

Innovation and SME

IPS-2000-0090

PVACCEPT

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1 General Project Information

1.1 Duration and Funding

PVACCEPT / IPS-2000-0090 started officially on the 1st of July 2001 after almost one and a half years of preparation and with a planned duration of 36 months. It was funded by the EC within the 5th Framework Programme and the special programme “Promotion of innovation and encouragement of SME participation”. The work was very complex and comprehensive, including research, demonstration, and dissemination activities. In 2004 it was extended by six months until the 31st of December 2004 due to an earlier change in the consortium composition and delays in decision-making processes on the side of involved communal partners. Despite the extension, the total eligible costs of the project and the maximum Community contribution remained under the contractual figures of about 2.2 Mio Euro respectively 1.6 Mio Euro.

1.2 Objectives and Theses

The project was focussed on the acceptance and dissemination of solar energy conversion by photovoltaic (PV) systems. In the past PV systems and modules have been designed predominantly by technical criteria, i.e. the industrial development of PV modules was primarily aimed at performance, such as high efficiency and low cost, and little regard was dedicated to their aesthetic aspects. The consequence was that often no real architectural integration occurred when they were applied to buildings, and investors abandoned the idea of installing a PV system due to their aesthetic appearance. “Good” application of the commercially available PV modules was thus limited mainly to new modern buildings. In our opinion this has lowered the acceptance of PV and therefore its market diffusion.

Consequently to this premise, the project was based on a number of theses:

- 1 Broader implementation of photovoltaics will contribute to the reduction of environment-damaging emissions.
- 2 There are non-technical (respectively non-economic) barriers for the acceptability of photovoltaics.
- 3 Design is an important and so far underestimated acceptability factor. Improved design can improve the acceptability of PV technology.
- 4 If innovative PV design stands the integration test in highly sensitive areas under landscape and monument protection, it can be applied everywhere.
- 5 Tourism in sensitive areas is a market for PV technology and a possible tool for information transfer and marketing.
- 6 A comparison of North and South European countries with differences in climate, architecture, and landscapes offers a wide range of PV application scenarios.

To enable wider application of this environmentally friendly energy generation, the project aimed therefore at designing and developing marketable photovoltaic modules, whose design enables their sensitive and inconspicuous integration into old buildings, historical sites, and (protected) landscapes. Since tourism in such sensitive areas was regarded as a vehicle for information transfer to foster further dissemination of (innovative) PV, corresponding sites for demonstration plants with application of the innovative modules were to be chosen.

Important further objectives were to test / prove the thesis that design is an important acceptability factor, and to evaluate the acceptance of the innovative modules and their application in the so-called demonstration objects. Another important aim of the research was to assess the environmental impacts of the PV systems by means of a life cycle assessment study.

As far as dissemination is concerned, the work plan included training activities for SMEs to instruct them in dealing with innovative PV plants. In addition to the project website, set up in an early stage of the project, other dissemination tools, like an itinerant exhibition and a design manual, were to be developed already within the project.

1.3 Work Plan and Deliverables

The project activities were structured in 13 work packages (see also figure 1.1). The approach was very complex and comprised basically six phases:

- Phase 1** Evaluation of the political, socio-economic, legal and ecological framework conditions, relevant for PV installations, in Italy and Germany, and proof of the main thesis - design is an important acceptability factor - by a first acceptability study.
- Phase 2** Definition of regional demand and selection criteria for demonstration objects; at the same time definition of technological development interests and possibilities.
- Phase 3** Development of innovative PV products in cooperation between designers and technology producers in parallel with development of designs for demonstration objects in accordance with the needs of the communes involved.
- Phase 4** Application of different types of the developed innovative modules in demonstration objects with touristic purposes in both countries.
- Phase 5** Test run and in parallel life cycle assessment of the demonstration objects, and further acceptability studies with relation to the built objects.
- Phase 6** Development and production of appropriate means for the dissemination of the knowledge gained to guarantee the “survival” of the results after the formal end of the RTD project.

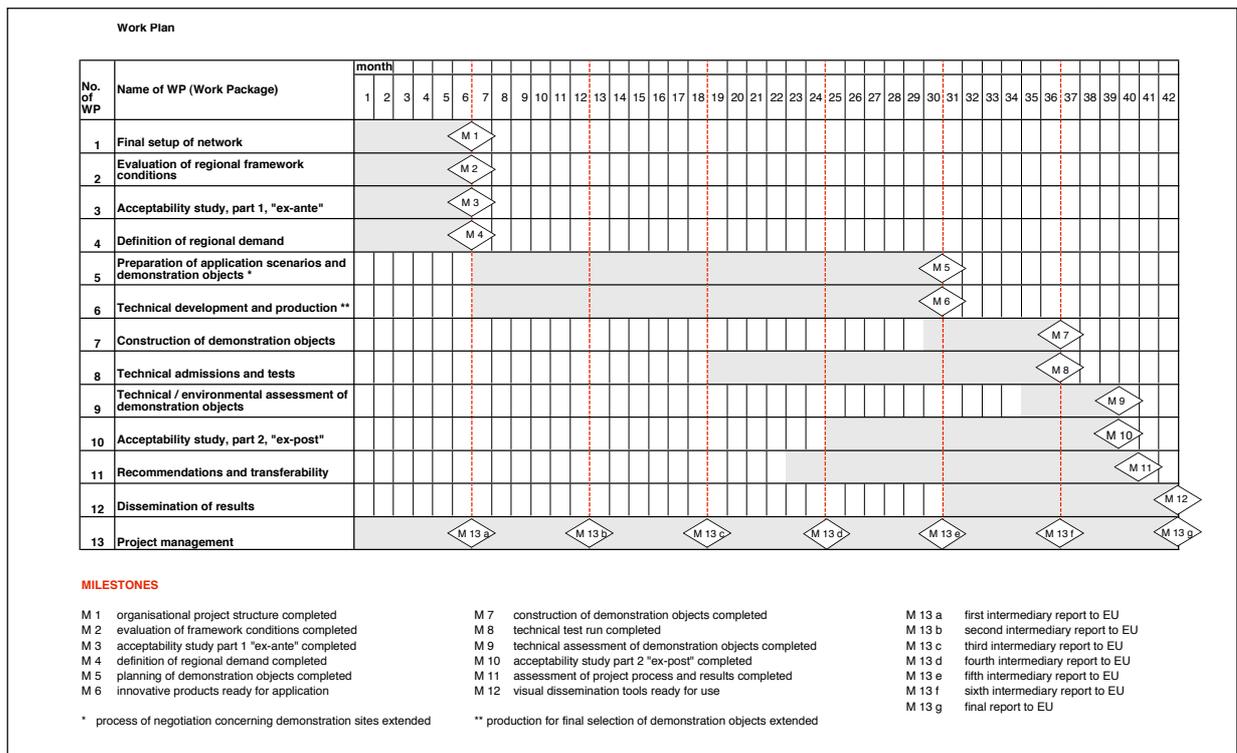


Figure I.1: PVACCEPT: Overview on work packages and milestones

The main results of these different project steps and deliverables, which are reported in detail in the following chapters, are:

- Innovative PV modules;
- Built demonstration objects;
- Life Cycle Assessment of demonstration objects;
- Acceptability studies;
- Internet presentation;
- Itinerant exhibitions;
- Design manual;
- SME training.

1.4 Project Network and Division of Labour

1.4.1 The Consortium

The project objectives were achieved by a cooperation of

- Designers (UdK Berlin);
 - SMEs / PV technology producers: Würth Solar (CuInSe₂¹ thin-film modules), Sunways (crystalline silicon modules);
 - PV system installers: BUSI / ANIT;
 - Research institutes: Ambiente Italia, IÖW, University of Siena;
- from Italy and Germany.

The division of labour within the consortium is shown in the following table:

¹ Copper Indium Diselenide

Consortium member	Main tasks
Universität der Künste Berlin	project coordinator design development / innovative PV modules design and planning of demonstration objects execution of SME training units organisation of workshops and final conference in Germany production of dissemination tools: website, itinerant exhibition, design manual further dissemination of results
Università degli Studi di Siena	Life Cycle Assessment of demonstration objects scientific support
Istituto di Ricerche Ambiente Italia	coordination of activities in Italy acceptability studies organisation of workshops in Italy dissemination of results
Institut für ökologische Wirtschaftsforschung	acceptability studies scientific support
Würth Solar (SME)	technology development / innovative PV modules delivery of modules and carrying structures to the demonstration sites technical test runs execution of SME training units
Sunways (SME)	technology development / innovative PV modules delivery of modules and carrying structures to the demonstration sites technical test runs execution of SME training units
BUSI / ANIT (SME)	delivery of additional system components to the demonstration sites installation of demonstration objects and supervision of data logging execution of SME training units

Table 1.1: Division of labour

A total of 238.9 man/months has been invested by the consortium until the official end of the project on 31st of December 2004, of which 214.4 man/months were attributed to the RTD phase and 24.5 man/months to the demonstration phase of the project.

1.4.2 European Observers / Clustering

PVACCEPT was based on two example areas representing Northern and Southern Europe (Germany and Italy). The project results, however, were to be given a wider dimension and dissemination, i.e. they should be applicable within other European countries as well. Only a wider dissemination can bring about the aspired ecological advantage on the one hand, and the opening of new markets for the SMEs on the other hand.

To make sure that the main relevant aspects of transferability to other European regions would be taken into consideration, a monitoring group of “European observers” from different North and South European countries was integrated into the project. The aim was to include not only academic institutions, but also research institutes and SMEs. Despite the limited possibilities of financial compensation, it was possible to “recruit” very qualified observers from four countries:

Austria:

- RESPECT, Institut für Integrativen Tourismus und Entwicklung, Vienna;
- 17&4 Organisationsberatung GmbH, Vienna;

France:

- ARMINES / ENSMP, Centre d'Energétique, Ecole des Mines de Paris, Paris;
- CSTB, Centre Scientifique et Technique du Bâtiment, Paris;

Holland:

- IIUE, The International Institute for the Urban Environment, Delft;
- EDC, European Design Centre, Eindhoven;

Spain:

- AGENER, Agencia de Gestión Energética de la Provincia de Jaén, Jaén;
- SIARQ, Studio Itinerante de Arquitectura, Barcelona.

After having become involved into the project by taking part in general discussions on the scientific and methodological approach, the observers attended two meetings with the consortium and other experts: the PVACCEPT workshop in Berlin in May 2003, where the PV module prototypes and the designs for demonstration objects were presented and discussed, and the PVACCEPT final conference in Berlin in November 2004, where the project results and dissemination tools were discussed and recommendations formulated. Between the two events, they were involved in an acceptability assessment of the PVACCEPT demonstration objects.

The participation of the observers must be regarded as very important and extremely fruitful, especially concerning the transferability and dissemination aspects. This concerns general engagement for the PVACCEPT project, critical feedback on acceptability and transferability, support for the dissemination tools and the distribution of information on the topics of the project, as well as translation of the results into ideas for future cooperation. It can be said that the involvement of European observers in the project has also led to a new network of highly qualified and motivated experts that complement each other in their activities and will certainly make efforts for joint new projects in the future.

It is worth mentioning here that two of the observer institutions – IIUE Delft and EDC Eindhoven – could be won for a participation in the project during EU cluster meetings, in which PVACCEPT members took part in three occasions². This shows that the exchange of experience and mutual support, which are objectives of the EU clustering activities, can indeed manifest quickly on the practical level.

1.4.3 Partners at Local Level

Communal representatives and local key actors in both research regions were involved from the beginning and were essential for the definition of appropriate demonstration objects. Legal contracts were signed to define the obligations of the PVACCEPT consortium as well as of the communes as the future owners of the photovoltaic plants and to assure the quality and functioning of the demonstration plants for a period of at least 10 years.

Despite their early involvement, the procedures and negotiations with the communal authorities turned out to be a much more complex and time-consuming process than expected.

² Cluster meetings in: Luxemburg / 18th of September 2001; Potsdam / 4th – 6th of December 2002; Florence / 1st – 3rd of December 2003

The decision-making processes were influenced to some extent also by political changes and the implied personnel changes on communal level.

One of the main lessons learnt from the project therefore is that adequate timing must be foreseen for the necessary discussion, negotiation and authorization processes (see also chapter 8 – Conclusions and Recommendations).

1.4.4 Other Partners

As mentioned in section 1.1, a change in the consortium composition occurred in 2002. The original consortium member ANTEC Solar, an SME that produces PV modules in thin-film technology on the basis of Cadmium Telluride (CdTe), had to leave the consortium due to insolvency.

As a consequence the design innovations, which had been developed especially for solar modules and production technologies of ANTEC Solar and in close cooperation of UdK and ANTEC Solar, could not be used further in the project. Some of them were adapted to the modules and production technologies of consortium member Würth Solar, which meant a complete re-start of the development process in some aspects. Some other designs had to be given up for further development and application in demonstration sites, but were included e.g. in the Technological Implementation Plan as intermediary results, as they still can be easily produced by ANTEC Solar under its new ownership.

The project leader on behalf of ANTEC Solar was, after the insolvency, subcontracted by the project coordinator UdK as a consultant to maintain the continuity of the discussion and development process. He accompanied the project with his expertise until its end, including the follow-up of production aspects of ANTEC Solar's PV modules.

2 Overview on Results and Deliverables

The following gives a brief summary of the multiple project results and reference to the chapters of this report, where more detailed information related to them can be found.

2.1 Results and Deliverables: Innovative PV Modules

In close cooperation between designers and PV technology producers a total of 12 innovative PV cells, modules, and multifunctional objects have been produced, ready for application, following different development lines:

Innovative aspect: colour

- Printed module, different designs;
- Coloured silicon POWER³ solar cells in grey or gold;
- Printed CIS⁴ module;
- Coloured CTS⁵ module, semitransparent;

Innovative aspect: semitransparency

- Semitransparent CIS modules, stripes or punch hole structure;
- Semitransparent silicon solar cells of varied transparency;

Innovative aspect: surface structure

- Matt module, structured, matted front glass;
- Brilliant green CTS module, structured front glass;

Innovative aspect: multifunctionality

- Cut-to-size CTS module;
- Pergola module, CIS submodules;
- Pergola module, polyacrylic;
- “Solar flags”, integrated LEDs⁶.

Three basically different module types have been applied in the four demonstration objects. Details on the innovative modules and their development process are reported in chapter 3 – Innovative Modules and Development Process.

2.2 Built Demonstration Objects

Demonstration was an aspect of utmost importance for PVACCEPT. In agreement with communes in Liguria / Italy and the South of Germany it was achieved to realize four demonstration objects, equipped with the innovative modules, in 2004:

- A solar information plate with oversized printed modules at *Castello San Giorgio*, a protected monument, which houses a museum, in La Spezia / Italy;

³ Trademark of Sunways for semitransparent solar cell

⁴ Copper Indium DiSelenide (thin-film)

⁵ Cadmium Telluride Selenide

⁶ Light Emitting Diodes

- A solar Schiller-quotation plate at the (protected) historic city wall in Marbach am Neckar / Germany, also using oversized printed modules;
- The installation of 18 self-lighted “solar flags” in the courtyard of the protected monument *Castello Doria* in Porto Venere / Italy;
- Three solar pergolas with semitransparent modules in special size at a river promenade in Bocca di Magra / Ameglia.

All Italian demonstration objects are stand-alone systems, i.e. the produced energy is stored in batteries, while the object in Marbach am Neckar is grid-connected. All demonstration objects are equipped with data logging systems.

The demonstration objects are described in detail in chapter 4.

2.3 Data of Test Phase

Due to the experimental character of the innovative modules applied in the demonstration objects, a technical test phase was regarded as highly important from the beginning. It provided insights into the use and function of the innovative modules. All four demonstration objects have been equipped with a data logging system especially for the purpose of direct transfer of such data to be processed by the partners concerned.

The results of the test phase are included in chapter 4 - Demonstration Objects.

2.4 Energy and Environmental Assessment

A Life Cycle and Environmental Impact Assessment (LCA) was performed of the three kinds of advanced PV technologies, both considering stand-alone, unmounted PV modules and also the finished PVACCEPT demonstration objects.

The adopted multi-criteria approach includes four different assessment methods (namely Material Flow Accounting, Emodied Energy Analysis, CML2⁷ and Emergy Analysis), which complement one another and contribute to providing a complete environmental profile of the analysed systems.

The main deliverable results are:

- Energy Pay-Back Time, a measure of the energetic profitableness of the PV devices under study;
- Material Intensity factors, quantifying for the depletion of natural resources associated to the production and use of the PV devices;
- Global Warming Potential, Acidification Potential and Eco-Toxicity Potential, quantifying the contribution to the three important specific environmental impact categories;
- Emergy Intensity, an indirect collective measure of the total environmental support provided by the biosphere, also taking into account the natural resources needed for the formation of the input stocks.

The results of the LCA study are reported in detail in chapter 5 - Life Cycle and Environmental Impact Assessment.

⁷ Method developed by the Centre of Environmental Science of Leiden University, NL

2.5 Acceptability Study

The acceptability study was divided in two parts, carried out respectively before and after the construction of the demonstration objects.

The first part of the acceptability study (ex-ante) was carried out in 2001. It was based mainly on questionnaires for experts and local people concerning their knowledge on PV, their opinion on aesthetic factors, and their theoretical willingness to accept PV also on old buildings, monuments, and in landscape. Further information was gathered through direct interviews and talks with experts and key persons in workshops held in Göhren / Germany in September 2001 and in Porto Venere / Italy October 2001. This ex-ante study was crucial to prove the several basic theses of PVACCEPT.

Other clear indications were that on the one hand the local population is strongly in favour of solar technologies and would welcome more local promoting activities, on the other hand the level of knowledge of the technology and of existing support programmes is still low (lower in Italy than in Germany). These results encouraged the continuation and optimized the orientation of PVACCEPT research and demonstration activities.

The second part of the acceptability study concentrated on evaluating the effects of the built demonstration objects on acceptability, i.e. on the actual acceptance of the innovative developed PV systems. Questionings e.g. of architects as important intermediary players, as well as questionings of local population and tourists at the demonstration sites, were part of this second (ex-post) study. Additional information from experts and other key persons was gathered at the workshops / SME trainings in Porto Venere / Italy in September 2004 and in Marbach am Neckar / Germany in October 2004.

Both survey target groups confirmed the results of the first part of the study, i.e. in terms of importance of design and of applicability of PV on protected buildings, if the design is appropriate. This was also confirmed by the fact that both architects and tourists / local population showed a (very) high degree of acceptance of the built demonstration objects. Moreover, architects and experts provided valuable information for the applicability and transferability of project results

The results of the acceptability studies are reported in detail in chapter 6.

2.6 Dissemination

For detailed information on the dissemination instruments website, itinerant exhibition, design manual, SME training units and the actual state of dissemination of results, please see chapter 7.

3 Innovative Modules and Development Process

The approach of PVACCEPT was very specific, as cooperations between designers and PV technology producers are not common. Therefore, before describing the final results in terms of innovative PV modules, we want to give some insight into the design and technology development process and share the experience and knowledge gained from the work process.

3.1 Cooperation between Designers and Technology Producers

The development of new PV module design for architectural integration required a close cooperation between the architects / designers and the solar technology producers in the consortium. This kind of cooperation is not very common in this production sector up to now, which meant that both sides needed to learn about each other's different "languages" and approaches. The technology producers had to become more open for design aspects and their importance in general and to discover the marketing potential of design beyond cost considerations; the designers had to learn to deal with the limitations of design ideas, mainly defined by production technologies and processes on the one hand, and development interests of the involved SMEs on the other hand, and to make clear decisions about differing priorities (costs / design) in each individual case. Solutions had to be sought (and were found) that combine a minimum technical effort with a maximum of convincing aesthetics and transferability.

The actual design and technology development process followed the planned form of the cooperation and decision-making, as shown in the figure below⁸. The output were prototypes, which were tested and further developed, until they were ready for application in the demonstration objects that were selected and designed in parallel.

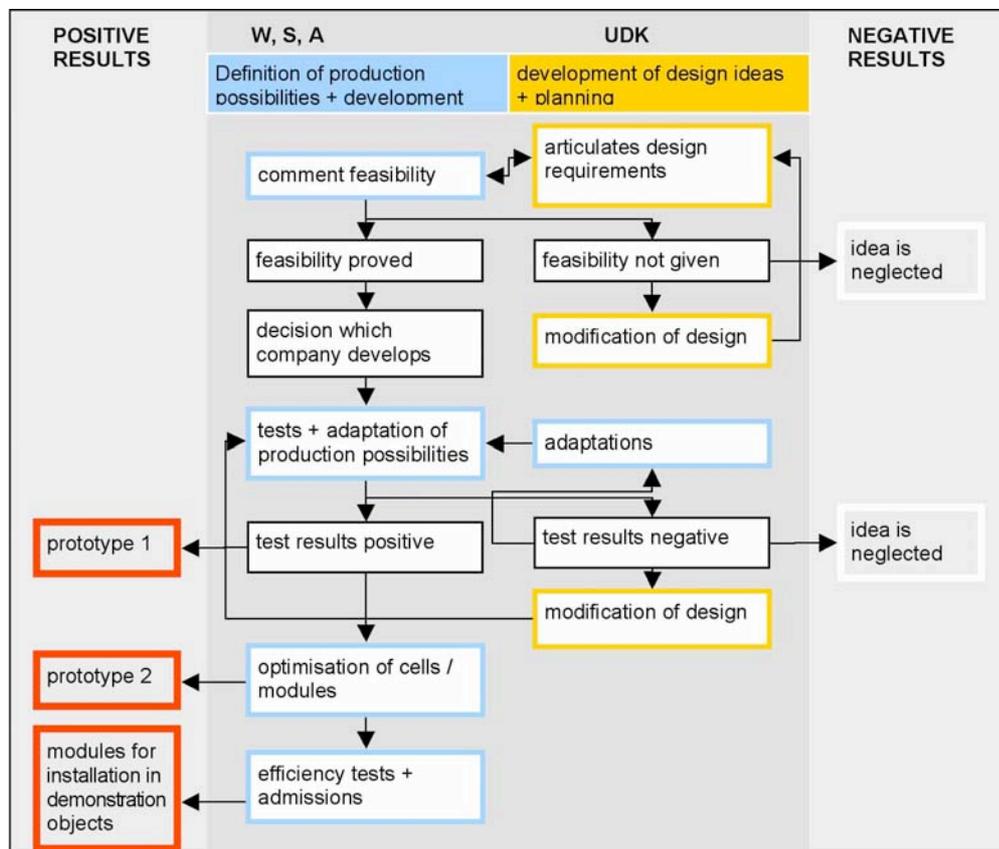


Figure 3.1: Design and technology development process

⁸ W, S, A = SMEs Würth, Sunways, Antec; UdK = Designers

3.2 Development Approach

The designers from UdK followed three different approaches concerning architectural design aspects in parallel:

- The "function type" approach;
 - i. e. PV systems were regarded concerning their functional integration into facade systems, light-weight systems, composite systems, special systems, mobile systems, artificial vegetation elements, artificial topographic elements, stone wall elements;
- The "scenario" approach;
 - i. e. integrated ideas for synergies concerning PV application in architecture, landscape, transport and communication were developed in form of "application scenarios" and visualised;
- The "building element typology" approach;
 - i. e. typical building elements were identified in the two research regions; they were checked concerning their "transferability" respectively their existence in other European regions, and concerning their design potential for PV integration and application.

The most promising systems, ideas, and elements were taken as a basis for the designs of innovative cells and modules to be produced.

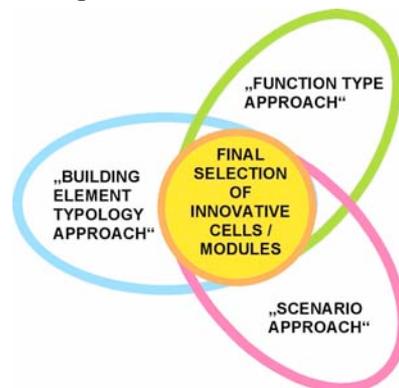


Figure 3.2: Development approaches

As the innovative modules were to be applied in concrete demonstration objects, the search for and selection of appropriate sites was as important and happened in parallel. It was influenced by a variety of factors on different levels: the complex set of selection criteria, which had been chosen, the requirement of representing innovation, the limitations defined by the SMEs in the consortium, and the political and economic conditions of the involved communes (see also in more detail in chapter 4 – Demonstration Objects).

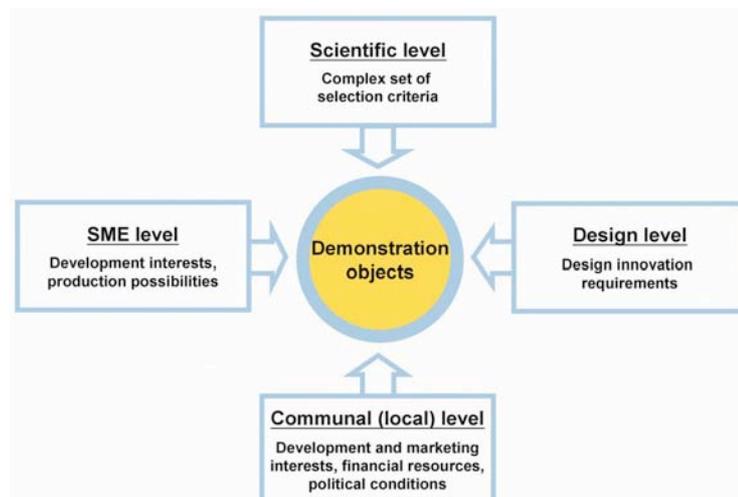


Figure 3.3 Influences on demonstration object selection and module development

3.3 Innovative Module Types

The innovative modules, which were finally developed and which are presented in section 3.5 of this chapter, can be grouped according different innovation aspects or “development lines”:

Innovative aspect: colour

- Printed module, CIS, printed front glass, different designs;
- Coloured silicon POWER solar cells in grey or gold, for custom sized modules;
- Printed CIS module, full size, by laminating printed 3rd glass onto finished module;
- Coloured module, semitransparency by wider scribing lines and wider border region, using coloured cover glass, full size CTS module (60 x 120 cm);

Innovative aspect: semitransparency

- Semitransparent CIS modules, stripes or punch hole structure, clear or coloured glass, full size;
- Semitransparent silicon POWER solar cells of varied transparency, silicon-based, custom-sized;

Innovative aspect: surface structure

- Matt module, structured, matted front glass, custom-sized, silicon cell-based;
- Brilliant green module, structured front glass laminated as third glass onto finished standard CTS module, full size;

Innovative aspect: multifunctionality

- Cut-to-size module; CTS submodule, cut from standard module, laminated onto large glass; two types: cut-to-size and shading module;
- Pergola module, custom sized module 30 x 240 cm², made by cutting of standard CIS module to submodules, laminated onto 30 x 240 cm² glass of 1 cm thickness (plus partial ablation if transparency is required);
- Pergola module, custom-sized polyacrylic module, silicon cell-based;
- “Solar flags”, curved custom-sized polyacrylic module, silicon cell-based; integrated LEDs for illumination.

3.4 Development Process

Before presenting the final results (information on innovative modules), we want to describe the preconditions in terms of production possibilities and development interests on side of the SMEs, from which we started, and the relevant aspects of the development process. With regard to the latter, we summarize here the main experiences without repeating the data of the different types of technical tests (measuring of electrical output, stability tests, etc.), through which the prototype modules had to pass. These were described in detail in the intermediary reports and would exceed the scope of this final report.

3.4.1 Würth Solar

3.4.1.1 Preconditions

The production facility of Würth Solar is divided into clean room thin-film processes (sputtering, evaporation, patterning) and the finishing processes (like contacting and encapsulation of the modules). The standard processes for depositing the semiconducting and metal films and the patterning of these films for series interconnection of the single cells are described in detail in publications of Würth Solar. Differences and modifications from standard module fabrication for the specially designed modules like the ones used in PVACCEPT include only changed procedures and materials in the finishing processes.

3.4.1.2 Development Interests and Innovative Developments

Würth Solar focussed within PVACCEPT on:

- Modifications of semitransparent CIS modules;
- Implementation of modules carrying a printed front glass.

The experimental production led to the results and experiences described below.

Semitransparent modules

Semitransparent structures were improved to reach a higher flexibility in design. Subsequently several prototypes combined with an insulation glass and overhead construction prototypes were manufactured. The technology for the production of the semitransparent structures in the CIS layers was developed by Würth Solar partly before and partly in parallel with the PVACCEPT project.

The processing steps aiming at achieving semitransparency were optimized regarding quality and variability of designs. Semitransparent modules are achieved by selective ablation of cell material in a structured way. Semitransparency thus means variable ratios of “open” to “closed” areas in the film structure.

It is now possible to create different transparent symbols and patterns in the layers of the CIS modules. In the following we present the main production aspects of the semitransparent modules.

Semitransparent CIS insulation glass element

A combination of a semitransparent CIS module with a (double glazing) insulation glass was manufactured. Insulated glass is mainly used in buildings for thermal and acoustical improvement. By connecting semitransparent photovoltaic modules and insulation glass, a new product was created as a device for high-quality facade or roof constructions.

Five semitransparent CIS laminates (similar to standard double-glass modules) as test modules were produced and delivered to a subcontractor (*Glaswerke Arnold*), for processing them further to achieve an insulation glass photovoltaic module by connecting these modules with double-glass panels.

First tests with one module showed problems (leakage), caused by disharmony between the lamination-foil of the CIS module and the material of the edge insulation needed for the connection of the two entities. *Glaswerke Arnold* continued the experiments to achieve

prototype modules, using modified materials for edge insulation. The achieved results were satisfying.

Würth Solar is actually applying various technologies to produce transparent stripes, punch-holes and other designs. The applied techniques are proprietary of Würth Solar and have been qualified independently and already before the design developments in PVACCEPT started. After completion of the separate and additional film-removing step the modules can be processed like standard modules in the fabrication line.

One aim concerning the development and production of the innovative modules was to change as few processing steps as possible in order to minimize additional costs. This was achieved by external fabrication steps.

The aim of the integration of printed front glass into the CIS modules was to reach a better harmony with the environment or to create exclusive signs (information or advertisement plates).

Modules with printed front glass

The UdK designers had suggested to use a printed dot structure on the front surface of modules to change their colour with minimum means (the idea has been protected as an “utility model”). The visual appearance of such modules thus can be adapted better to the local environment; any pattern and even the generation of information (text, logos etc.) in printed or graphical form is possible.

A prototype of a CIS module with a printed front glass (detail of the information plate designed for La Spezia) was manufactured. The output power of this module was measured, using a solar simulator, before and after the lamination of the front glass to determine the influence of the shadowing printed dots.

After subtraction of absorption and reflection of a standard transparent front glass, the influence of printing could be calculated. The experiments showed, as expected, that the influence of shadowing the cells by the printed design is a linear function: A 1 % additional printed area will reduce the generated current (and power) by 1 %, if the printing area is homogeneously spread over all series-connected cells. This means that a very meticulous design of the printed patterns is required.

A loss in performance has to be traded-in for these new aspects and advantages, which will be kept at 20 % or less depending on the percentage of the surface covered by print. This has led to new PV modules, which can be used e.g. as signs and marketing elements or to reach an improved integration into, among others, monument protected structures such as castle walls etc.

Würth Solar cooperated in this aspect with *Glas Sprinz*, a subcontractor, which is specialized in printing multicolour designs on glass. The colours are based on ceramic pigments and must be heated at temperatures of about 600° C to achieve good adhesion. This print has high weather-resistance, which is very important, and can show intensive colours.

To get best results regarding efficiency and power output, all series-connected cells have to be covered in the same ratio of dot area to total area. Because the printed area is lost, i.e. ineffective for producing electricity, the aim is to reduce the printed area to a minimum. Therefore all prototypes were printed with designs, which were transformed into a dot-screen (diameter of dots: ~ 1 mm, ratio of printing: 10 – 25 %). The look of the final design is strongly influenced by the background, which consists of the black colour of the absorber layer, i.e. the actual module. This means in practice that very bright colours have to be used for the printing, since the black background reduces the brightness of the total colour appearance.

The front glass can be printed on either surface. Printing on the free (weather-exposed) side may lead on the long term to reduction of stability and intensity of the colours by dirt and corrosion, which has to be tested on the demonstration objects, where this type of module has been applied. Printing the (inner) laminate-side has the negative effect that the outer (not printed) surface of the module will show reflections, which disturb the optical appearance of the printed pattern. The prototypes are printed on the weather-exposed side.

The printed modules used in La Spezia and Marbach am Neckar were produced completely by Würth Solar. On the standard substrate glass a specially printed front glass was laminated. The front glass was manufactured and delivered by subcontractor *Glas Sprinz*, that has a high experience in printing glass, on the demand of Würth Solar and according to the design of UdK.

Some iterations were introduced mainly regarding design to adjust the computer graphics to the visual appearance of the printed product. Several samples and tests had to be made to gain sufficient experience. The main problem was the naturally black colour of the CIS modules, which is the background of the design and required adjustment and optimization of all designs in this aspect.

For the lamination of front glasses in special dimensions (1200 mm x 1200 mm x 10 mm), as used for the demonstration installations, a modified process for the lamination with new parameters had to be developed. After its implementation, the lamination of the modules was made successfully without additional problems.

One aspect, which is important for the future production of this type of module is that all specially designed modules in smaller but relevant numbers have to be carefully inserted into the production work flow, and the workers have to be introduced and trained in all new production steps, because one failure could cancel the whole production run.

In order to reduce the reflectivity of the module front glass, different small prototypes of CIS modules with variations of the front glass were produced and tested with a sun-simulator: slightly structured glass (front and backside), another glass with prisms on the backside and slightly structured on the front side, and a module with matted, sandblasted front glass. This last one was the most interesting experiment, because irregular patterns can be produced, which allow adaptation to many natural surfaces. The described variations of the front glass did not show a significant effect for the performance of the modules, i.e. they can be applied without energy efficiency losses.

3.4.1.3 Business Aspects / Implementation of the Innovative Products

These new products, being only partially standardized, are customer designed and generally manufactured in small quantities. Therefore fabrication costs are higher. In the case of printed modules, maybe only a single piece with special design might be needed.

The high weight and the big dimensions of the modules deployed in the demonstration objects required several special solutions in handling and transport, which raised the production costs in these cases, too. However, oversized modules are not necessarily needed to realize a design.

The advantages of the innovative modules developed by PVACCEPT and their exhibition in public areas are a favourable opportunity to open new market niches for PV modules in general and enhance the acceptance of PV installations. Würth Solar is not expecting a very big market for these modules very soon due to the higher fabrication costs. Nevertheless their availability enlarges the product portfolio of the company by high value products.

3.4.2 Sunways AG

3.4.2.1 Preconditions

The innovative developments by Sunways AG in PVACCEPT were based on modifications / adaptations of its semitransparent POWER solar cell production process.

3.4.2.2 Development Interests

Sunways focussed within PVACCEPT on:

- Developing and manufacturing of innovative silicon solar cells;
- Developing and manufacturing of adapted PV modules in cooperation with different subcontractors.

The complete process flows for the fabrication of standard silicon solar cells as well as for the semitransparent POWER solar cells (additional production steps) used in PVACCEPT are shown in the following list:

- Mechanical grooving front (additional step for semitransparent POWER cells);
- Saw damage removal;
- POCL diffusion⁹;
- Plasma etching¹⁰;
- LP/PECVD SiNx deposition¹¹;
- Mechanical grooving rear (additional step for semitransparent POWER cells);
- Screen printing of front and rear contact;
- Co-firing of front and rear contacts in belt furnace.

