RESHYVENT

Cluster Project on Demand Controlled Hybrid Ventilation in Residential Buildings with Specific Emphasis on the Integration of Renewables

Contract No: ENK6-CT2001-00533

WP 3 Renewables integration support unit

Report Title:

GENERAL INFORMATION ON RENEWABLE APPLICATIONS FOR AUXILIARY ENERGY - SUITABLE FOR USE IN HYBRID VENTILATION SYSTEMS

(Deliverable DWP 3.1)

RESHYVENT Working report No:

RESHYVENT-WP3.1

Prepared by:

Signe Antvorskov, Esbensen Consulting Engineers

Rune Winter Andersen, Esbensen Consulting Engineers

Dennis Aarø, Gaiasolar A/S

Jan Willem Hendriks, Gaiasolar A/S

Content

1 The RESHYVENT project

Within the Fifth Framework Programme of the European Commission a research project RESHYVENT (Renewable Energy Systems Hybrid Ventilation) has been started, running from January 2002 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.

This report is deliverable 3.1 (D3.1) of the Reshyvent project and thus it is part of work package 3 (WP3) of the project. The main objectives for this deliverable are:

- To give a general overview of renewable energy solutions for integration into hybrid ventilation systems.
- To investigate new renewable applications suitable for integration in hybrid ventilation systems.
- To give recommendations to how and where to integrate renewable energy solutions into hybrid ventilation systems.

Overview of deliverables in work package 3

Five deliverables have been defined for work package 3 in the Reshyvent project. These are as follows:

D3.1 Report on development of applications of renewables for support energy.

D3.2 Specifications of applicable renewable energy sources (including product descriptions) for integrating in four market ready concepts.

D3.3 Report about impact of RESHYVENT concepts on heating, cooling and electricity from renewables

D3.4 Evaluation report on characteristics and performances of a solar chimney

D3.5 Tool for assessment, feasibility and pre-dimensioning of renewables in ventilation systems

2 Introduction to WP 3.1

The integration of renewable energy technologies in the RESHYVENT project focuses on solar and wind applications to substitute fossil fuel in the operation of hybrid ventilation systems. The term, integration of renewables, covers a very large field of applications. This report only touches upon the application of wind and solar as renewables. On the basis of existing renewable energy technologies this report will give an overview of the possibilities for integration of renewable energy into hybrid ventilation components. The different technologies are not explained in detail, only mentioned as possible options.

3 The trias energetica approach

In the context of RESHYVENT the trias energetica approach is followed. The trias energetica approach is a method to ensure that the use of conventional energy is reduced in the most efficient and economical way. The method includes three steps:

1. Minimize the energy demand from the components as much as possible
2. Supply the remaining energy by renewable energy
3. Supply the remaining energy demand, if any, by conventional energy sources (fossil fuels). This third step includes optimization of the efficiency of the conversion of fossil fuels.

The approach is graphically illustrated in figure 3.1, where also the focus within the RESHYVENT project is illustrated.

<u>Trias energetica approach</u>

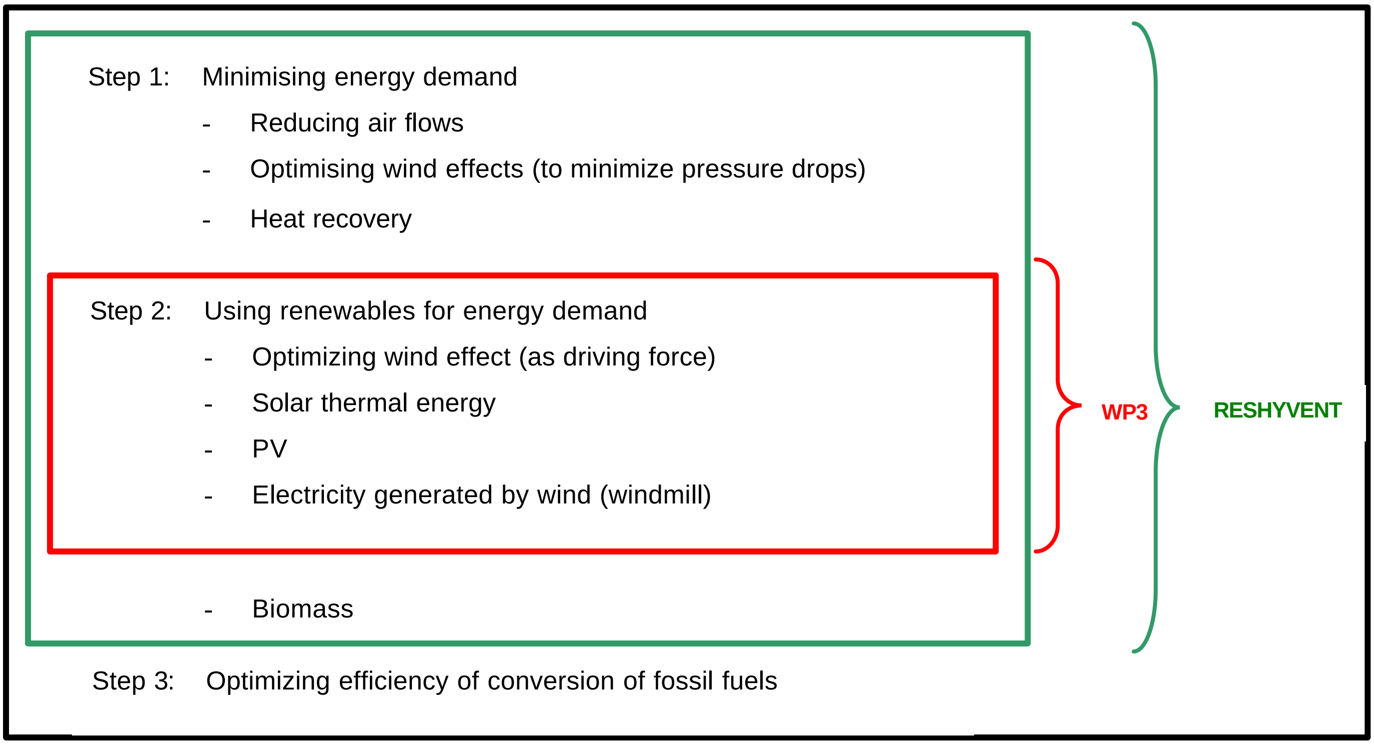

Figure 3.1 The trias energetica approach

4 Introduction to integration possibilities for renewable energy

After having implemented all possible and feasible energy efficient ventilation principles and controls, according to the trias energetica approach (step 1), this section gives an overview of the possibility for implementing renewable energy technologies and replacing the remaining minimised energy consumption of a hybrid ventilation system.

