IEA INTERNATIONAL ENERGY AGENCY

PV in Non Building Structures

- a design guide

Task 7
Report IEA PVPS T7-02:2000
April 2001

PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

This work was carried out within the IEA's PV Power Systems Programme Task VII and was included in the Swedish national co-operation programme "SOLEL 97-99"

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Edited by Carl Michael Johannesson

Stockholm, Sweden, April 2001

Cover: Carl Michael Johannesson - Olympic Boulevard PV Lighting Towers, Sydney, Australia

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Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation amongst its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (PVPS) is one of the collaborative R&D agreements established within the IEA and since 1993 its participants have been conducting a variety of joint projects concerned with the application of photovoltaic conversion of solar energy into electricity. The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (Tasks) is the responsibility of Operating Agents. Currently activities are underway in seven Tasks.

The twenty one members of IEA PVPS are: Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), European Commission, Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR), United States (USA).

Within PVPS, Task 7 is the international collaborative effort focusing on building integrated PV, linking developments in IEA countries worldwide. The overall objective of Task 7 is to enhance the architectural quality, technical quality and economic viability of photovoltaic power systems in the built environment and to assess and remove non-technical barriers for their introduction as an energy-significant option. Task 7 started its work in January 1997, building on previous collaborative actions within the IEA (Task 16 of the Solar Heating and Cooling Program).

The primary focus of this Task is on the integration of PV into the architectural design of roofs and facades for all types of building and other structures in the built environment (such as noise barriers). Task 7 motivates the collaboration between urban planners, architects, building engineers, PV system specialists, utility specialists, the PV and building industry and other professionals involved in photovoltaics.

This report has been reviewed by experts from Task 3 of the PVPS programme. Task 3 aims at the use of photovoltaic power systems in stand-alone and island applications. This report is relevant for both Tasks since many of the issues are similar for both stand-alone and building integrated applications. More information on the activities and results of the Tasks can be found on www.task7.org or *www.iea-pvps.org*.

This report has been prepared under the supervision of PVPS Task 7 by:

Miguel Angel Romero and Mats Andersson and has been edited by Carl Michael Johannesson

in co-operation with the following countries:

AUS, AUT, CAN, CHE, DNK, DEU, FIN, ITA, JPN, NLD, ESP, SWE, GBR, USA

and approved by the PVPS programme Executive Committee.

The report expresses, as nearly as possible, an international consensus of the opinions on the subject dealt with.

1 Introduction

Photovoltaic (PV) modules can be incorporated in Non-Building Structures such as bus shelters, information signs, street lights and sound barriers. The potential for using PV in Non-Building Structures in the built environment is large, even in a modern society where the electricity network is well developed.

For applications with a low power requirement PV can be suitable as a commercial alternative to grid connection, avoiding the need to dig up roads or pavements to lay cables. PV in these niche-applications can also be offered as an attractive design component that could be incorporated into structures combining economical benefits and attractive esthetical appearance.

In addition one purpose could be easy recognition and visibility of the PV energy production for added value. Another purpose could be the opposite: a discrete adaption to a sensitve environment.

PV systems integrated into Non-Building Structures need to consider a range of criteria such as irradiation, shading, orientation, visual impact, available surface and other technical requirements. Past experience has also shown that theft and vandalism can be a problem for the introduction of PV in these kinds of applications. This report summarises necessary considerations and the problems faced. It also presents some design strategies to facilitate the successful use of PV in Non-Building Structures. A number of case studies are included. These illustrate the versatility of PV in the urban environment.

This document is a condensed version of a report produced by Miguel Angel Romero of ECoCoDE, Sweden, entitled: ‘PV in Non-Building Structures – Design Issues’, and a paper written by Mats Andersson of Energibanken AB and Miguel Angel Romero. The work was carried out within the IEA’s PV Power Systems Programme Task VII and included in the Swedish national co-operation programme “SOLEL 97-99”.

2 NBS Typologies and Description

In order to identify the different NBS typologies, the following classification establishes 5 groups:

	Applications	Dimensions	Electrical Requirements	PV Surface Requirements
Urban Street Equipment	Parking meters, information signs, ticket vending machines, information boards, etc.	Height 1.2-1.5 m	25-100 W	0.2-1.0 m^2
Barriers	Fences, gates, noise barriers, etc.	Height 1.2-2.5 m	100-500 W/m	1.0-5.0 m^2/m
Shelters	Bus stops, telephone boxes, parking, umbrellas, information stands, etc.	Height <3.0-3.5 m Area: 1-9 m^2	50-200 W	0.5-2.0 m^2
Kiosks	Pavilions, toilets, refreshments, news-stands, etc.	Height <3.0-3.5 m Area: 5-20 m^2	1.000-10.000 W	10.0 - 100 m^2
Single "Upper-floor" Structures	Street lights, street signs, commercial signs, road signposts, etc.	> 3.0-3.5 m	10-100 W	0.1-1.0 m^2
Multi "Upper-floor" Structures	Screen road signs, screen publicity structures, etc.	Height > 3.0-3.5 m	500-1000 W	5-10 m^2

The characterisation for each group is based on the following aspects:

Dimensions: The scales of the different NBS have a great influence on a further analysis when other aspects are taken into consideration, such as structural and technical solutions, surface requirements, electricity production, etc.

Structural requirements: While this aspect is affected by dimensions it is more related to the mechanical performance required. The analysis is focused on type of material, the wind and weight loads, etc.

Functional requirements: The technical solutions and construction systems are determined by the function that the NBS should provide (water tightness, wind protection, shading devices, safety and equipment control, etc.).

Wear and tear: The way in which people use these structures affects certain characteristics of each typology, such as durability, accessibility, material strength, control and security, etc.

Peak power, storage and surface requirements: The quality and quantity (number and type) of functions provided by the structure will determine, the electrical needs and photovoltaic surface requirements, which determine the final dimensions of the structure.

Storage capacity: Operation criticality is an important aspect due to the need of batteries to store the produced energy and related aspects to be considered such as ventilation, overheating, safety and maintenance.

3 PV Implementation Problems

Location

Shading and low irradiation

When PV modules are to be installed in city areas, streets, roads, etc. it may be a problem to avoid situations suffering from shading or low irradiation. The NBS might already exist and the orientation may not be in the optimum direction at all.

