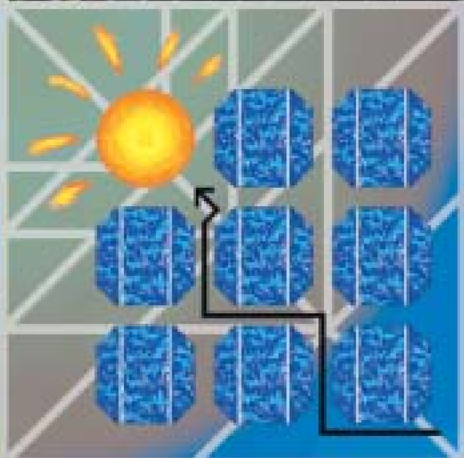
New Solutions in Energy Supply

Solar ElectriCity Guide



ENERGIE

This Energie publication is one of a series highlighting the potential for innovative non-nuclear energy technologies to become widely applied and contribute superior services to the citizen. European Commission strategies aim at influencing the scientific and engineering communities, policy-makers and key market players to create, encourage, acquire and apply cleaner, more efficient and more sustainable energy solutions for their own benefit and that of our wider society.

Funded under the European Union's fifth framework programme for research, technological development and demonstration (RTD), Energie's range of support covers research, development, demonstration, dissemination, replication and market uptake — the full process of converting new ideas into practical solutions to real needs. Its publications, in print and electronic form, disseminate the results of actions carried out under this and previous framework programmes, including former JOULE-Thermie actions. Jointly managed by the European Commission's Directorates-General for Energy and Transport and for Research, Energie has a total budget of EUR 1 042 million over the period 1998-2002.

Delivery is organised principally around two key actions, 'Cleaner energy systems, including renewable energies' and 'Economic and efficient energy for a competitive Europe', within the theme 'Energy, environment and sustainable development', supplemented by coordination and cooperative activities of a sectoral and cross-sectoral nature. With targets guided by the Kyoto Protocol and associated policies, Energie's integrated activities are focused on new solutions which yield direct economic and environmental benefits to the energy user, and strengthen European competitive advantage by helping to achieve a position of leadership in the energy technologies of tomorrow. The resulting balanced improvements in energy, environmental and economic performance will help to ensure a sustainable future for Europe's citizens.

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Foreword

The sun is the inexhaustible source of energy which we are now increasingly able to use more efficiently. With photovoltaic cells (PV) we are able to generate electricity directly from the sun. The possibilities of photovoltaics, especially as a building integrated element, are enormous. For this reason, the market development of this prestigious technique plays an important and permanent role in the move towards a more sustainable future and our joint battle against climate change.

Nowadays, across Europe, there is a proven track record of successful photovoltaic projects with diverse designs, applications and project financing mechanisms. In many of these projects, the role of municipalities was crucial. Fortunately, an increasing number of municipalities intend to make the integration of photovoltaic modules a more structural subject to be considered in daily city planning activities.

The objective of this guide is to provide actors within local and regional authorities as well as related professionals (urban designers and developers, project developers and builders) with the necessary information and instruments to define, evaluate, plan and implement photovoltaic projects in an urban environment. It gives access to the existing wealth of information, experience and expertise in this emerging sub-sector of the renewable energy market, one in which Europe has an indigenous manufacturing industry, a lead role in the global market.

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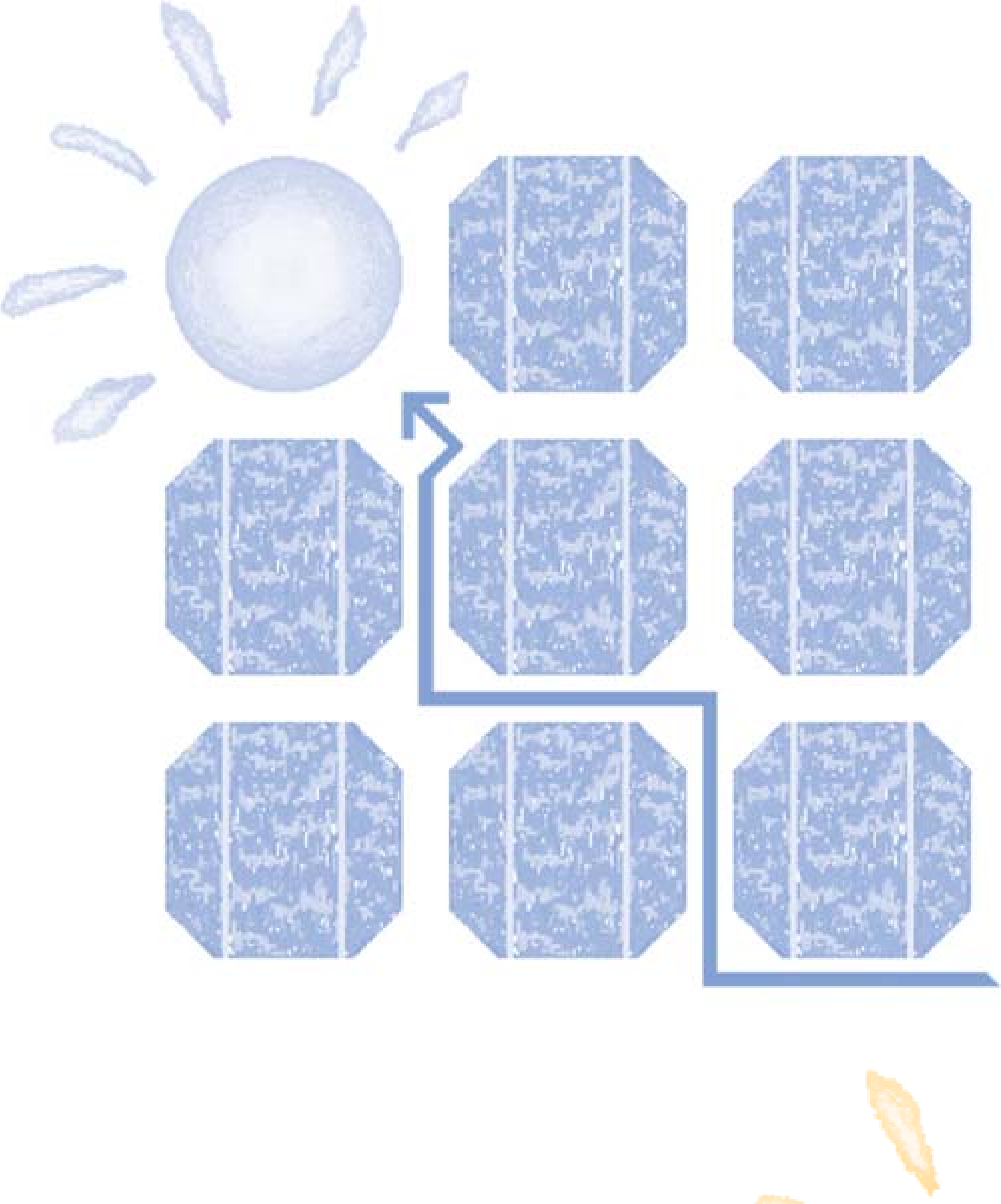


Introduction

Photovoltaics offers unique opportunities to produce (solar) electricity in the urban environment. There is in fact hardly any other renewable energy technology with such a potential in the urban context. This makes photovoltaics particularly interesting in relation to local urban design as well as in the local energy portfolio. Consequently, photovoltaics can contribute considerably to sustainable development at the local level.

Municipalities and the related professional sectors have a crucial role to play in the exploitation of these solar opportunities. This is why this publication targets municipalities as well as local professionals and institutions in order to highlight the key issues to be taken into consideration in individual applications. It also offers indications and recommendations on how strategic urban policies can be developed in order to increase the use of photovoltaics.

▲ *Figure 0.1: Solar power in a refurbished façade in Berlin - Marzahn - Germany. Source: NET Ltd, St. Ursen, Switzerland.*

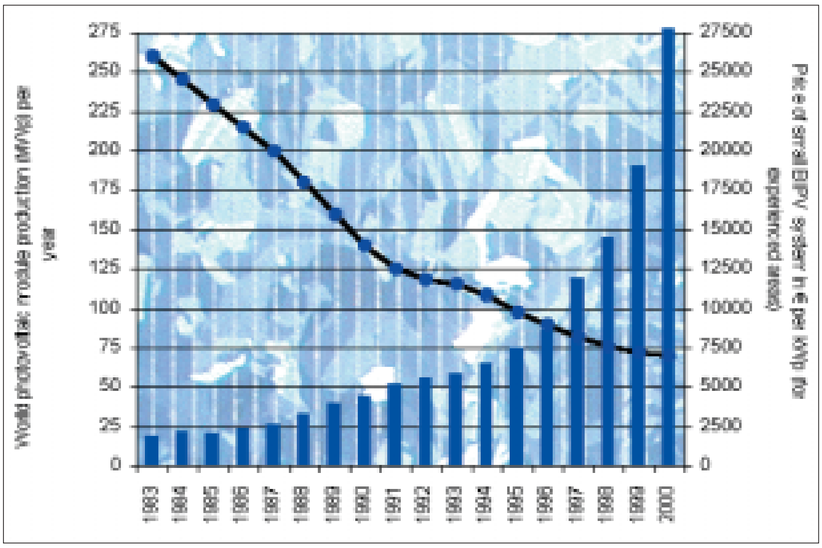
▲ *Figure 0.2: Roof to be clad and turned into a multifunctional building skin. Source: Ecofys, The Netherlands.*

◄ *Figure 0.3: Attractive shopping mall in Zurich. Source: energiebuero® Zurich, Switzerland.*

▲ *Figure 0.4: Photovoltaic power in the night at the bus stop. Source: Atlantis, Switzerland.*

▲ *Figure 0.5: No digging for grid-connection, just plug the sun. Source: Tymandra Blewett-Silcock.*

Benefits of photovoltaics



▲ ***Figure 0.6:*** *Annual world photovoltaic module production and costs in recent years. Compilation: NET Ltd., St. Ursen, Switzerland.*

Photovoltaics has many attractive features in addition to useful local environmental, socio-economic, architectural and technical benefits.

Photovoltaics is **environmentally benign**. Globally it represents an important component of our energy future and helps prevent depletion of valuable natural resources. Locally, solar electricity can be produced almost anywhere and on any scale and can thus make a considerable contribution to sustainability in your city now and in the longer term.

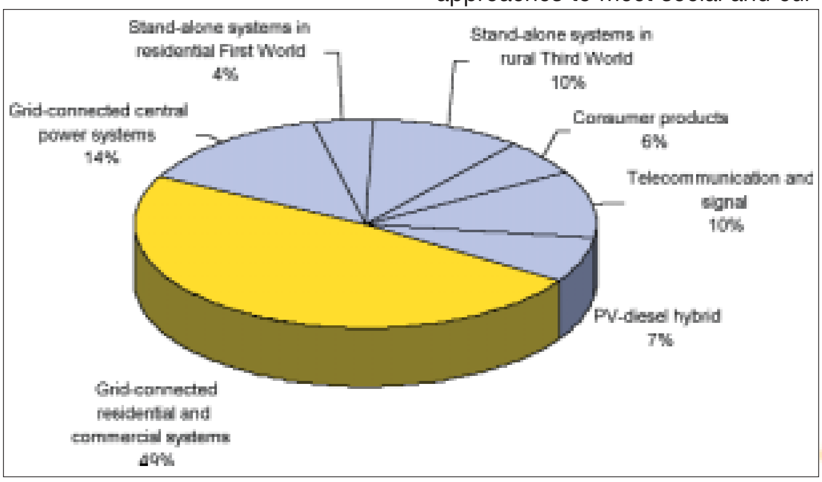
Today, photovoltaics can already offer a number of **economically viable and competitive applications** within the built environment. Photovoltaics can be part of new, attractive and prestigious design approaches to meet social and cultural demands. It also creates new employment and emerging business opportunities as well as raising social awareness about sustainability, energy saving and commitment to environmental protection.

Photovoltaics is both **versatile in application** and modular in structure and fits well into buildings and other structures. Integrating photovoltaic elements has a double benefit - they can produce electricity and replace construction materials - be it for building components or for parking meters. As a matter of fact, cities offer numerous opportunities for photovoltaic deployment.

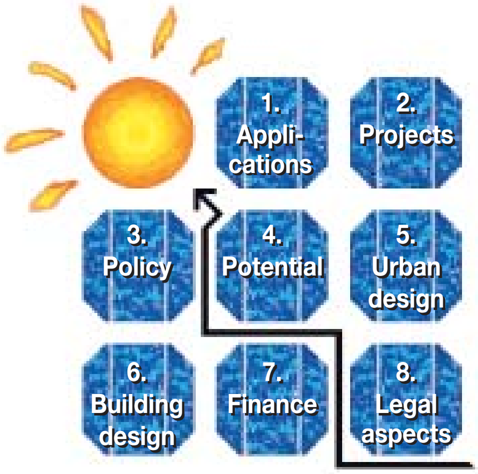
The operation of photovoltaic systems is **technically reliable**, generates energy virtually free of emissions (CO_2, NOx and SOx), needs little maintenance and recovers the energy used in production of the cells several times over. This makes photovoltaics strategically interesting within the local Agenda 21 as well as international initiatives such as the European White Paper on Energy or the Kyoto Protocol.

The **world of solar electricity is growing** and changing rapidly. Setting up photovoltaic projects or photovoltaic policy means joining a market which is doubling in size every three years (see Figure 0.6). Grid-connected photovoltaic systems are gaining importance, especially in Europe. The biggest potential application for photovoltaics in Europe is as embedded generators installed in the built environment and connected to the local electricity network. Building integrated photovoltaic systems are expected to account for about 50% of the global photovoltaic market share by the year 2010. In Europe the figures are even higher. Stand-alone photovoltaic systems can supply energy for a great variety of modern structures and remote applications (see Figure 0.7)

▼ ***Figure 0.7:*** *Photovoltaic world market in 2010 for seven segments. The global market size will be more than 1400 MWp. Source: Bank Sarasin Cie, Switzerland.*



Reading the Solar ElectriCity Guide



▲ *Figure 0.8: Structure and key topics of the Solar ElectriCity Guide.*

The Solar ElectriCity Guide offers 8 key topics.

1) Applications: The photovoltaic industry is experiencing a boom growing 30 % annually with an associated increase in the range and variety of products and design solutions available tailored to even more urban applications and demanding requirements. All such applications have one of two functions. They either function as a solar power station and feed electricity into the grid or they autonomously power remote applications avoiding the expense of digging for grid-connection.

2) Projects: Municipalities and local actors can play a crucial role and facilitate the management of photovoltaic projects and benefit from the attractive features of solar electricity.

3) Policy: Lessons learnt from projects show how local policy in urban and energy planning can set an attractive framework and network for successful deployment of photovoltaics in the local environment.

4) Potential: In relation to strategies for sustainable development, a way of assessing the potential for photovoltaic use within the local building stock is shown. Throughout Europe - and not only in the South as one might think - building integrated photovoltaics can considerably contribute to the electricity supply.

5) Urban design: The relationship between the key urban design factors and their implications for exploiting the photovoltaic potential is explored by providing examples and comparisons.

