INTRODUCTION TO INTEGRATION OF RENEWABLE ENERGY IN DEMAND CONTROLLED HYBRID VENTILATION SYSTEMS FOR RESIDENTIAL BUILDINGS

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ABSTRACT

In the scope of the EU supported project RESHYVENT, the possible integration of Renewable Energy Solutions (RES) into hybrid ventilation systems has been analysed. The focus has been on solar and wind applications to substitute the use of fossil fuel. The feasibility of the investigated options depends on the ventilation concept the RES is integrated into, the location of the building geographically, placement of the RES in the building and on the urban environment. This paper describes the different renewable technologies, options and constrains in connection with integration into hybrid ventilation systems.

KEYWORDS

Renewable energy integration, Solar, Wind, Urban environment restrains, Requirements to hybrid ventilation components.

INTRODUCTION

The RESHYVENT project (RESidential buildings HYbrid VENTilation) is a research project within the Fifth Framework Programme of the European Commission, which started in January 2002 and continues until December 2004. The aim of the RESHYVENT project is to research, develop, and construct demand controlled hybrid ventilation concepts for residential buildings with optimal use of renewable energies.

THE TRIAS ENERGETICA APPROACH

When integrating renewables in a hybrid ventilation system it is recommended that the Trias Energetica approach is followed. The trias energetica approach is a method to ensure that the use of conventional and renewable energy is optimised as much as possible. The method includes three steps: First the energy demand from the components is minimised as much as possible, secondly the energy demand is supplied by renewable energy and third the remaining energy demand, if any, is supplied by conventional energy sources (fossil fuels).

This means that before supplying the hybrid system with renewable energy, the energy demand of the system and individual components i.e. the fan, actuators, controls and sensors must be optimised and brought to the lowest possible level. When this is done, the evaluation and design of renewable energy options can be carried out. If it is not possible to fully supply the system with renewable energy, then conventional energy may be used. S. Antvorskov (2004)

POSSIBILITIES FOR RENEWABLE ENERGY FOR HYBRID VENTILATION SYSTEMS

For use and integration into a hybrid ventilation system six (6) general concepts have been identified on the basis of previous research work carried out in the framework of IEA and EU. The systems are the following:

- Photovoltaics (facade and roof integrated)
- Solar wall and solar air collector
- Glazed balcony
- Solar Chimney
- Wind turbine
- Wind cowl

Under the right circumstances and in the right combination these concepts can meet the demands of support energy in a hybrid ventilation system. However, in most cases it is realistic that only part of the system is supplied by renewable energy. Figure 1 shows the possible placements of the different renewable technologies.

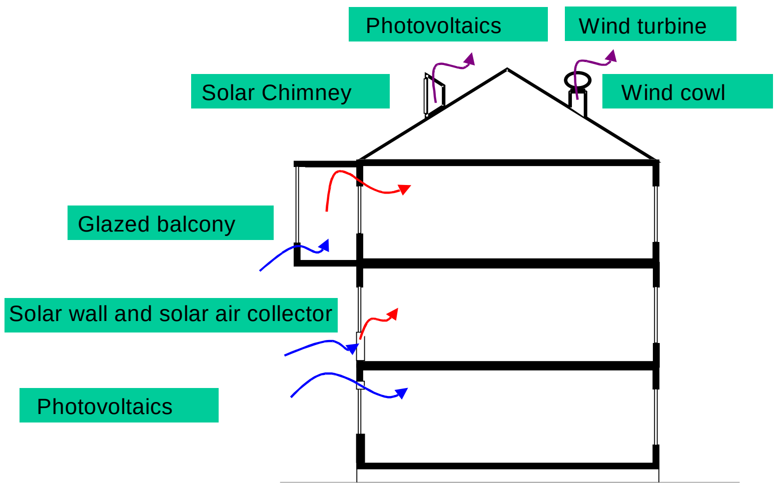

Figure 1: Concepts and placements of renewable energy solutions for hybrid ventilation systems.

INTEGRATION AND USE OF SOLAR ENERGY

Stand alone Photovoltaic Systems (PV systems)

A photovoltaic cell is a semiconductor device that produces electricity from photons (sunlight). A stand-alone PV system, suitable for use in a hybrid ventilation system, consists of a PV panel, an inverter and a battery. The battery is used as an energy storage for periods with low or no solar radiation, no other energy source is therefore needed. In combination with wireless control, all wiring to and from the different PV supplied components can be omitted, this makes the stand-alone PV solution very attractive especially in retrofit situations.

It is very difficult to generalise the required PV area and battery size for the different components in a hybrid system as this entirely depends on the energy use of the component, geographic location and placement in the building. A careful review of each component's energy consumption profile is required to establish the feasibility of economic and practical PV use. The parameters which need to be considered are illustrated in table 1.

