



pvnord





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## 1 Preface

A thesis for the PV-NORD project is, that there is a universal need for buildings making use of renewable energy – in this context photovoltaics (PV). The aim of the project is, by providing necessary knowledge and direct demonstrations, to catalyse the widespread exploitation of Building integrated PhotoVoltaics (BiPV) in North European countries.

This aim may be reached by eliminating or reducing barriers which till now has held widespread use of BiPV back e.g.: financing, electrical codes and installation regulations, management of PV systems, environmental issues – and aesthetics.

Experience from some of the first, searching, examples of BiPV in the Nordic countries has made architects and city planners as well as builders hesitate to use BiPV. An often-repeated phrase is: "I would be interested in building sustainable buildings - were it not for the fact that so-called sustainable buildings are aesthetically of a minor quality."

We believe, however, that lessons learned from the eight PV-NORD demonstration projects and the critical, yet sympathetic, evaluations of these by qualified architecture critics will convince Nordic architects, city planners, builders, and others that it is possible to design buildings with BiPV of a major architectural quality.

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## 1.1 Introduction

### 1.2 PV-NORD context

The PV-NORD project is an international research and development project aiming at widespread exploitation of Building integrated PhotoVoltaics (BiPV) in the Northern Dimension of the European Union.

The 3-year (2001-2004) project is financially supported by the European Commission, DG5, Energy and Transport (5th FW Contract no. NNE5/2001/264). Five countries are co-operating in the project: Denmark, Finland, Norway, Sweden – and Holland, though not a Nordic country, was included in the project due to its extensive experience with PV in buildings.

In eight demonstration projects, six new buildings and two renovations, BiPV is designed, installed and managed, and the process as well as the results are monitored and evaluated. The 16 participants from the five countries include architect offices, engineering consultants, construction companies, industry, public organisations, and two research institutions for monitoring and evaluation.

The work of the project has been structured in Work Packages and Tasks according to the goals of the project and the identified barriers for a widespread exploitation of BiPV: Financing, electrical codes and installation requirements, management of PV systems, environmental issues – and *aesthetics* or in other words: Architectural quality.

Danish Building and Urban Research (DBUR) is the main responsible for the monitoring and evaluation of architectural quality of the eight demonstration projects. The process and the findings of Work Programme, Task 3.1: Aesthetics, are documented in this report.

### 1.3 Aesthetics, task

In the PV-NORD programme of October 2001 Task 3.1: Aesthetics is identified:

- "The Northern countries are more conservative regarding architecture than countries in Central Europe. Located in the outskirts of Europe we are less influenced by changes in international architecture and the hard winter climate makes it more difficult to try new ideas. This situation has a strong influence on the attitudes towards using PV modules as building elements."
- "PV-NORD will identify ways to integrate BiPV with the well-defined aesthetic expressions of Northern Europe. Aesthetically integrated and well functioning PV projects will help to change attitudes".

- Danish Building and Urban Research (DBUR) – an independent research institute – is leader of Work Package 3, Task 1: Aesthetics. DBUR is responsible for monitoring and evaluation of the demonstration projects concerning aesthetics. The other PV-NORD partners are "actively involved in at least one building", DBUR and Kungliga Tekniska Högskolan (KTH), however, "participate for their well-renowned expertise in the area."
- In Task 3.1 "the architectural solutions and the integration methods applied in each building will be reviewed. Background information regarding the planning process is of great interest. It is also valuable to have a look at early architectural sketches to see how the final design was developed. The holistic approach of regarding aesthetics and PV integration as closely interrelated factors will be very beneficial for achieving results."
- In Task 3.1 "the architectural qualities and problems of BiPV in the Nordic demonstration projects will be analysed and evaluated during projecting and construction phases as well as during use, compared to the projects in the Netherlands."
- The target groups identified for the thematic area of aesthetics and PV integration are on the short view architects, city planners and builders, but on the long view aesthetic considerations will influence PV suppliers and installation agents.

#### 1.4 Aesthetics, participants and projects

Participants directly involved in Task 3.1 Aesthetics are:

- Danish Building and Urban Research (DBUR, Denmark): Task leader, independent research unit. Responsible for architectural evaluation of demonstration projects.
- Kungliga Tekniska Högskolan (KTH, Sweden): Independent source. Contributor to architectural evaluation.
- White Architects (Sweden), Architect Office. Responsible for demonstration project Holmen and Grynnan, Stockholm.
- Familjebostäder AB (Sweden), Housing Association. Responsible for demonstration project Lysande, Stockholm.
- De Vanføres Boligselskab for Københavns Kommune (VBKK). Cooperative housing society for disabled persons in Denmark, the Municipality of Copenhagen. Responsible for demonstration project Kollektivhuset, Copenhagen.
- NCC (Finland). Responsible for demonstration project NCC Head Office, Helsinki.
- Indirectly all other participants in PV-NORD have been involved in Task 3.1: Aesthetics, contributing with their knowledge and material on the demonstration projects.

## 2 Task

### 2.1 Background

The photovoltaic effect was discovered already in 1839. However, in spite of continuous research in this field, it was as late as 1954 before a solar cell of the contemporary kind was developed. It was the enormous investments in space science, which created the basis for the development of PV as an important producer of continuous electricity for space-crafts.

The development of PV for use in building is of a newer date. The development was promoted by the so-called energy crises in the 1970s and by the growing awareness of environmental issues, but was still slow (Cornell, 1968). In the Northern countries it was especially slow, as the economic yield as well as the influence on architecture was deemed negative.

However, PV was originally developed for goals of space science and thus without special considerations for aesthetics. But today and in the future there is a growing demand for PV which besides energy producing properties have aesthetic qualities which make it possible to use PV in architecture, not only to be tolerated, but to be preferred due to functional as well as aesthetic properties.

The use of PV in Northern building till now may be described as a development in three phases:

- In the first phase, the 1980s, some enthusiastic builders and architects, as a tribute to social conscience and ecology, adapted PV to buildings. Standard elements were placed on facades or on structures on the roof, often as decorations or even as demonstrations of progression. The effect on the architecture was often questionable. Examples from this period could be Elnasminde inn and camping, Tappernøje, Denmark (1989), and a renovation project in Slagelse, Denmark (1989).
- The second phase, the 1990s, showed the first examples of a deliberate effort to integrate PV panels with the architecture of buildings. The panels were still standard elements, but their size and placing were determined by a desire to achieve an architectural entity. This effort of integration was also inspired by early examples in Northern Europe, Germany and the Netherlands. Especially inspiring was the development of BiPV in the Netherlands, where the more southern location and a more diverse approach to architecture allowed for many interesting examples, eg. De Kleine Arde and Amersfoort. Among the first Nordic examples of BiPV from this phase are the IKEA office building, Älmhult, Sweden, and Nestlé Technology Centre, Porvoo, Finland.

- The third phase, the beginning of the 21st century, has just begun, and PV-NORD aims at paving the way for integration of PV in the building envelope.

## 2.2 On architecture

*Architecture, in short, is the art of building.* However, the concept of architecture applies not only to the building as such, but also to its manmade and natural environment – townscape and landscape – and to all the components and details which are parts of the building.

In our culture the concept of architecture is based on the thinking of Vitruvius (app. 100 B.C.), roman architect and engineer. In his monumental work, “De Architectura”, he explained the concept of architecture as an inseparable trinity of *firmitas, utilitas et venustas* – in contemporary words: Construction, function and aesthetics.

It is a common misunderstanding among lay people to think about architecture as a visual, aesthetic issue only. However, for a building claiming to be architecture, all three aspects must be included. If *firmitas* (construction) is absent, we have scenography, not architecture. If *utilitas* (function) is absent, we have a sculpture, not architecture. And without *venustas* (aesthetics), we merely have a building. But each of these three requirements to a building must be optimised and must interact with the others to result in a building of architectural quality. It may be considered odd that the old principle of trinity still holds. And this could also be considered a truth with limitations. Natural resources in the days of Vitruvius were plentiful, but this is not the case today. *Sustainability* is just as important a requirement as the three others mentioned. And behind them all is *economy* – as it was in ancient times.

Architecture has been defined as the aesthetical organisation of the practical reality (Cornell, 1968). A key issue in architectural theory from Antiquity to our days is the concept of decorum. This may be explained as “appropriate”, meaning that the form of the building must be the appropriate for the content of the building and the status of the owner. In other words, that the appearance of a building honestly tells us what kind of a building we face.

The architectural evaluation of the PV-NORD demonstration projects explicitly or implied refer to the above mentioned theses.

For lay people as well as architects Steen Eiler Rasmussen in his “Experiencing Architecture” (Rasmussen, 1964) offers a simple, yet sublime, introduction to the concept of architecture.

## 2.3 Hypotheses

On this background a set of hypotheses for the next and third phase of BiPV in the Nordic countries is advanced:

- *A joint effort of research, development, design and industry will result in design solutions for PV, which make it possible for architects, from the very start of the design process, to order standard or custom made PV components for full architectural integration in a multitude of projects.*
- *New PV components will be designed and produced to substitute existing components for the building skin, thus reducing the costs of employing PV in building.*
- *New PV components (cells, panels, installations, and fixtures) of high architectural quality will be developed to be preferred – not only tolerated – by architects.*
- *The PV-NORD demonstration projects and the architectural evaluations of these will help to change attitudes towards using PV modules as building components and will constitute a major contribution to the development of BiPV in the Nordic countries.*

### 3 Method

#### 3.1 Strategy

PV-NORD offers a unique opportunity of monitoring architectural considerations of BiPV projects from the start, during implementation, to the finish and furthermore after being taken in use.

Evaluation of architecture, as a matter of course, is a problematic exercise, architecture belonging to the realm of phenomenology. However, in many situations it is of importance to evaluate the architecture of a specific building, to – at the least – introduce ideas, themes, and words for a discussion of its architectural quality.

