PV-NORD – PAVING THE WAY FOR BIPV IN NORTHERN EUROPE

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Abstract – This paper summarises PV-NORD, an EU project on building integrated photovoltaic systems. In Northern Europe, the harsh climate, low energy prices and conservative construction traditions have limited the use of grid-connected PV systems in buildings. Too little attention has been paid to the fact that building integrated photovoltaics (BIPV) is the only high quality renewable source of electricity possible in an urban environment. Based on the EU White Paper, the purpose of PV-NORD is to catalyse the development of BIPV in Northern Europe and to provide the necessary knowledge and direct demonstration to put BIPV on the agenda of the coming years' energy planning. The partners represent different interest groups in PV exploitation, and form multi-knowledge groups, addressing the barriers from different angles, based on eight demonstration buildings in the participating countries. The thematic research is organized into five tasks: Aesthetics and PV integration, Power and electricity, Environment, Management and IT, and finally Financing and ownership. In this paper, the potential of BIPV is demonstrated by the PV-NORD building Kollektivhuset, central Copenhagen. This is a façade renovation project for a multi-storey housing block for handicapped tenants. The photovoltaic modules are mounted in the glazed balcony parapets with a coloured sliding panel behind. This panel can be slid so as to utilise the heat from the PV modules or block the radiating heat from entering the balcony. The modules thus have multiple functions: as radiators for the balconies, as sound insulation, as electricity generators and aesthetically as dynamic façade elements.

1. INTRODUCTION

Today, there are practically no Building Integrated PV (BIPV) projects in Northern Europe. A harsh climate, low prices of energy and conservative construction traditions have limited the use of grid-connected PV systems in buildings. The existing energy systems vary greatly between the different countries, and include both cheap energy from non-fossil fuels like hydro and nuclear power stations, and extensive use of fossil fuels. Traditional industries are typically dependent on high electrical demands and a large part of the building stock is heated by electrical energy. In fact, Sweden and Finland have Europe's highest electricity consumption per inhabitant!

However, there need not be a conflict between these facts and BIPV. By using energy savings and BIPV, the need for external electricity supply will be reduced. Thereby more renewable energy is provided on the electricity market to substitute more of the fossil fuel. Nordic electricity is still to a large extent being produced by fossil fuel and the possibility to extend hydropower has almost been exhausted. This is why BIPV is one of the technologies next to move the energy sector towards a sustainable situation.

By focusing so much on the relative high electricity price from BIPV as is the case now, too little attention is being paid to maybe the most important fact:

BIPV is the only high quality (electricity) renewable energy source possible in an urban environment, where an ever-increasing share of our total energy consumption is taking place. If BIPV is not introduced now, we miss a whole generation of renovation and new building projects, which in the future are likely to be very expensive to provide with aesthetically and technically good BIPV solutions.

In reality there is not a large resistance against BIPV. But as long as we only compare the direct electricity prices per kWh, without taking into account all externalities, added values and potential risks in lack of planning for future use of solar energy in our cities, no changes can be expected to happen.

In order to fulfil the goals of the EU White Paper on an increased use of renewable energy in Europe, it is of great importance that the development of BIPV also takes part in Northern Europe. In the Netherlands it has been shown how the market for BIPV, in only a few years, has been exploited on a large scale with single projects in MW-sizes being realised.

Kollektivhuset, Denmark, Domus Arkitekter. BIPV at its best.

The project PV-NORD, or *Widespread Exploitation of Building Integrated Photovoltaics in the Northern Dimension of the European Union*, aims to remedy this. The purpose of this project is to catalyse the development and to provide the necessary knowledge and direct demonstration to put BIPV on the agenda of the energy planning in North European countries.

The main objective of PV-NORD is to create conditions for a widespread exploitation of BIPV in the Northern Dimension (i.e. the policy of the EU for work in the North, within the EU and with its neighbours). The project will run for three years, during which time almost 200 kWp will be realised in eight pilot PV systems in Nordic countries and the Netherlands. This will pave the way for at least 5 MWp of grid-connected PV to be installed or planned in Sweden, Finland, Denmark and Norway.