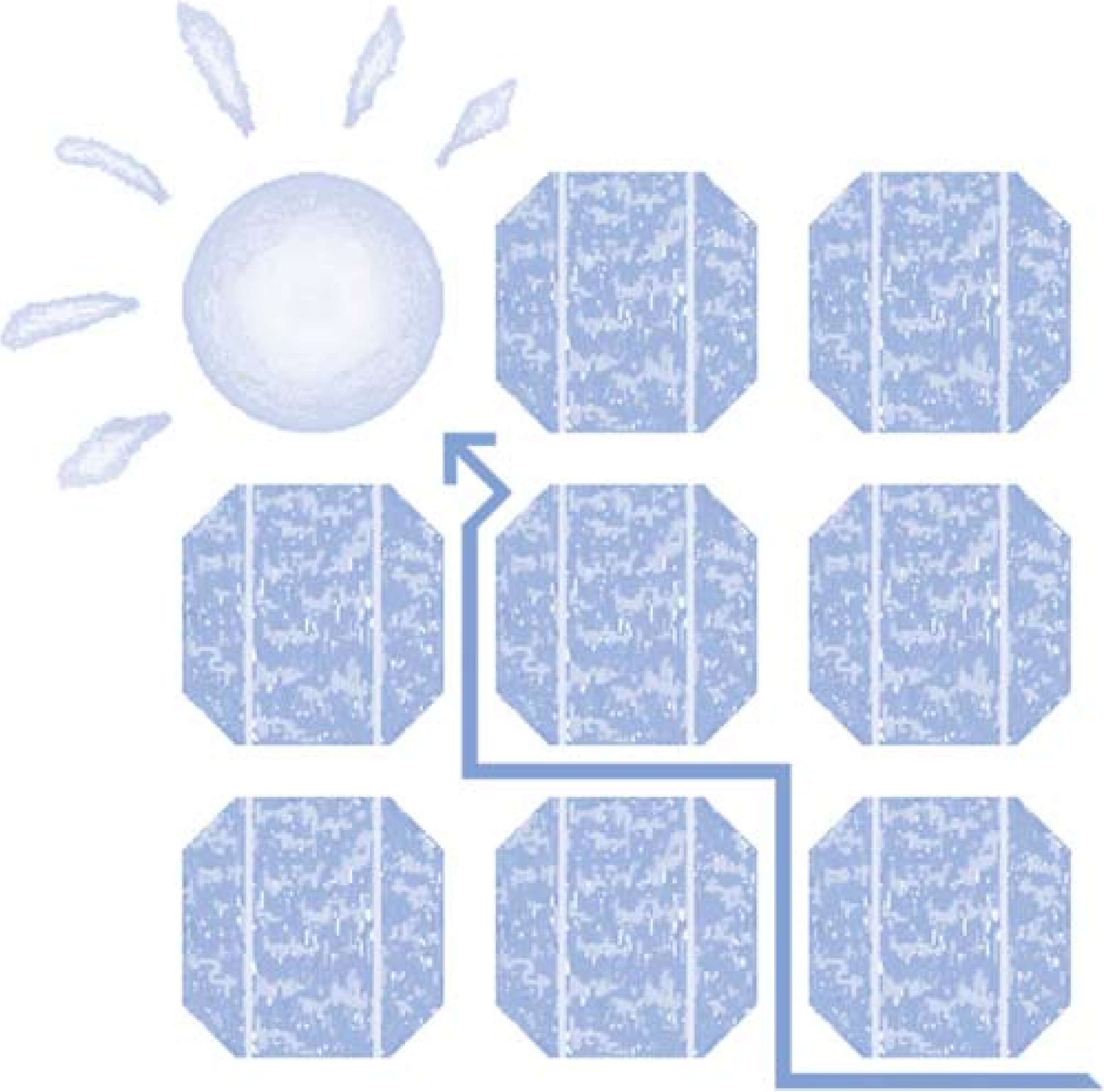
6) Building design: Photovoltaic elements not only meet the requirements of any good building material, i.e. mechanical strength, water tightness, sound proofing, thermal insulation, shading and fire protection but also offer various and high-value architectural solutions thanks to their versatility and expressive force. A checklist of factors to be considered in architectural design helps to keep the design process straightforward and successful.

7) Finance: Photovoltaic installations can be competitive in a wide range of application areas. However, although costs continue to fall, photovoltaic bulk power is presently more expensive than any other conventional bulk power production. Due to the benefits of photovoltaics, regional, national and local programmes promote photovoltaics by providing market incentives and financial support. Local initiatives can take advantage of these programmes and participate in accelerating the transition from innovative technology to fully cost-effective grid electricity supplied products and projects.

8) Legislation: Finally, legal aspects are also an important issue for projects and policy. Local public entities can play an important role by defining an adequate legal framework.

This guide aims to provide a concise yet comprehensive introduction to the world of photovoltaics by making reference to the wide ranging experiences, expertise and exemplary projects available throughout Europe. More detailed information, references and links to web sites can be found on the PV City Guide project web site: http://pvcityguide.energyprojects.net

By incorporating photovoltaics into their long-term strategies within urban and energy planning, municipalities and local partners can benefit from a reliable, benign and attractive technology enhancing and communicating sustainable development to their citizens.



Applications in the urban environment

80% of all Europeans live in urban areas, buildings account for 42% of Europe's total energy consumption and urban areas account for 40% of all CO_2 production. These figures indicate why sustainable energy use has become a key issue for cities and why using solar energy is a prime opportunity for more sustainable energy management.

Photovoltaics turns light into electricity without any noise or pollution. Apart from the technology it is also an expressive force in architecture indicating design for a sustainable future.

Photovoltaics is versatile. From multi-functional building elements contributing to the local electricity supply, to dedicated energy supply systems for public information boards, traffic control and telecommunications and other infrastructure systems, photovoltaics is ready for introduction into urban areas.

Photovoltaic Use in your City

▲ *Figure 1.1: The newly built suburb area of Nieuwland in Amersfoort gained fame for The Netherlands as a lead solar country. It included several hundreds of photovoltaic buildings totalling 1.35 MWp of photovoltaic solar power. The project gathered most relevant players like municipality members, building investors, utility and house buyers. Source: Ecofys, Utrecht, The Netherlands.*

Cities are places of intense energy use. They are also places with a large total constructed surface area suitable for the generation of solar electricity. Building integrated photovoltaic systems offer opportunities to generate electricity without occupying valuable urban land. In this way photovoltaics can contribute to the urban energy demand at source. Photovoltaics can therefore convert cities into electricity generators and also add new architectural texture to the city without requiring any dedicated land use.

Multifunctional Buildings

Buildings are usually places where energy is consumed. Photovoltaic elements can turn the skin of most buildings into a solar power station as the roof and façade areas can be clad with photovoltaics.

Photovoltaic elements can be combined with traditional building construction materials or even replace them. They meet the requirements of any good cladding material, i.e. physical strength, water tightness, sound attenuation, thermal insulation, shading and fire protection.

Furthermore, photovoltaics has visual appeal and supports the expression of progressive and prestigious architecture. Photovoltaic buildings can convey a message to society by using interesting design features.

Photovoltaics offers an attractive and innovative appearance to new buildings and can also contribute to appropriate solutions for historic buildings.

Building integrated photovoltaic (BIPV) systems are usually connected to the grid producing solar electricity that can be used either directly in the host building or fed into the electricity distribution network for use elsewhere.

◄ **Figure 1.2:** *Flat roof integrated photovoltaic installation with solar power of 270 kWp feeding the grid in Zurich. Copyright: Zollfreilager, Switzerland.*

▲ **Figure 1.3:** *Intelligent building design and construction process - mounting and integration of solar modules into the Mataró library building in Barcelona, Spain. The photovoltaic modules are at the same time façade elements and are part of the solar power station (53 kWp). Source: TFM, Spain.*

► **Figure 1.4:** *Ambience and light thanks to semi-transparent cells at the SolarCafé in Kirchzarten, Germany. Source: Sunways. Germany.*

Infrastructure plugged into the sun

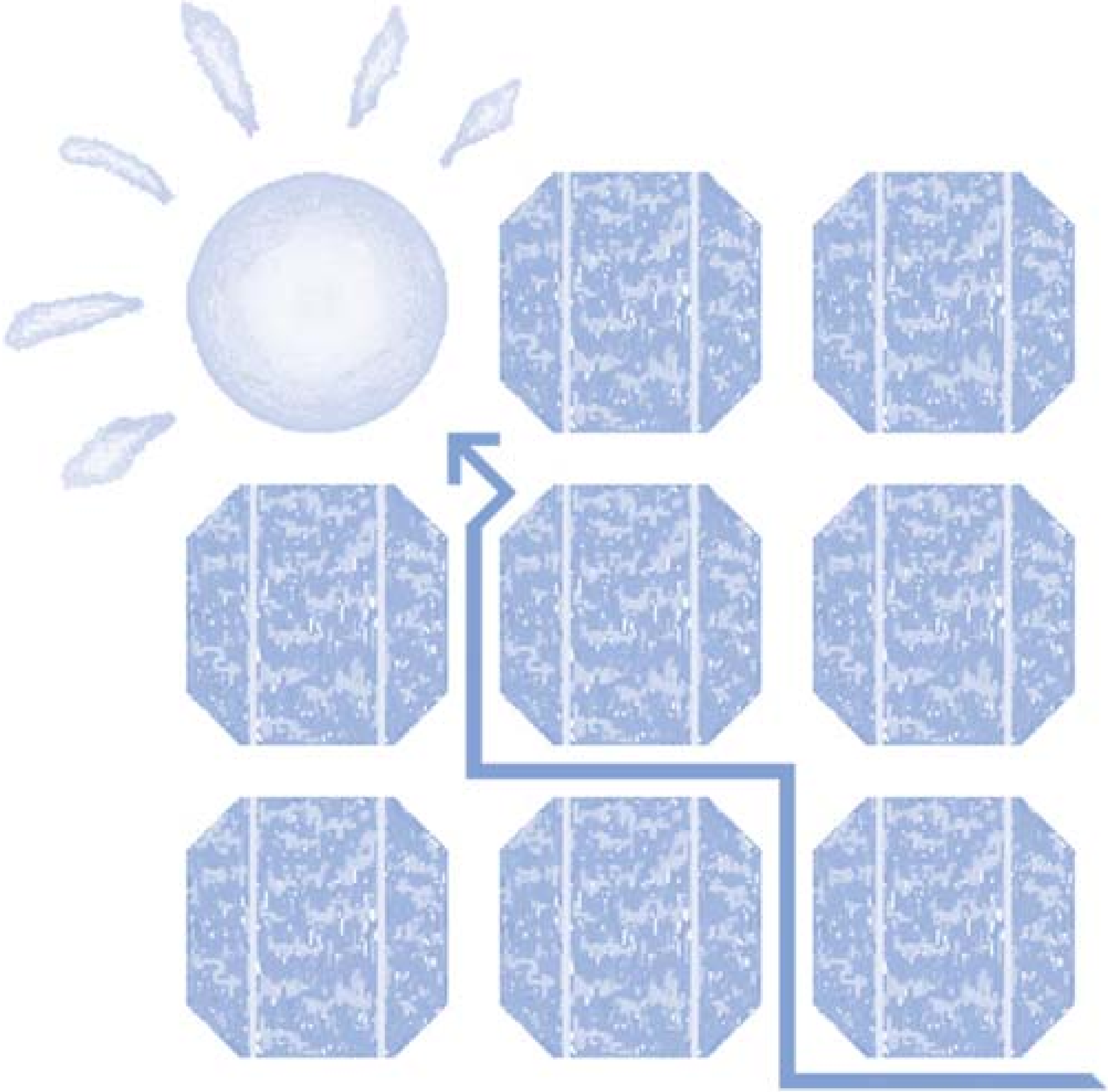
Modern societies and cities are based on complex and sophisticated infrastructures. Photovoltaics is a reliable, competitive and simple solution able to contribute to the successful functioning of this infrastructure. Stand-alone photovoltaic systems can also supply energy for parking meters, phone boxes, street-lights, information panels, signs, etc. Solar electricity is produced, stored and supplied by integrated elements without any (expensive) digging for grid-connection. Furthermore, these systems are characterised by high portability and low maintenance needs.

▲ ***Figure 1.5 a+b:*** *Display at the station powered with photovoltaics - day and night. Source: a) Fraunhofer ISE Freiburg, Germany and b) Ecofys, The Netherlands.*

▲ ***Figure 1.6:*** *There is a wide range of infrastructure elements (e.g. parking meter) that can get their energy supply through photovoltaic systems. Source: Ecofys, The Netherlands.*

▲ ***Figure 1.7:*** *Car shelter and photovoltaic power station in one. Source: Anit, Italy.*

◀ ***Figure 1.8:*** *Multifunctional use of infrastructure elements - Railway noise barriers in Zurich - Oerlikon, Switzerland. Source: TNC Consulting AG-Erlenbach, Switzerland.*



Projects

As the integration of photovoltaics is not a standard topic on a building project agenda it can be difficult to introduce. However, discussing photovoltaics long before the architectural design concept is established is a precondition for achieving an inspiring and well integrated final result within a budget set.

Municipalities have a central role in the building process and a very important part in BIPV project development. They are responsible for the legal regulation of building construction and safety standards and also have competence in town and country planning, they determine new building locations and control or co-ordinate large renovation programmes.

This chapter helps to understand the organisational aspects of complex photovoltaic projects. It shows why promoting the use of photovoltaics early in the building design process is so important and highlights the value of municipal involvement in photovoltaic project development.

The text focuses exclusively on building integrated photovoltaic projects (BIPV), as these tend to be the most complex. Nevertheless the information is equally applicable to other types of photovoltaic project.

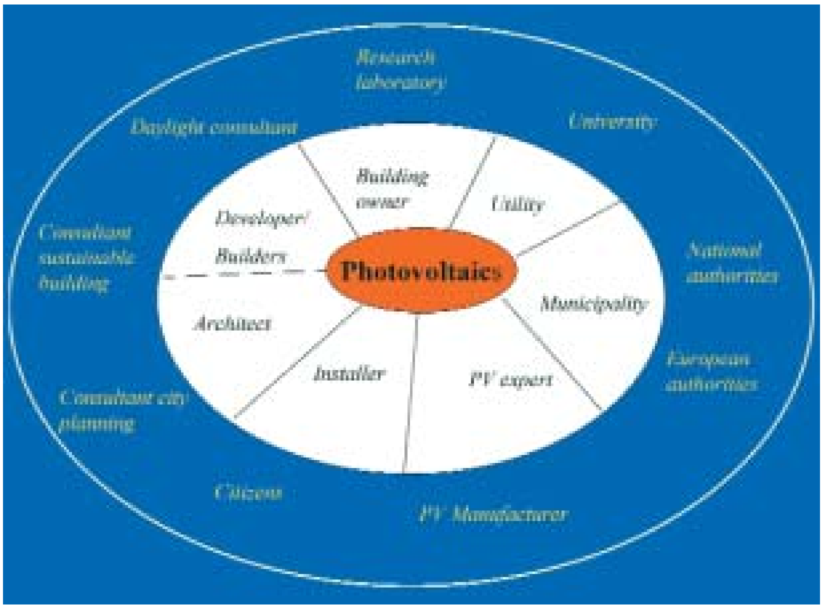
◄ ***Figure 2.1:*** *To have a smooth procedure, photovoltaic integration should be considered from the very start of a project. Solar panels are mounted onto the roof in Hünenberg, Switzerland. Installed power is 32.56 kWp and produces solar electricity equivalent to the electricity consumption of 8 "average" Swiss families. Source: Urs Bühler, Cham, Switzerland.*

Managing photovoltaic projects – what is important?

Photovoltaic projects can be divided into three phases: initiation, preparation and installation. An extensive evaluation of 20 European BIPV projects (for a project overview see http://pvcityguide.energyprojects.net/) revealed the following aspects of project management as characteristic of successful projects:

Phase1: Initiation	Phase 2: Preparation	Phase 3: Installation
• Attractiveness of photovoltaics to many diverse interests • Inspiration and motivation by municipalities • Prestige as an important motivation	• Investment in time and expertise • Facilitation by municipalities	• Use of reputed installers • Strong interaction between actors • Focus on quality control

Phase 1 - Initiation



▲ ***Figure 2.2:*** *Overview over possible initiators and participants. (Synthesis of 20 projects evaluated as part of this European project).*

Photovoltaics benefits everyone

Photovoltaics is an innovative technology and can be attractive to many actors. An increasingly diverse range of organisations are now taking the initiative in the promotion of photovoltaics as a clean, renewable energy solution by participating financially or even by realising photovoltaic projects themselves. This opening up of the photovoltaic marketplace is intensified by the liberalisation of the energy market: realising photovoltaic projects is no longer a specialist niche activity, as it can be concluded from the European White Paper on Energy, and the new European Directive 2001/77/EC on the promotion of electricity from renewable energy sources in the internal electricity market.

Solar energy has broad social appeal and captures almost everyone's interest. Photovoltaic technology provides the potential for widespread participation in the development of a more sustainable future at a local level as it can be applied in projects of almost any size and in a wide range of situations. The following observations will help to encourage others to start and realise photovoltaic projects:

1. Be aware of the broad social 'charm' of photovoltaics.
2. Ensure that many different actors are able to apply for any available information or financial support.
3. Be aware of the political value that photovoltaic projects can have: there may be good political reasons or strategic policy motives reasons for participation in photovoltaic projects.
4. In this respect timing is very important. Knowledge of the political timetables can be important to gather the (financial) help you need.
5. Likewise, media-campaigns can also have a strong positive influence on local support for photovoltaic projects.
6. Other initiatives such as hosting international congresses or events relating to renewable energy sources or environmental technology can provide a means for generating support and formalising local commitment, good intentions and ambitions in relation to local projects during their planning process.

Photovoltaics is a prestigious technique

Prestige is a very important motive for many actors in photovoltaic projects. Many companies are eager to attach their name to such projects providing that they look innovative, provide confidence in the design quality and are effectively marketed to provide a positive image of innovation and environmental responsibility.

