PV COOL-BUILD

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Other partners
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Executive Summary

Building designers are not aware of how PV modules/laminates exchange heat with their surroundings, and therefore cannot take the operating temperature into account when designing their system. The solution to this problem has been achieved by making available a user - friendly design guide for architects and building designers which allows them to make informed decisions about their system (www.pvcoolbuild.com)

Background Survey

A survey of the literature showed that extensive original work was needed to provide the models required by the project. New models were therefore developed, both for the determination of the duct flow and the heat transfer. These were initially for plain ducts and then for ducts with various obstructions that could occur in practice, such as closures at the entry and exit, to exclude rain, birds and insects, and structural members crossing the duct, as required to support the PV array. Extensive measurements were made on test rigs at Gavle, to provide the necessary validation of the modelling. When this had been done, a very simplified version of the procedure was devised, to meet the requirements fed back by users. Further studies were then needed to demonstrate that the use of monthly mean weather data would give the mean operating temperature with sufficient accuracy for routine use.

Indoor Experiments

A series of experiments and computer modelling gave the following results:

- The majority of the flow within PV cooling ducts is turbulent. The turbulent nature of the flow was found to be caused by the ribs or cross members behinds the PV panels as is the case in a typical installation of building integrated PV systems.
- That it is difficult to determine and quantify the pressure loss at exit from a PV cooling duct. The difficulty in quantifying this parameter is due to the contraction coefficient, which is very sensitive to the exact shape of the edge of the aperture.
- That a high pressure loss at low aperture areas is due to the effects of the contraction coefficient on the buoyancy-induced flow. A similar analysis for pressure loss at inlet to a duct was carried out and assumptions made to simplify the solution process.
- A variety of different duct geometries were simulated to see if some simple design rule might emerge. It was apparent after some trials that there is indeed an optimum condition, at which the highest temperature, at the end of the duct, passes through a minimum at a particular value of the ratio of the length of the duct to its hydraulic diameter. It was further found that this value of the ratio, which the minimum occurs, seems to be nearly independent of the other operating conditions.

The theoretical model was validated using indoor measurements over a variety of boundary conditions.

Outdoor Measurements

Outdoor validation used averaged daily PV panel temperature rise above ambient, determined from the measured data of three installations in Europe. These were plotted against those predicted from the model. The results show an agreement to within ±1.5^{o}C. Experimental data collected using the outdoor test facility, were compared with the design guide tool and the results were found to agree within the range of experimental error.

It has been demonstrated that the model agrees with measured data, for both the monitored systems and for the specific conditions tested with the outdoor facility.

Design Guide Development

In order to produce the guide, it has been necessary to bring together existing and new knowledge to produce a validated, simplified model of the process. This has then been converted into an easily user-friendly form for architects and building designers to use. The guide is being disseminated widely by CD ROM and website, and has been translated into German, since this is the language of the largest group of PV designers in Europe.

Conclusions

This project has performed theoretical and experimental work in order to produce a validated methodology of calculating the operating temperature of building-integrated PV. Thus the dimensions of mounting the system can be optimised at the design stage. By completing this project increased production of up to 500MWh/year of clean PV electricity may be achieved. Following this project all architects and building designers have access to the means to improve their use of PV either through a CD ROM or by using the website (www.pvcoolbuild.com).

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1 Introduction

The aim of the project is minimising the temperature of photovoltaics (PV) integrated in buildings in order to increase electrical output.

It is estimated that an average BIPV cell operates at a temperature of up to 50^{o}C above ambient. It is estimated that this is 10 deg C higher than that which could be achieved by better-informed design. This represents a loss of performance of up to 5% of power produced, as well as increasing thermal cycling stresses and ageing processes.

In a European context where l0MWp BIPV is projected to be installed annually, this represents a loss of 500 KWp capacity, or around 500 MWh/year of electricity generated.

Scientific objectives and approach

Building designers are not aware of how PV modules/laminates exchange heat with their surroundings, and therefore cannot take the operating temperature into account when designing their system. The solution to this problem has been achieved by making available a user - friendly design guide for architects and building designers which allows them to make informed decisions about their system.

This guide includes temperature profiles and indicators of effect on electrical performance. In order to produce the guide, it has been necessary to bring together existing knowledge to produce a validated, simplified model of the process. This has then been converted into an easily used form for architects and building designers to use. The guide is being disseminated widely by CD ROM and website.

Expected Impacts

The consortium was concerned that lack of design understanding is reducing the benefits of installing PV on Buildings.

Now that this problem is being addressed it is hoped that BIVP will achieve closer to its optimum output.

By completing this project increased production of up to 500MWh/year of clean PV electricity may be achieved. Following this project all architects and building designers have access to the means to improve their use of PV either through a CD ROM or by using the website.

2 Theoretical Modelling (Work Package 1)

A) Proposed work program from the contract.

Description of Work
PV-COOL-BUILD will evaluate and combine the best of the available 2-D turbulent flow models and use this as a tool to validate a 1-dimensional analytic flow model which will form the basis for the design guide. Easily identifiable input parameters will be established to make PV-COOL-BUILD an easily used design tool for architects and building designers. This has not been achieved anywhere in the world to date.

1.1) Review of existing work

- Review key candidate models
- Review areas where published data are unavailable
- Review Simplified One Dimensional Approach
    - convection coefficients
        - validate/refute hot-side ≈ cold-side coefficient
    - radiative exchange
        - validate/refute hot to cold side radiative ≈ constant
    - friction factors
        - generic model for forced convection
        - new theory for laminar flow in idealised channel flow
        - new theory for turbulent flow in idealised channel flow

1.2) Combination of the leading European models

- define a generic model of laminar flow
- define a numerical model for turbulent flow
    - review MS k-epsilon/ model
    - compare/contrast with numerical model
    - derive a suitable turbulent model for real system installations
        - examples from UK/Netherlands/Germany
- define a generic model for all flow regimes, variable tilt, variable aspect ratio, with wind

1.3) Parameterisation of the combined model

- define the Weighted Least Squares approach and statistical indicators needed
    - for parameter identification
    - for model hypothesis testing
- Validation using existing data sets using WLSR (weighted least-squares regression) and model hypothesis testing

B) Work actually performed

Most of this work package was reported using internal documents labelled as numbered notes. These range from Note 1 to Notes 14, each note presenting a solution step in the model. The notes are attached in Appendices.