The current situation is that Sweden, Finland and Norway together have less than 150 kWp of BIPV projects whereas Denmark through their "SOL 300" program started in 1998, have reached almost 1 MWp. As a comparison to this, the Netherlands expects to achieve over 50 MWp before 2005.

The goal will be reached by:

- Demonstrating the potential of BIPV in eight prestigious buildings in the Nordic countries and the Netherlands.
- Identifying and preparing for a removal of the main barriers that hinder a larger penetration in the countries in this region. We are already aware of many of these barriers but through co-operation between the involved countries we will have better possibilities to move forward.
- Making it possible to eliminate large parts of these barriers through first preparation of concrete instructions and tools, first dissemination to relevant target groups and so on.

2. THEMATIC RESEARCH AREAS

2.1 Holistic research groups

The work is divided into thematic research and demonstration buildings. The information source to be used in the thematic groups is mainly the demonstration buildings that will be built in the participating countries. The information collected from each building will be used as input to the conclusions of the different groups. Each thematic group will address the Northern Dimension and the corresponding problems throughout their work and produce first concrete recommendations for future BIPV projects. Dutch partners will share their experience from the last ten years working with BIPV exploitation and development.

Five Thematic Areas have been identified corresponding to five important barriers to BIPV exploitation. These Areas are grouped into the following two Work packages:

WP 3 Technical Aspects of PV Exploitation

Tasks:

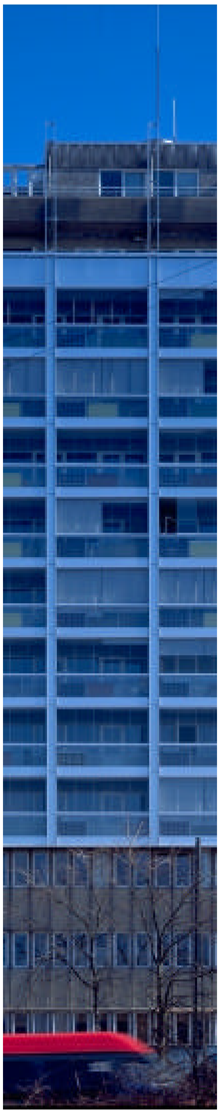
- 1 Aesthetic/PV-Integration (task leader DBUR, Denmark)
- 2 Environment (task leader White, Sweden)
- 3 Electricity (task leader Esbensen, Denmark)

WP 4 Management Aspects of PV Exploitation

Tasks:

- 1 Financing & Ownership (task leader KanEnergi, Norway)
- 2 Management/ICT (task leader Solpros, Finland)

Work packages 1 and 2 represent the co-ordination and dissemination of the project, respectively. The partners in WPs 3 and 4 represent different interest groups in PV exploitation, so as to form holistic and multi-knowledge groups, capable of addressing the barriers from different angles and perspectives. The Task Leaders are responsible for leading the discussions, compiling results and administrating all work in relation to each respective area.



Each group has the freedom to develop the contents of their work, but will follow a general work design. The groups will utilise the knowledge and experience that the participants have developed through years of work in the area, from participating in EU-funded and national projects and networks, and so on. They are analysing each building of the project, both by studying material on solutions and technology, and by visiting the buildings.

The fact that all involved participants represent or work in the construction industry is a guarantee that all information developed will be concrete and directly usable in the design, development and planning of PV installations in the Northern Dimension. All results will be disseminated in the Northern Dimension, e.g. in the form of written material or open spreading of information.

The outcome of all tasks will be recommendations on design of BIPV in future buildings and lessons learned from the PV-NORD demonstration projects.

2.2 Task 3.1 Aesthetics and PV Integration

Task 3.1 Aesthetics and PV Integration will review the architectural solutions and the integration methods applied in each building project. Background information regarding the planning process is of great interest as many BIPV projects are stopped already in a very early stage due to negative opinions from city planners or other decision-makers involved. It is valuable to see early architectural sketches in order to follow the development to the final design. Aesthetics and PV integration is closely interrelated factors. Examples are climate (e.g. snow, ice, heavy rains) and sun inclination (e.g. double function shading), which affect the design and reflect on the characteristics of the installation.