The tested developments are described in the following.

Facade modules

Several demonstration modules for facade applications were manufactured in collaboration with a subcontractor. The composition of the module with POWER solar cells (different sizes are possible) consists of:

- 5 mm *PLANIDUR*[®] *Diamant*¹²;
- Sunways POWER solar cell;
- 2 mm cast resin;
- 10 mm *PLANIDUR*[®] *PLX*¹³.

The rear side of the glass is equipped with *Point-XS*¹⁴ anchors. This allows an almost not visible mounting of the modules. Semitransparent grey solar cells could be combined also with white acrylic back sheets to thus be applied even to white or very light coloured facades.

⁹ Phosphorusoxychloride; diffusion process to introduce Phosphor into Silicon

¹⁰ Edge isolation by plasma discharge

¹¹ Silicon nitride deposited by low pressure plasma enhanced chemical vapour deposition

¹² Trademark of special glass

¹³ Trademark of special glass

¹⁴ Trademark of *St. Gobain Glas*: minimized glass-fixing system

The semitransparent POWER solar cell was further developed with respect to the requirements of the planned demonstration sites. The goal was to reach a high adaptability to the conditions of the different applications. Several experiments were conducted to determine the possible colours of the initial POWER solar cell as well as the encapsulated device. The colour of the solar cell is determined by the thickness of a dielectric layer on top of the silicon. This dielectric layer serves as antireflection coating, i.e. it reduces the reflection of the light thereby enhancing the power output. In the case of the investigated POWER cells, the dielectric layer consists of silicon nitride, which is deposited by means of Low Pressure Chemical Vapour Deposition (LPCVD). In the experiments the processing time was varied, which led to differences in the thickness of the SiN_x ¹⁵ between 15 and 80 nm. The optimum thickness with respect to the solar cell efficiency of standard solar cells corresponds to 75 to 80 nm, in case of reduced thickness more light is reflected from the front surface.

In order to achieve an optimum adjustment of the colour to the local environment, the produced solar cells with different colours were used for manufacturing demonstration modules. The encapsulating material reduces the reflection of the sunlight, and due to the difference in the index of refraction it also leads to the changes in colour.

After deciding for an optimum colour (light grey) regarding the integration into the local environment of the demonstration objects under discussion, the process parameters were optimized with respect to the reduced thickness of the silicon nitride layer, i.e. the firing temperatures of the belt furnace.

Matt module

The composition of the modules with opaque Sunways PLUS¹⁶ solar cells is:

- 4 mm *ALBARINO*[®] *S*¹⁷;
- Sunways PLUS-solar cell;
- 2 mm cast resin;
- 10 mm *PLANIDUR*[®] *PLX*.

Particularly in buildings, which are under monument protection, reflective surfaces are often regarded as disturbing. Reflecting surfaces are observed under the angle of specular reflection in standard modules. In order to reduce the reflectivity of the module glass, a specially textured front glass, *ALBARINO*[®] *S*, was used.

Multifunctional self-lighted object “solar flag”

UdK designed a slightly curved, self-lighted PV module for multifunctional applications (the idea has been protected as “utility model”). This so-called “solar flag” consists of 15 dark-grey POWER solar cells, embedded in polyacrylic glass, combined with a light conducting PMMA¹⁸ plate, which is illuminated by integrated LEDs.

Subcontractor *Sunovation GmbH* manufactured a first prototype of the “solar flag” according to the specifications given by UdK. This prototype did in several points not meet the ideas of the UdK designers. Therefore a more detailed specification was generated at UdK, and a new prototype was manufactured. This procedure had to be passed through several times. The difficulty of this process of development was to balance the aesthetic requirements with the technical and economical feasibility.

¹⁵ Silicon nitrid

¹⁶ Opaque multi-crystalline solar cell

¹⁷ Trademark of special glass

¹⁸ Polymethylmethacrylat (also referred to as “Plexiglass”)

The main technical challenges for the production of the “solar flags” were:

- Bending the modules;
- Fixing the electrical connections (a standard junction box could not be applied because of aesthetic reasons);
- Sealing the space between the PV module and the LED-module (side plate);
- Connecting two modules without mechanical stresses;
- Offering different possibilities for mounting (hanging, fixed, flexible).

The result of the efforts and the solution of these problems is a highly aesthetic multifunctional PV module with integrated LED illumination system.

Solar pergola module

The “solar pergola” is equipped with 78 dark-blue POWER solar cells. The estimated output power is approximately 60 Watt¹⁹.

The main challenges for the production of the solar pergola module were:

- Connecting several PMMA parts;
- Fixing the electrical connections (a junction box would disturb the light and transparent appearance of the module);
- The big dimensions demand expensive fixtures.

During the production of the first prototype, it was decided to better realize the demonstration object (pergolas in Bocca di Magra) with CIS modules from Würth Solar, mainly for cost reasons (the pergola module of Sunways was more costly through a high amount of manual labour involved). Therefore no further optimisation of the prototype was carried out.

3.4.2.3 Business Aspects / Implementation of the Innovative Products

The newly developed products represent only a small part of Sunways’ production capacity, but are indeed very important in the company’s strategy. On the one hand these niche products can help to enhance the acceptability of PV in general, and on the other hand the additional functions (i.e. the lighting of the “solar flag”) will raise the value of the PV modules.

In the next years the global production capacities for PV modules will rapidly increase, and therewith the competition in the PV market will get more severe. The future market will be dominated by large-scale production facilities with low production costs per W_p ²⁰, for standard PV modules, but with no flexibility regarding customers’ specific demands. Sunways AG as an SME must compensate the slightly higher production costs by higher electrical and especially aesthetic quality, and by an additional value of the PV modules. This additional value can be given by:

- PV as shading system;
- PV combined with energy effective illumination;
- PV as design elements (status symbol);
- PV as building element (e.g. instead of roof tiles, but not additional);
- PV as facade element (e.g. with thermo insulation).

For these reasons knowledge about the demands of the markets, i.e. in the architectural sector, and the development of innovative, multifunctional products are key factors to increase the future competitiveness of Sunways AG.

¹⁹ Electrical power; Power is the rate at which energy is delivered

²⁰ “Peak Watt” = watt produced by a solar module under maximum solar irradiation

3.4.3 ANTEC Solar

3.4.3.1 Preconditions

Due to the complexity of the manufacturing process and the required continuous operation of ANTEC Solar's production plant, no strong modifications could be made, i.e. all custom-sized modules had to be derived from the standard module of 60 cm x 120 cm size by cutting it to smaller sizes. The earliest moment at which a module can be taken out of the line is at the scribing station at the end of the deposition line.

3.4.3.2 Development interests

ANTEC Solar focussed within PVACCEPT on:

- Cut-to-size modules, based on two module sizes (e.g. 30 cm x 50 cm, 30 cm x 100 cm) to be mounted on the cut-to-size carrier glass, giving 10 cm cutting space on each side; application e.g. for window shutters;
- Shading modules based on 20 cm x 120 cm pieces cut from standard ATF modules, which will have 40 cm x 120 cm finished size; smaller modules of this type were foreseen e.g. for window shutters and façade integration;
- Modules with printed dot patterns (transmission 70 to 90 %); main application for adaptation to brick walls etc.

Possible modifications of ANTEC Solar's modules can be characterized into four classes as follows:

- Modifications during manufacture in the deposition line (scribing);
- Completed modules cut to smaller size, mounting on carrier;
- Modification of the substrate surface (after deposition and lamination), screen-printing, painting etc.;
- Modification of cover glass (coloration).

In the following we list the experiences made with the respective test modules.

Printed CIS module

ANTEC Solar was to study five modifications of screen-printing of a dot matrix onto the front side of a module in an orange / yellow colour, intending to assimilate the module to the stone or brick surface of a building. The printing degrees studied were 10 %, 30 % and 50 %.

Coloured module

A module was laminated by using coloured glass, which is commercially available. The colour shows on the front as coloured boundary, on the back homogeneously as one colour. This can be employed for modules with wider scribing lines, so that, if seen from the back, coloured lines of light appear.

Brilliant green module / modules with structured front glass

A test module was produced by using a different front glass, i.e. a prismatic structured glass. The surprising result was that it – like all other tested standard modules with structured front glasses as a third pane – had very good efficiency; there was only a marginal loss of 2.5 % for the module with antireflection glass and of 3.4 % for the module with prismatic glass as a third pane.

Cut-to-size module

Another idea was realized with the cut-to-size module. A smaller module was laminated to a larger sheet of glass, allowing cutting to size on the building site by the construction workers to adapt modules e.g. to window shutters of different sizes. The boundary of the glass was meant to be painted with a colour as close as possible to the appearance of the module.

Shading module

A similar system was developed, in which a module is attached to a sheet of clear glass, which can be used for shading systems in buildings.

3.4.3.3 Business Aspects / Implementation of the Innovative Products

Unfortunately ANTEC Solar could not stay as a partner in the PVACCEPT project, as it went insolvent in summer 2002. The significant new ideas, which had been generated up to then in cooperation between ANTEC Solar and the UdK designers, might still be used in the future. The company was sold in 2002, and the production was again taken up by the new owner. Due to the focus on standard production, however, there was no willingness of the new owner to cooperate in research and innovative development in the near future.

In any case at least a continuation of the work of ANTEC Solar for PVACCEPT on the theoretical level was provided by the fact that the former project leader on behalf of ANTEC Solar was subcontracted as a consultant by the coordinator UdK Berlin to guarantee that these intermediary results would not be lost. The intermediary results have, for the same reason, also been included in the Technological Implementation Plan and other relevant documents of the project.

3.5 Innovative Modules

In the following we present the main types of innovative modules developed by PVACCEPT in a systematized overview, indicating their main features, production aspects, use in the project etc. and showing some samples of visualized or built application.

The “classification” types are project internal classifications and help to find e.g. cost data with regard to the individual modules in section 3.6 of this chapter.

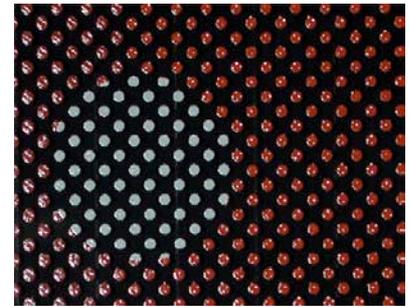
Module type: *Printed module*

CIS, printed front glass

Application: Architectural, landscape and public space integration; simulating structures etc., carrying information

Manufacturer: Würth Solar

Classification: W1

**Issue****Status of technology****Main positive features****Main negative features****Industrialisation, production aspects****Development requirement****BOS²¹-aspects****Cost / pricing****Power output****Lifetime, stability****Acceptance issues****Use in PVACCEPT****Built demonstration object****Implementation plan****Comments**

prototype production for PVACCEPT

close relation to standard modules, flexible design

adhesion of dirt may be a problem, reduced power output

printed cover glass uses standard technology

small

similar to standard module

additional cost by glass printing, depending on production volume

reduced by percentage of print-covered surface (-20 %)

similar to standard module

positive

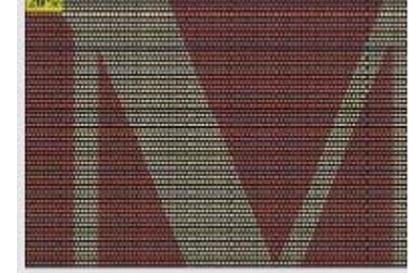
designs for "Marstall" in Putbus, castle in Tornow,

natural stone walls in La Spezia and Porto Venere

in La Spezia and in Marbach am Neckar

Implementation already started, by exhibition of samples at

Paris conference in June 2004



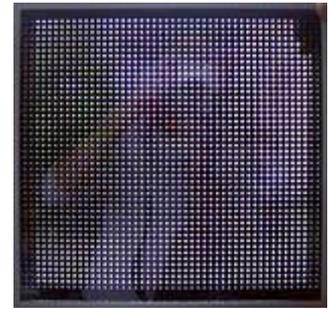
²¹ BOS = balance of system cost (mounting, connection, power management)

Module type: *Semitransparent module*
 stripes or punch-hole structure, clear or coloured glass,
 full size

Application: Architectural and public space integration

Manufacturer: Würth Solar

Classification: W2



Issue

Status of technology

Main positive features

Main negative features

Industrialisation, production aspects

Development requirement

BOS-aspects

Cost / pricing

Power output

Lifetime, stability

Acceptance issues

Use in PVACCEPT

Built demonstration object

Implementation plan

Comments

prototype production, developed basically before project start
 close relation to standard modules, laser ablation is proved
 technology

additional production step

standard technology

incorporation into production line must be engineered

similar to standard module

increased cost by selective ablation of semiconductor and
 metal films

output reduced by percentage of transparency

similar to standard module

positive

designs for "House of the Guest" in Göhren and pavilion in
 Sarzana, demonstration object in Bocca di Magra

in Bocca di Magra

on customer request, small exclusive market in the near
 future



Module type: *Pergola module*

Custom-sized module 30 cm x 240 cm,
made by cutting of standard CIS module to sub-modules,
laminated onto 30 cm x 240 cm glass of 1 cm thickness,
(extra fabrication step for achieving transparency is required)

Application: Shading module for pergola etc.

Manufacturer: Würth Solar

Classification: W3

**Issue****Status of technology****Main positive features****Main negative features****Industrialisation, production aspects****Development requirement****BOS-aspects****Cost / pricing****Power output****Lifetime, stability****Acceptance issues****Use in PVACCEPT****Built demonstration object****Implementation plan****Comments**

prototype production for PVACCEPT, basic idea and proof of principle developed before start of project

based on standard modules

standard modules must be cut to sub-modules

module of 240 cm length must be laminated

incorporation into production line must be engineered

similar to standard module

increased cost per W_p by additional process steps

output reduced by percentage of transparency

no problems expected

very good, but increased price must be considered

design for pergolas at several locations

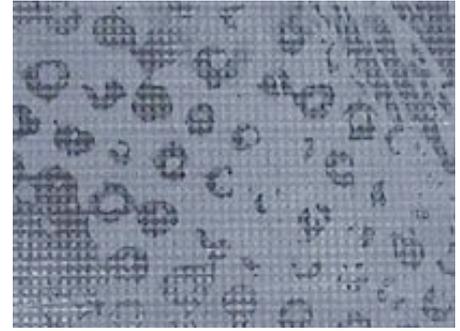
three pergolas in Bocca di Magra

on customer request, small exclusive market in the near future



Module type: *Matt module*

matted front glass, full size, CIS

Application: Architectural and landscape integration**Manufacturer:** Würth Solar**Classification:** W4**Issue****Status of technology****Main positive features****Main negative features****Industrialisation, production aspects****Development requirement****BOS-aspects****Cost / pricing****Power output****Lifetime, stability****Acceptance issues****Use in PVACCEPT****Built demonstration object****Implementation plan****Comments**

experimental production for PVACCEPT

close relation to standard modules

adhesion of dirt may be a problem

uses standard technology, surface matted by sandblasting or etching, irregular patterns can be produced

small

similar to standard module

low extra cost only by special surface of glass

no loss compared to standard modules

similar to standard module

positive

no

no

see TIP²²

²² “Technological Implementation Plan”, part of final report

Module type: "Solar flag"

Curved custom-sized polyacrylic module, silicon cell-based; integrated LEDs for illumination

Application: Public space and landscape integration (solar tree), for permanent and temporary use, any addition in number possible

Manufacturer: Sunways

Classification: S1

**Issue**

Status of technology

Main positive features

Main negative features

Industrialisation, production aspects

Development requirement

BOS-aspects

Cost / pricing

Power output

Lifetime, stability

Acceptance issues

Use in PVACCEPT

Built demonstration object

Implementation plan

Comments

pilot production for PVACCEPT

attractive appearance, elegant high-tech image, can be used for attractive installations (e.g. "solar tree")

high degree of manual work

production uses standard equipment

production technology for large numbers

standard

expensive, due to small series, manual work involved, and additional function (illumination)

rather low, ca. 15 W, but sufficient for self-illumination

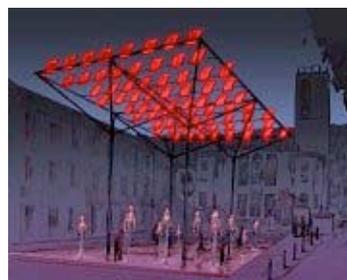
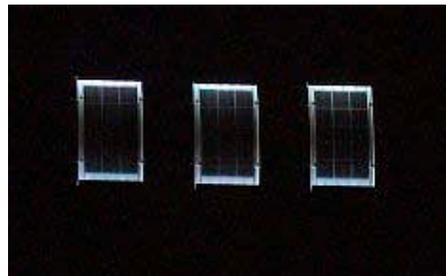
similar to production type of acrylic modules (S4)

positive

designs for different applications and mounting methods; e. g. solar tree in Putbus, installations in Lerici, Lauterbach etc.

demonstration object in Porto Venere

licensing negotiations with producer (Sunovation. = Sunways' subcontractor)

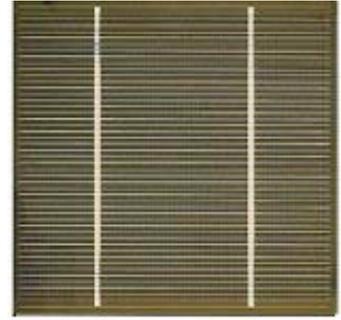


Module type: *Coloured Si module*
coloured silicon cells, in grey or gold; custom-sized modules

Application: Architectural integration, facade integration

Manufacturer: Sunways

Classification: S2



Issue

Status of technology

Main positive features

Main negative features

Industrialisation, production aspects

Development requirement

BOS-aspects

Cost / pricing

Power output

Lifetime, stability

Acceptance issues

Use in PVACCEPT

Built demonstration object

Implementation plan

Comments

experimental production for PVACCEPT

coloured standard modules using typified cells

extra costs

module technology is standard, cell technology not yet 100 % mature

no, small

similar to standard modules

extra cost for coloured cells

similar to standard modules

similar to standard modules

positive

designs for architectural integration in Putbus

no

see TIP



Module type: *Semitransparent Si module*

Cells („Power Cell“) of varied transparency in structure and percentage, silicon cell based, custom-sized modules



Application: Architectural integration

Manufacturer: Sunways

Classification: S3

Issue

Status of technology

Main positive features

Main negative features

Industrialisation, production aspects

Development requirement

BOS-aspects

Cost / pricing

Power output

Lifetime, stability

Acceptance issues

Use in PVACCEPT

Built demonstration object

Implementation plan

Comments

experimental production for PVACCEPT

transparency

loss of output by transparency , cost

standard module technology, cells are new

no

similar to standard cells and modules

higher cost due to additional processing steps

output reduced by percentage of transparency

similar to standard cells and modules

positive

designs for architectural integration

no

see TIP



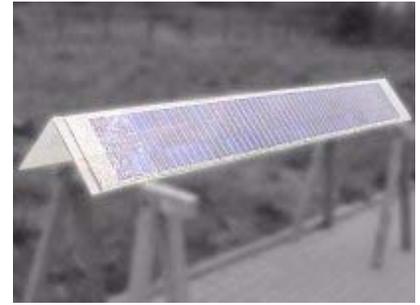
Module type: *Pergola module*

Custom-sized polyacrylic module, silicon cell-based

Application: Architectural and public space integration as building element, for pergolas, special roofing (shed-roof) and special lighting elements

Manufacturer: Sunways

Classification:S4

**Issue**

Status of technology

Main positive features

Main negative features

Industrialisation, production aspects

Development requirement

BOS-aspects

Cost / pricing

Power output

Lifetime, stability

Acceptance issues

Use in PVACCEPT

Built demonstration object

Implementation plan

Comments

pilot production for PVACCEPT

attractive appearance, 3-dimensional structure

gluing of acrylic difficult (expensive)

length of up to 3 meters requires special equipment,

difficult joints (gluing) related with higher costs

production technology for large numbers

standard

very expensive in pilot production due to manual work involved

standard

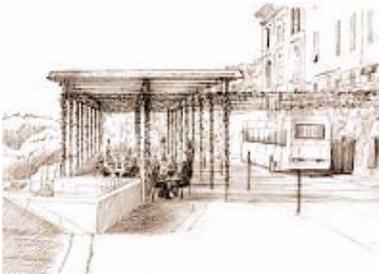
similar to other acrylic modules

very good

design for pergolas and street furniture

no

see TIP



Module type: *Matt module*
Matted, structured front glass

Application: Architectural and landscape integration

Manufacturer: Sunways

Classification: S5



Issue

Status of technology

Main positive features

Main negative features

Industrialisation, production aspects

Development requirement

BOS-aspects

Cost / pricing

Power output

Lifetime, stability

Acceptance issues

Use in PVACCEPT

Built demonstration object

Implementation plan

Comments

pilot production for PVACCEPT

attractive, non-reflective appearance

adhesion of dirt may be a problem

uses standard technology

no

standard

slightly higher costs for the structured glass

similar to standard module

similar to standard module

positive

designs for different applications

no

see TIP



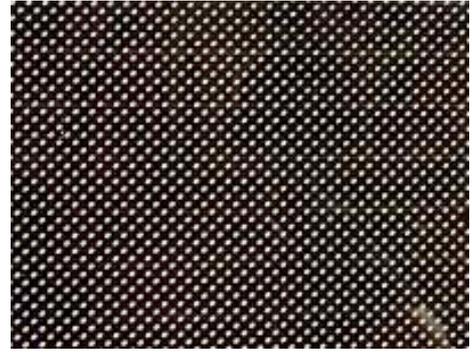
Module type: *Printed module*

full size, made by laminating printed third glass onto finished module

Application: Architectural, landscape and public space integration

Manufacturer: ANTEC

Classification: A1

**Issue**

Status of technology

Main positive features

Main negative features

Industrialisation, production aspects

Development requirement

BOS-aspects

Cost / pricing

Power output

Lifetime, stability

Acceptance issues

Use in PVACCEPT

Built demonstration object

Implementation plan

Comments

pilot production for PVACCEPT

attractive appearance, flexible design

increased weight by third glass due to requirements of printing technology

standard technology plus additional lamination step

production engineering

standard

increased by additional production steps

reduced by percentage of print covered surface

similar to standard modules

very good

designs for retention walls in Lerici, Bolano, Porto Venere

no

no (change of owner of ANTEC)



Module type: *Brilliant green module*

structured front glass laminated as third glass onto finished standard CTS module, full size

Application: Architectural and landscape integration

Manufacturer: ANTEC Solar

Classification: A2

**Issue**

Status of technology

Main positive features

Main negative features

Industrialisation, production aspects

Development requirement

BOS-aspects

Cost / pricing

Power output

Lifetime, stability

Acceptance issues

Use in PVACCEPT

Built demonstration object

Implementation plan

Comments

pilot production for PVACCEPT

attractive appearance, no specular reflection

increased weight by third glass, dirt may accumulate on "rough" surface

use of second glass with structure is not tested

yes, if structured glass is used as substrate

similar to standard modules

increased by additional production steps

no loss compared to standard modules

similar to standard modules

very good

designs for "hedges" and other elements for landscape integration

no

no (change of owner of ANTEC)



Module type: *Cut-to-size module*

CTS submodule, cut from standard module, laminated onto large glass; two types: „cut-to-size“ and shading module

Application: Architectural integration

Manufacturer: ANTEC Solar

Classification: A3

**Issue**

Status of technology

Main positive features

Main negative features

Industrialisation, production aspects

Development requirement

BOS-aspects

Cost / pricing

Power output

Lifetime, stability

Acceptance issues

Use in PVACCEPT

Built demonstration object

Implementation plan

Comments

experimental production for PVACCEPT

quasi-standard product for different areas (flexibility), coloured glass may be used

modules have uncovered boundaries

cutting of standard modules required, lamination step between glasses required

for lamination and cutting of sub-sized modules

mounting requires special solutions

increased by new production steps

reduced, depending on width of boundary

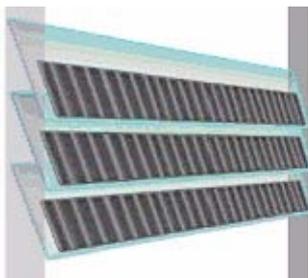
similar to standard modules

good, as areas can be covered which are not yet accessible by standard modules (window shutters etc.)

designs for lamella objects

no

no (change of owner of ANTEC)



Module type: *Coloured semitransparent module*
 semitransparency by wider scribing lines and wider border region, using coloured cover glass, full size module (60 x 120 cm)

Application: Architectural integration

Manufacturer: ANTEC Solar

Classification: A4



Issue	Comments
Status of technology	experimental production for PVACCEPT
Main positive features	attractive effects by light and transmission
Main negative features	technology for wider stripes not yet tested
Industrialisation, production aspects	see main negative features
Development requirement	"wide" scribing lines
BOS-aspects	similar to standard modules
Cost / pricing	extra scribing technology increases cost, coloured glass is more expensive
Power output	reduced, depending on width of scribing lines and transmission of coloured front glass
Lifetime, stability	similar to standard modules
Acceptance issues	good
Use in PVACCEPT	design for "House of the Guest" in Göhren (alternative to W2 module type)
Built demonstration object	no
Implementation plan	no (change of owner of ANTEC)



3.6 Business Aspects

The innovative modules designed and produced by PVACCEPT are characterized by a significant upgrading of their value by extra (cost-relevant) production steps in comparison to standard modules. This will mean an increased price. The new modules will also need a special marketing effort, in order to interest potential users. PVACCEPT has, by establishing the demonstration objects, paved the way in a very efficient manner. Nevertheless implementation of the new technologies and market entry needs a well elaborated plan for the industrial partners. The first step in planning has been incorporated in the “Technological Implementation Plan” (TIP). In any case the new modules will address a special clientele, i. e. institutions / individuals interested in demonstrating their taste and consideration of the visual appearance of their PV installation.

The industrial partners consider the new know-how acquired during the course of the project to be a positive asset, which will lead to an improved competitive position in the near future. It has to be taken into account, nevertheless, that the present PV market is characterized by a “boom”-situation, i.e. a “seller market” in contrast to the depressed general industrial condition in Europe. Industry is using this situation to sell standard modules to full production capacity in order to generate reserves for the future. This business situation will slow down the planned technology exploitation of the project results until the new modules can be manufactured, certified and sold.

The following table gives a rough ad hoc estimate for prices of new modules as a help for orientation, when considering the future market. The most important figure for photovoltaic application is the price per W_p . A price of 2.3 €/W_p presently is demanded for thin-film CTS modules by the new ANTEC Solar Energy AG and also for amorphous silicon modules. It is assumed that CIS modules will be priced similarly once production has started.

Additional cost for thin-film modules can more easily be calculated, as one large scale production plant is running. New modules based on silicon technology, such as solar flags and pergola modules, can only be calculated for special cases, as a significant part of manual work is involved. In addition printed and semitransparent modules will have reduced efficiencies, which have also been added and taken into the calculation. It is expected that such modules easily will surpass the 5 €/W_p mark. This means they will be used in special applications, such as the demonstration object in Porto Venere, where a special target is given, such as a double benefit by generation / illumination.

Module Type	Type	η	Price for standard module	Price per W_p	Additional Items	Price for additional items per module	Price per module	η	Price per W_p
Printed CIS (60 cm x 120cm)	W1	10 %	160 €	2.30 €	Printing of 60 cm x 120 cm glass	100 €	260 €	8 %	4.60 €
Printed CTS (60 cm x 120 cm)	A1	7 %	115 €	2.30 €	Extra glass sheet + printing + lamination	150 €	265 €	5.6 %	6.40 €
Brilliant CTS	A2	7 %	115 €	2.30 €	Structured glass instead of plane glass + extra handling	50 €	165 €	7 %	3.30 €
Coloured CIS	(W2)	10 %	160 €	2.30 €	Substitute standard glass by coloured glass	30 €	190 €	9 %	3.00 €

Module Type	Type	η	Price for standard module	Price per W_p	Additional Items	Price for additional items per module	Price per module	η	Price per W_p
Semitransparent CIS	W2	10 %	160 €	2.30 €	Make ablation pattern in cell structures	80 €	240 €	8 %	4.10 €
Coloured CTS	A4	7 %	115 €	2.30 €	Substitute standard glass by coloured glass	30 €	145 €	6 %	3.20 €
Coloured semitransparent CTS	A4	7 %	115 €	2.30 €	Substitute standard glass by coloured glass and make ablation pattern in cell structures	100 €	215 €	5.5 %	5.20 €

Table 3.1.: Price-estimates for special thin-film modules

The acceptability study has already shown that the new modules will meet a positive resonance. Furthermore the partners have met in personal discussions with experts and colleagues, e.g. at the recent 19th European PV Solar Energy Conference, a highly positive response. Visually improved modules are presently becoming a new topic in the PV press (e.g. *Photon*, July 2004). Glass manufacturers such as *Saint Gobain* are reported to be studying plate glass with a pyramidal-structured surface for application in standard silicon modules. Such glass is also used in the “brilliant green” module concept of ANTEC Solar, and lower price for such glass will reduce the cost of such modules. Other glass producers have already taken up the idea of printing on the front glass of modules and shown examples during the Solar Fair in Freiburg / Germany in June 2004. Compared to these efforts, the partners in PVACCEPT by means of the project have a meaningful competitive edge against other PV producers.

4 Demonstration Objects and Test Phase

4.1 Introduction

The demonstration objects formed the core of the project; firstly because of their general importance for the dissemination of innovative PV design; secondly because of their importance within the structure of the research project, which implied a certain dependency of results and deliverables on the existence of built demonstration objects. This concerned especially the second part of the acceptability study, the energy and environmental assessment, the collection of data from the technical test phase, the design manual and the itinerant exhibition.

The problems and barriers, which were encountered on the way to the realisation of the demonstration objects had been, to a certain extent, underestimated by the project consortium, at least in their time component. They occurred on the following levels:

- **Research, innovation and marketing**

None of the communes involved had any experience in collaboration with an international research project. Communal representatives therefore were generally reluctant and needed intensive and time-consuming “care”. In the original German research region (see below) on top of that the willingness for innovation in general and the comprehension of its general and touristic marketing value proved to be very low. Key persons there were reluctant to “dare” anything with this respect.

- **Complex selection criteria**

A structural problem was the difficulty to achieve decisions concerning the demonstration objects in accordance with the selection criteria defined by the project on the one hand, and the interests and needs as well as resources of the local communities on the other hand. One main problem here was that the communes own few buildings themselves, while the selection criteria excluded interested private owners from the project. The selection criteria to be fulfilled by the demonstration objects were:

- communal property;
- touristic function;
- visibility;
- feasibility;
- innovation;
- transferability.

- **Bureaucracy and decision-making**

Furthermore, bureaucratic structures and procedures proved to be an obstacle. Legal contracts were needed to define the tasks of the PVACCEPT consortium as well as those of the communes as the future owners of the photovoltaic plants, to assure the quality and function of the demonstration plants for a period of at least 10 years. The necessary decision-making procedures consumed more time and effort than foreseen. “Bureaucratic” problems were the main obstacle in Italy, where many levels in the communal hierarchy were involved in the process of decision-making, which, in addition, was in some cases influenced by political strategies and changes (e.g. changes of mayors or reaction of mayors to other projects, which they had been promoting and which failed). The designers of UdK were forced to produce new designs for new sites over and over again, which was extremely time consuming.

- **Lack of resources**

In the originally chosen research region on the island of Rügen in Germany the problems concentrated on the economic level. The region is economically generally badly situated, and capacities of the communes for financing additional construction works, which would have been necessary at least for the most interesting demonstration objects, were extremely low. Despite the fact that the coordinator UdK extended its activities to supporting the communes in organizing additional funds, which was very time consuming and not foreseen in the original work plan, the scarceness of financial resources on side of the communes led to the failure of several demonstration objects in an already very developed stage of planning. When it became clear that no project was possible on the island of Rügen, it was, in agreement with the Commission, decided to shift the activities to another region, since the demonstration aspect was regarded as more important than the regional aspect. The search for alternative possibilities in the following months led to a cooperation with the commune of Marbach am Neckar in the South of Germany.

4.2 Planning Process

In total concrete plans and designs were made for 16 possible demonstration sites in Germany, and for 27 sites in Italy between May 2002 and December 2003. The time span between first ideas about a potential demonstration site, first designs and visual simulations, and the final decision on the demonstration object was, in most cases, one of several months, sometimes up to more than one year. Each site was discussed with the communal authorities in several meetings.

Decisions on side of the communes exceeded the foreseen schedule, in a few cases a negative decision was taken at a stage of planning and discussion, when the project seemed to be only a small step away from realisation. Sometimes even designs for sites and assigned functions, which originally were based on a suggestion of the commune itself, were later rejected by the communal authorities without giving clear reasons. In consequence, at some points in time "exit strategies" had to be developed, i.e. the search for appropriate sites started almost from the beginning again. The fact that the search for sites had to concentrate on possible application cases for the innovative PV products, developed by the project in parallel, did not make the task easier.

The following table gives an overview on the time span of continuous work spent on all the different demonstration projects and briefly comment the reasons why a specific project could not be realized. The table includes only projects, which had reached a certain level of detailed planning and is split into German and Italian projects. The realized demonstration objects are marked in yellow.