Soiling and module degradation

Soiling is not a big problem for most PV installations. However, when modules are installed on sound barriers and other places with heavy traffic or close to industries that are strongly polluting it may be necessary to consider this problem. Module degradation can occur due to corrosion or extreme conditions with high temperatures and high humidity.

Small available surfaces

In some cases the modules are installed in areas where shading, low irradiation, esthetical conditions, physical limits, etc. reduce the available power production to a level which is not sufficient to meet the electrical needs of the installation.

Wind

Due to the relatively large surfaces of modules compared to the supporting structure (lights, etc.), the wind loads can cause problems for some installations.

People

Vandalism

Vandalism is a serious problem in cities and costs huge amounts of money. Damaged street furniture, wrecked urban equipment and broken cars and shop windows are a common sight after weekend nights, concerts, sporting events, etc. This problem cannot be solved by the PV community alone, and should be handled in the best way with appropriate design strategies.

Theft

The problem with theft occurs mainly when PV modules are mounted in public areas. People who steal modules do not see the connection between modules and their owner. The high price of modules and the fact that a second-hand market exists for this kind of product has a great influence.

Technical Performance

Maintenance, Repair & Replacement

It should be possible to deal with occasional module failures, etc. by repairing or changing the affected modules without destroying/dismounting the rest of the NBS elements.

Appearance

Installation in special areas

When PV is to be installed in locations such as historic centres, parks and gardens, non-urban areas, wild or natural landscapes, etc.; the integration in the environment should be carefully considered.

Visual Impact

Some PV NBS are not attractively designed, but are only an element of technical equipment, often resulting in the rejection of this type of installation.

Cost

This is not a problem specific to NBS but it is still necessary to minimize costs when designing a NBS. Using more sophisticated designs and materials could reduce costs, but the high cost of the PV components themselves may still be a problem.

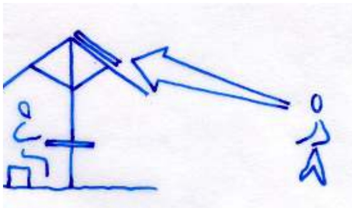
Implementation Problems for NBS Typologies

	Applications	Problems
Urban Street Equipment	Parking meters, information signs, ticket vending machines, information boards, etc.	Vandalism, theft, low irradiation, small available surface, repair & replacement
Barriers	Fences, gates, noise barriers, etc.	Vandalism, theft, soiling, repair & replacement
Shelters	Bus stops, telephone boxes, parking, umbrellas, information stands, etc.	Vandalism, low irradiation, repair & replacement
Kiosks	Pavilions, toilets, refreshments, news-stands, etc.	Vandalism, low irradiation, small available surface, repair & replacement
Single "Upper-floor" Structures	Street lights, street signs, commercial signs, road signposts, etc.	Vandalism, wind, small available surfaces, repair and replacement
Multi "Upper-floor" Structures	Screen road signs, screen publicity structures, etc.	Vandalism, wind, small available surfaces, repair and replacement

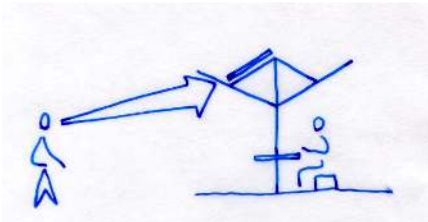
4 Design Strategies

Protection

Hiding	Integration of the module into the NBS shell in such a way that it will not be seen.
Smart designs	Odd/very special module sizes, colours, voltages, which render the module useless or difficult to use in everyday applications.
Safe mounting systems	Using rivets or screws that require special tools to operate.
Protection systems	To make it difficult to reach the module by using fences, posts, etc.

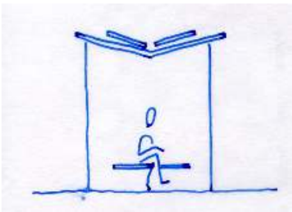


Non-Hidden PV modules



Hidden PV modules

Non-protected PV-module



PV modules protected from access by people

Technical Improvements

Strong/Flexible materials	Using extra strong/flexible materials such as plastic covers instead of glass
Strong mounting systems	Using extra strong joints and connections between the modules and the structural components to resist wind loads, etc.
Electronic remote operation	Electronic remote control and localisation systems can be incorporated into the modules and would therefore be necessary in order to operate the system. These could also avoid theft because it would not be possible to use the module without the remote control device.
Module etching	By etching the module with a specific code or sign, which could be identified and recognised on later inspection.
Energy efficiency	Use of energy efficient consumption devices such as sensors, LED lamps, etc. will reduce the photovoltaic area required.
Cleaning systems	Machines for efficient cleaning of modules (cleaning systems are used in Sweden for reflective posts along roads in wintertime using high-pressure systems)
Reflectors	By using reflecting irradiation elements/surfaces in order to increase the available solar gain of the PV modules when local conditions are not optimal.
"Elastic" structures	By using systems that could absorb wind loads through the elasticity of their structural elements.

Design Flexibility and Adaptability

Multi-oriented systems	Making flexible mounting systems to allow the modules to be moved to the optimum direction independently of the orientation of the NBS
Dismounting systems	Avoiding using permanent joints and connections makes maintenance, repair and replacement of modules easier.
Independent systems	Separation between PV mounting components and NBS in order to allow for mounting and dismounting operations independently.
Expandeble systems	The design easily allows the addition of new PV modules to the NBS.

Aesthetic Improvement

Integration	Integration of module into the NBS shape
PV aestetic characteristics	Use of the aesthetic performance of the PV cells and modules such as texture, colour, laminate materials, module framing alternatives, etc.

Others

Doublefunction	The addition of several simple functions in the same NBS is a simple way to reduce the costs of the installation.
Standardisation	Avoiding using permanent joints and connections makes maintenance, repair and replacement of modules easier.
Posts	Using a post for the module to increase the available irradiation or to make it difficult to reach the module.
Instructions/manuals	Providing mounting and dismounting instructions incorporated in a visible place in the NBS to guide maintenance personnel and prevent inappropriate operation.
Information	Use of environmental, economic information etc. in an effort to convince people not to steal modules, and to use them correctly, etc.

