meeting these requirements will be a condition of the developers' contracts. A guide to the possible use of renewables in the development, and methods of meeting the requirements, was prepared and issued with the developer briefing pack. Developers are now being sought to develop the area on a commercial basis.

The renewable energy requirements that were developed are based on two mechanisms, both important drivers for renewable energy in the UK:

1 The first are environmental building codes: for housing, the Code for Sustainable Homes, and for office buildings, the Building Research Establishment's Environmental Assessment Method (BREEAM). These systems work on a point scoring basis and various levels can be achieved.
2 The other mechanism, developed in the London Borough of Merton and hence known as the Merton Rule, is a planning requirement that can be set by local councils requiring all new developments over a certain size within their area to provide a certain percentage of the predicted energy consumption through the installation of on-site renewable energy generation capacity. The percentage is normally set at 10 per cent although higher percentages have been set in some areas.

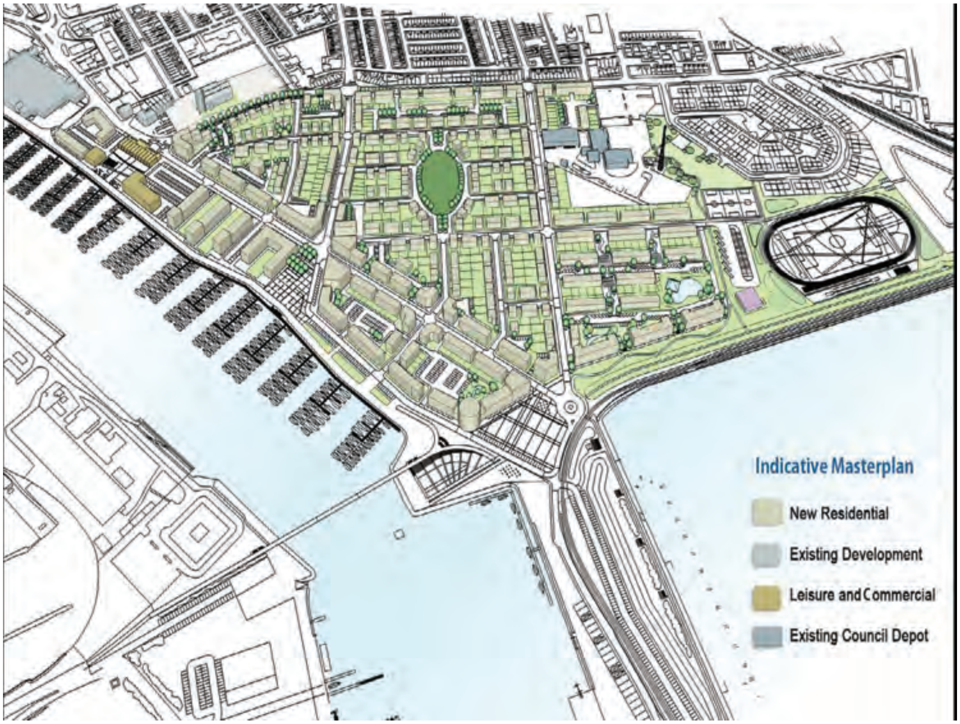
The requirements set for the Barrow Waterfront were:

1 All new housing developments above 30 homes will be required to achieve a minimum of level 3 of the Code for Sustainable Homes.
2 The Dockside area in Marina Village will be required to achieve a minimum of level 4 of the Code for Sustainable Homes.
3 A BREEAM assessment must be carried out for all new commercial development with a floor space above 1000m^2 and a rating of Very Good or better achieved.
4 Minimizing energy consumption requirements of new development through innovative and efficient design and alignment and expecting the use of renewable energy technologies to be incorporated into new development wherever practicable as follows:

- all residential development of ten units or more should incorporate renewable energy production to cover at least 10 per cent of predicted energy requirements;
- all non-residential development of 1000m^2 floor space or over should incorporate renewable energy production to cover at least 10 per cent of predicted energy requirements;
- small-scale community and on-site renewable energy projects will be encouraged.

The use of renewable energy is both an explicit requirement (with a 10 per cent target) as well as providing assistance in meeting the Code for Sustainable Homes.

Under the Code for Sustainable Homes, the minimum performance standards for level



Site layout for Marina Housing Village with solar access considered

Source: © West Lakes Renaissance

3 require a 25 per cent reduction in carbon dioxide emissions, in comparison to the relevant Target Emissions Rate (TER) set out in Building Regulations 2006 Part L, while level 4 requires a 45 per cent reduction. The reduction in CO_2 emissions can be achieved by energy efficiency measures or the use of renewable energy or a combination of both. The use of renewable energy provides extra points under the scoring system used in the Code for Sustainable Homes.

Marina housing village

The marina housing village is divided into four housing areas: one of these, Dockside, is the green quarter, with a Code level 4 minimum requirement; the other areas have to meet Code level 3. A minimum of 10 per cent of predicted energy

Cavendish dock is in the foreground with the location for the new housing village showing as a green oval next to the top right hand corner of Cavendish dock

Source: © West Lakes Renaissance

Work starting on the Waterfront Business Park with offshore wind farm in the distance

Source: © Donna Munro

demand for all the housing has to be generated by renewables. This renewables generation can be spread evenly over all the houses or can be concentrated into a smaller number of bigger systems. Some of these bigger systems need not even be on the housing, but for example could be part of a flagship renewable energy design for one of the other buildings on site.

The main options for renewable supply of power considered applicable in the area were:

- solar water heating;
- solar photovoltaics;
- wind power;
- biomass heating;
- heat pumps;
- district heating with CHP or heat pumps.

Calculations were performed to estimate the quantity of renewable energy needed to meet the requirements. Due to the complexity of the calculation method in the code only estimates could be given without a final design for the houses. These concluded that a 4m^2 flat panel solar water heater with PV-powered pump would allow a house design to reach level 3 of the Code and the addition of 0.45kWp–1kWp of PV could take a property up to level 4.

The 10 per cent requirements (approximately 1000kWh per year assuming standard housing) could be met by a solar water heating system of about 3.5m^2 or a 1.25kWp PV system.

The approach suggested for the level 3 housing was to focus on energy efficiency and passive solar design along with either solar water heating or heat pumps.

In the green quarter, where level 4 or above is required, it was suggested that:

- All houses should have good solar access and make use of passive solar design.
- Solar water heating should be provided on all family houses.
- 1kWp–2kWp PV systems be provided on some houses.
- PV on apartment blocks could supply communal areas or individual apartments. However, small PV systems of under 0.5kWp each supplying an apartment should be avoided, as they are likely to be more expensive in terms of installation and maintenance costs.
- For all apartment blocks consider communal water or space heating systems, either gas, solar or biomass based.

In addition, recommendations were made that:

- The houses are future proofed i.e. built so that renewable energy systems could be added in the future with reasonable ease. ‘If renewable energy is not installed on a dwelling, dwellings should be designed and constructed to facilitate the installation of renewable energy technologies during their design life. For example by including roof structure with identified fixing locations (PV and solar hot water), space for enlarged hot water cylinder (solar hot water), roofs orientated to face between southeast and southwest with minimal over shading and provision of identified and accessible electrical cable ductwork between electrical consumer unit and proposed location of generating equipment (small scale wind and PV)’(Energy Saving Trust, 2006).

- The approach taken for different properties should differentiate between the different types of expected occupants and building sizes. For example, properties likely to end up in the commercial rented sector with a high turnover of occupants may not be best suited to individual renewable energy systems where information on how to get the best out of them has to be passed on from one occupier to the next.
- Photovoltaics generate in the daytime and surplus power is not stored for later use, as is the case with solar water heating, but exported, so residents who are generally at home in the daytime will benefit most directly from PV systems. Retired people or families with young children tend to be in more during the day and can get maximum benefit from a PV system. Provision for such groups could focus on Dockside.

Most of the discussion focused on the buildings. However, the Marina Village also requires public footpaths and cycleways, public open spaces and public art. These can also provide opportunities for the use of renewable energy and can be a very visible symbol of the achievements in energy terms. Solar sculptures, clock towers and fountains have all been created in the past and solar streetlights or bus stop lighting, are now widely commercially available. The use of PV to power non-building facilities can lead to cost savings if it avoids the need to provide a standard electricity supply. It can also provide a cost-effective means of improving security through increased lighting on footpaths and cycle ways that are not close to grid connection points.

Problems, barriers, solutions and recommendations

Can genuine sustainability be imposed for new developments?

A workshop was held in Barrow during which concerns were expressed about the real level of sustainability achieved by mechanisms such as the Code for Sustainable Homes. It was feared that developers would simply aim to achieve the minimum score required with the lowest cost approach. This was a particular concern where points were achieved by replaceable fittings such as low energy lighting and appliances or low water consumption taps. It was feared that these could be replaced either by the developer once assessment was complete or by the householder over time.

This is a strong argument for incorporating a large proportion of the energy measures into the fabric and form of the building using passive solar design and insulation. Planning restrictions could also be put into place to limit house extensions and alterations over time that would reduce solar access to other houses.

Solutions to the issue of removing low energy appliances are hard to develop but may lie in convincing house purchasers of the benefits of low energy consumption and promoting pride in the sustainable and low energy characteristics of developments that meet the Code for Sustainable Homes. Information on the appliances that assessment results are based on should be provided both to the original house purchaser and to subsequent purchasers. It should be clear that the original rating no longer applies if lower quality appliances have been substituted.

A particular risk for PV, where its installation has been driven by mechanisms such as the Code for Sustainable Homes and the Merton Rule, is that insufficient thought may be given to the successful operation of the system. PV systems operate silently and inconspicuously. It may not be obvious to building occupants whether or not they are operating correctly. The current funding and legislative arrangements in the UK promote installation of systems with little incentive to ensure correct performance. One solution may lie in a feed-in tariff for renewables that would provide a more significant financial return to householders for the electricity produced and hence an incentive to ensure correct operation. Energy Service Companies (EsCos) may offer one solution to ensuring that on-site renewable systems operate effectively for the long term.

How important are renewables for Barrow?

The main aim of the organizations involved in the Waterfront development is the commercial regeneration of the area with the provision of jobs and good quality housing. While environmental sustainability is on the agenda, there are higher priorities and subsequently limited awareness of the potential for renewables to have a positive impact on the wider issues of jobs and quality of the built environment.

The development team is very busy and has an enormous range of issues to consider from the bird life on one side of the docks to the security of the nuclear facilities on the other side of the docks. While some work was focused on renewable energy in the development, this was over a limited period and had only a limited amount of success in involving others in the development team in issues relating to renewable energy. A development team member with his or her remit expanded to include renewable energy would provide significantly enhanced support for sustainable development.

Site layout and solar accessibility

The indicative layout of the buildings on the site was prepared taking into account the docks to the south of the site and the strong prevailing winds from the southwest. This led towards an urban layout with taller buildings along the water edge to provide a public frontage with facilities such as restaurants and shops and to provide a windscreen. However, it will also shade the buildings behind. Efforts were made in the layout to minimize shade problems but solar accessibility was not at the top of the priority list. One possible solution would be to perform shading simulations.