B 1.1 Review of Existing Work.

An analysis of all published material in the field of ‘Flow in a Duct due to Heating’ was performed by Professor Brinkworth with assistance from Dr Daniel Nuh and Professor Sandberg. It was found that information on the pressure loss in the entrance and fully developed regions of ducts is widely dispersed throughout the scientific and technical literature. Ducts such as those within air-cooled gas turbine blades and around the fuel elements in gas-cooled nuclear reactors were of particular relevance to this work.

A survey of the literature showed that extensive original work was needed to provide the models required by the project. New models were therefore developed, both for the determination of the duct flow and the heat transfer. These were initially for plain ducts and then for ducts with various obstructions that could occur in practice, such as closures at the entry and exit, to exclude rain, birds and insects, and structural members crossing the duct, as required to support the PV array. Extensive measurements were made on test rigs at Gavle, to provide the necessary validation of the modelling. When this had been done, a very simplified version of the procedure was devised, to meet the requirements fed back by users. Further studies were then needed to demonstrate that the use of monthly mean weather data would give the mean operating temperature with sufficient accuracy for routine use.

B 1.2 Combination of the leading European models

Following meetings held in UK, Sweden and The Netherlands, an acceptable generic model was defined. The other leading European model was that developed in the University of Gavle in Sweden by Prof. Mats Sandberg. This model predicts the temperature rise behind a PV panel backed by a cooling duct.

The series of experiments and modelling, showed that majority of the flow within PV cooling ducts is turbulent. The turbulent nature of the flow was found to be caused by the ribs or cross members behinds the PV panels as is the case in a typical installation of building integrated PV systems.

The generic model accepted cases where the flow is predominantly solar radiation driven and cases where the flow is predominantly wind induced driven. A sensitivity test on these cases gave a great simplification of the model which meant that most practical installation could be divided into two classes, facades and roofs, regardless of slope.

B 1.3 Parameterisation of the combined model.

The solution approach implemented was an iterative one. The normalisation and weighted least squares approach is better if the model is well defined and all the parameters are well known and characterised. In the generic model, there were parts of the model that needed more research, such as, the entry and exit conditions of a typical PV duct.

A series of indoor experiments and computer modelling were carried out to determine and quantify the pressure loss at exit from a PV cooling duct. The difficulties in quantifying this parameter is due to the contraction coefficient which is very sensitive to the exact shape of the edge of the aperture. It is therefore affected by a small amount of rounding, as might be produced by de-burring with a file or sandpaper. Indoor experiments showed a high pressure loss at low aperture areas due to the effects of the contraction coefficient on the buoyancy-induced flow. A similar analysis for pressure loss at inlet to a duct was carried out and assumptions made to simplify the solution process.

One of the objectives of PV Cool Build project is to widen the take-up of PV systems by encouraging architects and others to integrate them into buildings as a matter of routine. This would be greatly facilitated if the design of the cooling duct was very straightforward, for example if it could be expressed by one or more simple rules. Following the validation of the analysis procedure for smooth ducts developed under this project by comparison with measurements, a variety of different duct geometries were simulated to see if some simple design rule might emerge. It was apparent after some trials that there is indeed an optimum condition, at which the highest temperature, at the end of the duct, passes through a minimum at a particular value of the ratio of the length of the duct to its hydraulic diameter. Further, by great good fortune, this value of the ratio, which the minimum occurs, seems to be nearly independent of the other operating conditions.

The model has been validated using experimental data, both from indoor measurements and outdoor measurements.

B 1.4 Deliverables

The validated model

A validated model for heat transfer and flow in cooling ducts behind PV panels has been developed.

The solution approach for the model is as follows:

Step 1 - determination of the geometrical and climatic variables.

Step 2 - determination of mean velocity of the flow induced in the duct by the combined driving forces of the solar radiation and the wind.

Step 3 - determination of the temperature rise of the panel near the duct exit.

Step 4 – determination of the reference temperature, which is the connection between the incident solar radiation flux and the inwardly transmitted flux into duct.

Step 5 – calculate the electrical output of the PV system as a function of temperature of PV panel.

Journal papers

Two journal papers are being published as a result of the extra new content that this work has found.
The draft of the first paper titled ‘A validated procedure for determining the buoyancy-induced flow in ducts’ has been submitted to CIBSE journal *Building Services Engineering Research & Technology*.

The second paper will be on heat transfer and is under preparation. It will be entitled 'Design procedure for cooling ducts to minimise efficiency loss due to temperature rise in PV arrays' and will be submitted to Solar Energy (Journal of the International Solar Energy Society).

Conference papers

1) International Solar Energy Society conference and exhibition, Gotenburg, Sweden, 2003.
2) PV in Europe, ‘From PV technology to energy solutions’, Rome, Italy, 2002.
3) Intersolar, Freiburg, Germany, 2003.

3 Validation (work package 2)

A) Proposed work program from the contract.

Objectives to validate the best combined model against some measurements on real outdoor experimental systems
Description of Work (with sub-task titles) **2.1) Indoor to validate parameters in combined model** The test regime will include a range of values to provide data where none is available as identified in Task 1. The indoor test facilities will be used to perform tests over the range of parameters defined above. The data will be analysed to obtain values for the parameters identified in WP 1. **2.2) Outdoor evaluation of combined model** • obtain sufficient good test days, to achieve variability of irradiance 5-25 MJ/m^2day variable wind conditions, variable irradiance, variable aspect ratios by duct depth variable tilts: vertical, typical house, typical DIY/Supermarket variable inlet/exit duct geometries • identify the generic model parameters using WLSR and model hypothesis testing • validate the model using independent sample days A full-scale demonstration/test rig will be built outdoors on a suitable factory building. It will be constructed to allow variation of the above parameters. The test rig will be constructed and instrumented. Test operation and data analysis will be performed
Deliverables A validated combined model of thermal operation of PV on buildings

B Actual work performed

B 2.1 Indoor validation of combined model

The schematic layout of the indoor test rig is shown in figure 1. The airflow is driven by an axial fan connected to the duct. To change the airflow, a variable voltage transformer is used. The airflow has been measured by using four different sizes of orifice plates. For the largest flows, a calibrated 90-degree bend of an inlet duct 250mm is used. The pressure drop is measured by using an electronic micro-manometer (Furness FC012) with a resolution of 0.01 Pascal.