5 Case Studies

Urban Street Equipment

“DG Line” PV parking meter

Stand-alone PV vending machine with the solar generator integrated in the structure. Low risk of theft and vandalism because PV generator is hardly visible (height) and the structure does not look vulnerable.

Parking ticket vending machine (ECoCoDE, Schlumberger).

Design Strategies Applied	*"DG Line" PV parking meter*
Protection	Hiding, integration, strong structure, safe mounting
Technical Improvements	Energy efficient devices
Design Flexibility	
Aestethic Improvements	
Others	Small available surface

PV illuminated bus timetable

Stand-alone PV powered illuminated bus timetable. Very energy efficient through the application of energy efficient devices (a movement sensor that activates the lighting and energy efficient lighting by LEDs). PV is glued to the top part of the timetable and so small that it is not very vulnerable to steal..

Bus information system by Ebo Scherpenzeel beheer BV

Design Strategies Applied	*"PV illuminated bus timetable*
Protection	Smart design, safe mounting system
Technical Improvements	Energy efficient devices
Design Flexibility	
Aestethic Improvements	Integration
Others	Small available surface

“Infoconcept” PV Street Information Board

The standard information screen is equipped with a PV cell specially placed to protect the post boxes against rain. The aesthetic integration has also been considered in the design. This could be combined with the different elements and designs of the “Infoconcept”.

“Infoconcept” PV powered street information board: PV version, standard version and different standard designs.

Design Strategies Applied	*"Infoconcept" PV Street Information Board*
Protection	
Technical Improvements	
Design Flexibility	Combining systems
Aestethic Improvements	Integration, aesthetic appearance
Others	Standardisation, Double function

”ParkLine 2001” PV parking meter

The PV equipped version of the standard pay and display ticket machine has specially considered the esthetical and technical integration of the solar cells. Polycrystalline cells with a surface of 1900 cm2 and a peak power of 23 Wp compose the solar module. The PV parking meter is equipped with a 12V/60 Ah battery. The battery box is stored behind a strong door panel. The elements for maintenance and replacement are easily accessible only for the authorised staff.

PV parking meter: standard model and detail of the version equipped with PV. (Dambach-Werke Gmbh)

Design Strategies Applied	*"ParkLine 2001" PV parking meter*
Protection	Safe mounting systems
Technical Improvements	Energy efficiency
Design Flexibility	Multi-orientation
Aestethic Improvements	Integration, PV esthetical appearance
Others	Small available surface

"Mesap-Universal 2000" PV parking meter


A stand alone photovoltaic powered vending machine with the solar generator in an extra stand, especially safe from theft and vandalism, because the PV modules are completely invisible from the ground.

Vending machine for parking vouchers with different PV mounting solutions (Schlumberger, Fraunhofer ISE Freiburg)

Design Strategies Applied	*"Mesap-Universal 2000" PV parking meter*
Protection	Hiding, protection systems.
Technical Improvements	Efficient consumption devices
Design Flexibility	Multi-oriented systems
Aestethic Improvements	
Others	Posts

"TOM 94" PV parking meter


The standard ticket vending machine is equipped with a PV cell especially resistant against impacts. The consumption is very low and the battery provides about 2 months of autonomy.

PV powered ticket vending machine.

Design Strategies Applied	*"TOM 94" PV parking meter*
Protection	Hiding, strong materials
Technical Improvements	Efficient consumption devices
Design Flexibility	
Aestethic Improvements	Integration
Others	Standardisation

PV powered timetable lighting

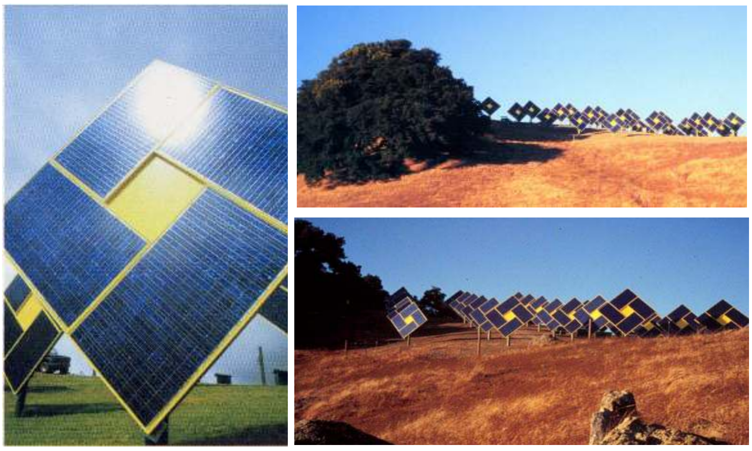
This public information device is equipped with a red blinking button active from dusk until daybreak. By pressing the button the blinking light turns off and the time table lighting is switched on for about 20 seconds. The illumination period can be extended for as long as necessary by repeated pushing of the button. At the end of the illumination time the button begins blinking, indicating readiness for renewed timetable lighting.

The electricity generated during the day is stored in a NiCd rechargeable battery. The electrical power consumption of the illumination unit has been reduced to about 0,6 W, by including a planar light guide. Extremely bright red LEDs are used as the light source. Multi-coloured route maps are illuminated with differently coloured LEDs.

PV powered timetable lighting (Fraunhofer ISE Freiburg)

Design Strategies Applied	*PV powered time table lighting*
Protection	Strong mounting system and materials
Technical Improvements	Efficient consumption devices
Design Flexibility	Dismounting systems, Independent systems, automatic operation
Aestethic Improvements	Integration
Others	Standardisation

Solar Electric "Sunflowers"



Nestled atop a hillside in Northern California 36 Solar Electric Sunflowers represent an elegant combination of art and technology. The client requested an unconventional and artistic installation. They got just that. Just like a sunflower, the Solar Electric Sunflowers look and act like nature's very own sunflowers. Using a two-axis tracking system the sunflowers wakeup to follow the sun's path throughout the day, enabling the system to produce enough energy for eight to ten homes.

