PV-VENT, Low cost energy efficient PV-Ventilation in retrofit housing

1. Introduction

In 1993, Cenergia in cooperation with a Danish housing association (Dansk Boligselskab) and the electricity utility in Copenhagen (Copenhagen Energy) received support from the EU-Thermie programme for the first EU-supported PV-project in Denmark.
In all 20 kWp of building integrated PV-area has been installed as part of this project. An example is the project shown in figure 1, where a crystalline PV-module is installed on a south-facing gable, and besides is utilised for preheating ventilation air.
In 1996 Cenergia got in contact with Neste-Naps from Finland (now Fortum), which had developed a new type of amorphous PV-modules which was very well designed for building integration, see figure 2. In figure 3 is an example of these PV-modules used for a facade renovation at Tøndergade 3,3A in Copenhagen. And based on a long term cooperation with the Danish ventilation company Temovex Denmark and an interesting retrofit housing project with the Danish housing association, FSB it was decided to make a proposal for an EU-Joule project where different prototype systems then were tested with an 1-3 m² building integrated PV-area per apartment together with energy efficient ventilation systems with heat recovery for housing ventilation.

2. Objectives of the PV-VENT project

The objective of the PV-VENT project is to research, develop and test low cost high efficiency PV-powered ventilation systems for apartments blocks where PV-modules are integrated in an architectural acceptable way in facades, gables and roofs.

The use of fans with new and reliable DC-motors for Temovex Denmark ventilation heat recovery systems makes it possible to use photovoltaic modules or PV modules to cover part of the electricity demand directly, which means that a further reduction of electricity use can be obtained to reach the future aimed low electricity use of only 25-40 W per dwelling for ventilation systems with heat recovery. This is equal to an electricity use of only 200-300 kWh per year.

Calculations shows that if 3 m² facade integrated amorphous silicon PV-modules, covering 30-50% of the reduced electricity use, are used with a direct link to a shared ventilation system with heat recovery and at the same time utilising the PV-modules for preheating of ventilation air, the extra PV costs per m² facade is today only 1680 DKK (224 ECU), equal to a simple pay-back time in Denmark of 21 years. With an expected 40% reduction of PV-modules costs in 5 years it should then be possible to reduce extra PV costs per m² facade to only 668 DKK, (89 ECU) equal to a simple pay-back time of 8 years.

In the PV-VENT project it is aimed to develop and test the following prototypes of innovative economically optimised PV-powered ventilation systems with a considerably reduced electricity use compared to normal.

1. An energy efficient shared ventilation system with heat recovery and direct PV-supply to fans with DC-motors.
2. Multifunctional solar energy ventilation elements for facade integration with a building integrated heat recovery ventilation system in combination with building integrated PV-modules and preheating of ventilation air.
3. An integrated energy efficient shared ventilation system with heat recovery and direct PV-supply to fans with DC-motors as mentioned under item 1 but including grid connection and a larger building integrated PV area per apartment more defined from the available facade area than having an optimised PV area determined by the level of electricity use for the ventilation fans.
4. A PV-powered cheap exhaust ventilation system with preheating of ventilation air in the PV-modules.
5. An energy efficient shared ventilation system with heat recovery as mentioned under item 1, but with the PV-modules integrated in an air solar collector surface which can also be used for preheating of DHW in summer through a water to air heat exchanger.

The above mentioned prototype PV-ventilation systems will be tested under realistic operating conditions in actual housing blocks in Denmark, as a complete system test to be able to have developed the highest possible reliability in practise both for the PV-systems and the ventilation systems.

The partners in the PV-VENT project is Cenergia Energy Consultants, who is coordinator. The FSB housing association, who is the builder, the ventilation company Temovex Denmark, Neste Naps from Finland, NTNU from Norway, Ecofys from Holland, the Danish Solar Energy Laboratory, PA-Energy and the Copenhagen Energy Utility.