TABLE 1
Design parameters for dimensioning and calculation of feasibility for a PV system

Main Item	**Sub Issues**	**Example**
Geography	Latitude	50° North (Brussels)
	Longitude	5° East
	Orientation	195° - 15° from south
	Tilt angle	90° - Vertical
Load profile	Input voltage range	6-12 Volt DC
	Power needed	2-6 Watts
	Time of consumption	6 Hours
	Period of consumption	Daily, summer and winter
	Consumption pattern	6-9 AM, 1-4 PM
Shadowing	Shadows occur	Yes / No
	Time of shadowing	Winter between 8-12 AM
Available area	PV	L_{max} = 900 mm, L_{min} = 400 mm
	Battery	H_{max} = 100 mm, L_{min} = 20 mm, W_{max} = 25 mm
	Control device	H_{max} = 100 mm, L_{min} = 80 mm, W_{max} = 50 mm
Wiring	Distance between battery and consumption	2 m
	Distance between PV location and battery	0,5 m
	Distance between PV location and controller	0,5 m
Weather Conditions	Average ambient temperature	Summer +22°C, Winter 2°C
	High / Low ambient temperature	-25°C to +42°C
	IP class needed for battery	IP 23
	IP class needed for controller	IP 65
Feasibility	Cost of kWh	0,13 Euro / kWh
	Price to power the component (AC transformer, cabling and installation cost, battery cost)	14 Euro
	Electrical maintenance cost	5 Euro per year
Integration	Possibility to integrate PV	Yes, front of inlet – 0,36 m^2
	Possibility to integrate battery	Yes, inside inlet – 20 cm^3
	Possibility to integrate controller	No
	Design requirements	"Black PV module look"

Under certain favourable conditions (low energy consumption and high solar gain) at least some components may be supplied with electricity through PV systems. Actuators are normally fit for supply by PV, as they have small energy demands and are close to the exterior. Probably most inlets can be supplied by rather small PV module and batteries. Fans have a larger energy use, and therefore need larger PV modules and a battery bank. However, fans are generally placed near the exterior, on the roof and there are usually more space available for mounting the PV.

The general design criteria for application of PV is a free horizon. This requirement may then exclude application of PV panels on facades in dense build environments as comprehensive shading on the facades typically will occur. PV operates best when facing south and with optimum tilt angle (mainly equal to latitude). S. Antvorskov (2004).

Solar Thermal Systems

There are different options for using solar thermal energy in a hybrid ventilation system. Glazed balconies, sunspaces, solar walls and solar air collectors can all be used.

Glazed balconies and sunspace are in principle the same technology. It consist of a glazed space located in front of the main building. The fresh ventilation air enters the closed space and is passively pre-heated by the sun and partly by transmission losses from the building. When designing a glazed balcony or sunspace it is important that the glazed elements are operable in order to prevent overheating in summer.

The advantages of using a glazed balcony or sunspace in connection with a hybrid ventilation system are:

- Passive use of solar energy to preheat the ventilation air,
- Reduction of transmission and ventilation losses,

Some of the more critical aspects are:

- Risk for overheating in summer,
- The high dependency of different user behaviour on the energy savings,
- Risk of condensation of moisture from the apartment on glazed elements

The price of a glazed balcony or sunspace depends on the building type, the size of the area that has to be glazed and specific features i.e. type of glass, frame etc. In general, a glazed balcony or sunspace is not cost-effective if it is considered only as a means to save energy and reduce maintenance. The additional added values connected to the integration must also be evaluated, such as: Increase in living space area, shorter heating season, reduction of outside noise and reduction in renovation cost. C. Boonstra et al (1997) (a) and (b).

A solar wall and solar air collector can also be used to preheat the ventilation air in a hybrid ventilation system. However, this is usually an active system where a fan is used to drive the air through the wall or collector, the energy to this fan can however easily come from a PV module (no battery backup are needed). S. Antvorskov (2004)

In a typical solar air system, fresh air is drawn across a heat absorbing south-facing wall or other sort of solar collector. The pre-heated air is then drawn into the building's primary heating system where it is further heated, then distributed throughout the building. J. Dalenbäck (1997).

Generally, the performance of a solar air system is in the range 50-250kWh/m^2 collector area in Nordic climates. The cost effectiveness is not possible to generalise as it is very dependant on the system, building and local climate. It must be noted that there are other benefits in addition to energy cost savings that can be gained by applying a solar system, e.g. environmental aspects and improved thermal comfort. C. Boonstra et al (1997) (b).