The experimental determination of flow and heat transfer coefficients were measured using this test rig. The measurements were extended to quantify duct end losses. The rationale for extending the measurement program was that results from flow measurements in the heated "facade rig" (5-m long mock-up of a facade with an air gap of 0.2-m depth) showed that the flow was controlled by the resistance of the crossrails and the net located at both the inlet and outlet. The net is a standard net used to exclude colonisation by birds and insects. The influence of these nets on the flow rate was greater than the effect of the crossrails. Therefore the nets control the flow rate.

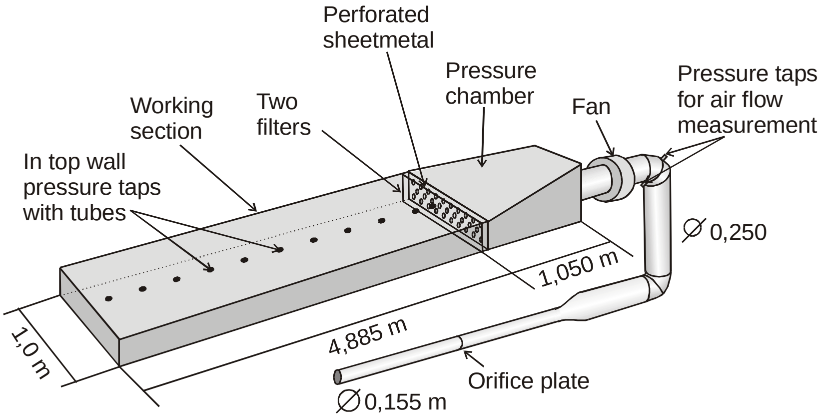

Fig. 1 Test rig for measuring end losses and the friction coefficient in a duct with a rib roughness

Furthermore, the loss is strongly velocity depended within the range that may occur in practical applications, se Fig. 2, which requires that the loss is monitored over an appropriate velocity range.

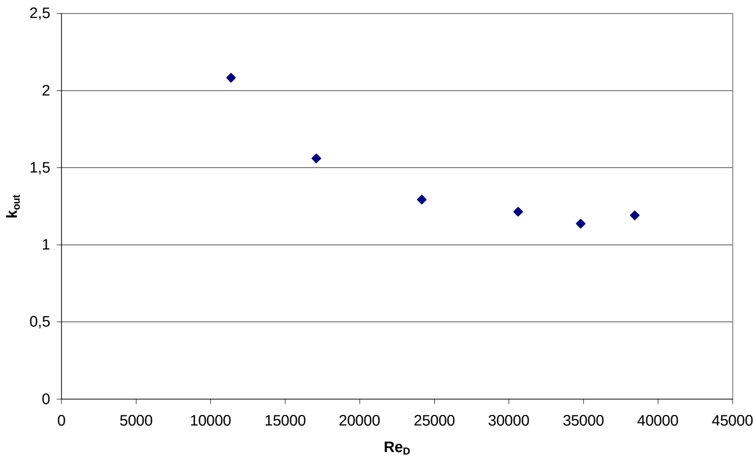

Fig. 2 *Loss coefficient for a net as a function of Reynolds number*

Measurements of the end loss caused by blockage of the outlet and inlet have been extended to include a wider range of ratios between free opening area and duct area. Correlations between recorded values and design parameter have been carried out as preparation for the use of the results in practical applications.

Fig. 3 *Smoke visualisation*

B 2.2 Outdoor evaluation of combined model

Comparison of the temperature behaviour of three different PV roofs in Cologne, Germany.

In the framework of the project, the University of Applied Sciences Cologne was given the task to evaluate three different types of PV roof installations. The systems were equipped with extensive data acquisition instruments. The three systems offer a good variability of irradiance, wind conditions, hydraulic duct depths and inlet and exit geometries. This measurement exercise studied the temperature dependency on the input variables. A regression analysis was used to compare changes from one set of data to another.

EETS outdoor test facility

Figure 3: EETS variable angle outdoor test facility.

Description of test Facility.

The facility was constructed using a variable depth roof integration system and standard PV laminates from 2 different manufacturers.

The system was mounted on a wooden base with a steel rear structure. The system was mobile and was held at a particular slope and orientation to the sun. Measurements were made of Solar Radiation, ambient temperature, wind speed, and module and duct air temperature. Values were taken until it could be established that a steady state condition had been achieved.

The facility could then be reconfigured to a different duct space, or entry condition.

Experimental data collected using this test facility were compared with the design guide tool and the results were found to agree within the range of experimental error.

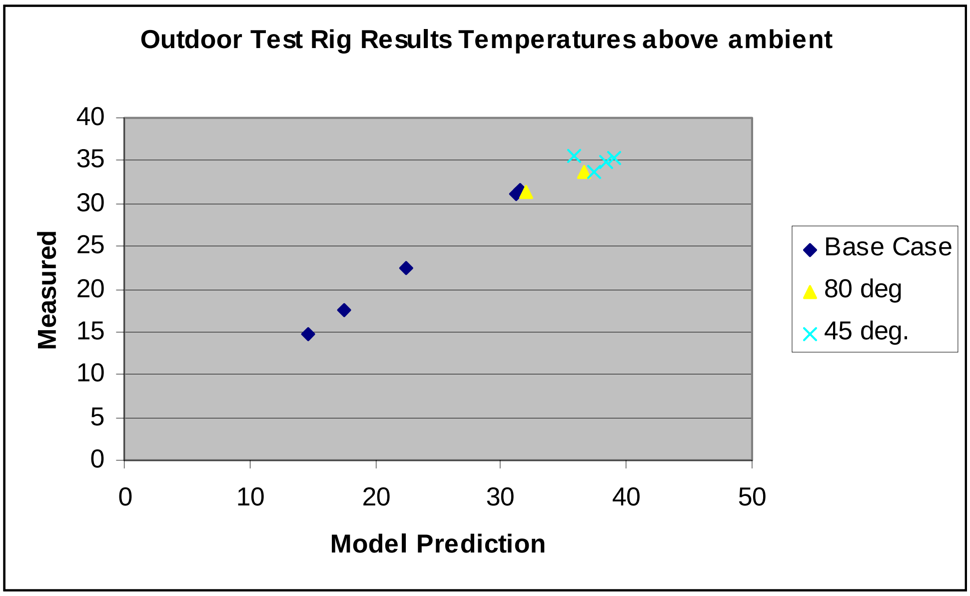

Figure 4: Outdoor test rig results.