Breaks in the chain

The standard approach in the UK is for developers to be responsible for much of the design and development of new urban developments. Local authorities and regeneration agencies set guidelines and limits but, at a certain point, responsibility for leading the design and development is handed over to a commercial developer. This break in the chain makes it hard to include detailed planning for renewables into early work before a developer is identified and at the same time gives developers a limited amount of time to consider renewables. The possibility of considering various site layouts and issues such a solar accessibility over various iterations can be hindered by these breaks in the chain. This problem has been recognized by the UK government, which proposed a more team-based approach for new eco-towns planned in the UK. It is hoped that the information provided will assist the developer in coming up with a truly sustainable new development.

Understanding the Code for Sustainable Homes

The scoring system and energy calculations in the Code for Sustainable Homes are extremely complex. They are designed to be assessed using computer models that include all details of the building fabric. This means that it is not easy for planners to see exactly what it means to ask that houses meet level 3 or level 4. It is also difficult to consider the effects of various design options and approaches to renewables at an early site layout stage. There is a lack of current benchmark data or rules of thumb and a very limited amount of practical experience in designing to the standard. An accumulation of experience over time should help to address these problems, as would the development of some current benchmark data. The other key factor in solving this issue is access to advice and information.

Provision of information

The provision of information on renewables is a key factor in the successful implementation of renewables. The Code for Sustainable Homes is very new and there is a limited amount of experience in building such developments. Renewable energy and photovoltaics are an unknown quantity to many developers and builders.

Possible solutions include:

- working with existing organizations in Cumbria to target their services towards this gap more effectively;
- gathering a group of experts to provide advice;
- strengthening the expertise available in-house from the Borough Council or the regeneration agency.

References

Energy Saving Trust (2006) Energy Saving Trust Best Practice Standard for Sustainable Housing, *Demonstrating Compliance – Best Practice* www.est.org.uk/housingbuildings/standards

4 Regulatory Framework and Financing

National planning process

Donna Munro

Introduction

Photovoltaics are installed within a complex framework of regulations, funding arrangements and planning policies. The framework not only varies between countries but also between provinces and even municipalities. In general the framework is designed to promote the use of renewable energy (RE), including photovoltaics, and to reduce carbon emissions. However, with national, regional and municipal governments involved and different departments responsible for different parts of the framework the result can be somewhat fragmented with a general trend towards the promotion of renewables but with some policies and regulations working against the general trend and having negative impacts on the implementation of PV.

The main elements of the framework that impact on PV are:

- building regulations;
- codes for 'green buildings';
- capital subsidies for PV;
- enhanced feed-in tariffs for PV;
- planning policy for renewable systems.

Building regulations

Building regulations exist in all countries; generally they are neutral regarding their impact on the installation of PV systems, covering such topics as structural safety and insulation levels. However. they can be used to require the installation of renewable energy systems. In Spain, many larger buildings are now required to have a PV system (this includes: commercial buildings, show grounds, offices, hospitals, clinics, hotels and hostels) and all buildings are required to have a solar thermal system. In Germany, the building regulations give credit for renewable systems that generate thermal energy, but not for electrical generation systems such as PV. This tends to encourage the installation of solar thermal systems that receive credit under the building regulations, instead of systems that generate electrical renewable energy such as photovoltaics.

Codes for 'green buildings'

Codes for 'green buildings' are available in many countries. In contrast to the compulsory building regulations that have to be applied to all buildings, these are optional. They tend to give credit for the installation of photovoltaic systems and can be an important driver for the inclusion of PV systems in buildings. For example, in the UK the Code for Sustainable Buildings credits PV systems and other renewable systems. A minimum sustainable buildings rating is now often required by funding bodies that may support regeneration projects or the construction of social housing. This is an important driver in the renewables market in the UK.

Capital subsidies for PV systems

Capital subsidies for PV systems are not as common as they were and have been replaced by feed-in tariffs in some countries. Capital subsidies through competitive grant application mechanisms are still available in Sweden and in the UK through the Low Carbon Buildings Programme and in local and regional schemes in Austria, Germany, France and The Netherlands. An income tax credit system is also available to private individuals in France (EPIA, 2008; IEA, 2008; NCSC, 2009).

Enhanced feed-in tariffs for PV

Enhanced feed-in tariffs for photovoltaic systems are available in Spain, Germany and France, providing a premium rate for all PV electricity. The German National Renewable Energy Act (EEG) assures a fixed feed-in tariff for grid-connected solar electricity over a time span of 20 years. Via the feed-in tariff (currently around €0.46/kWh, depending on the kind of system) the investment in a PV system can be recovered during its lifetime with a reasonable return on investment. A limited feed-in tariff-based support system is also available in Austria, but it has a limited budget so that only the first few applicants receive funding (EPIA, 2008; IEA, 2008; NCSC, 2009).

Planning policy for PV

Planning policies promoting renewable energy tend to be developed, at least at the detailed level, at a municipal or regional level. This may or may not link to a national planning policy for renewable energy:

- In Austria, there are no nationwide directives for the use of RE systems in the urban planning process or any rules or targets that set a certain percentage of electricity generation from RE systems for new buildings. Municipal bylaws may include planning requirements to increase energy efficiency of new or retrofit buildings and/or the use of RE sources.
- In Germany, local authorities may define urban areas where solar energy should be used based on a national legal framework. It is up to the local authorities to use the legal possibilities to realize urban planning with a focus on a solar development. The City of Marburg is about to launch the first solar obligation concerning thermal systems. This has caused some legal complications and controversy.
- In France, there is no specific national policy to encourage the use of RE sources in the urban planning process. In response to this lack of national policy, some local authorities have implemented local policies. For instance, Greater Lyon drew up on a voluntary basis a local policy to enforce the rational use of energy and the use of RE in new buildings.
- In The Netherlands, the emphasis in the urban planning process is with the municipalities. City councils prepare structural plans that provide details of how to transform national and provincial policy into concrete plans. This leads to the development of an urban design that may prescribe energy performance, sustainability aspects, etc.
- In Spain, land use legislation and energy planning are the responsibility of the Spanish regional governments called Autonomous Communities (ACs). Within each AC, urban planning is developed at a local level by the town councils. The General Urban Distribution Plan is the main tool for urban planning in Spain. Once developed and approved by the town council, the proposal must receive final approval by the government of the AC, in order to come into effect. Regional legislation depends on the ACs. For example, in the case of Madrid's AC, the Energy Plan 2004–2012 aims at doubling the energy contribution from RE sources and a 10 per cent reduction of CO_2 emissions. Among the actions foreseen related to photovoltaics, the promotion of PV systems in domestic and services sectors, and the support of municipal bylaws are mentioned. In September 2005, there were more than 30 municipal bylaws concerning solar technologies, most of them only dealing with solar thermal. The region of Catalonia

is by far the most active in this field, followed by Madrid and Valencia.

- In the UK, a National Planning Policy Statement specifies the encouragement of renewable energy at a local level. In response, local authorities draw up Local Development Frameworks. There is an increasing trend for authorities to include renewable energy rules in these. A typical rule is that all new large developments (ten or more dwellings or more than $2000m^2$) must generate a percentage of their energy requirements from on-site renewables; percentages range from 10 per cent to 40 per cent. This is one of the main drivers in the installation of renewables in the UK at present.

Options to finance PV projects

Sigrid Lindner

There are various options for municipalities to enhance PV and to use financial solutions other than self-financing.

Self-financing

The municipality assigns an enterprise with the building of a plant and will be the operator and owner of the plant. The incomes flow directly to the municipality. Investment and control are to be taken over and carried out by municipality. Because of the order of magnitude of the investment an advertisement is necessary. Due to the complexity of carrying this out, a planning office should be assigned with the execution of the advertisement, whereby further costs arise.

Lease of roof areas for PV systems

In return for a lease fee, external organizations operate the photovoltaic system on the rented roofs. The plant operator benefits from economic success. The image effect, however, is usually related to the building and its owners. Besides that, the building owner receives the lease fee. Nevertheless, many organizational and legal questions need to be clarified before the conclusion of a contract:

Municipality of Prüm, leasing model on school building

Source: © Ecostream

- Right of access for the operator of the plant: a third party operates a plant on municipal buildings, to which he must have access at any time over the running time of 20 years.
- Lease amount: the incomes flow in full to the investor; the municipality receives only the lease payment. Proposed leases in locations in North-Rhine-Westphalia are calculated at approximately €1/m^2.
- Involvement of the municipality: planning and building as well as the later management are handled by third parties; the municipality has hardly any influence.
- Guarantee problems: if unexpected problems influence the output of a PV system, disputes can occur between the operator and the municipality, e.g. in case of a roof renovation (who provides liability for defects?).

Municipal leasing model

The municipal leasing model unites the model of self-execution with the lease model. It strengthens the advantages of both models and reduces their disadvantages. The municipality agrees on a leasing contract for the financing of the PV plant and offers its roofs to be leased but remains the owner of the PV plant. The lease giver is, during the contract running time, the only occupier of the plant. Complete planning, completion and financing are realized by the contracting party. The overall enterprise remains, however, at all times under the control of the municipality. Special characteristics of the local leasing are:

- The contract running time amounts to up to 18 years to fix conditions.
- The municipality does not transact an investment, which households are not therefore affected by, since no indebtedness is present.
- The net yield is clearly higher than usual lease payments.
- A positive cash flow is always obtained; during the contract running time incomes are higher than the costs.

Europeschool Cologne, civic participation model

Source: © Ecostream

- After the contract running time, the municipality, the lessee, becomes the owner of the plant. The residual use of the plant is with the municipality. In years 19 and 20 the economic benefits revert totally to the municipality.
- The municipality is user of the plant and owner of the building. There are no interface problems.
- Over the contract running time a maintenance contract can be included, so that trouble free operation is ensured.

Civic participation

A very attractive option to get a PV system privately financed is presented by a civic participation plant. Four case studies were initiated in schools in North-Rhine-Westphalia for the 100,000W solar initiative. Teachers, pupils, parents and grandparents as well as interested citizens invested in a PV plant and energy efficiency measures. In an annual distribution the 'partners' profit from the financial success of the measures via the guaranteed returns of the German feed-in tariffs. The investment per school amounts to between €500,000 and €1,200,000.

The 100,000W solar initiative should contribute to the market development of photovoltaics. Beyond that, the initiative represents good, visible best practice for pupils, teachers and parents so that changes of behaviour are motivated.

Solar roof initiatives

In Germany several initiatives exist with the aim of increasing the amount of PV systems on public buildings. There are roof platforms like Solar-Lokal, which provide information about available solar-adequate roof areas on public or private buildings. They can be rented by companies or private partnerships to install PV systems.

SolarLokal stickers saying that roofs can be rented for the installation of PV

Source: © SolarLokal

References

European Photovoltaic Industry Association and Greenpeace (2008) *Overview of European Support Schemes,* December, Brussels

International Energy Agency Photovoltaic Power Systems Programme (2008) *Trends in Photovoltaic Applications. Survey report of selected IEA countries between 1992 and 2007*, Report IEA-PVPS T1-17:2008, St Ursen, Switzerland

North Carolina Solar Center (2009) *Database of State Incentives for Renewable Energy (DSIRE)*, www.dsireusa.org, accessed 29 January 2009

5 Design Guidelines

This chapter starts with an explanation of the basics of photovoltaics (PV) followed by a discussion on PV in architecture and the impact PV can have on building aesthetics. There are also sections on the use of PV in public spaces, PV and electricity distribution networks and top tips at various project stages.

Basics of photovoltaics

Wim Sinke

Introduction

This section deals with the basics of PV and PV systems and the design constraints, in order to understand the boundary conditions of PV systems when applied in the built environment.