The facades and roofs of buildings are given special attention in RESHYVENT. Hence, the building integration of renewable energy technologies are focusing on solar and wind applications to substitute fossil fuel in the operation of hybrid ventilation systems, which means that the buildings' exposures to sun and wind are of great importance and can encourage the use of solar and wind energy.

Six general concepts have been identified on the basis of previous research work carried out in the framework of IEA and/or EU. These concepts can to some extent meet the demands of the support energy in a hybrid ventilation system. The six concepts are:

1. Glazed balconies and sunspaces
2. Solar air collectors and solar walls
3. Photovoltaics
4. Wind cowls
5. Wind turbines
6. Solar chimneys

Placement possibilities of the six concepts are shown in figure 4.1.

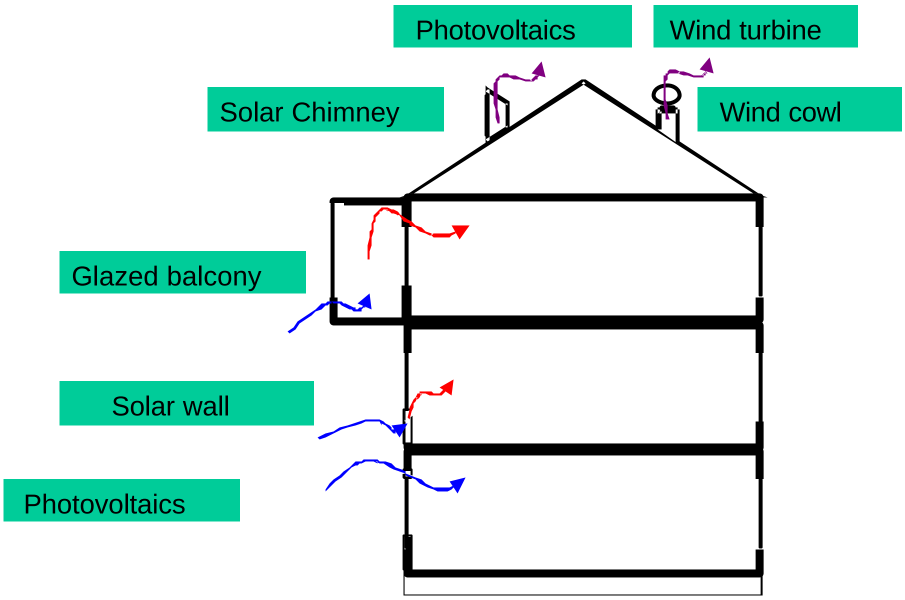

Figure 4.1 Six concepts of renewable energy for operation of hybrid ventilation systems.

The six concepts are described in more detail in the following sections.

5 Glazed balconies and sun spaces

5.1 General description

5.1.1 Glazed balconies

Glazing a balcony means enclosing the balcony with a glazed facade element, while keeping a separation between the balcony and the rooms behind it. The fresh ventilation air enters the balcony and is pre-heated by the sun and by transmission losses from the building. When designing a glazed balcony it is important that the glazed elements are operable in order to prevent overheating in summer.

Figure 5.1. Examples of glazed balconies (www.unl.ac.uk)

5.1.2 Attached Sun-space

An attached sun-space is a closed space where the external surface is made mainly of glass. The system could be connected with the internal space either by using a mass-wall or a trombe-wall. Usually a combination of the two is preferred.

In regions where the outside temperatures are very low in winter, the sun-space should be double glazed. In order to conserve thermal energy in specific internal places, these should be surrounded by well-insulated building elements.

To avoid overheating in the summer, it is necessary to provide shading of the sun-space's glass surface, preferably by moveable awnings or fixed overhangs, or even by deciduous trees. Furthermore, it must be possible to ventilate the sun-space through windows, or even better by removing all or part of the glazing in periods with excess heat.

Figure 5.2. Examples of glazed sunspaces (www.unl.ac.uk)

In principle the glazed balcony and the glazed sun-space are the same technology. Usually glazed balconies are applied to multi family housing with many levels, where only the facade is exposed to the surroundings. The glazed sun-space is more suited to one family housing or row houses, it is usually bigger and has more external surface.

Some advantages and critical aspects of the two types are listed in the following.

Advantages:
- Solar energy can pre-heat the ventilation air
- Reduction of transmission and ventilation losses
- Part of the heat losses can be recovered from the incoming ventilation air
- The utility of the space is enhanced
- Architectural image is enhanced
- Attenuate outside traffic noise.
- Protect existing facades

Critical aspects:
- Risk for overheating in summer
- The high effect of different user behaviour on energy savings
- Risk of condensation of moisture from the apartment on the glazed balcony or sunspace windows
- Static strength of the structure for the glazed balcony

5.2 The technology

Outside air usually enters the balcony or sun-space at the bottom and is ventilated through the whole dwelling. The optimal effect is obtained by having a regulated exhaust of the ventilation air. There is no need to introduce a balanced ventilation system. A principal sketch of a glazed balcony is shown in figure 5.3.