Comparison of temperatures of different PV roof types in Europe

EETS has been monitoring several of its PV installations in the past two years as part of this project. A further installation has been monitored in the Chamber of Handicraft, Cologne. The data from these installations have been compared with the output of the design tool and they agree to within 10% on average. A plot from three outdoor monitored sites is shown below.

The report of the experimental work is included as appendix X

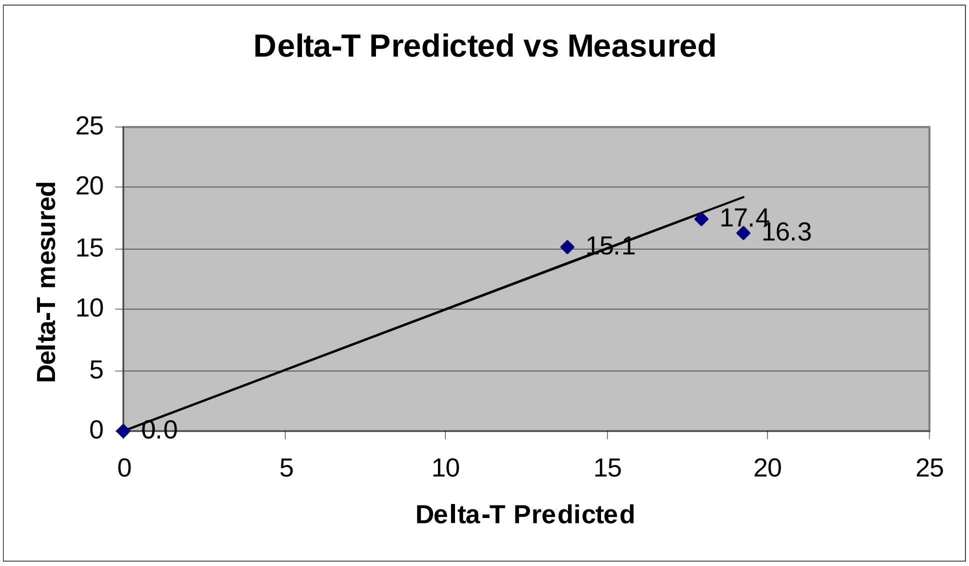

Figure 5: Outdoor measurement of fully integrated PV roofs in Europe.

B 2.3 Deliverables

A fully validated combined heat and flow model for design for optimum cooling of PV building integrated systems.

4 Design Guide

4.1 Preliminary Architects Trials (Work Package 3)

A) Proposed work program from the contract.

Objectives A design guide will be written and preliminary version tried by Architects
Description of Work (with sub-task titles) 3.1 The outcome of WP 2 will be discussed with the other participants The model and the calculation will be made into a spreadsheet form suitable for architects. This will be done in two levels: - a general level for rough dimensions (based on synthetic daily mean data values) - a second, more detailed level (based on synthetic hourly mean data values) - (note this will use data from the project F: European Solar Radiation Atlas) - 3.2 A draft guide will be prepared The tools for architects will be: - rules of thumb, - calculation forms, - software. There will also be a section of background on PV in buildings, illustrations, and example construction sectional drawings. These will give examples applied to the major building types of the different implementations, e.g. roof/façade with/without air gaps, with intermediate air gaps, in conjunction with transparent areas, as part of multi-layer systems, and linked with natural and hybrid ventilation systems. The design guide will be illustrated with sections and examples of calculations. To help the architect through the process, a step-by-step procedure will be described. 3.3 Architects Trial: The rough design guide will be tested among a group of more than 8 architects from different European countries. 50% of these architects are experienced with PV, the others not. 3.4 Response evaluation: The results of these trials will be incorporated in the final design guide.
Deliverables A draft design guide with practitioner feedback

B Actual work done

B 3.1 The outcome of work package 2 & discussions

The outcome of WP2 was discussed in a series of meetings throughout Europe. Reports of some of the meetings are shown below.

<u>Report of Expert Meeting at Schüco, Bielefeld on 6th of June 2002</u>
Participants:
MM Andreas Häger, SCHÜCO
Stefan Beisel, SCHÜCO
Olaf Gempfer, SCHÜCO
Tom Voorsluijs, XDMS
Prof. Wolfgang Wiesner , University of Applied Sciences Cologne

<u>Project Team PV-Cool:</u>

Bruce Cross, EETS
Dr. Daniel Nuh, EETS
Tjerk Reijenga, BEAR
Prof Mats Sandberg, BMG
Gerhard Nagel, for GEOSOLAR

The meeting started at 11.00 h with a facility tour showing the PV-facade on the office building of SCHÜCO, which is in operation since more than 10 years. Furthermore the new advanced technologies of SCHÜCO were presented.

After lunch Tjerk Reijenga described the tasks of the PV-Cool project with respect to the planned guide for architects and building engineers.

The details of the basic work for the development of the theoretical analyses of the temperature behaviour behind the installed PV-Modules were presented by Prof Mats Sandberg including the verification by corresponding test set-ups.

The presentation was followed by an open discussion with the invited experts, the main outcomes are as follows:
In accordance to existing standards for facade constructions a minimum gap of 150 mm^2 / m is required for moisture reasons. It was discussed that an evaluation of mechanical effort versus temperature advantages has to be performed in our future work. SCHÜCO handed over his latest “Architekten – Information” for aluminium facade profiles.