Object / Germany	design start	decision date	comments
Lauterbach / harbour quay	06/02	02/03	given up to the advantage of other, more appropriate sites for the application of the “solar flags”
Putbus / Marstall heating house	06/02	07/03	given up, representative only in combination with neighbouring other demonstration objects, only very small PV areas possible
Putbus / new House of the Guest	06/02	02/03	given up, time plans with preparatory communal and private investment for renovation of the building did not match
Putbus / old House of the Guest	06/02	10/02	given up, not representative enough, very small PV areas possible, selling of house to private owner was planned (selection criteria)
Serams / crossing	06/02	10/02	neglected, commune could not bear costs for necessary accompanying measures, surroundings would have needed considerable improvement to become a “demonstration site”
Göhren / new House of the Guest	07/02	02/03	cancelled by the commune in final stage of planning and application for additional funding, “financial problems” of commune as reasons
Göhren / beach promenade	07/02	02/03	neglected, time plans for accompanying measures of commune (reorganization of the promenade within the frame of a garden exhibition) did not match
Putbus / solar tree in front of Orangerie	06/03	08/03	rejected by commune, communal representatives found the site “too visible”, another site (at Marstall, see below) was proposed instead
Putbus / solar tree in castle park near Marstall	08/03	12/03	given up because of lack of necessary private sponsoring for metal structure and additional funding possibilities of commune
Putbus / Marstall	08/03	10/03	rejected by upper level of monument protection authority, while desired by commune and lower level of monument protection authority
Marbach / city wall	08/03	12/03	outside the originally defined research region, “exit strategy” project because of failure of all Rügen projects, accepted in December 2003, solar information plate, will be realized
Tornow / castle terrace	10/03	11/03	“exit strategy” project, outside the originally defined research region, neglected because of restrictions of the monument protection authority, which would have been too costly to realize
Object / Italy	design start	decision date	comments
Porto Venere / Welcome Centre	05/02	01/03	neglected, site not representative enough, expensive building measures would have been necessary, the financial possibilities of the commune remained unclear
Porto Venere / Piazza Spallanzani	05/02	01/03	neglected, would have been temporary installation during the summer season only, no interest of commune
Porto Venere / Pier	05/02	06/02	neglected, risks (protection of modules against salt water as well as vandalism necessary) were regarded as too high
Lerici / Piazza Bacigalupi / new fountain	05/02	01/03	neglected, no interest of commune after election of a new mayor
Lerici / Piazza Bacigalupi / parking	05/02	01/03	neglected, no interest of commune after election of a new mayor
Lerici / Town Hall	05/02	01/03	neglected, no interest of commune, only very small PV area would have been possible
Lerici / School	05/02	01/03	neglected, window shutters could not be further developed within the research project due to the insolvency of a consortium member (= producer)
Lerici / retention wall	06/02	01/03	neglected, suggestion of commune, structurally interesting, but site of very limited visibility alongside highway and near tunnel (selection criteria)

Continuation of table

Object / Italy	design start	decision date	comments
Lerici / camouflage nets	06/02	01/03	neglected, technical production problems would have gone beyond the scope of the project (triangular module shapes necessary)
Lerici / parking / retention walls	06/02	01/03	neglected, preparatory communal construction works were delayed, so that time tables did not match
Porto Venere / bus stop	06/02	01/03	rejected by commune after several presentations without clear arguments
Porto Venere / stone wall Seno dell' Olivo	08/02	01/03	rejected by commune after several presentations without clear arguments
Ameglia / Bocca di Magra / solar pergola	10/02	12/03	accepted, "solar pergola" will be realized in cooperation with the commune (preparatory works for the supporting pergola structure will be financed and built by the commune)
Bolano / retention wall	10/02	01/03	neglected, first discussions and agreements positive, but later no interest of commune in realization
Bolano / entrance ramp	10/02	01/03	neglected, first discussions and agreements positive, but later no interest of commune in realization
La Spezia / Agriturismo pool house	10/02	01/03	neglected, "exit strategy" project, site was privately owned (selection criteria)
La Spezia / castle	10/02	12/03	finally accepted by all authorities (December 2003), solar information plate with lighting at museum's entrance, will be realized
Porto Venere / castle	10/02	10/03	finally accepted by all authorities (October 2003), installation with self-lighted "solar flags" in castle courtyard, will be realized
Sarzana / Piazza San Giorgio	10/02	01/03	neglected, limited interest of commune, very small PV application possible
Sarzana / Piazza Citadella / bike station	10/02	01/03	rejected by commune without clear reasons

Table 4.1: Planned demonstration objects / Germany and Italy

Lessons, which can be learnt from this experience, are e.g. that any involvement of communal authorities in a project decision-making process has to be accounted for with sufficient time. The different decision-making levels within a commune, including differing opinions and sometimes also power plays of key persons, may lead to a complex discussion and decision-making process. Also the continuous engagement for a project can not be taken for granted, even if there are no financial obligations for the commune involved, if the commune does not realize the advantages in linking its own marketing strategies with the project.

In the following, we present the four built demonstration objects in detail, including comments on impressions and references to the applied innovative PV products.

4.3 Demonstration Objects

4.3.1 Self-lighted “Solar Flags“ at Castello Doria in Porto Venere



Picture 4.1: Castello Doria, upper terrace with mural arches and "solar flags"

The solar installation is situated on the upper terrace of the castle of Porto Venere, which is used as space for exhibitions and events. Six mural arches of the northern battlements, which have an orientation to the South, are equipped each with three self-lighting photovoltaic modules, so-called “solar flags”, which have been developed in the context of the research project PVACCEPT. The modules are used for the illumination of the arches next to the amphitheatre on the terrace. During cultural events, the white light of the “solar flags” can be dimmed or switched off.

Each one of the 18 “solar flags” consists of slightly curved transparent acrylic sheets (size approximately 40 cm x 70 cm), in which 15 semitransparent crystalline solar cells of Sunways AG are embedded (weather-proof). In addition, the modules dispose of an integrated lighting unit of low-current, durable LEDs, which uses the current produced during the day for the illumination of the modules at night.

The modules are fixed by special stainless steel clamps on two horizontal stainless steel ropes ($d = 4 \text{ mm}$), which are solidly spanned into the upper segments of the arches (steel rope and spanner nut system by *Carl Stahl*, Germany). The vertical distance between the mounting level of the modules and the ground level of the amphitheatre ascends from the eastern to the western arch in progressive stages from 3.5 m to 7.5 m. In order to protect the monument, existing openings and slots in the walls of the arches (formerly beam bearings) as well as mural splices were used as far as possible for the mounting of the anchor fittings.

These openings are used also for the horizontal installation of the connection cables of the solar equipment, which is fixed at the level of the steel wiring. The cables for the serial connected circuit of the PV modules “solar flags” as well as the parallel connected ports of the LED lighting unit are led through a protection tube, which is situated in the back corner on the right side of the last arch. Similarly, as protection against lightning, all steel ropes, which carry the modules, are connected with each other and grounded by earth anchors in the first and the last arch. In the corner of the first arch two electrical cupboards with counter and grid connection of the *ENEL* (local energy supplier in Liguria) exist already and can be used for the temporary operating of the amphitheatre (light and sound equipment). The electrical cupboard for the solar plant is installed next to them.



Picture 4.2 - 4.6: Construction phase

Two 12 Volt batteries as storage medium and the battery charger with low voltage protection are located in this weatherproof metal cupboard (IP 65). For the operating of the module-integrated LED lighting unit, the following components are also contained in the cupboard: master switch with fuse (overvoltage protection), twilight switch, programmable time switch (for adapting the lighting to the time of day), and dimmer (for special events).

The installation is a so-called stand-alone system, i.e. the produced electricity is not fed into the grid, but is stored in batteries and used on the site.

The 18 „solar flags" generate altogether a net yield of approximately 180 kWh²³ per year. Taking into consideration the low energy consumption of 4.8 Watt per illuminated “solar flag” and a maximum of 5 hours of lighting per day, one can calculate an annual consumption of 10 kWh for each module, i.e. an annual consumption of 180 kWh for all 18 “solar flags”. This means that the energy gained covers the energy consumed (on the average).

For the mounting of the solar modules, moveable scaffolding with three platforms was used, which was moved on the paved floor of the theatre gallery. The mounting area was easy to block off, and the construction works therefore did not interfere with the public traffic in the castle.

In accordance with the monument protection authority, an information plate was mounted to inform the visitors in two languages (Italian and English) about the installation and about the project PVACCEPT. On the 23rd of April 2004 the photovoltaic plant was put on stream for the first time. The data logging system was started some time later. The official inauguration of the plant took place on the 7th of June, 2004.

Impressions

The "solar flags" are lighted for four hours after sunset and one and a half hour before sunrise, programmed by a timer. After sunset, the luminous "solar flags" are only visible from the distance; in the tourist season e.g. from the numerous boats, yachts and international cruise liners, which anchor in the shallow lagoon of Porto Venere, and also from the beach and the terraces of the opposite *Palmaria* island. The illumination adds a new component to the typical silhouette of the village at night, for the first time including also the upper part of the castle site. The installation attracts attention rapidly. Inside the castle the diffuse light of the “solar flags”, mainly illuminating the mural arches, serves as an atmospheric lighting of the amphitheatre, where numerous festivities and concerts take place in summer. For special events, which could be disturbed by the light, the whole installation can be dimmed or totally switched off. Visitors tend to be fascinated by the quasi-meditative privacy, which is created by the PV installation.

²³ Kilo Watt hour: the energy delivered by 1000 watts of power over one hour

Applied Innovative PV Product

All 18 "solar flags" had been tested already in the factory of the German producer *Sunovation* and could be put on stream without problems. Only the connection points of the modules with the cables required a higher mounting complexity, because the four necessary unipolar cables could not be combined in one cable harness with a multi-connector. A new special development of a technically certified multi-connector with coupling would have disrupted the schedule and the financial frame, which had been available for the pilot production.

Already as a prototype, the product „solar flag“ has proved to be of value as an element, which is easy to handle concerning transport and mechanical mounting. Only the external cabling of the modules should be improved to accelerate the electrical mounting.



Picture 4.7: "Solar flags" seen from underneath



Picture 4.8: Three "Solar flags" in one arch



Picture 4.9: "Solar flags" illuminated at night

4.3.2 Solar Information Plate at Castello San Giorgio, La Spezia



Picture 4.10: Castello San Giorgio, main entrance with solar information plate

The solar plant is situated at the southwest oriented fortification wall of the castle *San Giorgio*, at the right side of the main entrance to the “*Museo Civico Archeologico Ubaldo Formentini*”. It is also a so-called stand-alone system, i.e. the current gained is stored in batteries and consumed on the site.

The solar information plate replaces the former printed plastic banner of which it took over the information text, the logo of the museum, and the colour of the synthetic texture. In addition, the new plate is illuminated at night, using the electricity, which has been gained and stored in a battery during the day. The bottom of the plate is about 2.58 m above the level of the entrance ramp to keep it out of reach. The entrance area of the museum is under the surveillance of a video camera.

The information plate with a size of about 3.61 m x 2.4 m consists of six thin-film photovoltaic modules of Würth Solar. The front glasses of the single modules are made of tempered safety glass (TVG), size 1.20 m x 1.20 m (thickness = 10 mm), the surface of which is printed with weather-proof colours using an innovative technique (ceramic screen printing). The total thickness of the glass module is 13 mm. The technique, which has been developed and protected in the context of the PVACCEPT research project, allows a high degree of adaptation of photovoltaic module surfaces to their surroundings with regard to colour, pattern, and structure.

The six single module plates are flexibly mounted and fixed with four clamps each (system ALUHIT, by *Wyss Aluhit AG*, Switzerland) on aluminium profiles, tested in the context of glass facade construction. These profiles are screwed into a statically stiff steel frame made of welded and galvanized tubes and U-profiles. This enables the reduction of the number of anchors, which are necessary for fixing the whole construction to the castle wall, to a minimum (about 6 to maximum 7 pieces M 12 = diameter 12 mm). The anchors for the mounting were put into existing joints of the wall, if possible. The steel frame is adapted to the existing steel handrails and therefore painted with dark grey iron protection colour (DEMURAG²⁴ “*Schuppenpanzer*” DB 703, dark grey 156 / corresponding “*Ferro Micacea*”); the aluminium profiles are anodized analogously in colour RAL²⁵ 7016 (dark grey).

²⁴ Trademark of NORIX Lackfabrik GmbH / Germany

²⁵ International norm system for colours



Picture 4.11 - 4.15: Construction phase

The six modules generate a maximum net power of approximately $350 W_p$, which corresponds to an energy yield of approximately 540 kWh per year. The electricity gained by the parallel-connected plant is conducted by a cable to a battery, the dimensioning of which allows lighting of the information plate for several hours at night. The lighting system consists of a round floodlight (*BEGA 8040 1 HIT-DE 70W*²⁶), which is embedded in the brick floor of the entrance ramp.

All connecting cables are conducted in a protection tube into the building through a window at the left bottom side of the information plate. In the interior (entrance hall of the museum) the cabling is conducted, hidden behind book shelves of the museum's shop, to a bigger niche in the wall, where the lockable electrical cupboard (IP65²⁷), minimum size 50 cm x 60 cm x 30 cm, is placed. This cupboard contains the 24 V battery, a charging regulator with protection against low voltage, and all necessary elements (switches etc.) for the control of the lighting system.

The mounting of the solar information plate was realized by means of a small crane with working platform from the street below (mounting of the steel frame), and after that by means of movable scaffolding, which had been set up on the entrance ramp (mounting of the carrying system for the modules, the cabling and glasses). The entrance of the museum was accessible during the mounting operations, so that the construction did not collide with the normal service of the museum.

In accordance with the monument protection authority, an information plate was mounted to inform the visitors in two languages (Italian and English) about the installation and about the project PVACCEPT. On the 28th of May 2004 the photovoltaic plant was put on stream for the first time. The data logging system was started some time later. The official inauguration of the plant took place on the 7th of June, 2004.

Impressions

Because the solar information plate for the museum fits so well into the ambience of the museum entrance, most visitors do not recognize it as being a solar plant. The colouring of the former textile banner has been matched very well, and the text is well legible. At night the castle was up to now lighted only for special events. Due to the solar powered spotlight in the floor its illumination is now independent of special events. Even in artificial light the colour reproduction of the print is very good.

Applied Innovative PV Product

Concerning electrical engineering all six CIS double modules consist of reliable PV technology and could be wired and put in operation without any problems. Regarding the printing technology the production of the enamelled surface printing on the front glasses of the modules

²⁶ Energy-saving lamp

²⁷ International norm for dust and water protected products

corresponds with the state of the art. The method of colour layering in multi-coloured screen-printing has to be individually defined for every application because the brilliance of the coloured points can be regulated with the colour of the prime coat. Additionally, the visibility of the active black module coat in the background significantly affects the viewer's perception of every coloured point. This effect cannot be sufficiently tested in computer simulations and needs test prints of the most complex parts of the respective motive.

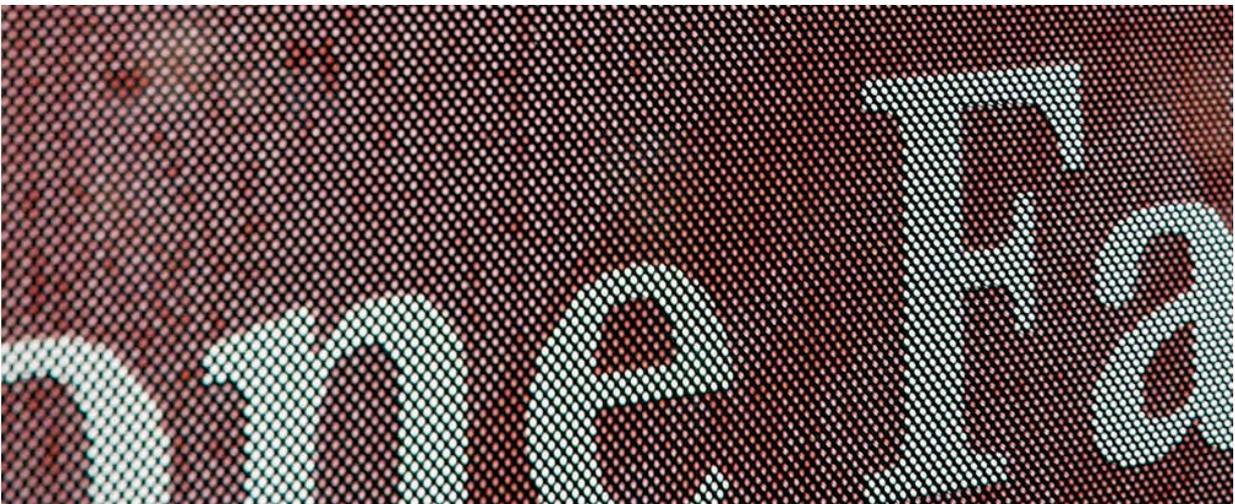
The product "printed modules" has already been well received as a prototype. For the reproduction of differentiated graphics and scripts a printing degree of about 20 % is recommended. For the reproduction of abstract structures and two-dimensional repeated patterns without sharp outlines the printing can be lowered to about 15 %. Test prints on glass, which is laminated or painted black on the back, should be made in any case to adjust the colours and to avoid expensive misprints.



Picture 4.16: Solar information plate (daytime)



Picture 4.17: Solar information plate at night



Picture 4.18: Detail of the solar information plate; dot-print structure

4.3.3 Solar Pergolas at River Promenade in Bocca di Magra / Ameglia



Picture 4.19: Bocca di Magra river promenade with solar pergola

The three solar pergolas are located at the river *Magra* promenade, which is the eastern border of the natural park “*Parco Regionale Montemarcello Magra*”. The promenade has been restored in 2004. At three different locations, the pergolas overarch the new promenade for cyclists and pedestrians. The solar pergolas are stand-alone systems, i.e. the electric current is not fed into the grid, but stored in batteries and consumed on the site. The generated electricity is used for lighting the promenade at night by LEDs placed in the wall as well as integrated into the frames of the pergolas.

Each pergola carries five lamella modules, developed within the PVACCEPT research project and fabricated in thin-film technology. They have a size of 2.40 m x 0.30 m each (with 10 mm thick safety glass as carrying front glass). The active PV layer has a 10 % punch-hole pattern to reach a semitransparent impression of the lamella. The modules are carried by a special metal support structure (length = 1.90 m) on rubber bearings. The lamella modules and the metal support were delivered by PVACCEPT and set on the metal frame constructed beforehand by the commune of Ameglia. For all three locations, identical construction elements had been prefabricated.

For each pergola a cut-stone wall was built, screening the promenade from the street, with a height of maximum 2.30 m and a depth of minimum 0.40 m, which is adaptable to the location (e.g. by integrating niches or seats and tables). This wall stands freely under the pergola construction. The weatherproof and lockable electrical cupboard (IP65) with the size 50 cm x 60 cm x 30 cm was delivered by PVACCEPT and embedded in the wall. The height above ground level of this cupboard was elevated due to the danger of floods.

The prefabricated metal structure (galvanized in advance and painted after construction) consists of two U-shaped frames (standard channel profile ST37, 160 mm x 80 mm x 5 mm), welded together with bending strength to form a frame with a height of 3.00 m and a length of



Picture 4.20 -4.23: Construction phase

4.60 m. These frames were erected on both sides of the promenade parallel to each other with a distance of 2.82 m.

The frames were screwed to four point bases with levelled sole plates and traction anchors. Then the two frames were connected with five metal rods ($l = 3.98$ m, $d = 0.0483$ m), one every meter, and welded circumferentially. All profiles have enough openings for ventilation. The metal rods carry the metal holding fixtures of the modules, which are screwed to the rods. The southeast oriented modules have an inclination to the horizon of 30° .

The cabling of the PV installation is conducted through the rods to the frame and from there through a steel protection tube ($d = 3$ cm) to the tube in the wall.

At each of the three locations, the five modules generate a maximum net power (after deduction of all reducing factors) of approximately $240 W_p$. The electricity gained (average: 1 kWh/d^{28}) is led to and stored in 12 Volt batteries (charging regulator with low voltage protection), which are designed to feed the LED lamps for several hours after sunset. For the lighting system, the following elements have been installed in the electric cupboard: master switch with fuse (overvoltage protection), twilight switch and programmable time switch (for adapting the lighting to the time of day), and dimmer (for special events).

The construction of the pergola frames and the walls, as well as the integration of lighting elements, and planting itself was done by the commune. For the mounting of the modules, the cabling, and installation of all electrical components, PVACCEPT used a movable scaffolding of an approximate height of 2 m.

In accordance with the monument protection authority, an information plate was mounted at the pergola next to the harbour to inform the visitors in two languages (Italian and English) about the installation and about the project PVACCEPT. On the 4th of June 2004 the photovoltaic plant was put on stream for the first time. The data logging system was started some time later. The official inauguration of the plant took place on the 7th of June 2004.

Impressions

After the constructions were completed, the commune painted the frames of the three pergolas in different shades of blue. The semitransparent lamella modules as well as the galvanization of the brackets appear light and graceful. They harmonize with the technical rigging of the yachts that are moored at the shore. Already during its construction, the pergolas found high acceptance by the public, also as “multifunctional street furniture”; especially in the evenings and at night they are used by locals, tourists and anglers as a meeting place. At night the pergolas and their walls become blue shining landmarks, which are visible widely across the river and the access road. The pergola areas are then dipped into a smooth light. Especially the

²⁸ KWh per day

interest of young passers-by seems to be aroused by the coloured LED light. As the PVACCEPT planners could detect, also the information plate is being read with interest.

Applied Innovative PV Product

Each pergola consists of 5 x 2 joined semitransparent CIS modules (with a 10 % rate of holes), which only have half the width of a standard module (30 cm x 240 cm). Electronically these so-called lamella modules consist of reliable PV technology. It was no problem to wire them and put them into operation. The brackets were especially conceived for these lamellas. They were deliberately designed to be statically stable, independent of the supporting structure, so that the pergola construction and the modules did not have to be installed at the same time. Thus, the simple installation also bore in mind that parts of the structure could be installed by unskilled communal workers. Thanks to the transparent holes and the reflection of the back of the module (at which one looks from beneath), the module lamellas and the brackets appear very filigree.

For further professional applications of the lamella modules it is advisable to reduce the bracket system to the statically necessary extent to emphasize the elegant effect of the lamellas. With another strengthening of the supporting tempered safety glass the lamellas could manage with so-called “frog fingers” with four installation points. Thus an extensive bracket-less free extension of the glass would be possible.



Picture 4.24: Solar pergola



Picture 4.25: Detail of solar pergola modules



Picture 4.26: Solar pergola at night

4.3.4 Schiller Quotation at City Wall in Marbach / Neckar



Picture 4.27: Marbach, city wall with quotation plate

The photovoltaic plant is situated at the southeast oriented city wall of Marbach am Neckar at a parking in *Grabenstraße* which is frequented by tourists visiting the medieval town centre. The square solar module area is adapted to the city wall as background in its colour and structure and carries a quotation of the famous German poet Friedrich Schiller (translation: “The educated man makes nature his friend.”). The plate fulfils two tasks in one object: It is a promotion for Marbach am Neckar as Friedrich Schiller’s place of birth, as well as a demonstration object for the application of renewable energies, for which the city generally makes an effort. The solar installation has been immediately included as a special site in guided Marbach city tours and is regarded as a Schiller memorial. The electricity gained is fed into the grid via an inverter and taken from there partly for the illumination of the plate at night.

The information plate with a size of about 3.61 m x 3.61 m consists of nine thin-film photovoltaic modules of Würth Solar. The front glasses of the single modules are made of tempered safety glass (TVG), size 1.20 m x 1.20 m (thickness = 10 mm), the surface of which is printed with weather-proof colours using an innovative technique (ceramic screen printing). The total thickness of the glass module is 13 mm. The technique, which has been developed in the context of the PVACCEPT research project, allows a high degree of adaptation of photovoltaic module surfaces to their surrounding with regard to colour, pattern, and structure.

The nine single module plates are flexibly mounted and fixed with four clamps each (system ALUHIT, by *Wyss Aluhit AG*, Switzerland) by aluminium profiles, tested in the context of glass facade construction. These profiles are screwed into a statically stiff steel frame made of welded and galvanized tubes and shaped flat steel ST37. This enables the reduction of the number of anchors, which are necessary for fixing the whole construction to the city wall, to a minimum (about 11 pieces M 12). The steel frame has been painted with dark grey iron protection colour (DEMURAG “*Schuppenpanzer*” DB 703, dark grey 156); the aluminium profiles were anodized analogously in colour RAL 7016 (dark grey). The bottom of the plate is about 3.00 m above the level of the parking and thus quite well protected against damages through cars, passers-by or vandalism.



Picture 4.28 - 4.31: Construction phase

The nine modules generate a maximum net power (after deduction of all reducing factors) of approximately $500 W_p$, which corresponds to a yield of approximately 400 kWh per year. The electricity gained is conducted through a protected cable to an electrical cupboard with inverter, counter, and grid connection, which is integrated into the city wall at an appropriate place.

In accordance with the monument protection authority, an information plate was mounted to inform the visitors in two languages (German and English) about the installation and about the project PVACCEPT. On the 30th of April 2004 the photovoltaic plant was put on stream for the first time. The data logging system was started some time later. The official inauguration of the plant took place on the 19th of October 2004 in connection with the workshop / SME training.

Impressions

The square solar quotation plate fits well into the ambience of the old city wall, which is already equipped with numerous openings and attributes. The base print of the quotation plate is taking up the colour and abstract structure of the historic stonewall. The frameless modules thus appear to consist of tinted, transparent glass, which floats in front of the wall without any visible holding devices. The legibility of the text changes depending on the angle of view and the angle of the light between “positive” (brighter than the background) and “negative” (darker than the background). The quotation text was at first deliberately held in an unobtrusive and relatively pale hue; following a request of the commune, however, adaptations of the first design were made to reach a more striking appearance of the text.

Applied Innovative PV Product

Concerning electrical engineering all nine CIS double modules consist of reliable PV technology and could be wired and put in operation without any problems. Regarding the printing technology the production of the enamelled surface printing on the front glasses of the modules agrees with the state of the art. The method of colour layering in multi-coloured screen printing has to be individually defined for every application because the brilliance of the coloured points can be regulated with the colour of the prime coat. Additionally, the visibility of the active black module coat in the background significantly affects the viewer’s perception of every coloured point. This effect cannot be sufficiently tested in computer simulations and needs test prints of the most complex parts of the motive. The product “printed modules“ has already been well received as a prototype. For the reproduction of differentiated graphics and scripts a printing degree of about 20 % is recommended. For the reproduction of abstract structures and two-dimensional repeated patterns without sharp outlines the printing can be lowered to about 15 %. Test prints on glass, which is laminated or painted black on the back, should be made in any case to adjust the colours and to avoid expensive misprints.



Picture 4.32: Panoramic view of the city wall with quotation plate and Marbach am Neckar



Picture 4.33: Close-up of the city wall with quotation plate



Picture 4.34: Detail showing the adaptation of the module to structure and colour of the city wall

4.4 Data of Test Phase of Demonstration Objects

As mentioned before, all demonstration objects have been equipped with a data logging system, which measures minute by minute the electrical energy generated by the PV module. The data are stored in the data logger and can be re-called via GSM²⁹ modem. In the following we present the first results of the ongoing “test phase”.

4.4.1 Solar Flags at Castello Doria in Porto Venere

The data from the system in Porto Venere were evaluated for the months August until October 2004; the result is shown in the following figure:

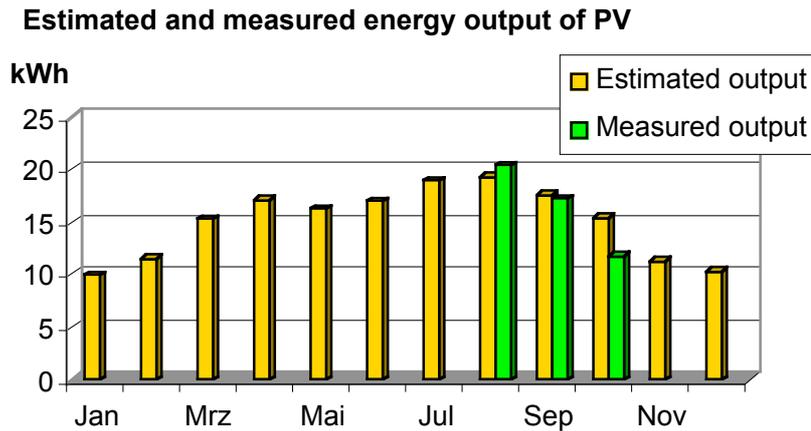


Figure 4.1: Estimated and measured energy output

In August 2004 the energy output of the PV installation was slightly higher than expected, whereas in October 2004 it was rather low. The detailed inspection of the data (see following figure) showed that the installation was working properly. The low daily energy outputs were presumably related to bad weather conditions especially in the second half of October.

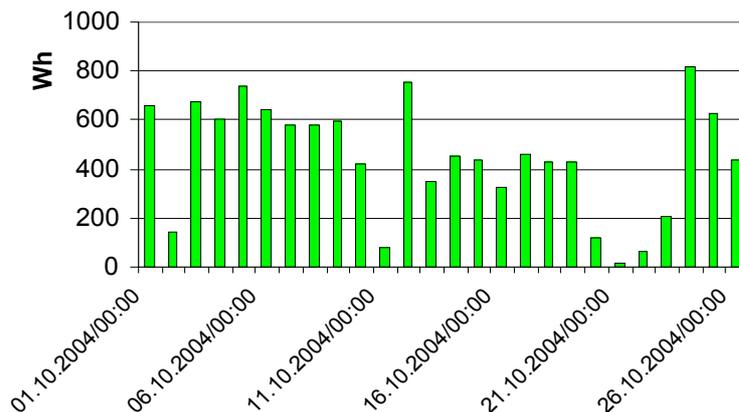


Figure 4.2: Daily energy output in October 2004

In December the batteries were defect and had to be exchanged. They are now working properly again. Regarding the monitored period the measured energy output corresponds in average to the estimated amounts.

²⁹ Global System for Mobile communication

4.4.2 Solar Schiller Quotation Plate at City Wall in Marbach am Neckar

The data were evaluated for the months of May to December 2004. Caused by the vertical orientation of the modules, a slightly untypical behaviour of the monthly produced energy harvest in comparison to optimally tilted systems is the result. Normally there is a peak in July / August, but in this case two lower peaks in March and September were observed.

The graphs below show the produced energy per month and the monthly solar irradiation for the months between installation and the end of the year.

In September the PV plant had to be adapted in different aspects: Four modules were exchanged for aesthetic reasons (see section 4.3.4); at the same time a failure in the cabling was repaired, which temporarily had disturbed the function of one third of the system. As a result of the repairs, the measured output increased in October.

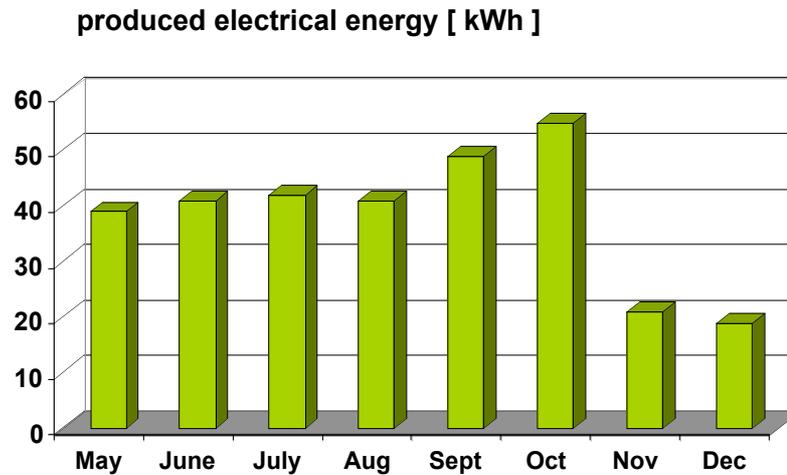


Figure 4.3: Produced energy during 2004 of the system in Marbach am Neckar

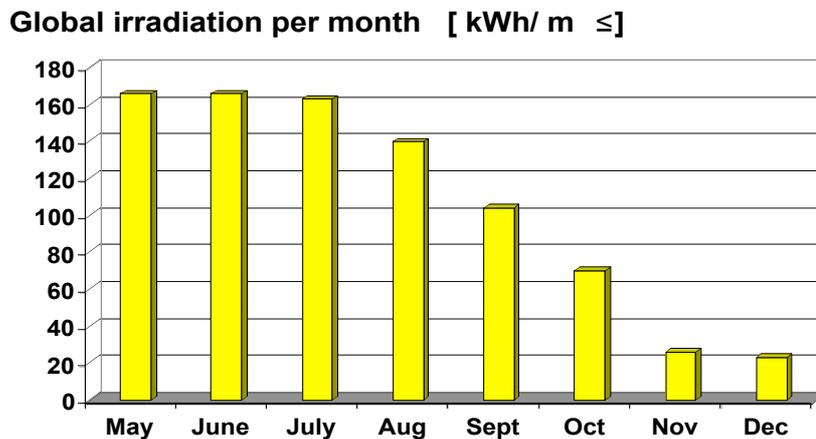


Figure 4.4: Global solar irradiation in the region of Marbach am Neckar

In November and December the data reflect the diminished global irradiation at that time of the year.

Based on these collected data, a higher calculated energy output can be expected than the originally aspired 400 kWh/a, which is a very good result.

4.4.3 Solar Information Plate at Castello San Giorgio in La Spezia

The installation can be compared with the demonstration plant in Marbach am Neckar, i.e. the same type of dot-printed modules has been applied. Due to initial difficulties in recalling the data from the data logging system and necessary adaptations in the configuration of the data logger (regarding e.g. the sensor), only the measured values for December 2004 can be presented here.

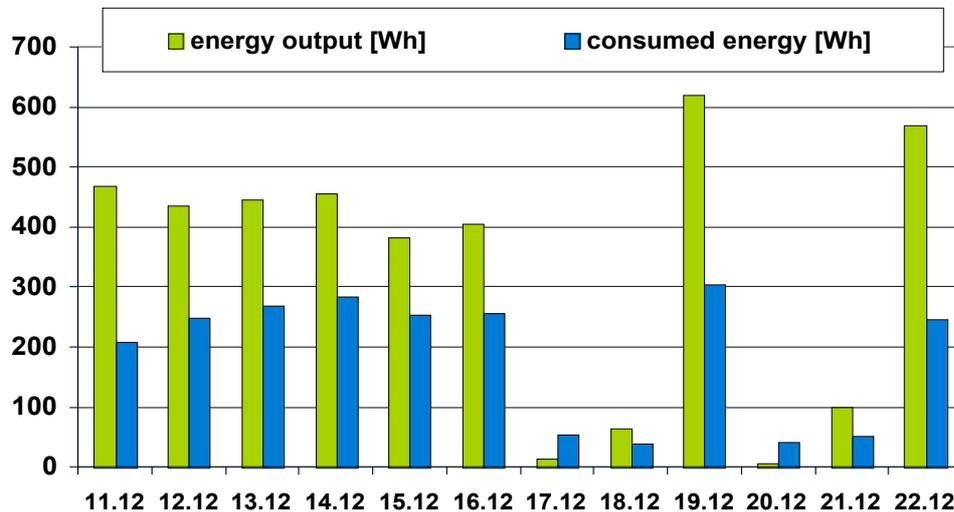


Figure 4.5: Daily energy output and consumption in December 2004

In December the output of the PV system was very low because of extremely bad weather conditions. The consequence was that the battery couldn't be filled up, and the energy gained on some days was sufficient only to feed the floodlight for one hour. (The working time of the floodlight can be calculated by the consumed energy divided by the power (70 W) of the lamp.) It can be expected, however, that during the summer months the PV modules will produce enough energy to feed the light for about seven hours per night, and the system will work as planned.

4.4.4 Solar Pergolas in Bocca di Magra / Ameglia

Also in the case of the pergolas in Bocca di Magra, it depends on the status of the batteries and the consumers (electrical lamps), how much energy can / must be produced and stored. The following graph shows the evaluation of the logged data for the months June until November 2004.

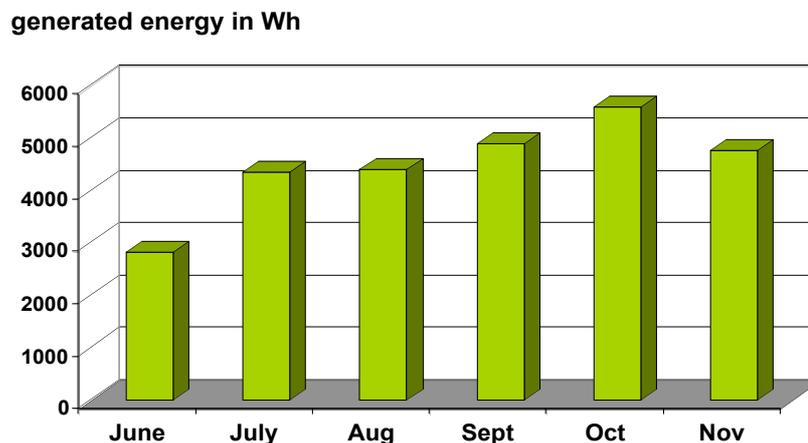


Figure 4.6: Produced energy of the system "Bocca di Magra" in 2004

The installed CIS modules of each one of the three pergolas have a measured maximum power of 240 W_p, tested with a sun simulator by Würth Solar. This means that the each pergola system has the capacity to produce about 200 kWh per year.