Over a period of more than ten years DBUR has developed a methodology of architectural evaluation of projects involving energy issues. The method is demonstrated in several research reports from DBUR. An example of these is listed in the biography Svensson & Wittchen (1998).

In its shortest form the strategy of the method is the following:

1. The researchers (DBUR) collect comprehensive information on the demonstration projects.
2. Professional writers of architecture evaluate the architecture on the basis of this information and visits to the projects.
3. The researchers conclude by summing up the evaluations in a discourse and in recommendations for future building projects.

#### 3.2 Information

DBUR has been involved from the very start of PV-NORD and close contact has been maintained between all participants of PV-NORD. DBUR has received the requested information and material on the demonstration projects. The researchers from DBUR have furthermore themselves gathered information through visits to the demonstration projects and interviews with technicians and administrators from the projects.

Special and valuable sources of information on the demonstration projects were the *pre-construction questionnaire on architecture* and the *post-construction questionnaire on architecture* to the participants responsible for the demonstration projects. These questionnaires (Sections 10.1 and 10.2) did not only provide factual information on the projects but also the ideas, hopes and difficulties during the whole process from start to end.

### 3.3 Critics of architecture

The criteria for the selection of critics of architecture are based on experience from previous projects by DBUR. The critics shall:

- be architects by profession
- be independent of PV-NORD, the demonstration projects and the people involved in these
- possess considerable experience from writing on Nordic architecture – in this case from evaluations of building projects, e.g. in the Nordic architectural periodicals
- be acknowledged as critics of architecture among fellow architects
- be concerned with as well the entity and detailing of the building as with its relation to the urban architecture of the surroundings
- be familiar with the practice of architects – without necessarily being practitioners themselves
- be un-dogmatic as to architectural style, trends and expression
- be qualified writers with a direct, concrete form of writing – in this case in English
- be prepared to follow guidelines for the evaluation, preconceived by the task leader (DBUR), and to attune their evaluations to the commentaries of the other critics.

Based on these criteria three critics of architecture were appointed: Tarja Nuomi, Olaf Lind, and Rasmus Wærn (section 7.2).

### 3.4 Content of evaluations

Already by the formulation of criteria for the selection of critics the content of the evaluations were indicated. However, the content was specified in the following *Guidelines* in order to help the critics and to facilitate the production of uniform and comparative evaluations.

- The goals concerning the architecture of the demonstration projects must be part of the basis for the evaluation (in the pre-construction questionnaire the goals were stated by the architects of the projects).
- The building's relationship to the surrounding urban architecture and city greenery must be described and evaluated (conflicts, compromises, etc.) especially concerning the effect of PV installations (form, colour, scale, expression; harmony or break; mirror images and reflections, etc.).
- The building as an entity and its details (harmony/break, expression, etc.), must be especially described and evaluated concerning the PV installations.
- Questions of building integration should be considered (fully or partly integrated or not integrated at all; visible, demonstrative or aesthetical effect, etc.).
- The architectural quality (form, function, aesthetics) of the PV installation as such should be considered (design, details, proportions, surfaces, colours, expression, etc.).

- The architectural evaluation should preferably conclude in a short overall statement characterising and evaluating the BiPV project and suggesting a perspective or a future development for similar future projects.
- The main theme of the evaluation is the architectural quality of the integration of PV in the eight demonstration projects. The architectural quality of the buildings themselves is not a separate theme, but merely an issue for reference.
- The concept of architectural integration is debatable: Fully integrated PV may be solar cell modules which substitute traditional panels in the building envelope, whereas solar cells mounted on a structure on the flat roof of a building may be deemed not integrated at all. In between these extremes are many degrees of integration of PV in buildings.
- The length of each evaluation text should be 1.000-1.500 words.

### 3.5 Procedure

After a search among Nordic critics three were selected for the task: A critic in Helsinki as the main responsible for evaluation of the two Finnish projects. A critic in Stockholm as the main responsible for the two Swedish projects. And a Danish critic as the main responsible for the Danish, the Norwegian and the two Dutch projects. The Danish critic had previously taken part in this kind of evaluation and could thus add valuable experience to the task.

By the selection of critics from three Nordic countries it was ensured that at the least one critic would see the actual buildings in Helsinki, Stockholm and Copenhagen. And travel costs of the task were thus kept low.

Instructions for the content of the evaluations and the procedure as well as the basis material of the demonstration projects were sent by DBUR to the critics. And the preliminary evaluations were circulated among the critics for commentaries and suggestions for the final evaluations.

This procedure has resulted in architectural evaluations of the demonstration projects, agreed by all three critics, "speaking with one voice".

### 3.6 Material for evaluation

The critics received as basis material on the demonstration projects:

- A short account on PV and relevant technical aspects concerning BiPV (orientation and placement of PV installations, technical and visual properties of different kind of PV, indoor climate, ventilation and solar screening in relation to BiPV etc. – issues which affect the architecture and reflect on the characteristics of the installation).
- "*Solar Cells in Architecture*" (Svensson & Wittchen, 2002) with examples of BiPV from Denmark, the Netherlands and Germany.

Besides this general introduction the critics received:

- A fact sheet with information on the demonstration project and PV installations.
- A statement on the architectural goals of the BiPV by the architects of the project.
- Plans and drawings of the demonstration project and its environment.
- Photos (urban environment, building – exterior, interior details – PV installations).

## 4 Eight demonstration projects

*In the following each of the eight PV-NORD demonstration projects is presented by*

- 1. A short description of the urban location, building type etc.,*
  - 2. A description of the PV installations,*
  - 3. Technical information – in a frame – on the PV installations and*
  - 4. An evaluation on the architecture, agreed upon by the three architecture critics.*
- Building data – address, construction year, architect, engineer, etc. – are to be found in section 8.1: Building data.*

## 4.1 Holmen and Grynnan, Stockholm, Sweden

### Description of buildings



This PV-NORD demonstration project, which consists of two housing blocks, Holmen and Grynnan, is located in a new urban area, Hammarby Sjöstad, at the edge of the city of Stockholm, on the site of a former industrial area. The urban area constitutes a further development of the dense European City, but with a more green, open and flexible structure. The city revised this planning concept in the middle of the design process, which caused some disturbance and change of the design.

The two similar buildings are situated side by side along a new, major avenue, Hammarby Allé. They are in seven storeys with shops on the ground floor, and dwellings on five upper floors and in a penthouse on top.

Planning requirements for building in this area call for a higher level of energy efficiency and environmental quality than ordinary. The two blocks, Holmen and Grynnan, thus have PV installations towards Southwest on the facade, on the parapets of the penthouse balcony and in the windows here.

### Description of PV installations



BiPV became part of the design only when the design was half through. After a discussion of more possibilities, it was decided to locate the cells on the facade, on the balcony parapets, and on the high windows in the penthouse apartments.

The yellow-ochre colour of the plaster on the building was decided by the city building authorities. For the designers this ruled out blue PV cells, even though these are the most efficient. Grey polycrystalline cells were chosen for aesthetic reasons. However, due to problems with the delivery of these, brown cells were accepted as a compromise.

Use of BiPV did not influence the architectural form of the facade or the building. BiPV made the design and negotiations with the building authorities more difficult but caused only minor problems and adjustments.

### Technical information

PV location:	Facade, windows and balconies integrated.
Cell type	Polycrystalline silicon
Orientation and tilt:	420 m <sup>2</sup> (104 modules) orientated 30 ° West in a vertical position.
Inverters:	17 Sunny Boy, SWR 850, 2100, 2500
Installed power:	34,8 kWp
Production:	Start of production: September 2003 resp. April 2004 Production: 14029 kWh from 17/9 -03 resp. 22/4-04 to 31/8 -04
Cost per m <sup>2</sup> :	952 €/m <sup>2</sup>
Cost per kWp:	11400 €/kWp

### Evaluation

*The two blocks Holmen and Grynnan are located in the densest part of Hammarby Sjöstad. In a close future, the houses will face a row of buildings on the opposite side of the avenue, Hammarby Allé. The distant view, from which the buildings can be perceived today, will not be possible in the future. The ambitions behind the planning of Hammarby Sjöstad are very urban, in the sense that the area will act as a seamless extension of the inner core of Stockholm when completed. These ambitions have had great influence also on the design of individual buildings. The plans for a more open grid had proceeded very long when the former political majority altered the plans, in favour of a more closed pattern. The houses were rapidly redesigned, and the openings in the facade toward the street were altered to glazed "urban windows".*

*The proposal to include PV panels in the design came after this turbulent phase, which is probably one reason why the integration of the panels in the architecture is rather poor. This judgement mainly concerns the large vertical parts on the corners of the two blocks, constituting a symmetrical motif linking them together. The idea of such a monumental gesture embracing the little alley can be discussed; more problematic from the PV design view is that this emblematic situation puts the headlight on the poor appearance of the arrays even more.*

*Even though the glazed surface of the PV panels in some sense correspond to the large "urban windows" of the facade, they lack relation to the building both in proportions, colour and the way they are mounted, as a layer on top of the existing facade. This is so much more evident as the array stand on top of another accent of the building, the almost "old-fashioned" bay window at the corner.*



*Holmen and Grännan along Hammerby Allé.*



*PV installations. Window and balcony parapet integration.*



*Window integration.*



*PV installation at facade, balcony parapet and windows.*



*Facade integration.*

*One reason for the result has already been mentioned. Another reason may be the importance of having the PV panels fully visible towards the street. According to the architect, the exposure of the PV panels to the public was more important than exposing them to the sun. The long-going ambitions to make Hammarby Sjostad the most sustainable housing area built, was the very reason why the PV panels were applied on the two blocks. As an important part of the idea of self-production of energy they were not to be hidden on the roof, but exposed on the Southwest facade. As the part chosen to carry the panels is not ideal in terms of efficiency, it is hard to see any beautiful logic behind the arrangement.*