Experiences with photovoltaic projects have also proven that good design is crucial to attract new partners and to keep all participants enthusiastic. Achieving such design relies on synergy between an architect with a good design concept and the photovoltaic experts' and suppliers' ability to provide appropriate solutions. For example: In the case of the fire station, Houten in the Netherlands (Figure 2.3), the quality of the design was the most important stimulating aspect of this project which included co-financing by a large utility.

▲ Figure 2.3 a+b: Fire Station Houten (Netherlands), 400m² photovoltaic (transparent), 24 kWp, 18000 kWh per year (10% of total electricity use). Architect: Samyn & Partners, picture by Richard Schropp.

◄ Figure 2.4: Participating in this project, the facility manager M+W Zander AG wanted to show the great variety of services the company could perform, like at the IBM building in Zurich, Switzerland. Source: NET Ltd, St. Ursen, Switzerland.

Municipality as inspiration for photovoltaic projects

Municipalities, utilities and photovoltaic experts all have key roles to play during photovoltaic project development. Evidence from case studies shows that municipalities take a leading role in many projects. The initiation, promotion and active management of these projects fits well with the public functions and formal responsibilities of municipalities. Their central position in the building process enables them to co-ordinate initiatives and mediate among diverse private interests. This is still a very important factor in the development of photovoltaic projects.

There are various ways of taking the initiative:

1. During the building process, the municipality can use leaflets, handy informative reports or even small-scale events informing all actors of the possibilities of photovoltaics.
2. The municipality is also well placed to organise the participation of photovoltaic experts or utilities with the knowledge and authority to provide the necessary support for such projects.
3. The integration of photovoltaics in public buildings sets a precedent for subsequent private action; the implementation contributes to the knowledge of civil servants and it can be used for demonstration purposes. It is an open invitation to others to start up photovoltaic projects.
4. Visualisation of the solar electricity production (by means of displays, etc.)

Phase 2 – Preparation

Investing extra time and knowledge in projects

In most cases integrating photovoltaics is not yet a standard technique. Successful realisation therefore requires perseverance and attention to detail by all actors.

Ideally, in the case of building projects, photovoltaic integration should be discussed before the first designs are formalised. The consequences of photovoltaic integration should be considered at every stage of project development so as to minimise costs by avoiding problems and optimising the construction process.

For example:

- Can the support structure for the photovoltaic elements be installed by the existing building contractors?
- How much of the electrical installation for the photovoltaic installation can be undertaken at the same time as the rest of the building's electrical installation?

This integral approach can be more complex, at the design and planning stages, as it differs from conventional practice. However, it provides benefits in the construction phase. If a municipality is involved in the building process it can:

1. Ensure attention to detail (for example) by making sure that enough time is taken to fine tune the integration demands of photovoltaic systems within building design before proceeding to construction. Thus saving time and money later on.
2. Introduce and (financially) support the participation of expert experienced photovoltaic installers or consultants in the preparation stage as this has proved to be important for successful subsequent implementation. Their knowledge of different products, characteristics, delivery times, etc., can help in getting things right first time.

Municipality as BIPV project facilitator

Where the municipality is not actively involved in photovoltaic project development it still has an important role in relation to legal and administrative procedures, such as building permits. The realisation of BIPV projects requires negotiation of technical, financial and sometimes institutional hurdles at many levels (from local to international, from private electricity companies to government agencies). Consistent political and technical support and encouragement from the municipality is a great help in this challenging process. This can be realised by, for example:

1. Ensuring that the relevant civil servants have sufficient basic knowledge to prevent misunderstandings (by use of this publication, other brochures and training workshops).
2. The introduction of an official directive on how to deal with photovoltaic projects supported by appropriate training and promotional activities. This can prevent that antiquated urban planning instruments, developed before the era of photovoltaics, restrain the realisation of photovoltaic projects.
3. Positive actions to calm public concern, gain support and avoid rejection of the project by the general public. BIPV projects can also generate the type of public debate more often associated with the installation of wind turbines. Not everybody likes the appearance of a photovoltaic roof or façade and some people distrust the installation because of perceived radiation or reflection issues. The best way to prevent public protest is to inform local inhabitants of the proposed installation at an early stage. They can even be challenged to make their best contribution by buying their own photovoltaic system – i.e. of financially supporting the project (it has been done!).

Phase 3 - Installation

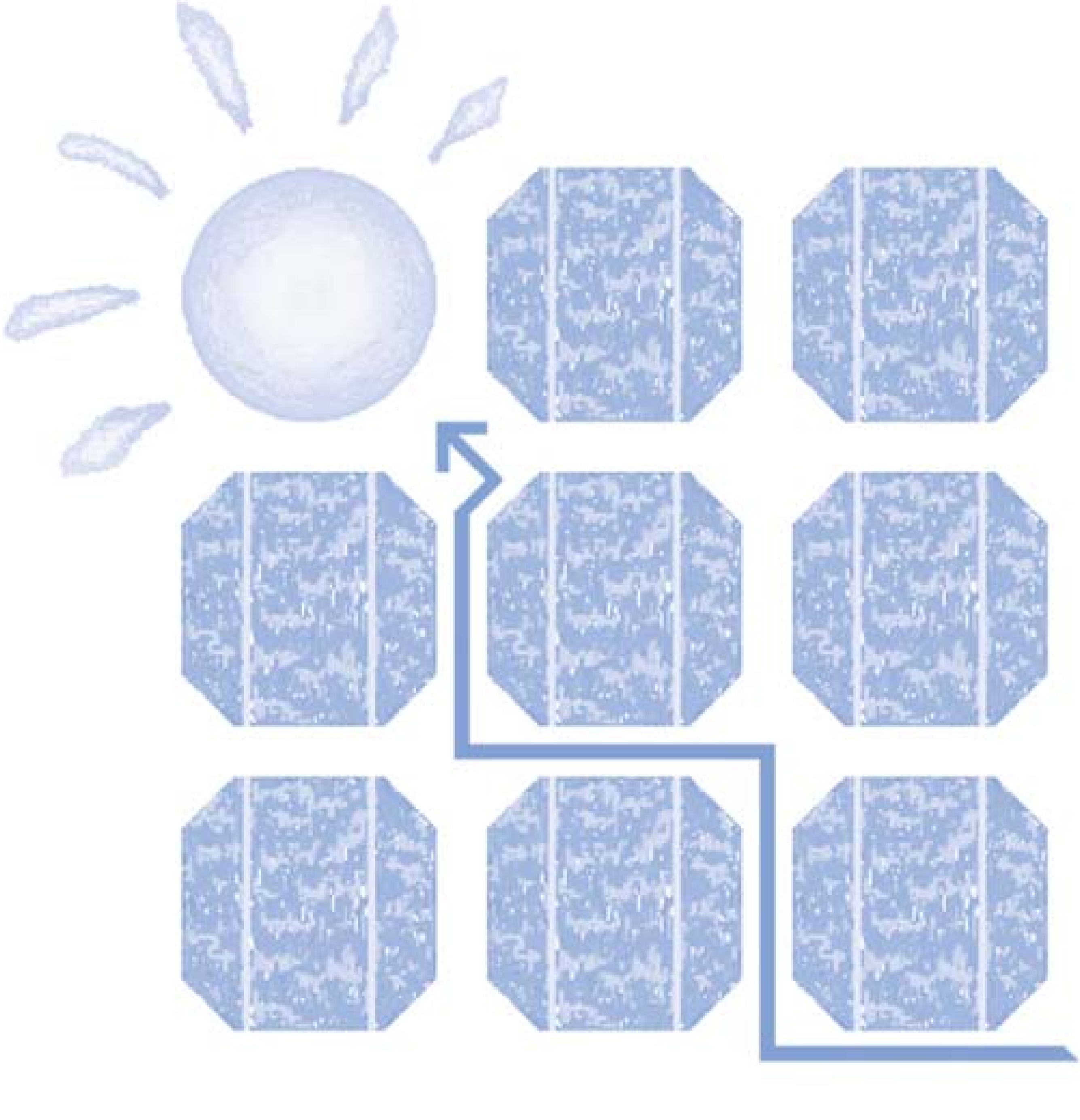
Quality control

It is well known that while good projects require a lot of publicity, the news about projects with problems spreads itself! Needless to say, problems should be avoided at all cost.

Until the installation of photovoltaic systems becomes standard electrical practice, the quality of the system will strongly depend on the quality of the designer/installer. As in any building process, an independent expert should check system design as well as installation work. Such requirements form the basis of minimal quality control that is recommended for any programme. For relatively new system designs or components a more extensive programme might be in order.

Municipal involvement in photovoltaic projects, whether it be photovoltaics in municipal buildings or financial support of private projects, gives the municipality scope and responsibility to control quality. Municipalities can act to ensure quality projects in a number of ways:

1. Developing registers of reputable installers (in some countries such registers already exist at regional or national level).
2. Ensuring that basic photovoltaic requirements are taken into account in the design of the area and the houses (e.g. solar access).
3. Contributing to good communication between the parties during the building process.
4. Instigating a quality assurance programme for projects with municipal involvement or support.
5. Support training and education initiatives for professionals.



Policy

In the preceding chapter, recommendations were made on the management of a photovolaic project. In this chapter important aspects of continuing local approaches and policies on photovoltaics are discussed.
All over the world, national governments have introduced innovative programs for the implementation of photovoltaic systems, e.g. market and production incentives, labelling and promotion of green electricity, support of pilot and demonstration installations, etc.
Although these programmes offer valuable support the detailed work of project and programme development will inevitably happen locally. For this reason this chapter also offers inspiration by summarising examples of successful local photovoltaic policies well thought out with respect to the goal to be reached, the target audience and the instruments available.

Municipal policies

Individual initiatives at a local level, in response to national programmes, often result in inspiring demonstration projects but fail to capitalise on all the hard work involved in the innovation and have little further impact. In contrast, when such initiatives are co-ordinated and encouraged by the development of local policies and programmes to support and promote the use of solar power, the positive effects are numerous and long lived as the examples in this section demonstrate.

The following steps will help to improve the quality and added value when setting up a local solar electricity policy or programme.

Project management in three steps:
Step 1: Goals
Step 2: Target audience
Step 3: Tools for implementation

Step 1
Establish the goals

Establishing goals helps to design an appropriate programme and measures that must be taken. For example:

- If the main goal is to increase the relative share of renewable energy in a local supply system with associated environmental targets, partnerships with the energy industry and financial institutions will be key aspects of the programme.
- If it is about contributing to the technological development, with benefits for the local knowledge base, small but innovative projects are the key.
- If it is about raising public awareness, interest and support for photovoltaics, a strong communication plan is fundamental.

Step 2
Establish the target audience

Although everyone is included in the target audience for photovoltaic projects it is advisable to focus efforts in order to achieve the goals efficiently. For example:

- To maximise installed capacity the target audience should be building developers and architects with emphasis on simple procedures and standard systems. There are also good examples of photovoltaic campaigns for citizens such as do-it-your-self packages (see http://pvcityguide.energyprojects.net/ for more information).
- To maximise gains in local know-how and expertise the target audience should be innovative local companies

Gleisdorf (Austria)

The Austrian municipality of Gleisdorf (5300 inhabitants) and the local utility Stadtwerke Gleisdorf GmbH aim to develop a more efficient and sustainable energy infrastructure.
They are replacing coal with natural gas as the main primary fuel for local utilties (widespread gas infrastructure is developed) and are also giving explicit support to renewable energy projects in the area.
In their programme 'Energy and Environment' cooperatives and dissemination programmes are set up between all kinds of (private) institutions and special initiatives are being taken to realise a significant number of photovoltaic projects.
A key example is the development of the "Straße der Solarenergie" (Solar Energy Street) - a special route of 5.5 kilometres through the city, showing the public 80 Solar projects.
Another example is the Solarbaum (Solar tree). This art object not only generates solar energy, it also emphazises the future ideology of the City of Gleisdorf.

Action 100 Delft Blue Roofs
(City of Delft, The Netherlands)

The goal of this programme is to improve society's acceptance of photovoltaics by demonstrating the following different integration techniques:

- Photovoltaic façades
- Photovoltaic roofs
- Standard construction
- Architecturally innovative systems
- Coloured photovoltaic systems
- Visible systems vs. undetectable systems

The primary target group is the population of Delft. The photovoltaic systems will be integrated in different types of buildings: schools, blocks of rented houses, houses for the elderly, monumental buildings, etc.
The City of Delft co-ordinates the programme. It is financed by:

- Photovoltaic system owners
- Regional utility (providing the same amount as the current national subsidy)
- National government
- City of Delft (providing the remainder)

and institutions. The emphasis should be on state-of-the-art projects and publicity beyond the level of the municipality.

- To maximise gains in public awareness, the general public must be the target audience and emphasis should therefore be on systems that are seen: façades, street furniture, and public buildings with interpretative displays and awareness raising activities.

Step 3
Check the available instruments

What instruments can be used to implement the policy? From the municipalities' perspective, instruments can be divided into four categories and used in combination:

Urban planning and building regulation
Facilitating the incorporation of photovoltaics in construction projects from the very beginning of the design phase. For example, incorporation of basic solar access criteria in new urban plans and provision of basic photovoltaic design information to architects or developers during preliminary building permit discussions.

Communication
Municipalities can inform society of the opportunities of photovoltaics or even demonstrate a photovoltaic system by installing systems on existing or new public buildings. Placing a photovoltaic installation on a public building is a valuable communication tool for developers, architects and citizens as well as good publicity. Such examples make civil servants capable of assisting other actors in entering the photovoltaic market - showing that photovoltaic projects are accessible and attractive.

Legal measures
The use of legal measures and regulations at a municipal level is often made difficult by lack of legal authority, conflicts of competence with national regulations and by the demands of private business interests.

For example, in The Netherlands municipalities are formally prohibited from demanding specific energy measures, because the national regulations already provide a general energy performance quotient. Nevertheless, some municipalities ask for an additional voluntary agreement on subjects such as energy-efficiency and sustainable building (The Hague, Tilburg).

Another prime example of the use of legal instruments is in the Solar Ordinance of Barcelona, Spain, which obliges all new buildings and buildings undergoing major refurbishment to use solar (thermal) energy to supply 60% of their hot water requirements (see http://pvcityguide.energyprojects.net/ for full text of this ordinance).

Financial measures
Policies can be set up together, either independently or with private companies, such as utilities, developers and financial institutions. In realising public-private partnerships a large number of photovoltaic projects can be realised (multiplier effect). Studies have shown that an effective programme can be developed with a relatively small financial commitment from a municipality. This can also be achieved without the need for the designation of a specific budget if financial incentives are offered in the form of discounts in municipal charges and taxes and charges related to building construction or occupation.

[1] Preference for East-West orientation of streets, south facing roofs, separation of buildings to prevent permanent shadows, etc. See subsequent sections for more details.

Sustainable development Barcelona
The 'Barcelona Renovable 2004' has been created with the aim of having an impact on the area which falls between the municipalities of Barcelona and San Adrià del Besòs. The aim is the incorporation of renewable energy sources in the rehabilitation and recovery of a formerly predominantly industrial area.
The urban renovation and reconstruction of this territory offer an excellent opportunity for application of the principle of sustainable development.
Under the general objective of promoting renewable energy and energy saving, some specific goals of the partnership 'Barcelona Renovable 2004' are:
- 4.5 MWp of photovoltaic systems
- 10.000 m^2 of solar thermal collectors
- 3 MWh/year of geothermal energy
- 50 apartments with biomass heating

Basel - Photovoltaics and Energy (Conservation) Act
The Swiss canton of Basel-City (Basel-Stadt) is pioneering in energy policy. First initiatives were taken in the year 1975; in 1983 the first Energy Conservation Act (Energiespargesetz) was adopted. This Act introduced an energy levy earmarked for energy conservation measures and renewables. Basel-City's commitment culminated with the Energy Act (Energie Gesetz) adopted in September 1998, which provides, for the first time in Switzerland, for incentive levies upon energy consumption with a return of revenue to consumers.
Besides the incentive levies, the act underpins new approaches to energy conservation and alternative energy generation:
- The Act empowers the city council to oblige all households and companies to undertake periodic energy analyses.
- The canton can cover the costs of the energy analyses.
- The canton can stand surety for contract energy management investments.
- A solar power exchange has been introduced, with cost-covering payments to all selling entities which feed into the grid.
- The energy-saving activities of the city's Energy Department have been in continuous expansion since they started in1995.