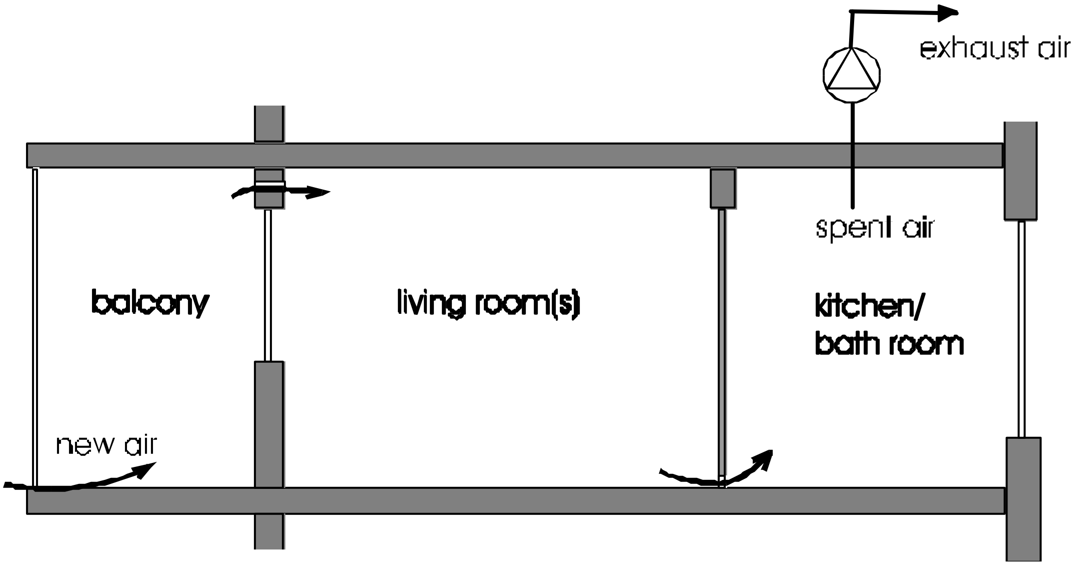

Figure 5.3. A principal sketch of a glazed balcony.

5.3 General design parameters

In the creation of an advanced glazed balcony or sun-space several design aspects are important. The main design parameters, which should be considered when building a glazed balcony or sun-space are listed below.

- Low-E glass should be used in either the inner or the balcony facade
- Windows should be operable in summer (1.2 –1.5 m^2)
- The ventilation air should be preheated using the exhaust ventilation system
- The facade elements must be made strategically more airtight
- Provision of adequate shading devices (IEA Solar renovation Concepts and Systems, 1999)

5.4 Feasibility

The feasibility 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 (IEA Solar renovation Concepts and Systems, 1999).

5.5 Product information

There are several available products on the market, which will match the requirements of existing balconies reasonably well. For single glazing, standard window frames or metal frames such as those designed for greenhouses in horticulture may be used. When double-glazing or low E glazing is used in the outer facade, heavier frames may be needed. In addition, standard sliding and hinged windows and doors are available. Most standard products are of good quality. The installation quality depends on the skill of the workers. Weak points are where the frames are sealed to the existing walls.

5.6 Implementation in Hybrid Ventilation Systems

Glazed balconies and sun spaces can be used in a hybrid ventilation system for preheating of ventilation air, the feasibility however depends on how many of the added values, that can be utilized.

6 Solar air collectors and solar walls

6.1 Active: Solar air collectors

6.1.1 General description

Active solar systems for air heating is a straightforward yet effective way of applying solar energy for space heating and tempering ventilation air. The systems offer some advantages over solar water systems, e.g. no boiling/freezing risks. The systems can offer improved comfort and larger use of solar gains than passive solar systems and are a natural fit with mechanically ventilated buildings.

The systems can be cost effective, with short pay-back periods, and can be used for space heating, pre-heating of ventilation air, water pre-heating, sun-shading, and to help induce cooling.

However, designers lack experience in planning, analysing and constructing solar air systems. Within the project "IEA Solar Heating and Cooling Programme Task 19 "Solar air systems", three publications have been made to bridge the information gap. This is done by illustrating a range of successful applications pointing out suppliers of the necessary equipment and offering a comprehensive handbook to lead designers through the necessary design process.

Some of the main advantages and critical aspects for solar air systems are listed below:

Advantages:

- Fast responding
- Easily controlled
- Leaks are not a problem
- No anti-freeze chemicals are needed
- No boiling problems

Critical aspects:

- Large channel cross-sections
- Potential noise problems
- Electricity consumption by fans
- Dust and moisture

6.1.2 The technology

A solar air heating system uses solar energy to preheat the ventilation air and may therefore also be used for space heating purposes. In a typical system, fresh air is drawn across a heat absorbing south-facing wall or other form of solar collector. The pre-heated air is drawn into a building's primary heating system where it is further heated, then distributed throughout the building.

The solar air system roughly consist of the following components:

- Collector
- Duct system
- Diffusers
- Fan, filters, dampers and noise reducers

There are 6 different types of solar air systems:

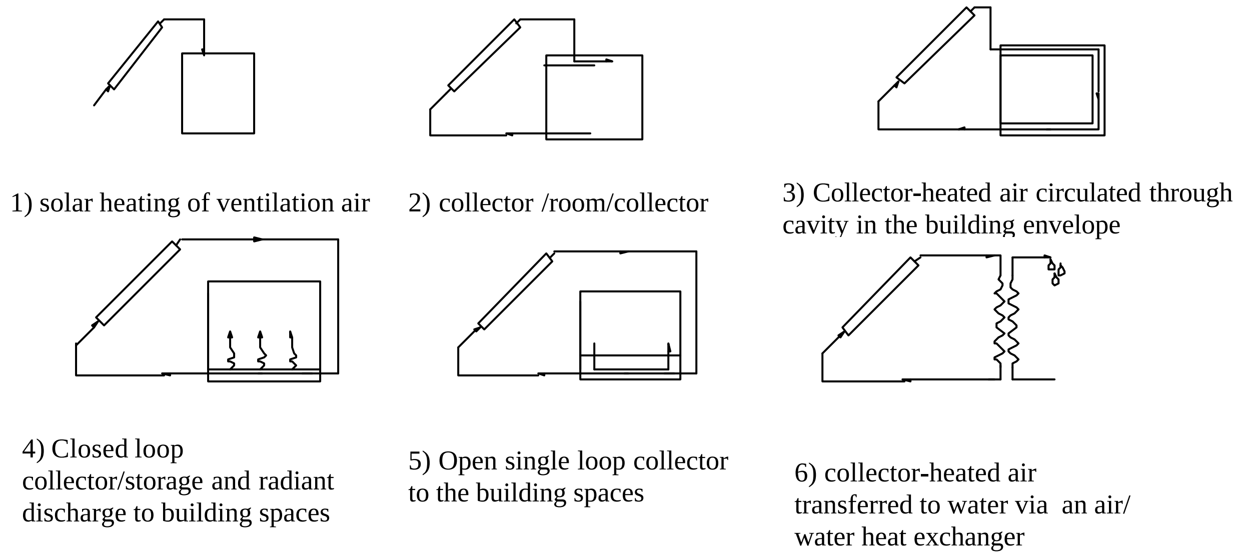

Figure 6.1. Overview of the different types of solar air systems. (Hastings and Mørck, 2000)

Of these systems, system no.1, solar heating of ventilation air, is the most relevant in relation to hybrid ventilation as this system preheats fresh air. The other systems are closed systems where room air is heated by circulation through the collector.

There are four main airflow principles in solar air collectors i.e. flow below the absorber, flow above the absorber, flow on both sides of the absorber and flow through a perforated absorber. The perforated absorber usually has the highest efficiency.

The airflow principles are illustrated in figure 6.2.

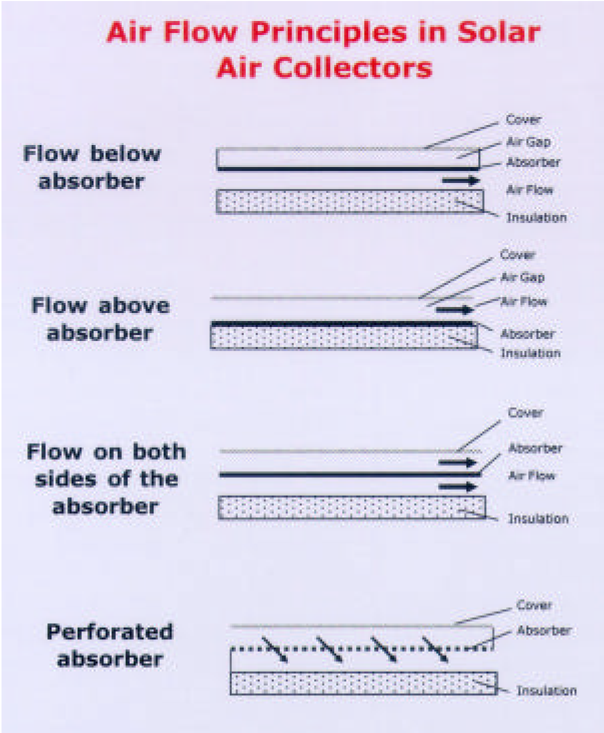

Figure 6.2. Air flow principles in Solar Air collectors. (Hastings and Mørck, 2000)

A number of commercial series produced solar air collectors have been tested in IEA Task 19 solar air systems, in 1999. These are:

- Solarhart (Austria)
- Grammer (Germany)
- Aidt Miljø (Denmark)
- Solarwall (Canada)
- The Friendly Wall (Norway)
- Secco (Italy)

The efficiencies of the tested collectors are illustrated in figure 6.3.

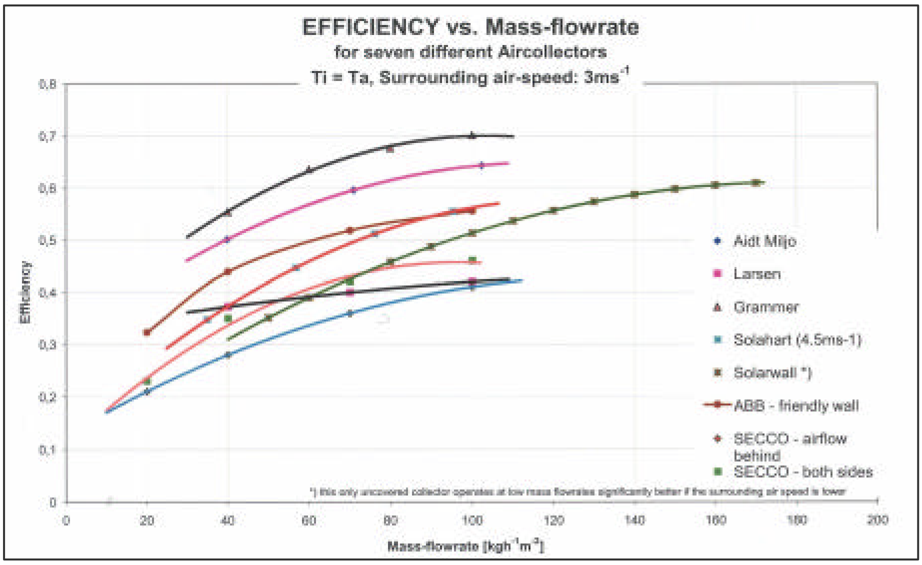

Figure 6.3. Efficiency verses the mass-flow rate for the seven different solar air collectors. (Hastings and Mørck, 2000)

The collector from Grammer is the most efficient. In general the efficiencies divagates with a factor 3, from lowest to highest.

A detailed sketch of how the solar air collector can be integrated into the facade is illustrated in figure 6.4.