Photovoltaics (PV) is the direct conversion of sunlight into electricity. The basic building block of any PV system is the solar module, which consists of a number of solar cells.

The discovery of the photovoltaic effect ('photo' = light, 'voltaic' refers to electricity) is usually attributed to Edmond Becquerel, who published a paper in 1839 (Becquerel, 1839). Practical applications for power generation only came within reach after the successful development, in the early 1950s, of methods for well-controlled processing of semiconductor silicon, the material that most solar cells are still made of. The research group at Bell Laboratories in the US played a key role in this development (Perlin, 1999). Although many people immediately saw the great potential of PV for large-scale use, the number and size of applications remained very modest until the 1980s. An exception was the use of PV to power satellites, which started successfully as early as 1958 and has remained the standard ever since.

Features of sunlight

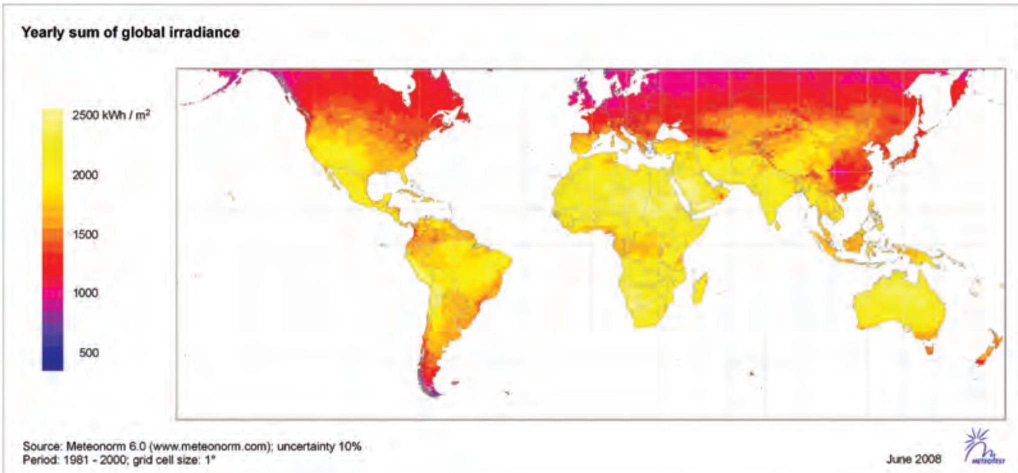
The total annual amount of solar energy per unit area (the insolation or irradiance) varies over the Earth's surface and roughly ranges from 700kWh/m^2 to 2800 kWh/m^2 for horizontal planes. The lowest values correspond to polar regions, the highest to selected dry desert areas.

When comparing the insolation on optimally inclined surfaces rather than horizontal planes the range becomes smaller, as the lower values increase to roughly 900kWh/m^2. This means that the global range of electricity production potential (per m^2 of fixed, optimally inclined surface area) varies by a factor of about three from the poles to the deserts. It is important to note that the maximum intensity of sunlight is approximately 1kW/m^2 everywhere. The reductions in energy production potential as one moves towards the poles are thus primarily due to weather conditions and longer times with low light levels due to low sun angles. Large seasonal variations in the amount of solar energy received may have important implications for system design and implementation. In the case of grid-connected systems, the grid acts as a virtual storage and the user is always assured of sufficient electricity, but in the case of stand-alone systems, storage has to be part of the PV system to get through hours, days or even months of low insolation.

Basic operating principles

The photovoltaic effect is based on a two-step process:

1 The absorption of light (consisting of light particles: photons) in a suitable (usually semiconductor) material leads to excitation and mobilization of negatively charged electrons.



Total annual amount of solar energy per unit area for horizontal planes

Source: © Meteotest, Meteonorm 6.0, www.meteonorm.com

The excited electrons leave behind positively charged 'missing electrons', called holes, which can also move through the material.

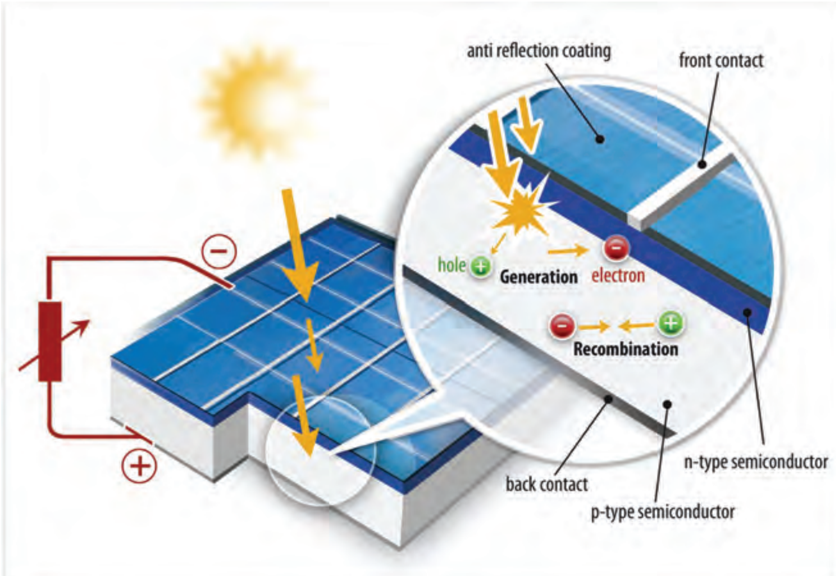
2 The spatial separation of generated electrons and holes at a selective interface leads to a build-up of negative charge on one side of the interface and positive charge on the other side. As a result of this charge separation a voltage (an electrical potential difference) builds up over the interface.

In most solar cells the selective interface (junction) is formed by stacking two different semiconductor layers: either different forms of the same semiconductor (so-called 'p' and 'n' type) or two different semiconductors. This junction can be formed by adding different types of impurities (dopants) to the layers on both sides of the semiconductor. The key feature of a semiconductor junction is that it has a built-in electric field, which pushes/pulls electrons to one side and holes to the other side. When the two sides of the junction are connected and an electrical circuit is formed a current can flow (i.e. electrons can flow from one side of the device to the other). The combination of a voltage and a current represents electric power. When light falls on the material electrons and holes are generated and collected continuously and electric power is produced.

Cell and module technologies

Cell and module technologies are usually categorized according to the active material(s) used for the solar cells: the semiconductors. Solar cells made of crystalline silicon have been the dominant technology since the beginning of the solar industry. Here individual cells produced from wafers cut from crystalline silicon are electrically connected and encapsulated in a module.

Thin-film technologies were developed more recently. Their market share has increased gradually as the technologies have matured. In thin-film technologies, the cells are deposited on a substrate (normally glass or metal foil) or a superstrate (glass) in the form of a very thin layer (in the order of 1 micron (0.001mm) thick). The individual cells are usually elongated areas, running from one side of the module to the other, and connected in series in the perpendicular direction.



Schematic cross-section of a typical solar cell, showing the basic steps in the conversion of light (photon) energy to electrical energy: generation of electron–hole pairs by the absorption of light and spatial separation of (negative) electrons and (positive) holes

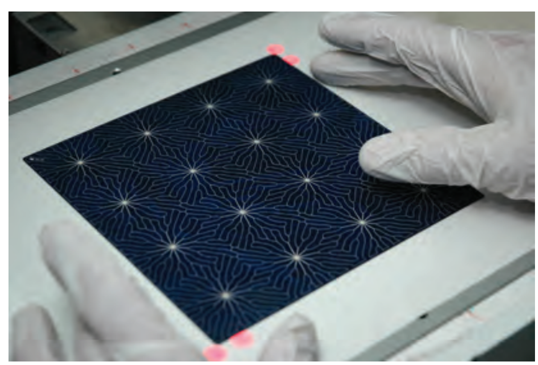
Source: © Hespul

PV systems and systems terminology

PV systems are often divided into grid-connected systems (building-integrated or ground-based) and/or stand-alone (autonomous) systems. It is also possible to have PV systems feeding into, or connected to, a mini-grid, which falls in between these categories.

Here we mainly consider grid-connected systems, because for the short and medium term this is the most likely application of PV in the urban environment.

Although grid-connected systems normally do not include electricity storage (the grid acts as virtual storage capacity) grid-connected systems with a small (battery) storage may perhaps enter the market in some situations. By adding storage it

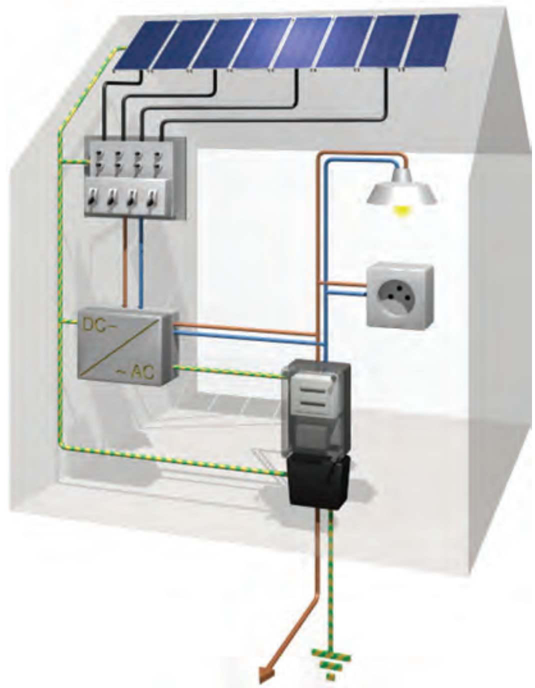


Silicon solar cell of Solland Solar, Sunweb, developed in cooperation with ECN, Energy Research Centre of The Netherlands

Source: Solland Solar

Thin-film solar cell

Source: © Hespul



Grid-connected system. Any excess energy produced may be fed into the grid, which acts as a virtual storage system

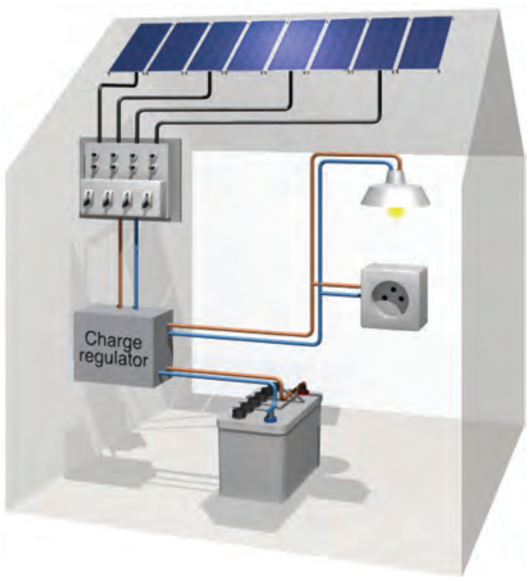
Source: © M.ART

becomes possible to supply electricity to the grid at moments when the value is highest rather than only when the sun shines. This advantage always has to be weighed against the cost increases and energy losses associated with adding storage.