PV "sunflower" integrated into the landscape. Detail and general views (Solar Design Associates, Inc)

Design Strategies Applied	*Solar Electric "Sunflowers"*
Protection	
Technical Improvements	
Design Flexibility	
Aestethic Improvements	Multi-oriented system
Others	Visual integration, esthetical appearance

Barriers

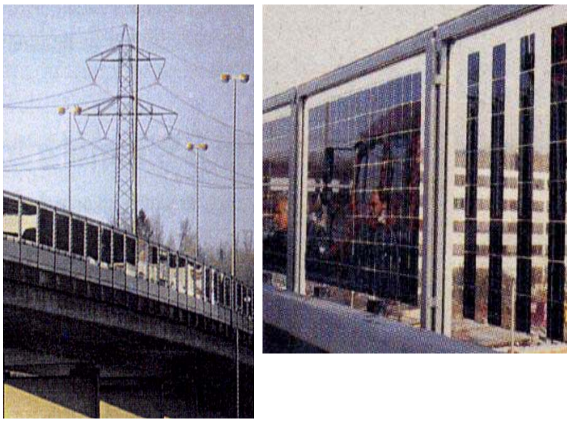
PV Wheel Block

This PV wheel block model has been carefully designed to be used in highly visible areas like parks, pedestrian streets, public and historic buildings, etc. It is powered by 0.25 Wp PV CdTe modules integrated into the top of each pole and with a range of 1 to 10 Wp. In order to reduce the energy needed, the lighting system is operated with LEDs.

PV powered Wheel Block: Detail and general view. (NEDO).

Design Strategies Applied	*PV Wheel Block*
Protection	Safe mounting system
Technical Improvements	Efficient consumption devices
Design Flexibility	
Aesthetic Improvements	Integration, aesthetic appearance
Others	Standardisation, Double function

Bifacial PV Noise Barrier

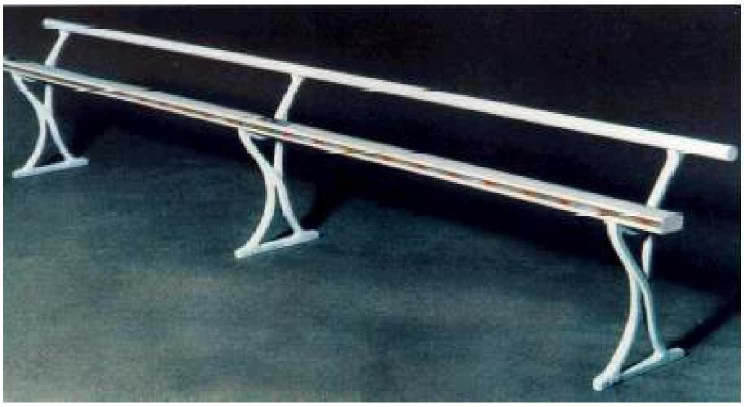


This innovative system allows the application of bifacial PV modules along motorways, running in a north-south direction. The system has been installed in Wallisellen (Switzerland) where the PV bifacial modules replace the existing concrete wall. This application shows the high level of integration possible to be achieved: the PV module is actually representing the noise dumping structure with dummy elements incorporated for a better visual appearance. The wall (total length 120 m) has a power density of 80 W/meter. For a Standard 3 meter wall it could be raised to about 200W/m, still allowing a certain level of transparency

PV noise barrier with semitransparent bifacial modules: details and general view. (ASE GmbH and Kohlhauer GmbH)

Design Strategies Applied	*Bifacial PV Noise Barrier*
Protection	
Technical Improvements	Bifacial modules
Design Flexibility	Expandable system
Aesthetic Improvements	Integration, esthetical appearance
Others	Standardisation, double function

PV Pedestrian safety handrail



This handrail is powered by 10 Wp PV a-Si modules integrated in the shape of the steel profile. With an interesting aesthetic appearance, this is designed to be placed in pedestrian streets, bridges, etc. for protecting people from car traffic. By using lights operated with LEDx, the energy consumption required is significantly reduced.

PV powered walk street Fence (NEDO)

Design Strategies Applied	*PV Pedestrian safety handrail*
Protection	Hiding, strong materials
Technical Improvements	Efficient consumption devices
Design Flexibility	
Aestethic Improvements	Integration
Others	Standardisation

"Zig-Zag" PV Noise Barrier

Different design of PV noise barriers: Type "zig-zag" by ARGE Crimmitschau (DLW Metecno)

The concept of the stacked alternating planes allows for the combination of PV, transparent surfaces and noise absorbing surfaces. Varying the distances between the cells of the PV modules allows different degrees of transparency. Transparency could also be obtained by alternating PV and glass planes. The modules are tilted approximately 75 degrees from the horizontal plane. Further pre-fabrication of the whole system will lead to a reduction of the mounting time and, therefore, the cost.

Design Strategies Applied	*"Zig-Zag" PV Noise Barrier*
Protection	
Technical Improvements	
Design Flexibility	Expandable systems
Aestethic Improvements	Integration
Others	Standardisation, double function

PV Road Noise Barrier

This noise barrier is placed by a motorway near Utrecht in the Netherlands. Two kilometres long, the system has about 4,000 PV modules, which means between 200-300 kWp installed.

PV powered sound barrier: detail, general view and mounting system. (ECoCoDE)

Design Strategies Applied	*PV Road Noise Barrier*
Protection	
Technical Improvements	
Design Flexibility	
Aestethic Improvements	Integration
Others	Standardisation

Shelters

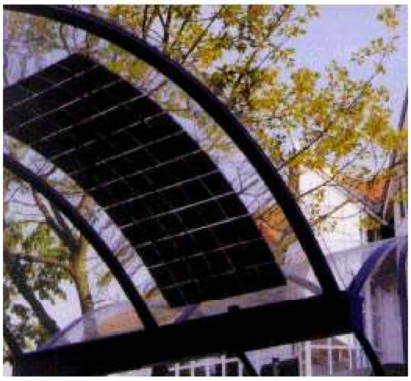
Bahnhof 2000 Station PV Roof

This photovoltaic powered station roof and showcase is a nice combination of a newly designed "standard" roof and the well integrated PV modules placed in a public location. The solar modules provide both, the required energy and a watertight roof covering. This is especially interesting because of the emphasis on architectural demands that have been considered in the roof integration design.