2.3 Task 3.2 Environment

Task 3.2 Environment is dedicated to the very important issues regarding materials used in the solar cells and other parts of the PV installations. The concept of Building Integrated PV should include that the solar cells are considered an energy source AND a building component similar to e.g. roof tiles, bricks or concrete. Compared to other EU-countries, Northern Europe has advanced greatly in the area of environmental legislation and norms and their implementation: These are to be taken into thorough consideration in PV-NORD.

2.4 Task 3.3 Power and Electricity

Task 3.3 Power and Electricity addresses the electrical design in each demonstration project. Which system voltage is selected, how can the connection of modules be solved, what about grounding, lighting and over voltage protection, what are the criteria for selecting inverters, are some examples of relevant issues. Safety is of course a high priority, as are the relevant electrical codes and installation recommendations. The connection to the utility grid will also be part of Task 3.3.

2.5 Task 4.1 Financing and Ownership

In Task 4.1 Financing and Ownership different financing solutions are evaluated. Subsidies might come from national or municipality programmes or in the form of rate-based incentives and so on. Several of the new innovative financing solutions such as BOOT (Build, Own, Operate and Transfer) and different financing partnership constellations could be transferred to the BIPV sector. The ownership of the PV installations can also vary from each flat having its own system or belonging to a co-operative tenants-owned building society. In some cases the local utility company is the owner. Different solutions also have varying effects on taxation.

2.6 Task 4.2 Management and ICT

Task 4.2 Management and ICT (Information and Communication Technology), finally, focus on how operation and maintenance of the PV systems is solved in the different demonstration buildings. Particular emphasis is put on the use of tools based on modern information technologies, ICT. In the Swedish buildings (Holmen/Grynnan and Lysande, see below) a local Intranet will be installed and IT will be a general tool for the surveillance of the buildings. The tenants will have access to data showing their energy consumption and it is foreseen that also monitoring of the PV installations will be included. For example, the Ekoviikki demonstration building (Finland) will involve advanced ICT for control of the PV installations in cooperation with the regional utility company. Advanced information technology solutions will be demonstrated where the production and consumption of PV energy would be constantly monitored and controlled. The tenants will even have access to real-time updates through the Internet or a mobile phone.

3. DEMONSTRATION BUILDINGS

3.1 Other features of the work

New principles of building integration will be demonstrated. The demonstration projects are varied, as some promote PV placing them on the facades in highly visible ways, while others try to blend the modules with the decor making them almost invisible. There is also the use of double functions of the PV modules, which makes the PV installation add more value to the building.

New and so far untried financing schemes are evaluated, balancing financial risk with long-term investment payoff and partnerships between the real-estate owner, the tenants and the local utility company.

Several of the buildings hold high environmental profiles in general, e.g. through low energy designs. To give an example, in building Holmen/Grynnan the total energy consumption per sqm residential floor area and year has been limited to 60 kWh (40 kWh heat and 20 kWh electricity). It is half the consumption compared to the best-applied technology in contemporary building designs.

Eight high-profile building projects in the Nordic countries and in the Netherlands are participating in PV-NORD:

Holmen/Grynnan	Sweden	Multi-family houses
Lysande	Sweden	Multi-family house
Ekoviikki	Finland	Multi-family house
NCC Head office	Finland	Office building
Vest Agder	Norway	Drug rehab. Clinic
PV-parking	the Netherlands	Parking building
Shell office	the Netherlands	Office building
Kollektivhuset	Denmark	Community home

3.2 Holmen/Grynnan, Sweden

40 kWp will be installed on two multi-family houses, located in a new residential area in the southern part of the city centre of Stockholm. PV modules will be integrated in the façade, in the balcony balustrades and as part of windows of the top floor. The innovative

challenge is to find solutions where the PV modules will harmonise with the building design and if possible also serve with a double function as in the case of the balconies and the windows. A construction company develops the building, and the apartments are sold to the tenants.

3.3 Lysande, Sweden

26 kWp will be installed on one multi-family house in the same area as Holmen/Grynnan. In this project PV modules will be integrated in a freestanding sunshade in front of the south façade and on the roof. From the very beginning the architecturally constraints were finding an application where the PV modules will be heavily exposed. A real-estate company, renting out the apartments, will own the building.