3. PV-VENT prototype systems for Lundebjerg in Skovlunde

In connection to the PV-VENT project an architectural competition has been realised aiming at a retrofit project for 513 apartments at Lundebjerg in Skovlunde near Copenhagen, Denmark, administered by the FSB housing association, as basis of a large demonstration of PV powered ventilation systems in practice.

To be able to utilise building integrated PV-systems in connection with optimised ventilation designs it is necessary with a very active involvement of builders and architects in practice. Because of this it was decided to hold an architectural competition in connection to the mentioned retrofit project with 513 apartments which should utilise energy efficient heat recovery ventilation systems with PV-supply. And to do this before the EU-Joule supported prototype ventilation systems were installed in the first housing block with 27 apartments.

5 of the best Danish architect companies where pre-qualified for the architectural competition, and an introduction material was developed and

presented to the architect companies prior to the competition at a special one afternoon seminar at Lundebjerg in Skovlunde. See also figure 4.

The results of the architectural competition were indeed very interesting, with many good ideas of how to integrate PV-panels in the building the best way, also ideas that the project team had not thought of before the competition were held.

The entries illustrate two different approaches regarding the integration of the PV elements in the architecture: Four of the entries integrate the PV elements in the east and west orientated facades. The ventilation aggregates are placed above suspended ceilings in the dwelling units and/or in the attic of the building. This east and west orientation results in a need for a somewhat larger PV area than a south orientation would do.

Only one entry orientates the PV elements to the south. This is done by adding new architectural elements, termed ventilation ”chimneys”, to the building and by integrating crystalline PV elements in the southern facades of these. The ”chimneys” also function as exhaust airshafts.

The jury found this last entry to be the best, as it in their opinion shows a clear and consistent way of solving the architectural problem of PV integration. At the same time it also best solves the other challenges, providing a solution that is both architecturally, functionally and technically attractive as well as economically acceptable.

The basis for the jury’s decision was, naturally, the published program for the competition, including the report on the existing condition of the building. The following issues were key to the jury’s decision:

- that the building’s existing architectural qualities are respected
- that the building’s architectural expression is improved and that the integration of the PV based ventilation system is consistent with this
- that the proposed solutions to the technical problems with the building are part of the architectural solution
- that a PV based ventilation systems is a convincing part of the resulting architectural expression
- that the cost of the proposal as a whole is within reasonable, realistic limits

Based on an evaluation of the five entries against all these criteria, the jury found, as stated above that the entry with the ventilation ”chimneys” from the architectural firm ”Tegnestuen Vandkunsten”, in Copenhagen, to be the best. See figure 5.

The retrofit of the first building will start in the summer of 1999, and this will also include other PV-integrated solutions e.g. use of amorphous PV-modules on the gable to the south.

A large part of the PV-area in Lundebjerg is placed on the south facing facades of the 3 ventilation chimneys which will be installed on the roof. In all

21 m² of crystalline PV-modules are placed here, approx. 3.6 kWp. Furthermore approx. 3 m² of crystalline PV-modules are placed on the west-facing facade of the building also preheating ventilation air for 3 apartments. And 60 m² amorphous PV-modules are placed on the south facing gable supplying 3 apartments with PV-electricity.

For most of the ventilation systems which are utilised, there is a direct PV-supply to the fans of the ventilation systems via a so-called PV-mixer (a DC/DC converter) which allows PV-electricity to cover as much as it can and then take supplemental electricity from the grid.

For the three apartments near the gable approx. 0.8 kWp PV-electricity will be installed per apartment. In this case the PV-electricity is grid connected, but at the same time supplying electricity for local electricity use in each apartment. For these apartments electricity meters which can run both ways will be installed so a ”roof top system” function can be realised. In these 3 apartments it is at the same time foreseen to install so-called ”Energy guard” electricity and heat consumption displays to ensure a motivation for energy saving user habits.

In all 4 shared PV-VENT prototype systems, each for 3 apartments, will be installed at Lundebjerg. For all systems a design with preheating of ventilation air in the PV-modules will be utilised.