Station PV roof: General view. (Atlantis Photovoltaik)

Design Strategies Applied	*Bahnhof 2000 Station PV Roof*
Protection	Hiding, smart designs
Technical Improvements	Efficient consumption devices
Design Flexibility	
Aestethic Improvements	Integration, aesthetic appearance
Others	Double function

PV bus shelter



The lighting for spotlighting of the bus shelter is provided by the so called PLEXIGLAS semi-transparent solar modules. By combining solar cells with highly transparent PLEXIGLAS, daylight can be used for natural lighting in addition to artificial light sources. This kind of module is sandwiched between two sheets of PEXIGLAS in a permanently elastic structure. This encapsulation means that the PV modules can be designed at will. The resulting product is lightweight, weather resistant and durable. These modules could therefore replace any type of existing sheets in entrances, canopies, etc. without changing the geometry of the structure in question.

PV Bus-stop shelter with semi-transparent curved modules composed of polycrystalline cells. (Röhm))

Design Strategies Applied	*PV bus shelter*
Protection	Smart designs
Technical Improvements	Flexible materials
Design Flexibility	Design flexibility and adaptability
Aestethic Improvements	Integration, aesthetic characteristics
Others	Double function

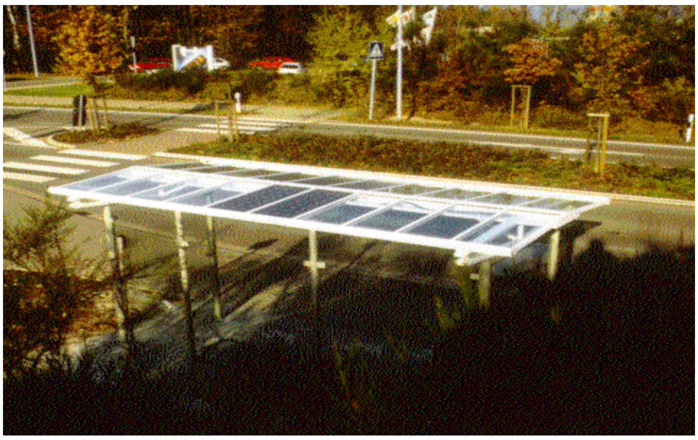
PV Railway Station Canopy

The structure of this railway platform canopy consists of a horizontal steel tube with a roof, glazed on both sides of the tube. This is intended to let the daylight through to the central part of the platform but also to mark the border between the waiting and the boarding area. About 50% of the glazed area contains PV cells.
Special attention has been paid to ensure compliance with Swiss standard requirements regarding wind and snow loads. Studies regarding electromagnetic fields and soiling were also carried out.

Railway station PV canopy at Morges, Switzerland. (EPFL-LESO)

Design Strategies Applied	*PV Railway Station Canopy*
Protection	Strong mounting system
Technical Improvements	
Design Flexibility	
Aesthetic Improvements	Integration, esthetical appearance
Others	Double function

PV bus shelter



PV powered lighting of bus-stop shelters and showcases. The modules provide both the required energy for the main lighting and the showcase and a watertight roof covering lighting and power requirements. This is especially interesting, since PV modules are replacing standard glass modules, so for each individual shelter the number of PV modules can be adjusted easily to the energy requirements (and allows easy subsequent additional PV installation). The PV modules are completely invisible from beneath the shelter.

PV Bus-stop shelter and showcase (Fraunhofer ISE Freiburg)

Design Strategies Applied	*PV bus shelter*
Protection	Hiding, smart designs
Technical Improvements	Efficient consumption devices
Design Flexibility	Dismounting systems, independent systems, and expandable systems.
Aesthetic Improvements	Integration
Others	Double function

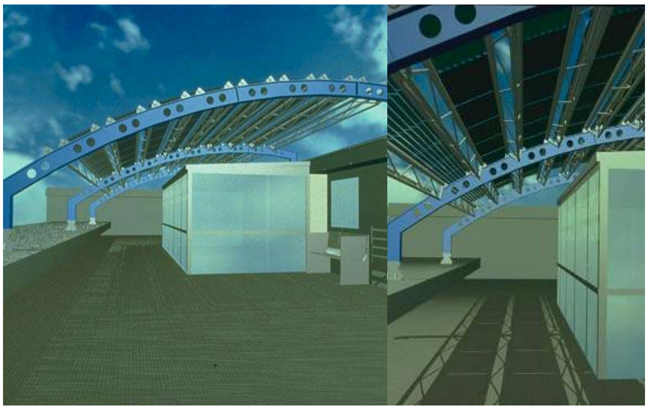
ENEL PV Canopy

ENEL *tilting PV canopy. (Officine di Architettura, Cinzia Abbate)*

The shelter was designed for ENEL and selected for its wide range of possible uses in areas where the excavations for electrical cabling could be particularly difficult; for example parks, archaeological sites, recreational areas, and sea resorts.
The structure can be inclined from 0 to 20 degrees, by tilting the specially designed capital of the two supporting columns.

Design Strategies Applied	*ENEL PV Canopy*
Protection	
Technical Improvements	Efficient consumption devices
Design Flexibility	Multi-oriented system, dismounting systems, expandable systems
Aestethic Improvements	Integration, esthetical appearance
Others	Double function, Standardisation

ENEL Roof canopy



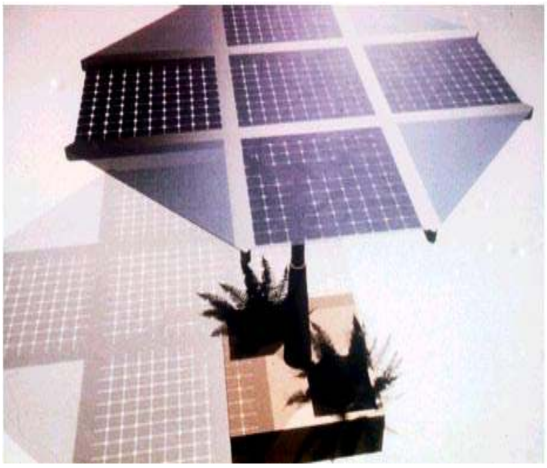
ENEL *tilting canopy*

The steel shelter was realized on the roof of ENEL headquarter in Rome. The canopy was built using standard PV modules and mechanical oriented shadowing lamellas. The entire installation concept works as a roof "curtain" for the small press office located on the roof.