Complete PV systems consist of modules (also referred to as panels), which contain solar cells, and the so-called balance-of-system (BoS). The modules are the smallest *practical building block* of systems and produce the electricity. However, modules produce *direct current* electricity (DC) at a relatively low voltage (<100V). Modules are therefore connected in series. Several strings in parallel form an array (note that other configurations may occur, see next paragraph). The DC output from the array is converted to alternating current (AC) of the correct voltage and frequency for feeding into the grid. The conversion from DC to AC is done in a so-called inverter. Apart from the inverter there may be other electrical/electronic components (e.g. safety devices). In addition, any system obviously has cabling and some form of support structures. Stand-alone systems that are not connected to the electricity grid usually have batteries for electricity storage (except for e.g. water pumping systems). Systems may also include light-concentrating optics to enable the use of small area, very high efficiency (and very expensive per cm^2) solar cells and/or sun trackers for increased output. Note that concentration and tracking are normally not an option for building-integrated systems. The BoS *costs* also include site preparation (if applicable) and labour costs for turnkey installation.

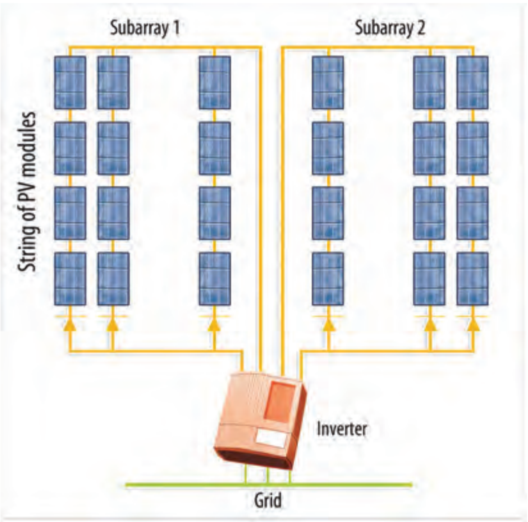
An array or sub-array is wired up by joining up modules in series and parallel to produce the required current and voltage. Modules are joined in series to produce a string; this will have the same output current as a single module but the output voltage will be the total of the individual module voltages. A number of identical strings can be joined in parallel to produce an array. The total current will be the sum of all the string currents.

Note there cannot be just any number of modules in an array, there has to be a multiple



Stand-alone system. The energy produced is stored in batteries if it is not used to cover an immediate demand

Source: © M.ART



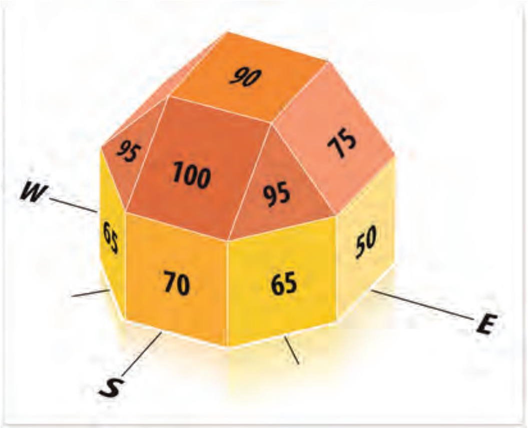
An array or sub-array is formed by connecting modules in series and in parallel to produce the required current and voltage

Source: © Hespul

of the number of modules in a string. The resulting array has to have an output current and voltage within the acceptable input range for the inverter being used.

Orientation and tilt

The positioning of the PV array (orientation and tilt) influences the quantity of electricity produced, known as the yield, considerably. Typically, the most favourable orientation is south in the northern hemisphere and north in the southern hemisphere with the optimal tilt angle (deviation from the horizontal) roughly related to the latitude of the given location. If we only consider direct solar radiation the optimal tilt angle for maximum energy production over the year would be equal to the latitude of the location. However, in many locations, a major part of the incident irradiation comes as diffuse radiation from other directions than the sun. This moves



Percentage of optimal energy production that can be expected from PV arrays at different orientations and tilt angles for locations with a latitude around 50° north such as central Europe

Source: © www.demosite.ch

the optimal tilt angle slightly towards horizontal so that the modules 'see' more of the sky.

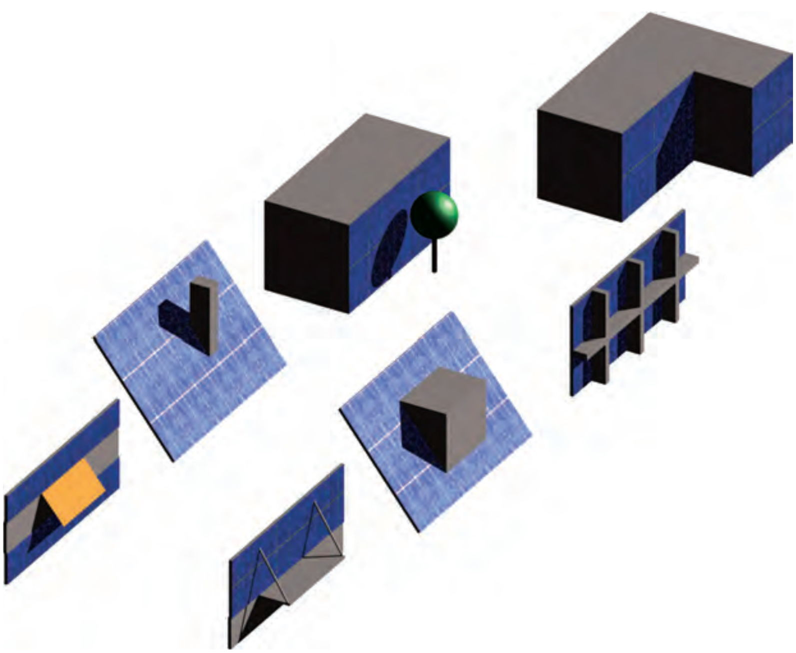
In winter an array at a higher tilt angle (i.e. more vertical) will produce more energy while an array with a smaller tilt angle will produce more energy in the summer. For example, in a northern European winter, when the sun's elevation is low, PV façade systems have a higher yield than horizontal installations on roofs (the reverse is the case during summer months).

The optimal orientation for any specific project is also dependent on local weather conditions and topography. For example, if morning fog is common the optimal orientation will be slightly west of south. The same is true if there is a mountain or tall building east of the site.

PV system performance in practice

Influence of shading

A very important parameter determining the actual output of PV systems is the absence or occurrence of partial or complete shading. This may occur due to the presence of trees, buildings or other 'external' objects, or as a result of the design features of the building the PV system is integrated into or mounted onto. Shading inherently varies with the time of the day and the time of the year. Generally speaking shading should be avoided as much as possible since the output loss may be larger than would expected due to the reduction in solar energy captured. This is particularly the case when partial shading occurs.



Sources of shading generated by the building itself can drastically reduce the annual energy output. These must be taken into consideration while designing buildings. The negative effect of shading can be reduced by careful PV module positioning and electrical system design (wiring schemes)

Source: © M.ART

It is important to consider shading in the design phase and to optimize the electrical system design to minimize the number of strings shaded at any one time. Fortunately it is possible to make quite accurate calculations of shading-related losses in advance.

Consideration should also be given to the height, width and evergreen/deciduous characteristics of potential tree obstacles. Growth patterns of certain kinds of trees can give an idea whether the PV modules are likely to be threatened or not in the future. In some cases it may be reasonable to replace or remove existing older trees that may shade the PV.

The building geometry should preferably avoid self-shading of the installed PV modules. Details like chimneys, protruding and higher parts of the construction, skylights, satellite and receiver communication systems, hanging or moving elements should be designed with regard to the course of the sun during the day and over the year. Potential shading impacts can be determined with the help of sun charts or simulation programmes. Where shading cannot be avoided, an adapted electrical design may be used.

For aesthetic reasons it can be desirable to install dummy PV modules at shaded places. These look exactly like PV modules but they have only an aesthetic function. Their price can, as a result, be substantially lower than real modules.

Influence of temperature

A PV module sitting in the sunshine can get much hotter than the ambient temperature, as much as 50°C hotter on a sunny day. This is a problem because the efficiency of PV modules generally decreases with temperature increases. For crystalline silicon cells the efficiency decreases almost linearly by 0.4 per cent (relative) for every degree rise in temperature. For thin-film modules the effect is somewhat or substantially smaller, depending on the specific technology considered. The 'temperature co-efficient' of the efficiency is usually given as part of the information on the datasheet.

High (behind) module temperatures could also cause problems for the roofing materials. Different types of problems might occur, such as softening or even melting of the roofing material or stresses related to the difference in the coefficient of expansion between the PV modules and the roof, leading to tear, leakage or damaging of the PV laminate.

The temperature the module actually reaches depends on how well it can dissipate the heat (note that most of the light absorbed by the modules is converted into heat, since the electrical efficiency is less than 20 per cent). If the PV module is insulated at the rear side, it can only dissipate heat at the front side, which leads to higher operating temperatures. A ventilated air gap at the rear of the modules lowers the temperature by (at least) 10°C.

Generally, it is strongly recommended that an air gap is left between the modules and the roof or the façade, to allow cooling by natural convection. This air gap also has an insulating function, resulting in lower roof temperatures. Typical roof cover materials are bitumen, metal (zinc, copper and aluminium), thatch, glass and shingles. PV on a thatch roof may not be feasible because of practical problems related to the connection of modules to the roof. For bituminous roofs, the temperature will present a problem if an air gap is not present. The bitumen softens due to the temperature and a PV module positioned directly on the roof will slowly migrate into the roof, which will cause problems if the PV laminate has to be replaced. Especially for bituminous roofs, therefore, an air gap between the roof and the module is of critical importance. For most other roofing materials, the PV temperature is not a problem since their melting temperature is much higher than the typical temperatures induced (up to 70°C).

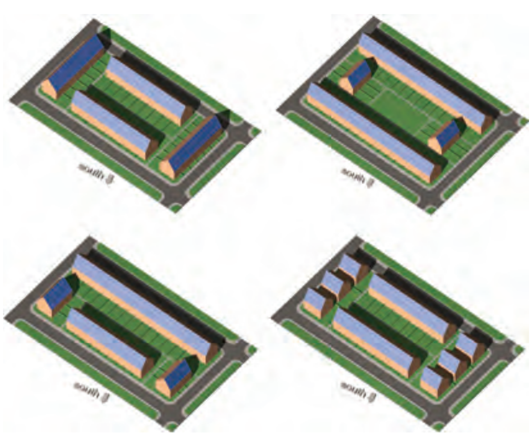
The connection between the PV modules and the roof usually leaves some room for expansion. Therefore, thermal expansion of the modules usually does not cause problems.

Influence of urban planning and site design

Site design strongly influences the performance of PV systems mounted on buildings. If building orientation is not optimized at this stage, this will result in reduced annual energy production compared to ideally oriented PV systems. Also, if the distance between buildings does not take account of shading by neighbouring buildings, annual energy production will be reduced. This can also occur if high-rise buildings are placed to the south of a site and lower buildings in the north (in the northern hemisphere).

Planned or probable building activity nearby should also be taken into consideration. Trees and high buildings, even if they do not block direct sunlight, can block a substantial amount of diffuse light.

For a given site, several site layouts can be imagined. Some will be better from an electricity production point of view than others. Generally it is very possible to combine good solar access with a pleasant urban structure. This is greatly helped by the fact that 'sun friendly' design and planning by no means requires strictly south (or north) facing systems or a predetermined tilt angle. Due to the large fraction of diffuse light, the sun is quite forgiving in many countries.



Several ways of designing blocks are possible for a given site. The choice made may be a compromise between system performance and freedom of design

Source: © M.ART

Inverter types and positioning

There are two main approaches to inverter selection. One is to use larger inverters for complete arrays or sub-arrays. The other approach is to use smaller inverters for each string of modules. This means that bigger systems simply use more inverters. Because a standard range of smaller inverters can be used for any size of system, standardized and bulk manufacturing techniques can be used. This can reduce costs compared to larger inverters.