It was agreed that after distribution of the detailed meeting report the communication with the invited experts will continued in order to consider realistic conditions of available standard constructions.
The results of these communications will be implemented in the final issue of the guide to be prepared by Tjerk Reijenga.

It was offered by Prof. Wolfgang Wiesner to perform onsite temperature measurements on different PV-constructions during this summer period at IHK-Cologne. He will prepare a proposal for this work.

<u>PV in Europe Conference and Exhibition, Rome.</u>
This project was presented briefly within the one of the workshops and the usefulness and the need for the design tool was discussed in an open forum. The general feedback was a keen interest from architect for such a tool.

B 3.2 Design Guide

PV Cool calculations

The design guide was programmed in Excel and then converted into html code for online website calculations. The designer is requested to follow the procedure below.

There are three areas within the front screen.
1. Meteorological information
2. Building information
3. Results

Step 1:
The First step is to select the nearest city to your location from the drop down menu of 70 European cities provided. This will then provide 12 monthly averages for the following three (3) Meteorological Parameters:
1. Solar Flux, in Wh/m^2d. (Average highest instantaneous for location at particular time of the year.)
2. Local mean wind speed at 10m meters above ground level, in m/s.
3. Ambient temperature, in ^oC.
Further, the table provides the Latitude for the selected city.
(Click on the 'Irradiation Values of European Cities' link to see these values).

Step 2:
The Second step is to enter values for the following five Building Parameters:
1. Inclination angle of PV array in degrees. 90 is vertical, 0 is horizontal
2. Length of PV array from bottom towards top of roof, in meters.
3. Width of PV array from left to right, in meters.
4. Depth of the duct space behind the PV array, in meters.
5. PV module efficiency in %. Monocrystalline is usually in the range 12-14%, polycrystalline in the range 10-13% and thin film 6-10%. However, a manufacturer's figure for total module efficiency should be used if available.

Step 3:
The results given are:
1. Actual PV panel temperature at the top of the installation, in ^oC. This value is of interest for those who are interested in the selection of materials for gaskets, cabling, mounting components, etc.
2. Flux transferred into duct, in W/m^2. This value is for academic evaluation.
3. Optimum Duct Depth, in metres. This is the ideal gap space behind the PV to achieve maximum electrical output. The user can alter this value (step 2 point 4) to investigate the sensitivity.
4. Weighted average efficiency, %. over the year.
5. Reduction in performance, % relative to STC. This value gives the performance of the installation compared to rated system output at standard test conditions. This is useful for the overall cost benefit of the system
6. Predicted efficiency, %.

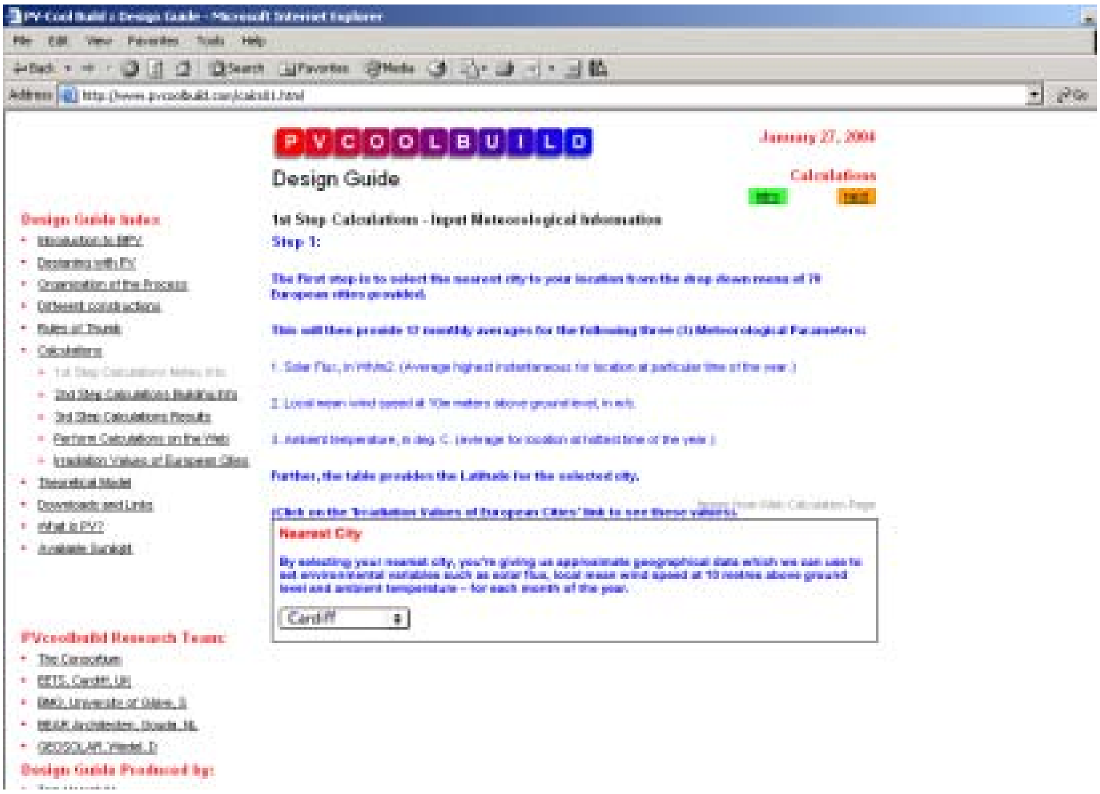

Figure 6: The First step is to select the nearest city to your location from the drop down men

Figure 7: The Second step is to enter values for the following five Building Parameters

