PUBLISHABLE FINAL REPORT

CONTRACT N°: **NNE5-2001-00550**

TITLE: **LIGHTWEIGHT PV LOUVRES FOR MULTI-FUNCTIONAL SOLAR CONTROL AND DAYLIGHTING SYSTEMS WITH IMPROVED BUILDING INTEGRATION**

ACRONYM: **PV-LIGHT**

CO-ORDINATOR: **ZENTRUM FÜR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WÜRTTEMBERG (ZSW)**

PARTNERS: **COLT INTERNATIONAL HOLDING B.V. (NL)**
KOCH MEMBRANEN GMBH (D) - ***withdrawn 31.01.04 -***
GSS GEBÄUDE – SOLARSYSTEME GMBH (D)
WÜRTH SOLAR GMBH & CO. KG (D)
ISOVOLTA AG (A)

REPORTING PERIOD: **1. FEBRUARY 2003 TO 30. SEPTEMBER 2006**

PROJECT START DATE: 01.02. 2003 **DURATION: 44 MONTHS**

Date of issue of this report: **30.10.2007**

Research funded by the European Community
under the Fifth Framework Programme (1998 – 2002)

Table of contents

1. Executive publishable summary

Objectives

PV louvres in front of glass façades and windows fulfil several tasks such as efficient shading of the direct portion of the sunlight to prevent overheating of the building, sufficient daylighting to avoid artificial lighting, and PV energy generation through the embedded cells. The general objective of this project is the development and field testing of lightweight PV solar control systems with an enhanced PV and daylighting performance and higher market diffusion potential. Weight reduction is achieved by substituting glass components of PV modules (at least in part) by flexible membranes. Solar tracking optimises both temporal (daytime, seasons and weather) shading and PV energy generation. The project evaluates the potential of the ZSW-patented Counter-Tracking Louvre (CTL) technique for roof and façade applications.

Results

Well balanced building concepts in connection with the professional integration of daylighting systems are key criteria to achieve excellent visual conditions and saving of energy. In a first step the architectural, energetic, engineering and economic design criteria for light weight multifunctional architectural systems for PV generation, solar control and daylighting have been defined to identify the most appropriate system for facade and roof integration. The basic configuration of a PV louvre solar control system is the classical way as a curtain façade covering the full glass façade/window. In this configuration, the CTL-Technique can be applied in any kind of vertical, horizontal or inclined façades or roofs and with any kind of axis orientation within that plane. Conventional glass louvres (6/4 mm laminated PV glass louvre) have a weight of around 30 kg/m². Replacing the glass by membranes can reduce the weight at least by 50%.

The kinematics and the support structure for the Counter-Tracking Louvre technique, which avoids the mutual shading of adjacent louvres, has been developed and optimised in combination with a passive thermohydraulic drive system. The CTL-technique ends up in an energy harvest advantage of 18% - 33% over the conventional synchronous tracking mode depending on climate and application.

For the implementation of the new light weight louvre technology, laminates for the sun control systems with crystalline silicon and CIS solar cells have been produced, tested and optimised with respect to tear resistance, light transmission, water vapour transmission, uv durability and mechanical shrinkage. It has been demonstrated that it is possible to use the polymer film alone without additional membrane to build up the module.

For the system test phase (from December 2004 to December 2006) prototypes with these components have been installed at test platforms to measure the daylight characteristics, thermal performance and PV energy generation. No degradation has been observed during the field tests. During summer months the louvres in CTL configuration generate up to 20% more energy than a fixed module related to the installed peak power.

A first full scale PV-LIGHT demonstrator system was presented in the conference exhibition of the 19th EU Photovoltaic Solar Energy Conference in Paris (June 2004). An improved version was on display during the PV Conference in Barcelona(June 2005) and was afterwards used for extensive field tests. A final version has been prepared for the Dresden Conference (September 2006) which has reached a weight of 17.2 kg/m^2 for the entire system comprising PV louvres, kinematic components, drive and mounting parts.

2. Publishable Synthesis Report

2.1. Objectives and strategic aspects

PV louvres in front of glass façades and windows fulfil several tasks such as efficient shading of the direct portion of the sunlight to prevent overheating of the building, sufficient daylighting to avoid artificial lighting, and PV energy generation through the embedded cells. The general objective of this project is the development and field testing of lightweight PV solar control systems with an enhanced PV and daylighting performance and higher market diffusion potential.