In making a choice as to which approach to use there are a number of considerations. One is obviously cost; others are electrical efficiency, wiring losses and access for maintenance. All the modules connected to a single inverter should ideally be receiving the same irradiance, which means the same orientation and shading conditions. If there are multiple orientations or issues with shading, string inverters can improve the yield.

Wiring runs also need to be considered. The inverter should be positioned as close as possible to the PV array. The wiring from the array to

Inverters used for grid-connected systems

Source: © H. F. Kaan

the inverter will be DC wiring. Fuses do not work in DC wiring as they do in AC wiring; this creates a safety issue that should be considered. For safety double insulated cable will be needed. Low voltage, high current, double insulated DC wiring can be thick and heavy and difficult to bend making long routes impractical. String inverters are small and can be located close to the modules, for example under the eaves of a house roof, instead of in a plant room. A larger inverter may need to be located in a ventilated cupboard or plant room in a central location.

Access for maintenance also needs to be considered. Inverters are the component in any PV system most likely to require maintenance. A central location may be more convenient than having inverters distributed around a site. This can make a significant difference to long-term operation and maintenance costs.

Additionally, inverters should be located in an area where the heat generated during operation (up to 10 per cent of their nominal power) can be removed, since overheating will lead to lower energy efficiency (the power may be lowered to reduce dissipation of heat or the inverter may be switched off completely). In small cabinets forced ventilation may be necessary. Since some inverters may produce a little noise, one should pay attention to the inverter location and avoid living areas, etc.

Inverters located outside a building have to comply with regulations regarding safety, watertightness, etc. There is an international classification system for inverter electronic protection levels using codes.

Sustainability issues

A persistent misconception about PV systems is that it would require more (fossil) energy to manufacture and install them than the (renewable) energy they generate over their lifetime. Although this may have been true for the first generation systems built decades ago, the current generations have a so-called energy payback time (not to be confused with economic payback time) of typically 1.5 to 2 years in relatively sunny regions (insolation 1700kWh/m^2 per year) and 2.5 to 3.5 years in regions with moderate insolation (1000kWh/m^2 per year) (Alsema and de Wild-Scholten, 2007). These values may be compared with system technical lifetimes of 25 years or more, implying that PV systems are indeed excellent net producers of renewable energy. Moreover, the energy payback times decrease constantly and may soon be shorter than one year.

In addition to the energy needed to manufacture and install PV systems the materials used should also be considered in a sustainability analysis. For PV systems to be used on a very large scale it is important that they are based on 'Earth-abundant' materials. If that turns out to be impossible for all materials, closing the materials cycles is the next best solution, although this would not solve availability restrictions in the long term.

Photovoltaics and aesthetics[1]

Henk Kaan and Tjerk Reijenga

Introduction

This section discusses ways in which PV can impact on the architectural design of buildings, how this relates to the views of different stakeholders and what they want from buildings. It provides a framework to assess PV in architecture and should help to structure any discussion of architectural integrity by raising the argument above the usual level that simply looks at 'beautiful or ugly'. It aims to help architects, urban planners, property developers and local authorities by providing knowledge of PV systems that can help them to stimulate the application of PV in urban areas and remove prejudices with regard to large-scale urban application of PV.

1 This section is an adaptation of an article 'Photovoltaics in an architectural context' that was written by the same authors and published by John Wiley & Sons Ltd in: *Progress in Photovoltaics: Research and Application* (2004), vol 12, pp395–408.

PV and the built environment

Around 40 per cent of the energy consumed in Western countries is used by the built environment, in some form or another, with electricity taking an increasingly larger role. Generating electricity from renewable sources is therefore becoming increasingly important, and PV can play a prominent role in this.

In contrast to wind energy, biomass and hydropower, PV is extremely well suited to the built environment. In developed counties, PV is often integrated into the building envelope. This avoids having to use a separate mounting construction for the PV modules and overcomes the physical lack of space. It also ensures that the electricity generator is very close to the user. If high quality sustainable energy is to be encouraged, then PV is the obvious solution, at least as far as the built environment is concerned.

PV, architect and client

The number of building-integrated PV (BIPV) systems that can be seen remains limited. While there are quite a few good examples showing PV as an aesthetically neutral or visually attractive element in architecture, many BIPV systems display few architectural and urban qualities. Many architects and urban designers have never considered using PV as a means of architectural expression and have therefore not produced good solutions for architectural and urban integration of PV. Inexperience and lack of PV knowledge by clients and local authorities means that architects often have to work hard to convince them to consider PV. When it comes to costs, maximizing revenues and implementation/technical requirements, the architect often has no convincing argument for combining the architectural and aesthetic qualities with the possibilities offered by PV systems.

In the following paragraphs the position of property developers and institutional investors, private persons, local authorities and urban designers will be briefly discussed.

Renovated apartment buildings, with roof-integrated PV, Ludwigshafen, Germany

Source: © H. F. Kaan

Property developers and institutional investors

Property developers and institutional investors often see a building as a means of generating a certain, pre-calculated, return on their investment. These organizations build for the rental market or for anonymous house buyers. They often feel that a building should be as neutral as possible, both architecturally and operationally. In order to encourage these clients to consider PV the architect may need to present it as neutrally as possible, with regard to aesthetics and costs. This is certainly not impossible, as PV is a good alternative for existing exterior façade materials, such as those used for office buildings. PV also has most of the physical building characteristics of conventional façade materials, so that the building engineering remains fundamentally the same. Since conventional façade materials for non-residential buildings are generally not cheap, PV can often also represent a financially competitive alternative.

Private clients

In contrast to property developers and institutional investors, private clients often have specific ideas about how they want their building to look. For

Tsukuba Open Space Laboratory, Tokyo, Japan. PV has replaced the conventional glass façade. Architect: Jiro Ohno, Tokyo, Japan

Source: © H. F. Kaan

'Plus-Energie' house, Weiz, Austria. PV adds to the image of the building. Architect: Erwin Kaltenegger, Austria

Source: © H. F. Kaan

non-residential buildings these ideas often reflect the type of work and attitude of the building owner. These private clients can be attracted by the fact that PV sends a very clear message. If well applied, PV can increase a building's character and value. Although Bequerel discovered photovoltaic principles as far back as 1839, PV still has a 'high-tech' image and is therefore ideally suited for buildings with a non-traditional character. A few examples are given below.

Another important symbolic function of PV lies in the way it highlights the autonomy of the building – and its user. By expressing their individuality users show a clear wish to be less dependent on the energy supplier.

The aesthetics of an urban area are largely determined by the architectural quality of the buildings; both the individual buildings and the aesthetic relations between the various buildings. For that reason, in many countries local authorities set architectural and visual conditions relating to the appearance of new or renovated buildings. Environmental initiatives and political goals may be halted due to opposition by urban designers who are reluctant to accept PV in the urban design due to a lack of knowledge of the aesthetic possibilities of building-integrated PV. On the other hand, urban designers who try to prescribe the large-scale application of PV in an urban area may expect similar opposition from investors and housing associations nervous of the unfamiliar technology.

Local politicians may be tempted to give in to the opposition of property developers when considering prescription of large-scale PV in the urban environment. However, balanced against this is an appreciation of the role PV can play in reaching CO_2 reduction goals. Politicians can be helped with this discussion by providing knowledge about PV, its aesthetics and its costs.

Architectural and urban integration of photovoltaics: criteria for good design with PV

Architects have to confront questions on whether or not to incorporate PV into a design, what the building's physical, mechanical, electrical, financial and organizational conditions will be and the

Overview of the criteria for good PV architecture (Schoen et al, 2001)

1	Natural integration of the PV system
2	The PV system is architecturally pleasing, within the context of the building
3	Good composition of colours and materials
4	The PV system fits the gridula (visual pattern of the grid), is in harmony with the building and, together, form a good composition
5	The PV system matches the context of the building (contextuality)
6	The system, and its integration, are well engineered
7	The application of PV has led to an innovative design

J-House, Tokyo, Japan. Natural integration of the PV system in the building. Architect: Jiro Ohno, Tokyo, Japan

Source: © H. F. Kaan

question of how to incorporate PV into the aesthetic aspects. The numbers of architecturally unsatisfactory solutions that can be seen show that many architects are still struggling with this problem.

The aesthetic criteria below were developed in the late 1990s by a group of experts working within the International Energy Agency task focused on Photovoltaics in the Built Environment (Schoen et al, 2001). The group studied which key requirements needed to be complied with (design criteria for good-quality PV projects) in order to produce successful PV integration and formulated a number of (not too subjective) criteria whereby integration of PV in buildings could be architecturally classified and evaluated. The criteria can be used as a guideline for both the designer and the architectural critic.

1 Natural integration of the PV system

This means that the PV system seems to form a logical part of the structure and adds the finishing touch to the building. The PV system does not have to be that obvious. In renovation situations the result should look as though the PV system was there before the building was renovated.

2 The PV system is architecturally pleasing, within the context of the building.

The design must be architecturally pleasing. The building should look attractive and the PV system should not noticeably improve the design. This is a very subjective issue, but there is no doubt that some buildings are considered more pleasing than others.

3 Good composition of colours and materials

The colour and texture of the PV system should be consistent with the other construction materials.

4 The PV system fits the gridula, or visual pattern of the grid (is in harmony with the building and, as a whole, forms a good composition).

The dimensions of the PV system should match the dimensions of the building. This will determine the

'De Kleine Aarde' , Boxtel, The Netherlands. The PV system is architecturally pleasing, within the context of the building. Architect: BEAR Architekten, Gouda, The Netherlands

Source: © Ronald Schlundt Bodien

dimensions of the modules and the building grid lines used. (Grid = modular system of lines and dimensions used to structure the building.)

5 The PV system matches the context of the building (contextuality)

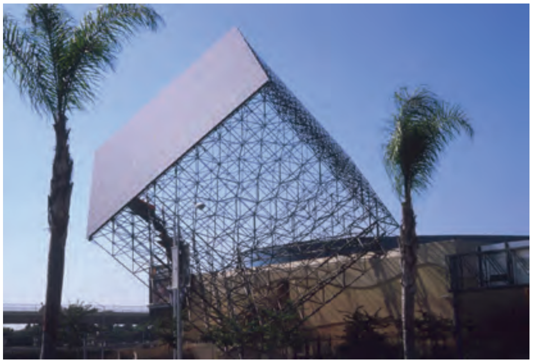
The appearance of the building, as a whole, should be consistent with the PV system used. In a historic building, a tile-type system will look better than large modules, if the PV system cannot be placed out of sight. A high-tech PV system, however, would look better on a high-tech building.

6 The system, and its integration, are well engineered

This does not refer to the waterproofing or reliability of the construction, but the elegance of the details. Did the designer pay attention to detail? Has the amount of material been minimized? These considerations will determine the influence of the working details.

Apartment block in Amersfoort, Nieuwland, The Netherlands. The colour and texture of the PV system is consistent with the other construction materials. Architect: Studio Z, Rotterdam, The Netherlands

Source: © H. F. Kaan



The 'Solar Cube' at the Discovery Science Museum in Santa Anna, Los Angeles (US). The PV system is in harmony with the building and, as a whole, forms a good composition. Architect: Steven Strong, Solar Design Association, Harvard, US

Source: © T. H. Reijenga

Roof outline of the UBS bank in Suglio (Switzerland). The detachable PV console modules form a total concept with the 'high-tech' image of the roof outline

Source: © P. Toggweiler

7 The application of PV has led to innovative designs

PV systems have been used in many ways but there are still countless new ways to be developed. This is all the more reason to consider this criterion, in addition to the other considerations.