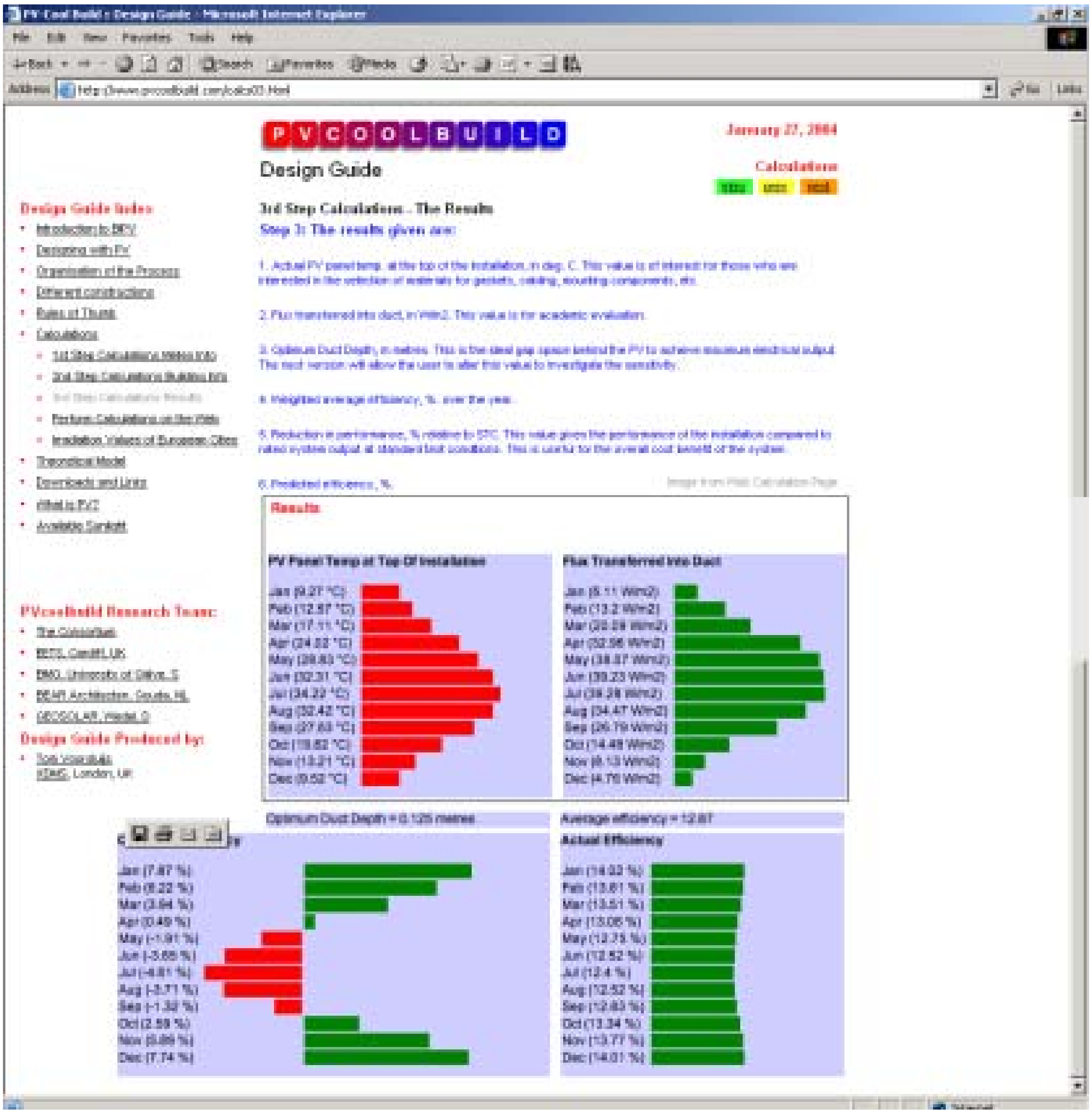

Figure 8: The output results

B 3.3 Architect trials

The design guide has been tested by more than 8 architects so far. Their feedback has been included in the tool which is currently been hosted on the PV Cool Build website.

Technical group:

Hans Bloem - JRC Ispra
Frank van de Heuvel - Scheuten Solar
Jos Schlangen - Shell Solar
Hans Oldegarm – TNO Bouw Delft
Prof. Wiesner – University of Köln
Bernd Faßbinder - University of Köln
Christian Roecker – University of Lausanne (EPFL-LESO)
Reinhard haas – University of Vienna
Henrik Soerensen – Esbensen Copenhagen
Hermann Laukamp – Fraunhofer Institute Freiburg
M. van Schalkwijk – Ecofys Utrecht
Frank Wouters – Ecofys Köln
Nico van de Born – ECN DEGO
Maurice Jong – ECN Petten

Architects group:

Officine di Architettura Cinzia Abbate – Rome
David Lloyd Jones – Studio E Architects London
Ir. H.F. Kaan – architect
Han van Zwieten – Architectenbureau van Straalen
Wouter Borsboom

B 3.4 Response evaluation

Deliverables

A design guide that has been tested by architects.

4.2 Implementing companies trials (Work Package 4)

A) Proposed work program from the contract.

Objectives PV Building companies to verify the applicability of the optimised geometry in real installations
Description of Work (with sub-task titles) 4.1) PVIB installation companies will asked to comment on the practicality of implementing the designs as produced in WP3, this will be performed during the planning of such PV-projects, which is part of the standard procedures 4.2) Design partners of participant 5 (such as architects and building engineers) will be identified and comments from them and their clients about applicability incorporated in the design guide developed in WP 2 and 3. 4.3) Due to the close information loop in the project participant 5 will take care to advise their present and future installation partners to design in accordance to the interim result of WP 2 and 3.
Deliverables User feedback for design guide verification

B Actual work done

B 4.1 The design guide has been reviewed by the list of practitioners below.

Technical group:

Hans Bloem - JRC Ispra
Frank van de Heuvel - Scheuten Solar
Jos Schlangen - Shell Solar
Hans Oldegarm – TNO Bouw Delft
Prof. Wiesner – University of Köln
Bernd Faßbinder - University of Köln
Christian Roecker – University of Lausanne (EPFL-LESO)
Reinhard haas – University of Vienna
Henrik Soerensen – Esbensen Copenhagen
Hermann Laukamp – Fraunhofer Institute Freiburg
M. van Schalkwijk – Ecofys Utrecht
Frank Wouters – Ecofys Köln
Nico van de Born – ECN DEGO
Maurice Jong – ECN Petten

B 4.2 The design guide has been reviewed by the list of architects below.