*A third reason to the weak appearance is the design of the panels themselves. The fact that the aluminium framework lacks relation to anything else on the facade is perhaps the most important single factor behind the sense that the panels have been added afterwards. The meeting between the panels and the window is especially unhappy. The glazed surface of the panels invites to a flush mounting of the windows. The current location deep in the wall would on the other hand have called for a frame, something that made the border between window and panel distinct. Without neither a flush flatness nor a distinct division, the window openings appear almost haphazardly in the array. On a closer distance the cord connecting the individual cells is also disturbing, as it runs in an uneven pattern. It is obvious that greater interest must be taken to the visual appearance of the PV panels if they are to achieve the status of an attractive building material.*

*The PV panels on the top floor do not have these problems at all. For the pedestrian the cells applied on the balustrade as well as the ones on the windows are very unproblematic. It can't be said that they add visual qualities to the building, but if the aim was to make solar energy visible to the public realm, they add value in terms of complexity. The belt with PV cells gives the attic a meaning attics normally do not have.*

*The reason why the PV panels on the top floor are so much more integrated is partly because the architecture of the attic is somewhat different from the architecture of the rest of the house. The building has a classical division in three different parts: Basement, body, and attic. The attic is outspokenly horizontal, with long, continuous lines, where the middle section of the building, the body, is divided in smaller, mainly vertical, parts. It is obvious that a design with larger, or at least longer, parts would have been better suited to carry a technical system like PV panels on the facade. As the attic and the body works as separate parts in the building design, the two parts of the installation are not possible to read together as a united form. With a building concept from the beginning designed to carry PV panels, there should be many possibilities to make interesting large-scale ornaments or figures on the facade using the panels.*

*The ornamental aspect is today most relevant at the cells adapted to the windows in the penthouses. It is of course possible that not every tenant will admire the presence of new technology. The cells themselves are not beautiful, even thou the arrangement has deco-*

*rative qualities. One great benefit with the position they have is that they can easily be hidden with curtains for example.*

*To sum up, the two blocks Grynann and Holmen are clearly not originally designed to carry PV panels. Of the three places chosen to carry the panels, the balustrade has been the most successful. That is the only place where the panels works in more than one way - they are not only energy-producing elements, but a visual benefit to the facade and a good visual protection for the tenants. The panels in the apartments do not do any harm in the public realm, but may give a negative reaction from the inside. The big panels on the wall are finally very poorly integrated with the architecture.*

*Holmen and Grynann may serve as a good example of how to, and how not to, adapt PV cells to an existing building. For new buildings it is necessary to integrate the cells in the design at an earlier stage.*

## 4.2 Lysande, Stockholm, Sweden

### Description of building

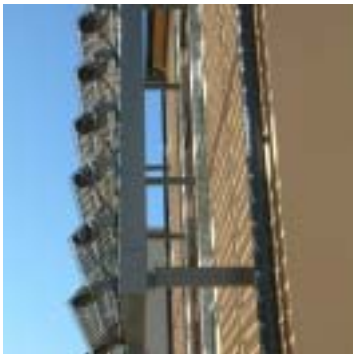


Hammarby Sjöstad in Stockholm is an old dockland and industrial area under transformation to become a larger city area with as much as 30.000 new inhabitants in year 2010. The area is meant to have a strong environmental profile and to be a spearhead for future building projects in Sweden. Use of PV plays an important role in this context.

The demonstration project, Lysande, is a multi-family building where PV is installed partly on the South-Southwest facade and partly on the roof. The facade part is designed as a lamella structure mounted half a meter outside the building as an independent element. The modules are installed on the structure with a tilt of 45 °. The PV panels on the roof are installed as a cover on top of the normal roof.

This house is designed to be an experimental building with high demands on the environmental standard. A neighbouring house with a similar architectural exterior is built as a reference with normal (for Hammerby Sjöstad) environmental standards.

### Description of PV installation



BiPV was suggested by the architect and became part of the building project, when the project design was half through.

The visibility of the cells was decisive for the architectural expression of the building. Blue polycrystalline cells were chosen as they were said to be the most efficient. Only moderate design adjustments were made due to the BiPV: windows were moved away from the facade behind the PV installation.

It was difficult to get a building permit from the city authorities due to aesthetical and integration aspects.

### Technical information

PV location:	PV modules installed on the roof facing East, South and West PV modules mounted on a separate steel structure in front of the entrance facade facing South-Southwest
Cell-type	Polycrystalline silicon
Orientation and tilt:	169 PV modules (12,5 kWp) are mounted integrated on top of the roof with a total area of 125 m <sup>2</sup> . (1/3 facing South, 1/3 East and 1/3 West). 305 PV modules (9,4 kWp) with a tilt of 45 ° are mounted on a detached steel structure with a total area of 110 m <sup>2</sup> .
Inverters:	10 Fronius
Installed power:	21,9 kWp
Production:	From January 29 to June 1, the PV system has produced a total of 7504 kWh divided as follows: <ul style="list-style-type: none"> <li>• Distributed to grid: 2590 kWh</li> <li>• Used in building for elevator, fans etc: 1100 kWh</li> <li>• Used by apartments 3814 kWh</li> </ul>
Cost:	215 000 Euro + 43 500 (approx.) (+ 10 800 VAT) €for the grid.

### Evaluation

*The PV modules are adapted to two parts of the building; the roof (hardly visible) and to a free standing screen on the front facade (very visible). As the ostentatious facade catches all the attention in this building, this will be in focus for my evaluation. When I talk about the “PV panels” etc, it is the facade I have in mind.*

*Hammarby Sjöstad is a rather heterogeneous housing area, with very high demands on sustainability. To express the ecological ambitions in the design has been an important task, and it is therefore not surprising to find odd solutions here and there. This house is one of them.*

*As the dramatic gesture has been a calculated feature, the surprise of a detached screen mounted outside a conventional facade was a desired effect. The temporal character is not only a technical feature. It expresses an attitude, indicating that this is an experiment, something attached that can and will be removed sometime. This is a problematic approach, if the intention is to express sustainability.*



*Lysande*



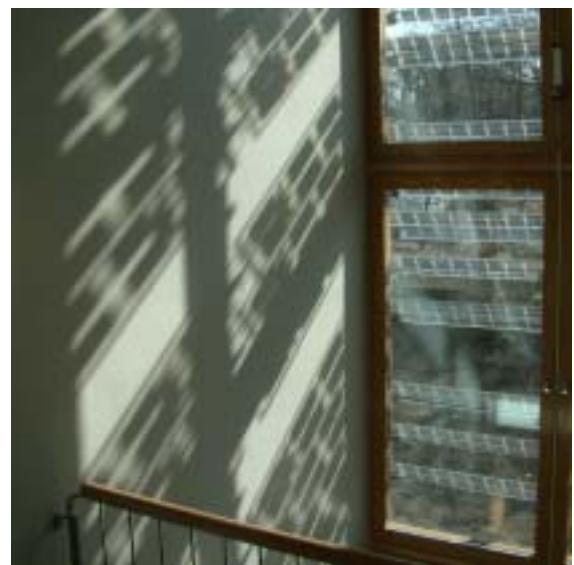
*Lysande and similar neighbouring building.*



*PV installation on metal frame in front of facade.*



*Roof top PV installation.*



*PV installation on facade seen from the stairwell.*

*The house serves mainly as a technical support. The screen could have been standing alone, with other aesthetic pros and cons. That would have emphasised the sculptural qualities in the object. Here, on the other hand, the shadows that the PV panels cast on the plaster is one of the most successful aspects of the design. A more uniform design of the facade would have emphasised this quality. One could say, that the character of the screen is stronger than the character of the conventional facade, and these disparate characters do not blend very well.*

*A more substantial problem is the dust on the panels. As every visible panel is protected from rain by the panel above, dust and dirt rapidly reduces the impression of technical brilliance. The cables hanging from one panel to the next one is another part in this decay. A different solution would have been both desired and possible.*

*From within the house it is hard to see any qualities with the arrangement at all. Even though some of the panels have been removed to open up the view, the remaining panels do not harmonise with the windows. The missing panels emphasise the arbitrary union of the two elements – the house and the screen.*

*Even though the screen itself is an interesting object, and the house is neat and properly designed, the combination is inappropriate for three reasons:*

- 1. It is falling out of the context with the row of rather conventional houses. It gives the domestic building an industrial character, which could have been good in another location, or appropriate if the function actually would have been something else than housing.*
- 2. The design of the screen does not communicate with the design of the building.*
- 3. The selected location for this technical experiment seems irrelevant, as a hill with trees reduces the most affordable winter sunlight.*

*The expressive design is not a surplus to the housing unit, but it is on the other hand not a big disadvantage. If the ambition was that the solar power should be more visible in the city, it is obvious that the design must be more integrated and not added halfway, as the case so obviously have been here. In this situation, the PV panels transmit the impression of something undesired but apparently necessary. The conclusion of the experiment must be that PV panels must not be added afterwards as a second layer on top of an existing, conventional, facade.*

### 4.3 Ekoviikki, Helsinki, Finland

#### Description of building



Ekkoviikki is a new housing area approximately 8 km North of Helsinki. From the very start this area was planned by the City for buildings with passive and active energy properties. To acquire land here developers had to satisfy planning demands for sustainable buildings. The PV-NORD demonstration project is one of five similar 8-story tower blocks here.

#### Description of PV installation



BiPV became part of the building project on the request of the City, when the design was almost finished. BiPV did not influence the basic form of the building, only the appearance of the balconies. The visibility of the cells was not decisive for the architectural expression.

The other blocks have glazed-in balconies for passive solar heating, and the glass facades are held in subdued colours.