In its implementation of these measures, the canton is supported vigorously by the municipally-owned multi-utility of Basel, Industrielle Werke Basel (IWB).
Finance issues for photovoltaics
The promotion of photovoltaics - in addition to the solar power exchange - is completed by further financial support mechanisms. First, there is support of CHF 1500/kWp (around 950 Euros). The remaining installation cost is subsidised at 40 %. The global support approaches but must not exceed 50 %.
The time frame of the global support package is 6 years from 2000 - 2005. Every year some 300 kWp of photovoltaic solar power is installed, so a total installed capacity of 1800 kWp is foreseen. If there is a "permanent" demand for solar electricity within the solar stock exchange higher than planned, then more subsidies can be given.

Support is, in principle, granted on a "First come, first served" basis subject to meeting certain basic requirements are respected. After installation 80 % of the support is paid. The remaining is paid after one year's operation time or an operation check. When each year's budget is used up then applications for support are passed over to the following year's budget.

Potential in your city

Integrating photovoltaics in buildings enables cities to generate electricity without dedicating land to power stations and without producing pollution.

Approximately one quarter of the current electricity demands of urban areas can potentially be met by installing photovoltaic systems in suitable buildings. The potential will also increase in the future with improved system efficiency.

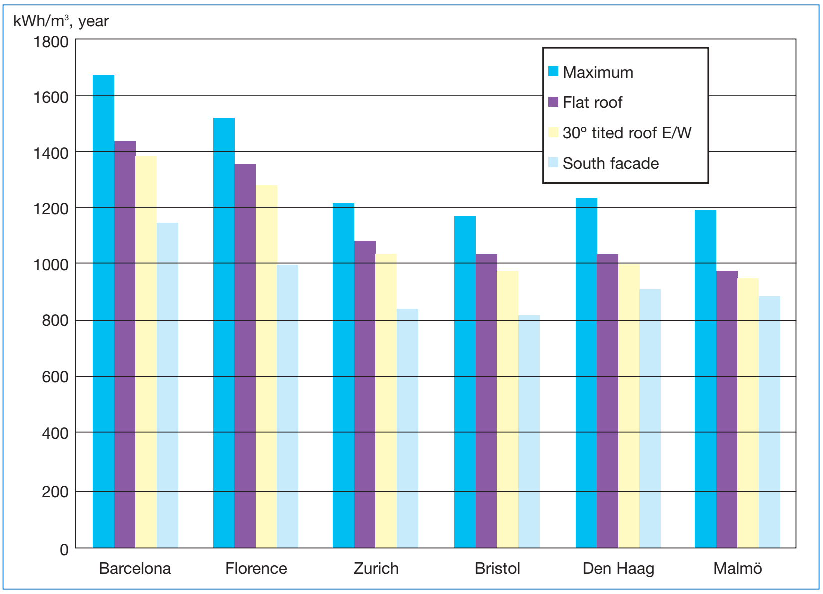
The estimated potential for building integrated photovoltaics is large throughout Europe: in the South due to the large solar resource and in the North as large building areas compensate for the lower irradiation levels.

The calculation of the potential is a powerful planning tool that can be used in relation to long-term strategies for sustainable development such as Local Agenda 21 plans. It involves consideration of three main elements: available irradiation, system efficiency and potential building area.

This chapter provides a basic Rule of Thumb for the calculation of this potential and, by way of example, shows the results of potential calculations in six European cities.

Irradiation and solar yield

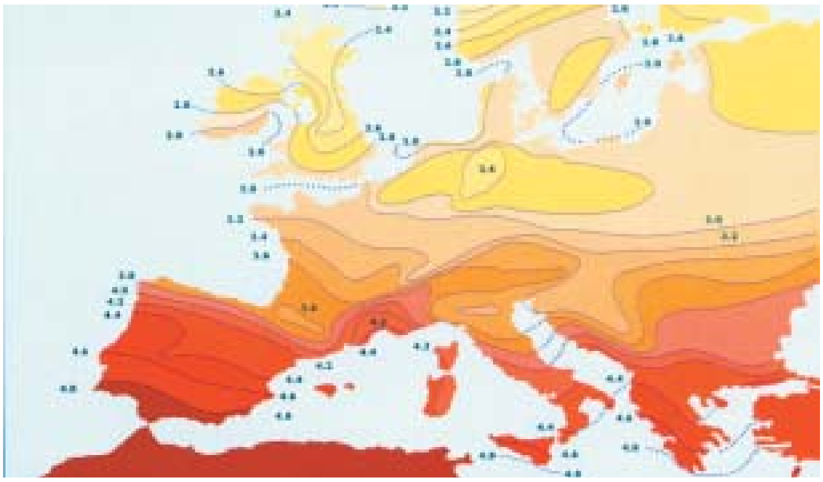
The graph below shows the difference in the solar resource available in various European cities.



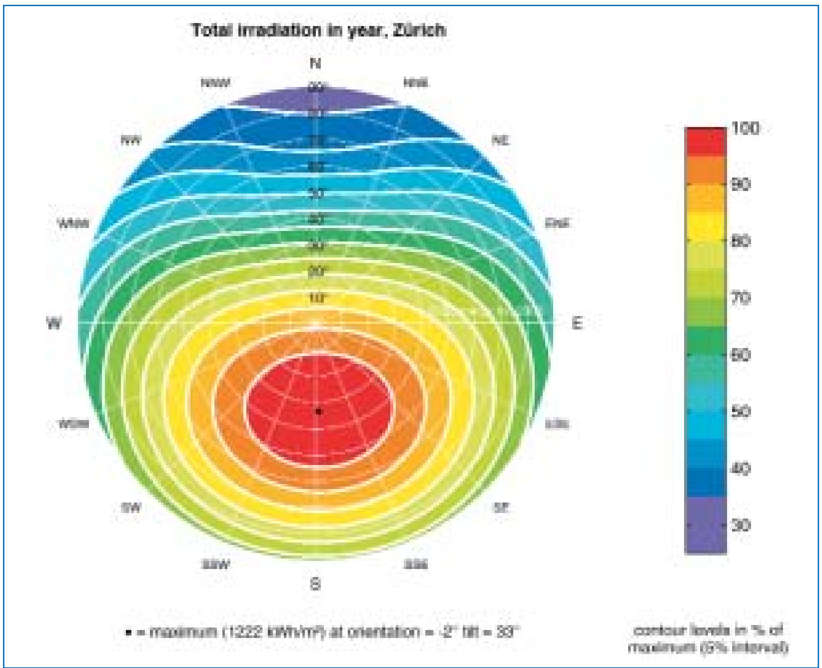
▲ ***Figure 4.1:*** *Annual solar irradiation in the six European cities: Barcelona, Florence, Zurich, Bristol, Den Haag and Malmö for maximum (30-36° south tilted roofs), flat roofs, 30° tilted roofs facing east or west, and south facades respectively (kWh/m², year).*

The amount of irradiation received depends on the orientation and inclination of a surface. The highest yield is achieved by a south-facing surface tilted vertically at an angle calculated so that it faces the sun as much as possible. Different surface configurations receive less irradiation but can still be useful for electricity generation.

The annual solar yield also differs from location to location (see Figure 4.2). Comparing the six cities shows that although the more southerly cities such as Barcelona and Florence receive more irradiation the difference is not as big as some people might imagine.
To summarise, the same photovoltaic module will produce different



▲ ***Figure 4.2:*** *European solar radiation map (GJ/m², year). Source: TFM, Barcelona.*



◄ ***Figure 4.3:*** *Annual solar yield for all tilts and orientations. Good solar yield is more than 80% of the maximum irradiation (yellow, orange and red coloured area). Design: EcoConcern Econergy (all rights reserved).*

amounts of electricity depending on its orientation, inclination and the latitude of its location. The Figures 4.2 and 4.3 illustrate this point very clearly.

A strategic urban plan for solar electricity production will ideally give priority to areas of highest solar yield. However, building areas with less than ideal solar yield can also be useful where other factors such as visual impact, building design and correlation of seasonal or daily supply and demand (see also section building design) are taken into consideration.

Figure 4.3 also illustrates this concept of solar yield. It can be seen that flat roofs obtain about 90% solar yield and south facing façades around 70 %.

Note: Diagrams for other cities can be downloaded from: http://pvcityguide.energyprojects.net/

Suitable building areas

Building areas suitable for photovoltaic use are not only defined by solar yield but also by architectural criteria such as building envelope structure, shading, urban form, historical restrictions and so on. Although there are wide variations between cities and areas, experience indicates that about 55% of the roof area tends to be suitable for various reasons.

Once the solar irradiation and the suitable building area is known, the electrical output of a given area of building integrated photovoltaics can be calculated, taking into account the efficiency of the photovoltaic system.

The following Rule of Thumb can be used for calculations of the potential for roof integrated photovoltaic systems in cities in the Western European areas:

Annual production of solar electricity (kWh) = population size
X maximum solar irradiation (kWh/m² per year)
X module efficiency X net area per capita (m²/cap.)
X global system and area factor = P x I x 0.1 x A x 0.4

The following table shows the potential for electricity production from building integrated photovoltaics in the six cities calculated with this Rule of Thumb for good solar yield (80% and more of the maximum irradiation).

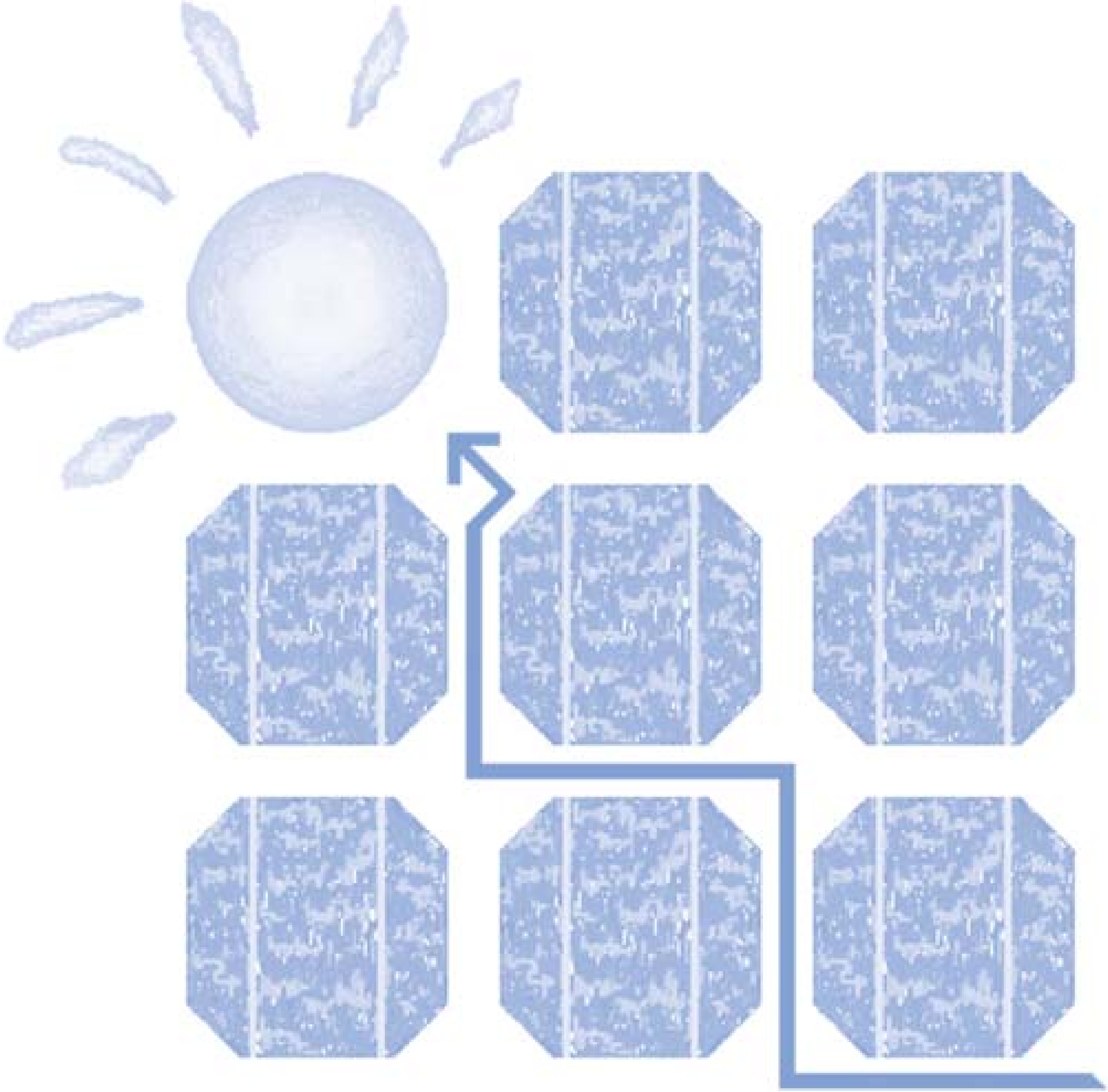
Cities	Latitude	Population (P)	Max. solar irradiation (kWh/m²/year) (I)	Net area/cap. (m²/cap.) (A)	Annual production /cap. (kWh/cap.)	Total potential annual production (GWh/year)	PV production of the total electricity use (%)
Barcelona	41.4 N	1.509.000	1672	11	736	1.110	21%
Florence	43.8 N	559.088	1523	10	609	341	13%
Zurich	47.4 N	361.000	1222	17	831	300	11%
Bristol	51.4 N	401.000	1181	15	709	284	14%
Den Haag	52.2 N	440.000	1239	9	446	196	12%
Malmö	55.6 N	255.000	1191	20	953	243	13%

Notes:
- Maximum solar irradiation = annual total irradiation on a south facing plane with an optimal tilt (which is 33-41° for the latitudes between Barcelona and Malmö).
- Module efficiency = 5% for amorphous silicon, 12% for crystalline silicon (standard modules) and 8-10% crystalline silicon semitransparent modules (depending on the gap between the cells). Used value 0.1 (10%).
- Net area per capita = gross roof area reduced with reduction factors for shading, architectural reasons (factor 0.45).
- System and area factor/good yield: Global good yield system and area factor = system factor (0.7) * good yield area factor (0.7) * good yield solar factor (0.8) = 0.4.
- System factor = different kind of losses, depending on the ventilation, low irradiance levels, inverter and dirt. Used value 0.7.
- As the potential electricity production depends both on the irradiation and the available roof areas, the result from the comparison between the cities is that Malmö, with the largest potential area per capita also has the largest potential annual electricity production (953 kWh/cap.) even though it receives less solar irradiation than the cities with the highest irradiation, Barcelona (736 kWh/cap.) and Florence (609 kWh/cap.).

This estimate only considers the use of the optimum surfaces in terms of solar irradiation (solar yield > 80%) and takes into account any potential restrictions. The potential production is even higher if other surfaces such as unshaded façades and other systems, such as non-building applications, are taken into consideration.

This significant electrical power generation capacity requires no dedicated land use: the photovoltaic elements can be installed on top of existing structures or, in new construction, can replace conventional building elements. Exploiting this potential provides benefits in terms of reductions in pollution and reduced electricity distribution losses, given that the electricity production is as close to the demand as is possible.

To conclude, urban areas present great potential for the introduction of photovoltaic systems. At present, economic factors constrain the achievement of this potential but in the future the optimisation of photovoltaic potential will depend on the ratio of the building regeneration, urban geometry and the acceptability of photovoltaics in the urban environment. Planning decisions made today regarding solar access, and orientation of street layout will affect the ability of future generations to take advantage of their renewable solar resource. The following chapter explores these issues.



Urban design

The optimisation of photovoltaic potential will depend on the urban geometry and the acceptability of photovoltaics in the urban environment. Urban geometry includes the key urban design factors such as:

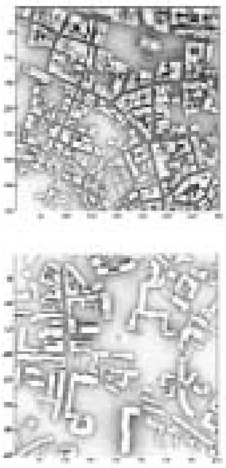
- density of development,
- orientation,
- obstruction heights,
- reflectance, etc.

These variables, and the acceptability of photovoltaics, are determined by numerous non-physical parameters:

- planning and construction traditions for existing and new buildings,
- historical and cultural values,
- planning regulations and restrictions.

By exploring the relationship between urban design variables and photovoltaic potential, this section of the Guide aims to help planners and architects design for the integration of photovoltaic systems within new or existing urban areas.