The installed LEDs at each pergola have a power of about 10 W; on the basis of the measured energy data it can be calculated that the LED lighting can work during an average of about 10 hours per night.

4.4.5 Resumé of Test Phase

Apart from some minor necessary adaptations and repairs concerning system components like batteries or monitoring instruments, all demonstration plants worked properly; this refers especially to the innovative modules that have stood the test in “reality”.

5 Life Cycle and Environmental Impact Assessment

5.1 Introduction

This chapter deals with the Life Cycle Energy and Environmental Impact Assessment of the photovoltaic (PV) technologies and of two of the final PVACCEPT demonstration objects, which was performed as an integral part of the project by the team from the University of Siena (hereinafter referred to as UNISI). Literature references are summarized in section 5.7 at the end of this chapter.

5.2 The Analysed Systems

The PVACCEPT consortium originally included three commercial enterprises which produce three different kinds of PV systems, respectively: Sunways AG Photovoltaics (semitransparent microperforated mc-Si³⁰ cells); Würth Solar GmbH (thin-film CIS modules); ANTEC Solar GmbH (thin-film CdTe³¹ modules).

Here follows a very concise, simplified description of the three technologies.

- **Multi-crystalline Silicon (mc-Si):**

In this technology the photoactive material is a thin (250 ÷ 350 µm) layer of high-purity silicon, which is “doped” on its opposite sides by introducing into its lattice structure a small number of atoms of the third and fifth chemical groups, respectively (e.g. boron and phosphorous). This procedure effectively turns the Si layer into an electrical P/N³² junction, characterized by an energy gap between the bonding and the conducting electronic bands that corresponds to the wavelengths of visible light. These fragile Si cells are then electrically connected in series and sandwiched between two transparent glass panes to form the finished module.

- **Copper Indium diSelenide (CIS) thin-film:**

In this technology the photoactive P/N junction is made up of two semiconductor compounds, CuInSe₂ and CdS, which are directly deposited in extremely thin layers (2 µm and 0.05 µm respectively) on a transparent glass pane by means of a vacuum vaporization process. Series connection of adjacent P/N junctions is achieved by means of a repeated automated mechanical scribing process, and then a second protective glass pane is added on top to form the finished module.

- **Cadmium Telluride (CdTe) thin-film:**

This third technology shares many similarities with the previous one (CIS), the main difference between the two consisting of the chemical compound used for the P part of the heterojunction, i.e. CdTe instead of CuInSe₂ (other minor technical differences exist between the two production processes, of course, but these are outside of the aims of the present simplified description).

The production lines of the three partner firms were visited by UNISI representatives during the first year of the PVACCEPT project, and detailed information on the production data for the three kinds of PV systems was collected, in part during these visits and in part in the following months. The remaining missing data were obtained from the available scientific literature and adapted to the investigated case studies (more details on the implied assumptions are given in the following paragraph).

³⁰ multi-crystalline Silicon

³¹ Cadmium Telluride

³² positive / negative

In the later part of the PVACCEPT project, ANTEC abandoned the consortium because of bankruptcy, and consequently the CdTe modules produced by them have not been employed in the final demonstration objects.

Nevertheless, by that time the UNISI team had already collected complete information on the production of CdTe modules, and therefore the latter are also included in the present analysis. In order to provide a useful and meaningful report on the environmental and thermodynamic performance of the analysed PV systems, the choice was made to carry out two separate (but interconnected) lines of analysis.

- Firstly, we performed a comparative assessment of three “*typical*” frameless PV modules, respectively employing each of the three available technologies (mc-Si, CIS and CdTe). The results for the three technologies can thus be compared among themselves on the common basis of a similar basic installation, as well as to other more conventional means of electricity production.
- Secondly, a complete assessment of two of the finished demonstration objects was performed, extending, integrating and modifying the previous analysis where appropriate, so as to provide relevant information on the final performance of these innovative installations. The two chosen demonstration objects were: (1) the “*solar flags*” in Porto Venere, Italy; (2) the “*solar information plate*” in La Spezia, Italy. Even though the resulting indicators are thus strictly only applicable to the specific demonstration objects, they are nonetheless still interesting from a more general perspective, since they enable the analyst to gauge the influence of the original design-oriented implementations on the final performance of the PV devices.

5.3 Assumptions

First of all, before going into any details, it must be clearly stated that the objects of the present analysis were in all cases either prototypes or limited-production items, often employing novel technology which has not yet been optimised for large-scale production. As a consequence, all the results presented here should be regarded as provisional, and subject to possible further improvement in many important respects. It is however interesting and meaningful to discuss and compare these findings, however preliminary they may be, since they can provide scientifically sound indications of what the future may have in store, and also some useful recommendations on the possible energy and environmental choices of tomorrow.

5.3.1 General assumptions:

General assumptions made are the following:

- The average yearly irradiation rate for the Liguria region in Italy, i.e. $1700 \text{ kWh}/(\text{m}^2 \cdot \text{yr})$, was chosen as the common basis for all the analyses.
- Module decommissioning was not included in the analysis, because of lack of reliable data for the new technologies employed. All waste materials used in the production phase are assumed to be recycled.

5.3.2 Assumptions on mc-Si modules:

- The PV cells used in the modules are the semi-transparent “POWER Cells” produced by Sunways, and all the input requirements for them are those provided by Sunways.
- One fundamental assumption regards the preliminary production of the silicon wafers that are employed in all kinds of mc-Si-based PV cells. In fact, it must be acknowledged

that there is very wide range of different literature data for Si wafer production, and there is still a lack of agreement in the scientific community as to which values are to be considered the most representative. This state of matters is caused by several factors. Firstly, there exist two main process chains for the production of Si wafers for PV applications. The traditional method relies on the re-melting of Si scraps deriving from the production of high grade wafers meant for the electronic industry, which is itself a three-step process entailing a very energy-intensive step known as the Siemens process. The second production method is a newer and more direct technology developed for the specific needs of PV technology, and is still gaining ground on the international market. In the case of the first method, assumptions need to be made on the degree of integration between the various stages of the process, which varies considerably, as well as on the proportion of the costs and impacts to be assigned to the PV wafers vs. the “electronic” wafers. Lastly, the relative representativeness of the two production methods on the international scene is constantly changing and very dependent on external factors such as market prices and the level of technological advancement of the hosting country. In the present analysis, it was our choice to provide two possible and somewhat “extreme” scenarios: (i) a “*worst case*” scenario, using values that are consistent with the bulk of available scientific literature (e.g. ETH-ESU 96), corresponding to the exclusive employment of the traditional manufacturing method, with the percentage of costs and impacts assigned to PV wafers on a purely material basis; (ii) a “*best allocation*” scenario, where the same traditional manufacturing method is also assumed, but a radically different allocation of the costs and impacts of Si wafer production is made (i.e. 30% to PV and 70% to the electronic industry), which appears to be more representative of the current economic situation on the world market.

- The conversion efficiency of the PV cells is assumed to be equal to 10%, which is the value declared by SUNWAYS for their semi-transparent “POWER Cells”, where 10% of the photoactive surface is lost due to the mechanical structuring process. It is important to note that for the similar (but non-transparent) “PLUS Cells” a higher 14% value is declared to be attainable.
- The percentage of Si wafers that are damaged and consequently made useless during the production process is assumed to be 10%, according to the information provided by the manufacturer (SUNWAYS).
- The expected lifetime of the finished modules is assumed to be 20 years. This one single assumption, of course, has a large, inversely-proportional impact on the calculated indicators per kWh, since a lifetime of only 10 years, for instance, would automatically double all the costs and impact indicators of the electricity produced by the modules.
- The additional input requirements for the assemblage of the “*typical*” frameless modules are average values taken from the available literature, also including wastes, i.e. 12.5 kg/m² of glass and 1.3 kg/m² of Ethyl Vinyl Acetate (EVA).
- Frames (aluminium and/or steel) and cables (copper and rubber) are not included in the analysis, since their quantities can vary significantly depending on the type of installation (rooftop, facade, etc.), and in any case they are generally independent of the specific PV technology employed.
- The DC³³ to AC³⁴ inverter necessary for connection to the electrical grid is likewise not included in the analysis.

³³ Direct Current

³⁴ Alternating Current

5.3.3 Assumptions on CIS modules:

- The PV modules are the CIS modules produced by Wuerth, and all the input requirements for them are those provided by Wuerth, including glass and EVA³⁵.
- The conversion efficiency of the PV modules is assumed to be equal to 11%, which is the value declared by Wuerth for the current state of their pilot production, as of November 2004. It should be noted that Wuerth has expressed confidence that this value will probably increase by a few (1 - 3) more percent in the next future.
- The expected lifetime of the finished modules is assumed to be 20 years. This one single assumption, of course, has a large, inversely-proportional impact on the calculated indicators per kWh, since a lifetime of only 10 years, for instance, would automatically double all the costs and impact indicators of the electricity produced by the modules.
- The additional input requirements for the assemblage of the “*typical*” frameless modules are: 25 kg/m² of glass and 0.9 kg/m² of Ethyl Vinyl Acetate (EVA).
- Frames (aluminium and/or steel), cables (copper and rubber) and the DC to AC inverter are not included in the analysis.

5.3.4 Assumptions on CdTe modules:

- The PV modules are the CdTe modules produced by Antec, and all the input requirements for them are those provided by Antec, including glass (with the only exception of EVA, for which an average literature value is used).
- The conversion efficiency of the PV modules is assumed to be equal to 8%, which was the value declared by Antec for the current state of their pilot production, as of July 2002. No updated value was available due to the termination of the collaboration with Antec.
- The expected lifetime of the finished modules is assumed to be 20 years. This one single assumption, of course, has a large, inversely-proportional impact on the calculated indicators per kWh, since a lifetime of only 10 years, for instance, would automatically double all the costs and impact indicators of the electricity produced by the modules.
- The additional input requirements for the assemblage of the “*typical*” frameless modules are: 25 kg/m² of glass and 0.9 kg/m² of Ethyl Vinyl Acetate (EVA).
- Frames (aluminium and/or steel), cables (copper and rubber) and the DC to AC inverter are not included in the analysis.

5.3.5 Assumptions on Demonstration Object “Solar Flags” in Porto Venere:

- The PV cells employed for the demonstration object are the mc-Si based “POWER Cells” produced by SUNWAYS as described above, and all the relative assumptions apply. The two scenarios due to the different assumptions on Si wafer production are also retained.
- The installation consists of a total of 18 “FLAGS”, corresponding to 2.7 m² of module surface.
- The protective glass of the modules is substituted for by PMMA “Plexiglass”.

³⁵ Ethyl Vinyl Acetate; material for embedding PV cells

- All the additional material and energy inputs necessary for the actual installation of the “solar flags” (steel plates and cables, electrical wires, fuels, etc.) are included in the analysis, and the data are those provided by BUSI Impianti S.p.A.
- Conversely, because of the prototype nature of the demonstration objects, the labour costs and material inputs for the necessary research and development (architectural design, small-scale prototypes, etc.) were left out of the analysis.
- The rechargeable batteries and LED lamps that are also part of the finished installation were not included in the analysis, since these were considered optional, and their inclusion would have strongly affected the results, both on the local and on the life cycle scale of analysis. In fact, in the demonstration site virtually all the energy produced by the panels during the day is then used at night for the lighting of the objects, but this is only one possible use for it, a more general case being that in which the electricity is fed back to the grid via an inverter.

5.3.6 Additional Assumptions On Demonstration Object -“Solar Information Plate” in La Spezia:

- The PV modules employed for the demonstration object are the CIS modules produced by Wuerth as described above, and all the relative assumptions apply.
- The installation consists of a total of 6 modules, corresponding to 1.44 m² of module surface.
- The protective glass of the modules is screen-printed, making 15% of the photoactive surface inactive; the assumed electrical conversion efficiency is consequently lowered to 9%.
- All the additional material and energy inputs necessary for the actual installation of the “solar information plate” (steel plates and cables, electrical wires, fuels, etc.) are included in the analysis, and the data are those provided by BUSI Impianti S.p.A.
- Conversely, because of the inherent difficulty in quantifying them, the labour costs and material inputs for the necessary research and development of the final chosen demonstration object (architectural design, small-scale prototypes, etc.) were left out of the analysis.
- The rechargeable batteries and LED lamps that are also part of the finished installation were not included in the analysis, since these were considered optional, and their inclusion would have strongly affected the results, both on the local and on the life cycle scale of analysis. In fact, in the demonstration site virtually all the energy produced by the panels during the day is then used at night for the lighting of the objects, but this is only one possible use for it, a more general case being that in which the electricity is fed back to the grid via an inverter.

5.4 The Method Of Analysis

The analysis consists of a thorough Life Cycle Assessment (LCA), carried out in accordance to the relevant recommendations of the International Standardisation Office (EN ISO 14040 and updates), and is performed in four stages: (1) definition of goals, (2) inventory analysis, (3) impact assessment, and (4) improvement analysis.

In particular, as regards the evaluation of the impact caused by the mass and energy flows associated with the life cycle of the analysed system (stage 3), the choice of the method to be applied is often left to the analyst. This, of course, in its turn strongly affects the interpretation stage and whatever conclusions can be drawn from the results of the LCA.

It is the authors' firm belief that no single method is by itself capable of providing an all-encompassing picture of the environmental performance of a technological system, each and every one only being appropriate within a limited field of applicability. The choice is then made to perform a multi-criteria analysis, in which the results of several different methods are compared and integrated. Using their original "*SUstainability Multicriteria Multiscale Assessment*" (SUMMA) approach (Ulgiati et al., 2004), the authors employed a selection of methods, which offer complementary points of view on the complex issue of environmental impact assessment. The inventory analysis (stage 2) forms the common basis for all the subsequent impact assessments, which are carried out in parallel, thus ensuring the maximum consistency of the input data and inherent assumptions. The calculated impact indicators are then interpreted within a comparative framework, in which the results of each method are set up against each other and contribute to providing a comprehensive picture on which conclusions can be drawn. In the following paragraphs the individual methods are briefly introduced.

5.4.1 Material Flow Accounting

Each flow of matter supplied to a process has been extracted and processed elsewhere, and additional matter is moved, processed and disposed of. Accounting for the material directly and indirectly involved in the whole process chain has been suggested as a measure of environmental disturbance (Hinterberger and Stiller, 1998). A quantitative measure is provided by means of *Material Intensity factors*, measured in kg/unit, which are calculated for the two main categories of input matter, namely: abiotic and water.

5.4.2 Embodied Energy Analysis

Not all of the energy invested in a production process is available to the user, since a large part of it has been used up and is not contained in the final product. Energy analysts refer to the total commercial energy directly and indirectly used up as to "embodied energy" (Slessor, 1974; Herendeen, 1998). The resulting indicator, Gross Energy Requirement (GER), represents the total commercial energy directly and indirectly used up in the production chain, and is a measure of energy efficiency of fossil fuel utilisation, as well as a proxy for the depletion of fossil fuel reserves. In the specific case of energy-producing devices, such as the PV systems under study, an *Energy Pay-Back Time* (EPBT), measured in years can also be calculated as the ratio of the GER to the total energy produced by the device in one year, under normal working conditions.

5.4.3 CML 2 baseline 2000

In this method (developed by the Centre of Environmental Science of Leiden University, NL), several ecological impact categories are considered, and the possible environmental damage caused by the airborne, liquid and solid emissions of a process over its whole life cycle is evaluated by means of appropriate indicators. These indicators are based on equivalence factors to reference compounds, the contribution of which to the relative impact category is well known. In particular, we will focus our attention on the important categories of *Global Warming Potential* (GWP), measured in kg(CO₂-eq), *Acidification Potential* (AP), measured in kg(SO₂-eq) and *Freshwater Ecotoxicity Potential* (EP), measured in kg(1,2-dichlorobenzene-eq).

5.4.4 Emergy Synthesis

Odum (1988, 1996) introduced the concept of emergy as "the total amount of available energy (exergy) of one kind (usually solar) that is directly or indirectly required to make a given product or to support a given flow". Emergy is measured in "solar equivalent Joules" (seJ), and also accounts for the free environmental inputs (sunlight, wind, geologic cycle) which are

usually neglected in more traditional energy analyses, as well as economic inputs, translated into energy terms by means of appropriate energy/currency ratios. This concept of embodiment supports the idea that something has a value according to what nature invested into making it. The amount of input energy dissipated per unit output is called Specific Energy, measured in seJ/unit, or Transformity, measured in seJ/J, and can be considered a "quality" factor which functions as a measure of the intensity of biosphere support to the product under study (also referred to as "Ecological Footprint").

5.5 RESULTS AND DISCUSSION

5.5.1 Definition of goals

As already discussed while describing the analysed systems above, the goal of the present analysis is two-fold.

Firstly, the environmental and thermodynamic performance of the three different PV technologies that were employed in the PVACCEPT project, i.e. semi-transparent mc-Si ("POWER Cell" modules manufactured by Sunways), CIS (modules manufactured by Wuerth), and CdTe (modules manufactured by Antec), are assessed per se, by considering a standard unmounted square metre of PV module in each case. This is done in order to compare and discuss the results for the three kinds of modules on a level ground, so as to highlight the pros and cons of each and to be able to reach conclusions of wider interest and applicability.

Secondly, the analysis is extended to two complete, finished demonstration objects (the "solar flags" in Porto Venere and the "solar information plate" in La Spezia), in which the two mc-Si and CIS modules are respectively employed. This allows the assessment of the environmental and energetic performance of the PV modules in actual working conditions, when embedded in the kind of design-oriented structures for which they were intended and are particularly suited.

5.5.2 Inventory analysis

As far as the construction phase of the "typical" frameless PV modules is concerned, the main input items necessary for the three technologies are listed in the table below:

mc-Si modules	CIS modules	CdTe modules
Si wafers (B-doped)	Mo	ITO (In ₂ O ₃ /SnO ₂)
POCl ₃	CdS	Sn
SiH ₄	Cu	CdS
NH ₃	In	CdTe
Al/Ag alloy	Ga	CdCl ₂
EVA	Se	Ni/V alloy
Glass	ZnO	Sb ₂ Te ₃
Electricity	EVA	EVA
	Glass	Glass
	Electricity	Electricity

Table 5.1: Main input items (for explanation please see section 5.7)

Exact amounts for the inputs are not listed here because of the confidentiality agreement requested by the manufacturers.

When the analysis is extended to the complete demonstration objects, further inputs are accounted for, i.e.: steel and/or aluminium for the frames and support structure, copper, rubber and plastics for the contact boxes and cables, and fuel oil for transport and installation. Moreover, as already mentioned while discussing the assumptions, in the case of the "solar flags" the glass input is substituted for by plexiglass.

5.5.3 Impact assessment

All the calculated environmental impact and performance indicators (EPBT, MI factors, Transformity, GWP, AP, EP) are illustrated in Figures 1 to 6.

The choice was made to include in each Figure the results for all the investigated systems, in order to highlight on the one hand the comparison between the three technologies per se, and on the other hand the difference between their application to “typical installation” cases and to the PVACCEPT demonstration objects. As previously explained in the “Assumptions” section, the results for the Si-based systems are given in two separate columns, one for the “worst case” scenario and one for the “best allocation” scenario. It should also be noted that the “worst case typical installation” scenario is also essentially representative of older-generation PV systems; therefore, an interesting comparison can be attempted in this respect, too. Data for CIS modules by Wuerth are taken from a pilot production line, and therefore the resulting indicators must be taken with care, since the production conditions are not yet optimised.

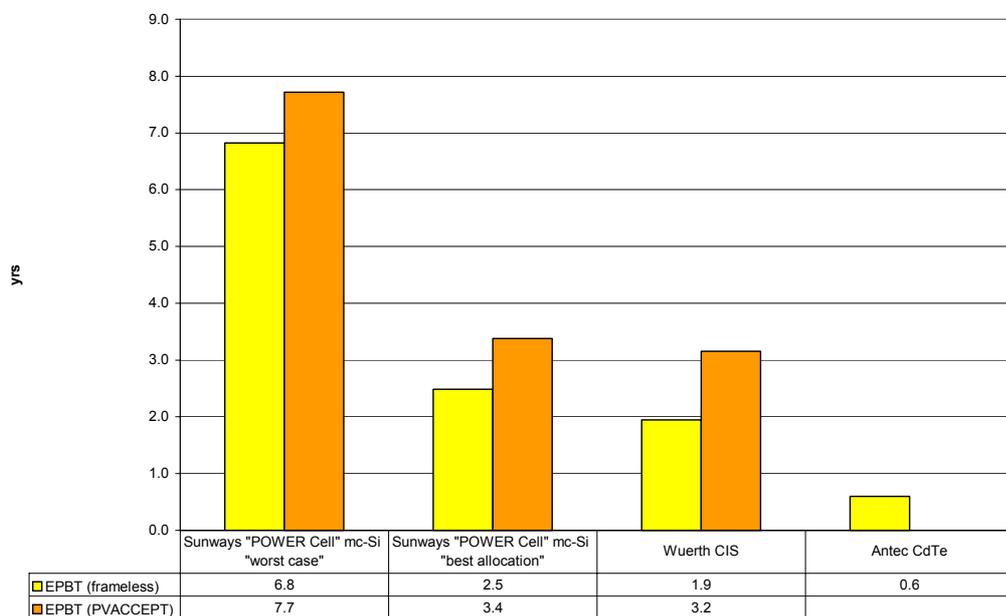


Figure 1 – Energy Pay-Back Time

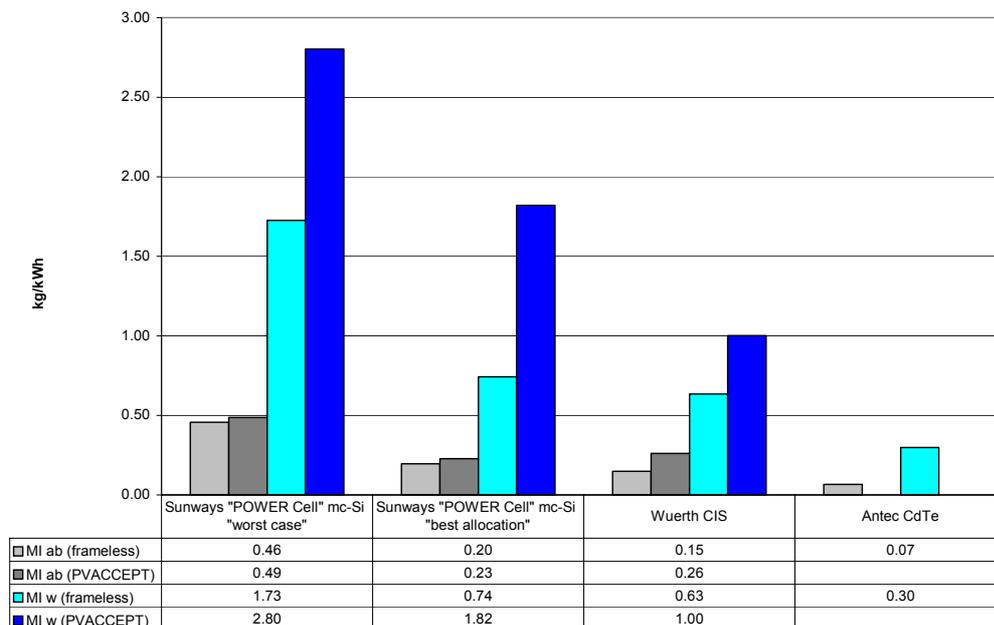


Figure 2 – Material Intensity factors

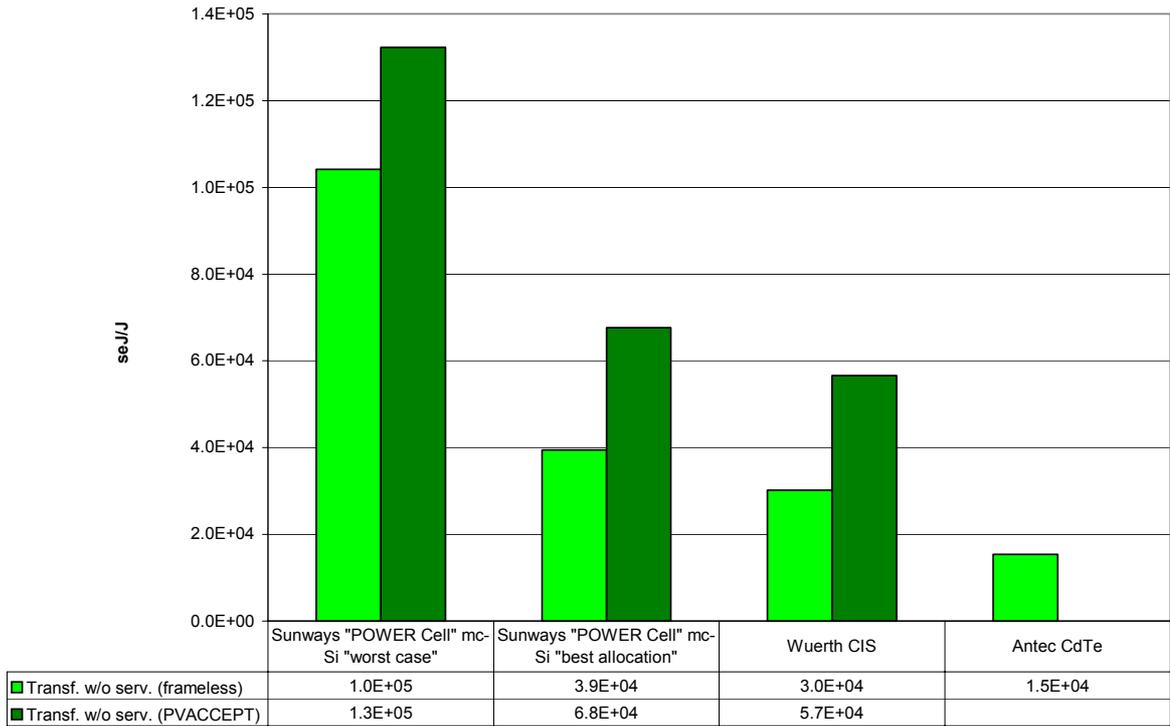


Figure 3 – Transformativity

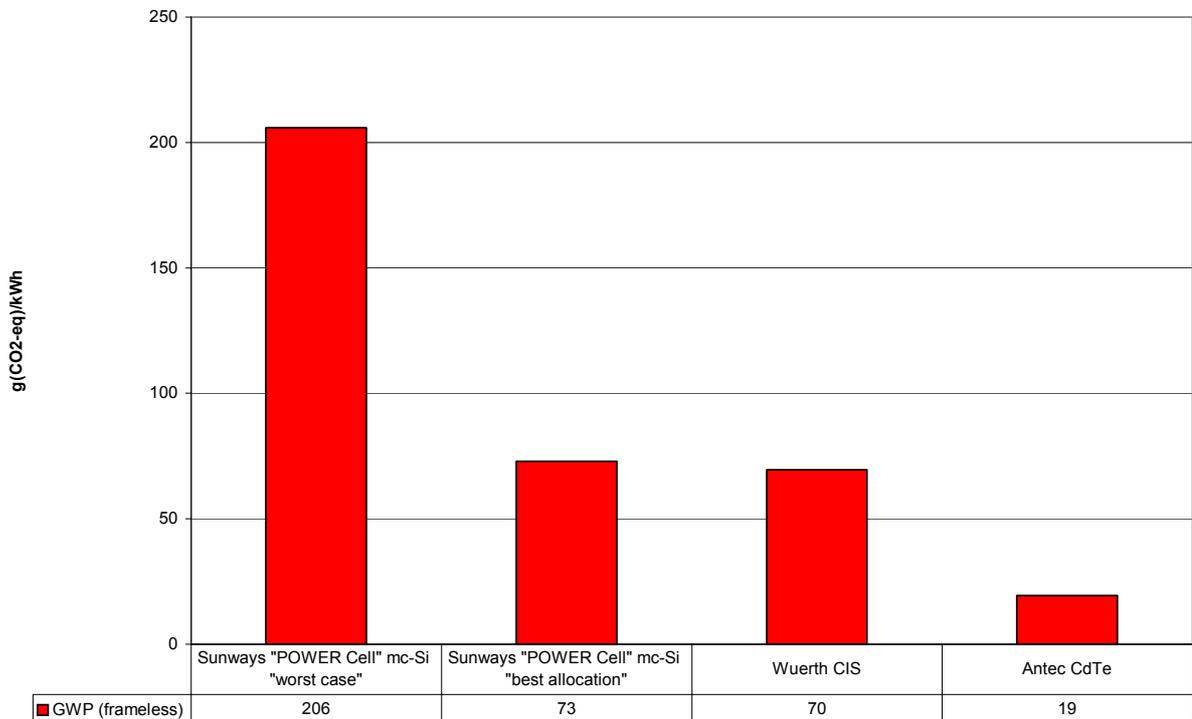


Figure 4 – Global Warming Potential

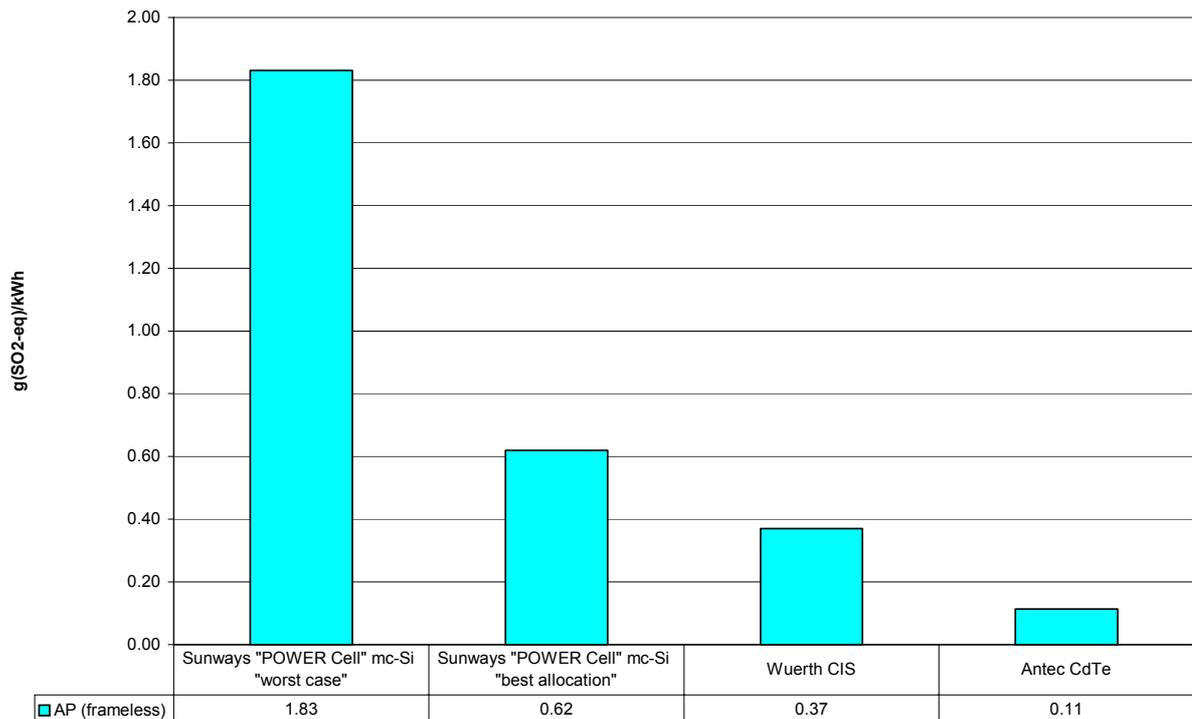


Figure 5 – Acidification Potential

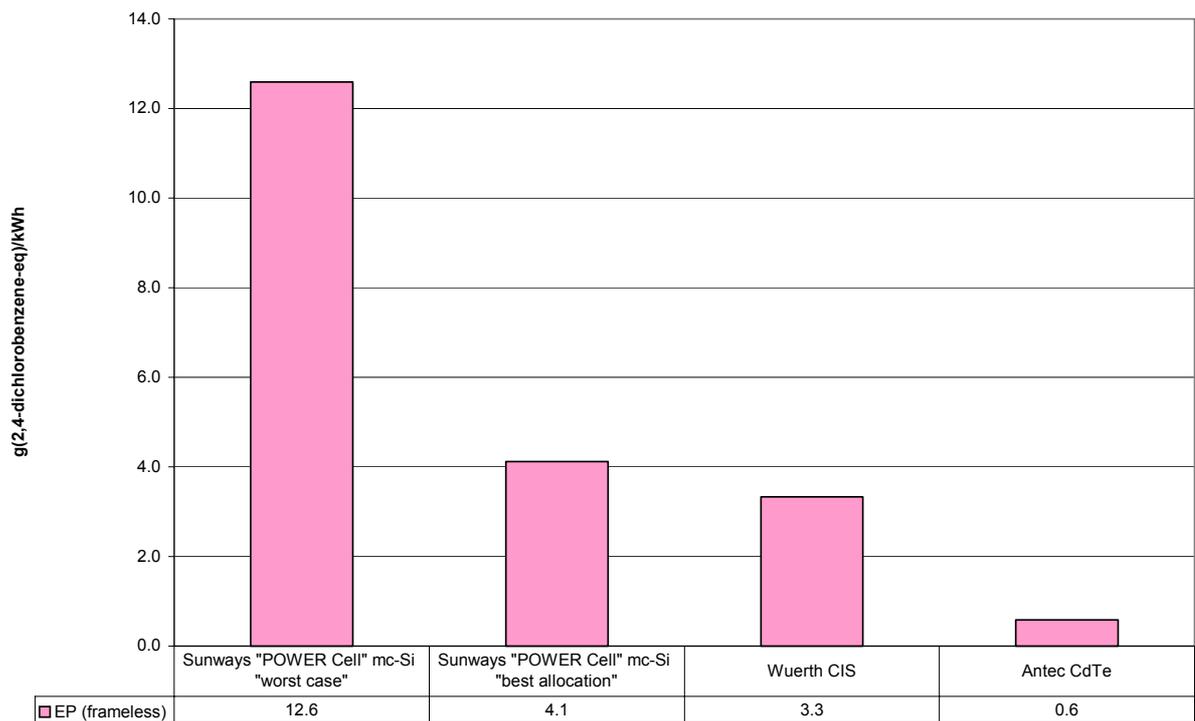


Figure 6 – Freshwater Eco-Toxicity Potential

To all the calculated indicators, the following general considerations apply:

- A marked difference is always present between the two allocation scenarios for the mc-Si systems, confirming the very large influence that the wafer production process has on the final environmental and thermodynamic performance of such systems.
- The performance of thin film systems (CIS and CdTe) can already be considered satisfactory, especially considering their early developmental stage. In fact, both compare

favourably to the well-established Si systems, especially when the comparison is made to the more conservative “worst scenario”. Modern non-transparent Si modules are more efficient (14% vs. 10%), and would be characterised by correspondingly better calculated indicators per kWh, however the relative orders of magnitude of the comparison would not change significantly. One important reason for the comparatively low impact indicators exhibited by thin film systems lies in the very small quantities of the chemical compounds that are deposited on the glass panes, an inherent advantage of thin film technologies.