The demonstration block, however, instead of glazed-in facades, has open balconies with PV panels mounted in a pattern on the parapets towards South and West.

With their prominent location and strong blue colour the PV panels have a strong impact on the architectural expression of the building. The colour was accepted as “there was no other possibility”.

#### Technical information

PV location:	Balcony parapets
Cell-type	Polycrystalline silicon
Orientation and tilt:	81 modules South and 90 modules West. A total of 290m <sup>2</sup> vertical.
Inverters:	12
Installed power:	11,3 m <sup>2</sup> facing South and 12,3 m <sup>2</sup> facing West



*Ekoviikki.*



*Ekoviikki and similar neighbouring building. Ekoviikki, back facade.*



*PV facades.*



*PV in balcony parapet.*

## Evaluation

*The Ekoviikki area in the North-Eastern part of Helsinki is supposed to be a flagship of experimental ecological building and architecture in Finland. The area also houses a considerable amount of Helsinki University buildings, devoted to bio-science. In one of them, the "Korona" library (ARK-house Architects), general sustainability aspects have been taken into consideration in a way which also adds to the architectural and aesthetic quality and pleasantness of the building.*

*Apart from a few pioneering buildings by Mr. Bruno Erat, a Swiss-born architect and ecologist, there are in Finland considerably few examples of "classic" or avant-garde sustainable architecture and design. That is in part surprising, us all knowing how avant-garde many pioneers of modernism have been in the country and how deep the tradition of building - especially with wood - with little means in a rough climate Finland has in general.*

*There is, of course, exceptions within the field of timber construction and sustainable holiday dwellings, plus a few so-called eco-villages according to various ideologies - as well Nordic as American.*

*The architectural profession is rather pragmatic in views concerning sustainability. Therefore it is not considered to be especially hip to deal with matters of ecology in buildings. The often-repeated phrase, also, is: "I would be interested in building sustainable buildings - were it not for the fact that so-called sustainable buildings are aesthetically of a minor quality." It often is repeated that cheaply produced "ecology" in buildings means undesirable aesthetics. New technical innovations are also considered to be too difficult or "unfit for Nordic latitudes".*

*The leading names of Finnish architecture seldom use sustainability as a positive argument, and the Ekoviikki area is partly looked down upon, even for its very modest, prototype-like experimentation with contemporary ecological building technologies. As a housing area it even is a mixture of very normal-looking blocks of flats, occasional composts and glazed winter gardens plus both flat and funny shaped roofs that seem to be lacking something: the occasional sun collector or PV panel that somehow have been left out of the final design after all. In Finland the point of saving energy by better insulation and better window design often makes buildings more sustainable without all of that presenting itself in the architecture of the buildings themselves. On the other hand, only a few of the cream of the crop of the often-published design teams consider themselves to be experts in sustainability. This is very regrettable indeed.*

*King of the hill: Entering the Ekoviikki housing area from the south and past the Gardenia complex, one first glimpses the cold and glassy-looking, slightly stuffy-coloured university buildings in the left corner of the eye. Frontally, on the other side of the fields and*

*when one enters the street towards the housing area, there is a group of peaceful-looking cream-coloured blocks of flats to the left, by Brunow & Maunula Architects, and a shining-looking, blue- and white-striped block of flats in the middle, leaving the experimental low-rise area onto the right hand side.*

*The patriotic blue- and white-striped appearance of the first house is a bit surprising, considering that it is the first and foremost of a group of similar houses - the rest of the group not having these glistening, horizontal blue fields of PV panels that replace the glazing of the balcony balustrades. The buildings behind the very diagonally frontal PV panel house are rather nice, simple, low-key and elegant houses, and they are by the same architect, Professor Reijo Jallinoja.*

*The floor plans with south and west-facing balconies are about the same in every house, but the other buildings get their interesting balcony facade rhythm through translucent, narrow vertical glass planks, almost randomly placed here and there. Here we see the original design of the balconies. It, now, becomes obvious, that the PV building has been created just by clumsily replacing the glass panels of the balconies and placing PV panels also into the same horizontal field underneath some windows: the glistening, blue-and-white house was not designed as special object of architecture. It appears to be a prototype experimentation with added technical elements.*

*If experimenting with integrated PV panels should be an issue for the public, this building is more than visible enough. It is in its right context in the Ekoviikki area, but one could truly be impressed even with a less obvious situation.'*

*Also, a question rises: The architect is well known for his rather courageous use of colours in the Huopalahti housing area. And here, alas!, this nondescript solution. Why? As one in a group with rather similar buildings this PV panelled building seems to be aesthetically of a very minor quality. One keeps wondering why the idea of vertical curtain-like solution like the glass planks in the other houses has not occurred to the builders. And why the dull white colour on other parts of the facade, why not a blue rainbow of colours? Or: do all the photovoltaic glass panels have to be of one and only blue colour, if the rest of the facade is dull with its white?*

*Of course it is obvious that the PV panels have just been added to one of the buildings, with little consideration as to the overall architecture and aesthetics of the house. From the inside of the private balconies they seem to be just partly transparent, dotted glass panels with extra technical details and gear and lacking of any kind of "soft" ecological qualities one would expect to see in ones private "sustainable" home.*

*I know this architect can do better. But did they all run out of ambition? Or did they run out of money? Or time? Or is this meant to be a statement to underline that sustainable building technologies do not mean better architecture, or - at least - are not meant to? One leaves the building and the Ekoviikki area with mixed feelings. On the other part, there are the very small-scale, modest and halfway experiments in the two-storey area with its small gardens. And then, like a king on a hill, this glittering, striped building that - amongst its more modest sisters and brothers - is a bit bigger and more visible than the white and glassed ones. In this way the PV building only adds to the confusing image of the Ekoviikki ecological experimentation.*

*I would say: we seem to need more experimenting with integrated PV technology in Finland, please! But if the builders and the constructors have so little ambition and the architect is left with nothing other than the possibility of placing PV elements as stripes between balcony railings, please, hide these buildings in some remote parts of the country.*

*And please, give Finnish architects and engineers more of a challenge than just the chance of pasting on some new technical parts on otherwise ordinary and nice-looking buildings. Have faith in their ability to experiment - and give the needed extra money for them to reach beyond a point of a clumsy prototype!*

#### 4.4 NCC head office, Helsinki, Finland

##### Description of building



This PV-NORD demonstration project, the head office of NCC in Finland, is an office building with internal services for the app. 400 employees.

The building is located near the centre of Helsinki close to a major road in the city. Use of PV in the building reflects the company's wish to demonstrate concern with environmental as well as aesthetical demands.

NCC has stated that the central location of the office makes the PV installation very important, and that the colour of the modules as well as the integration technique chosen should be carefully selected.

##### Description of PV installations



BiPV became part of the building project already when the project was initiated, on the request of the NCC managers.

Originally PV integrated on a facade was considered. But as the building authorities of the city would not allow glass facades, several other locations of PV were discussed. Finally, however, PV was installed on racks on a part of the flat roof and integrated in a smaller area of the windows in the building.

The visibility of the cells was not decisive for the architectural expression of the building. No major adjustments to the form of the building were made due to the use of PV cells.

##### Technical information

PV location:	On racks on the flat roof and window integrated.
Cell type	Polycrystalline silicon
Orientation and tilt:	139 m <sup>2</sup> (165 modules) South facing with 45° tilt and 8 m <sup>2</sup> (7 modules) East facing with 90° tilt
Inverters:	6 inverters of type SWR 2500
Installed power:	16,5 kWp on the roof, 0,8 kWp on the windows.
Production:	1124 kWh (8.9.2004 - 11.10.2004)
Cost per m <sup>2</sup> :	1020 €
Cost per kWp:	8.500 €



*NCC head office.*



*Roof-line with PV installations.*



*Roof-line with PV installations.*



*Window integrated PV installation.*



*PV installation on roof.*

## Evaluation

*The NCC Finland head office is situated in an environment where post-war housing has dominated for a long time. It is located on Mannerheimintie, a very busy main artery northwards from the city centre. On the West side of this newly finished office building lies the pastel-coloured, slightly experimental and also a bit controversial housing area called Pikku- Huopalahti, and there are a few business buildings nearby on Mannerheimintie. Many Helsinki and metropolitan area main bus lines and the tram number 10 pass by the new, rather dominant 30 000 m<sup>2</sup> NCC building which was taken into use in August 2004. The building houses workspaces for about 400 employees and has four to seven floors.*

*In the city plan it was not allowed to build facades with glass, so the building is rather traditional and in its – on the backdrop of recent Finnish hard and cool aesthetics office buildings - softness and warm colours a bit “Swedish” by its outer image. Its plastered walls are coloured in yellowish and brownish shades and the windows are rather traditional openings in the wall surfaces, with a few exceptions on the top floor. On the Mannerheimintie side the ground floor is surrounded by rather a bland arcade with traditional shop windows behind it. There is public access to the shop-like exhibition spaces, which demonstrate the housing production of NCC. Part of this ground floor space has office workstations, and there is a visual connection through glass to the entrance foyer on the other side of the building.*

*The main entrance on the backside includes, surprisingly, an atrium-like well lit entrance hall, but it has no resemblance to Central European glass atriums which in best buildings also serve as a buffer zone which, again, can also be naturally ventilated and might be full of plants and even have fountains or water pools, thus giving the business building its own identity and image – even a sustainable one. The entrance gives more of a message of a no-nonsense Helsinki office building than of a flagship building which has something to do with sustainability and energy-saving.*

*Both the entrance foyer and some street-level spaces are open to the visiting public and professionals. It could have been possible here to demonstrate the special quality of the building with its state-of-the-art PV panel system. Now there is no clue whatsoever, that the headquarters of a major building company uses renewable energy in the building. In this sense some loved labours are lost and the building lacks in PR-value in relation to sustainable energy. This is a bit surprising, because such ideas might tempt more people to come and see the building and maybe get excited also by the products – housing and flats – demonstrated on the ground floor.*