INTEGRATION AND USE OF WIND ENERGY

Wind Cowls

The expression wind cowls covers a large range of wind augmentation techniques, which are able to improve driving forces, eliminate dependency of wind directions and stabilise the air flow. Wind cowls are normally placed on the roof, to take advantage of the higher wind speeds, which are normally present on roofs. They are suited for natural ventilation systems as they can provide an extra driving force for the ventilation. In addition they can be used to avoid down draught in chimneys and exhaust outlets. Many different designs of wind cowls are on the market. Their efficiency is to date not very well documented. Test conducted over a two-year period by J.Orbesen show that the wind cowl produced by Nova-air shows quite good efficiencies with extraction rates ranging from 265 m^3/h to 2300 m^3/h depending on wind speed, air temperature and duct size, however tests conducted in the EU project Photo-Vent showed that the efficiency of the wind cowls was close to zero i.e. the wind cowls did not have any real effect compared to normal wind huts. S. Antvorskov (2004)

Small wind Turbines

Small wind turbines transform the kinetic energy in the wind to electricity or mechanical energy. They can be placed on rooftops, where the wind speed is normally higher than on street level. Some turbines can be placed in the middle of the roof to take advantage of the horizontal wind speeds and some are to be placed near the edge, to utilise the vertical wind speed. It is recommended to use a vertical axed wind turbine for integration in the build environment as this form is independent of the wind direction, and works efficiently in all horizontal wind directions. On rooftops the wind directions vary much and can change very quickly. A wide range of small-scale wind turbines are available on the market today, but is it still a market which it is under development. As is the case for the other RES, it is not possible to generalise the cost-effectiveness of a small scale wind turbine, as the energy production depends on a range of local factors, e.g. the speed and direction of the wind and the ventilation systems demand for electricity. S. Antvorskov (2004)

CONSTRAINTS OF THE URBAN ENVIRONMENT

The facades and roofs of buildings must be given special attention when integrating renewable energy into a hybrid ventilation system, the buildings' exposures to sun and wind often determine weather a system is feasible or not.

The dimensions and orientation of urban canyons vary greatly in the urban environment. As a result the sun/shade conditions vary equally much. Solar renewables are effected by shade from adjacent buildings and trees, it is therefore important to analyse the sun/shade conditions in each specific case before setting up a solar renewable technology.

PV systems are very sensitive to shadow. If only a small fraction of the PV panel is shaded the output of the entire string of panels will decrease drastically. Therefore, it is essential that shading of the panels is kept to an absolute minimum. If the panels are placed in an urban canyon, they should be mounted as high as possible to ensure that shade from other buildings is minimised as much as possible. This is especially important if the panels are facing east or west because the sun is at a low angle when rising in the east and setting in the west. If the panels are facing south it is easier to avoid shadow from other buildings because the sun is at a high angle over the horizon in the middle of the day, when the sun is to the south. It is not recommended that the panels are mounted facing north.

The wind conditions in the urban environment is greatly influenced by the layout of the buildings in the area, wind canyon effects can be created which is favourable or not favourable for applications of wind cowls or wind turbines. Therefore, the micro wind climate must be analysed for each individual case.

RECOMMENDATIONS FOR USE OF RENEWABLE ENERGY FOR DIFFERENT CLIMATE ZONES

When integrating renewables in a hybrid ventilation system it is recommended that the Trias Energetica approach is followed. This method ensures that the use of conventional and renewable energy is optimised as much as possible. Following this, dynamic computer simulations should be used to dimension and evaluate the RES in detail. A rough overview of the characteristics, urban constraints and recommendations for the use of the different renewable applications are shown in table 2.

TABLE 2
Overview of the different solar energy technologies, the constrains and recommendations

Concept	Description	Constraints	Recommendations
Photovoltaics	Auxiliary energy for operation of fans and controls in a hybrid ventilation system	Very sensitive to shadows and shelter in canyons	Recommended in open courtyards, at free exposed facades facing south or at roofs. Especially fit for supplying actuators in inlet grills. Can be applied in both warm and cold climates.
Glazed balconies	Existing or new balconies glazed for increase of the living area. Reduction of noise and for preheating of inlet air	Shadows, and building configuration	Recommended in retrofit situations for multifamily buildings. Mostly applicable for cold climates.
Solar walls	Existing or new facades with glazing to improve the insulation level and for preheating of inlet air	Shadows	Recommended in open courtyards or at free exposed facades. Mostly applicable for cold climates.
Wind cowls	Increase of wind induced flows in extracts	No technical constraints	Recommended at roofs. Can be applied in both warm and cold climates.
Wind turbines	Auxiliary electricity for fans and controls in the ventilation system	No technical constraints	Recommended at roofs, possible in connection with a PV module, creating a stand-alone hybrid solar and wind system. Can be applied in both warm and cold climates.

More detailed information on the integration possibilities for RES into hybrid ventilation systems is described in S. Antvorskov (2004), this document will be available at the end of the RESHYVENT project.

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