Tsukuba Open Space Laboratory, Tokyo, Japan. Example of a well-engineered PV system. Architect: Jiro Ohno, Tokyo

Source: © H. F. Kaan

How can PV be incorporated into the building design?

The aforementioned criteria partially apply to all construction materials and building components. The fact that most of these criteria are automatically applied to traditional materials, but have to be explicitly formulated and discussed for PV, stems from the fact that PV is not automatically considered an indispensable material in architectural terms. It is not seen in the same light as windows, roof coverings, load-bearing constructions and façades. Buildings without windows are generally unacceptable, and buildings without load-bearing constructions are absolutely impossible. But this cannot be said for PV systems. This is why, no matter how well it is integrated, PV remains an 'added' element. Architects can take this as their starting point and can use one of the design approaches below.

ECN building 42 and 31, The Netherlands. PV has led to an innovative building design. Architect T. H. Reijenga, BEAR Architekten

Source: © Het Houtblad, John Lewis Marshall

Types of PV integration, listed according to the increasing amount of architectural value

1	PV is applied invisibly
2	PV is added to the design
3	The PV system adds to the architectural image
4	The PV system determines the architectural image
5	The PV system leads to new architectural concepts

1 PV is applied invisibly

The PV system is incorporated invisibly (and is therefore not architecturally 'disturbing'). The PV system harmonizes with the total project. The Maryland (US) project is a good example, where the architect has tried to integrate PV modules into the design invisibly. This solution was chosen

Single-family houses in Amersfoort Nieuwland, The Netherlands. The PV systems cannot be seen from the public space

Source: © H. F. Kaan

because the entire project concerned 'historic' architecture. A modern high-tech material would not be appropriate for this architectural style.

2 PV is added to the design

The PV system is added to the design. Building integration is not really used here, but this does not necessarily mean that architectural integration is also lacking. The 'added' PV system is not always visible either.

3 The PV system adds to the architectural image

The PV system has been integrated beautifully into the total design of the building, without changing the project's image. In other words, the contextual integration is very good.

4 The PV system determines the architectural image

The PV system has been integrated into the design in a remarkable and beautiful way, and plays an important role in the total image of the building.

5 The PV system leads to new architectural concepts

Using PV modules, possibly in combination with other types of solar energy, leads to new designs and new architecture. The integration of PV modules has been considered at a conceptual level, which gives the project extra value.

Renovated apartment buildings, Ludwigshafen, Germany. PV is added to the design, thus strengthening the architectural appearance

Source: © H. F. Kaan

Single-family houses in Freiburg, Germany. PV adds to the architectural image of these 'Plus-Energie' Passive Houses

Source: © H. F. Kaan

The above categories are classified according to the increasing extent of architectural integration. However, a project does not necessarily have to be of a lesser quality just because the PV modules are not visible. A visible PV system is not always appropriate, especially for renovation projects with historic architectural styles. The challenge for architects, however, is to integrate

Single-family houses 'Gelderse Blom' Veenendaal, The Netherlands. PV is determining the architecture. Architect: Han van Zwieten Architekten

Source: © Han van Zwieten Architekten

Single-family houses ‘De Keen’, Etten-Leur, The Netherlands. The application of PV has led to a new architectural concept. Architect T. H. Reijenga, BEAR Architekten

Source: © Ronald Schlundt Bodien

PV modules into buildings properly. PV modules are a new building material that offers new design options. Applying PV modules in architecture should therefore lead to innovative new designs.

Final comments

The above criteria have been defined taking building-integrated PV in architecture as a starting point. As buildings, and consequently building-integrated PV, form a part of the perception of urban aesthetics, the above criteria may also be applied when it comes to giving a value judgment of the urban environment.

The criteria presented here are important to architects and architectural critics in determining why a BIPV project, be it their own design or that of a colleague, in an urban context or alone, may not be aesthetically pleasing. This offers learning opportunities and reasons for follow-up or improvement options. Architects who apply PV in a well thought-out way can make their clients very happy, and thereby contribute to greater acceptance of PV technology.

Photovoltaics in public spaces

Bruno Gaiddon and Joana Fernandes

Introduction

Although roofs and façades offer large unused surfaces, which are often well suited for the use of PV, buildings are not the only structures suitable for the installation of PV systems. In numerous cities around the world, PV has been successfully integrated into non-building structures. This integration in the urban space takes advantage of the architectural quality of PV and its ability to supply electricity suited to the needs of products used in urban areas. Many products are available and a wide variety of concepts can already be seen in some cities, both as off-grid and grid-connected systems.

In public urban spaces, PV can be used to generate electricity and to provide additional functions such as shading or sheltering paths. PV installed in public spaces on non-building structures is generally more visible than roof-integrated PV and can actively contribute to enhancing a city's image and fostering public awareness of PV. Particularly when products are well designed and demonstrate that PV can perform multiple functions, PV on non-building structures can actively promote dissemination and provide education on sustainable urban energy solutions.

Public spaces equipped with PV systems can:

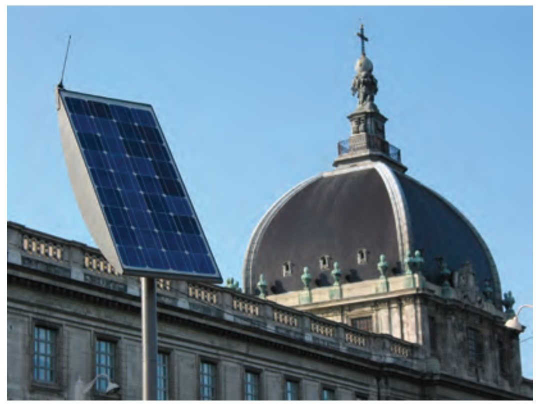
- offer additional surfaces suited for the installation of PV in order to increase the amount of locally produced renewable electricity;
- bring PV closer to people and help to inform visitors about sustainable energy solutions;
- promote the sustainability of the area, particularly as PV on non-building structures is sometimes more visible than building-integrated PV.

The possibilities for integrating PV in public spaces are almost unlimited and depend on the designer's creativity. PV installed on non-building structures can be classified in the following categories:

- urban street equipment;
- shelters, barriers and shading structures;
- urban art.

Urban street equipment

Urban street equipment provides conventional functions that require electrical power such as streetlights, parking meters, zebra crossings and information signs. The electrical needs of these types of equipment tend to be low, and can be provided by a small PV array, from $0.2m^2$ to $10m^2$ of PV. The amount and



In Lyon, France, PV is used to power bus stops to display the waiting time for the next bus

Source: © Hugues Perrin - Hooznext.com

In Freiburg, Germany, PV is used to power an electric scooter recharging station

Source: © Solon AG

In Amersfoort, The Netherlands, PV is used to provide shelter in public spaces

Source: © Hespul

In Barcelona, Spain, PV is used as a shading device for a large exhibition area at the 2004 Forum

Source: © Joseph Puig

cost of the PV required can be reduced by maximizing the energy efficiency of the equipment. The cost can be competitive with conventional equipment, particularly if the cost of installing a conventional electricity supply can be avoided.

Shelters, barriers and shading structures

One of the most explored properties of PV is its potential to provide shade from the sun and shelter from the rain. It can be used on buildings as awnings, and also in bus and car shelters and other structures. PV has also been used on sound barriers where it can ally optimized orientation for electrical output with noise-protection functions.

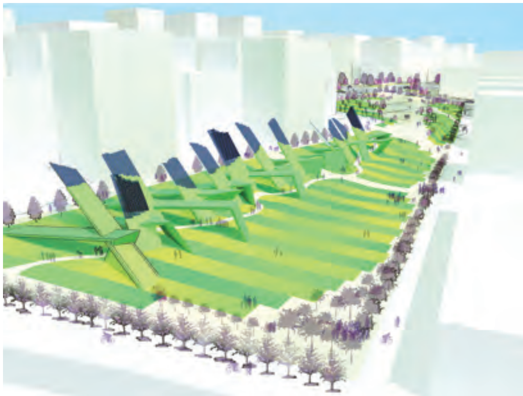
Urban art

Street art and sculpture can use new materials in innovative applications to present aesthetically pleasing ideas. The use and integration of PV into new concepts and innovative structures can increase awareness among the public and also tap into the enthusiasm of architects and designers for using new components in their work.

Smart solutions that take advantage of an electricity production material can be developed into products that provide an optimal combination of physical and aesthetic integration of PV technology in urban structures, maximizing the overall value of the PV system. The intent is that, for each object designed, there will be a balanced combination of form and function, which will deliver a high-value product (Rodrigues, 2004).

PV used as urban plants to catch the sun and provide shade

Source: © Wolfgang Krakau Architekt / 2nd Lisbon Ideas Challenge



PV used as upper part of kindergarten structure

Source: © Chien Kuo Kai/2nd Lisbon Ideas Challenge

Implementation issues and design strategies

Solar resource

In the built environment, the likelihood of shading and low irradiation is higher than in open spaces. Design strategies and integration options should take this aspect into consideration when selecting system locations and sizes.

Visual appearance

Visual impact is a key issue in promoting the acceptance and deployment of PV. The appearance of the structures will determine if they have a positive or negative impact on the community. The installation of non-building PV structures in the city, and especially in historic city centres, should not only consider the integration of the PV system in the structure, but also the integration of the structure within the surrounding environment.

Vandalism and theft

People are the key for all urban strategies. The possibility of vandalism and theft should not be ignored and both the PV industry and the urban furniture industry need to cooperate and adopt appropriate design strategies to minimize the problem. The problem is worsened by the high prices of PV modules and the existence of a second-hand market.

Maintenance

Maintenance, repair and replacement of PV modules in non-building PV structures also need to be considered. The design of these structures should take into consideration maintenance and manageable module replacement in case of module damage. With off-grid PV systems special attention must be paid to the maintenance of batteries.

Cost

The final issue that one must take into account when implementing PV in non-building structures is the cost. PV modules are still expensive and their inclusion in mass produced structures should be cost-effective. For this, well-integrated designs that consider PV as a material that can perform a wide range of functions in parallel with electricity production is essential.

Photovoltaics and electricity distribution networks

Estefanía Caamaño-Martín, Bruno Gaiddon and Hermann Laukamp

Introduction

When planning or designing developments incorporating PV systems, developers have to inform the local distribution network operator (DNO) that PV systems will be installed and that connections to the local distribution grid will be necessary.

In some cases DNOs are reluctant to interconnect PV systems to distribution grids due to concerns about interactions with their networks. The objective of this section is to help developers and DNOs to understand the impacts and effects of PV systems on distribution grids in order to build a constructive dialogue and allow projects to go ahead.

A constructive dialogue is necessary with distribution network operators to make urban-scale PV projects successful

Source: © EnergiMidt, photo Jakob Jensen

The impacts/effects of PV on distribution networks

PV systems, as sources of power connected to the low voltage or medium voltage networks, may impact electricity distribution grids (Caamaño et al, 2007b). Possible impacts of PV power generators on distribution grids can be classified under three headings:

1 safety of DNO employees in the case of grid maintenance or failure;
2 quality of the electricity produced;
3 management of distribution grids with PV systems.