*The photovoltaic panels are located high on top of the highest part of the house and can hardly be seen from the street. They are well visible from some of the neighbouring buildings, but for the general public they remain a mystery. On the eastern side there are a few*

*windows on the 7th floor that have in their topmost part integrated PV window fields. These can be seen in the inside from a couple of offices and the elevator foyer, seldom visited by outsiders. The amount of this window-integrated PV technology is so small that it makes one wonder if anybody even notices a difference from a distance.*

*The actual PV technology can from the building itself only be explored by climbing onto the roof and again climbing ladders: the demonstrative value of the panels goes missing because it is very difficult for visitors - especially in business clothes – to have any kind of an idea about how the panels look and how and where they have been installed.*

*The integrated PV panels are located high on the flat roof and are not visible from the sidewalks. From a further distance they can of course be seen both by drivers in private cars, buses and trams plus pedestrians and bicycle riders in the nearby recreational green areas. The majority of the PV panels are in no way an essential part of the architecture, but installed as separate slanting units on the roof. This makes the application very different from the Viikki apartment building, where the blue, glittering panels are very (maybe within the context a little bit too obviously) visible even from a distance. In fact, they are the most “visible” part of the house just because of the strong colour and the omnipresence in the otherwise white balconies.*

*Knowing how very few in numbers are the PV buildings in Finland, it is easy to give credit to NCC for the application as such. In my view, though, building integrated PV technology means something other than adding things or objects to an actual building. It is an easy application to install panels on a flat roof, so one would have expected a little bit more creativity and avant-garde approach from a leading building company.*

## 4.5 Kollektivhuset, Copenhagen, Denmark

### Description of building



This PV-NORD demonstration building, Kollektivhuset, is located along a major access motorway at the edge of the city. The 12-storey building from 1957-58 stands as a landmark at the entrance to the inner city. It was originally designed as a successful, early example of industrialised housing.

The building with its 224 flats was from the beginning organised as a collective for disabled people, many of whom move about in wheelchairs. In the lower three storeys are various common facilities: restaurant/cafeteria, gym, doctors' offices etc. The renovation in 2003 including the PV panels only concerned the upper nine storeys with apartments.

### Description of PV installations:



BiPV became part of the project at the beginning of the design phase at the request of the owner and the architect.

The original concrete parapets of the balconies were removed to provide more outdoor space here and to be substituted by glass parapets with integrated PV modules.

The use of BiPV influenced the architectural form. From the beginning BiPV was thought to be just an integrated part of the facade system. But in the final design it is used very specifically to provide the impression of an ever-changing facade as the coloured sheets of glass contrast with the transparent solar panels. In the design process the architect considered PV cells as any other "material" and tried to use its possibilities to an absolute maximum.

The visibility of the cells was decisive for the architectural expression of the building. Black mono crystalline cells were chosen due to their colour and overall character.

BiPV made the design more complicated as the architect had to work closely together with the BiPV engineering company and the manufacturer of PV. Also it was necessary to get special approval from the City Architect; this, however, proved to be no problem.

### Technical Information

PV location:	Balcony parapet integrated.
Cell type	Mono crystalline.
Orientation and tilt:	166 m <sup>2</sup> vertical, facing West-Southwest.
Inverters:	Three Sunny Boy 2000 and one Sunny Boy 1100E, String inverters.
Installed power:	10.1 kWp.
Production:	Start of production: 15. September 2002, Production: 8000 kWh from start to 17. November 2004.
Cost per m <sup>2</sup> :	1270 €/m <sup>2</sup>
Cost per kWp:	20900 €/kWp

### Evaluation

*The renovation from 2001-02 designed by the architect firm DOMUS has added a new curtain wall to the west facade respecting the original construction framework in the building, and the PV modules constitute a part of the parapet in the new, glazed balconies. The glazing, which allows for a total closure of the balconies, has a high degree of flexibility with several options for opening to the outdoor climate by means of sliding parts. Moreover a sliding plate behind the PV module provides flexible utilisation of the heat generated on the PV module.*

*In the presentation material it is stressed, that this building is situated in central Copenhagen close to a motorway (Lyngbymotorvejen), which probably carries the heaviest traffic in the capital, and the west facade of the building is facing the highway. Therefore this PV project has an extreme exposure to the public - within the limitations given by the nearby highway and for passengers in motorcars passing there by speeds up to 110 km/h.*

*From a perpendicular distance of approx. 100 meters the PV modules are hardly visible as such, since they appear only as darker parts of the parapets in the glazed facade. One has a similar impression, when the building is seen from a narrow angle, which is the typical condition for spectators in motorcars on the highway. In these situations ordinary people will barely recognise any unusual details in the west facade such as the PV modules.*

*At closer range the building's proximity to the highway forces pedestrians to view the west facade on very narrow angles either horizontally or vertically. These situations do likewise not allow for any clear visual impression of the PV modules. On very special standpoints, e.g. the railway bridge crossing the highway not far north of the building, it is possible to get a better - but not sufficient - view of the facade and its details.*



*Kollektivhuset.*



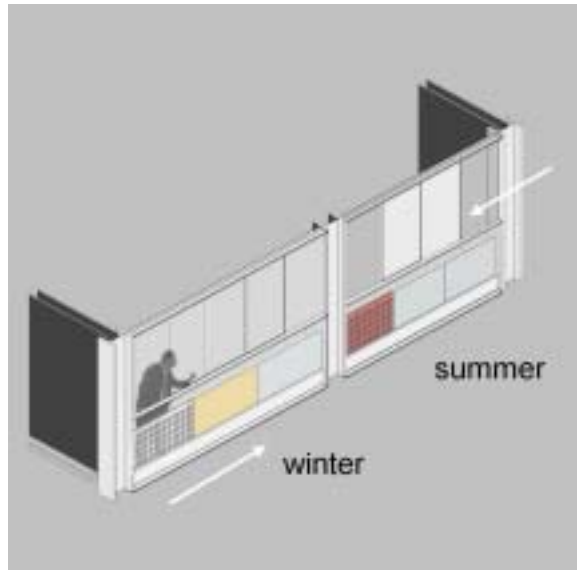
*Kollektivhuset along the motorway.*



*PV in balcony parapets.*



*Sliding screen and PV installation.*



*Principle of thermal solar utilisation.*

*From the inside of the balcony there is obviously a closer view to the PV module, which consists of 35 solar cells appearing either with their silvery backside, or - when a sliding back-plate is covering the module - as a grid pattern dimly visible through the semitransparent back-plate. The effect of this arrangement is, that the surplus heat created by the solar cells can be used to raise the temperature of the closed balcony room during cool seasons, or the surplus heat can be directed into the open air by warm weather. The two situations can be chosen by the tenant, who can respectively slide the back-plate aside to or behind the PV module. According to the architect, who has designed the renovation project, the backside of the PV module can reach a temperature of 60-70 °C. This explains why the surplus heat must necessarily be removed from the module.*

*In order to summarise the above observations, the evaluation of PV integration for this building/renovation must be divided in two different judgements, corresponding the outside and the inside viewpoint. Seen from the described positions on both sides of the highway and from the highway itself - all of which do not allow for an ideal view of the renovated west facade - the integration of the PV modules must be characterised as almost total, since the modules are barely visible. From this point of view the present project is therefore close to the one extreme described in Guidelines for evaluations: "Fully integrated PV may be solar cell modules which substitute traditional panels in the building envelope..."*

*From the tenants' point of view that is from the inside of the balcony the PV module presents itself as a far more visible and directly useful part of the building. Whether the sliding back-plate is behind the PV module or not, the grid pattern of the module is recognisable as an aesthetic quality in the parapet - an ornament. In addition the side effect of the PV module, the surplus heat, can be exploited by means of a low-technological system of a sliding plate. As part of the interior balcony the PV module therefore can be considered as very well aesthetical and functional integrated, although - or because - it is clearly visible.*

*In its dualistic appearance this PV project may be considered as a comment to "the debatable concept of architectural integration" as mentioned in the Guidelines.*

## 4.6 Vest-Agder clinic, Kristianssand, Norway

### Description of building



Kristianssand is one of 4 cities in Norway given a status of "Environmental city" by the Ministry of the Environment in 1993. The four cities are pointed out for pioneering activities to improve the local environment socially as well as physically.

The demonstration project, Vest-Agder Clinic, from 2003 is situated about 3 km from the city centre in a landscape with large trees, gardens and recreation areas. The clinic, which is built as an expansion of a psychiatric clinic, is a treatment centre for alcoholism and drug abuse. The new building is part of a complex, including an old farmhouse, a barn and an office building from 1988.

The new clinic is a 3-storey building with facades in natural stone and wooden cladding.

### Description of PV installation



BiPV was introduced at the beginning of the design phase at the request of the building owner.

The Southwest facade was originally designed with an aluminium curtain wall system with integrated PV modules. On this facade were also designed two shading devices with PV modules over the first and second storey windows. However, due to a change of the project and limited economy, the design was altered. As a final result the facade has only the two shading devices with BiPV.

The visibility of the BiPV installations was decisive for the architectural expression of the building. Blue cells were chosen for aesthetical reasons, as blue was considered to look good together with the other colours of the building.

It only took minor adjustments to include BiPV in the building design, and the building authorities caused no problems.



*Vest Agder clinic.*



*PV solar shading devices at the facade.*



*Vest Agder clinic.*



*PV panels above the windows.*



*East facade.*

### Technical information

PV location:	Shading device structure.
Cell type	Polycrystalline silicon.
Orientation and tilt:	39 m <sup>2</sup> (48 modules) facing South-Southwest with 35 ° tilt.
Installed power:	5 kWp.