- As far as “typical installation” stand-alone unmounted modules are concerned, the best environmental and thermodynamic performance is invariably that of the CdTe thin film modules, in spite of their lower efficiency. It is important to note that this is also true for the calculated Eco-Toxicity Potential indicator. In fact, even though this technology is based on the much-dreaded element cadmium, it must be realised that the thin CdTe layer is encapsulated within sealed glass panes, and that CdTe itself is a very stable compound with a virtually zero vapour pressure at normal operating temperatures, and a very high 1700°C melting point. Thus, the potential Cd emission from CdTe PV panels is essentially negligible; furthermore, this should be put into perspective by comparing it to the typical routine emission of approx. 14 µg(Cd)/kWh for coal-powered thermal power plants.
- Moving on to the finished demonstration objects, the inevitable negative influence of the supporting structure and of the additional necessary material and energy inputs reflects in the worsening of all the calculated indicators. However, in order to correctly frame the results of the analysis of the completed demonstration objects, one must keep in mind the fact that these are one-piece production units, the energy and production costs of which are inevitably higher than run-of-the-mill products. It is also interesting to note that the impact indicators for the finished objects still compare favourably to the “worst scenario” values for the unmounted Si modules, which can be regarded as representative of average literature values for PV electricity of a few years ago. This is a clear indication that PV technology is advancing, and that new applications such as these are not a mere vision but could well be introduced on a wider scale in the near future.

5.5.4 Improvement analysis

The first consideration that applies to all analysed systems, and in particular to design objects such as the ones employed for demonstration purposes in the PVACCEPT project, is that larger production runs would certainly improve their environmental and thermodynamic performance. What could be regarded as a purely economic matter is instead closely related to the environmental impact too, since process optimisation can reduce wastes and hence the requirement for environmental support. This is especially true for the thin film systems, which are not burdened by the intrinsically energy intensive step of silicon wafer production.

One particular point of possible improvement for CIS module production could be a reduction of the electricity consumption, which by itself is responsible for the largest percentage of the overall energy requirement, and consequently also of the related GWP and AP. Furthermore, in the case of a future large upscaling of production, the limited global availability of raw indium could possibly become a matter of concern, unless recovery of this element from decommissioned modules is made standard procedure.

For Si-based systems, on the other hand, the one most important chance of improvement lies in the more widespread use of the more energy-effective direct method of PV-grade Si production for the wafers.

Last but not least, the need for the development of specific recycling strategies for the decommissioning of PV modules (especially for thin film types) is recognised. Of course, this

point is also economically linked to the aforementioned upscaling of production, but it should not be underestimated if these systems are bound to turn into anything more than a niche product.

5.6 Conclusions

The overall results of the Cycle Energy and Environmental Impact Assessment performed by UNISI indicate a possible rosy future for architecturally-integrated applications of advanced PV technology. A wider application of these systems could not only spur public acceptance and awareness, but also actively contribute to the renewable energy budget of our urban environments.

5.7 References

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Explanation section 5.5.2:

Cu = Copper

Ga = Gallium

In = Indium

Mo = Molybdenum

Se = Selenium

Sn = Tin

SiH₄ = Silane

NH₃ = Ammonia

Al/Ag alloy = Aluminium/silver alloy, used for contacting silicon solar cells

ZnO = Zinc oxide, used as transparent contact film material

ITO (In₂O₃/SnO₂) = Indium/tin oxide, used as transparent contact film material

CdCl₂ = Cadmium chloride, used for activation of CdTe thin-film solar cells

Ni/V alloy = Nickel vanadium alloy, used for contacting CdTe thin-film solar cells

Sb₂Te₃ = Antimony telluride, used as intermediate layer in contacting CdTe thin-film solar cells

6 Acceptability Study

This chapter is a shortened version of the full report of the acceptability study. The latter will be shortly available online on the websites of the two author institutions IÖW (www.ioew.de) and Ambiente Italia (www.ambienteitalia.it). The report is also likely to be published in the IÖW *Schriftenreihe* in 2005.

6.1 Introduction and Contents

The acceptability study was divided in two parts, carried out respectively before and after the construction of the demonstration objects. The first part of the acceptability study (ex-ante) was carried out in 2001. It was based mainly on questionnaires for experts and local people concerning their knowledge on PV, their opinion on aesthetic factors and their theoretical willingness to accept PV also on old buildings, monuments, and in landscape. Further information was gathered through direct interviews and talks with experts and key persons at the workshops held both in Germany and Italy in October and November 2001.

This ex-ante study was crucial to prove several basic theses of PVACCEPT, i.e.:

- Design and aesthetic aspects are important acceptability factors for the diffusion of PV, which have been underestimated so far;
- PV can be installed even at historical buildings, if this is done with an appropriate design;
- Tourist areas are well suited for increasing the awareness / knowledge of PV (multiplier effects).

Other clear indications were that on the one hand the local population is strongly in favour of solar technologies and would welcome more local promoting activities, on the other hand the level of knowledge of the technology and of existing support programmes is still low (lower in Italy than in Germany). These results encouraged the continuation and optimized the orientation of PVACCEPT research and demonstration activities. They are presented in section 6.5.1.

The second part of the acceptability study concentrated very much on evaluating the effects of the built demonstration objects on acceptability, i.e. on the actual acceptance of the innovative developed PV systems. Questionings e.g. of architects as important intermediary players, as well as questionings of local population and tourists at the demonstration sites, were part of this second (ex-post) study. Additional information from experts and other key persons was gathered at the workshops / SME training in Porto Venere and Marbach am Neckar. The results of the ex-post study are presented and discussed in detail in section 6.5.2.

All survey target groups confirmed the results of the first part of the study, i.e. in terms of importance of design and of applicability of PV on protected buildings, if design is appropriate. This was also confirmed by the fact that both architects and tourists / local population showed a (very) high degree of acceptance of the built demonstration objects.

Moreover, architects and experts provided valuable information for the applicability and transferability of project results by indicating:

- Gaps of current information / needs for further education and training;
- Target groups of PV applications and their motivations;
- Success factors and barriers for PV diffusion as seen by clients;
- Current bottlenecks and future opportunities of administrative and authorization processes;
- Priorities for the design of innovative and new PV installations.

6.2 Acceptance and Acceptability

The terms of *acceptance and acceptability* are often mixed in the habitual language use. In some scientific debates they are well differentiated, but unfortunately not always in the same way.

In the context of sociological research the term *acceptability* is often linked with the prospective estimation e.g. of measures planned in the future. As the population or target group cannot have any experiences with the measures, the term *acceptability* describes this construct of attitudes. *Acceptance* on the other hand denotes the statements given after the introduction of a measure as well as the behavioural reactions (Schade / Schlag 2001³⁶, Schrader 2001³⁷).

As it has already been proved in many investigations, there is a significant gap between individual attitude and behaviour especially when it concerns environmental awareness and behaviour (see e.g. in Kuckartz 1998³⁸). Values that are agreed with theoretically are not automatically considered in daily acting. This leads to a divergence between acceptance and acceptability of environmental measures.

Within this study we follow the definition of Lucke who uses the term of *acceptability* as acceptableness of a social, political, economic etc. aim, while *acceptance* means the willingness to agree to a concrete person, measure, decision etc. (Lucke 1995³⁹, 104 et seqq).

Due to this typology, the object of acceptance in our study is photovoltaics in general and in addition specially designed PV solutions. The subjects of acceptance are on the one hand the population in our research regions (inhabitants, tourists, possible investors) but on the other hand intermediates or “crucial” decision-makers like authorities, architects and craftsmen. In addition these actors can play an important role as relevant stakeholders for the decision of investors for or against PV (“multipliers”). At last further framework conditions, like regulations, authority processes, costs etc., are important context relations that influence acceptance and that one has to be aware of.

6.2.1 Acceptance of Renewable Energies

Regardless of the success of actual implementation of renewable energies in the EU member states, there are (still) a lot of political and societal barriers and special acceptance problems on the one hand, but on the other hand a relatively high acceptance of renewable energies and especially of solar technologies in general.

According to the results of a representative survey 85 % of the German population favour the advancement of renewable energies (Emnid-Institute, 2004⁴⁰). Those figures underline the public interest in climate protection and a general acceptance of renewable energies. Another capacious study of the *Bundesumweltministerium* (Kuckarts & Rheingans-Heintze 2004⁴¹) affirms that two thirds of the German population - and one third even resolutely - argue for the

³⁶ Source: Schade, Jens / Schlag, Bernhard (2001): Akzeptierbarkeit von Nachfragemanagement- und Preismaßnahmen in europäischen Städten. In: Internationales Verkehrswesen, Nr. 3, S. 72-77, 2001

³⁷ Source: Schrader, Ulf (2001): Konsumentenakzeptanz eigentumsersetzender Dienstleistungen: Konzeption und empirische Analyse, Frankfurt a.M.

³⁸ Source: Kuckartz, Udo (1998): Umweltbewußtsein und Umweltverhalten, Berlin

³⁹ Source: Lucke, Doris (1995): Akzeptanz – Legitimität in der „Abstimmungsgesellschaft“, Opladen

⁴⁰ Source: Emnid Institute (2004): Opinion poll executed by Emnid-Meinungsumfrageinstitut for Greenpeace Magazin, Hamburg

⁴¹ Source: Kuckarts, Udo / Rheingans-Heintze, Anke (2004): Umweltbewusstsein in Deutschland 2004, Studie im Auftrag des BMU und UBA, Berlin

extension of the renewable energy sector. The IPSOS-Institute approves those numbers in an opinion poll for the *World Wildlife Fund* (IPSOS 2003⁴²). A similar result is shown by the recent representative survey conducted by ISES⁴³ Italia and Kyoto Club in Italy. Asked about their opinion on the 2010 EU target of doubling the energy production from renewables, 46 % of respondents answered that Italy should do more, because it is a large importer of energy. Another 42 % responded that Italy should respect the EU targets and just 5 % think that this would negatively affect the national economy (ISES / KC 2003⁴⁴). In contrast only 20 % of the French people see a priority for renewable energies within their environmental policies⁴⁵ (ADEME 2004⁴⁶).

However, the acceptance of renewable energy in Germany is ambivalent too, even though the general approval seems strong at the first sight. But asking people's opinion regarding specific matters of the renewable energies, it comes to different results. Behind the general approval one can find often more concerns for specific cases. Here we have to consider the well-known gap between theory and practical experience or between attitude and active behaviour. In terms of social science (e.g. Fischer 1993⁴⁷) it is the so-called "*NIMBY effect*" (not in my backyard)⁴⁸, that means that renewable energies often have a very high acceptance in general as far as they are not implemented in front of the homes or within the range of vision of the respondents. Here the difference between attitude- and behaviour-oriented acceptances has to be regarded (see section 6.2).

Factors, which influence the acceptance of renewable energies, are of general, economic, ecological and socio-cultural nature.

An example of economic factors is given by the willingness-to-pay of the Italian population with respect to the purchase of green electricity: While almost 70 % of respondents are generally in favour of buying green electricity, just 14 % are ready to pay more than 10 € per month for it (ISES / KC 2003).

A typical issue of ecological acceptance often recurring in public debate is given by the case of wind energy. The acceptance of windmills concerning the natural scenery as a popular example divides Germany more or less into equal halves: 49 % are bothered by windmills, whereas 51 % do not see a negative impact on the characteristic landscape (Kuckarts / Rheingans-Heintze 2004).

⁴² Source: IPSOS-Meinungsumfragesinstitut (2003): Opinion poll executed by IPSOS-Meinungsumfrageinstitut for WWF [World Wildlife Fund], Mölln

⁴³ ISES = International Solar Energy Society

⁴⁴ Source: ISES/KC (2003): Opinion poll executed by ABACUS for ISES Italia (International Solar Energy Society Italy) and Kyoto Club; also published in RAPPORTO ENERGIA E AMBIENTE 2003 - Le fonti rinnovabili, ENEA (Ente per le Nuove tecnologie, l'Energia e l'Ambiente), Rome, 2004.

⁴⁵ Responding the question "Which actions must carry out in priority the government in the field of the environment?" (ADEME 2004)

⁴⁶ Source: ADEME (2004): Perception and acceptance of RES in France, statistical survey; Louis Harris Institute

⁴⁷ Fischer, Frank (1993): Bürger, Experten und Politik nach dem „Nimby“-Prinzip: Ein Plädoyer für die partizipatorische Policy-Analyse, in Héritier, Adrienne: Policy-Analyse. Kritik und Neuorientierung. PVS-Sonderheft 24., Opladen, Westdeutscher Verlag, P. 451-470

⁴⁸ Phrase attributed to Walton Rodger and widely linked to British conservative politician and Minister Nicholas Ridley (1929-1993). There are always those who attempt to exclude themselves from the consequences of policies, which in general they support. NIMBY, as an observation about the behaviour of both individual citizens and their parliamentary representatives, was gleefully applied to many public figures. Nimby effect describes a political and ethic position, which is concerned not to tolerate certain problems in the immediate surroundings.

As a final example of socio-cultural influencing factor, the individual knowledge about renewable energies is relevant. The BMU study proves that e.g. 48 % of the German population see the reason, why they do not purchase green power, in that they are not informed well enough (Kuckarts / Rheingans-Heintze 2004). Similarly, higher education in Italy seems to be connected with higher acceptance: The ISES / Kyoto Club survey indicates that most people in favour of a stronger commitment towards renewable energy by Italy have high education, are independent workers and live in the North-East (ISES / KC 2003). The conclusion is that a higher knowledge level leads to a higher acceptance.

6.2.2 Acceptance of PV Technologies

Within the renewable sector solar energy has got an especially positive image (Möller 1999⁴⁹). A solar module can be seen as a symbol for a “peaceful” and “conflict-less” change within the energy industry, as it stands - contrary to the conversion of other energy resources - for a long-term, quite, clean, emission-free, maintenance-free, peripheral operation in a small scale that everyone is benefiting from. According to P.M. science magazine 96 % of the German population approve solar energy (*P.M. Wissenschaftsmagazin* 2004⁵⁰). 81 % even believe that if laws would require solar modules on every roof, the technology could be a real alternative to conventional energies. Also in Italy solar energy has an extremely positive image among the population. 58 % of the respondents of the ISES / Kyoto Club survey think that Italy should invest and focus on solar energy as principal technology to respond to the energy needs of the country (ISES / KC 2003).

Asking French people why they would disagree to install PV on their houses, 31 % reply that PV is unsightly, 16 % that PV is too expensive, 15 % that they do not want any refurbishment building work, and 6 % that PV is unsuitable for the French climate (ADEME 2004). Obviously there are still barriers when it comes to the behaviour-oriented level. It is remarkable that one can especially note the fact that a higher percentage of respondents attributes to the aesthetic design a higher importance than to the economic factor.

Orientating to the typology of acceptance factors mentioned above, we come to following factors concerning the acceptance of PV:

- **Factors concerning the general attitude-oriented acceptance**

General attitude-oriented acceptance is widespread since people reflect PV as environmental friendly energy conversion and as a political and local action against climatic change. The French ADEME study proves this impression, saying that in France 90 % of the interviewed persons agree that PV should be installed on every roof of public buildings and 83 % state that they could imagine having a PV installation on their own roof (ADEME 2004). In Italy, a striking majority of 89 % of respondents would be in favour of a law obliging the installation of solar systems in all new buildings (ISES / KC 2003). Obviously general acceptance of PV can also be lowered by the “*NIMBY effect*” especially when PV modules are installed close-by.

- **Factors concerning the technical and economic acceptance**

In the centre of the discussion about the diffusion of PV technical and economic aspects are usually dominating. Solar technology still affords quite an economic investment. Compared to the other RES⁵¹ technologies it is the most expensive technology so far,

⁴⁹ Source: Möller, Lars (1999): Akzeptanz von Solaranlagen; www.iundm.de/lars, 1.12.2004

⁵⁰ Source: P.M. Wissenschaftsmagazin (2004); Opinion poll executed by TNS-Emnid-Meinungsumfrageinstitut

⁵¹ RES = Renewable Energy Sources

based on conventional energy prices respectively cost analysis (e.g. not regarding external effects).

The cost effectiveness depends highly on the kind and level of supporting programmes and subsidies. The economic barrier can therefore be highly dominant or negligible for potential investors. The most important technical and/or economic barriers are (based on *Forum für Zukunftsenergien* 1997):

- Low level of conventional energy prices (based on actual primary energy resources);
- Centralized energy systems and large-scale power plants;
- Research, development and support (loan) policies of RES;
- Technical and economic (e.g. feed-in payment, costs for grid use) conditions of the feeding into the electricity grid;
- Fluctuating offer of RES energy (depending on climatic factors);
- Further legal and administrative framework conditions (e.g. concerning technical approval etc.).
- In a wider focus of economic barriers the market compositions and the (economic) power structure of the existing set of market players in the energy sector has also to be taken into account (see Hirschl / Hoffmann 2001⁵²).

- **Factors concerning the ecological acceptance**

(e.g. compatibility of PV with nature conservation)

There is big evidence from the ecological point of view that PV technology has an ecological benefit; for instance, according to German researchers, PV technology has a CO₂-reduction potential of 60 % per kWh, comparing photovoltaic power generation to the current energy mix generated by German power plants (Hagedorn 1997, Quaschnig 1999). An often heard argument against PV is that the life cycle assessment has a poor balance. Indeed PV technology has a longer energy pay-back period than most other renewable energies. Since mass production and research continue the tendency, however, is going down.

Since the newly amended Renewable Energy Act became effective in Germany in 2004, building solar power plants in the landscape (and not on / at buildings) gets more lucrative, which is reflected by a distinct tendency towards such installations. From the point of aesthetic and ecological awareness this could be a turning point. A *Forsa* opinion survey states that 66 % of the interviewed persons do not agree with PV in open space (Solarenergie Förderverein 2003). In 2004 e.g. the inhabitants of Schmiechen, Bavaria, voted against a building permit for a PV plant in open space (Solarenergie Förderverein 2004). With this kind of PV plants the technology might have to face new ecologically motivated acceptance problems.

- **Factors concerning the socio-cultural acceptance**

Attitudes and perceptions concerning the appearance of PV also play a crucial role. PV technology appears in different designs. Design aspects, which affect the acceptance, are colour, material, scale, form and the immediate local context of a PV module or plant. The more visible a PV plant is, the more importance is attributed to its design. Concerning design, the socio-cultural background is important.

⁵² Source: Hirschl, Bernd / Hoffmann, Esther (2001): Vorwärts und nicht vergessen. Erneuerbare Energien und ihr Beitrag zu einer nachhaltigen Entwicklung. In: Ökologisches Wirtschaften Spezial: Energiewende in Sicht?; Ausgabe 3-4, P. 2-3/2001, München

Knowledge and available information concerning solar energy and PV systems also influence the social acceptance of this technology. People have to know about the functioning and potentials of PV to be able to accept and/or use it.

Imitation can be a factor of PV diffusion. To see that the neighbour installs PV on his roof and to hear about his good (financial) experiences, seems to have impact on acceptance.

Recapitulating the issue of acceptance of PV, one has to state firstly that there is a very strong public approval for PV technology in general. Acceptance-related problems appear when it comes to a more concrete and detailed approach. Acceptance is influenced by factors and barriers on different levels (economic, ecological, socio-cultural). Considerable lack of research exists regarding these aspects of PV acceptance. Many of them, e.g. the influence of knowledge, are not tackled at all. Knowing the impacts of these factors will enhance the possibilities to raise PV acceptance further. PV design has to be considered more as an evident acceptance factor.

6.3 General Methodological Approach

The general methodological approach of the acceptability study is linked with the central research aspects like design, knowledge, and barriers and chances in tourist areas. Furthermore investigation of the role of important intermediates plays a crucial role. Generally the intention was to use the same methods in the case studies in Germany and Italy. This could be realized in most cases; some methodological differences will be explained. The design, contents, and also methods of the second part (ex-post) were in a way influenced by the outcomes of the first part (ex-ante); this interrelation will also be described in the following sections.

6.3.1 Methods of “Ex-Ante” Study

The first part of the acceptability study was carried out in the first work phase of the project, (July until December 2001) and had two main aims: on the one hand the general investigation of acceptance-related questions, and on the other hand the preparation of the local activities of PVACCEPT, i.e. the implementation of PV in the selected regions in Germany and Italy. The investigation of the acceptance implicated a mixture of investigation and influencing. This was partly due to the fact that main elements of the project itself (e.g. the workshops) were important inputs for the acceptability study. In the “ex-ante” study so-called “experts” and “normal population” were questioned. While experts are an important part of the context of acceptance, the population represents the subject of acceptance in our perspective (see also section 6.2).

The main subjects within the “ex-ante” study were knowledge, design and also the context of PV in protected and in tourist areas. It included three main empirical blocks, described in the following.

6.3.1.1 Workshops and Expert Talks

One central element of the first project phase was carrying out workshops with local participants in the Italian and German research regions. These workshops had multiple functions, which had to do with the acceptance of PV in general and with the acceptance of the planned project(s) respectively the building of PV demonstration objects. In addition, the workshops should improve (“actively”) both mentioned levels of acceptance (PV in general and project-related). The “passive” function of the workshops was to get to know the specific problems, barriers and attitudes of local people concerning PV technology (via discussions and observation). The intention of the workshops was not only to bring together all the important key actors regarding the execution of the research project and to inform all the participants

about the project, but also to provide a common level of knowledge concerning PV technology and to present and discuss a first selection of possible PV demonstration sites.

6.3.1.2 Questioning of Regional Key Persons

The project-related experts or key persons were additionally interviewed by using a standardized questionnaire. The experts had been chosen because of their possible - positive or negative - influence on the feasibility of the ongoing project and the building of demonstration objects. The aim of the questioning was to gain a deeper insight into the PV-related knowledge and the attitudes concerning the aesthetic appearance of PV modules as well as PV installations in tourist areas. Therefore nearly identical questionnaires were sent to all invited participants and also distributed during the workshops in both countries.⁵³

The amount of return was the same in Italy and Germany: 23 of the addressed experts answered the questionnaire in each country - nearly half of the invited persons. Most of the people had participated in the workshops. In both cases a wide allocation regarding the selected invited institutions could be reached.

6.3.1.3 Questioning of Local Population (“Non-Experts”)

The questioning of the local population (“non-experts”) of the research regions (Germany: island of Rügen, Italy: involved communes in Liguria) represents the third and most extensive empirical part. The aim was to know more about people’s knowledge about PV, their attitudes concerning the design of PV modules and the installation of PV in tourist areas in general. The issues of the questioning and their composition were almost similar to the questioning of experts. Nevertheless some special characteristics of the inquiry groups had to be considered, on the one hand regarding their status as “non-experts”, on the other hand considering country-related (respectively information-related) differences. The questionings of the local population covers a larger amount of respondents compared to the expert questioning.

The execution problems mentioned above, especially the degree of knowledge, had different appearance and frequency in the two countries. Therefore we chose different execution methods: in Germany we made telephone surveys, in Italy a written questionnaire was distributed. According to the size of the regions the number of households was limited. For the telephone survey it turned out to be quite challenging to find enough people who were in addition able to answer the selecting questions on PV technologies in the beginning. Due to the different methods we received data bases different in quantity (in Germany a set of 222 and in Italy a set of 81) and in quality; nevertheless plausible and comparable results could be achieved.

6.3.2 Methods of “Ex-Post” Study

The design of the second part of the acceptability study built up on the main results of the first part and the developments and changes during the project. Due to the fact that the project could not realize PV installations in our both research regions⁵⁴, the empirical design had to be adjusted. Furthermore the focus was shifted from considering specific developments in the research regions to more general aspects.

⁵³ Little differences between the German and Italian questionnaires referred only to some phrases concerning the different knowledge of the subject and use of terms.

⁵⁴ In Germany no solar project could be realized on the island of Rügen, but instead one in Marbach, Baden-Württemberg, was built (see chapter 4).

In addition we used the findings of the first part as starting points for developing the design of the second study. The main results of the first part as described in section 6.5.1 deal with the following important acceptance factors and related questions:

- **Knowledge**
How can we broaden the knowledge of people about solar technology and who can play an important role?
- **Design**
How can we overcome the design restrictions and broaden the knowledge of already existing possibilities?
- **Barriers and chances in tourist areas**
How can we improve the actual and restrictive situation, overcome the barriers and then use the chances of multiplier and publicity effects of PV implementation in tourist areas?

One main subject of the ex-post study was to focus on important intermediaries for the diffusion of PV and for the context of design and architectural implementation: the architects (see also Hold 2002⁵⁵). In addition the administrative situation, which was partly defining our context of acceptance, was stressed (see section 6.2). Finally we asked for the population's reaction to the built demonstration objects. The general methods we used in the ex-post study are described in the following.

6.3.2.1 Questioning of Architects

First of all we focussed on architects as important intermediate players concerning the transfer of PV-related knowledge to their clients: building owners, communes, companies and authorities. Architects play a crucial role for the diffusion of solar technologies; they can help to improve the degree of PV-related information and create and foster "designed" and aesthetically attractive PV installations. Moreover they know a lot about potential PV plant operators: the building owners' needs, attitudes and expectations concerning PV technology and PV designs.

Compared to craftsmen, the architects are less investigated and addressed by campaigns up to now.⁵⁶ The actual degrees of knowledge, attitudes and needs of architects concerning solar technology are not investigated so far and seem to be important factors of the diffusion of PV. To identify the general level of knowledge, needs, attitudes, and expectations of architects concerning PV and in order to evaluate their potential role as multipliers we carried out a two-fold inquiry:

- **Quantitative part in both countries**
In a quantitative questioning we surveyed 16 German and 27 Italian architects. In Germany the questionings were executed as an internet survey via a specific internet platform addressing architects by giving broad information about building-integrated PV⁵⁷. In Italy we sent e-mails to 300 architects of the whole national territory, teaching in universities or working as professionals. Regardless the different methods, structure and subject matter were the same in both countries.
The questioning via internet seemed to be a good opportunity as we could reach the right target group and could combine it with the publicity of the launch of the site. Users could answer the questioning with an animated tool. But in the end the amount of answers was not as high as expected and the quality of answers is not assured. At least some plausible

⁵⁵ Source: Hold, Gerhard (2002): Gebäudeintegrierte Solarverstromung in Österreich. Knittelfeld

⁵⁶ See for example: Duscha/Schüle/Groß 2002: Kampagnen für erneuerbare Energien - die Evaluation von "Solar-na klar!" und Empfehlungen für neue Kampagnen. UBA-Texte 22/02, Berlin.

⁵⁷ See www.solarintegration.de

answers could be gained. Therefore this quantitative method was complemented by qualitative interviews.

- **Additional qualitative part in Germany**

Six in-depth interviews with selected architects for the investigated context (“professional” solar architects) were done by telephone with the aim to get more information about the situation in Germany.

6.3.2.2 Questioning of Experts / Workshops

Dealing with the problem of implementing PV in tourist areas (under monument and landscape protection) is often a question of knowledge. But it also depends on (mostly regional) administrative processes⁵⁸ and their (local, personal) interpretation - facing normally a lack of information and of good examples. Therefore we stressed the rules, regulations and the local practice by making them subject of a workshop in Italy and a questioning of experts in Germany respectively. Thus we aimed at gaining information about administrative processes and associated obstacles in protected areas. The instruments are described below.

- **Workshop in Italy**

The Italian workshop took place end of September 2004, in connection with the SME training. 37 external relevant local and regional actors - SMEs, authorities, universities and associations - participated. Furthermore, also a representative of the Ministry for the Environment joined the meeting. The workshop was a forum for the dissemination of knowledge on existing or possible examples for innovative PV technology in protected areas. Moreover, the objective of the workshop was to give an overview on incentive schemes and other support framework measures fostering PV diffusion. Last but not least, another goal was to raise transparency on current authorisation procedures in protected areas and to identify best practices in order to tackle with regulation and permit constraints. Another objective of the workshop was to facilitate communication and networking among the participants.

- **Expert interviews in Germany**

As the planned workshop with representatives from local authorities and monument protection authorities could not take place (several participants cancelled their inputs and participations short-termed), we focussed on several in-depth interviews and written questionings with a selection of the invited experts. The interviewees are representatives of the island of Rügen and the federal state Baden-Württemberg. Two of them were involved in the planning of demonstration objects; one was involved in a process of a not realized project, and another one was involved in the building of the demonstration object in Marbach am Neckar. Both positive and negative cases have been regarded, the latter to learn about the formal and informal obstacles and problems.

6.3.2.3 Feedback of Population: “Ex-Post Questioning”

Finally we wanted to get a short local feedback on our built PV demonstration objects. To obtain an acceptance-related feedback from the local inhabitants (as permanently perceiving actors) and tourists (as ad-hoc perceiving actors), the research coordinator UdK gave out a standardized, short questionnaire in all four demonstration sites in Italy and Germany. In this questionnaire the focus was on aspects like the first optical impression and attitudes towards PV installations on protected buildings and in the landscape.

⁵⁸ In Germany authorisation processes are necessary if it comes to PV installations in protected areas and since 2004 also in open space. At the same time in Italy there is no specific law concerning the integration of PV in buildings but the local building legislations are varying. For more detailed information see report no. 1.

The following table gives an overview of the methodological structure within the whole acceptability study.

	Germany	Italy
“ex-ante” part 2001	<ul style="list-style-type: none"> • Workshop and accompanying expert talks • Written questioning of experts • Written questioning of local population 	
“ex-post” part 2004	<ul style="list-style-type: none"> • Questioning of architects (written and telephone) 	
	<ul style="list-style-type: none"> • Written questioning and interviews of experts 	<ul style="list-style-type: none"> • Workshop and accompanying expert talks
	<ul style="list-style-type: none"> • Written questioning of tourists / local population 	

Table 6.1: Methodological overview of acceptability study

6.4 Methodological Risks “Ex-Ante” and “Ex-Post”

The empirical parts of the acceptability study automatically appear with methodological risks. Several theoretical problems have to be assumed when working with qualitative and quantitative methods of social research.

Within this survey potential risks could arise from the different conditions in Germany and Italy. These difficulties were prevented by introducing slight changes in the questions, taking country-specific differences into consideration. Gaining access to an adequate amount of local key actors, for both the workshop and the questioning, was also a theoretically critical point within the qualitative part of the ex-ante study. But in practice we reached an adequate amount of these relevant actors, and the number of participants was satisfying. Important local multipliers of different institutions took part.

Nevertheless, the acceptability study was confronted with several actual problems. In quantitative questionings problems concerning amount and quality of the returned questionnaires may generally occur. This is a problem with which we had to deal during the ex-post study, when the return rate of the architects questioning in Germany was lower than expected. In order to gain sufficient data we carried out an additional telephone questioning with German architects. An omnipresent risk of surveys containing several interrelated methodological units is that one of these units fails. This happened within the ex-post study in Germany, when several participants cancelled their participation and the workshop could not be realized. This problem was solved by initiating an expert questioning including in-depth interviews and written questionings with a selection of the invited experts. Additionally we had to adjust the ex-post study since the project could not realize PV installations in the original research region island of Rügen, i.e. instead of concentrating on specific developments in the research regions we concentrated on more general aspects.

6.5 Empirical Results

In this section we present a summary of the empirical results of the acceptability study. Section 6.5.1 deals with the results of the first part (ex-ante, before the building of the demonstration objects) that influenced the empirical design of the second part. Section 6.5.2 comprehends the results of the second (ex-post) part of the study. The outcome of each part is structured into indicator-related clusters regarding the factors knowledge, design and barriers and chances in tourist areas as they were introduced as important acceptability factors before.

6.5.1 Results of “Ex-Ante” Study

The empirical results of the first part of the acceptability study are derived from workshops and different surveys (questionings of experts and of local population as well) that had been carried out in 2001 both in Germany and Italy.⁵⁹ The investigations of this first part dealt with the following questions:

- What can we learn in general concerning different PV-related factors of acceptance (focussing on our main aims and theses)?
- What can we learn for the processes within the project PVACCEPT itself?

With regard to our central subjects and theses we focussed within the presentation of main results on the following aspects:

- Knowledge about PV;
- Role of design and aesthetic influences;
- PV in protected tourist areas;
- Project activities and local acceptance.

In the following sections we present the results with regard to these aspects.

6.5.1.1 Knowledge about PV

As it was assumed that knowledge is a fundamental factor for the acceptance in general (main thesis), the investigation of the role, degree, character etc. of PV-related knowledge was an important part of this phase. Concrete questions were about the degree of knowledge concerning solar technologies, promoting policies and subsidy programmes as well as design possibilities.

General knowledge about PV

At the beginning of the questionings (population and experts) we asked about basic (technical) knowledge of solar technologies. Knowledge of the different solar heat and power generating technologies is a fundamental condition of acceptance.

A central result of the population surveys says that PV-related knowledge has to be indicated in both countries as low: less than one third know the difference between the technologies of solar heat (thermal) and solar electricity (photovoltaics). The German degree of knowledge is slightly higher than the Italian (see figure 6.1). The reason for this can be seen in the higher degree of implementation and therefore better information in Germany.

⁵⁹ The first part of the acceptability study within PVACCEPT is available as extended version at www.pvaccept.de.

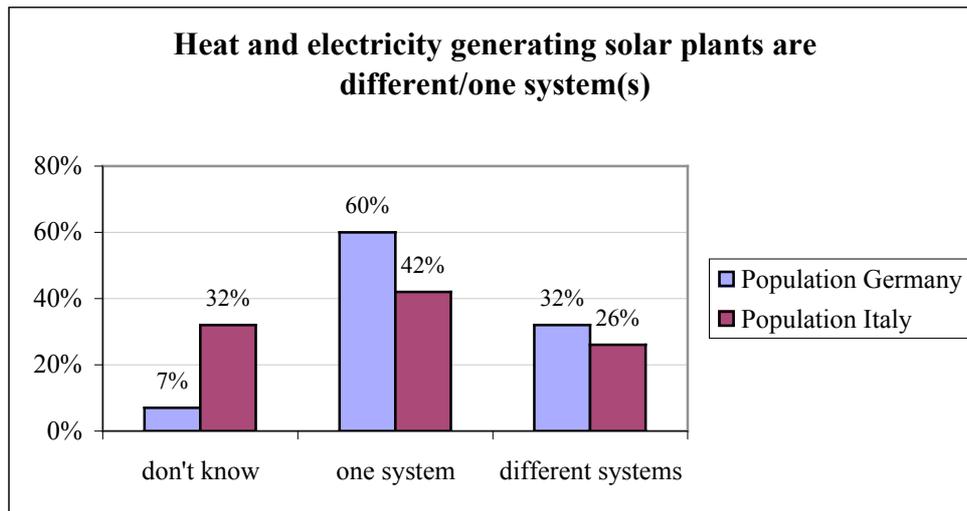


Figure 6.1: Population's knowledge about the difference between heat and electricity generating solar plants

The knowledge rate of the interviewed experts was significantly higher compared to the population's knowledge; again the Italian rates were slightly below the German ones.

Knowledge about support programmes

Within this part of the questioning we asked the experts and population about their knowledge of loan or subsidy programmes for PV and furthermore how detailed their knowledge was.