3.4 Ekoviikki, Finland

24 kWp are installed on one multi-family house in a new residential area close to Helsinki city centre. Special considerations have been given to ecological and sustainable planning principles. The PV modules are installed in the balcony balustrades acting as shading devices. In addition to this double function feature, an IT-approach has been taken for the management of the system.

3.5 NCC Head office, Finland

15 kWp will be installed on the roof and partly integrated in the windows of the new NCC head office building in Helsinki. The modules will face east and south. The project will demonstrate how PV can be incorporated into a modern high-class office building fulfilling the aesthetic demands. This building will give experiences about PV installations and effectiveness of modules at such high latitudes as Helsinki.

3.6 Vest Agder, Norway

5 kWp will be installed on this drug rehabilitation clinic that is run by the Vest-Agderklinikkene (a leading institution for alcoholic rehabilitation). It has 2.200 m^2 area with room for 38 tenants. The PV modules will be integrated in an aluminium façade in the southeastern corner of the building and as sunscreens in the southwestern façade.

3.7 PV-parking, the Netherlands

30 kWp of amorphous PV modules will be integrated in the southwest and southeast facing façades of a parking building. The colour and the relatively low price per sqm have led to the choice of using a-Si modules (thin-film amorphous silicon) in this project. This gives an important contribution to PV-NORD, as all other demonstration buildings will be using crystalline silicon cells.

3.8 Shell office building, the Netherlands

40 kWp of multi-crystalline PV modules are integrated in a "PV Pergola" – a glass cover over an open space – of a new Business and Technology Centre in Rijswijk. The project will give valuable input to the Northern partners through the architectural integration in the building design.

3.9 Kollektivhuset, Denmark

The Danish Kollektivhuset building is used as an example of the principles discussed above, notably the functional and aesthetical building integration of PV modules. It merits its own heading, see below.

4. KOLLEKTIVHUSET

4.1 General information

Kollektivhuset is a building for disabled people, and located close to one of the busiest roads to the centre of Copenhagen. The building works along the principle of commune living, with mutual services in the lower floors. In this project, 12 kWp have been installed as part of a façade renovation. The renovation of the open balconies to glazed balconies with integrated PV-systems, have dramatically improved the comfort and reduced the energy consumption of the building. This specific building has a panoramic view and is a good example of buildings from the early 70's. Kollektivhuset is a valuable building, worth the effort of remodelling and improving. With its location the project can be expected to be one of the most visible and well-known PV projects of Copenhagen.

The main objective of the demonstration project Kollektivhuset is to demonstrate how BIPV can be utilised in a façade renovation of a housing block. The principle is that PV-modules are fully integrated in the new glazed balconies of the building, allowing the possibility to individually expand the PV-modules to cover the whole parapet area of the façade.

Kollektivhuset, Hans Knudsens Plads, Copenhagen.

4.2 Innovative BIPV Architecture

The renovation of the building was initiated in order to extend the lifetime of the open concrete balconies and at the same time enlarge the balconies to allow access by wheel chairs. By glazing the balconies the heavy traffic noise problems from the main road can be reduced significantly.

The new concept developed within the project focuses on the integration of the climate envelope of the building and individually AC-modules. The new facade profile system allows for opening of the windows in the glazed balcony and in the parapet of the balcony, a flexible system for individually sliding back-plates behind the PV-modules are installed to provide flexible utilisation of the heat generated by the PV-modules.

Mostly disabled tenants are occupying the house, many in wheel chairs, and an ordinary installation of PV-panels in the parapet would have radiated a large fraction of heat directly to the legs of the tenants. The solar cell installations in effect work as radiators for the balconies. The moveable back-plates invented here, provide a flexible way of controlling this heat emission from the panels and even support the controlled airflow around the panel in order to remove the excess heat. Hereby a dynamical control of the heat emission is provided without the use of advanced ductwork for ventilation air, with cleaning and regular maintenance needs.