### Evaluation

*The clinic consists of several buildings of different age. The 3-floor building with BiPV is constructed 2.002-04 in a partly traditional architecture: slightly sloping basement walls of natural stone with aluminium windows and doors, the facade of the upper floors is made of wood in the form of a brownish, horizontal timber cladding. Here windows also have aluminium frames, and the facade at the buildings south corner is entirely clad with aluminium. The one-sided, low sloping roofs are covered with red tiles.*

*The BiPV are to be found only at the Southwest facade, where they function as solar shading device above the windows at the first and second floor. The solar panels are mounted on a steel frame with an inclination of 35° to the horizontal level. Solar panels were also foreseen integrated at the aluminium facade at the south corner, but this idea was abandoned due to economic considerations.*

*According to the questionnaire the BiPV has had "no influence on the architectural form". This is probably correct, since the solar shadings appear to be merely added to the facade without much design effort. However the photos of the building demonstrate, that the shining surface of the solar panels diverge quite distinctly from the other facade materials and especially from the timber cladding, thus adding to the impression of an indefinable architecture between traditionalism and something more up-to-date.*

*The modest extent of the BiPV in this project makes it less suitable for an evaluation of BiPV in a general sense. It is an isolated and small case, where moreover the solar panels seem to have foremost a signalling effect. A technical or architectural integration of solar panels on this building has not really taken place. The design process has apparently only included the elementary addition of a shading device.*

## 4.7 PV parking, Zwolle, The Netherlands

### Description of building



Zwolle is a city of approx. 100 000 inhabitants. In the city centre are located a large hospital, a school, government buildings etc. Many people visit daily the city centre, and there is a great need for parking spaces here.

The PV-NORD demonstration project, PV parking, is a multi-storey parking structure with 360 parking spaces and 6100 m<sup>2</sup> office floor area. The parking in itself is innovative, as the cars are automatically parked with the use of electrical lifts. This makes it possible to park more cars per m<sup>2</sup> than normally. But it also increases the consumption of electricity.

For this reason, and as the parking structure is seen and used by many people each day, it was decided to use BiPV.

### Description of PV installation



BiPV was introduced at the very beginning of the design phase by the developer, an energy company, and the architect. The project is meant to demonstrate how PV can be integrated in a non-residential inner-city building replacing a conventional skin, e.g. glass. PV here has an added value – having both the functions of the normal skin and that of producing energy.

The PV parking has approximately 650 m<sup>2</sup> PV modules integrated in the Southwest and Southeast facades. This amount of PV is expected to provide 100 % of the parking's electricity consumption.

Amorphous PV panels have been chosen mostly for aesthetical reasons because of their subdued colour. The panels are placed in special frames, which are placed at the beams of the building's structure. Each frame contains a number of panels. No major design adjustments have been necessary to include BiPV in the architectural concept.

As part of the project the users of the parking structure will be involved in the operation of the PV project: The energy production will be monitored and data presented on a display, located in a place, where people will see it.



*PV-parking.*



*Facade integration.*



*PV panel back.*



*PV parking during construction.*



*Multi-storey car-park behind existing buildings.*

Technical information

PV location:	Facade integrated.
Cell type	Amorphous silicon.
Orientation and tilt:	Southeast and Southwest – vertical.
Inverters:	5 Siemens Sitop 4600.
Installed power:	Approx. 8,8 kWp SE and S 17,75 kWp.
Production:	Start date: 1. July 2004.

Evaluation

*Zwolle is a major city in the Northeastern part of The Netherlands. With a population of approx. 100 000 parking in Zwolle is an increasing problem. The PV parking meets this problem with an automatic system based on electric lifts, which is the first to be realised in The Netherlands. The novelty of the system should be emphasised by the use of BiPV on the facades, which will be exposed to a wide public in the middle of the city.*

*The parking is connected with an office building, which has no BiPV; therefore the architectural aspects of the relations between the two buildings is not part of this evaluation.*

*The parking itself is a 7-floor building constructed with steel frames. On the upper five floors the facades to the south and east have a climate screen mainly consisting of PV panels with amorphous silicone that – according to the photos – have a brownish colour. Smaller parts with normal glass separate the panels. The frames for the panels cover up to two floors and are mounted in a way that creates a diagonal zigzag pattern on the facades, because the frames are overlapping each other horizontally and vertically. Thus the frames have a slight inclination in both directions in relation to the basic structure of the facades.*

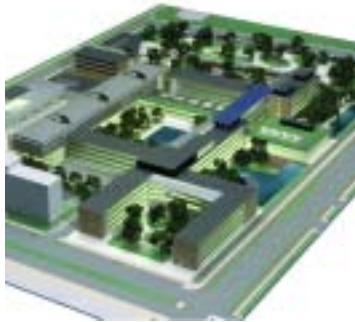
*Notwithstanding the architect maintaining that the BiPV did not influence the architectural form of the building, this integration of PV seems very natural in terms of both form and function. The overlapping frames for the panels have a super-graphic effect that accentuates the exposure of the project. However the slight vertical inclination of the panels will hardly have any effect for the production of electricity.*

*Given the parking as an entirely technical building with a precise and limited function, the cool and technical look seems to be most suitable for the building’s architecture. This impression is repeated when the facades are seen from the inside floors where the panels openly show their wires and junctions. From the outside the different colours of amorphous silicone and normal glass create an interesting and discrete variation, which would not have been equally cultivated with crystalline silicone.*

*The conclusive evaluation of this project is that the integration of PV panels is carried out with small and effective means and in a natural correspondence with the character of the building.*

## 4.8 Shell office building, Rijswijk, The Netherlands

### Description of building



Rijswijk is a city area between The Hague and Delft. The PV-NORD demonstration project, Shell office building, is located in an area under development for offices and institutions. The building is the home of SIEP, Shell International Exploration and Production.

Shell office building is not one building, but a complex of renovated and new buildings with offices and various services for the many employees working here. The complex faces the main street of the area, Huis te Landelaan.

The PV part of the demonstration project is a pergola on one roof of the complex.

### Description of PV installations:



BiPV was introduced at the very beginning of the design phase on the request of the management. For Shell it was important to create an image of an innovative and sustainable company. Therefore the visibility of the PV was considered of importance.

It was discussed where to place BiPV – on a facade or on a roof. First it was considered to place PV in shading devices on the facade towards the main street. But finally it was decided to place PV on the roof. To include BiPV in the project a pergola was added to the project. The pergola structure in itself has become an architectural element that helps visually to connect the buildings in a rather complicated modal point in the complex.

Blue crystalline cells were chosen as they were recommended by the supplier as the most efficient. However, the PV panels were not tilted for maximum exposure to the sun, but were for aesthetical reasons placed almost horizontally on the pergola roof. The panels are tilted, but only slightly, to allow rainwater to run off.

## Technical information:

PV location:	PV is integrated in a large pergola on the roof of an office building complex.
Cell type	Polycrystalline silicon.
Orientation and tilt:	742 m <sup>2</sup> (716 modules) horizontal (South facing, tilted 2 degrees).
Inverters:	3 x Sunny Boy 1700; and 21 x Sunny Boy 2500.
Installed power:	65,2 kWp.
Production:	Start: 29. December 2003. Production: 50.979 kWh from 01/01/2004 to 31/10/2004.
Cost per m <sup>2</sup> :	687 €/m <sup>2</sup> .
Cost per kWp:	7.849 €/kWp.

## Evaluation

*The acronym SIEP means Shell International Exploration and Production, and this project is based on high ambitions for the promotion of alternative energy, as part of a Shell policy: "The Shell Group is working hard on a more environmental friendly imago ..." (quote from the presentation material). The circumstances for this purpose are good, since the small town Rijswijk is close to The Hague and to principal motorways and airports.*

*However, this project is part of an existing converted office complex, and the only BiPV in question for evaluation is the roof on a pergola containing a technical room for lifts, climate control systems etc. The pergola is situated on the roof of one building in the vast office complex. Further BiPV installations are foreseen on roofs and walls of other buildings of the complex, but these are not part of this evaluation.*

*The pergola is placed on top of a 4-floor building in the middle of the complex, and its function, as a technical room does apparently not allow for general access. Thus the exposure to the public of the BiPV will be limited. The architectural importance of this BiPV is likewise limited in view of its out-of-sight situation.*

*None the less the construction of the BiPV, which simply constitutes the roof on the pergola is interesting, because the solar panels are mounted in a nearly horizontal position. This is the result of a design process, which started with the panels in a traditional shed-position, but for architectural reasons this was altered into a horizontal position – as stated in the pre construction questionnaire: "The architect had a preference for horizontal placement of the PV panels. Although the yield per element is less, the total capacity and the economics of the system were acceptable."*

*It shall be interesting to learn about the actual energy efficiency of these horizontal panels, which have the potential for a consequent integration in buildings, even if the presented project does not really do justice to the idea.*



*Shell office building.*



*PV pergola on roof under construction.*



*Detail of PV installation.*



*PV pergola.*



*PV roof.*

## 5 Conclusions

### 5.1 Discourse

*References to this discourse are the evaluations of the demonstration projects (quotations marked e), the pre- and the post-construction questionnaires (quotations marked q), and the presentations and discussions, which took place in Work Group 3.1: Aesthetics.*

#### BiPV and architectural integration

BiPV is an acronym for Building integrated PhotoVoltaics. In lack of an official definition, *BiPV are solar cells – often in panels – which are fixed parts of the building envelope.* BiPV covers a wide range: from panels, which are merely cladded onto a facade, over PV, mounted on the building with a structure, to PV panels, which substitute traditional facade or roof panels and thus, besides producing energy for the building, save the cost of traditional building components.