Furthermore at Lundebjerg exhaust ventilation systems with PV-supply will be installed for 9 apartments. For three of the apartments an increased PV-area will as already indicated be built into the gable and will be utilised, in this case with grid coupling of the amorphous PV-modules (2.4 kWp), which are at the same time used for preheating ventilation air in winter and supplying natural ventilation in summer.

Besides 6 individual PV-VENT ventilation systems for 6 apartments will be installed. For these systems individual user control and moisture control on ventilation rates will be utilised. For 3 of the apartments approx. 1 m² of crystalline PV-area will be installed on the west facing facade, supplying PV-electricity to the individual heat recovery ventilation system, and at the same time preheating ventilation air.

In figure 6 there is a copy of an engineering drawing from the Lundebjerg project.

Also as part of the PV-VENT, EU-Joule project prototype systems will be installed at two sites in Copenhagen.

At Vesterbro in Copenhagen 12 individual prototype PV-VENT systems will be installed from April 1999 with facade mounted PV-modules and a transparent insulation solar wall also preheating ventilation air. The prototype ventilation systems used here have been tested at DTI/Solar Energy Lab. before installation.

And at Rymarksvænge at Østerbro in Copenhagen 2 prototype PV-VENT systems for 8 apartments will be installed from August to the end of October 1999.

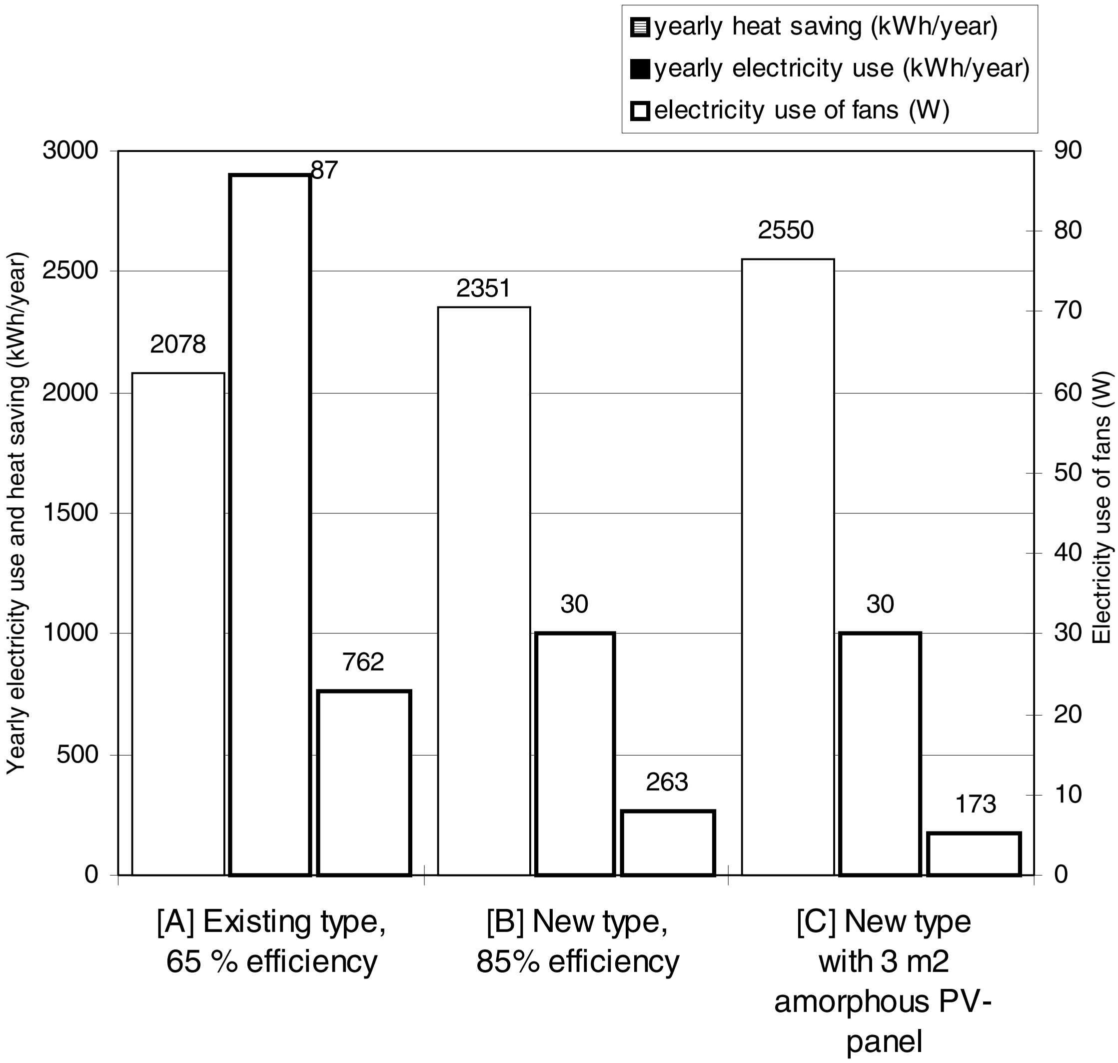
4. Example of possible economy of the developed PV-VENT systems.