The orienting elements can be operated from each room of the press office in order to satisfy individual optimum shading without covering the panoramic view of the roof. In the summer months, the canopy provides significant passive cooling for the indoor climate.

Design Strategies Applied	*PV Roof Canopy*
Protection	
Technical Improvements	Passive cooling
Design Flexibility	Mechanically operated shading devices
Aestethic Improvements	Linear design for easy insertion in different urban contest
Others	

PV Umbrella



The structure can be inclined from 0 to 20 degrees, to respond better to the local solar conditions, and give optimum shading. The umbrella consists of a steel structure capable of supporting a maximum of five photovoltaic panels of one square meter each. The design of the large square base, besides counterbalancing the structure, also offers the placement of several accessories such as the seats that hide the batteries, a table, planters, and a small light fixture. The project allows the use of coloured fabric or polycarbonate at the four corners of the cover, so that the object may blend into the environment in which it is used, tourist villages for example, or to display company logos.

Rendering of the umbrella (Officine di Architettura, Cinzia Abbate)

Design Strategies Applied	*PV Umbrella*
Protection	
Technical Improvements	Easy mounting and installing technology
Design Flexibility	Flexibility of accessories
Aesthethic Improvements	Integration
Others	Double function, Standardisation

PV car shelter

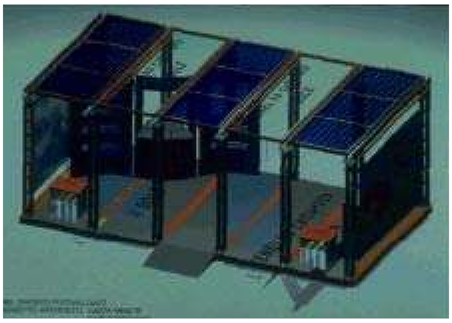
Design of a standard flexible, lightweight structure for a carport roof.

PV carport roof (NEDO)

Design Strategies Applied	*PV car shelter*
Protection	Hiding.
Technical Improvements	Flexible materials
Design Flexibility	
Aesthethic Improvements	Integration, aesthetic appearance
Others	Double function

Kiosks

ENEL PV Kiosk



PV Kiosk version 3 with 9 PV Modules and version with 5 bays powered by 9 PV Modules and two transparent bays (ENEL)

The PV kiosk is designed to accommodate a small office space and an exhibition area for temporary public events. The kiosk is modular; each module is conceived as a bay of three PV modules Depending on the space available for the temporary event and the electrical requirement of the kiosk it is possible to assemble from 3 to X number of bays. The small version of 3 bays, (9 PV modules cm. 120x120) is sufficient for the indoor lighting, the energy of a computer, and other exhibit displays. The wiring of the PV system is visible through the wooden composite pilaster of the kiosk. The two small seats located on the side of the entry hide the batteries. Both the UV resistant Plexiglas roof and the fabric used for the exterior walls, can be silkscreened with publicity or logos of the events.

Design Strategies Applied	*ENEL PV Kiosk*
Protection	
Technical Improvements	Modularity of the system and easy mounting technology
Design Flexibility	Maximum flexibility of space
Aestethic Improvements	Integration
Others	Double function

Single "Aerial" Structures

"Solight" PV Street light

This model is designed to be used in highly visible areas like parks, pedestrian streets, public and historic buildings, etc. PV Streetlight made of high grade steel with special attention paid to the aesthetic design of the support structure and to the integration of the PV modules. It is equipped with energy saving lamps of 27 W and a maintenance-free battery controlled by an IMS (Intelligent Management System). The battery and the IMS system are incorporated inside the battery box under the lamp case. The two 50 Wp PV modules are fixed with special anti-theft screws.

PV streetlight by Engcotec: Model FRO. (NEDO)

Design Strategies Applied	*"Solight" PV Street light*
Protection	Safe mounting systems
Technical Improvements	Efficient consumption devices, IMS
Design Flexibility	
Aesthetic Improvements	Integration, aesthetic appearance
Others	Standardisation

PV Street Sign

A photovoltaic powered public transport information board. Safe from theft of modules, since the PV component is an integral part of the board. Very efficient energy use, since the boardlight is based on LED and will only operate after pressing the button (switches off after 20 seconds). Integrated energy management system.

Public transport information board (Fraunhofer ISE Freiburg)

Design Strategies Applied	*PV Street Sign*
Protection	Hiding, protection systems, safe mounting systems
Technical Improvements	Strong mounting systems, efficient consumption devices, IMS
Design Flexibility	
Aesthetic Improvements	Integration, esthetical appearance
Others	Poles

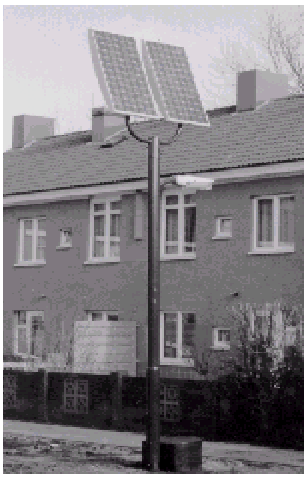
PV Road lighting Sign

This road sign is equipped with a polycrystalline cell safety mounted on the top of the supporting pole. The warning lighting is operated with an LED device for low energy consumption. A nickel-cadmium battery is encapsulated within the light "box".

PV powered road warning sign. (ECoCoDE)

Design Strategies Applied	*PV Road lighting Sign*
Protection	Safe mounting systems
Technical Improvements	Strong materials, efficient consumption devices
Design Flexibility	Multi-oriented system
Aestethic Improvements	Integration
Others	Poles

"Soluna Stroomwerk" PV Streetlight



Stand-alone PV powered streetlight. Specially interesting because the light can be controlled between 35% and 100% according to the state of charge of the batteries. Attention has been paid to the design of the mounting structure at the backside of the modules, which makes them look less fragile.