Architects group:

Officine di Architettura Cinzia Abbate – Rome
David Lloyd Jones – Studio E Architects London
Ir. H.F. Kaan – architect
Han van Zwieten – Architectenbureau van Straalen
Wouter Borsboom

B 4.3 Geosolar has been in discussions with all their partners to recommend the guide to their partners in PV installation and design.

Deliverables

Expert user feedback on the design guide.

<u>Results</u>
The main results achieved are:

- Background data have been made available for guidance definition and web site presentation.
- The PVCOOL draft guidance incl. software-tool and internet presentation was presented to various potential users. In performing this GEOSOLAR contributed to exhibitions and workshops and carried out presentations.
- Mailing actions (questionnaire) and discussions were carried out.
- PV-system designer were encouraged to compare different construction types prior to the selection of a construction supplier.
- Inputs to update the guidance have been transferred based on first clients responses.
- Based on experts and initial user feed back the design tool seems to be suitable for an application in photovoltaic project optimisation with good reproducibility and accuracy.
- Architects and solar module manufacturer/system house response requires the necessity of guidance simplification.

Task description
In the following the main tasks related to study work and dissemination are described.
<u>Presentation of tasks to invited experts</u>
An expert meeting was coordinated at the system house Schüco in Bielefeld (Germany). This meeting was carried out to define and/or compare theoretical background data of façade constructions.
Schüco is a leading building construction supplier in Europe with long-term experience in photovoltaic systems. The planned PV-Cool guide was presented to the experts including the details of background work performed for the development of theoretical analyses and verification tests. Schüco presented its more than 10 years old PV-façade and new advanced construction technologies. Requirements for façade constructions as defined in actual general standards and its applicability to PVCOOL have been discussed.
(ref. attached meeting report dated Sept.2, 2002).
The outcome of this meeting was used for the draft design guide definition input.
<u>Comparison of the temperature behaviour of different PV-systems</u>
It was investigated to perform site temperature measurements at a 20 kWp photovoltaic facade designed and build by GEOSOLAR in the year 2002. This facade is based on a Schüco construction system with different PV-building elements. Due to several constrains however (required rebuild of a representative panels with temperature sensors, impact on system warranty, hesitations of the customer etc.) this approach was agreed to be cancelled.
For verification of temperature coefficients data for PV-systems in addition to the already established theoretical data basis for building integration systems (facades) a subcontract was placed to the University of Applied Sciences Cologne for an evaluation of measured data of different PV-training roof-systems.
The systems evaluated are “on-roof”, “roof-tile” and “in-roof type” constructions

They are part of a training installation of the Chamber of Handicrafts in Cologne, Germany and are equipped with extensive measurement and data acquisition installations.
As a result of this work a good estimation of temperature coefficients could be made available for comparison with the theoretical PVCOOL model.
The results were presented in the December 2002 workshop at Schipol and are described in the attached report.

Workshops

Workshops have been visited and/or conducted to transfer the information to concerned parties through providing them with background knowledge about the theoretical work performed within the PVCOOL development and definition.
For the **Rome conference** 2002 preparatory actions have been taken with WIP for a separate workshop for PVCOOL. As this was not possible due to organizational constrains a presentation was prepared by the team to participate in the architectural session with an oral presentation.
At the **Amsterdam – Schipol** workshop 2002 the study results for the measurement of different technical PV-constructions where presented and discussed.
A workshop was conducted in the frame of the **Intersolar 2003** in Freiburg (international solar exhibition and specialists conference) with participants from Europe and other countries.

Exhibitions

In order to advertise the PV-Cool features GEOSOLAR presented the development program and the software tool on the occasion of the "9.th Eckernförder Solartage"(2003-exhibition and local architects-and expert meeting in Schleswig-Holstein, northern Germany).

Internet presentation

The PVCOOL design service was described on the GEOSOLAR internet presentation and a link was set to the PV-COOL web site.
Interested people were informed about the background and the tool offered for testing free of charge with comprehensive information about the state of program as well as latest results from research and development.
It is our aim to ease the presentation and to tailor the tool to meet the needs and demands of users individuals.

Contacts and mailing

To get a good spread of information feedback, GEOSOLAR contacted "user groups" at different program status (issue of draft design guide and internet presentation).

Target audience

The user groups listed in the table below where identified as target audience. Out of these groups of partners, customers and potential users were invited to participate.

User Group	Subgroup	No. invited
Architects		4
Building designer		2
Vocational schools		2
Solar organisations		1
Handicrafts schools		1
Universities		2
Technical supervision (TÜV) organisations		1
PV-System houses		3
Manufacturer	Solar Modules	5
	Construction systems	2
Installer	Electrician	5
	Roofer	1
	Heating plants	1

User groups not invited in the first run respectively giving no response may be requested later after receipt of comments and corresponding judgement.

Questionnaire

A questionnaire was developed to ask for clients feed back on the application of the design guide.
More than 20 representative potential users were requested to participate and to support the study work by trying out the tool and giving response.
To test the opinion of users of the tool GEOSOLAR concentrated on contacts in Germany; EETS and BEAR brought in their experience gained from response of their clients.
The initial questionnaire objective was to get first a reaction / impression and to improve the tool step by step on the basis of corresponding feed back.

Clients feed back

Considering the importance of energy and - as a result of the PVCOOL program -the success in developing an effective design tool for photovoltaic applications many of addressed users showed their willingness to review and try out the web presentation and the calculation software. The web site presentation and the calculation tool were evolving step by step due to improved and more comprehensive presentation of results based on clients feed back.
Response was mainly given by phone, but some clients answered in writing.
Also some participants did not reply because of lack of time ore due to computer system and or download problems. Above all it was necessary to repeatedly get into contact with the user to get as many written responses given with a constructive feedback.
To develop and promote the knowledge and expertise gained training sessions were carried out with selected partners. Practical experience is needed to make a good judgement. It is important to accumulate experience oneself and then to use the tool.