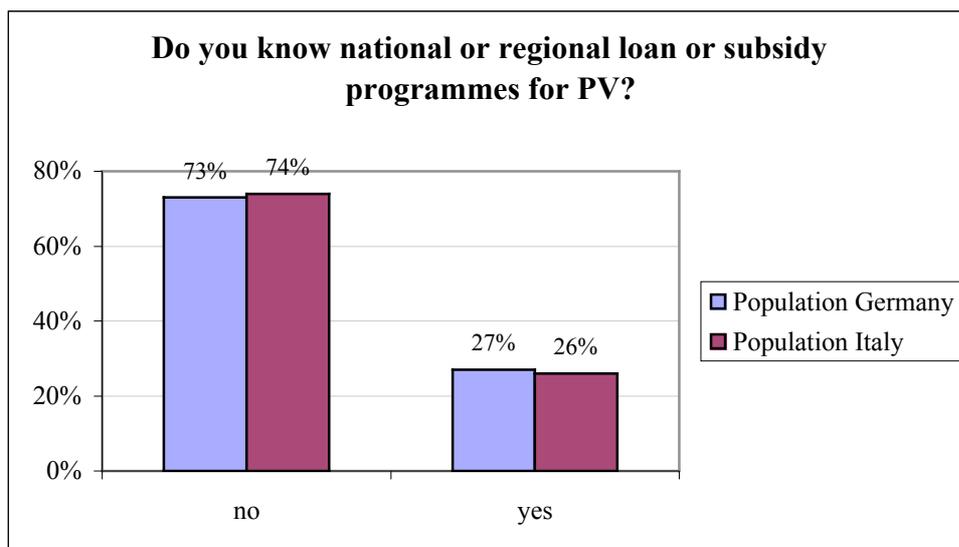


Figure 6.2: Population's knowledge about national or regional loan or subsidy programmes for PV

As expected the majority of the Italian and German experts knew in general (and at least in some detail) about loan or subsidy programmes for photovoltaics. But still some of our respondents (in Italy only two, in Germany four experts) did not know anything about these programmes.

In contrast the population's knowledge of national or regional support programmes had also a (in both countries comparable) low level of less than 30%. In Germany the knowledge corresponded to the German 100.000 roofs programme and the German Renewable Energy Act (EEG). The specific knowledge of the Italian PV roof programme was about 20%.

Knowledge about suppliers of solar technology

In addition we were interested in the population's knowledge of local companies offering solar technologies. This level of knowledge (respectively the name recognition of solar firms) indicates in a way the publicity of the subject in the research region. The ascertained local publicity of solar offering firms was almost the same in Italy and Germany: about one quarter of the respondents knew solar companies in their region.

Communication and cultural aspects

The impact of knowledge on acceptance could be asserted at the workshops and in the expert talks. During such "participation processes" (especially the workshops) the incomplete information could be compensated, which seemed to shift the attitudes in a way that helped the ongoing project (the planned realization of PV projects in our research regions). What we learnt – mainly from different reactions and experiences in the German and Italian workshops and expert talks – is that acceptance and knowledge interrelate partly with cultural factors. This conclusion influenced our further work (talks, workshops and interviews) with the regional actors in the different countries. Generally spoken it has to be taken into consideration in communication processes about contexts like "technology and design".

6.5.1.2 Role of Design and Aesthetic Influences

Relating to our theses the appearance of PV modules is an important acceptability factor as the design influences social acceptance. Therefore the attitudes of the interviewed experts and "non-experts" (population) concerning aesthetic aspects were examined. The main results concerning the role of design and aesthetic influences are presented in the following sections.

Appearance of standard modules

In order to find out about perceptions concerning the appearance of "standard" solar modules (normally in dark colours - black, dark-blue -, sleek, rectangular and in uniform shapes, in most cases with visible metal contacts) we asked the population for their opinion on aesthetical aspects of standard modules.

Only a minority regarded the existing standard modules as "good looking", the large majority votes neutral or against. More specifically, 62 % of Italians respondents regarded PV modules as not very aesthetic, while 71 % of Germans had mainly a neutral impression.

Relevance of variability of design

To investigate the relevance of variability of the design of PV modules, we asked experts as well as the local population to name the most important factor for the diffusion of PV. Two statements had to be evaluated: While one said that lowering of costs principal is a diffusion factor of PV technology, the other one concerned development of PV modules in a more appealing and variable design.

The respondent experts agreed strongly with a majority of about two-thirds in both countries that the design variability of PV modules is an important influence factor for the diffusion of the technology. Even the population in both countries voted this influence as strong with an impressive rate of about 50 % (see figure 6.3). In Italy the development of more variable designs is even rated higher than the reduction of costs of PV modules.

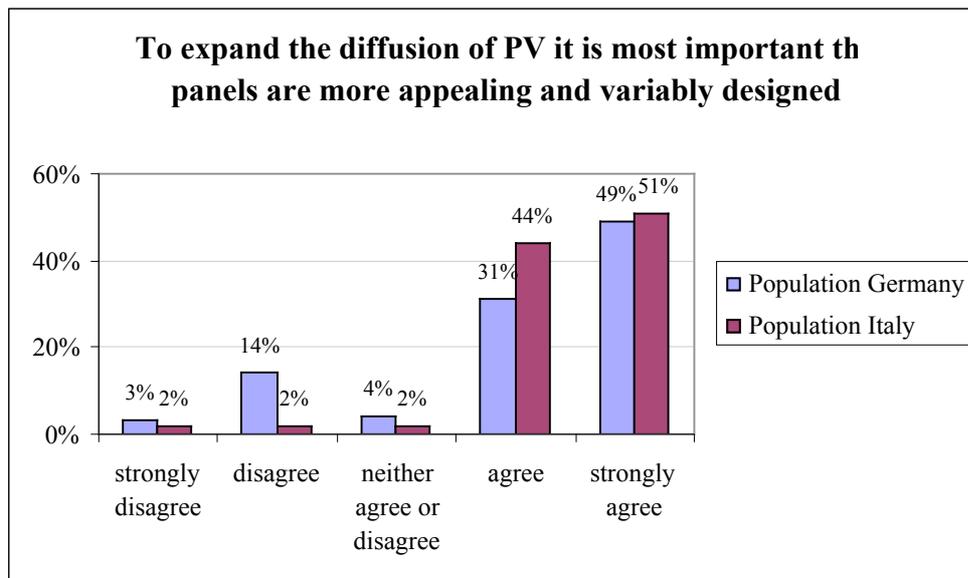


Figure 6.3: Population's view concerning the importance of more appealing and variable designed PV modules

PV on protected buildings

As the study focussed on PV implementation in tourist areas with a high degree of monument and/or landscape protection, the installation of PV modules on such objects was one focal point. Therefore we asked both, experts and population, about their attitude concerning PV installed on protected buildings.

Both expert groups in Germany and Italy expressed a more distinct pro PV attitude than the interviewed population. This different degree of emphasis may reflect the bigger interest, knowledge, and open-mindedness of the majority of the involved experts. Within the German population there was a significantly stronger agreement compared to the Italian interviewees. But in total the majorities of both countries favoured an installation of PV at / on historical monuments with the qualification that it should be done in a specially designed way (see figure 6.4).

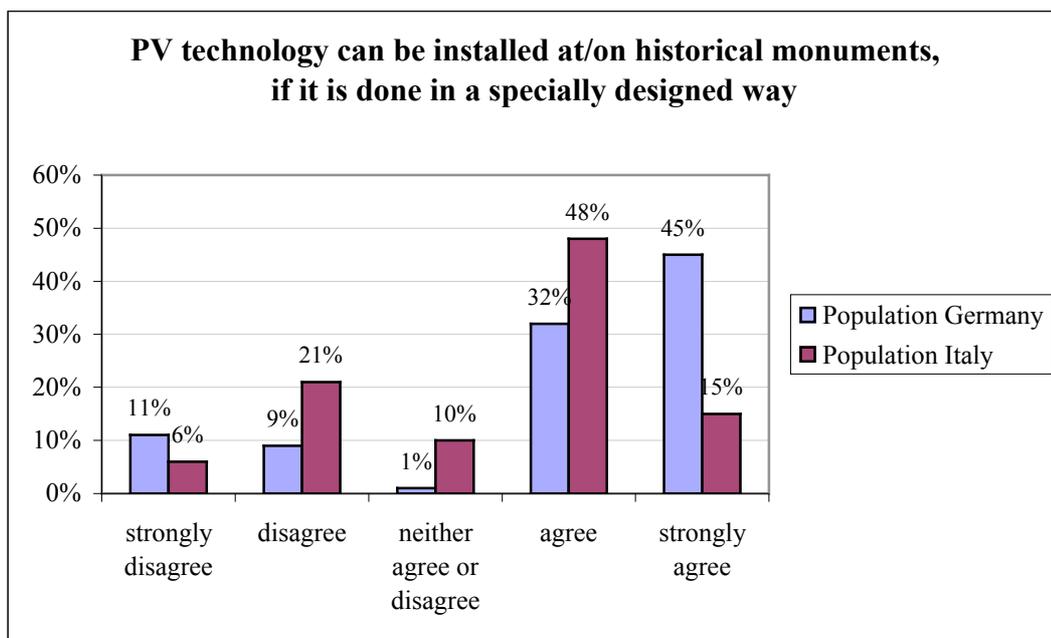


Figure 6.4: Population's agreement to install specially designed PV at / on historical monuments

These results can be seen as distinct indication of the validity of our theses about the actual role of the traditional design as a barrier for a larger diffusion of the technology. Therefore, a conclusion coming out of this result may be that aesthetics / design is a more important

influence factor than assumed so far and should be taken more into account concerning the development of new modules and integrated (architectural) design solutions.

6.5.1.3 PV in Protected Tourist Areas

As the implementation of PV technologies in protected tourist areas was seen as a possibility for creating multiplier effects and increasing the acceptance of this technology, we also investigated several aspects concerning these possibilities and the hindering factors given at present.

Barriers in protected tourist areas

As a general and fundamental barrier, we have to notice at first the problems concerning the “normal” exclusion of solar technology on / at historical monuments at present. Dealing with monumental protection such plants need an authorisation, and the practice at present is in both countries more likely deprecatory. The situation in Italy seems to be a bit more pronounced, as the expansion of protected (“forbidden”) areas and the number of listed buildings achieves a much larger scale.

Multiplier effects in tourist areas

Nearly all of the experts and also a broad majority of the population agreed to the thesis that tourist areas are specially suited for the increase of publicity of PV technology (see figure 6.5).

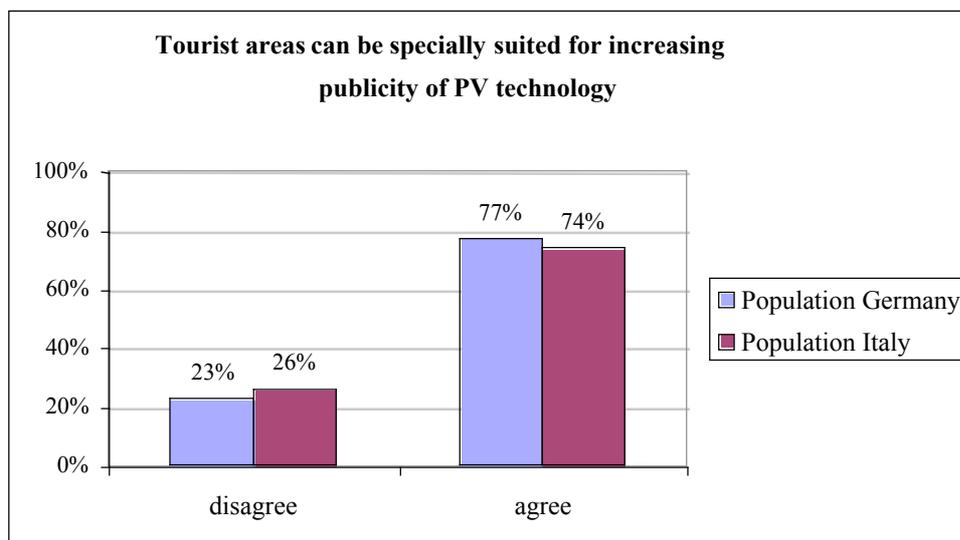


Figure 6.5: Population's view concerning tourist areas' potential to increase publicity of PV technology

These results proved our theses about the suitability of tourist areas to create multiplier effects and increase the diffusion of PV technology. For that reason, we conclude that more demonstration objects (“good examples”) should be built in these sensitive regions.

Local policy aspects

One complex of the questions dealt with the role of the local community, respectively its more active role regarding the promotion of PV technology and possible financing instruments. In other words: How do the inhabitants think about the promotion and financing of PV installations within their own communities?

Nearly all questioned inhabitants of both research regions were clearly in favour of local supporting programmes, as well as the enlargement of PV installations by the community itself (see figure 6.6). This strong agreement is a sign of the explicitly positive opinion of the population regarding PV technology.

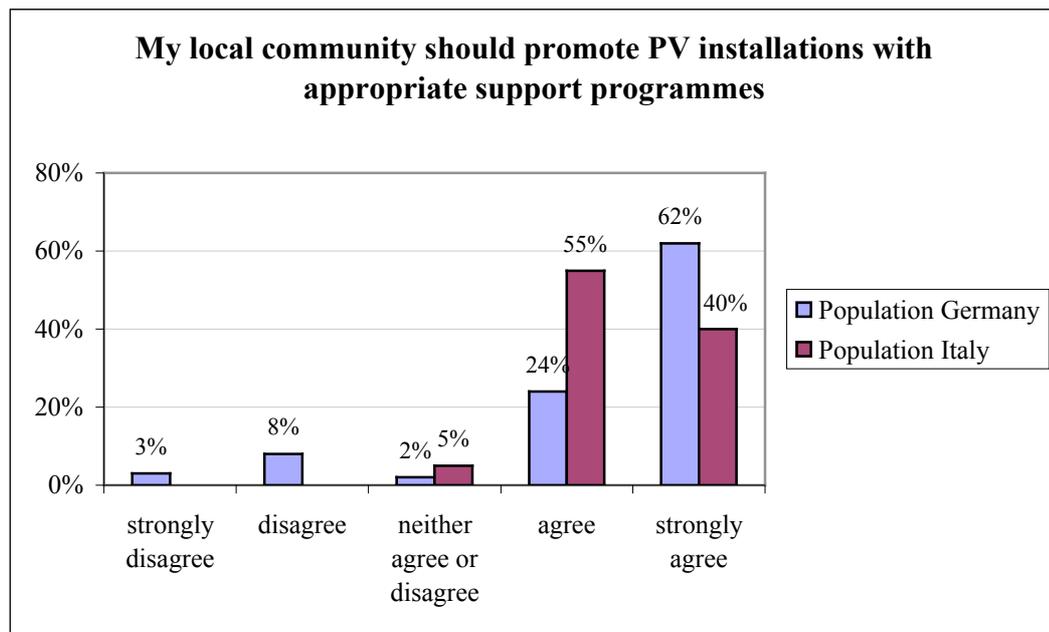


Figure 6.6: Population's view concerning their communities' promotion of PV installations with appropriate support programmes

In both countries even more than 40 % of the population agreed that PV plants related with tourism should at least partly be financed by instruments like tourist taxes. And large majorities in both countries would welcome, if their local community built or supported more solar plants, to be a role model for the people.

Another important aspect for local policy and economy regards the local demand for solar technology. In the German research region 14 % of the respondents showed interest in solar collectors and 11 % in PV plants. Compared to the current percentage of actual plant owners, these rates mean an enormous potential for the regional economy and the diffusion of solar energy.

6.5.1.4 Project Activities and Local Acceptance

Besides investigation and generation of research results, the project itself had an impact on local acceptance by its activities. Central activities were the workshops, several expert talks, provision of information by press conferences and interviews, and of course the networking throughout the processes of realising the PV demonstration objects.

Measuring direct impacts of these activities of the first phase is not seriously possible and was no part of explicit empirical work. But at least in the questionings of the population we asked for the knowledge of our project PVACCEPT. The result was that 12 % of the Italian as well of the German respondents had already heard of PVACCEPT (see figure 6.7).

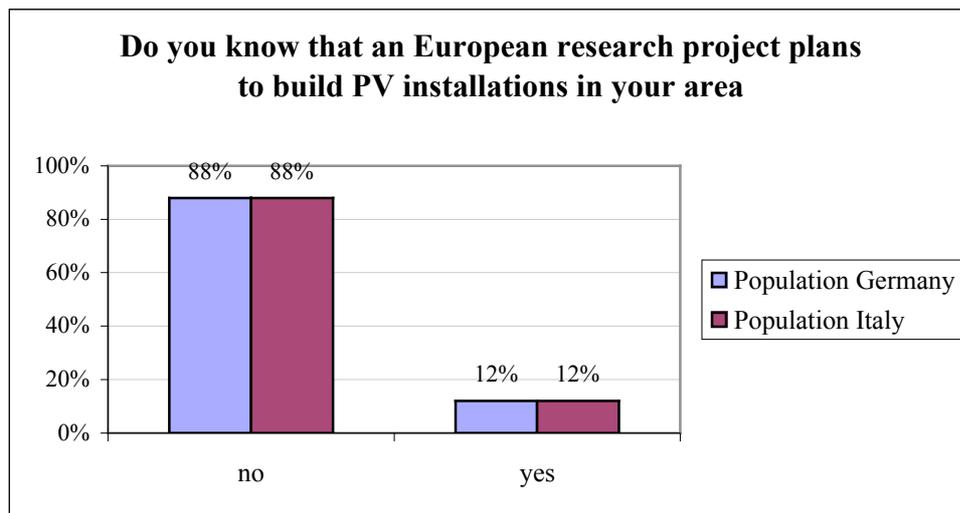


Figure 6.7: Population's knowledge about the PVACCEPT research project

6.5.2 Results of “Ex-Post” Study

The second part of the acceptability study focussed on architects as important intermediaries concerning solar technologies and actors in the context of design and acceptance. Besides we focussed on administrative problems in protected areas and the acceptance of local bodies and population. Here we made deepening interviews and tried to evaluate some of the practical experiences of PVACCEPT. Finally we evaluated the reactions to the built demonstration objects.

The following questions were asked:

- What is the actual degree of knowledge, attitudes and needs of architects as important intermediaries concerning solar technologies and PV?
- What are hindering and supporting factors for the broader diffusion of PV technologies?
- What kind of problems arise from authorisation processes and how can they be solved?
- What are reactions of architects, tourists and inhabitants to the planned and built demonstration objects?

Comparable to section 6.5.1 the empirical results of the second part were structured according to the following central investigation aspects and indicators:

- Architects' knowledge and education;
- Architects' attitude towards the role of design and aesthetic factors;
- Success factors for PV acceptability and diffusion;
- Administration and authorisation processes;
- Reviews of built PV demonstration objects.

6.5.2.1 Architects' Knowledge and Education

PV-related knowledge and education of architects is an important factor of diffusion of PV technologies since architects can influence their customers in their decision pro or contra a PV plant. Therefore we investigated several aspects of the architects' state of knowledge.

Own experience

In order to investigate the architects' knowledge and the state of their education we first asked them about their direct experience with PV. All of the questioned German architects but only about half of the Italian architects had own experience with this field, the Italians mostly (74 %) in connection with the planning of new buildings, while the Germans had planned PV applications both to existing and new buildings.

Education

Furthermore, we wanted to know in which way the architects reached their PV-related knowledge. We also asked them if and in which field they see need for their own further education. An overall result was that there seem to exist deficits in the field of the architects' professional education, as most of the interviewees in both countries acquired their knowledge on PV auto-didactically in private studies. The majority of the Italian and German architects would like to know more about (good) examples of solar architecture. Similar deficits have been stated also by surveys in other countries, e.g. in Austria⁶⁰.

There are country-specific differences concerning the interest in further education. The Italian architects are significantly more interested in further education than the German ones: all of the architects interviewed in Italy mentioned their interest in further training, while only half of the German architects did. This result may be a sign for the bigger difficulty of getting information on solar technologies in Italy compared to the German situation.

Knowledge about subsidy programmes

One aspect of PV-related knowledge is also the architects' information about corresponding subsidy programmes. Country-specific differences can be observed with this respect. In Italy, 81.5 % of the respondent architects declared to be aware of the "Italian PV roof Programme", but just 15 % knew it in detail. The German architects knew more and also in more detail about PV supporting subsidy programmes than their Italian colleagues.

6.5.2.2 Architects' Attitude towards Design Aspects

As the architects' attitude and perception of the appearance of PV plants is a crucial factor concerning PV acceptance, we examined several aspects with regard to their attitude towards design of PV modules.

Appearance of standard modules

In order to find out about the architects' perception concerning the appearance of standard solar modules, we wanted to know what they think of installations with standard modules at facades and on the roof.

Concerning the appearance of PV plants country-specific preferences of design became obvious: The Italian architects were much more bothered by the look of standard solar modules than the architects in Germany; and the German architects favoured PV installations at the facade, while their Italian colleagues preferred them on the roof (see figures 6.8 and 6.9).

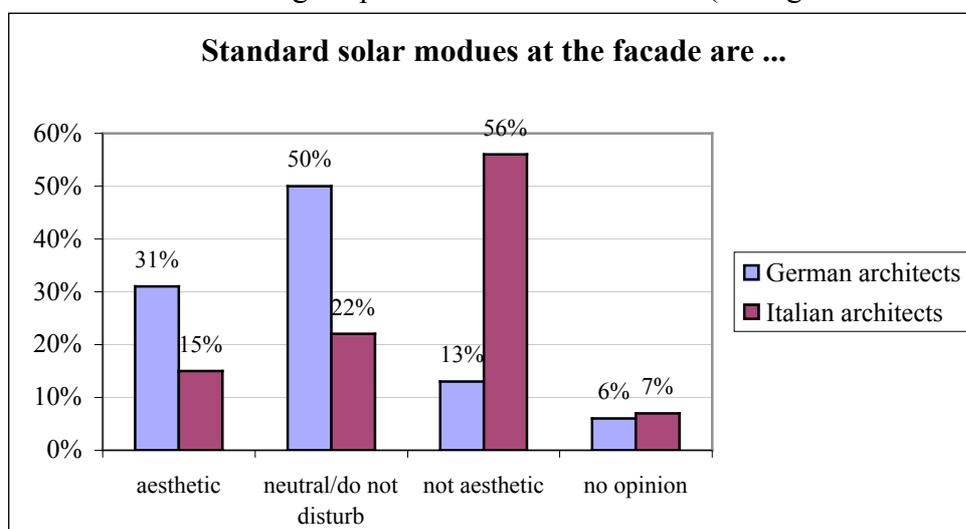


Figure 6.8: Architects' attitude concerning standard solar modules at the facade

⁶⁰ Hold, Gerhard (2002): Gebäudeintegrierte Solarverstromung in Österreich, Knittelfeld

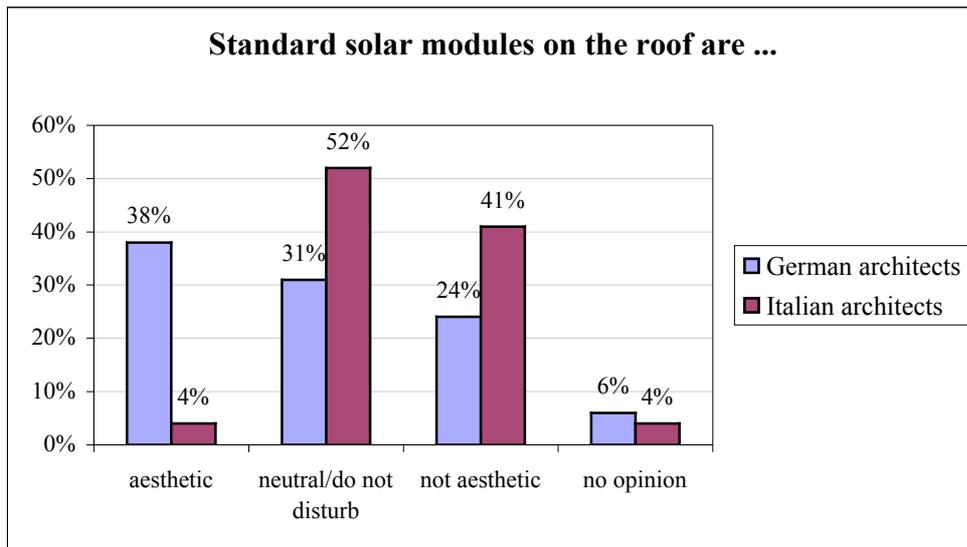


Figure 6.9: Architects' attitude concerning standard solar modules on the roof

Relevance of new design priorities

To investigate the relevance of design-variability of PV modules we asked the architects to name central aspects for the development of innovative PV modules. Concerning the question of design vs. efficiency of PV there are also country-related differences: 70 % of the Italian architects gave priority to the design development, even if it comes along with loss of efficiency, whereas 63 % of their German colleagues favoured the increase of efficiency instead (see figure 6.10). Expectedly most of the asked architects in both countries saw it as most important to reduce costs for an improved dissemination of PV technology.

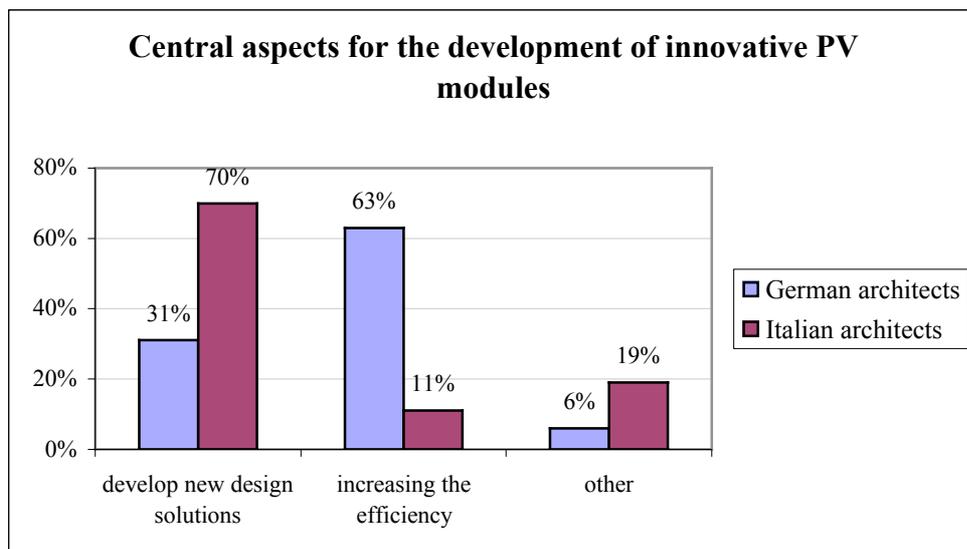


Figure 6.10: Architects' view concerning central aspects for the development of innovative PV modules

The qualitative questioning of German architects also focussed on the importance to develop newly designed modules. It was pointed out that design solutions concerning “shapes, colours, proportions and type of fixing are important”. The majority of architects in both countries thought that new elements should be independent but harmonically integrated into buildings. Roughly one fifth of respondents declared that new innovative PV elements should be integrated in inconspicuous manner into buildings, i.e. attract as little attention as possible.

(Expected) market potential for modules with innovative design

It was also interesting for us to know how architects value the market potential for PV modules in a greater variety of designs.

The architects from both countries saw a high market potential of innovative PV modules, meaning modules in more different designs, shapes, colours etc. Here a significant difference between the two countries showed: While nearly all Italian architects (96 %) saw a big market without restrictions, most of the German architects (73 %) saw the potential of these modules only as a niche product.

PV on protected buildings

Questioned about PV on protected buildings, the architects gave country-specifically differing answers. We asked for the “permission” of integration of PV in such buildings in any case, or only if suitable solutions could be found. An astonishing result was the clear position of the Italian architects: A large majority thought that PV can be installed there in any case (because they are environmentally-friendly). Compared to this a narrow majority of their German colleagues favoured PV at / on historical monuments only if it is integrated in a suitable way (see figure 6.11).

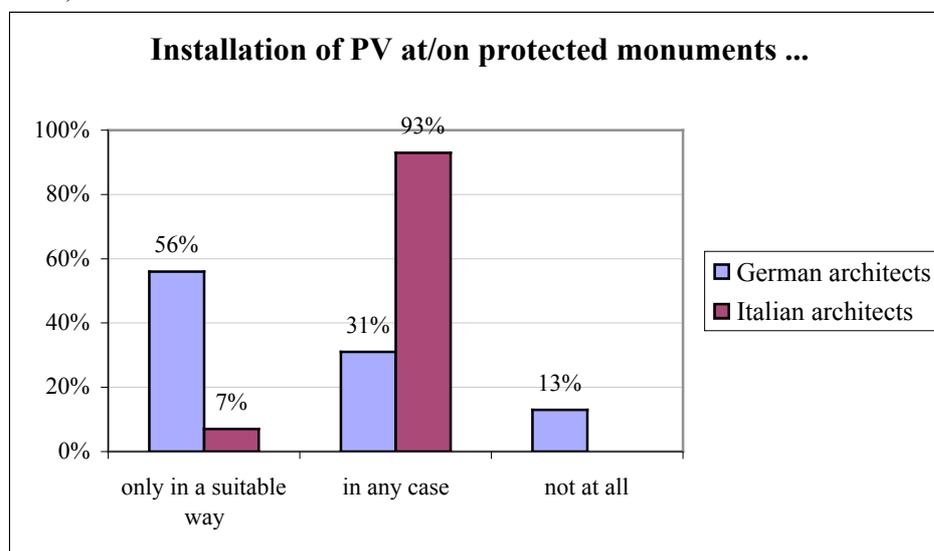


Figure 6.11: Architects' agreement to install PV at / on protected monuments

6.5.2.3 Success Factors and Barriers for PV Diffusion

In the qualitative questionings of architects and administrative representatives (respectively in the Italian workshop) several success factors of PV were discussed or mentioned by the experts. We categorized the arguments into the following central aspects.

- Target groups for PV and motivations

To analyse target groups for PV technologies, we asked about principal clients and initiators of designed PV plants. Both the German and the Italian architects saw companies as the main clients of designed PV plants.

Within the companies SMEs could play a crucial role, as some of the interviewees pointed out. It turned out that SMEs are often interested in PV as an ecological or innovative technology. This was also indirectly confirmed by the high interest of SMEs in the offered training activities. In particular medium enterprises took / take this opportunity to improve their sustainability and image.

As main motivation for building a PV plant the architects of both countries see the economic interest of clients, followed by their interest in innovative technologies and in ecological protection. In Germany also imitation was seen as a possible important factor.

- **Importance of intermediaries**

The survey confirmed the validity of our approach to focus on architects as important triggering actors for the realization of PV plants. For instance, in Italy in 57 % of the cases, the architects were the initiators of a PV application in a building. Referring to the German architects also building owners play an important role, especially when they are ecologically motivated. If PV installations are not initiated by the clients themselves, also architects, craftsmen, planners, local politicians, and suppliers of subsidies can be initiators.

- **Hindering factors for PV diffusion**

Both the interviewed architects and their clients considered high costs as the main reason for not building a PV plant. Other barriers are missing knowledge and - as last ranked hindering factor - design and aesthetical reasons. These aspects are also in accordance with the results of the mentioned Austrian study saying that barriers of PV in Austria are firstly high acquisition costs and secondly insufficient and/or lack of information regarding support programmes.

To reduce the comparatively higher costs of PV, it was stressed by some architects that state-running financing programmes should be improved (or introduced at all in some case). In order to widen the knowledge about these programmes also the idea of information centres providing facts about costs, feed-in tariffs etc. was proposed (Hold 2002).

Another emerging central restraint was insufficient knowledge not just within the population, but also among architects and installers. Although most of the German architects saw a slight improvement of their education concerning PV installations within the last years, they still saw a lot of deficits in current education programmes. Furthermore the German architects required a more practical orientation of trainings. For example, it was mentioned that architects should be taught more about used materials or concrete examples of PV applications. Moreover, communication among different intermediary actors speaking different “languages”, i.e. architects, engineers, technicians, should be improved.

The German architects regarded missing examples “for solar dream houses” as another barrier to a wider diffusion of PV. For this purpose tradeshows, knowledge transfer (self-improvement actions), and especially good examples of PV installations in “daily life” (PV installations at the roof of public buildings etc.) were suggested. Another opinion was that even if PV installations have already a positive reputation, e.g. via good examples in architecture magazines, there is still a big gap between good notions and the fortified realisation of PV projects.

6.5.2.4 Administration and Authorisation Processes

The current predominant ban on PV in protected areas concerns many, partly large and well-located areas. The outcome of authorisation processes depends principally on the knowledge and goodwill of administrators. We questioned German architects and administrative representatives and Italian experts about this subject.

Moreover, the PVACCEPT consortium had direct both positive (in Italy) and negative experience in this specific respect (in Germany the demonstration object was built in Baden-Württemberg instead of the original research region in Mecklenburg-Vorpommern).

Administrative barriers to PV

According to the interviewed German architects, some administration departments and regional authorities dealing with historical monuments are primarily retardative actors when they get in contact with planned PV installations (both for application in old and new buildings). Monumental conservation is described as “very restrictive in practice, which requires a lot of power of persuasion”.

As a crucial obstacle to PV, the asked administrative representatives in Germany saw the problem of too many and too tough regulations concerning redevelopment, especially in the field of monumental protection. These may lead to long and complex authorisation processes in both countries. The German experts mentioned regulations like the law of monument protection and the building law as one essential reason amongst others, why the realisation of some PVACCEPT projects in Germany failed.

But these restrictive rules are not the only constrain for the diffusion of PV in protected areas. German experts think that authorities lack of knowledge about PV and have prejudices concerning the appearance of solar modules. In fact, authorities are generally very sceptic against PV on protected buildings. They argued, “there are enough other, not protected buildings where PV plants could be installed”; so they do not see the need for PV installations on protected buildings. Additionally they said, “not every building is suited for a PV plant“. Even if the authorities are open for solar architecture in general, they would only support PV if it is installed at “architecturally simple old buildings“ in an inconspicuous way. They are generally bothered by the not-aesthetic design of standard modules. In the interviews they describe them as a “considerable optical source of friction” with “smooth, reflecting surfaces”, “a special dark colour” and “enormous sizes”. Obviously prejudices like these result in formal orders that can be found e.g. in Baden-Württemberg, Germany, where PV plants are automatically banned in protected areas.

Administrative instruments favouring the diffusion of PV

The questioned experts in both countries mentioned several possible administrative tools in favour of the diffusion of PV. First of all the German experts expressed their preference for binding orders supporting PV, e.g. for PV plants on new buildings. Other possible tools are incentives; this refers for instance to the German Renewable Energy Act, that has a special feed-in tariff for PV at facades.

On the other hand, if it comes to an authorisation process, more “flexible” regulations concerning PV are seen as necessary to simplify and to shorten the process. According to the German architects a possible reaction to prevent a denial of planned projects could have been to “change the legal situation or to make exceptions”.

A clear outcome of the Italian workshop is the importance of clear framework programs. This is the case of the *Regione Liguria*, which approved in 2003 its Framework Plan for the territory and landscape (*Piano Territoriale di Coordinamento Paesistico*). Moreover, local environmental action plans (e.g. the local Agenda 21 in La Spezia) can be further facilitator factors.

Both Italian and German experts think that it is crucial to start communication with local authorities early, provide important information about the project from the beginning, and keep them involved. In this manner “good solutions are reachable and good examples can get a diffusion effect”. In this way the authorities might be more open for the planned project, and the processes will be facilitated. This is what actually happened with the monument protection authority (*Sovrintendenza*) in Liguria. As a matter of fact, the existence of a regional territory framework plan, and the early involvement of the monument protection were crucial success

factors for the realisation of two of the three demonstration objects in Italy. Another point in terms of changing the authorities' attitude towards PV technology is their education. According to the Italian experts, local authorities need to be educated concerning PV in general and innovative design possibilities.

6.5.2.5 Reviews of PV Installations with Innovative Design

In order to gain some reactions on planned and realized demonstration objects within PVACCEPT, we asked the German and Italian architects for their reviews of these designed PV installations. Furthermore we asked tourists and inhabitants of the regions where demonstration objects were built in both countries about their impressions of the installations.