In order to overcome market penetration barriers due to weight and/or static restrictions, the glass content of the PV louvres will be minimised. Weight reduction is achieved by substituting glass components of PV modules (at least in part) by flexible membranes. Crystalline silicon as well as CIS thin-film photovoltaic cells are embedded in foils and textile membranes to obtain lightweight solar-control louvres. Glass can be totally avoided for c-Si technology. For CIS technology a substrate glass is still needed in the medium term. However, even in this case, more than 50% of glass- and thus weight-reduction is possible.

The technical target is to reach a louvre weight without frame < 2.5 kg/m² (c-Si technology, short term) and < 0.5 kg/m² (CIS technology, long term).

The potential of the ZSW-patented Counter-Tracking Louvre (CTL) technique is evaluated for roof and façade applications. The inherent self-shading effect of synchronous tracking PV louvres can be overcome now by two sets of counter-tracking louvres. This development is expected to give the access to the highest specific energy harvest possible for flat plate PV. Furthermore, it enhances the daylight autonomy of the building. Prototype systems are tested indoors and outdoors to assess the performance improvements. Demonstrator systems support the market introduction of the new technology.

During the last century the transparent fraction of a building envelope has increased steadily. The larger the transparent fraction of the buildings envelope becomes the more important is the control of the solar energy flow to keep acceptable thermal and visual comfort levels in the rooms. In consequence, today’s buildings are dominated by technical systems for heating, cooling, ventilation and artificial lighting – often resulting in high conventional energy consumption and poor daylight use.

Combined with low-energy building technology within an integrated total-energy planning, a multi-functional PV solar control system has a high conventional energy reduction potential and can cover the major - if not the total - electrical energy consumption of buildings.

2.2. Scientific and technical description of the results

In a first step the architectural, energetic, engineering and economic design criteria for light weight multifunctional architectural systems for PV generation, solar control and daylighting have been defined to identify the most appropriate system for facade and roof integration. The basic configuration of a PV louvre solar control system is the classical way as a curtain façade covering the full glass façade/window. In this configuration, the CTL-Technique can be applied in any kind of vertical, horizontal or inclined façades or roofs and with any kind of axis orientation within that plane. Simulations have demonstrated that the CTL-Technique gives access to both: - a 20% higher specific PV energy gain compared to any other fixed or movable PV system concept- and a 20% higher daylighting potential. Therefore it is possible to obtain the same energy harvest per m² with only 80% of PV cell power.

Conventional glass louvres (6/4 mm laminated PV glass louvre) have a weight of around 30 kg/m². Replacing the glass by membranes can reduce the weight at least by 50%. This figure has already been reached with the first full scale PV-LIGHT demonstrator system presented in the conference exhibition of the 19th EU Photovoltaic Solar Energy Conference in Paris (June 2004), where a specific louvre weight of 14 kg/m^2 has been achieved.

PV laminates based on the high transparent front foil have been manufactured with c-Si cells on an aluminium carrier in order to perform high voltage tests according to 61215 Standard; all tests have been passed. Additionally damp heat and temperature cycling tests have been performed without optical or mechanical degradation.

Figure 1: The Paris demonstrator

Special flexible materials for the substitution of glass in standard CIS modules have been produced and tested with respect to stability, light transmission, barrier properties, adhesion and processability. To improve the properties of the single raw material layers multilayer composites have been investigated. However, even with multilayer composites the water vapour transmission could not be sufficiently reduced to completely prevent degradation effects in CIS modules under long lasting damp heat tests. Therefore it was decided to use CIS modules in glass/glass technology fixed on a transparent foil for the louvre manufacturing. This configuration passed damp/heat, thermal cycling and hail impact tests without problems. The mechanical strength of the assembly is high enough to bear the load of a whole module build-up.

In addition to the introduction of the new louvre structure the mechanical and kinematic concept of the Paris demonstrator was completely redesigned: the louver banks are now in front of the verticals at any time to completely avoid partial shading, the counter louvres reduce the mechanical load acting on the drive and all the kinematical components are on or in the mullions to allow maximum pre-assembly. The result was demonstrated at the PV-conference in Barcelona 2005. After the exhibition the system was transferred to the ZSW test site for comprehensive outdoor tests.