Massing characteristics and the effect of spacing between buildings



▲ *Figure 5.1 a+b: These two images show the "Sky View Factor" output from street to sky for an old part of Athens, Greece (a) and Grugliasco, Italy (b). Source: The Martin Centre, Cambridge, UK.*

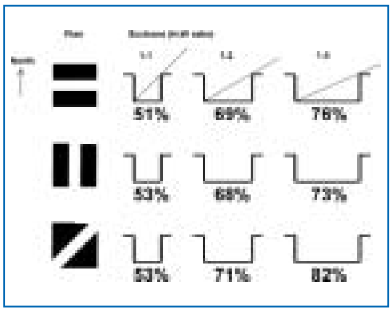
As a general rule, it can be said that areas with compact development but fairly even roof heights will be ideal for roof mounted photovoltaic systems. Conversely, where the urban form is less compact and there are a variety of building heights then there will be good potential for building integrated photovoltaic (BIPV) façade systems.

This can be described by massing characteristics and the effect of spacing between buildings and is determined by the "sky view factor".

Strong differences in shades of grey at street level, between the two sites indicate the **relative building height**: the darker the street the deeper the canyon. Strong variation of shades of grey on roofs gives an indication of the **urban roughness**: the higher the occurrence of greyness on roofs the 'rougher' the urban canopy.

The area in Figure 5.1a (Athens) offers a large surface area suitable for roof-mounted photovoltaics but few unobstructed façades. The area in Figure 5.1b (Grugliasco) has a relatively small potential for roof mounted systems but offers scope for appropriate façade installations.

Effect of spacing between buildings

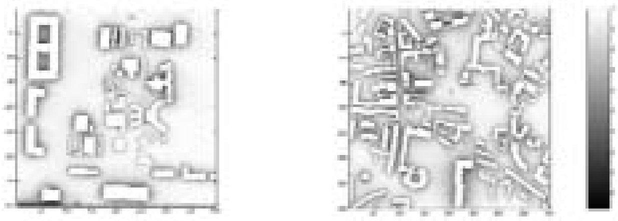


◄ *Figure 5.2: Effect of spacing between buildings on solar access to street, at a latitude of 44ºN and various street orientations. Note that height-to-width ratio is typically much more significant than orientation, and that North-South oriented streets offer, on average, slightly less solar access. Source: Energy Research Group, 1999.*

As expected, a street with West and East façades provides least potential for solar availability, but (interestingly) a diagonal street (45° from South) gives better overall solar access than a street with due South and North facing façades. This shows that precise orientation is not critical and there is a significant amount of flexibility in planning for photovoltaics (As illustrated by Figure 4.3 in the preceding section).

Sky view factor

Wider spacing and a southerly aspect (e.g. buildings around squares and parks or along wide streets) will be particularly suited to façade BIPV. A tighter urban arrangement will mean that roof BIPV is most interesting.



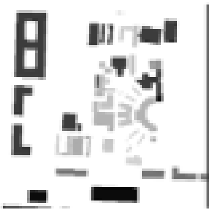
◄ *Figure 5.3 a+b: Sky View Factor output from street to sky for (a) West Cambridge, UK and (b) Athens, Greece. Strong variation of shades of grey on streets gives an indication of the exposure of streets to the sky and therefore spacing between buildings (the darker the street, the narrower the street and therefore the more obstructed the façades are). Source: The Martin Centre, Cambridge, UK.*

Typical glazing ratio

◄ *Figure 5.4 a+b: Photovoltaics incorporated as shading elements – building for the University of Erlangen, Germany (a) vs. semi-transparent photovoltaics – Doxford office building, UK (b). Source: (a) Solon AG, Berlin, Germany. (b) Studio E. Architects, London, UK.*

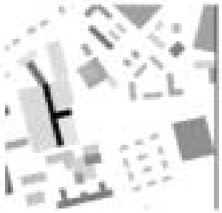
In cities where buildings tend to have high glazing ratios photovoltaics can be incorporated as a shading strategy. In cities where small windows are the norm BIPV can take the form of cladding. In both cases, BIPV is likely to be most effective higher up the façade where the effect of obstructions is minimised.

Surface to volume ratio

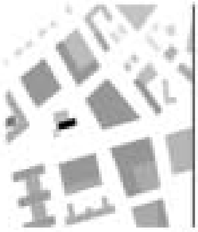


a) West Cambridge, UK, (SSC: 20%, S/V: 0.27).

b) Fribourg / Freiburg, Switzerland (SSC: 21%, S/V: 0.24)

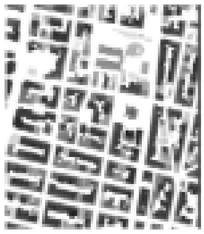


c) Trondheim (present), Norway (SSC: 29%, S/V: 0.23)

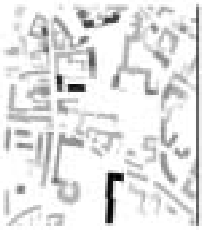


d) Trondheim (proposed), Norway (SSC: 36%, S/V: 0.14)

e) Athens (old part), Greece (SSC: 49%, S/V: 0.31)



f) Athens (modern), Greece (SSC: 51%, S/V: 0.25)



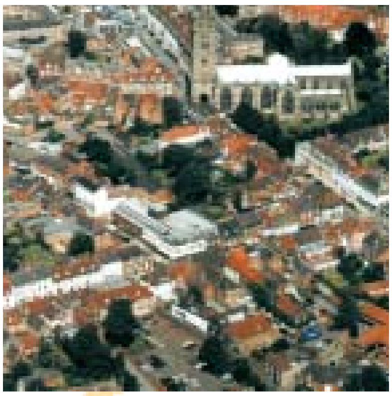
g) Grugliasco (old part), Italy (SSC: 30%, S/V: 0.35)

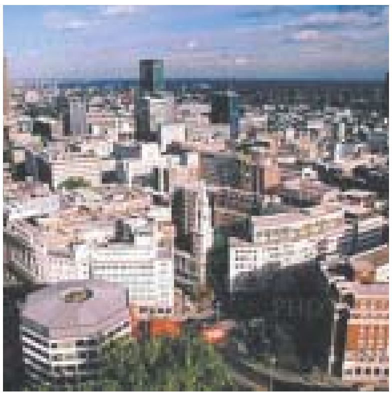
h) Grugliasco (modern), Italy (SSC: 19%, S/V: 0.28)

Figure 5.5 a-h: Summary of surface to volume ratios and surface coverage values for various European sites. Source: The Martin Centre, Cambridge, UK. (SSC = Sites Surface Coverage, S/V = Surface /Volume).

While higher surface to volume ratios indicate a higher proportion of façade area potentially available for façade integrated photovoltaics, it also tends to imply more obstructions for a given density of development. Lower values indicate larger uninterrupted roof area for potential photovoltaic application.

Building and façade height



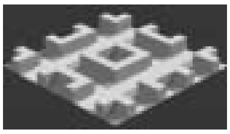
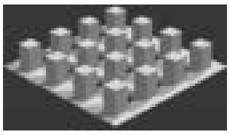
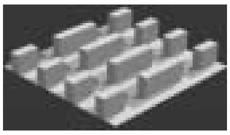
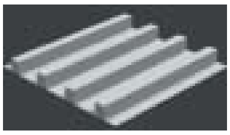


◄ *Figure 5.6 a+b: Building height legislation results in different cityscapes; relative uniform heights (a: Warwick, UK) vs. occurrence of towers and skyscrapers (b: London, UK).*

Planning legislation will clearly affect building heights. Where this results in all building heights being similar (Figure 5.6a) there is little obstruction to roofs, which are thus the best location for photovoltaic systems. In a city with more varied building heights (Figure 5.6b) it becomes more important to identify key locations for BIPV (e.g. on the unobstructed façades of tall buildings).

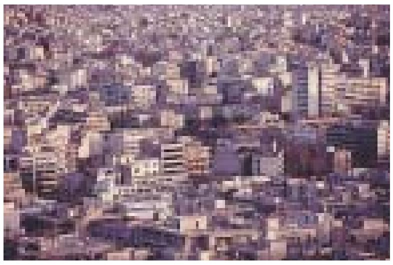
The following diagram shows various possible layouts of an urban development. All have the same plot ratio of 1:7 (plot ratio = constructed floor area/total site area).

The diagram shows how the potential for photovoltaic electricity generation, in this case on the façade, is affected by urban design.

Urban Form (Plot ratio 1.7)	**View**	**Climate**	**% of facade area with annual irradiation ≥800 [kWh m²]**
Pavilion-Court		Athens, GR	**30 %**
		Torino, I	17 %
		Fribourg, CH	6 %
		Cambridge, UK	2 %
		Trondheim, N	7 %
Pavilion		Athens, GR	**24 %**
		Torino, I	13 %
		Fribourg, CH	4 %
		Cambridge, UK	1 %
		Trondheim, N	6 %
Slab		Athens, GR	**39 %**
		Torino, I	23 %
		Fribourg, CH	7 %
		Cambridge, UK	2 %
		Trondheim, N	9 %
Terrace		Athens, GR	**50 %**
		Torino, I	38 %
		Fribourg, CH	11 %
		Cambridge, UK	2 %
		Trondheim, N	14 %

◄ *Figure 5.7: Relationship between urban form and the potential for photovoltaics. These results indicate that a regular array of south-facing terraces has the greatest potential and an equivalent density of towers (pavilions) has the least. Source: Raphael Compagnon, EIF, CH.*

Roof profiles



▲ *Figure 5.8 a+b: Roof profiles vary according to cities; pitched (a: Deventer, Netherland) vs. flat (b: Athens, Greece).*

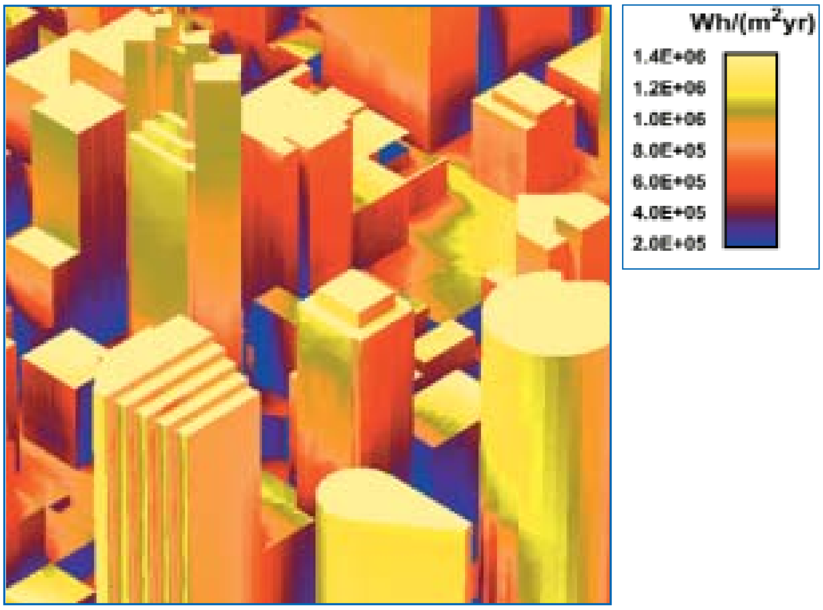
Flat roofs offer greater flexibility with respect to orientation. Pitched roofs need to be selected for their photovoltaic potential with respect to tilt and orientation.

Typical surface reflectances

High reflectance means that there is significantly more diffuse light available for photovoltaic systems and therefore optimising orientation becomes less important. For low reflectance zones, photovoltaic systems need to be designed for direct solar radiation access.


▲ Figure 5.9 a+b: *Typical surface reflectance varies among cities; high reflectance are found in Athens, Greece (a) compared to darker ones in Siena, Italy (b). Source: (a) Centre for Renewable Energy Systems (CRES); (b) Ediz. M. Romboni.*

Irradiation mapping



▲ Figure 5.10: *: Image showing the total annual irradiation for a complex city model (San Francisco). Source: J. Mardaljevic, IESD, De Montfort University, Leicester, UK. http://www.iesd.dmu.ac.uk/~jm*

Irradiation mapping allows accurate prediction of the total annual solar energy received by all surfaces within a suitably mapped area. Images showing seasonal aggregates or components of the total (e.g. sun, sky, inter-reflected radiation etc.) can also be created. It can be applied at any architectural scale from simple 'sketch-book' designs to highly complex city models.

The technique produces images that are easy to understand. Areas with high total annual irradiation can be precisely and easily identified and the possible shading effects of planned new constructions can also be quantified. This is of obvious value to solar planners. As the images are very attractive and recognisable to those who know the area are also very useful for the general promotion of solar technologies.

Acceptability of Photovoltaic Systems

Conservation areas

▲ Figure 5.11: *Listed buildings and conservation areas present a challenge for BIPV potential (Cambridge, UK).*

In city centres of particular historic merit the use of photovoltaics demands careful integration and innovation. This may mean using alternative non-building integrated photovoltaics or BIPV in newer, light industrial suburbs.
An understanding of the existing building stock and of the latest photovoltaic technologies should be considered in order to promote the integration of photovoltaics in any given situation.
This may include opting for light-weight 'clip-on' photovoltaic systems with no effect on a building's structure or fabric, or sourcing appropriately coloured photovoltaic cells to blend-in visually.

Aesthetic value of Photovoltaics

In contrast to conservation areas, where a modern and futuristic image is required, the use of photovoltaics can be a valued asset - this is often the case in new office and industrial premises.

◄ *Figure 5.12: The Doxford office building in the UK shows the integration of photovoltaics in a contemporary setting of a business park. Source: Studio E. Architects, London, UK.*

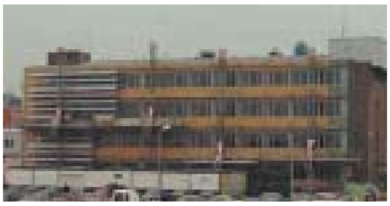
Building tradition

▲ *Figure 5.13a: Building traditions will influence photovoltaic exploitation potential and may limit integration potential (Poundbury, UK). Source: HRH The Prince of Wales, 1989.*

◄ *Figure 5.13b: Combining photovoltaic integration and respect for traditional building styles in new construction is possible as this example clearly shows. (Lielahti Citymarket in Tampere, Southern Finland), Source: Naps Systems Oy.*

Integration of photovoltaic elements into traditional buildings presents a unique set of challenges. In the type of buildings illustrated in Figure 5.13 a) the potential to integrate and exploit BIPV will clearly be influenced by local building traditions (construction type, materials, aesthetics). In these crisumstances installations will tend to be “invisible” rooftop systems where conservation regulations permit them. Figure 5.13 b) shows that where new construction is planned there is indeed scope for integration of photovoltaics providing attractive construction solutions that are harmonious with traditional styles.

Refurbishment potential - fabric, structure and aesthetics



▲ *Figure 5.14a+b: Before (a) and after (b) refurbishment and integration of photovoltaic modules to façade as shading devices (building in Petten, NL) Source: http://www.pz.nl/bear/bearecn8.html (Thermie project SE 100/97/NL/DK - photovoltaic projects).*

BIPV is a particularly exciting option for refurbishment where a building façade, or roof, is in need of improvement. As a building component photovoltaics can simultaneously fulfil a number of functions.

In conclusion, many urban design criteria - which will have a long-term impact on the urban pattern- and the grain and character of existing urban areas affect the potential for exploiting existing or new urban structures for photovoltaic electricity generation. This potential is part of the natural capital that current generations are responsible for managing and enhancing for future generations. Consideration of photovoltaics in the development of urban design criteria is therefore a very positive contribution to sustainable urban policy and will ensure that present and future photovoltaic projects are able to extract maximum benefit from the available solar resource.

Building design

The potential of photovoltaics for energy production offers a new dimension to architecture making buildings active contributors both to their own energy demands and to those of surrounding urban areas. The increasing variety of finishes, formats and appearances of photovoltaic materials offer innovative design solutions for new and refurbishment building projects and other urban applications. They also make photovoltaic integration a possibility for interventions in historic and protected buildings.

From a design point of view the advantages of integrating photovoltaics in a design, rather than simply installing standard modules as an add-on to a design, are:

- the improved final appearance
- the potential of building multifunctionality: electricity production, regulation of light, noise, and temperature
- the possibility of offsetting the cost of the photovoltaic element by the avoided cost of the construction element it replaces (roof, curtain wall, etc.)
- the reduction of risk of vandalism or theft.

What does photovoltaics have to offer?

Photovoltaic (PV) systems produce electricity directly from daylight - silently, without producing noise, emissions or other sorts of pollution. This enables urban areas to actively contribute to their energy needs whilst also reducing the environmental impact of an urban lifestyle. Building Integrated Photovoltaic Systems (BIPV) can be designed so that they also serve as construction components: roofs, glazing, walls, shading devices etc. They can either be visible and symbolic or virtually invisible to the building users and the general public. As such photovoltaics is not only a clean power source but also an attractive new construction element that provides a clear architectural message about sustainable development and can be used as part of a policy to raise environmental awareness.