Architects' review of PV installations with innovative design

While asking German and Italian architects for their review of pictures of four realized projects and also two planned demonstration objects of PVACCEPT, that could not be built, we had mainly positive reactions:

- In Germany five out of six presented projects are generally seen as interesting (“should be repeated”). Only one project, the solar tree in Putbus (not realized, picture 6.1) got more negative evaluations than positive ones. The most positive evaluated project is the one of Bocca di Magra (picture 6.2) followed by the project “Marstall” (not realized, picture 6.3), La Spezia (picture 6.4), Porto Venere (picture 6.5) and the city wall in Marbach (picture 6.6).
- Two thirds of the Italian architects think that the projects are interesting and could or should be repeated; 27 % even see the projects as aesthetically appealing.



Picture 6.1: Solar tree in Putbus, not realized



Picture 6.2: Bocca Di Magra



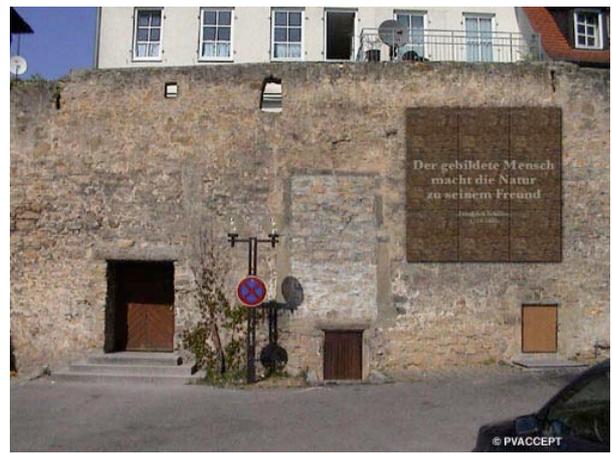
Picture 6.3: Marstall in Putbus, not realize



Picture 6.4: La Spezia



Picture 6.5: Porto Venere



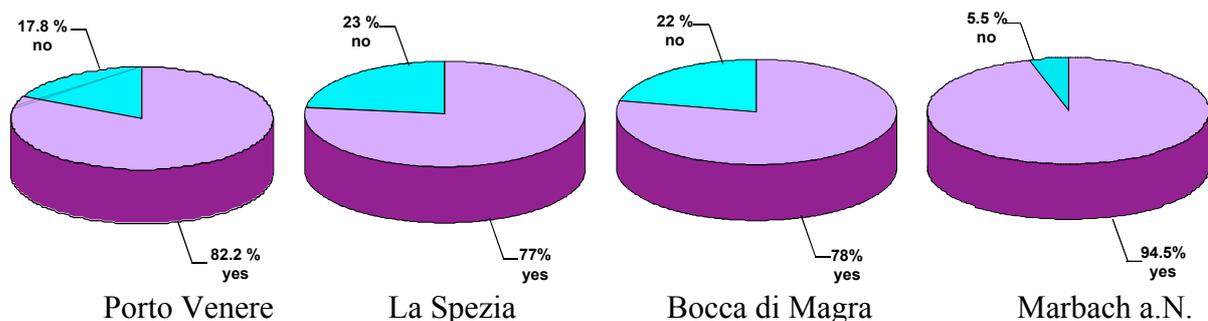
Picture 6.6: Marbach

Tourist / population feedback on built demonstration objects

At the end of the realized solar projects within PVACCEPT surveys in Bocca di Magra, La Spezia and Porto Venere (Italy) and in Marbach am Neckar (Germany) were carried out.⁶¹ Tourists and inhabitants gave feedbacks concerning their impressions and attitudes concerning the realized PV installations (see pictures above). The clear result is that all of these projects reached a commonly very high acceptance – in terms of positive reactions to the objects. In two cases the samples had been relative small but the results show clear directions. The questioning contained six questions, the results are described briefly as followed.

1. Have you ever seen a photovoltaic installation or module (on a building, in a shop, on a picture, in a newspaper, in other information material?)

In Germany almost all interviewees (94.5 %) answered this question positively whereas in Italy only between 77 and 82 % did, which confirms again a higher level of knowledge about solar technology in Germany – but also an increased level in Italy.



2. If yes, what did you think about the aesthetic appearance of these installations / modules?

The second question illustrates the acceptability of the design of standard installations, which had to be compared with the acceptability of the innovative PVACCEPT designs later. In the evaluation only those questionnaires were considered, in which the first question had been answered positively. About 40 % of the Italian interviewees regarded the standard installations, which they had seen, as not well integrated. In Germany more interviewees than in Italy considered integration positive (about 75 %).

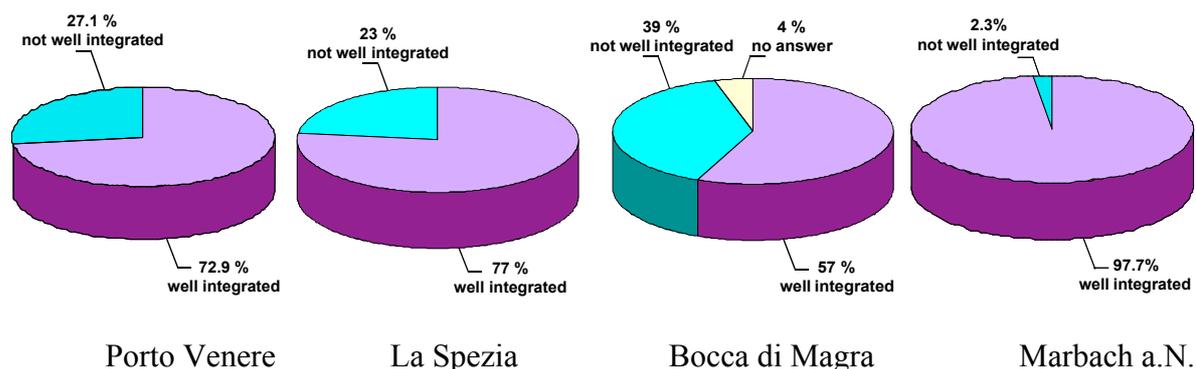
⁶¹ The tourist questioning was carried out between August and December 2004 by UdK in cooperation with the four communes where the demonstration objects had been built. In total 190 persons answered the questionnaire.

3. When you first saw the installation, did you recognize that it is a solar installation for generating electric current?

The question referred to the specific PVACCEPT demonstration object, where the questioning was carried out. The answers to this question illustrate that the PVACCEPT installations were not so easily recognized as photovoltaic plants. Especially high were the rates of non-recognition in the cases of the information board at the La Spezia castle and the Schiller quotation plate in Marbach am Neckar, Germany, where the same design method and module type has been used, followed by the pergolas in Bocca di Magra, while the “solar flag” installation in the courtyard of the castle in Porto Venere was recognized by far more than two thirds of the interviewees as photovoltaic plant obviously due to its more technical “look” and the visible power cables.

4. What do you think about the design of this installation?

This question intended to check the acceptability of the specific design of the object, especially what people thought about its integration into the building and surroundings. The highest number of positive answers was obtained by the Schiller quotation plate in Marbach am Neckar, which was judged as well integrated by the overwhelming majority (97.7 %). The installations in Porto Venere and La Spezia had been voted with a majority of about 75 % as well integrated. The pergolas in Bocca di Magra received the lowest percentage (still almost 60 %).



5. What do you think about the idea of designing solar modules in such a way?

The idea of designing solar modules in such a “designed” way found even more acceptability than the integration aspect of the objects: between 77 % and 97.7 % of the interviewees liked the idea; in all Italian cases these figures exceed these positive answers to the previous question about integration, in Germany the share is identical to question number four.

6. Do you think that solar plants should be installed also on monument protected buildings?

The final question asked for the acceptability of installing PV on monuments. The majority of interviewees answered that they can imagine such installations on monuments, if the design is well adapted (between 54 % and 79 %), and a smaller percentage (between 9 % and 23 %) can even imagine that standard PV is installed on monuments. This confirms again the results, which were already gained in the first part of the acceptability study (ex-ante) at the beginning of the PVACCEPT project. Only a relatively small percentage of interviewees (between 4 % and 23 %) answered completely negative to this question.

As main results of the tourist questioning can be summarized:

- The general acceptance (positive reactions) of the built PVACCEPT demonstration objects is very high in both countries, in Marbach am Neckar / Germany it is almost complete.
- A significant amount of respondents voted the appearance of standard modules as not aesthetic.
- Concerning integration aspects: Modules which are easily recognized as a technical installation meet with criticism (e.g. the “solar flags” / cabling - in Porto Venere).
- The idea of PV on monuments is acceptable for a majority if the design is adapted.

6.6 Final Conclusions, Recommendations and Needs for Further Research

In the following we present the final conclusions of the overall study referring to the central indicators of our theses and results:

- Knowledge about PV and need for further education;
- Role of design as important factor for the acceptability and diffusion of PV;
- Economic factors;
- Positive multiplier effects in tourist areas;
- Administration and authorisation processes;
- Acceptance-related effects of the project PVACCEPT.

Additionally we supply recommendations on possible consequences from these results. At last some needs for further research are pointed out.

6.6.1 Knowledge about PV and Need for Further Education

The acceptability study shows clearly that firstly, knowledge about PV is an important acceptance factor, and secondly, the current level of knowledge is still low. Population as well as relevant stakeholders like architects, SMEs and local administrators need to be enlightened on PV systems to increase the diffusion of this technology.

6.6.1.1 General Knowledge of Population

The population surveys show that the general public has little knowledge concerning PV, although there are some country-specific differences, as people in Germany are slightly better informed than people in Italy. Most notably more than 60 % of questioned population are not acquainted with the fundamental difference between solar energy and solar heat. We therefore recommend increasing knowledge on solar technologies in general.

- The first step towards this goal would be to include mandatory courses on solar technologies and renewable energies in general in theory and practice into the curriculum of every type of school (including higher education centres). It is our notion that if solar technology is covered in the curriculum these days, this is often confined to high schools, and coverage is fragmentary at best. At this point, one crucial problem here is the disregarded teachers' education concerning renewable energies.
- Secondly, special information campaigns should be created (TV spots, campaigns of communal utilities, leaflets for households etc.) that work with easily understandable information. It is crucial that in the emerging national and/or local incentive schemes a part of financial resources is devoted to organize information and awareness-raising campaigns.
- Information about photovoltaics could be integrated into subject-related consultation or customer contacts. E.g. the integration of PV into energy (saving) consulting that is often offered by local energy agencies or utilities, could be seen as an effective instrument since

PV could be thematically connected with heat and efficiency consultation without difficulty. This is actually foreseen in the decrees for energy efficiency, which entered in force in Italy in summer 2004. The decrees provide significant incentives for energy efficiency, but the installation of both solar thermal and PV systems are included as well. They further promote the development and diffusion of ESCOs (Energy Service Companies), which may act as important multipliers of knowledge.

6.6.1.2 Knowledge and Education of Architects, Engineers and SMEs

Important intermediaries like architects, designers, engineers, but also small and medium-sized companies in the building and energy sector, are in the position to create multiplier effects and help the further diffusion of PV since they influence the demand side. As the results of the surveys on architects demonstrate, in many cases the architects (and not the clients) are the initiators of the realisation of a PV system in a building. However, the survey also shows that there is a discrepancy between a high demand for education concerning solar energy and PV technology, expressed by the architects in both countries, and a striking lack of such education. While the demand expressed by Italian architects is at a very high level, the demand in Germany is somewhat lower, but still high. Whereas architects can be seen as central intermediaries concerning the diffusion of PV, here exists an urgent call for action.

- Improving knowledge of these important intermediaries concerning PV technology in general, design possibilities, and subsidy programmes, is necessary. For this we recommend to involve professional associations / orders and universities.
- The integration of PV into secondary education as well as into further education of architects should be obligatory, and special study paths have to be created. A correspondent to the further training of German craftsmen as “solarteur” involving a specialization on renewable energies is supposable. E.g. the *Donau-Universität* in Krems, Austria offers solar architecture as postgraduate studies. In view of the divergences between Germany and Italy, country-specific adoptions would be useful. Taking into account the high sensibility for design aspects in Italy (see section 6.5.2.2), more accentuation on design aspects in education there should be taken into consideration.
- In both countries a country-specific assortment of good examples of solar architecture has to be integrated into education to make the topic more concrete and vivid for students.
- SMEs are seen as important customers for PV (see section 6.5.2.3); but companies working in the fields of the building and energy sector are also important multipliers and suppliers. This was also confirmed within the trainings (done by PVACCEPT partners on the local level in Germany and Italy), where many firms showed their interest in PV. Due to the high amount of firms in general, the potential – on the demand and supply side – can be seen as high. As main constraint to exploit this potential, limited knowledge, lack of financial resources and of time were mentioned by interviewed architects and experts or by the SMEs themselves.

In particular, SMEs need easily accessible PV-related information. This requires both specific and tailored information tools and training activities. As a matter of fact, potentially interested SMEs need:

- Concise information on technologies, applications, and incentive programmes, including relevant links and tools;
- Information in their own “language”, simplified and understandable by non-experts;
- Online solutions and easy access to expert consultants.

As far as this is concerned, the dissemination tools prepared within PVACCEPT (website, design handbook, itinerant exhibition) are considered appropriate and important instruments.

In Italy it would be very important to organize trainings to SMEs concerning PV and renewable energies in general, maybe combined with energy efficiency aspects. For this we recommend the involvement of associations active in the renewable energy and energy efficiency sector (e.g. ISES Italia, Kyoto Club, REEF⁶²) and of universities.

6.6.1.3 Knowledge about Subsidy Programmes

In addition, the overall knowledge about subsidy programmes for PV plants is still incomplete within the questioned architects and population in both countries. Again, there is some country-specific difference in so far as people in Germany seem to be slightly better informed than people in Italy. This is not surprising, as these programmes and technologies are more popular and diffused in Germany. Since information on subsidy programmes is highly complex and easily outdated, due to often-changing general conditions (changes in the political framework, new subsidy programmes, shifting subsidy instruments in a new legislative period etc.), this has to be kept in mind for effective information tools.

- Therefore, efficient and target group oriented information campaigns are required, especially campaigns aimed at architects and craftsmen as they are very important intermediates.
- As subsidy programmes are complex and changeable, special target group-oriented and “flexible” information systems could be an answer. Information campaigns should focus both on national and local incentives. Very often, it is the combination of these incentives, which renders projects economically viable and effective. Nowadays, the most flexible way to provide information is probably via internet, therefore special internet platforms containing all information, relevant to the respective interest groups like architects, craftsmen, consumers etc., should be created.⁶³ Other channels are local energy and environmental agencies, the Agenda 21 committees, and the ESCOs.

6.6.1.4 Knowledge of Public Administrators

Public administrators - both local governments as well as monument and environment protection bodies – can obviously play a major role for the diffusion of PV. However, these bodies very often lack of specific knowledge about solar and PV systems, which prevents them to exploit opportunities in this field and act as positive multipliers. On the contrary, sometimes this lack of knowledge turns the same actors as important bottlenecks against the application of PV systems. Therefore, it is crucial to find effective ways to increase the awareness and knowledge of PV among public administrators. This is described in more detail in section 6.6.5.

A clear conclusion and recommendation is that the development of adequate, target group-specific educational programmes for architects, SMEs, administrations, and other key decision-makers is essential.

6.6.2 The Role of Design as Important Factor for Acceptability and Diffusion of PV

The acceptability study demonstrates that the role of design of PV technology has been significantly underestimated so far. The appearance of PV modules strongly influences the social acceptance of PV technologies. Designed PV modules help to improve the acceptance of all relevant actors and consequently increase the diffusion of PV. In short words: An important result of the study is that design matters.

⁶² REEF = REnewable Energy Foundation

⁶³ A good example of an effective and especially target group oriented internet platform is the German homepage www.solarintegration.de, that addresses especially architects.

As several results of the different surveys illustrate, especially the Italian interviewees are significantly in favour of new design solutions. Both German and Italian respondents see newly designed modules as crucial for good building-integrated solutions. In particular Italian architects think that there is a large market potential for these products in general, whereas the German architects rather think that they have a good potential, but in the high-price segment. Additionally it has to be mentioned that both the interviewed architects and population look very favourably upon the new design solutions of the built demonstration objects. A prerequisite for a successful implementation of these modules is that they have to be highly adaptable for the use in various environments.

- Considering the design aspects the creation of more good examples in general and an increasing promotion of more “public” and striking demonstration objects are desirable. This should be the object of local, national and EU support programmes.
- As already mentioned, more aspects concerning design options and aesthetical aspects of PV should be brought into education and further education of architects and craftsmen.
- Another crucial factor is a design-based marketing and the creation of markets. Therefore campaigns and concepts of the opening up of new markets should be generated. Concepts like the so-called strategic niche management could be used as an important mechanism for the creation of new markets. This concept focuses on strategy, implementation and evaluation of new technologies that can solve social problems but also will not find a market without support. For these technologies niches can be developed via learning and embedding into the environment (Truffer 2004⁶⁴). As an example for a possible strategy to open up of new markets or for a marketing-campaign a motto like “PV designed facades instead of marble” (or other expensive facade materials) could be used. This would target at companies interested in prestige-afflicted demonstration objects for their corporate buildings or headquarters. But also the intention of PVACCEPT – integration of PV in historical buildings – could be a suitable niche concept e.g. in Italy, where there are large historical centres and therefore a lot of possible applications for innovative “newly-designed” PV applications.

The interviewed architects provided also valuable indications for the applicability and transferability of innovative PV design solutions: The majority of architects in both countries think that new PV elements should fit into the existing structures in a harmonic way, but should stay independent. Roughly a fifth of respondents declared that new innovative PV elements should be integrated in inconspicuous manner in buildings, i.e. attract as little attention as possible.

Finally, the significant role of design as acceptability factor for PV was confirmed by the (ex-post) questioning of local population and tourists about design aspects of PV (in general) and of the built demonstration objects. While 40 % of interviewed people in Italy (25 % in Germany) consider standard installations as not well integrated, the vast majority of respondents in both countries (up to 97.7 % in the case of Marbach am Neckar) consider the design of PVACCEPT installations as well integrated. In two cases it was a successful inconspicuous integration, i.e. the people did not recognize at glance that the installation is a PV system.

In line with this high acceptance of demonstration objects, the majority of interviewees answered that they can imagine PV installations in general on monuments, if the design is well adapted.

⁶⁴ Source: Truffer, Bernhard (2004): Strategisches Nischenmanagement am Beispiel Mobilität – Experimente in evolutorischer Absicht. In: Ökologisches Wirtschaften 2/2004, P. 22-23

6.6.3 Economic Factors

Although the interviewees perceive design as an essential acceptability factor, they still see high costs as the main obstacle hindering clients from installing a PV plant. It is clear for everybody that appropriate incentive programmes are required to overcome the gap between good intentions and the realisation of PV projects and to foster an effective diffusion of PV. Existent examples for these instruments are:

- The most prominent and successful instrument in terms of installed capacities at the national level in Europe is the German EEG (*“Erneuerbare Energien Gesetz”*, Renewable Energy Act).⁶⁵ A similar feed-in law is very effective in Spain. Furthermore, Italy is expected to shift from the former capital subsidy incentive used in the years 2001-2004 within the Italian Roof Programme to a feed-in law with similar remuneration levels, in terms of kWh economic value and time length of the incentive⁶⁶. At present 17 countries of the EU 25 have already realized or are planning the implementation of feed-in tariffs (but not in all cases it is sure that PV will play a significant role, see Reiche 2004⁶⁷). A clear outcome of the discussion at the workshops was that a crucial aspect of an effective incentive programme is its long-term orientation. The guarantee to receive a reasonable but certain premium over a long period significantly decreases the risk of investment and attracts private investors. On the contrary, “stop-and-go” incentives risk to destroy the market⁶⁸.
- Whatever the incentive scheme, it is crucial that it actually fosters innovation. More specifically we recommend that the incentive is reduced every year in order to ensure cost reduction (as it happens in Germany)⁶⁵. Moreover, it is essential that it gives a premium to well integrated designed PV solutions (in order to avoid that most PV systems are simply standard modules put on flat roofs as it has happened for example in Italy in the last years).
- The realisation of PV projects can also be enforced by the creation of communal obligations that stipulate the installation of solar modules, as has been prominently done, e.g. in Barcelona within the Barcelona Solar Thermal Ordinance⁶⁹ and in other Spanish cities and communities like Seville and Madrid. Presently Barcelona is planning to widen its ordinance also for PV. Such an instrument can also be implemented at a larger regional (Germany: federal states) or national level like it has happened e.g. in Israel and Cyprus for solar thermal systems.
- An interesting example of a voluntary initiative of a city to make PV more financially attractive is the solar power roof initiative in Berlin⁷⁰. For this purpose, the communal government of Berlin offers private investors the opportunity to install PV plants on roofs of public buildings. For its service, the senate earns an agency fee. Programmes like this guarantee that also communities receive financial incentives for supporting the diffusion of PV. Another interesting voluntary initiative is currently being introduced by the city of Rome: it gives allowance to constructors applying bio- and ecological architecture criteria

⁶⁵ The Renewable Energy Act (EEG) in Germany was installed in 2000 and actually modified. It provides compensation for electricity generated by roof-top plants with a rate of 57.4 ct/kWh for plants with more than 30 kW_p, 54.6 ct/kWh for plants with more than 30 and less than 100 kW_p, and 54.0 ct/kWh for plants with more than 100 kW_p. An extra bonus for plants installed on facades is 5 ct/kWh. This rate can be obtained for over 20 years. Every year, the compensation rate for new plants is reduced by 5 %.

⁶⁶ Taking into account higher isolation levels in Italy with respect to Germany

⁶⁷ Source: Reiche, Danyel (2003): Governance towards Renewable Energy Sources in the EU Accession States, lectured at Berlin Conference “Governance for Industrial Transformation” 2003

⁶⁸ Unfortunately, this is precisely what is happening in Italy at the moment, where the national capital cost incentives are no longer available, but the feed-in law has not been introduced yet.

⁶⁹ For additional information see: http://www.eurosolar.org/solarzeitalter/solarzeit_3_01-3.html

⁷⁰ For additional information see: <http://www.stadtentwicklung.berlin.de/umwelt/klimaschutz/solardachboerse/>

(including solar and PV) to build 5 % cubic volume more than the one allowed by conventional permits.

In addition to these promotion instruments, there are other possibilities to create economic benefits concerning PV:

- Increasing the development of multifunctional PV modules, like combined electricity / heat producing modules;
- Developing integrated PV components, like solar roof tiles, facade elements etc. E.g. in context of PV as facade or skylight elements additional functions of this “energy generating cladding components” are heat insulation, transparency, and design. These aspects have to be included in a comparison of costs. As it is difficult to generalize benefit/cost ratios for such applications, we recommend to create a database of good examples, i.e. to always provide design and economic data together.

6.6.4 Positive Multiplier Effects in Tourist Areas

Positive imitation and multiplier effects are seen as essential in both countries for the diffusion of PV plants in general and also for the circulation of advanced design of PV modules. Especially tourist areas are suited for the increase of publicity of PV technology as they offer more visibility and marketing opportunities compared to “normal” places. Moreover, protected tourist areas (like the *Golfo dei Poeti* in Liguria) imply higher constraints and needs concerning the appearance of PV installations, so that if an application fulfils these high requirements it will possibly be accepted everywhere else.

- Accordingly, more (prominent) demonstration objects should be developed and exemplarily well designed modules should be used subsequently to create multiplier effects. Integration of PV examples into local tourist advertisement campaigns could also help to achieve these effects;
- Changing regulation concerning PV in order to allow new design solutions also in old parts of towns could facilitate the diffusion of PV and therefore foster multiplier effects;
- As proved by the ex-ante survey, the population would strongly be in favour of promotion of PV by local administrators. Therefore, oriented local / regional policies are recommended.

6.6.5 Administration and Authorisation Processes

The construction of the PVACCEPT demonstration objects in protected areas obviously required to undergo a series of authorisation processes. The experience made with the administrative staff and potential promoters, like mayors or politicians was predominantly challenging or negative. On the one hand, administrative personnel still holds many prejudices about the appearance of PV, and their knowledge about PV is incomplete. In addition to this, authorisation processes are long and complex, both in Germany and in Italy. Often regulation is strictly against the implantation of PV in protected areas.

- These processes can be speeded up by influential advocates inside the administration, who are highly motivated and strongly (personally) interested in the success of the project. These people may eventually escort the process, influence decision-makers and stand up for the implementation of the project. It is important to identify such persons and to involve them as soon as possible.
- Since the authorities' requirements for PV design usually are very high, the range of possible designs of PV modules should cover unobtrusive, adaptable and variable solutions.
- Moreover, the authorities have to be involved in the PV project as early as possible, presented with attractive design examples, asked for advice and kept informed on the progress, if successful authorisation is to be accomplished.

- Finally, the process can be facilitated by the existence of clear framework programmes. As discussed in the workshop in Porto Venere, this is the case of the *Regione Liguria*, which approved in 2003 its Framework Plan for the territory and landscape (*Piano Territoriale di Coordinamento Paesistico*).

As a matter of fact, despite several issues and delays, the combination of these factors, i.e. the existence of a regional territory framework plan, the early involvement of the monument protection and the presence of highly interested and committed subjects within local administrations, were crucial success factors for the realisation of the demonstration objects in Italy and Germany.

As a more general recommendation, effective ways to increase the education and awareness of public administrators with respect to solar technologies should be found. This can be done through several already mentioned instruments, i.e. flexible and easily accessible information tools (e.g. online tools, see below) and training activities through professional orders, associations and universities.

6.6.6 Acceptance-Related Effects of the Project PVACCEPT

A number of PVACCEPT project activities had positive acceptance-related side-effects, as they helped spreading information about PV technologies and new design solutions. In this way the project itself helped to strengthen the acceptance of PV in the local / regional context and within the “connected” (e.g. scientific) community. Examples for these project activities are:

- The built PV demonstration objects in both countries as well as several advanced design examples can be seen as “good examples”, as they provoked mainly very positive feedback from the population and from architects.
- The project PVACCEPT itself can be seen as a multiplier affecting knowledge and (local) acceptance, as it resulted e.g. in contacts with local and regional decision-makers and authorities (talks, authorisation processes, workshops etc.) or other communication and information processes (trainings, press conferences, inaugurations of demonstration objects, design manual, exhibition; see also chapter 7 - Dissemination).
- PVACCEPT has its own website and evoked a positive media resonance both in Germany as in Italy. Thereby publicity was created around the subject of PV.

Summarizing it can be said that there is a strong indication that knowledge and design of PV play a crucial role within the acceptance of PV, and that these aspects of acceptance are underestimated (and unexplored) so far. In some cultural contexts the role of design plays an even higher or equal role as the economic factors (costs). Another important result is that acceptable solutions for PV implementation in “difficult surroundings” like monument protected buildings or landscapes could be effectively realized, as large majorities of architects and population voted positively for the pictures or real PV objects. A positive multiplier effect of these examples and of the implementation in tourist areas can be assumed as some results of our surveys indicated this conclusion. But it must be stated that the realisation of the demonstration objects was a very complex, long and mainly very difficult process, because of the lack of PV-related promotion and knowledge, hindering regulations and other barriers within the administrations and local authorities. The conclusion is that on the one hand a change in regulations, authorisation practice and education of administrators, and on the other hand more good and visible architectural design examples are needed to overcome the problems of acceptance.

6.6.7 Needs for Further Research

A set of further research needs can be identified from our results :

- Deeper and broader research concerning the role of aesthetic aspects is needed. If our results were proved right, e.g. via representative surveys on a wider European level, this would affect production of PV. For instance the prevailing “technology-oriented goal of increased cell efficiency should be partly replaced with increased requirements concerning the design of PV.
- Despite showing common trends, our survey also identifies important country differences in results. As far as the transferability of the latter is concerned, it is crucial to carry out further research in other countries. The knowledge of detailed framework conditions is central for the acceptability of PV applications. These conditions include both socio-cultural and economic aspects (e.g. different incentive schemes in each country).
- Further research of economic acceptance factors of PV is also needed. On the one hand, the assessment of incentive schemes fostering (both technical and design) innovation should be assessed. On the other, methods for the microeconomic calculation of cost / benefit ratios of PV in buildings should be improved and further developed. This should include the assessment of the benefits deriving from material substitution but also from additional functions like insulation, light control, shading and thermal control, etc.
- In order to create new markets of well-designed modules, the development of strategies and concepts that are suitable for SMEs is another important prerequisite. Finding out more about the chances of strategic niche management could be useful with this specific regard.⁷¹

⁷¹ In the project "Strategic Niche Management as a Tool for Transition to a Sustainable Transport System" (1996 – 1999) the European Commission already did some research about this currently new instrument within the field of mobility.

7 Dissemination

7.1 Instruments

As dissemination of the knowledge gained is an important issue of research and demonstration projects, PVACCEPT had included the development of appropriate dissemination tools into its work plan from the beginning. The different dissemination tools were integrated into the work process in different subsequent steps, according to the state of (intermediary) results reached; they were discussed between consortium and observers, and were consequently adapted and updated.

The main dissemination instruments are:

- Website;
- Itinerant exhibition;
- Design manual;
- SME training units;
- Teaching activities.

7.1.1 Website

Already in November 2002 PVACCEPT started its own website under the URL www.pvaccept.de. The pages provide the user with:

- A short summary of the main aspects of the project PVACCEPT;
- A short explanation of the functionality of photovoltaics, solar modules and solar cells;
- A link collection for those who are either interested in more information about research institutes, organisations and projects, or in news about the current company activities concerning solar energy.

To reach interested persons in several countries, the whole content is available in three languages: English, Italian and German.

According to several surveys about web usability, the most widespread mistake within the design of websites is a slow download time because of a complicated page structure, large graphics and the use of unnecessary java script or flash functions. To avoid this the homepage of PVACCEPT has a simple layout and a clear source code, which can be read even with older browser versions. The whole code is written in html to enable search engine spiders to read and index the whole content.

The website got its own domain name “pvaccept.de” to make it easy to find, since all information and PR material on the project always carries the project acronym, which is easier to remember than the names of the partners etc. The top level domain “de” was chosen, because the coordinators of the project are located in Germany and international top level domains like “com”, “net”, “org” do not fit for a research project.

Usually the websites of research projects are only run and updated during the funded research period. Thus important information, e.g. on the availability of newly developed products on the market, is not forwarded to the users. As PVACCEPT regards it as important that its results and the link collection to other relevant sites in the “solar” field are available also after the end of the research project, its website, which is being run by the project coordinator UdK, shall be maintained from the 1st of January 2005 for at least three years. Also the e-mail address will be maintained and the e-mails forwarded to whom they concern.

The website fulfils the function to:

- **Establish a Presence and a Network**
Basically the website now serves as a kind of business card. On the one hand it gives scientists, potential industrial partners etc. a short up-to-date impression of the project to encourage networking and discussion; on the other hand the pages provide information to any interested user, even if he or she does not know anything about photovoltaics.
- **Make Research Results Available and Rise Public Interest**
On the long run the website aims at several target groups for a broad and cost-effective dissemination of research results and the promotion of good practices:
 - Consumers, especially builders and building owners (private or public);
 - Companies that plan and install photovoltaic systems;
 - Architects and other planners;
 - Scientific and research institutions;
 - Educational institutions and professional organisations.

It publishes information on the innovative modules and demonstration objects, and will inform about dissemination instruments, which are available for hire or to buy, like the itinerant exhibition and the design manual, as soon as distribution of those starts. Furthermore it provides links to the PVACCEPT consortium members, which can be addresses directly and individually according to the interest of the website user, and to other well-known portals, which deal with solar energy or research in the field.

7.1.2 Itinerant Exhibition

The itinerant exhibition addresses different target groups with different interests and levels of knowledge, like e.g. universities (education of architects, engineers, planners), craftsmen's associations, institutions dealing with "ecological" topics, and also schools.

It disseminates information concerning:

- The technical functioning of PV and existing standard PV products;
- Background and partners of the research project;
- The innovative products developed by PVACCEPT and their application possibilities;
- The general range of PV application at existing buildings (roofs and facades), in urban space and landscape;
- The demonstration objects built by PVACCEPT as examples for protected settings;
- Other best practice examples;
- Relevant websites for further information.

The exhibition, which has been produced by the designers / architects at UdK Berlin, consists of 17 posters in format 42.0 cm x 59.4 cm with the following titles:

- Research Project (1 Poster);
- Solar Energy (2 posters);
- Innovative Modules (4 posters);
- Range of Application (5 posters);
- Demonstration Objects (4 posters);
- Further Information (1 poster).

It is available in three languages - English, German and Italian – and can be ordered by e-mail at team@solar-lifetsyle.de or exhibit@pvaccept.de. It will be distributed by Solar Lifestyle, Kurfürstenstrasse 14, D 10785 Berlin, Germany, starting from beginning of March 2005.

To provide a wide distribution, costs will be limited to transport costs by a messenger service. A nominal charge will be raised to safeguard that the exhibition will be returned by the different users, and refunded after the exhibition has been sent back. The number of seven sets produced (three in German, two in English, two in Italian) guarantees that the exhibition can be shown in different occasions in parallel. The number of German versions is higher mainly because up to now the highest interest in the exhibition has been expressed by institutions or communes in Germany.

Information about the exhibition – including pictures – will be available on the project websites www.pvaccept.de and www.solar-lifestyle.de, starting from beginning of March 2005.

The first booking of the exhibition has been made already by three communes in Germany that are organizing a joint “solar” event for the months of March to May 2005 (see section 7.2).

7.1.3 Design Manual

The design manual was originally conceived as a more technically oriented handbook, which would give information on building elements, which are suited for PV application, technical details of different types of installations, fixing and carrying structures etc. in the context of old buildings, urban space, and landscape in a systematized way.

However, in the course of the project, the focus was shifted. It became clear in the different workshops organized by PVACCEPT (two in Italy, two in Germany), in the expert and non-expert interviews of the acceptability study, in the discussions with the European observers and in the final conference, that there is a lack of knowledge on a broad level concerning architectural PV application possibilities, design variations and basic requirements. This refers to private and public decision-makers, authorisation bodies, architects and installers as well as to the general public.

It was found that, instead of detailed technical information, what was needed most was demonstration of convincing examples of PV application in the setting of existing architecture, old buildings and monuments, urban space, and landscape, to transport the usefulness and possible aesthetic quality of PV installations. Therefore it was decided to make a good and extensive presentation of best practice examples the core of the design manual.

The target groups addressed by the manual are key persons in the process of planning and building: intermediaries like architects and installers, authorisation bodies like monument protection and building permission authorities, and potential private or public investors.

The focus is, as mentioned, on installing PV in a built environment. This includes integration into old buildings and monuments, but refers also to urban public space. The aspect of landscape integration is also considered.

The design manual

- Presents arguments, why there is a necessity as well as a considerable potential for installation of PV in the mentioned fields;
- Explains different architectural approaches towards PV installation, namely “application”, “addition”, and “integration”;

- Displays the innovative modules developed by PVACCEPT, including simulations of possible application scenarios;
- Explains the possible range of PV application in old buildings, urban space and landscape, using theoretical as well as practical (i.e. built) examples;
- Presents best practice examples, which fulfil high architectural quality requirements, from different European countries, structured according to installation on roofs, at facades, in public urban space, and in the landscape;
- Informs the reader about solar technology in general and basic technical requirements of PV installations;
- Gives references to websites with relevant information on consulting agencies, funding, legislation etc. on European level.