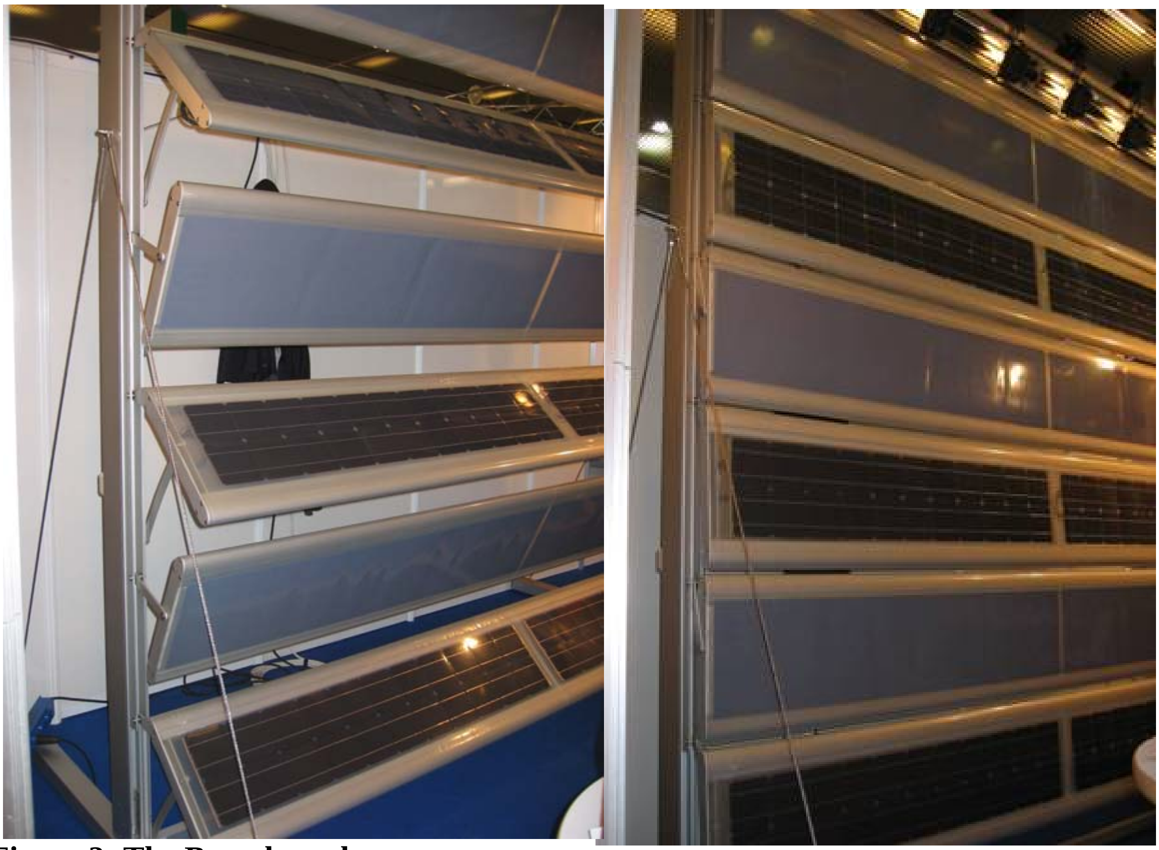
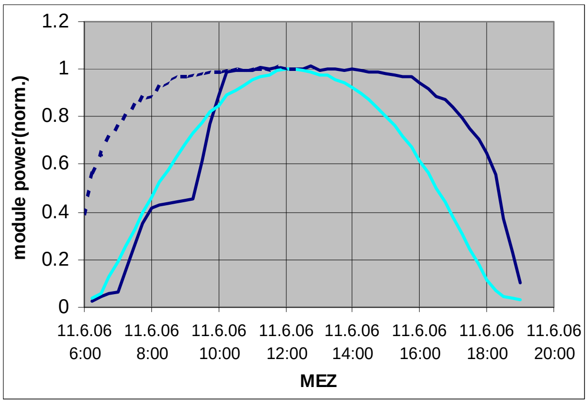


Figure 2: The Barcelona demonstrator

For PV louvre sample analysis under outdoor operation conditions a test bed has been prepared for the experimental evaluation of the CTL-technique and the thermohydraulic drives. Furthermore kinematic layout principles have been tested on this test stand to optimise the static and kinematic system layout.
Prototype louvres have been investigated from December 2004 to December 2006. No degradation has been observed during the field tests.