Design examples in new buildings

◄ *Figure 6.1: Photovoltaic roof (Shopping centre entrance, Zurich, Switzerland). Here 30.5 kWp of photovoltaic cells are integrated into an atrium roof. The system is multifunctional - in addition to electricity it also provides optimum natural lighting levels, shading, weather protection and a suitable light reflection surface for night lighting. The installation was contracted by the Migros company as part of their corporate environmental policy. Power is sold via the innovative Solar Stock Exchange scheme of the local electricity utility (See the following chapter for further details). Source: energieburo® Zurich, Switzerland.*

▲ *Figure 6.2: Photovoltaic façade (Library, Mataró, Spain). Here a total of 52.7 kWp is incorporated into the library roof and southerly façade. In addition to electricity production the system optimises natural daylight and shading. The heat generated by the cells contributes to the space heating of the building in winter and provides natural ventilation currents in summer to help cool the building. Source: TFM, Spain.*

Design examples in refurbishment projects

▲ **Figure 6.3:** *University of Northumbria, UK. This 39.5 kWp installation is the result of a refurbishment project at the University of Northumbria in Newcastle. Photovoltaic panels have been incorporated into the new overcladding of the building and the electricity produced contributes to meeting the building's needs for lighting, computers and other appliances. Any surplus electricity can be fed into the University's internal distribution system to supply other buildings on the campus.*
Source: Tymandra Bewett-Silcock.

▲ **Figure 6.4:** *ECN office and laboratory buildings.*
Architectural value for new and refurbished buildings - Images of the ECN office and laboratory buildings in an innovative design. Roof integrated PV system and refurbished façade with photovoltaic shading elements (102.9 kWp).
Source: ECN, Petten, The Netherlands.
Picture: M.Van Kerckhoven, BEAR Architecten, Gouda, The Netherlands.

Design principles in listed buildings

For those keen on raising awareness of photovoltaics the fact that technology is silent, motionless and often invisible due to roof top location can sometimes be frustrating. However, in the case of listed buildings these characteristics are advantageous. Refurbishment restrictions designed to respect buildings of historic importance often limit the potential for renewable energy integration.

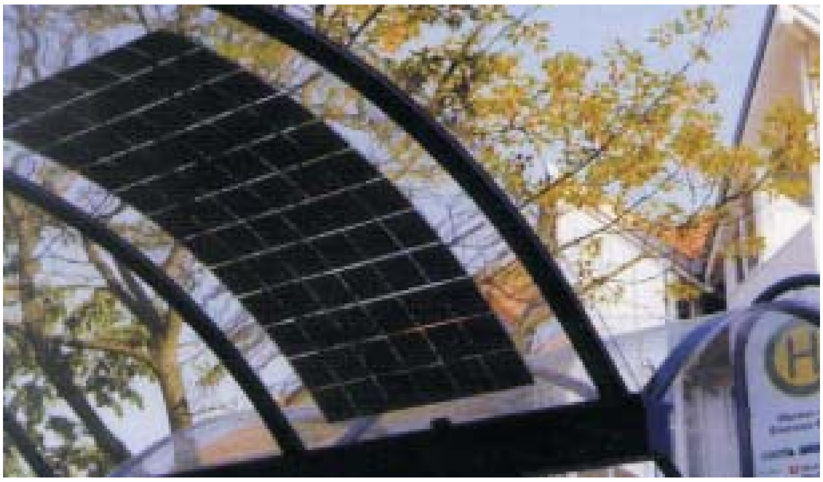
If the restrictions are solely structural, photovoltaics can be included as an add-on roof system that will be invisible from street level. In this case the criteria will be to design a system that is non-intrusive in the building fabric and an easily reversible modification to the building

If the restrictions include visual criteria that make roof top modules unacceptable photovoltaics can be included in the form of cells integrated in other building components such as roof tiles, skylights etc. In this case careful choice of cell type, shape, colour, etc. can ensure that the result is a harmonious addition to the original building.

Design examples in non-building applications

Transport shelters are obvious applications for photovoltaics. The power produced can be utilised for both lighting and information displays. Modules that are well integrated will reduce the risk of theft and vandalism. The following images illustrate the potential these and other non-building urban photovoltaic applications have (see also section 1 applications).

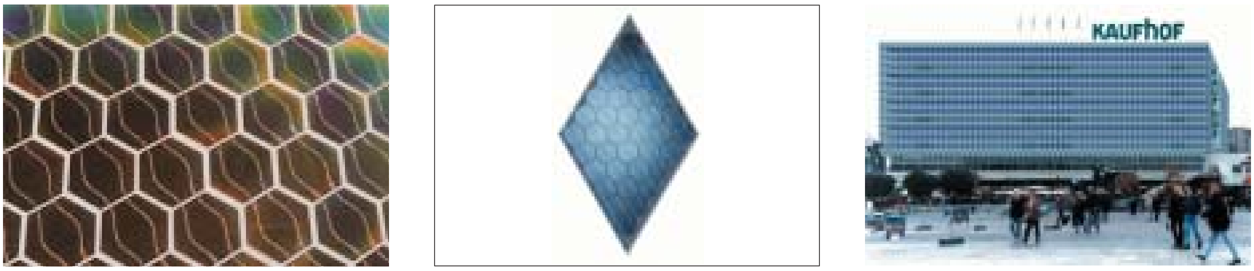
▲ ***Figure 6.5 a-c:*** *Parking meters can be designed and adapted to suit local taste. Many different models are readily available. They have a common advantage: there is no digging needed for grid-connection. Source: Schlumberger, Fraunhofer ISE Freiburg, Germany.*



▲ ***Figure 6.6:*** *Modern elegant design can be realised with, e.g. so called plexiglas semi-transparent, curved solar modules. Source: Rähm, Germany.*

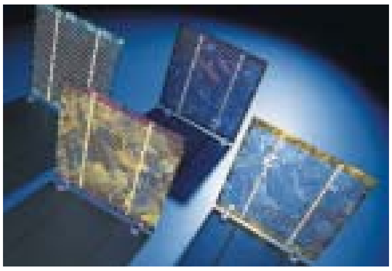
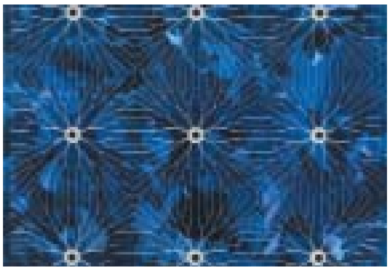
▲ ***Figure 6.7:*** *Artistic expression and impression with photovoltaics. This solar sail stands on the lawn in front of a curative home in Münsingen, Switzerland. Source: NET Ltd., St. Ursen, Switzerland.*

Design versatility



▲ ***Figure 6.8 a-c:*** *Different solar cells were designed within the European project BIMODE. Colours and forms (here: hexagonal) can vary according to the architectural and aesthetic requests. Source: Astrid Schneider, Germany.*

The design versatility of photovoltaics as a building material is developing as rapidly as new cell types emerge and products tailored to the needs of the building sector develop. As illustrated in the Figures 6.8 - 6.12, cells are now available in a wide range of shapes, sizes and colours, these can be built into weatherproof modules using a variety of materials with varying characteristics. This wide range of production techniques and design solutions results in a versatile building element.

▲ Figure 6.9 a + b: Differently coloured transparent Sunways POWER cells as well as differently structured cells can be found on the market. Source: a) Sunways, Germany and b) back contacted (PUM) solar cell by ECN.

▲ Figure 6.10: Flexible roofing laminates for membrane roofing are available on the market. Source: Uni-Solar - Bekaert ECD Solar Systems LLC, Belgium.


▲ Figure 6.11 a + b: Metal roofing with laminates realised by Rannila (Rautaruukki-Group) in Helsinki, Finland. Source: Source: Uni-Solar - Bekaert ECD Solar Systems LLC, Belgium.

▲ Figure 6.12: Installation of solar membrane roof equals standard installation techniques. Source: Uni-Solar - Bekaert ECD Solar Systems LLC, Belgium; Picture: Alwitra GmbH, Germany.

Building Design - checklist of factors to consider

Any BIPV design should optimise electricity generation criteria (area, orientation, inclination, etc.) and cost with other building design factors such as impermeability, thermal performance, daylight control and aesthetics, etc. The design process should also be optimised to reduce costs and assure clients regarding project timescales and any perceived risks.

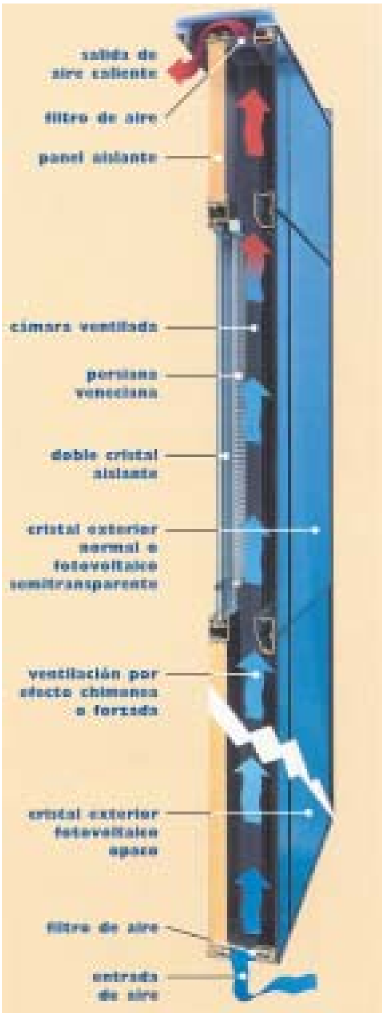
The following checklist includes the basic factors that a design should consider. Attention to this list should help address the concerns associated with any innovative construction element or practice such as BIPV:

Climate and location – South-facing installations with an optimal inclination for the given latitude will give maximum output. There is, however, scope for compromise. A system with an optimal inclination (+/-20%) and a southerly orientation (+/-30%) will still yield over 90% compared to an ideal system. Likewise, east or west facing vertical façade systems still yield 60% of an optimal system due to the low angle of the sun early and late in the day (see Figure 4.3). Other parameters such as a building's electricity load profile or hourly variations in the price paid for power sold to the grid may also affect the definition of optimum.

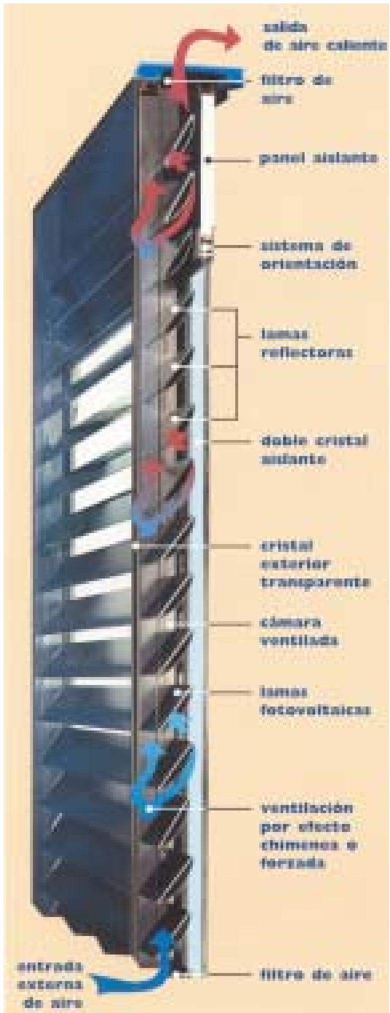
Temperature of the cells – It is important to note that the efficiency of solar cells decreases as their temperature increases. The effect of this characteristic is that the maximum output is not always obtained from systems designed for maximum yield. Ventilation is important in order to keep cells as cool as possible and in some instances non-optimal yield solutions such as façades can produce a better annual production as they receive more irradiation when the sun is low in the sky (morning and evening) when the cells are cooler.

Site – Care must be taken to avoid or at least reduce shading, as this will adversely affect the system performance. A study of shading should be made. Software applications exist to help make such studies. There are many ways around shading problems such as the use of amorphous silicon (less affected by shading) or the use of dummy modules (same appearance but without costly cells) in areas shaded for many hours of the day and months of the year.

Architecture – Photovoltaic modules are simply versatile building components with wires attached. The modules can be described as glazing, roofing, cladding or shading elements. The technology offers myriad opportunities and few restrictions to a creative architect as long as maximum output/m^2 of photovoltaic material is not considered the only important factor. The multi-functional potential of photovoltaic systems should also be explored in relation to other building needs. Fig. 6.13 and Fig. 6.14 show examples of multifunctional modules designed as curtain wall elements. They can perform many functions: electricity production, space heating, shading, daylighting, insulation, weather proofing and ventilation.



▲ *Figure 6.13: Ventilated photovoltaic curtain wall. Source: TFM, Spain.*



▲ *Figure 6.14: Adjustable photovoltaic laminas in a curtain wall construction. Source: TFM, Spain.*

Regulations and By-laws – The design must respect any site specific local planning or building regulations regarding external installations and the visual appearance of buildings. Installations must also comply with current electrical installation, fire and safety regulations.

Type of module – As indicated above, there is an ever-increasing range of potential PV components: cell types, module sizes and shapes, framing or encapsulation systems. This means that the days of ugly bolt-on panels are over. Attractive solutions are now available for all situations (see the section on applications in the urban environment for examples and details).

Installation – Careful and creative design can help reduce costs. Photovoltaic elements can substitute other elements (windows, walls, roof tiles, etc.) thus reducing the additional costs associated with renewable energy use, exploiting synergy with other building needs ensuring that photovoltaics contributes to other building functions.

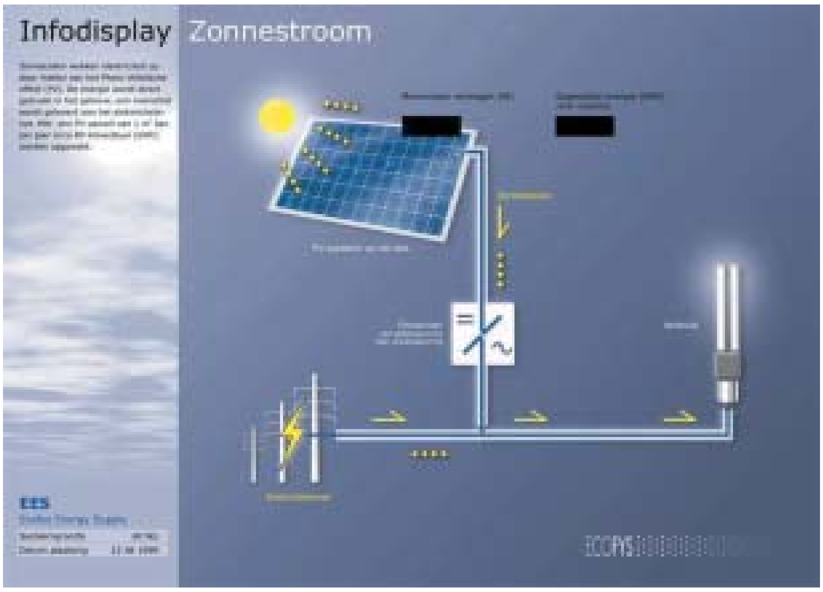
The installation process must aim to minimise any additional costs due to photovoltaics and potential risks of malfunction. For example:

1) An installation process that fits in with conventional construction practise reduces the need for specialist labour and tools and reduces risk of human error.
2) The use of industrial techniques such as the pre-assembly of arrays and installation using cranes can reduce installation time.
3) The use of techniques that allow electrical connections and subsequent maintenance to be made from inside the building reduce complications and associated costs.

Other design details

- Ensure that the installation location is secure – reducing the risk of theft, vandalism or injury. (A basic Dutch guideline suggests that installations should be at least 3 metres from ground level).
- Leave space in a moisture-free area of the building for electrical control equipment (inverters, meters, etc.)

- Consider dissemination and interpretation: A photovoltaics installation is unobtrusive – silent, has no moving parts etc. If the "green" electricity aspects of the installation are to be actively promoted, some sort of display will be necessary. There is an increasing number of off-the-shelf interactive, real time displays available.