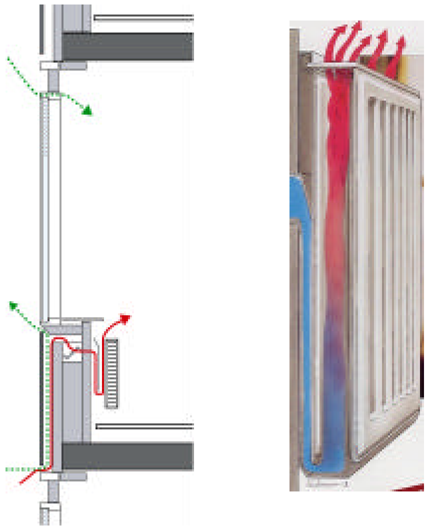

Figure 6.4 Principal sketch of the integration of a solar air collector

6.1.3 General design parameters

The main design parameters for a solar ventilation system is the ventilation rate i.e. the total air change in the building including the infiltration.

In the book “Solar air Systems - A Design handbook” /Hastings and Mørck 2000/ different nomograms have been generated based on different climatic conditions. By using these, the system performance of a solar air system can quickly be approximated.

For system 1, preheating of ventilation air, the following table shows the necessary design parameters and an example.

Main design parameters	***Example***
Location	Denmark
Weather condition	Cloudy, temperate climate
Size of building	100 m^2
Tilt	45°
Orientation	15° from south towards east
Collector type and size	Optimized collector of 5 m^2 i.e. 0.05 m^2/ m^2_{floor}
Air flow through collector	100 m^3/h, i.e. 1 m^3/h m^2_{floor}
Control strategy	Temperature controlled. The fan of the solar heating system starts at a collector temperature of 18°C and stops at a collector temperature of 16°C. The fan also stops if the temperature in the building exceeds 23°C.
Fan power	100 W with 50% dissipation in the air stream
Space heating demand	12,500 kWh/year, i.e. 125 kWh/m^2_{floor} per year
U-value of roof	0.75 W/m^2K

Table 6.1 Necessary design parameters and an example of a air solar collector

When these parameters are identified the nomograms are used and the annual saved energy is found.

Using the design parameters listed above the savings will amount to 176 kWh/m^2 collector per year. When including the dissipated fan energy and the saved energy loss through the roof (or facade), the annual saved energy amounts to 200 kWh/m^2 collector per year.

A more detailed description of the design method is found in (Hastings and Mørck, 2000).

6.1.4 Feasibility

Generally, the performance from a solar air system is in the range of 50-250 kWh/m^2 collector area. (BPS-publication 133, 2000). It is however, not possible to generalise the cost-effectiveness of a system for pre-heating of ventilation air and / or space heating, as it usually is very dependant on the system, building and local climate.

It must however 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. (IEA Solar renovation Concepts and Systems, 1999)

6.1.5 Product information

- Solarhart (Austria)
- Grammer (Germany),
- Aidt Miljø (Denmark),
- Solarwall (Canada),
- The Friendly Wall (Norway)
- Secco (Italy)

6.1.6 Implementation in Hybrid Ventilation Systems

Solar air collectors can be used in a hybrid ventilation system for preheating of ventilation air, the feasibility however largely depends on the air flow rate and need for preheating in spring and autumn.

6.2 Passive: Ventilated solar walls

6.2.1 General description

Solar walls may be designed as either passive or active systems. They can be integrated into the building facade or added to the façade at a later time. A ventilated solar wall is characterised as a solar air system, which makes use of the thermal mass in the facade.

6.2.2 The technology

The principle of a solar wall is illustrated in the figure below. The thermal mass in the facade is heavy e.g. concrete, which is well suitable for storing and conducting heat. The principle is illustrated in figure 6.5.

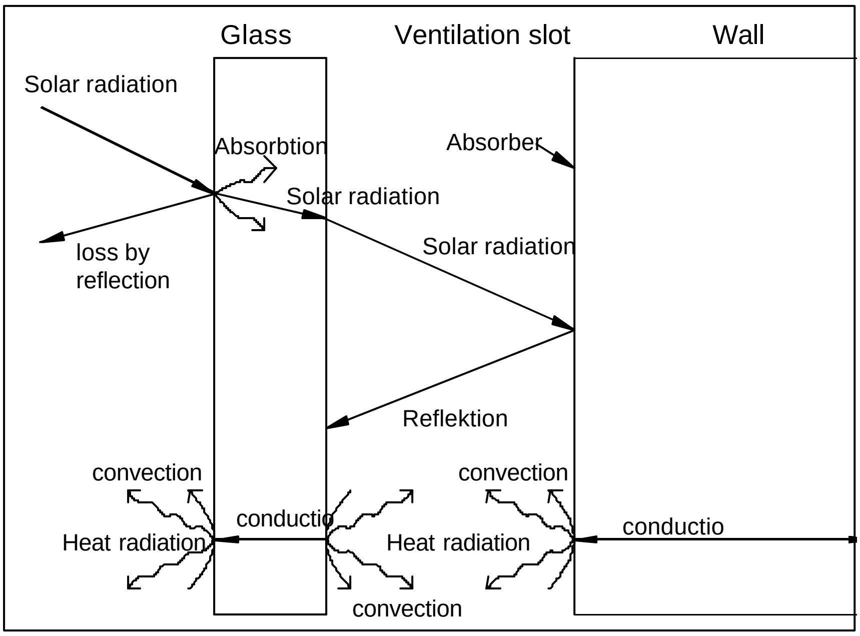

Figure 6.5 The principle of energy transfer for a solar wall.

The solar wall system where fresh air is preheated is the only type of solar wall relevant for hybrid ventilation and this project. Therefore only this system is described in this report.