Figure 3: Test stand for louvre sample analysis, first generation louvres (see Paris demonstrator)

Some typical clear day profiles demonstrate the mutual shading effects of adjacent louvres.



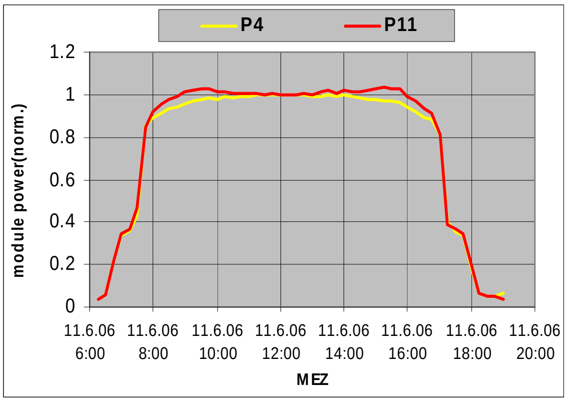


Figure 4: Fixed louvre (left, light blue), synchronous tracked louvre with nearest neighbour shading in the morning (left, blue), synchronous tracked louvre without nearest neighbours (right, yellow), counter tracking louvre (right, red).

During summer months the louvres in CTL configuration generate up to 20% more energy per month than a fixed module related to the installed peak power.

Additional test containers have been installed to evaluate the operation of a solar control system with respect to thermal, daylighting and photovoltaic performance. The floating room temperature method has been confirmed to be applicable for the precise determination of the energy flow through the façade, which avoids complex and costly air-conditioning equipment. Based on the experimental data, a validated parameter set has been extracted for the dynamic simulation of different building types in different climatic conditions.

Figure 5: Test containers: CTL PV louvre system with second generation louvres, see Barcelona demonstrator (left) and reference façade (right)

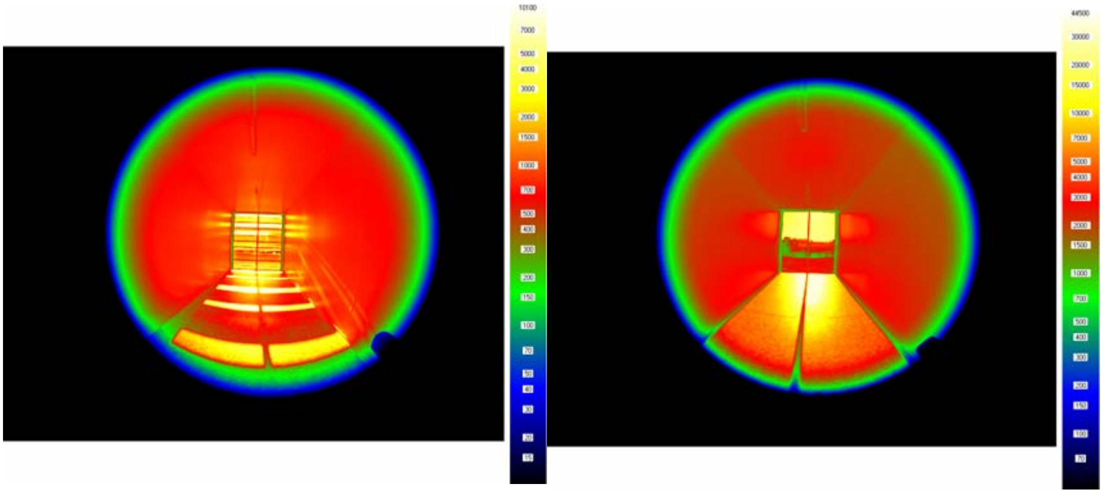


Figure 6: Light distribution inside the test containers: CTL PV louvre system (left) and reference façade (right)

The field tests have identified some weak points of the 'Barcelona' design, which lead to the development of an upraded version. In particular the attachment of the the PV laminate to the metal frame has been improved. Moreover, the material demand for the framing could be reduced and the mechanical components have been further standardised which has a positive impact on assembly and maintenance procedures.
A final version has been prepared for the Dresden Conference (September 2006) which has reached a weight of 17.2 kg/m^2 for the entire system comprising PV louvres, kinematic components, drive and mounting parts.

Figure 7: The Dresden demonstrator: with open (left) and closed (right) louvres.

In summary, the PV-LIGHT project has achieved significant improvements for the development of the multifunctional PV and Solar Control system as an economical and ecological valuable standard BIPV product.