◄ *Figure 6.15: Interpretation display showing climatic data and building energy production in real time. Source: Ecofys, The Netherlands.*

Financing mechanisms

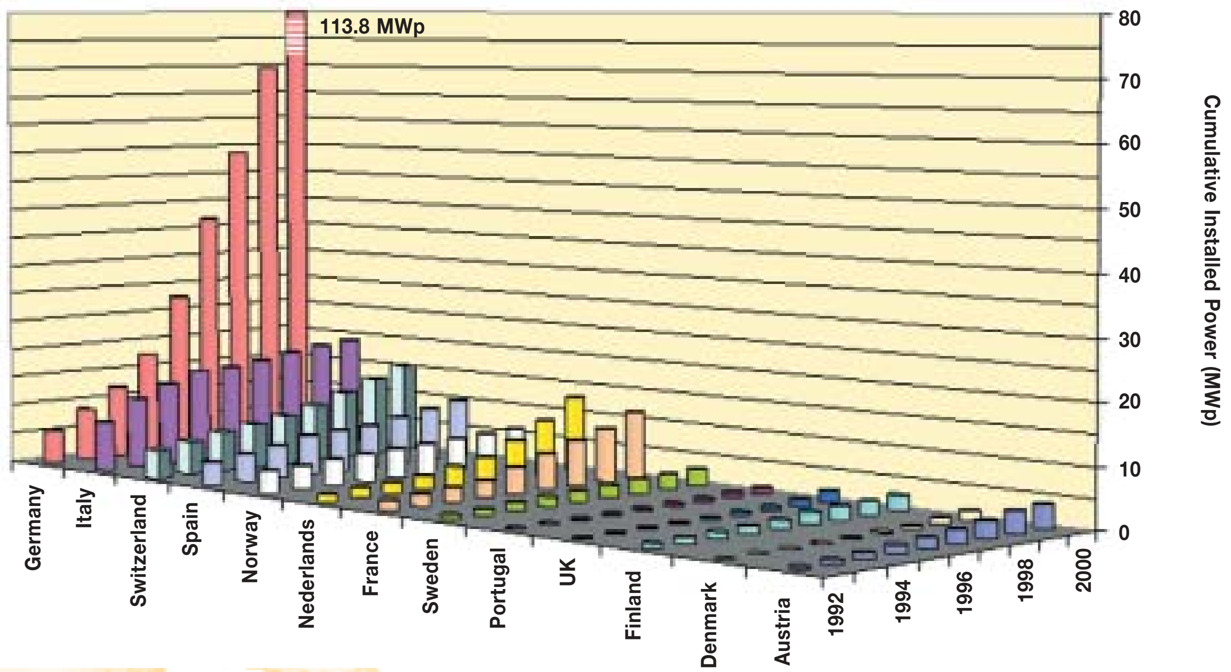
The importance of photovoltaic energy in the portfolio of renewable energies (REs) and the intention of maintaining a European presence in the global market is clear as reflected by European and national policy and incentives. Photovoltaics is already commercially competitive in many markets although not yet in grid-connected power supply. The timetable for transition from subsidised demonstration to commercial take off of the grid-connected photovoltaic market is closely linked to the capital cost of the photovoltaic modules which, in turn, depends mainly on the global annual production capacity and on the commercially available cell technology.

Different European countries have set up regional and national programmes aimed at promoting photovoltaics by providing market incentives and financial support. The European Commission also supports research, development, demonstration and dissemination activities related to photovoltaics. These initiatives, in conjunction with favourable energy policies and growing public environmental awareness, have promoted photovoltaic installations -particularly grid applications- in recent years.

This section explores these cost issues and the finance mechanisms that aim to develop the potential and accelerate the transition from innovative technology to fully cost competitive grid electricity supply products.

Market Development since 1992

The rapid development of the photovoltaic market – in terms of installed capacity – can be observed in the Figure 7.1, showing the historical trend in European IEA countries from 1992 to 2000. The total installed capacity in these countries rose from 32 MWp in the year 1992 to over 200 MWp by the end of 2000, an increase of over 600%, with a growth of approximately 30% per annum.

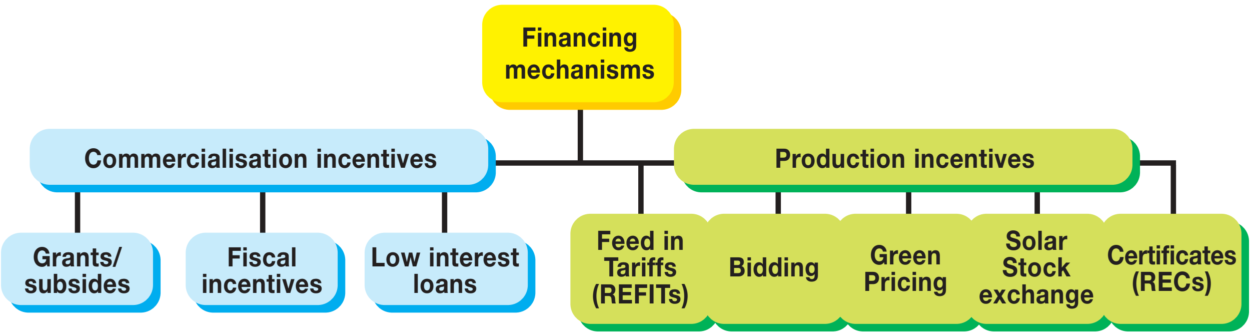


▲ *Figure 7.1: Historical cumulative installed power (from 1992 to 2000) in EuropeSource: IEA Photovoltaic Power Systems Programme, Statistics, http://www.iea-pvps.org.*

How can solar electricity be financed?

The budget globally allocated for photovoltaics – research and development, demonstration and market stimulation - by Western Europe governments was about 400M€ in the two year period 1998-1999. Germany was the largest single investor with more than 114M€ in two years. The Netherlands, Switzerland and Spain also emerged as leaders in supporting photovoltaic energy worldwide. Large-scale photovoltaic roof programmes have also been successfully implemented in Japan and in the United States, Japan investing 300M€ in photovoltaics in 1999 alone. (All figures from IEA-PVPS reports).

Financial support for photovoltaic electricity exists in several European states in diverse forms. The aim of the support instruments is to compensate for the inability of conventional financial analysis to account for the environmental benefits of this clean, silent, modular non-polluting energy source. The specific objective is to increase the use of photovoltaic electricity, by making investment in photovoltaics more attractive and less risky in comparison with conventional electricity generation technologies and alternative building construction elements (in the case of BIPV).
The most commonly used financing instruments in Europe can be subdivided in the following two categories: **commercialisation incentives** and **production incentives** (see Figure 7.2).



▲ *Figure 7.2: : Overview on financing mechanisms.*

▲ *Figure 7.3: De Vergulde Wagen, Stadtskwartier, Amersfoort-Nieuwland, The Netherlands, Source: REMU, The Netherlands.*

Example: AMERSFOORT – the Dutch PV City
1 MW photovoltaic project in Nieuwland

The project consists of the installation of more than **12000 m² of photovoltaic solar panels** on several hundred houses and a number of public utility buildings in the Waterkwartier district of Amersfoort -Nieuwland. It is expected that these panels will be capable of generating 1000000 kWh annually (equivalent to the average electricity consumption of more than 300 households)
The project is an initiative of the Dutch energy supplier REMU and has been developed in collaboration with NOVEM (The Dutch National Energy Agency), the Amersfoort local authority, Overeem and the BOOM environmental research and design agency. The project was funded by a **combination of different financing instruments made up** of grants from NOVEM, buy-back rates and support from the EC.

Example: Barcelona – 40 kWp installed in a municipal building

The aim of this project was to provide a symbolic demonstration of the possibilities of photovoltaics in urban areas; to provide stimulus for other projects and to also contribute to Barcelona's objectives regarding sustainable development in general and in particular renewable energy targets.
The Barcelona City Council financed this project with support from the THERMIE programme of the EC. The installation now sells electricity to the grid at the prime feed in tariff established by the law RD 2818/1998.

▲ *Figure 7.4: Barcelona City Council roof installation. Source: Ajuntament de Barcelona.*

Commercialisation Incentives

Commercialisation incentives are mechanisms used to defray the initial capital costs of photovoltaic installations. They include:

Grants or subsidies

These are the most commonly used investment subsidies, provided by almost every European state with an average range of 30-50% of the capital costs. Grants range from 14% of the capital costs in The Netherlands to 75% in Italy. Details of this type of financing mechanism currently available in various European countries can be downloaded from http://pvcityguide.energyprojects.net.

Fiscal Incentives

These are also effective cost reduction tools. Some European countries offer tax write-offs for the cost of purchasing and installing photovoltaic systems or accelerated depreciation. For instance the Italian government offers a tax reduction of 36% for investments in renewable energy sources which can be written off in 5 or 10 years.

Low interest loans

Low interest loans provide another mechanism to support photovoltaic installation. Low interest loans at 1-1.5% less than market rates reduce loan payments and generation costs. Interest rates may be fixed throughout the loan term - usually around 10 years but may reach, in some cases, up to 20 years. In addition, a grace period for loan repayment can be granted.

Example: Photovoltaics at the IKEA office in Älmhult, Sweden (1997)

This was the first large grid-connected photovoltaic plant in Sweden with 60 kWp. It comprises a roof system (378 m^2) and a façade system (250 m^2). The total cost was 478000€, financed by 40% governmental support and 60% by the owner, who used this first installation to increase its knowledge and experience of photovoltaics technology, for possible further commercial installations in other parts of the world.

▲ *Figure 7.5: IKEA offices, 60kWp roof and façade. Source: Energibanken, Jättendal, Sweden.*

Example: The Italian Programme "Photovoltaic Roofs"

In March 2001, The Italian Ministry of Environment launched the Programme "Photovoltaic Roofs". The 16 March 2001 Decree gave start to the programme and supports the installation of grid connected photovoltaic plants installed / integrated in buildings (roofs, façades and other elements of urban infrastructure) with an installed capacity between 1 to 50 kWp. The financial support is constituted by a grant to the initial investment not higher than 75% of the eligible cost of the plant (VAT excluded).
The Ministry made 32.5 M€ available for the year 2001, with the objective being the installation of about 2200 photovoltaic systems integrated in buildings with a total capacity of 7 MWp. The programme is organised in three sub-programmes. The first one is dedicated to public entities (province capitals, municipalities in regional and national parks, provinces, universities and national research institutes). The maximum allowable costs vary between 8000 to 7230 € per kWp depending on the plant size. The second one is for small municipalities, private entities, the citizens and all those which did not fit into the first sub-programme. In this case the programme will be financed partly by the Ministry, partly by the relevant region. The third sub-programme regards the integration of photovoltaic plants with a capacity higher than 30 kWp in architectural high value buildings. The maximum contribution granted by the Ministry amounts to 85% of the investment costs (VAT excluded) at allowable costs equal to 12900 € per kWp.
More details about the programme at:
http://www.minambiente.it/Sito/settori_azione/iar/FontiRinnovabili/bandi_decreti/elenco.asp

▲ *Figure 7.6: Pilot Project "Institute Frankenberg".*
Location: City of Bolzano (Italy).
Installed capacity: Grid-connected 3.1 kWp.
Financing: Italian Ministry of Industry (MICA) and autonomous Province of Bolzano. Source: courtesy of Gechelin Group Sistemi Fotovoltaici, Italy.

Production Incentives

Example: The German 100000 photovoltaic roof programme

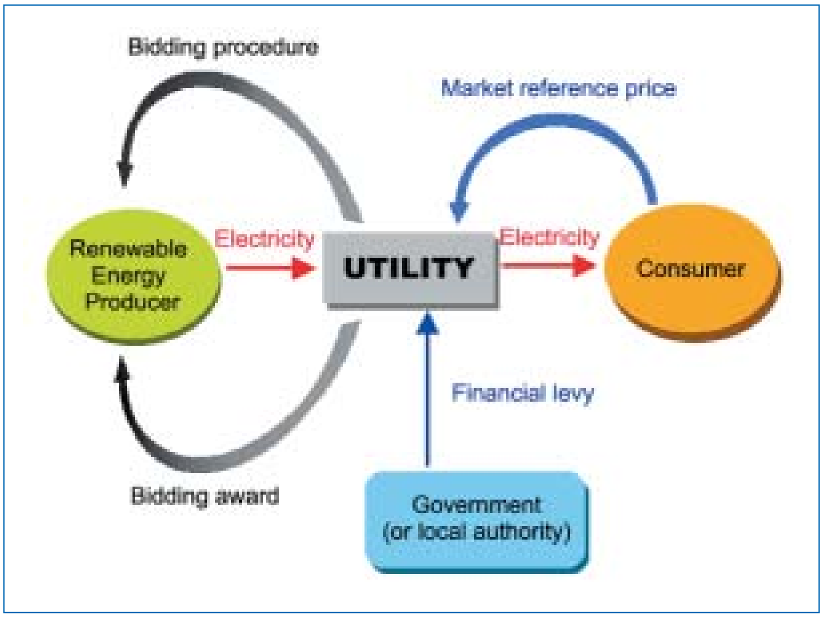
The **German** 100000 photovoltaic roofs installation programme is considered as the most important programme of its category in the world. The aim is to simplify investment by individuals and small- and medium-size companies in photovoltaic installations linked to the power grid. In combination with the "Renewable Energies Law" providing 0.49€ for each solar kWh fed into the grid, Germany has equipped itself with the important means necessary for the take off of photovoltaic solar energy and its industry.

Feed in Tariffs

Government set **feed-in** or **buy-back rates** and **competitive market bidding** (public tendering) are the two most commonly used production incentives currently working in Europe.
For example, in **Spain** the take off of photovoltaic installations was sparked off by a law passed in December 1998 making it mandatory for the electricity utility to purchase electricity generated by a renewable energy source at a prime rate of up to 0.39 €/kWh for photovoltaic installations from 1-5 kWp and 0.18 €/kWh for plants in the size of 5 kWp to 50 MWp. By means of comparison, the spot market price for electricity is about 0.036 €/kWh and the domestic tariff is 0.099 €/kWh.
During the past ten years, various countries have introduced **Renewable Energy Feed-In Tariffs (REFITs)** forcing electricity companies to purchase electricity from renewable energy sources at a minimum price defined by law. Feed-in tariffs are seen as a means of developing local markets – the target group being mainly private customers – with the aim of long-term market stimulation. Where implemented, these REFIT laws accelerated the rate of increase of renewable energy generation capacity in general and photovoltaics in particular.
Note: in this type of incentive, the duration of the guaranteed payment is as important as the amount to be paid. Rates must be guaranteed for a sufficient time to give an acceptable return on investment.

Bidding

Bidding is applied by governmental bodies to ensure that the most efficient and economic photovoltaic (and other renewable) projects are promoted. Bids are invited from private generators specifying the total generation capacity to be contracted and the maximum price per kWh.



▲ *Figure 7.7: Scheme of the bidding process.*

The **United Kingdom**'s Non-Fossil Fuel Obligation (NFFO) was an example of bidding and was the main instrument in the UK for encouraging the deployment of renewable energy resources in the 1990s. In accordance with the best-bidder principle, the contracts were awarded in order of cost-effectiveness until the required generation capacity has been met. Contracts were established for a 15 year period. The difference between the bid and market reference price was subsidised by a national levy on electricity generated by fossil fuels.

The **Domestic Photovoltaic Systems Field Trial Programme** encourages field trials of domestic photovoltaic systems in the United Kindom using the design, construction and monitoring of the installations as a learning opportunity for the utilities, building developers and other key players in the process. In this way, any significant barrier to the installation of domestic photovoltaics could be identified and supporting work to remove these barriers could be defined and undertaken as appropriate.

The programme supports photovoltaic installations in clusters of around 5 to 25 on new-build housing developments or major domestic refurbishment projects for the demonstration of a variety of photovoltaic system designs in different types of buildings.

A new **Large-scale Photovoltaic Public Building Field Trial** has also just been announced in the UK with other initiatives expected in the near future.

Green pricing for "Green electricity". Energy utilities offer an optional service to the consumer to purchase electricity generated from renewable energy - including photovoltaics. Consumers who choose to buy "green energy" pay a premium price to use electricity that causes less environmental damage. Green pricing is gaining popularity, particularly in Germany, USA, The Netherlands and Switzerland.

Once the European energy market is fully liberalised and all consumers are able to choose their electricity supplier, it is anticipated that green pricing will gain importance as a renewable energy finance mechanism. The attraction of green pricing is that it allows individuals and companies to make a direct contribution to energy policy by deciding to purchase some or all of their energy from renewable sources.