Pre-heating of ventilation air

The fresh air is circulated behind a transparent cover in front of the outer wall, which may be a mass wall (thermal heavy) or insulated wall. The air is hereby being preheated before entering the room. If the wall is a mass wall, the heat accumulation will absorb heat during the daytime and release heat during the evening and night those it will act as an energy storage. A mass wall will also reduce the heat loss from the building. If the wall is traditionally insulated the wall will minimise the heat loss but not deliver any noticeable heat storage. The system is illustrated in figure 6.8. In principle this is the same method as used for the solar air collectors. (BPS publikation 133, 2000)

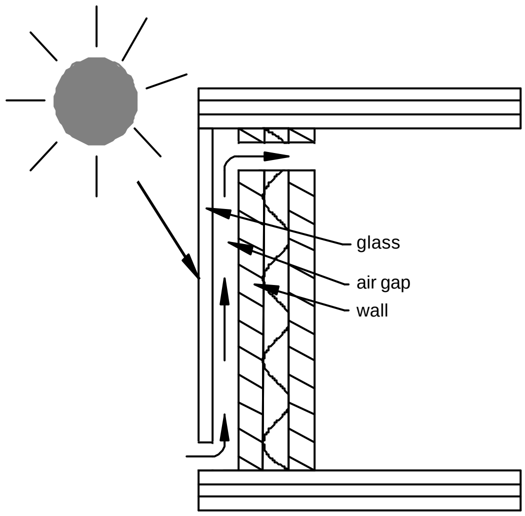

Figure 6.6 Principle sketch of a solar wall with pre heating of fresh air.

6.2.3 General design parameters

Some of the general design parameters, which must be considered when installing a ventilated solar wall are listed in the following.

<u>The building:</u>

The solar facade should not be more than 45 degrees from south-facing.

Avoid shadowing of larger portions of the facade.

<u>Heat transport and storage:</u>

The cover system should be designed to have a high solar transmittance and absorbency.

The heat loss coefficient from the absorber to the surroundings should be as low as possible.

<u>Thermal comfort precautions:</u>

Bypass of the solar wall must be possible or shading of the solar wall must be installed in order not to experience over heating. Inlet with diffusers (max 0.25 m/sec in comfort zone) must be used in order to avoid drafts.

The efficiency of the ventilated solar wall largely depends on the correct combination of the solar wall components and the characteristics of the facade wall. The joints between the components must be tightly sealed. The more precisely the airflow and heat energy is controlled, the larger the efficiency (BPS publikation 133, 2000)

The pictures below illustrate a solar wall installed on a balcony for preheating of ventilation air.

Figure 6.7 Illustration of a construction of a solar wall on a balcony seen from the outside. Housing company Østerbro, EU project FLEXREN.

Figure 6.8 Illustration of a construction of the inlet from the solar wall, installed on a balcony.

6.2.4 Feasibility

It is not possible to generalize the cost-effectiveness of a system for preheating of ventilation air and /or space heating, as it is usually very system and building-specific. It must however 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 (IEA Solar renovation Concepts and Systems, 1999).

6.2.5 Product information

There are only a few manufactures that specialize in solar air systems. Most air-based systems used in existing renovations projects have been custom made designs (IEA Solar renovation Concepts and Systems, 1999).

6.2.6 Implementation in Hybrid Ventilation Systems

A solar wall can be used in a hybrid ventilation system for preheating of ventilation air, the feasibility however largely depends on the air flow rate and need for preheating in spring and autumn.

7 PV systems

7.1 General description of Stand-alone PV systems

From a technical point of view photovoltaic (PV) technology is relatively simple. However there are still some crucial steps that must be taken in both the design and installation stages.

7.1.1 Types of systems

Stand-alone systems are usually categorised into three types, depending on whether they use battery storage and / or auxiliary power sources. Figure 7.1 illustrates these categories.

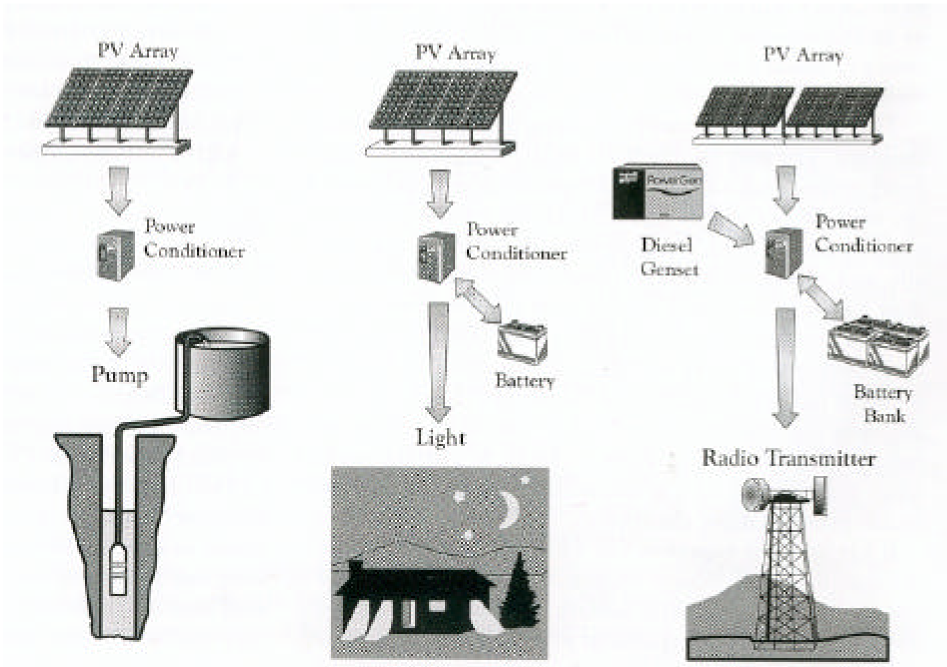

Figure. 7.1. Types of Stand-Alone systems

The first type of stand-alone is referred to as PV-direct because it powers the load directly, without using a battery. Such a system has the simplest configuration and is normally used either for applications that are not critical and match the availability of sunlight, such as calculators and ventilation fans, or when storage is already part of the system, such as water pumping or refrigeration. Despite the fact that PV powers the load directly, some form of power conditioning is still required to operate the load properly and maximise the PV output.