PV powered streetlight by Soluna Stroomwerk.

Design Strategies Applied	*"Soluna Stroomwerk" PV Streetlight*
Protection	Pole, smart design, safe mounting systems.
Technical Improvements	Energy efficient devices
Design Flexibility	
Aestethic Improvements	
Others	

PV Information pole

The a-Si PV module is integrated in a discreet way within the structure design of the information pole.

PV powered ticket vending machine. (ECoCoDE)

Design Strategies Applied	PV Information pole
Protection	Hiding
Technical Improvements	Efficient consumption devicess
Design Flexibility	
Aestethic Improvements	Integration
Others	

Emergency PV Phone post

This type of device is especially useful to avoid the connection to the grid and the extension of the phone lines. The PV cells are installed on top of the post with a mounting system that allows orientating the module to the sun independently of the disposition of the post itself. Different tilt angles can also be chosen for the PV element.

Emergency PV phone post with different orientations and tilt angles. (ECoCoDE)

Design Strategies Applied	Emergency PV Phone post
Protection	Hiding, smart design
Technical Improvements	Efficient consumption devicess
Design Flexibility	Multi-oriented system
Aestethic Improvements	Integration
Others	

Multi "Aerial" Structures

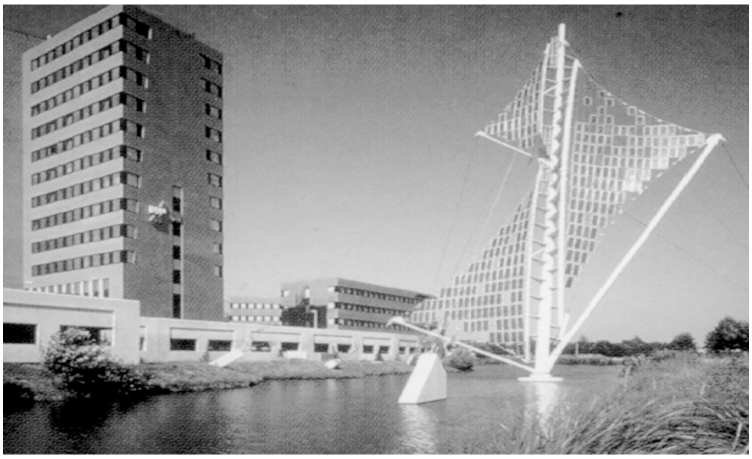
Olympic Boulevard PV Lighting Towers

Perspective view of the Olympic boulevard and details of the PV

The Olympic Boulevard Pylons are primarily urban sculptures designed to bring a sense of movement and festivity to the central pedestrian spine of the Olympic precinct. The towers serve as indicators of scale and direction within the very large boulevard as well as giving signage, generating electricity, providing power outlets for activities in the boulevard, providing shade, providing night illumination and conveying graphic information through digital screens. The visibility of the PV is also designed to showcase solar energy production and screens at boulevard level will display the amount of energy being generated to passers by.

Design Strategies Applied	*Olympic Boulevard PV Lighting Towers*
Protection	Safe mounting system, protection system
Technical Improvements	Module etching, energy efficiency
Design Flexibility	Independent system, dismountable system
Aestethic Improvements	Integration - simple mounting system is developed intoan aesthetic feature at concept level.
Others	Dual functionality, Standardisation, Information

Grid connected PV system



"Solar Sail" grid connected PV system

A grid connected PV system was installed by the Dutch electricity company PNEM for promotional purposes. Problems with theft, vandalism, wind and aesthetics were solved in an innovative way. The structure was inaccessible by the use of a natural barrier: water, by designing an open structure the wind load was decreased and special attention was paid to the aesthetics. Among others, coloured bright panels were placed between the PV modules.

Design Strategies Applied	*Grid connected PV system*
Protection	Pole, protection systems (water), strong mounting systems
Technical Improvements	
Design Flexibility	
Aestethic Improvements	Bright coloured panels between PV modules, artful design
Others	

Annex - Outcomes from the workshop held at the 8th IEA PVPS Task 7 meeting in Stockholm, September 2000

Introduction

The aim of the workshop was to discuss problems and issues related to "photovoltaic in non building structures" based on outcomes from the draft report: "*PV in Non Building Structures*"

Invited speakers

Some components in an NBS system were emphasized in presentations by invited speakers: module with special design, light emitting diodes (LED's) and energy management systems EMS.

Leif Selhagen, Fortum Sweden, presented some modules with unusual design with respect to number of cells, color and possibility to add buyers logotypes in the encapsulation. The modules were designed as "Heavy duty" products by means of composite material, tempered glass and strong stainless steel backing (Fig 1).

Fortum have gained experience to solve theft problems, from their PV powered bus shelters in Gothenburg (Fig 2, 3).

Figure 1 Special design
Unusual number of cells and shape and a rigid design with composite material helps to prevent theft and damage. The module on the figure has a thick stainless steel backing and is equipped with an integrated 12-volt battery regulator mounted on the rear side of the module.

Figure 2 Problem
In Gothenburg 80 modules were stolen from a total number of 360 shelters, as they were easily accessed mounted directly on the top of the shelter.

Figure 3 Solution
After mounting the modules on the top of high poles with some unusual type of bolts, requiring special tools, all module theft ended.

Hermann Laukamp, Fraunhofer ISE presented in his "National case" a module with oval outer shape and with 11 cells that is used to power a "multifunctional emergency call and information post" (Fig 4).