Safety – unintentional islanding

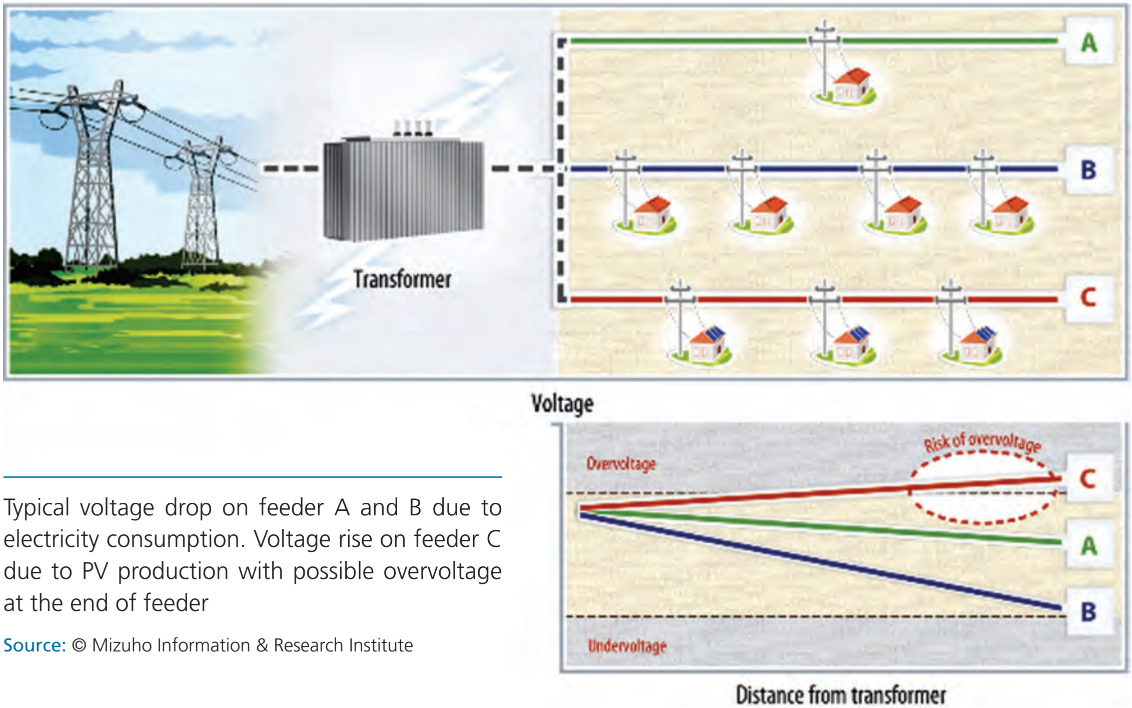
PV systems are connected to distribution grids through inverters that convert DC current into AC current. The inverters are equipped with automatic detection and disconnection devices to stop the power supply in the case of grid failure and to prevent 'unintentional islanding'.[2] Unintentional islanding from PV inverters is a theoretical situation observed in laboratories but which has never been reported under real conditions, even in areas with a large number of PV systems connected to a distribution network. This suggests that internal disconnection devices are efficient and perform reliably; in fact, the most recent scientific studies (Caamaño et al, 2007b) conclude that with currently available technologies, the risks associated with unintentional islanding can be kept at acceptably low levels. Islanding should therefore not be considered a barrier for the integration of PV systems in distribution networks, even under high penetration scenarios.

Power quality – voltage rise

PV inverters are electronic power devices which convert DC power from a PV generator into a near pure sine current AC waveform with high efficiency conversion rates. The quality of electricity is defined by international and national standards including parameters such as voltage and frequency variations, power factor, harmonics, etc. Most recent studies show that modern PV inverters deliver good quality electricity with high efficiency conversion rates. However, when a large number of PV systems are connected to a distribution network, it is possible that under particular circumstances (low consumption demand coincident with high PV generation) PV systems located far away from the local transformer (feeder) may pull the voltage over the acceptable limits.

In fact this is the main impact observed in reality with PV systems on distribution grids. It can cause problems for electricity consumers, as some electric appliances may not operate properly, and for the PV system since the

2 Unintentional islanding is a situation where a part of the grid can be unintentionally maintained live by local generation when the primary network is disconnected, either for grid maintenance or in case of failure.



Typical voltage drop on feeder A and B due to electricity consumption. Voltage rise on feeder C due to PV production with possible overvoltage at the end of feeder

Source: © Mizuho Information & Research Institute

inverters' automatic overvoltage protection may disconnect the system from the grid, leading to production losses. Nevertheless, overvoltage effects have never been reported in European urban networks, with only a few examples in rural areas. There are several ways to prevent this event such as:

- good network design in the case of new distribution grids (or reinforcement of existing networks), to allow for decentralized PV systems interconnection;
- adapting the existing voltage regulation techniques used in distribution networks, according to the expected periods of low demand and local PV production;
- to use the new generation PV inverters that will in the future be able to provide additional services to the grid such as voltage control.

Finally, it is worth mentioning the fact that, with the changes in electricity systems arising from the liberalization of electricity markets and the increasing concern for security, quality of supply and environmental issues, new developments of PV inverters are currently under way which, in coordination with grid management, can improve the power quality of the networks (active filtering, power factor regulation, reactive power control, phase symmetry control, etc.). Also, in combination with local energy storage, more options are possible for PV systems to contribute to grid stabilization, operational (controlled) islanding and peak shaving. To fully exploit these possibilities appropriate regulatory frameworks need to be developed, which are expected to come into effect in the near future.

Feed-back and the opinion of DNOs with PV experience

In Europe, more than 30 DNOs from countries representing more than 95 per cent of the PV power installed have been interviewed, in order to share their experience with PV systems connected to their distribution networks (Caamaño et al, 2007a). Overall, it can be concluded that the experience and perception of PV systems by European utilities is positive: grid-connected PV plants have demonstrated compatibility with low voltage distribution networks, even at high densities. Some potential concerns are not PV specific, but common to most distributed generation technologies (e.g. wind turbines, combined heat and power devices, etc.). Consequently, technology advances and harmonization of technical requirements in the field should facilitate the integration of PV systems in the future.

For the DNOs interviewed, unintentional islanding is not an issue as PV inverters must comply with existing standards designed to prevent such situations. Regarding voltage rise from PV systems, this effect is not a big concern in urban areas, although it could be a potential concern at high PV penetration levels in rural or weak distribution networks. Concerning power quality, DNOs are more concerned about decreases in the quality in distribution networks due to existing electrical appliances (some of which generate high current harmonics), than from power generators such as PV systems. Finally, new ancillary services from PV inverters such as active filtering, voltage regulation and reactive power control are deemed of interest by DNOs, in the context of future intelligent networks.

It is important to highlight the fact that the DNOs with the greatest previous experience with PV from countries like Germany and The Netherlands are less concerned by the impacts of PV systems on distribution networks than those with less experience. This can be attributed to good experiences with PV technology and strong urban grids as well as clear responsibilities for DNOs in their particular electricity markets. It is also worth noting that DNOs mostly concerned by PV systems negatively affecting distribution grids had generally no or little experience with PV.

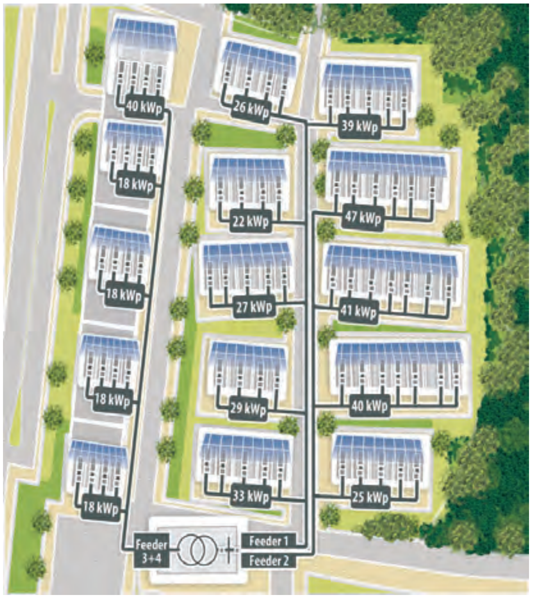
Lessons learned from on-site monitoring campaigns

In Germany and in The Netherlands, three urban real estate developments with a high density of distributed PV generation have been monitored in order to analyse the quality of the voltage supply and the maximum tolerable level of PV that can be connected to a low voltage distribution network (Cobben et al, 2008).

For each of these PV projects the PV power is a significant proportion of the transformer power and for one project even surpasses it. The conclusion drawn from these monitoring campaigns is that existing urban electricity grids can accept a large amount of solar electricity. A typical urban European low voltage grid segment can, for instance, accept PV power up to 70 per cent of the rated power of the feeding transformer without causing any trouble. Also, no detrimental effects on power quality were noticed during the analysis except, in one case, a very specific mutual disturbance effect due to an incompatibility between one inverter type and the local grid.

Holidaypark Bronsbergen in The Netherlands with a PV power representing 80 per cent of the feeding transformer power: 315kWp of PV on a 400kVA transformer

Source: © Continuon



Distribution network of the Solarsiedlung 'Am Schlierberg' with PV power larger than the feeding transformer power: 440kWp of PV on a 400kVA transformer

Source: © Solarsiedlung GmbH

Recommendations

- When designing an urban area with PV, stakeholders responsible for the infrastructure design must anticipate and inform the local DNO that PV systems will be installed in the area.
- DNOs must take PV systems into consideration in the planning phase of new distribution networks in order to prevent possible voltage rise at high PV production and low consumption levels (especially for rural or weak grids).
- In order to avoid any problems caused by the PV capacity in a low voltage grid segment, PV power should be limited to 70 per cent of the rated power of the feeding transformer (Laukamp et al, 2008).
- Even if voltage level rise along a feeder is not critical for inflexible urban grids, in the case of a new residential area with PV, cable cross-should be the same all along a feeder and should not be reduced at the end of the feeder as is usually done (Laukamp et al, 2008).

Top tips at various project stages

Donna Munro

These tips cover all stages of promoting, designing, constructing and living with PV systems in urban areas. They are based on the collective experience of a group of PV specialists.

Policy stage – to promote PV in an area

- Build political commitment at all levels, national to local.
- Add to policy framework; stimulate to have short, medium and long-term goals.
- Put resources into a dedicated environment/sustainability department if department exists; if not, create one!
- Use obligations and incentives.
- Provide free information and initial assistance to help get projects started.
- Arrange visits and tours.
- Feed back results from positive projects to policy-makers (environmental, social, visual and economic benefits) to create a positive cycle leading to strengthening of policy.
- Ensure positive results and awards are publicized.
- Learn from problems with earlier projects.

Project start-up

- Take solar energy into account in urban planning as early as possible.
- Talk to all relevant stakeholders. Especially talk to the DNO about possibilities as early as possible (if not facilitated by law).
- Emphasize synergy where possible – PV as shading device, construction material, image builder.

- For existing buildings explore synergies with retrofit measures (roof tiles, insulation, etc.)
- Identify the value the different stakeholders see in PV and the different information needs for each stakeholder. Architects may want design specifications while engineers may want energy production specifications. It helps when these differences between stakeholders are identified at an early stage of the project.
- Include renewables in site brief from the beginning if possible.
- Require proof of relevant PV experience in design team.
- Define what stage the system is when handed over (technical and contractual), i.e. commissioned and export contract signed or earlier stage?
- Require plan for informing/training rest of design team with some basic understanding of PV and implications for them.