Architecturally integrated PV adds one more dimension to BiPV: Aesthetics or architectural quality (section 3.1.:On architecture). Architectural integration may either be in harmony with the architecture of the building as such or in contrast to or in dialogue with this.

#### Architecture as a barrier for PV

Today only a limited number of examples of BiPV are found in the Nordic countries. The two main reasons for this are, that 1) *Till now the economic yield of PV here is not competitive with traditional means of energy production,* and 2) *The distinct tradition of architecture in the Nordic countries is not directly compatible with the present format and expression of PV cells and panels.* Experience from some of the first, searching examples of BiPV has made architects and planners as well as builders hesitate to use BiPV. An often repeated phrase is (Ekoviikki, e): “I would be interested in building sustainable buildings – were it not for the fact that so-called sustainable buildings are aesthetically of a minor quality.”

*It is a paradox that we should be happy that PV is not economically competitive – and therefore widely and uncritically used – at this stage, where the aesthetical qualities of PV are not yet clarified.*

It is self-evident that a building of poor architectural quality will not become fine architecture just by the addition of solar cells to the building envelope. And self-evident as well that even a building of high architectural quality may be degraded as architecture by poorly designed PV cells or panels, integrated in or mounted on the building in an un-artistic way.

The three critics of architecture have evaluated the demonstration projects critically, and yet with sympathetic understanding. *The result of their evaluations is not a list of ideal examples, but a discussion of some solutions, which are promising, and some other solutions, which should be avoided in the future* (Holmen and Grynna: "... may serve as a good example of how to, and how not to, adapt PV cells to an existing building."(e)).

### Visible or invisible PV

PV as we know it today was developed to produce energy to spacecrafts and – as a matter of course – without aesthetical considerations. And in spite of the fact that PV has been used in building for more than 30 years, only a limited development of its architectural form and appearance has taken place. *It is obvious that a development of the architectural quality of cells and panels are necessary to make them attractive and widely used building components.*

As the kind of PV cells and panels, which are available today, are rather obtrusive of expression, *it is an artistically difficult task to achieve a harmonious integration.* However, among the eight PV-NORD demonstration projects are two examples (Kollektivhuset and PV parking) where this obviously was the intention and the visibility of PV was not decisive for the architectural expression of the building. (In Kollektivhuset "the integration of PV modules must be characterised as almost total, since the modules are barely visible."(e). In PV parking "the integration of PV panels is carried out with small and effective means and in a natural correspondence with the character of the building."(e)).

In the majority of the projects use of BiPV changed the architectural form of the building to some degree. In only two projects this was not the case (NCC, Finland, where the city authorities did not allow facades of glass and thus prevented a more ambitious architectural integration of PV, and in PV parking, where BiPV was included in the design from the very beginning).

PV modules on a building may be visible, not only from the exterior, but also from the interior, e. g. where the modules are integrated in balcony parapets or in windows. *PV installations on close quarters have aesthetical qualities.* Two such cases are Kollektivhuset ("As part of the interior balcony the PV modules (therefore) can be considered as very well aesthetically and functionally integrated, although – or because – it is clearly visible" and Holmen and Grynna ("The cells themselves are not beautiful, even though the arrangement has decorative qualities.").

In most of the projects the visibility of the cells were decisive for the architectural expression of the building. PV was planned to be visible in order to signal ecological and social conscience in three commercial buildings (NCC, Finland, Shell office building, and PV parking). In the NCC, Finland project, however, this was impeded by local planning requirements, and "the majority of the panels are in no way an essential part of the architec-

ture.”(e). PV visibility may well have been the aim for all the demonstration projects – *PV today is not economically competitive, but it is certainly politically correct.*

*If PV becomes economically attractive, the signal value will disappear, as PV will be a natural part of any building envelope. Then two alternative scenarios are possible: 1) BiPV has by research and development acquired architectural quality or invisibility which ensures general acceptance of PV as a common building component; this is what PV-NORD aims at. 2) BiPV has not been aesthetically developed, but because it is economically attractive, the market mechanism will force architects and builders to use PV systems anyhow; this could mean a disaster for our visual environment for as long as the buildings in question last.*

### Circumstances

In all architectural work a fine result depends not only on the talent of the architect, but as well on the circumstances of the project as such. The circumstances are especially important in these demonstration projects where most of the architects involved did not themselves choose to use PV, and had no or only little practical knowledge of BiPV.

In most of the demonstration projects BiPV was part of the project already when this was initiated or in the beginning of its design phase. In one case (Lysande), however, BiPV was introduced late, when the design phase was almost halfway through, and in one case (Ekoviikki) even later than that: "when the design phase was almost finished" (q). It is only fair to point out, that *the later BiPV is introduced the more difficult it is to achieve architectural integration of PV* (in Lysande “the panels transmit the impression of something undesired but apparently necessary.” And in Ekoviikki “it is obvious that the PV panels have just been added to one of the buildings with little consideration as to the overall architecture and aesthetics of the house.”(e)).

Typically the building owners or the building developers requested BiPV, but in one project (Ekoviikki) the request came from the City authorities. The architects were involved in the decision to use BiPV in only two projects (Kollektivhuset and PV parking). The processes and results of these two projects reflect positively this involvement. *Commitment is a key to success.*

In six out of eight demonstration *projects the time for design increased due to the integration of PV, estimated 1-15 %*. In two projects, however, it was reported that the time for design did not increase (Vest-Agder, maybe the most simply integrated project, and PV parking, maybe the most totally integrated project).

In seven of the demonstration projects *BiPV would not have been a part without the subsidies from participating in the PV-NORD project*. In the eighth project (Shell office building), however, it would have been included anyway, to “add to the image of an in-

novative and sustainable company.”(q). A request from the evaluation of Ekoviikki: “We seem to be needing more experimenting with integrated PV technology in Finland, please!” – give the “... Finish architects and engineers more of a challenge than just the chance of pasting on some new technical parts on otherwise ordinary and nice-looking buildings.” *Should these requests be limited to Finland?*

*The City planning authorities were generally in sympathy with the BiPV projects. And in two cases (Holmen and Grynann, Lysande, and Ekoviikki) city-planning regulations directly requested sustainable buildings, e.g. with PV. In one case, however (NCC, Finland), local planning regulations prevented glass facades and thus the originally planned BiPV. And one demonstration project (Lysande), perhaps the most provocative example of BiPV, hardly got a building permit. Lysande “is falling out of context with the surrounding houses.”(e).*

### Which kind of cells

For the architects of the eight demonstration projects the choice of PV cells to use in their design was *polycrystalline cells*, which come in several colours, of which blue is the most efficient; or *amorphous cells*, which are less efficient but come in panels with a uniform glass surface in many – also subdued – colours. Only one project uses the *mono crystalline cells*, which are the most efficient, but also the most expensive, of them all.

Blue polycrystalline cells were chosen in the majority of the projects “because the blue cells are the most efficient” (q) or “because the producer advised them to do so” (q). However, in one project (Vest-Agder clinic) the blue cells were chosen for architectural reasons, “because the colour looks good with the other colours of the building“ (q). And then in one project (Kollektivhuset) black mono crystalline cells were likewise chosen for aesthetical reasons, “mainly the colour and overall character of the PV cell” (q).

In only one project (PV parking) out of the eight amorphous PV panels (brown) were chosen, and for aesthetical reasons mainly: “good colour and comparable with glass panels”(q). But also the cost was mentioned: “*Low cost per m<sup>2</sup>*” (q) – *because the PV panels here serve a double function, as they not only produce energy but also substitute traditional facade panels.*

### BiPV according to the architects

The questionnaires concluded in three questions directly to the architects responsible for the demonstration projects. The first question was: Are you happy with your effort regarding BiPV, now you see the final appearance of your project? *The majority of the architects declared to be happy with this.* One answered Yes and No, and one preferred not to answer. Only one architect declared not to be happy with his/her effort, but did not expand on the answer.

The second question to the architects was: Do you have any suggestions for future BiPV? Surprisingly only half of the architects answered. *The suggestions concentrated on the development of 1) more (and better) colours of cells, 2) more flexibility of format of cells and panels, 3) amorphous cells/panels, 4) better designed wiring and inverters, 5) more sophisticated mounting systems, and 6) BiPV products which are compatible with other building components.*

The third question to the architects was: do you foresee widespread use of BiPV in architecture of your country? *Half of the respondents answered No and the other half Yes. Is a glass with water halfway to the rim half-empty? or half-full?*

## 5.2 Recommendations

*These recommendations are based on the evaluations, the two questionnaires on architecture, the discourse and the presentations and discussions in Work Group 3.1: Aesthetics. The target group is on short-term architects, city planners and builders, and on the long-term PV suppliers, installation agents, and in general decision-makers.*

*The first recommendation to the interested reader is thoroughly to read the evaluations (sections 5) and the discourse (section 6.1).*

### Support

- Financial support should be given to the development of BiPV projects and products of high architectural quality,
- Competitions for architects and designers should be held in order to produce BiPV solutions and products (cells, panels, installations, structures etc.) of high architectural quality,
- Information on BiPV techniques and aesthetics (articles, examples, manuals, etc.) should be disseminated,
- Demonstration projects – like PV-NORD – should be carried out to support the development of BiPV and to illustrate its possibilities.

### Process

- BiPV should be part of the project already when this is initiated,
- The architect should be involved in the decision to use BiPV,
- The advice from the PV supplier regarding the kind and colour of cells to use, should be weighed against architectural considerations,
- BiPV should not just be considered another building component to be added, but should be an interactive element in the design process.

## Design

- More flexibility and variation of BiPV cells and panels (forms, sizes, colours, etc.) should be developed,
- BiPV cells and panels with aesthetically pleasing colours (inclusive subdued colours) should be developed,
- Aesthetically satisfying design of BiPV cells, panels and technical installations (wiring, inverters etc.) should be developed,
- Aesthetically satisfying design of structures, racks, fixtures etc. for BiPV should be developed,
- BiPV cells and panels which can substitute traditional facade and roof components should be developed in order to save costs of the building envelope,
- BiPV products (cells, panels, installations, structures, etc.) which are compatible with other products from the building industry, should be developed.