Calculations show that with PV-VENT systems you can already today have an electric thermal performance ratio of 1:14.7 (electricity use compared to heat saving), a pay back time of 7 years and a saving of primary energy per housing unit of 4000 kWh per year (calculated as heat). See also figure 7.

For conventional HRV systems these figures are 1:2.7 - 8 years and 2080 kWh. When there is a real market the pay back time should be reduced to around 4 years even for the HRV systems with PV-supply.
So with an optimised approach for HRV systems which includes PV-supply and the above mentioned features it can be concluded that it seems realistic to ensure a high quality ventilation with a very little thermal and electricity use. It is aimed in the PV-VENT project that it should be possible to document that such a development as described above can be true in practice. If this is possible there are prospects of a very large market for this type of solar assisted ventilation systems in housing.

List of figures:

Illustration of positive economy of new energy efficient heat recovery ventilation systems with PV-supply.



[A] Existing type heat recovery ventilation system (HRV), (cross flow) 65% efficiency, 87 W electricity use according to new Danish Building Regulation (BR95).
[B] New type of counter flow HRV, 85% efficiency, low pressure loss and good fans with only 30 W electricity use.
[C] As [B] but with 3 m² amorphous PV-panel for preheating of ventilation air and supplying electricity use for fans.

Relation between:	**[A]**	**[B]**	**[C]**	
Yearly heat saving/electricity use:		2.7	8.9	14.7
	bad	very good	extremely good	
Saved primary energy use:	2078	3598	4023	
Pay-back time today (years)**(***:		7.7	4.0	7.2
Pay-back time when there is a market (years)**(****:	-	2.4	4.0	

Extra costs for HRV ventilation including saving on installed heating effect (5.000 DKK). Type A extra costs: 5.000 DKK., type B extra costs: 5.000 DKK., type C extra costs: 10.000 DKK. Yearly maintenance is 1% of extra investment.
(*: heat price(HP): 0.36 DKK./kWh, electricity price(EP): 1.04 DKK./kWh, yearly heat saving (HS) includes 50% of electricity converted into heat, yearly electricity use (EU), pay-back= investment costs

/((HS*HP)+(762-EU)*EP). Primary energy use of electricity is 2.5*yearly electricity use (EU). Yearly heat demand in low energy housing for ventilation is calculated to be 2610 kWh at 126 m^3/h ventilation rate (35 litre per second).
(**: 20% expected savings when there is a market in investment costs of heat recovery ventilation and 50% expected savings on PV-panels in 5-10 years.)

Figure 7. Comparison for one housing unit between different types of heat recovery ventilation systems (HRV) including systems with PV-supply for the electricity use.