In this context we got some negative feedback from partners not being happy with the handling of the draft guide. The clients understood very well the intention and the approach of the program however they require a “plug and play” tool.
The business partners interviewed had a realistic understanding of their needs, potential difficulties/complexities, etc. There was a clear indication that only a very simple and easy tool would be used for work. Depending on their skills/ability and dedication user accepted or denied the tool.
Some do not like to go into too much detail with the internet presentation and the extensive scientific knowledge behind. The structure of the internet presentation and the calculation system therefore should be more simplified. An appropriate measure would be also the distribution of CD-ROMs.
Experienced designers were able to use the tool and to give their pros and cons” without assistance.
The ways in which the user answered reflect their different views.
Some architects don’t see the power optimization as the essential act of their planning.
The physical characteristics of PV products must meet architectural requirements (colour, size, materials) sometimes with negative economic (power-output) consequences.
Installers of roof systems usually rely on standard construction systems. They normally do not check the system with regard to power output vs. temperature. As roof systems have a significant share in photovoltaic we also invited a leading roof construction manufacturer to participate in the try-out and to possibly adapt his design.
During the course of the contract it became apparent that the try-outs made are mostly theoretically because the time span from project design to hardware manufacturing for photovoltaic projects normally is to long or the analyses and the intended hardware completion did not timely match.
A good demonstration of the validation of the theoretical model was made at the Intersolar workshop in Freiburg.
After presentation of the design guide and the calculation software a participant requested to perform a calculation with actual system and environmental input parameters of an existing photovoltaic project in Canada.
The result of the calculation performed interactive perfectly corresponded with the temperature measured at site.

Conclusion
Different users were encouraged to participate in the try-out phase in performing project design optimisations.
Inputs for design guidance improvement have been communicated.
A good demonstration of the validation of the theoretical model was possible.

It is intended to continue communication with experts (Schüco, etc.).

To accomplish its tasks GEOSOLAR will focus to increase user involvement.

GEOSOLAR will continue with information and training. The basic goal can best be reached by working with users who have a key interest in PV optimised systems.

We like so to improve the feed back rate and get more results of real user applications. Intensive distribution via a wider network may be required to achieve this target.

Recommendations will be worked out how to reach potential user by further promotion and distribution. Possible links with other institutes and marketing groups will be evaluated.

To conclude:

- Meeting report “Expert meeting at SCHÜCO-Bielefeld of June 6, 2002”
- Report “Comparison of the temperature of three different PV-roof-systems
- GEOSOLAR questionnaire for clients feed back
- Meeting report “INTERSOLAR 2003 – Freiburg of June 27,2003
- Representative photos of typical clients PV-projects.

4.3 Design Guide Production and Dissemination (work package 5)

Objectives
To incorporate the comments and information from WP 4&5 into the draft guide produced in WP3

Description of Work (with sub-task titles)
5.1)
- The draft guide will be turned into a useable booklet and it will incorporate the comments relating to content and presentation from 3 & 4 above. Options for inclusion of temperature profiles will be explored, in addition to predicted operating temperature and its effect on electrical output.
- The guide will be implemented as a website on the internet with a design guide for architects. The design guide will be based on the design process. Information is short and only the information will be given that is necessary for the stage of the design.
- The website will also be distributed as a stand-alone CD operating as a complete off-line system.
- The website will give examples of calculations, solutions and constructions. For that reason different constructions that have been realised will be calculated with the model and the outcomes will be available on the website. Descriptions of different products will be made available to give the possibility to choose the right product to the right solution.
- The model is downloadable from the website.
- The website will be linked with other websites and PV portals on the internet.

5.2)
- The guide will be distributed (at cost of CD media and distribution only) widely (also downloadable from websites of the participants, EU sites, and international contacts)
- The guide will be demonstrated and offered to the industry at suitable European building, architectural and PV conferences and trade fairs.
- The guide will be published in the form of articles with examples in the Specialist building and architectural press in all the countries of the participants, and in European publications.
- The guide will be made freely available for incorporation into suitable EU and international guides for PV in buildings (e.g. LIOR CD)
- The guide will be implemented in the PV-SYSt software package
- All those consulted in WP3&4 will be given copies to distribute, and to form an ad-hoc user group.
- The guide will be made available, through the website and by giving lectures, to schools of architecture, to support the teaching of PV in general education of the profession. A specific guidance sheet for teachers will be developed.

Deliverables

A user-friendly design guide for minimising the temperature of PV in building applications in the form of a paper document, a computer CD and a website.

Actual work done

- The draft guide has been turned into a useable booklet.
- The guide has been implemented as a website on the internet with a design guide notes for architects. www.pvcoolbuild.com
- The website has been burnt onto a stand-alone CD-ROM which is operating as a complete off-line system.
- The website performs calculations online. Example calculations for different type of PV roof constructions are presented on the web site.
- The design guide tool is downloadable from the website
- There is a links section within the website that links to other websites and PV portals on the internet.
- The guide is being distributed widely throughout the industry, using a selection of 2000 recipients of ‘Renewable Energy World’ who are PV professionals.
- The guide has been demonstrated and offered to the industry at 3 PV European shows.
- Parts of the work have been published in 3 conferences so far and there is one journal publication pending and another in preparation.
- The guide has been made freely available for incorporation into suitable EU and international guides for PV in buildings.
- The guide will be made available for implementation into PV-SYSt software package.
- All those who have been consulted in WP3&4 have been given copies to distribute.
- The guide was translated into German to allow its better use in the largest group of PV professionals in Europe.

5 Conclusions

A user interactive PV on buildings design guide has been produced and disseminated.

The development of the methodology behind the guide has required that new areas of scientific and experimental work be performed. This has had the effect of increasing the breadth of knowledge in the subject area, and has been published in the scientific literature.

The guide has been evaluated during its development by a group of European professionals directly involved in the industry. Their input has ensured that the guide will be of the most use to practitioners, and so will have the best influence on the output of PV systems being installed around the EU.

The ability to use the model on-line, or to download it for use on the users PC gives the opportunity for access to all.

By explaining and demonstrating the model at seminars associated with specialist exhibitions, the awareness of the model has been raised. A significant number (2000) CDs of the model are being distributed to a targeted audience, along with a printed booklet for guidance.

The guide development will not stop here. It is hoped that the steering group will continue to give input into the project, and the collaborators will maintain and update the website, from which all the documents are downloadable.