## 6 References

### 6.1 Building data

<b>Holmen and Grynnan</b>	
Address:	Hammarby Allé, Stockholm Sweden
Architect:	White Architects AB
PV engineer:	Energibanken
PV contractor:	Naps Sweden AB
Building owner:	Brf. Holmen, Sickla Kaj

<b>Lysande</b>	
Address:	Hammarby Sjöstad, Stockholm Sweden
Architect:	White Architects AB
PV engineer:	Energibanken (Consultant)
PV contractor:	Gaia Solar (provider)
Building owner:	AB Familjebostäder, a non-profitable housing company.

<b>Ekoviikki</b>	
Address:	Tilanhoitajankaari 23, 00790 Helsinki Finland
Architect:	Arkkitehti Oy Reijo Jallinoja,
PV engineer:	Naps Systems Oy,
PV contractor:	Naps Systems Oy,
Building owner:	AsOy Helsingin Salvia,

<b>NCC head office, Finland</b>	
Address:	Mannerheimintie 103a, 00280 Helsinki, Suomi, Finland
Architect:	Juha-Pekka Rindell/Optiplan Oy
PV engineer:	Kari Kavonius/Optiplan Oy
PV contractor:	Naps Systems Oy
Building owner:	Nordisk Renting Oy

<b>Kollektivhuset</b>	
Address:	Hans Knudsens Plads 1 2100 København Ø Copenhagen Denmark
Architect:	DOMUS arkitekter a/s
PV engineer:	Esbensen Rådgivende Ingeniører A/S
PV contractor:	GAIA Solar A/S
Building owner:	De Vanføres Boligselskab for Københavns Kommune

<b>Vest-Agder clinic</b>	
Address:	Vest-Agder Klinikkene Kongsgård alle 71 4632 Kristiansand Norway
Architect:	Egerdahl & Nordbø AS
PV engineer:	
PV contractor:	GETEK AS
Building owner:	Sørlandet Sykehus HF

<b>PV parking</b>	
Address:	Luttenbergstraat 2 Zwolle The Netherlands
Architect:	Rudy Uytenga Architectenbureau B.V.
PV engineer:	Oskomera Solar Power Solutions
PV contractor:	
Building owner:	Parking Luttingstraat B.V. Dhr. Ory

<b>Shell office building</b>	
Address:	Kessler Park 1 2280 AB Rijswijk The Netherlands
Architect:	Van den Broek en Bakema
PV engineer:	Oskomera and Shell Solar
PV contractor:	Shell Solar and Oskomera
Building owner:	SIEP B.V.

## 6.2 Critics of architecture

Three critics of architecture were selected to conduct the architectural evaluation of the eight PV-NORD demonstration projects. The critics are:

### Architect MAA Olaf Lind

*Olaf Lind (\*1936), architect and writer, graduated 1964 from The Royal Academy of Fine Arts in Copenhagen. Conducted his own studios 1965-87 mainly occupied with housing and town planning project along with teaching at The Architect School in Århus DK and 1980 at Ball State University, Indiana USA. 1976-2000 he has been a member of the council and several committees in The Federation of Danish Architects. 1987-2000 he was an architectural critic at the Danish newspaper Jyllands-Posten. He has written a number of books and articles on architecture, f.ex. architecture guides for Copenhagen, Jylland and The Danish Islands, published in three volumes 1996-2006.*

### Master of Architecture SAFA; Architectural Critic Tarja Nurmi

*Tarja Nurmi is an architect SAFA and architectural critic. She lives in Helsinki and has also worked with the media ever since she studied architecture at the University of Technology in Helsinki. She has also been involved with television work and has for a long time been writing about the topmost sustainable buildings in Europe and overseas. She has since 1997 written about architecture for the leading business daily in Finland, namely Kauppalehti.*

*At the moment she does not do traditional design work as an architect but has recently started to work on a special exhibition about Finnish architecture as curator in collaboration with the famous Aedes architectural gallery in Berlin.*

*Tarja Nurmi was also member of the jury for the exhibition on Finnish architecture 2002-03. The exhibition was organised by SAFA, Th AlvarAalto Academy and the Museum of Finnish Architecture.*

### Architect, Ph. D. SAR/MSA Rasmus Wærn

*Rasmus Wærn is an architectural critic and architectural historian. He has been an editor at the Swedish review of Architecture and contributor to numerous books, exhibitions and magazines with texts on Swedish 20th century architecture.*

*Today he is preparing the launch of an international magazine on architecture and design from the Nordic countries.*

*He is also teaching history of architecture at the Royal School of Technology in Stockholm.*

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## 8 Appendixes

### 8.1 Pre-construction questionnaire on architecture

#### General information

*Building:*

*Address:*

*Architect:*

*BiPV engineer:*

*Structural engineer:*

*PV supplier:*

Your name and affiliation (if different persons have filled in the three different parts of the questionnaire, please indicate the name and affiliation for each person):

- Aesthetics and Integration:
- Environment:
- Electricity:

#### Graphic information

- Sketches of the different ideas (dated or numbered) leading to the final design.
- Drawings of the project showing positioning and layout of BiPV (*in scale 1:100 and 1:20*).

#### Task 3.1 - Aesthetics and Integration

*When did BiPV become part of your building project?*

- When the project was initiated.
- At the beginning of the design phase.
- When the project design was half through.
- When the design was almost finished.
- Other, please specify:

*Why did BiPV become part of your building project?*

- Demand or request from the building owner.
- Suggestion from architect already attached to the project.
- Suggestion from engineer or project developer.
- Request from utility company.
- Other, please specify:

*What type of PV cells do you plan to use in your project?*

- Monocrystalline silicon.  
 Polycrystalline silicon.  
 Amorphous silicon.

*Why did you choose this type of solar cells?*

Please specify:

*Would BiPV have been a part of the project without subsidies?*

- Yes  No

*Did your design change during the design phase?*

- Yes  No

*If "Yes", why?*

*Which special BiPV related difficulties, e.g. demands from authorities, delivery of asked for modules/cells, did you meet during the design phase (which and why)?*

Please specify:

*Did the use of PV make the design more difficult?*

- Yes  No

*If "Yes", please specify:*

*Have you made any design adjustments to include BiPV in your building project?*

- Yes  No

*If yes, why and which?*

*Please specify:*

*Did the time used for design increase due to use of BiPV?*

- Yes  No

*If "Yes", why and how much (percentage and total design time)?*

*Please specify:*

*Did the building costs increase due to use of BiPV?*

- Yes  No

*If "Yes", why?*

*Did the use of BiPV influence the architectural form?*

- Yes  No

*If "Yes", how?*

## 8.2 Post-construction questionnaire on architecture

### General information

Building:

Address:

Architect (firm):

Please state name, company, address and e-mail of the person(s) who have answered this questionnaire.

	Architectural
Name:	
Company:	
Address:	
E-mail	

### Graphic information

Please include simple sketches or architectural drawings if such are necessary for a professional to understand your answers to the questionnaire.

### BiPV and design

*When did BiPV become part of your design?*

- When the project was initiated
- At the beginning of the design phase
- When the design phase was half through
- When the design phase was almost finished
- Other, please specify:

*Which part of the building envelope was discussed to use for BiPV?*

- Roof
- Facade
- Balcony parapets
- Windows
- Other, please specify:

*Which part(s) was finally used for BiPV?*

- Roof
- Facade
- Balcony parapets
- Windows
- Other, please specify:

*Was the visibility of the cells decisive for the architectural expression of building?*

- Yes
- No

*Is the surplus heat, produced by the cells utilised and if so, did it influence the architectural expression?*

- Yes  
If Yes, how:
- No

*Which kind of PV cells did you use in your project?*

- Monocrystalline PV cells
- Polycrystalline PV cells
- Amorphous PV cells

*Colour of PV cells?*

Please specify:

*Why did you use this particular type and colour of PV cells in your project?*

- Demand or request from the owner of the building
- Suggestion from the engineer, project developer or utility company
- Aesthetical reasons, please specify:
- Other reason(s), please specify:

*Did you have any special architectural demands to other parts of the PV module than the cells? If yes, to what parts?*

- Yes  
If Yes, which parts:
- No

*Did your design change during the design phase?*

- Yes  
 If "Yes", please specify:  
 No

*Which special BiPV related difficulties did you meet during the design phase (e.g. demands from the authorities/delivery of specified modules or cells etc)?*

Please specify:

*Have you made major design adjustments to include BiPV in your building project?*

- Yes  
 If "Yes", which and why? Please specify:  
 No

*Did the time used for design increase due to use of BiPV?*

- Yes  
 If "Yes", why and how much (percentage or design time)?  
 Please specify:  
 No

*Did the use of BiPV influence the architectural form of the building project?*

- Yes  
 If "Yes", please specify how:  
 No

*Have city planning, guidelines or tradition influenced the BiPV concept?*

- Yes  
 If "Yes", which and why? Please specify:  
 No

*Has there been a reaction to BiPV from city planners during the project phase?*

- Yes  
 If "Yes", which and why? Please specify:  
 No

*Are you happy about your effort regarding BiPV now you see the final appearance of your project?*

- Yes  
 If Yes, why?  
 No  
 If No, why?

**BiPV in future architecture**

*Do you have suggestions for future BiPV?*

<i>Suggestions on:</i>	<i>Reasons for this suggestion:</i>
Kind of cells: Format of cells and modules: Colours: Mounting systems: Other?	

*Do you foresee widespread use of BiPV in architecture of your country?*

Yes

If "Yes", specify any preconditions:

No