The design manual is bilingual (English / German) to reach a wider dissemination. It will be distributed, starting from May 2005, by *jovis Verlag*, a publisher in Berlin, which is specialized on architecture and arts books and acts on the international level.

A publisher as distributor is necessary, because only a professional marketing and established distribution channels can guarantee maximum dissemination, and this would go beyond the respective capacities of the consortium partners. The involvement of a publisher can be regarded as a dissemination success in itself, since it acknowledges the quality of the book, produced by the designers / architects at UdK Berlin, and confirms that there is a need and a market for it. The book fills a gap in the public presentation of PV topics, which so far concentrates on PV in new buildings, by its focus on good practice and innovative PV exclusively with regard to old buildings and monuments, landscape and urban space.

Information about the book, its price etc. will be installed on the project website as soon as the distribution starts officially and the book can be ordered from a bookshop or the publisher directly.

7.1.4 SME Training Units

A specific instrument for dissemination of knowledge were the SME workshops / training units, which were carried out in both countries in the last project phase, as foreseen in the work plan. The aim of the training was to inform SMEs, interested architects, craftsmen, and installers about:

- Technical requirements of photovoltaic installation in general;
- General possibilities to install PV on existing buildings, in landscapes, and in urban space;
- The innovative possibilities and the design potential developed by PVACCEPT;
- The technical details of the demonstration objects and applied innovative modules.

The training workshops took place in La Spezia / Italy, in September 2004; and in Marbach am Neckar / Germany, in October 2004.

Besides presentation and discussion of design and technology aspects, the workshop participants could examine the original test modules and their innovative features in detail. Furthermore, a first version of the itinerant exhibition enabled them to deepen the information of the presentations. Coordinator UdK and SMEs of the consortium – in the Italian workshop in addition also representatives of consortium member Ambiente Italia and the SME (subcontractor) that had installed the demonstration plants in Liguria - were ready to answer questions and take up suggestions, and the workshop participants made extensive use of this. Contacts were made also with the intention to establish new cooperations in the future.

The workshops / training units can be regarded as a success. While the participants in the German workshop were all SMEs, in Italy 37 external relevant local and regional actors from SMEs, authorities, universities and associations participated. Furthermore, also a representative of the Ministry of the Environment and a representative of the region (*Regione Liguria*) joined the meeting. Apart from the above mentioned objectives, the workshop / training raised transparency on current authorisation procedures in protected areas and allowed to identify best practices in order to tackle regulation and permit constraints. It also increased networking among participants from SMEs and universities.

7.2 Current State of Dissemination of Results

7.2.1 Public Relations

Since the official start of the project in July 2001, PVACCEPT has developed activities to make its aims and results public. 40 articles on the project, of which the coordinator has knowledge, have since then been published in newspapers and professional magazines in Germany and Italy; the project has been presented and discussed in a dozen of national and international meetings like conferences or workshops; two different exhibitions concerning PVACCEPT have been shown in five occasions in Italy and Germany.

These activities, together with the PVACCEPT website, created widespread interest in the project results. Especially since the pictures and data of the built demonstration objects have been published, the amount of requests has risen and added up to an average of about two per week, which is a good result taking into consideration that the project has just been officially finished on the 31st of December 2004, and that the marketing of the innovative modules has not yet officially started.

The requests up to now can be roughly grouped as follows:

- 35 %: international requests, including some from the United States or Asian countries, by architects, planners or communes for more information on the innovative modules or planning aspects;
- 25 %: requests by private building owners and companies mainly from Germany and Italy, concerning the feasibility of aesthetically innovative PV installations on specific buildings;
- 15 %: international requests, mostly from European countries, for business cooperation by SME;
- 10 %: international requests for future research cooperation by researchers;
- 10 %: requests, actually concentrating on Germany, by communes and institutions concerning the renting of the itinerant exhibition;
- 05 %: requests by postgraduates, students, and pupils from different levels concerning general information on PV or support with their studies, mostly from Italy and Germany.

This overview shows that the main target groups of PVACCEPT are reached by the information already now, a process, which will be enforced by the marketing of the modules as well as the distribution of the itinerant exhibition and the design manual.

7.2.2 Forthcoming Activities

Forthcoming international events during which the project results will be presented are e. g.

- “*Aktion Solar im Hochtaunuskreis*”, 1st of March to 31st of May 2005;
- “*Energietage*” in Berlin, 2nd to 4th of May 2005;
- European Photovoltaic Solar Energy Conference in Barcelona, 6th to 10th of June 2005;

- *Paolo Soleri* exhibition at the National Museum of the Arts of the 21st Century (*Museo Nazionale delle Arti del XXI Secolo*) in Rome in autumn 2005 on invitation of the Ministry of Cultural Assets (*Ministerio per i Beni e le Attività Culturali*).

Distribution of the exhibition will officially start end of March 2005; but already now the exhibition is booked for the so-called “*Aktion Solar im Hochtaunuskreis*” from 1st of March to end of May 2005, and will be shown in three communes near Frankfurt/Main: March 2005 / Königstein; April 2005 / Friedrichsdorf; May 2005 / Oberursel. In Oberursel the start of the exhibition will be combined with a workshop on the 30th of April 2005, organized by the regional Chamber of Architects, where PVACCEPT will present its results.

The distribution of the bilingual design manual will start in May 2005. Information on its availability and costs, as well as on the availability and renting conditions of the exhibition will be installed on the PVACCEPT website beforehand, as mentioned already.

A wider European distribution of the design manual as well as of the exhibition is planned to be achieved in cooperation with the observers from Austria, France, Spain, and the Netherlands. The project network aims at organizing national funds for financing further translations of the exhibition and the design manual into French, Spanish and Dutch and can, at the same time, provide distribution facilities in these countries.

A forthcoming book, which will include the PVACCEPT experience, is: “*Sistemi Fotovoltaici*” to be edited by L. Cavallari, University of Pescara, in 2005; “*Sviluppo e applicazioni di prodotti fotovoltaici innovativi – Esperienze dal progetto PVACCEPT*”.

The full version of the acceptability study (the version in this report is shortened) will be installed on the author websites and will most likely be available also within the publication series of IÖW starting from March 2005. Respective information will be installed on the project website as well as on the IÖW and Ambiente Italia websites beforehand.

7.2.3 Teaching

Furthermore, the PVACCEPT experience and results have already been introduced into professional teaching and will be subject of teaching also in the future:

- University of Rome: Master course on bioecological architecture and sustainable technologies for the environment (“*Architettura Bioecologica e Tecnologie Sostenibili per l’Ambiente*”), years 2003, 2004, and 2005 (forthcoming);
- University of Rome: Master course on energy management in natural parks, protected areas, minor islands and rural areas (“*Gestione dell’energia nei Parchi, nelle aree protette, nelle isole minori ad in zone rurali*”), year 2003;
- Politecnico di Milano: Master RIDEF Energia, years 2004 and 2005 (forthcoming);
- University of Venice: Master RIDEF Energia, year 2005 (forthcoming);
- University of Florence: Course on impact of renewable energies, year 2005 (forthcoming).

The importance of design for the acceptability of photovoltaics has been proved by PVACCEPT, and already now there is considerable interest of architects and installers in the innovative PV modules. It is expected that the incentives given by PVACCEPT, especially the built demonstration objects and the dissemination tools, will contribute to stimulate innovative PV applications as well as further research and product development in this field.

8 Conclusions and Recommendations / Summary

8.1 Research and Development Methodology

Conclusions, which can be drawn from the PVACCEPT experience on the methodological level, concern mainly the following fields:

- Cooperation between SMEs, designers and researchers;
- Involvement of local clients and stakeholders;
- Involvement of authorisation bodies.

The cooperation between SMEs (whose interests concentrate on technical aspects and technology production), researchers (who are interested primarily in sociological aspects like acceptability factors and non-technical barriers as well as in environmental aspects), and designers (who concentrate on the importance, quality, and communication of design), requires flexibility on all sides. Generally speaking: If there are partners with completely different backgrounds involved in a project, there must be enough time and effort be considered from the beginning to find a common language, i.e. to come to understand each other's expectations and limitations. This process of adaptation must be based on common interest and equal commitment. The project coordinator plays an important role in trying to bundle up the different interests.

This is particularly important in all cases (such as PVACCEPT), in which the results of parallel project steps are dependent on each other. In that case, if the objectives of one or more research levels are not met, this might endanger the success of other research steps. This risk is to be kept to the lowest minimum level as possible.

Decision-making processes, which involve external partners, especially public bodies, have to be accounted for with sufficient time; it cannot be taken for granted that the external partners show the necessary commitment over a longer period of time, especially if there are changes on the personnel level involved. Local political and economic conditions are a strong influence factor. A permanent intensive contact between the project management and these levels is necessary to guarantee smooth cooperation and good results. Legal contracts should be made to define tasks on both sides.

The involvement of other local stakeholders and at least of a fraction of local population is crucial. It may be very useful to have good links with local professional, cultural, and environmental associations and get them involved in the decisional steps. This also constitutes a significant help in the relation with local administrators - always concerned with budget and image problems - and with the general public, sometimes worried by what they perceive as an "excess" of innovation.

In the case of PV application in protected areas, an early involvement of authorization bodies in the first design and planning stages of the project is also crucial. This allows them to have a better understanding from the very beginning and participate in a constructive way to the decision-making process. In this way, they can feel and/or become more committed to the project. As a matter of fact, the early involvement of the monument protection authority, which took a constructive and committed attitude, was a success factor for the realization of the demonstration objects in Liguria. Also in the case of the demonstration object in Marbach am Neckar, which came into discussion in a rather late stage of the project, the constructive attitude of both monument protection authority and communal representatives enabled quick realization. Other factors, which were helpful here, were that Marbach is the seat of consortium member Würth Solar, and that the commune is also for this reason generally very interested in fostering PV projects.

8.2 Technology and Production

Here we summarize the main aspects related with

- Market introduction;
- Actual and future costs;
- Permission procedures;
- Committed subcontractors / SME partners.

The project has yielded a number of interesting new module configurations, which in the opinion of the partners will find a market. This has been clearly confirmed by the market research of two partners and the Life Cycle Analysis of one partner. The required technology has been demonstrated in its essential steps and verified by real modules exposed in the demonstration objects.

Before these special modules can be sold on a commercial basis, a certain amount of production optimisation and cost-reduction must be achieved, so that a set of “standard”, “off the shelf” modules is available to customers. This is not a very expensive task. It is only a matter of integrating a few extra processing steps into or beside the standard production lines. As discussed in this report, additional cost (given by Euro/ W_p) is determined mainly by the cost (Euro per module) of extra production steps (e.g. printing on a glass sheet), but also by the reduced power (W_p per module) by the opaque printing dots (20 %) for printed modules, and by the transparent areas for “transparent” modules (some estimates are given in this report in chapter 3 – Innovative Modules and Development Process). Price degradation can be expected by the “dimensions of scale”.

In addition, customers expect certification according to existing international norms, although not demanded by law. Typically this “type approval” can be abbreviated, as only a few test procedures (and not the complete set) will have to be repeated. In addition to the certification stamp buyers expect a warranty similar to that for standard modules, typically 20 years for 80 % of the initial performance. This will be only a marginal additional risk for the manufacturer.

In many cases the incorporation of new modules into buildings need a special permit by the building authorities. In general only modules laminated with PVB (Poly Vinyl Butyral) are automatically allowed as construction material. This requirement will also be easy to fulfil, as the authorities generally have a very positive attitude towards PV integration into buildings. Recently (13th of February 2005) a working group within the German VDE⁷² has been established in order to prepare a norm for building modules, which will evidently also be valid for the new PVACCEPT modules.

In the production of the innovative modules within PVACCEPT a number of subcontractors (SMEs) had to be involved by the producing SMEs in the consortium. This concerned e. g. one SME to realize the ceramic printing on the front glass of the modules used in the demonstration sites in La Spezia and Marbach am Neckar, and one SME that had the technical know-how to embed solar cells in bent acrylic as used for the “solar flags” in Porto Venere. Since developing design ideas in PVACCEPT was part of the research, i.e. the concrete need and specification of subcontractors was not clear when the consortium was composed, all subcontractors were involved only after about one year of project duration. Their commitment was therefore limited to certain production steps and not to the research project as a whole, which led to some difficulties in communication of the design ideas and some related deficiencies in the quality of the first prototypes. Based on this experience we recommend that already from the beginning

⁷² Verband der Elektrotechnik, Elektronik, Informationstechnik e.V. = Association of German electronic engineers

of RTD projects potential subcontractors should be integrated as full consortium members to ensure their involvement also in the theoretical approach, their full commitment, and direct communication channels.

8.3 Environmental Aspects

Here we present conclusions and recommendations concerning the following aspects:

- Environmental performance of innovative PV (Conclusions from LCA study);
- Issues and data gaps for crystalline silicon and thin-film modules;
- Future issues: end-of-life and recycling of modules.

Given the fact that PV systems have no direct emissions during the use phase, it is crucial to assess their impacts over their whole life cycle. This holds both for the PV modules themselves and for the “Balance of System” (BOS). The main conclusions of our LCA study can be summarized as follows:

- All the analysed systems exhibit overall good thermodynamic and environmental performance, both when compared to other energy production devices and when specifically compared to older-generation PV systems.
- For crystalline-Si-based systems, the silicon wafer production process is confirmed to be the production step having the largest (negative) influence on the final environmental and thermodynamic performance of the completed systems. Since there is a lot of intrinsic variability as well as some significant data gaps in the available literature on some crystalline silicon production phases (e.g. Si purification – also refer to the EC projects ECLIPSE [ENG2-CT-2001-00520, www.eclipse-eu.org], CRYSTALCLEAR [SES6-CT-2003-502583, www.ipcrystalclear.info/default.aspx] and NEEDS [SES6 CT-502687]), further research should be focussed on this point.
- Both kinds of thin-film modules show remarkably good results, despite their early stage of development and the inevitable lack of large-scale optimisation. CdTe modules, in particular, seem to be especially environmentally friendly in spite of employing cadmium as a manufacture component. Of course, some significant data gaps are also related to thin-film technologies, essentially because of their being in the pilot production stage (see also SENSE [ENK5-CT-2002-00639, www.sense-eu.net]).
- The finished PVACCEPT demonstration objects are of course burdened by somewhat higher environmental impacts than the stand-alone modules, but these additional impacts could be significantly reduced if the object were produced in series.

For the future, envisaging a medium / long-term wide diffusion of PV systems, it will be crucial to assess in advance the impacts related to their end-of-life options (e.g. the feasibility and related impacts of PV module recycling). The project SENSE is focussed on this particular topic. Two PVACCEPT consortium members, i.e. Ambiente Italia and Würth Solar, participate in this project.

In any case, we strongly recommend that any innovative design of PV modules and applications is accompanied by an “ex-ante” screening / simplified LCA study. This is to avoid negative environmental effects (e.g. by the use of rare materials in modules or in the BOS) to be created in the production phase or to the end-of-life of the PV modules and applications.

8.4 Acceptability

Here we want to highlight the following aspects and conclusions:

- Support of population, lack of knowledge, importance of design;
- Acceptability of PV in monuments / acceptance of built demonstration objects;
- Role of authorisation bodies;
- Economic factors.

Concerning the acceptability of photovoltaic technology it was found that there are similar attitudes in Germany, Italy, France, Spain and the Netherlands. In general, the population shows a strong curiosity and generally high support in favour of PV. However, a certain degree of confusion and lack of information is observed. With specific regard to our project, one main result of our acceptability study in Germany and Italy and of a similar survey carried out in France is the striking evidence that the aesthetics of standard photovoltaic modules is a major obstacle for broader diffusion of the technology, i.e. the clear conclusion is that “design matters!”. Some people ranked the relevance of design as a barrier at the same level as of costs or even higher.

A high percentage of experts and non-experts were found to be willing to accept photovoltaic installations even on protected monuments, if the PV plants are designed in a way, which maintains the character of the monument and achieves harmonic integration into the existing architecture. This high level of acceptability of PV in monuments and protected buildings was confirmed by the ex-post questioning of tourists and local population: the vast majority considers the built demonstration objects as well integrated.

Monument protection authorities themselves proved to be more difficult to convince in Germany than in Italy, even though in none of the two countries many built examples on PV on monuments have been tested. The judgement seems to be based on prejudices and lack of knowledge and also a lack of appropriate technological elements more than on experience. This implies that also authorisation bodies need to be “educated” about innovative solar technologies. As mentioned, this can be done by applicants and designers through an early involvement of monument protection functionaries. However, for a future larger diffusion of PV we recommend to seek for more systematic ways of training and education of local administrators and authorisation bodies (see also section 8.7).

It became clear that there is still a considerable lack of knowledge on side of all actors involved in the process of planning and installing a photovoltaic plant at buildings or in an urban or landscape setting, and that knowledge therefore has to be improved to disseminate the technology further and strengthen its acceptability. It was found that the role of local administrations in the process of PV diffusion is very important and that they should be involved in such processes as early as possible.

The economic aspect must be regarded as a key factor, i.e. without financial incentives today PV actually would not have much chance. The existing incentives have to be made more efficient with respect to innovation and design. This can happen for instance by finding new ways of promotion, by demonstrating good architectural integration, and by emphasizing the multifunctional role of PV. Multifunctionality means also cost savings, since PV elements can e.g. replace parts of the outer skin of a building or include functions, which would otherwise have to be fulfilled by additional elements. Very clearly, PV should be embedded whenever possible in a broader concept and design of efficient energy-using buildings. Cost / benefit assessments (and incentive schemes) should be tailored accordingly, taking into account the value of the final service provided, and not just the cost of the kWh.

Another important outcome of the discussion at the workshops and the final observer conference was that that appropriate financial support systems should be long-term oriented, in order to decrease risk and attract private investments. Last but not least, given the present lack of information among all relevant stakeholders and the public, an effective incentive scheme should devote part of the financial resources to promotion and information dissemination activities.

In the training workshops realized by PVACCEPT the interest of the participants (SMEs and architects) concentrated to a considerable extent on costs and amortisation aspects and the question how much improved aesthetics can cost more than the standard version to be accepted by investors. It was regarded as realistic that investors are willing to pay more for better architectural integration and the improved image linked with this. Costs for the innovative PV modules developed by PVACCEPT will go down in parallel with a good dissemination and increase in production numbers.

8.5 Transferability

Relevant aspects for transferability are:

- Focus on PV in the built environment;
- Adaptable / variable solutions;
- Indications from architects and experts;
- Market potential of innovative PV modules and applications;
- Education of decision-makers;
- Economic country-related differences;
- Administrative and authorisation framework;
- Multiplier effects.

It was found on the European level that PV is applied already well in modern buildings, contributing to good modern architecture, for which transferability is not a problem. Therefore the focus of transferability considerations has to be on the built environment. This includes singular old buildings as well as the erection of new buildings in an old setting.

During the final conference with the European observers and other experts in Berlin, the discussion focussed on the transferability of innovative design PV modules and systems with respect to the intervention in buildings. A proposal for a (possible) classification in four types of interventions was made:

- Conventional (PV added to building as extra element);
- Transformation (modern change of existing building using PV);
- Mimicry (PV adapted to be hardly recognized);
- Integration (PV as new building element with additional functions).

There is no prioritisation involved in this list, as the type of intervention depends on the attitude of the architect / investor / building authority with regard to the question of how to bring modern technological elements and existing structures together. Yet the first type of intervention is still the most common one (therefore “conventional”) and also the one, which mostly imposes aesthetical problems, as the technological element is monofunctional and usually very visible. While “integration” can be applied to both, old and new buildings, it is more common for new buildings, as in old buildings it implies bigger restructuring work. It means multifunctionality of the technological element. “Transformation” and “mimicry” concern exclusively old buildings and imply adaptation of the technology to the existing

structures. Here, as well as in “integration”, lies also the potential for future research in design and technology development.

As far as this specific issue is concerned, valuable information came from the interviewed architects: The majority of architects in both countries think that new PV elements should fit into the existing structures in a harmonic way, but should stay independent (“transformation”). Roughly a fifth of respondents declared that new innovative PV elements should be integrated in inconspicuous manner in buildings, i.e. attract as little attention as possible (“mimicry”).

Another important outcome of the acceptability study was that interviewed architects in both countries see a high market potential for innovative new-design PV modules in buildings. German architects think this is mainly limited to the higher price segment of the market. With specific respect to the built demonstration objects, the large majority of architects in both countries considered them interesting and “to be repeated”.

Again, also with respect to transferability, a lack of knowledge on side of important decision-makers has to be stated, so that demonstration can be regarded as an important factor. The experience of PVACCEPT has proved that the first important step of demonstration is to have good examples of visual simulations and presentations. New software tools can support this, like e. g. “augmented virtual reality”, which enables the viewer to see the planned changes of spaces or structures in a three-dimensional way and *in situ*. Even more important is to have built demonstration objects as best practice examples.

The best ways of convincing decision-makers are to

- Show them prototype modules in high aesthetic quality, which are applicable in their context and project;
- Show them demonstration objects built somewhere else and make clear that such projects are feasible and therefore can be repeated; eventually put them in contact to the owners of such objects to make them profit from their experience;
- Use models as well as innovative technical tools, such as virtual reality, to help them to better understand the three-dimensional aspects of a planned object;
- Initiate marketing actions in the planning area, like e.g. presenting an exhibition or holding lectures.

This was not only the experience of the UdK designers (PVACCEPT coordinator), but was also confirmed by the questioning of architects, as they ranked first good examples of solar architecture and then technical support as important convincing factors.

PVACCEPT showed a poster exhibition in some of the places involved, and this came out to be a good way to spread the information and get important feedback. If the people are convinced and the demand for PV technology is created, administrators will follow. Of course, this can only be done if the objects have good design, technical and environmental characteristics.

As far as economic aspects of transferability are concerned, we face the issue that incentives for PV strongly vary from country to country. Therefore, what is possible in one country is not necessarily (easily) feasible in another one.

The harmonization of policies supporting renewable energies in the EU is a big issue, which is certainly out of the scope of PVACCEPT. We might just indicate some criteria / incentives, which seem to be effective for PV diffusion and innovation:

- Feed-in laws (like in Germany and Spain) seem to be the most effective incentive to boost the PV market. However, the incentives should decrease with time, in order to foster real innovation and production cost decreases. Moreover, they should include specific premiums for good design and architectural integration as well as for multifunctional devices.
- The triggering role of public authorities is also important. Specific incentive programmes (like the Italian roof programme in 2001-2002) or regulations (like the obligation of installation of solar systems in new public buildings) are effective means for PV transferability and dissemination.
- In the final conference in Berlin the possible role of Energy Service Companies (ESCOs) for implementing the use of this technology was also discussed. These Companies have generally good knowledge about funding programmes and opportunities and can help possible users not to give up for financial reasons.

As a general - almost trivial - recommendation, further demonstration projects should be initiated first in those countries, where effective and innovation-oriented incentive schemes are in place.

This recommendation also holds with respect to administrative and authorisation framework conditions. The first step for effective transfer of results in other protected areas is to verify “ex-ante” the presence of:

- A framework plan with clear guidelines (like e. g. the *Piano Territoriale di Coordinamento Paesistico* in Liguria or the instruments of the German *Bauleitplanung*);
- Other local promotion plans and initiatives (e.g. the Agenda 21 in La Spezia);
- Open and committed functionaries in the monument protection.

The combination of these three aspects and an early involvement of authorities was a key success factor for the realization of the demonstration objects in Italy, as mentioned before.

Finally, a crucial aspect for effective transferability is not just to produce a good design for PV solutions, but also to find the right place where to apply them. The acceptability study clearly proved an important basic thesis of PVACCEPT, i.e. that protected tourist area can play a multiplier role. Therefore, we recommend to further focus the attention on these areas, which combine high visibility and value of the natural context. Other multiplier target applications mentioned in the discussion with the European observers were large and visible (public and private) buildings and PV design in urban space.

8.6 Dissemination

The crucial aspects for effective dissemination are:

- Relevant target groups;
- Filling knowledge gaps;
- Special information needs of SMEs;

As most important specific target groups for fostering PV dissemination can be identified:

- Architects and designers;
- Industry (in particular SMEs);
- Ministries and local authorities;
- Environmental associations;
- Building owners / public and private investors.

These target groups should be addressed also by workshops and training courses.

In particular, SMEs need easily accessible PV-related information. This requires both specific and tailored information tools and training activities. As a matter of fact, potentially interested SMEs need:

- Concise information on technologies, applications, and incentive programmes, including relevant links and tools;
- Information in their “language”; simplified and understandable by non-experts;
- On-line solutions and easy access to experts / consultants.

The PVACCEPT website is an appropriate and important instrument, meeting all these requirements. Beyond information on a website, also other means of dissemination should be used to address different target groups. Good tools still prove to be exhibitions and publications (articles, books, design manuals etc.). “Chains of dissemination” can thus be established: an article refers to a website where you find information on respective books, which you can buy, or exhibitions, which you can rent.

The ensemble of these dissemination tools can be used to address:

- PV and solar production and installation companies (SMEs), interested / willing to innovate their range of products;
- Energy Service Companies (ESCOs, mostly also SMEs), interested in including effective and efficient PV solutions in their services of rational and efficient use of energy;
- Architects / engineers / planning firms and professionals willing to include innovative PV solutions in their products and services to clients;
- Communities, regional or national authorities interested in dissemination of PV technology, who are or may be involved in the definition of innovative incentive schemes, with specific regard to the built environment and protected areas;
- Environmental associations, who might play an important triggering and intermediary role to promote PV technology and innovative products;
- Other local stakeholders and the general public in occasion of events, seminars, public reunions at local level.

Also new dissemination and marketing ideas and channels should be used. Good examples of innovative strategies with this regard should be evaluated in their effects: In Berlin e. g. a recent initiative of the Senate has concentrated on renting roofs of public buildings to investors for the installation of PV; the public administration is thus setting an example and also makes PV more visible; and in the reconstruction of big housing projects in Germany PV is being used to improve the “image” of the buildings as well as of their owners. Further dissemination channels are constituted by international networks (see also section 8.8).

8.7 Training and Teaching

While dissemination tools are to be used immediately, we also recognize the need for more systematic and long-term activities, such as training and teaching. In this section we summarize our conclusions and recommendations concerning:

- Need for focussed training and teaching courses;
- Specific education for local administrations and the role of ministries.

As mentioned before, training of architects and SMEs concerning photovoltaic technology and its architectural application possibilities is highly important. It has to be included to a much higher extent than up to now in the professional training at schools, technical colleges and universities. Also architects' chambers or handicraft associations must guarantee a regular update and exchange of information. Apart from that information / training of local administrations is a crucial issue.

In particular in Italy, and in other countries with a lower level of knowledge and awareness of PV technology and its possible applications is still relatively low, it is very important to organize training to SMEs concerning PV and renewable energies in general, maybe also combined with energy efficiency aspects. For this, we recommend the involvement of associations active in the renewable energy and energy efficiency sector (e.g. in Italy: ISES Italia, Kyoto Club, REEF) and of universities. As far as this is concerned, we wish to highlight, that the results of PVACCEPT will be introduced in the teaching courses of five Italian universities very soon.

As already mentioned, local administration and authorisation bodies can play a major positive role for the diffusion of PV. However, most of them currently lack of appropriate information and often represent a barrier instead of a triggering factor. Therefore, also these important actors need specific training and teaching tools. With this respect, ministries play a major role to involve / support local administrations. In Italy, the results of PVACCEPT have been presented to both the Ministry for the Environment and the Ministry for Cultural Assets.

8.8 Networking

Another form of dissemination of results can occur through networking. In PVACCEPT the involvement of European observers (see also chapter 1, section 1.4.2) has resulted in establishing a new interdisciplinary network of institutions and professionals, who can support each other's activities and create synergy effects in their work. The constructive critical comments and suggestions of the observers have already influenced project results on the dissemination level (exhibition, design manual) in a positive way.

Activities like workshops also lead to synergies and stimulate new cooperation. As an example may serve here that one of the SMEs participating in the PVACCEPT workshop in Marbach am Neckar had developed an innovative technical component (inverter) especially suited for small photovoltaic plants; small PV applications as suggested by PVACCEPT e. g. for facades of old buildings can create a demand for this product. A cooperation between this SME and the consortium SMEs (module and cell producers) as well as the designers could contribute to make such PV solutions more easily feasible. Cooperation would bring advantages for all partners by extending the professional "horizon" of each side and jointly creating new ideas.

9 Community Added Value and Contribution to EU Policies

Finally we want to summarize some aspects concerning the possible contribution of the project to Community added value and EU policies.

9.1 Background / Introduction

From the European point of view, the development and diffusion of solar photovoltaic energy technologies can be looked at in two different ways: as a chance for economic competitiveness of EU firms with respect to producers outside Europe, and as a market for the technology itself with considerable medium / long-term energy potential, especially in southern Europe. As far as the market diffusion of PV is concerned, this contributes to the EU policy targets on greenhouse gas emission reduction and use of renewable energy sources.

Any photovoltaic product, which is able to overcome specific non-technical barriers, which stand against broad implementation of photovoltaics (PV), contributes to both aspects. One important non-technical barrier is the fact that the primarily “technological” design of standard PV limits the application possibilities of PV, which are accepted by potential public and private investors as well as those public bodies that are responsible for authorisation of building and planning. Contributing to overcome technical and design barriers actually contributes to the EU dimension.

The potential of existing buildings from different historic periods in all European countries is by far bigger than the number of sites available for potential new buildings. Therefore communes together with urban planners and architects have a strong interest in adapting new technologies to existing buildings. It must be noted that very often additions to these buildings are constrained by monument protection regulatory acts and by local community opposition due to “aesthetic” reasons, rooted in the desire not to modify the traditional aspect of buildings.

New design and integration possibilities, as provided by PVACCEPT, widen the application range of PV modules by addressing a more and more “design sensitive” clientele on the one hand, and by tackling the problems, which result from architectural preservation and landscape protection, on the other hand.

9.2 Socio-Economic Aspects and Dissemination

Strategic objectives of European policy address the achievement of an enhanced competitiveness of European industry, the reduction of greenhouse gases and pollutant emissions, the security of energy supply, as well as the increased use of renewable energies. Developing new PV technologies and facilitating their market penetration by means of improved design creates new business opportunities at the level of SMEs. Furthermore, the achieved research collaboration between academic institutions and SMEs is also a premise for the implementation of stronger links towards technical, design and environmental innovation. The contribution of PVACCEPT results to the environmental aspects lies in a broader dissemination of PV that can be achieved.

Innovative products, which can be sold at reasonable prices, are essential for industrial competitiveness. The demand-oriented development of new attractive PV products ready for the market can contribute to create new jobs in PV production and related industries (e. g. glass production and processing, printing technologies, acrylic production), especially on the level of SME.

The tested development and production of PV modules with innovative aesthetic features will put the SMEs of the consortium as members of the European industrial community in a favourable market position. This includes positive perspectives for the employment and training of personnel for production, distribution, and deployment of such modules.

Special training of SME involved in electrical and installation services as well as of architects, engineers and planners, as realized by the PVACCEPT consortium at the end of the project, capacitates the SMEs for consulting and convincing their clients better with regard to renewable energies, in this case photovoltaics, and enhance the demand for PV systems.

The dissemination of project results, with special focus on the existence of operating installed objects, by all means available (books, papers, website) will be a powerful amplifier of the confidence of the public and the policy makers on the proposed innovative PV technology, so that any additional resource investment on dissemination will very likely have a significant return in terms of PV market penetration. Especially the existence of demonstration plants with applied innovative PV modules in areas frequented by tourists from all over the world - as this is the case of the PVACCEPT demonstration objects - will contribute to increase this demand.

Activities to increase the still insufficient knowledge in European populations regarding the advantages, requirements and potentials of PV technology are highly important. PVACCEPT contributes to achieve an improvement by offering easily understandable information tools, which can be used by different target groups. Decision-makers like building authorities and important intermediaries like architects and planners are addressed, but also institutions of general or professional education like schools, universities, craftsmen's associations.

9.3 Ecological Aspects and Acceptance

Extended use of photovoltaic energy in general will improve the quality of life in European countries by avoiding corresponding CO₂ emission in the first instance. Making PV installations more acceptable to the general population by improved design and better possibilities of integration into existing urban and rural surroundings, as realized by PVACCEPT, will certainly contribute to extend the use of PV. The - in their vast majority - positive reactions to the built demonstration objects, and many respective information requests, addressed to the co-ordinator and the consortium members, illustrate this tendency.

Showing that these products can be generated at low energy and environmental cost (overcoming past, still insufficient, results) will facilitate acceptability by the public and by local administrators, who are very sensitive to the idea of getting local advantages without also accepting any additional local burden.

A high percentage of the energy use, harmful to the environment, takes place in buildings. The use e. g. of solar energy in architecture and urban planning is a crucial task as well as a big chance for creating a future sustainable energy system. PV integration is already rather easily possible with positive aesthetic results as far as new buildings are concerned; it was, however, highly important to develop PV modules, which can be applied to the much bigger number of existing buildings, including even those, which are part of the European cultural heritage. PVACCEPT draws the attention to this part of architecture and urban space and offers new types of suitable modules.

Design is, as has been proved, a factor of acceptability and thus as well one of competitiveness. The desired future large-scale application of renewable energy sources, which are affordable and flexible in their application, will depend on significant improvement of their costs and other aspects of competitiveness (like convincing design) against conventional

energy sources within the overall socio-economic and institutional context in which they are deployed. A favourable mix of design, efficiency, environmental assessment, cost is needed for market penetration.

Sustainable development and environmental protection cannot be implemented if the proposed alternatives do not generate business opportunities, nor will these opportunities emerge if the public opinion is not captured by very creative design and results. Market penetration requires innovative characteristics capable to become self-promoting driving forces.

Conventional and non-renewable energy sources have been very often successful because only one step of their whole life cycle was openly shown (just think of the environmental burden generated by the nuclear fuel cycle, or by the extraction and refining of fossil fuels). Instead, we achieved in this project, the full awareness that innovative PV modules are much more environmentally friendly over their whole life cycle, from raw material extraction to final disposal. In order to confirm this statement, we developed and used a multi-criteria multi-scale procedure for LCA assessment, not to be blamed for only relying on one single, although powerful, indicator. Project results show that the investigated technologies and modules do not generate any significant environmental problem over their whole life cycle. We ascertained the need for a low energy investment for module production and a significant energy return. Several indicators (energy, exergy, material intensity, ecological footprint, environmental impact categories) were calculated, all converging towards underlining a much better performance of the innovative PV objects compared to previous PV technologies.

9.4 S&T Cooperation at European Level

The technological products, their application and the knowledge gained by technical tests as well as acceptability studies and energy and environmental assessment, are the result of an interdisciplinary international co-operation. In this cooperation were not only designers / architects, social scientists, chemists, physicists and technology producing SMEs from Germany and Italy involved, but also various communes and regional authorities in both countries as well as observers from Austria, France, Spain and the Netherlands.

Thus, and by additional clustering activities, a network has been established, which assessed and guaranteed the European transferability of the project results. Furthermore, based on these results, new project ideas have been developed and new cooperations are being built up. Know-how gained is being made available via the project website, an itinerant exhibition and a design manual on a wider European level. All Partners brought in their previous expertise in the field and expressed their commitment to amplify the research results by disseminating projects findings and by building further research on present achievements.