The front glass of the parapet is a normal glazed balcony glazing, ensuring water tightness and sound protection from the main road in front of the building. The PV modules are laminated directly to the back of the parapet glass. The flexible sliding back-plate moves in the same mounting profile as the glass. Hereby the users of each dwelling can decide whether or not utilise the solar heating, which builds up on the PV-panel. In the summer case, the users will be most interested in ventilating the heat from the PV-panels to the outside. This is done by sliding the moveable back-panel in a position just behind the PV-panel (top picture). Hereby the heat will be forced to leave the parapet-zone through the ventilation slits at the top and bottom of the PV-panel. In case the user wants to have the heat to enter the glazed balcony, the back plate is moved to the side (middle picture). In this position, the PV-panel will radiate heat to the balcony. In the spring and fall, the heat from the solar cells can thus extend the possibilities to use the balcony.

The system is prepared for the addition of another solar module in each balcony. The current economy only allowed for one module per balcony. In order to use the sun to maximum effect, the modules are put to the left on the balcony (as seen from the outside, bottom picture), where they avoid shading from the structure.

pvnord

Regulator in closed position – summer.

PV-module with open regulator – spring / fall.

External view of a balcony.

The solar cell aesthetics are worked through thoroughly, especially when it comes to semi-transparency, effects of layers and so on. Mono-crystalline cells were chosen for the beauty of their deep-blue colour. The glass façade on the balcony lets light through to the inside. A low opaque part (the hand-rail, approximately 70 cm) gives a sense of safety, while still giving the opportunity to look down from a sitting position (which is important for handicapped tenants). An interesting, deliberate effect is that the moving of the regulators will create a living, dynamic façade. This brings the spark of life to a strict building.

4.3 Innovative electrical connections

In ordinary projects the electrical wiring of the systems would be based on string wiring, where each floor of the building would be connected to one string inverter. In order to provide more flexibility in the future expansion of the system, the approach is different in this project. The string wiring is established in vertical zones fully integrated in the facade construction collecting the power from each panel. All electrical connections are based on the Multicontact® PV-cables, which allow the connectors to be accessed directly at each balcony without any risk of electrical shocks. The sliding system of the panels described above is designed so that further panels can be inserted at each balcony and directly connected to the string wiring, allowing flexible expansion of the system.

Furthermore the installation is also very easy to carry out, since all manual installation work and expansion of the system can be done from the balcony and does not require expensive scaffolding of the building. Hereby the relative installation costs of the system will be relatively low compared to traditional installations of PV in high-rise buildings.

4.4 Energy and environmental performance

Through the carefully designed PV-system an electrical yield of approximately 85 kWh/sqm is expected from the system. Due to the net-metering possibility in Denmark, the value of the power produced will be equal to the amount the tenants would have paid for the electricity including environmental taxes and VAT. The installation costs were approximately 11.2 Euro per Wp. This amount must be seen in connection with the high degree of flexibility and large potential of replication.

4.5 Kollektivhuset in summary

Kollektivhuset is a very visible housing block located at the Hans Knudsen Square. More than 30.000 citizens of Copenhagen pass the building during rush hours. The facade of the building is likely to be one of the most visible and well-known demonstration projects with building integrated photovoltaic systems in Denmark. The individual wiring of the PV-panels, and combination of sliding back-panels and fixed front glazing is a unique concept in Europe. It is very likely that the system will mark a new standard for providing PV to Scandinavian housing block tradition, where the tenants can be expected to have individual priorities and possibilities to further expanding their solar system.

5. CONCLUSIONS

PV-NORD is the first step towards the widespread exploitation of building integrated photovoltaics in the Northern Dimension of the European Union. All the building owners, construction companies, PV manufacturers and designers involved in PV-NORD believe BIPV to be an important area of work for the future energy supply for society. It is clear from the early results, that the cost of the solar modules still is too high for BIPV to be a realistic alternative in the open market. It is also clear that the added values, inherent in BIPV, can be a feature better utilized for the increased use of BIPV, as shown by the Kollektivhuset building. It has shrewdly been suggested in the group, that the additional costs from PV (compared to other energy sources) can be covered by the funds usually reserved for artistic decoration of buildings.

6. ACKNOWLEDGEMENTS

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