Raising funding

- Consider all possible options (regular and innovative): subsidies, income from electricity, feed-in tariff, loans, sponsors, solar funds and share schemes.
- Consider cost savings from combining functions (e.g. PV also providing shading).
- Consider the balance needed between complexity and effort required to raise funding and benefits potentially obtained. Having multiple sources of funding can make for complications.
- Timetables of funding and construction must be compatible.
- Consider who is eligible to claim the various funding options (from occupants to municipality to installers).

Design stage

- Take passive solar design and energy efficiency into account during the whole design process.
- Future proof (allow for the future addition of renewables) e.g. roof structure with identified fixing locations or provision of identified and accessible electrical cable ductwork.
- Follow design guidance, available from many (Prasad and Snow, 2005).
- Consider guarantee periods required and form of guarantee (components, system and energy output).
- Ensure clear lines of responsibility, guarantees of roof, PV, etc.
- Consider the range of building-integrated PV styles available and choose the look wanted from highly visible design feature to invisible.
- Design to maintain output over the life of the system (facilitate easy maintenance, system checking and monitoring).
- Consider end of life safe dismantling and recycling.
- Match complexity of system and level of effort required to keep operating to prospective occupants.

Construction/realization

- If the project is innovative for the region ensure that design and construction are well done with the help of a PV expert.
- Safety guidelines need to include PV.
- Use experienced/trained installers.
- Coordination between contractors and installers is vital.
- Plan PV mounting process within building process.
- Minimize risk of damage to roof or PV during installation by installing together.
- Just in time delivery of modules minimizes risks of damage or theft.
- Arrange a safe storage location for modules and insurance.
- Uncertainty/risks increase costs so provide information to other contractors to avoid cost mark ups due to concern about delays or unforeseen problems.

Handover

- Ensure information is provided to occupants (sturdy format), including guarantee documents.
- Ensure interface/display confirming PV operation is available and understood by user (visual signal for operating/problem and electricity generation data).
- Ensure electrical commissioning has taken place and permission to connect to grid given.
- Ensure export tariff agreed and contracts signed if needed (in Germany some feed-in contracts may be worse than the default conditions required by law).
- Ensure maintenance plan in place and well documented and filed.
- Arrange insurance.

Operation

- Foster pride in the sustainability of the area.
- Information needs to be passed on if building occupants change or technical personnel change, consider if a formal procedure is needed.
- Provide information about expected power and yields to allow poor performance to be detected.
- Providing good metering and feedback to occupants helps to keep them aware of energy saving and can result in extra energy savings.
- If displays are not clear problems are not picked up and incentive to save energy not provided.
- Responsibility for checking performance needs to be with someone.
- Reliable point of contact for queries and maintenance needed.

Risk points – initial planning

- Initial urban plan not solar aware.
- Not in brief so nobody's problem.
- DNO not aware when installing electricity supply network and so not strong enough or not enough supply points = extra costs to refit.
- Incompatibility of funding and development timetables.

Risk points – handover

- Handover to occupants without export contracts signed, paperwork difficult for householders to deal with.
- Changeover of occupants and information lost.
- Lack of output and nobody notices or has sufficient incentive to fix.
- Income needed or no incentive to keep operating.

References

Alsema, E. A. and de Wild-Scholten, M. J. (2007) *Reduction of Environmental Impacts in Crystalline Silicon Photovoltaic Technology – An Analysis of Driving Forces and Opportunities*, Proceedings of the Materials Society Fall Meeting, Symposium R – Life Cycle Analysis for New Energy Conversion and Storage Systems, MRS online proceedings, www.mrs.org, accessed 29 January 2009

Becquerel, E. (1839) 'Mémoire sur les effets électriques produits sous l'influence des rayons solaires', *Comptes Rendues* vol 6, p561

Caamaño, E., Suna, D., Thornycroft, J., Cobben, S., Elswijk, M., Gaiddon, B., Erge, T. and Laukamp, H. (2007a) *Utilities Experience and Perception of PV Distributed Generation*, Deliverable D4.2 of the PV UP-SCALE project, Madrid

Caamaño, E., Thornycroft, J., De Moor, H., Cobben, S., Jantsch, M., Erge, T., Laukamp, H., Suna, D. and Gaiddon, B. (2007b) *State-of-the-Art on Dispersed PV Power Generation: Impacts of PV-DG and electricity networks*, Deliverable D4.1 of the PV UP-SCALE project, Madrid

Cobben, S., Laukamp, H. and Gaiddon, B. (2008) *Impact of PV Systems in High Capacity PV Settlements*, Deliverable D4.3 of the PV UP-SCALE project, Freiburg

Laukamp, H., Caamaño, E., Cobben, S., Erge, T. and Thornycroft, J. (2008) *Recommendations for Utilities*, Deliverable D4.4 of the PV UP-SCALE project, Freiburg

Perlin, J. (1999) *From Space to Earth: The story of solar electricity*, aatec publications, Ann Arbor, MI, US

Prasad, D. and Snow, M. (2005) *Designing with Solar Power, A Source Book for Building Integrated Photovoltaics* (BIPV), Earthscan, London

Rodrigues, M. (2004) *1st Lisbon Ideas Challenge – Urban Design with Photovoltaics*, IN+/IST Technical University of Lisbon, Lisbon

Schoen, T., Prasad, D., Ruoss, D., Eiffert, P. and Sørensen, H. (2001) *Task 7 of the IEA PV Power Systems Program. Achievements and outlook*, 17th European Photovoltaic Solar Energy Conference, 22–26 October, Munich

APPENDICES

Sources of further information

Chapter 1

PV UP-SCALE projet www.pvupscale.org
IEA PVPS Task 10 www.iea-pvps.org

Chapter 2

Australia, Sydney Olympic Village

Mirvac LendLease Village Consortium www.newingtonvillage.com.au
BP Solar www.bpsolar.com.au

Austria, Gleisdorf

Energy region Gleisdorf/Weiz www.energieregion.at
Feistritzwerke www.feistritzwerke.at
City of Gleisdorf: www.gleisdorf.at

France, Grand-Lyon, La Darnaise

OPAC Grand-Lyon www.opac-grandlyon.com
The City of Vénissieux www.ville-venissieux.fr
Grand-Lyon Energy Agency www.ale-lyon.org
Tenesol www.tenesol.com

France, Saint-Priest, Les Hauts de Feuilly

SERL www.serl.fr
Groupe MCP www.groupemcp.com
PV-Starlet project www.pv-starlet.com

Germany, Solarsiedlung

Architect Rolf Disch www.rolfdisch.de
Energy-Surplus-House® www.plusenergiehaus.de
Solarsiedlung GmbH www.solarsiedlung.de
Solar Funds www.freiburgersolarfonds.de
The City of Freiburg www.solarcity-freiburg.de

Italy, Alessandria

The City of Alessandria www.comune.alessandria.it

Japan, Jyosai Town

The New Energy and Industry Technology Development Organization www.nedo.go.jp
The City of Ota www.city.ota.gunma.jp

The Netherlands, Amsterdam, Nieuw Sloten

PV Database www.pvdatabase.org
BIPV Tool www.bipvtool.com

The Netherlands, Amersfoort, Nieuwland

PV Database www.pvdatabase.org

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

The City of Heerhugowaard www.heerhugowaard.nl
HAL Project www.ceesbakker.nl

Spain, Barcelona

Barcelona Energy Agency www.barcelonaenergia.cat
Barcelona City Council www.bcn.es
Real-time monitoring data, Canal Solar Barcelona www.canalsolar.com

Sweden, Malmö

Solar City Malmö www.solarcity.se
The City of Malmö www.malmo.se

UK, Croydon

The Merton Rule www.themertonrule.org
Croydon Council www.croydon.gov.uk
Creative Environmental Networks www.cen.org.uk
Solarcentury www.solarcentury.com

UK, Kirklees

Kirklees Council www.kirklees.gov.uk
The Ashden awards www.ashdenawards.org

Titanic Mill www.lowryhomes.com/titanicmill
SunCities www.suncities.nl

Premier Gardens New Home Development, Rancho Cordova, CA

Sacramento Municipal Utility District
www.smud.org
Premier Homes www.premierproenergy.com

Chapter 3

Denmark, Valby, Sol i Valby

Sol i Valby project www.solivalby.dk
Resurgence project www.resurgence.info

France, Lyon, Lyon-Confluence

Lyon-Confluence www.lyon-confluence.fr
Lyon-Confluence www.laconfluence.fr
Grand-Lyon council www.grandlyon.com
Renaissance project www.renaissance-project.eu

Germany, Solar Urban Planning Berlin

Urban Development Department Berlin
www.stadtentwicklung.berlin.de

Germany, Solar Housing Estate Cologne-Wahn

Wohnen am Elzhof
www.wohnen-am-eltzhof.de
Energy Agency North-Rhine-Westphalia
www.energieagentur.nrw.de

Germany, Solar Quarter Gelsenkirchen-Bismarck

Solar City Gelsenkirchen
www.solarstadt-gelsenkirchen.de

Portugal, Lisbon, Bairro do Padre Cruz

Lisbon Ideas Challenge
www.lisbonideaschallenge.com.pt
Competition organizer http://in3.dem.ist.utl.pt

UK, Port of Barrow Redevelopment

Barrow Borough Council
www.barrowbc.gov.uk
West Lakes Renaissance
www.westlakes renaissance.co.uk
The Code for Sustainable Homes
www.breeam.org
The Merton Rule www.themertonrule.org

Case study matrix

	Municipal policy	Innovative financing	Site design	Building-integrated PV	Retrofit	Utility involved	Housing associations	Private developers	Grid issues	Non-building structures	Energy efficiency / other renewable energy sources	Occupant feedback	Operation and maintenance
Chapter 2													
Australia, Sydney Olympic Village						X		X		X	X		
Austria, Gleisdorf	X	X				X				X	X		X
France, Grand-Lyon, La Darnaise				X	X		X				X		
France, Saint-Priest, Les Hauts de Feuilly			X	X				X	X		X		
Germany, Freiburg, Schlierberg Solar Estate		X	X	X				X			X	X	
Italy, Alessandria	X		X		X		X			X			
Japan, Jyosai Town						X			X				
The Netherlands, Amsterdam, Nieuw Sloten			X	X		X			X				X
The Netherlands, Amersfoort, Nieuwland			X	X		X	X	X	X			X	X
The Netherlands, HAL region, 'City of the Sun'	X	X	X	X		X		X					
Spain, Barcelona	X			X	X						X		X
Sweden, Malmö	X			X	X						X		
UK, London, Croydon	X			X				X			X		
UK, Kirklees	X						X	X			X	X	X
US, Premier Gardens				X		X		X	X		X	X	X
Chapter 3													
Denmark, Valby, Sol i Valby	X	X		X					X				
France, Lyon, Lyon-Confluence	X		X	X				X	X		X		
Germany, Solar Urban Planning Berlin	X				X		X	X					
Germany, Solar Housing Estate Cologne-Wahn			X	X				X					
Germany, Solar Quarter Gelsenkirchen-Bismarck	X		X	X				X					
Portugal, Lisbon, Bairro do Padre Cruz				X			X			X			
UK, Port of Barrow Redevelopment	X		X					X			X		

Index