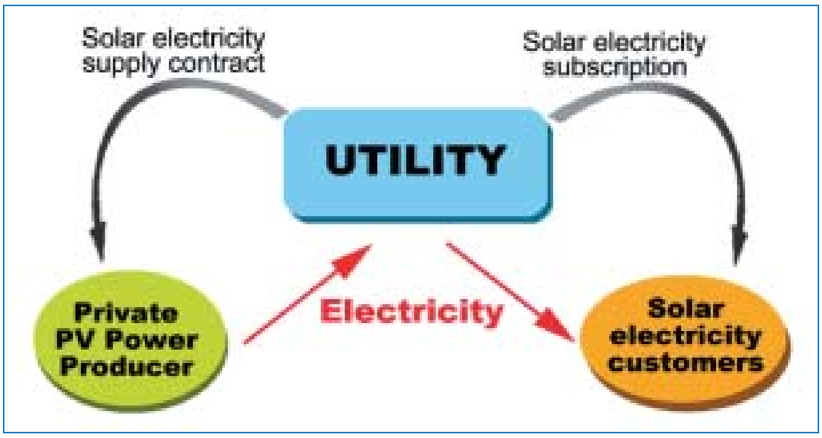
In The Netherlands, more than 350 million kWh of green energy were purchased in 1999. This is around 0.5% of the total electricity consumption and the market for green energy is growing rapidly. Between September 1999 and January 2000 the number of green energy customers of Dutch energy companies increased by 40%. There are various Internet sites, which also allow you to see not only how this green market operates but also which companies are buying and selling green power. A good example of these is: http://www.greenprices.com.

The Solar Stock Exchange

The concept of the utilities being a "solar broker" is an idea first realised in the early 90's by local Swiss utilities (Birseck, Neuchâtel). Zurich's electricity utility EWZ baptised this concept the "Solar Stock Exchange" and made it very famous thanks to a successful marketing strategy and a definite demand from clients for solar electricity. The "Solar Stock Exchange" acts as broker between producers and consumers.

Electricity generated by private-owned grid-connected photovoltaic systems is purchased by the utility at cost-covering prices, and resold by the utility at the same rate to its customers.

The aims and results of this initiative are to provide photovoltaic power to small-scale users, to promote cost-efficient photovoltaic installations in the built environment and to reduce system costs. Given the success of the first initiatives, the approach was subsequently extended towards a national initiative within the National Action Programme Energy 2000, supported by the Swiss Federal Office of Energy and the Swiss Electricity Supply Association.



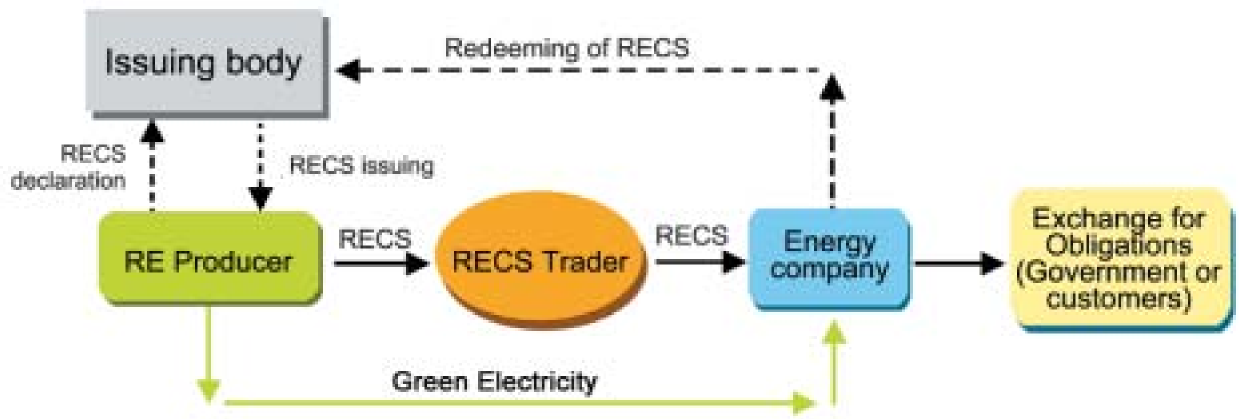
◄ *Figure 7.8: The Solar Stock Exchange Concept.*

The citizens of Zurich even have the possibility to order their "Solar-Abo" from home via Internet (http://www.ewz.ch). Today, over 100 Swiss utilities are selling photovoltaic electricity generated from photovoltaic installations with a total capacity of 3500 kWp to over 25000 customers at a unit energy cost of between 0.65–0.78€. As a result of this utilities' initiative allied with the Swiss Government incentives, Switzerland is the European leading country in photovoltaic solar energy (close to 2 W solar power installed per capita)

◄ *Figure 7.9: Migros Limmatplatz Solar Power Station in Zurich, Switzerland.*
Installed capacity: 30 kWp.
*Energy production: **24000 kWh/yr**.*
*Photovoltaics surface: **360 m²**.*
*Investment cost: **190000 €.***
*Financing: **Solar Stock Exchange.***
Source: energiebüro®, Zurich, Switzerland.

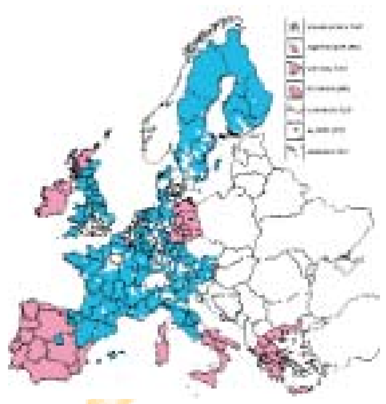
Renewable Energy Certificate System (RECS)

RECS is a new method of financing renewable energy technologies This system is unique in that environmental benefit is marketed separately to energy. The energy produced from renewables is traded and consumed locally by adopting the usual tariffs, whereas the surplus value due to the related environmental benefits is reflected in **certificates**, which are issued by institutional certification bodies. This enables market participants of all sizes to participate in the renewable energy market. In the very near future, it is expected that RECS trade will gain importance in the international market (RECS information: http://www.recs.org)



▲ ***Figure 7.10:*** *RECS concept.*

European Commission initiatives supporting and promoting photovoltaic electricity
The initiatives of the European individual member states are supplemented by programmes carried out by the European Commission for the benefit of the member countries.
Research, technology development and demonstration of photovoltaics are financed by the European Commission **multi-annual Framework Programme on research, technology development and demonstration** – at the time of writing the current the Fifth Framework Programme (1998-2002) is coming to an end and the next framework programme for 2002-2006 is under development. For more information see http://www.cordis.lu.
Another non technical support programme of DG TREN is the **ALTENER-SAVE Programme**, providing 30-50% support for studies and technical evaluations, assistance in defining standards and training and information activities. For more information see:
http://europa.eu.int/comm/dgs/energy_transport/index_en.html



▲ ***Figure 7.11:*** *Map of the European Regional Development areas.*

Structural funds – European Regional Development Fund (ERDF)
Photovoltaic projects can be co-financed by the European Regional Development Fund. Funds provided by ERDF are non-refundable assistance made available to development projects that respond to national priorities agreed between the Member State and the European Commission, DG REGIO.
The priority objectives of ERDF are:

- Objective 1: Development and structural adjustment of regions whose development is lagging behind (pink in the Figure 7.11)
- Objective 2: Economic and social conversion of areas facing structural difficulties (blue in the map)

Programmes supported between 2000 and 2006 by ERDF are:

- Development of the most disadvantaged regions (Objective 1)
- The conversion of regions facing structural difficulties (Objective 2)
- Interregional co-operation (Interreg III)
- The sustainable development of urban areas in crisis (Urban II)
- The development of innovative strategies to support regional competitiveness (innovative actions)

For the photovoltaic City community, the URBAN II is the most appropriate programme providing support for photovoltaic installations in your city. The Urban initiative aims at promoting the design and implementation of innovative development models for the economic and social regeneration of urban areas in crisis. Programme priority for actions of interest for photovoltaics Cities are:

- Renovating buildings in the context of creating employment, integrating the local population, respecting the environment and generally improving urban life
- Encouraging the introduction of more efficient energy management systems and the use of renewable energy

Around 50 towns with 10000 inhabitants or more may be eligible for the Urban initiative (further information available at: http:// www.inforegio.cec.eu.int).

Legislation

Apart from technical, economic and architectural design concerns, there are also numerous aspects of a photovoltaic project either subject to legal considerations or prime for regulation. These may be described in three broad categories:

- ✓ Specific legislation or standards related to products, components and systems.
- ✓ General legislation that photovoltaics must comply with.
- ✓ Emergent areas of legislation and regulation.

These categories are explained below and relevant examples given as means of illustration. By definition, this is a very wide-ranging subject which however plays a crucial role when photovoltaic projects come to realisation in specific frameworks. More detailed information of relevant legislation and examples is available via the PV City Guide web site and associated links.

Specific legislation or standards related to products, components and systems

Commercial products: A common certificate for crystalline photovoltaic modules is IEC 1215, as adopted in the CEC 503 procedure (often called the ISPRA test) or the UL test 1703. These tests specify the electrical characteristics as well as safety aspects following well-determined test procedures (mechanical, climate, etc.).

System components: Although there are specific product test and type approval codes for photovoltaic modules (e.g. IEC 61215 – crystalline modules, IEC 61646 – thin-film modules), specific building integrated photovoltaic component codes do not really exist yet. This can make the situation more difficult, in particular in relation to high-rise buildings where issues such as fire and safety are important.

Systems: Again, no specific standardisation for system design exists; several countries have however developed schemes for successful project design. The criteria used by experienced authorities in the administration of public support mechanisms offer effective guidelines for regulating acceptable performance of systems.

In general, different pre-normalisation schemes or guidelines for recommended practice are available in areas not yet covered by appropriate standards.

General legislation that photovoltaics must comply with

Building, planning and land use regulation

The appearance of photovoltaics is novel and systems are likely to be judged for their aesthetic aspects (see also the chapters on urban and building design). There are two ways of handling this type of impact: either emphasise the multifunctionality of photovoltaic building elements and their appeal or hide it. Both ways should result in a holistic integration of the photovoltaic system with the built environment.

There are a variety of (indirectly) photovoltaic friendly regulations due to the environmental benefits of photovoltaics. For example:

- An Italian law foresees that buildings in public ownership or for public use are obliged to satisfy their own energy needs, for heating, air-conditioning, lighting, and the production of hot water, favouring renewable energy sources.
- In The Netherlands a building permit is legally required for the erection of, or extension and adaptations to buildings, the permit also implies appraisal of reasonable demands of aesthetics, so called Welstand. Obtaining a building permit involves a lengthy procedure. To stimulate sustainable building the new Dutch Housing Law may exempt domestic solar hot water systems and photovoltaic systems on existing buildings from the required building permit.
- Similar legislation has been applied in Zurich for several years. No special construction permit has to be acquired for solar installations in the following circumstances:

- If it is realised on a roof
- If the building is within the planning zone for buildings except in the (historical) city zone
- If the building is not listed (this has to be checked before installation)
- If the area is less than 35 m_
- If the area is coherent (not several dispersed portions)
- If the roof is not projected by more than 10 cm

Electrical installation safety

Electrical installation safety and grid-connection regulations can be found on several levels: international, national and local, IEC, national examples, and municipal utility regulations.

By way of example an IEC working group (TC82, WG3) has drafted safety rules for photovoltaic systems "Safety regulations for Residential Grid Connected PV-Power Generating Systems" based on the standard IEC 364. These rules offer several "protective measures" against electrical shock. Basically, if the open circuit voltage is higher than 120V the modules should be installed in such a way that they cannot be reached by people.

On a national level, different bodies prescribe and make regulations with respect to electrical installation safety and grid-connection (see http://pvcityguide.energyprojects.net). On a local level, municipal utilities sometimes have specific grid-connection regulations as illustrated by the following examples:

- The Netherlands certification authority allow connection of modules of up to 2.25 amps (up to four 100W modules) to the grid without demanding additional switching groups or safety measures. This has opened the market to the installation of AC modules on individual properties.
- Switzerland does not require any specific heavy current inspection for installations with photovoltaic power capacities of less than 3.3 kWp per phase.
- In Spain and the UK, recent laws have established grid connection requirements and procedures specific to photovoltaic systems.
- The Italian Authority for Electric Energy and Gas defined the techno-economic conditions for the exchange with the local utility of the electricity produced by photovoltaic plants of up to 20kWp capacity.

Insurance requirements

Given the comprehensive electrotechnical standards, photovoltaic systems are automatically covered in an insurance policy in Switzerland. The premium to be paid depends on the value of the photovoltaic installation and the building. There is usually no extra risk premium. A considerable insurance market has already developed in Germany, where a lot of private companies try to attract photovoltaic clients.

Economic and tax regulations related to the sale of electricity

If the electricity produced by a photovoltaic system is sold, issues regarding invoicing, accounting and tax liability may arise. The complexity of these issues varies between countries and may also vary depending on the size of the system and the type of sale contract. It is crucial to harmonise both technical and economic aspects. For example, in Spain since 1998 attractive economic rates have been available but initially only served to reveal legislative gaps regarding grid connection and the legal status required for small BIPV installations to invoice for the sale of electricity. Many of these issues have now been clarified both by subsequent legislative advances and the experiences of demonstration projects setting precedents.

Emergent areas of legislation

Certification of energy sources

The emerging Renewable Energy Certification System (RECS) offers promotional possibilities for photovoltaics. See the previous chapter on financing mechanisms for details

Certification of solar electricity professionals

The accreditation of schemes providing educational packages to the professional sector is an emerging topic but a harmonisation has so far not occurred. Certain experienced administrations only support projects to be constructed by reputable, certified professionals. Such policies offer quality assurance for both the final customer and financier and are usually welcomed by experienced installers and designers.

Glossary

A	Area
BIPV	Building Integrated Photovoltaics
cap	Capita
CHF	Swiss Franc (Swiss currency)
CO_2	Carbon dioxide
DG TREN	Directorate General Transport and Energy
€	Euro (European Currency Unit)
ERDF	European Regional Development Fund
GWh	Gigawatthours
IEA	International Energy Agency
IEA-PVPS	International Energy Agency Photovoltaic Power Systems Programme
I	Irradiation
kWh	Kilowatthours
kWp	Kilowatt peak
m^2	Square meter
MWh	Megawatthours
MWp	Megawatt peak
N	North
NFFO	Non-Fossil Fuel Obligation
NOx	Nitroxide
P	Population
PV	Photovoltaic / Photovoltaics
R&D	Research and Development
RECS	Renewable Energy Certificate System
REFITs	Renewable Energy Feed-In Tariffs
RES	Renewable Energy System
SOx	Sulphur oxide
PVPS	Photovoltaic Power Systems
RTD	Research, Technological Development and Demonstration
UK	United Kingdom
VAT	Value Added Tax

OPET NETWORK:
ORGANISATIONS FOR THE PROMOTION OF ENERGY TECHNOLOGIES

The network of organisations for the promotion of energy technologies (OPET), supported by the European Commission, helps to disseminate new, clean and efficient energy technology solutions emerging from the research, development and demonstration activities of Energie and its predecessor programmes. The activities of OPET members across all Member States, and of OPET associates covering key world regions, include conferences, seminars, workshops, exhibitions, publications and other information and promotional actions aimed at stimulating the transfer and exploitation of improved energy technologies.

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NOTICE TO THE READER

A great deal of information on the European Union is available on the Internet. It can be accessed through the Europa server (http://europa.eu.int).

The overall objective of the European Union's energy policy is to help ensure sustainable energy system for Europe's citizens and businesses, by supporting and promoting secure energy supplies of high service quality at competitive prices and in an environmentally compatible way. The European Commission's Directorate-General for Energy and Transport initiates, coordinates and manages energy policy actions at transnational level in the fields of solid fuels, oil and gas, electricity, nuclear energy, renewable energy sources and the efficient use of energy. The most important actions concern maintaining and enhancing security of energy supply and international cooperation, strengthening the integrity of energy markets and promoting sustainable development in the energy field.

A central policy instrument is its support and promotion of energy research, technological development and demonstration, principally through the Energie sub-programme (jointly managed with the Directorate-General for Research) within the theme 'Energy, environment and sustainable development' under the European Union's fifth framework programme for RTD. This contributes to sustainable development by focusing on key activities crucial for social well-being and economic competitiveness in Europe.

Other programmes managed by the Directorate-General for Energy and Transport, such as SAVE, Altener and Synergy, focus on accelerating the market uptake of cleaner and more efficient energy systems through legal, administrative, promotional and structural change measures on a trans-regional basis. As part of the wider energy framework programme, they logically complement and reinforce the impacts of Energie.

The Internet web site address for the fifth framework programme is:
http://www.cordis.lu/fp5/home.html

Further information on Energy and Transport DG activities is available at the Internet web site address:
http://europa.eu.int/comm/dgs/energy_transport/index_en.html

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