An important component in an autonomous NBS system is the energy management system (EMS). Hermann Laukamp presented the EMS used in the MEI (Figure 4,5). It has the following features:

- Battery charge control
- Power management (disconnects low priority outputs in case of low battery)
- DC-DC inverters to power individual subsystems with different voltage
- Data acquisition and system monitoring
- Communication with the emergency call telephone

Figure 4. *"Emergency Call and Information Post", MEI Hermann Laukamp, Fraunhofer ISE, Germany*

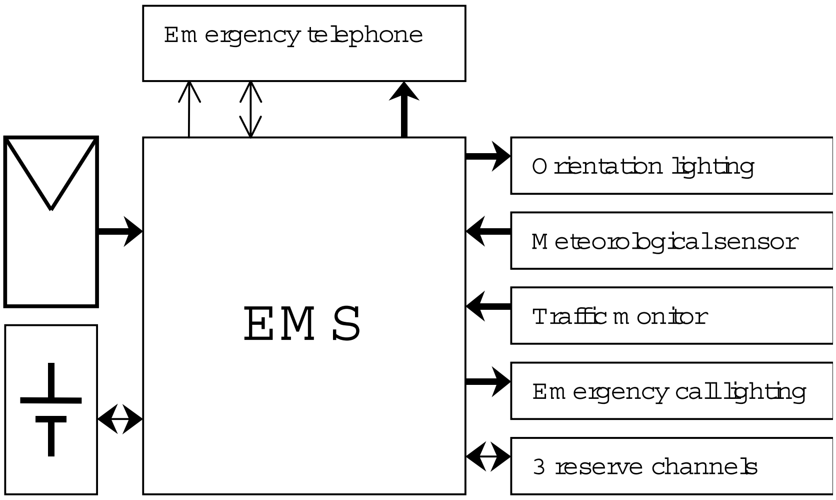


Figure 5. *Energy management system used in the emergency call in figure 4. (From Hermann Laukamp, Fraunhofer ISE)*

Esko Niemi from KTH, Royal Institute of Technology, Sweden, presented the latest development and trends in light emitting diodes (LED) and Christian Bendel from ISET, Germany and presented approaches for new PV / LED applications. They showed that LED's are low energy consuming carriers of information and illumination. Listed below are some feature of the LED Technology:

- Low energy consumption - 100 lumen/W (record device) compared to 12 lumen/W for a normal light bulb
- Low maintenance - 100.000h expected lifetime compared to 1000h for a normal light bulb
- DC powered – can be directly used in a PV system without inverters
- White LED's – The future trend is white LED's with twice the performance of today's record devices.
- Rapid on/off – A LED device is instantaneously turned on or off

Working in small groups

The topic of the work was to design a bus shelter that is supposed to be manufactured in an industrial line and which is to be placed in a Scandinavian type of climate. When designing the shelter the following issues were to be dealt with.

- Theft and vandalism
- Module orientation
- Bus driver attention
- Protection against wind, rain and snow
- Lighting of the shelter
- Low energy consumption
- Information to the passengers

Three design groups were formed and at the end of the day the resulting bus shelters were presented. In figure 6 is the result from the group 2 presented.

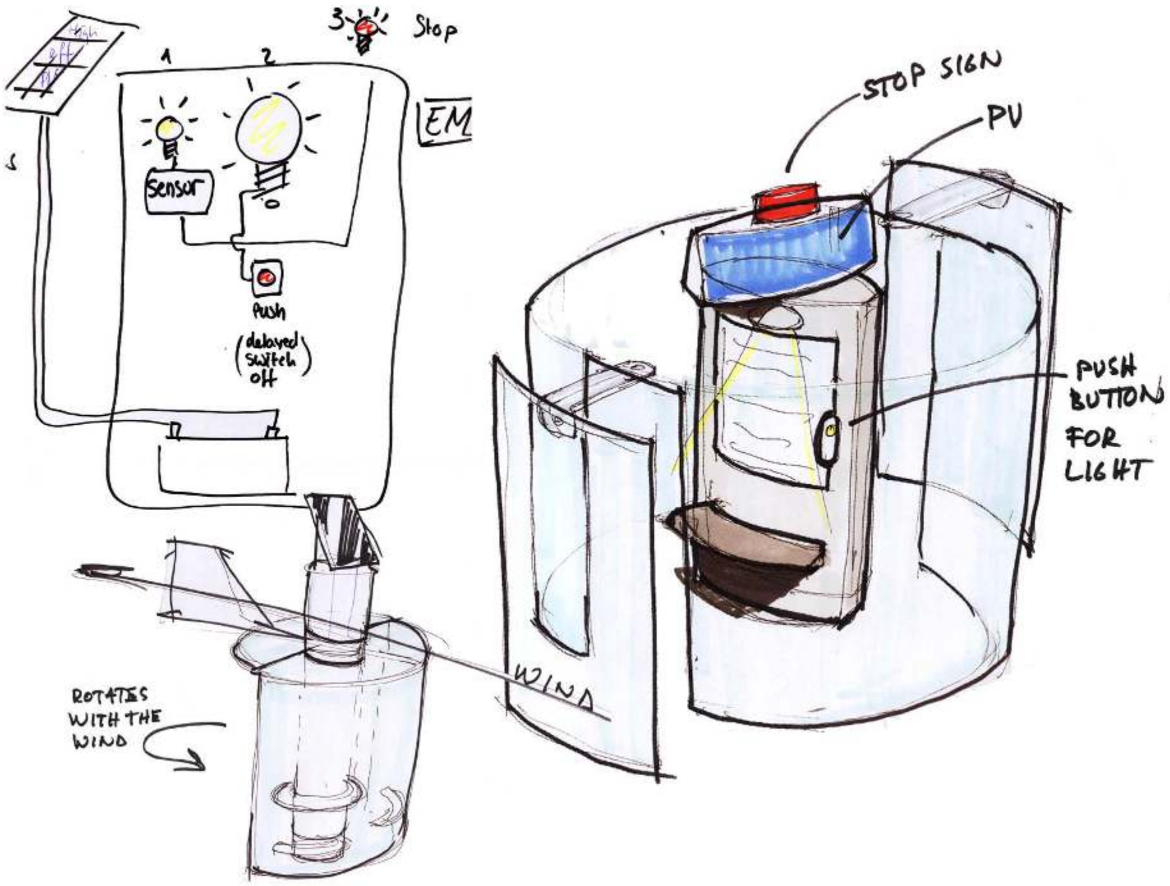


Figure 6. *The bus shelter designed by group 2. Special care has been taking to increase the comfort and safety by designing with a transparent material and providing the shelter with two entrances. (You can see who is in the bus shelter and there is an escape exit so you can't get trapped). The specially designed PV module can easily be oriented in the most efficient direction. A clearly visible stop signs on the roof to catch the attention of the bus driver and push buttons to decrease energy consumption.*