The second type of PV system is PV with a battery. This system includes storage that allows the load to be powered when the PV array cannot supply power directly (e.g. at night or during periods of low sunlight). This is the most common type of PV system as it suits a wide range of stand-alone applications world-wide.
The third type of PV system, called PV hybrid, includes systems that rely on an auxiliary source to compliment the low solar resource, generally a fossil fuel or wind generator. This type of system generally uses batteries too, for short-term variations of sunlight condition (on a daily or weekly basis). It is particularly suitable for applications that are critical (need additional backup) or those found in regions with large variations of sunlight conditions throughout the year, such as high latitude locations.

7.1.2 System control

All stand-alone PV systems normally require some form of control or power conditioning. The complexity of the control function depends on system user requirements, the type of system and the number of power sources included. In simple systems, battery charge-controllers interface between the battery while the inverter interfaces between the battery and the AC-load. However, in case of hybrid systems, energy management can become more complex in order to improve the efficiency of the system. Some controllers integrate all the necessary functions to run a system.
Nowadays, sophisticated power conditioners offer options such as periodic equalizations, energy metering, temperature compensation, multi-power source management capability (PV-Wind-Diesel hybrid for example), monitoring and remote access via modem.

7.2 General design parameters to consider before using PV

Before it can be determined whether PV is a feasible option or not, there are a number of parameters that should be considered. The below table illustrates these parameters.

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 during summer, weekends in spring / autumn, none during 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”

Table 7.1 Important parameters in PV design and example

7.3 Photovoltaic technology

A photovoltaic cell is a semiconductor device that produces electricity from photons (sunlight). The panel output is rated according to an international standard. The unit used is Watt peak (W_p), which is the panel output under a given light spectrum with an intensity of 1 kW per m^2 at a cell temperature of 25°C. In the field peak power only occurs occasionally and as a yearly average, panels will produce no more than 20% of their rated output over a 24 hour period. Series of cells (generally 36 or 54 or 72) are interconnected, “sandwiched” with glass, EVA and tedlar and laminated, boxed and framed into a solar panel, with electric output ranging up to 300 Wp. The function of the solar panel or solar module is to allow building integration and to protect the cells from the weather. Multiple panels may then be interconnected to form a string, and several strings may be used in parallel to form an array.

Silicon is the main semiconductor used in commercial cells. Panels marketed are mostly made from mono-, polycrystalline or amorphous silicon cells. Many other materials are being developed but have not yet achieved the production level of silicon cells.

While conventional mono-crystalline cells have an efficiency of 13-17% and poly-crystalline about 12-15%, relatively high efficiencies (about 20%) are achieved by using new mono-crystalline cells with embedded contacts and a grooved surface area. Amorphous silicon is the least efficient of the commercial silicon based products. Its efficiency is in the 8-10% range when new. Instability of the material though lowers efficiency to a stabilised efficiency of about 4-7% after a few months exposure to sunlight.

Light conditions vary throughout the day and the PV array output will vary accordingly. Among the other factors that affect the PV output, temperature is the most significant. In general, a rise in temperature reduces the performance of the PV array. In a similar way, when temperature drops, the voltage increases and PV panels produce more electricity.

The table below sums up the technologies:

Technology	Commercial efficiency (%)	Commercial size (m^2)	Yield per m^2 (Wp / m^2)	Price pr. Wp (Euro / Wp)
Monocrystalline	13-17	0.5-1.5	160	3.0 – 4.2
Polycrystalline	12-15	0.5-1.5	150	2.8 – 4.0
Amorphous	4-8	0.2-0.8	40	1.8 – 2.5

7.2 Cost and efficiency of different material for PV cells, as of 2004.

7.4 Battery Technology

For the applications requiring energy at night or during periods of low sunlight, a storage medium must be used to ensure the autonomy of the system. Most stand-alone systems require storage. The usual storage equipment used with stand-alone systems is rechargeable batteries. The following is a brief overview of the different types of batteries used with PV systems.

Two battery technologies are generally found in PV systems: lead acid and metallic (NiCd – Lithium). Both can be found in a variety of sizes and capacities. Metallic batteries present some technical advantages over lead-acid and are preferred for certain applications. However, these are 3-4 times more expensive per unit of energy stored and consequently lead-acid batteries are more commonly used.

Lead-acid and metallic batteries are divided in two categories: open units (often referred to as "vented"), and sealed units (also called "valve-regulated"). When overcharged, batteries produce hydrogen and oxygen, and there is also a consequential loss of water. In open batteries, this loss needs to be compensated at intervals. Sealed units, when properly operated, will minimise this loss. For this reason these are generally considered to be “maintenance-free” batteries. However, if they are mistreated and over-charged, a valve will let the battery vent, which will result in permanent damage, since water cannot be added to these units.

Other characteristics, such as the construction of the plate and the type of electrolyte used, make some batteries more appropriate under certain operating conditions. For instance, solar powered telecommunication systems including batteries designed to provide power. The duty cycle involves frequent and relatively light discharges compared to batteries used in most other duty cycles. Starter batteries as applied in vehicles are designed to accommodate frequent very short, but deep discharges. Batteries designed for renewable energy systems must withstand regular long-lasting deep discharges. Because batteries are designed to suit a particular duty circle it is important that the correct type of battery is selected for a given application.

The table below sums up the technologies and costs:

Technology	Commercial size (cm^3)	Voltage level (Volt)	Rated power (Ah)	Ambient temperature (°C)	Price pr. Wh (Euro / Wh)
Lead Acid – Open	120 – 25,000	2 – 12	6 – 2,000	-20 to +50	0.05 – 0.40
Lead Acid – Closed	120 – 50,000	2 – 12	6 – 2,000	-20 to +50	0.10 – 1.00
NiCd	5 – 50	1.2 – 9.0	0.36 – 2.4	-20 to +50	1.00 – 2.00
Lithium – Ion	10 – 30	3.7 – 9.0	3.7 – 7.4	-20 to +50	2.75 – 3.25

Table 7.3: Battery prices

7.5 Load vs. Supply

In dimensioning PV systems it is necessary to define the load profile and the solar irradiation. In periods with insufficient sunlight, a backup medium is required. This is symbolized in figures 7.2 and 7.3:

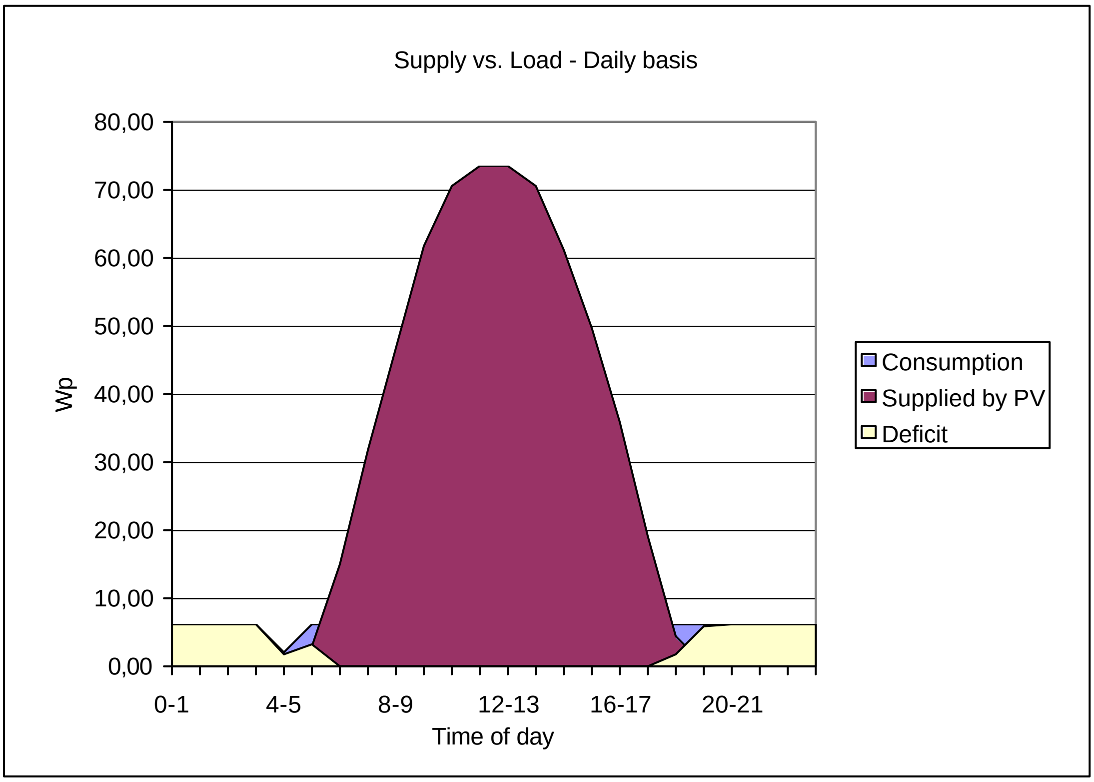

Figure 7.2. An example of the s upply vs. load on daily basis.

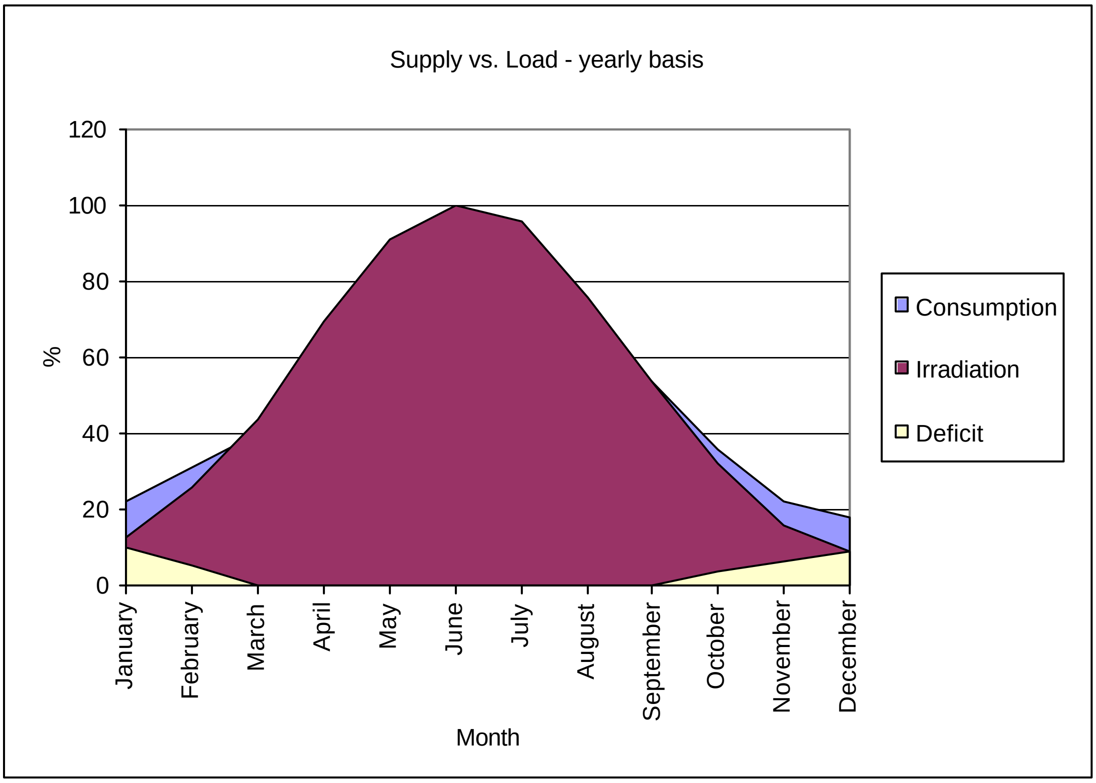

Figure 7.3. An example of the s upply vs. load on yearly basis.

7.6 Dimensioning of a PV system

7.6.1 Expected areas needed for PV

The tables shown below show the expected area needed for PV systems (as a rule of thumb). A number of assumptions have been made, as it is crucial to look into every component specifically.

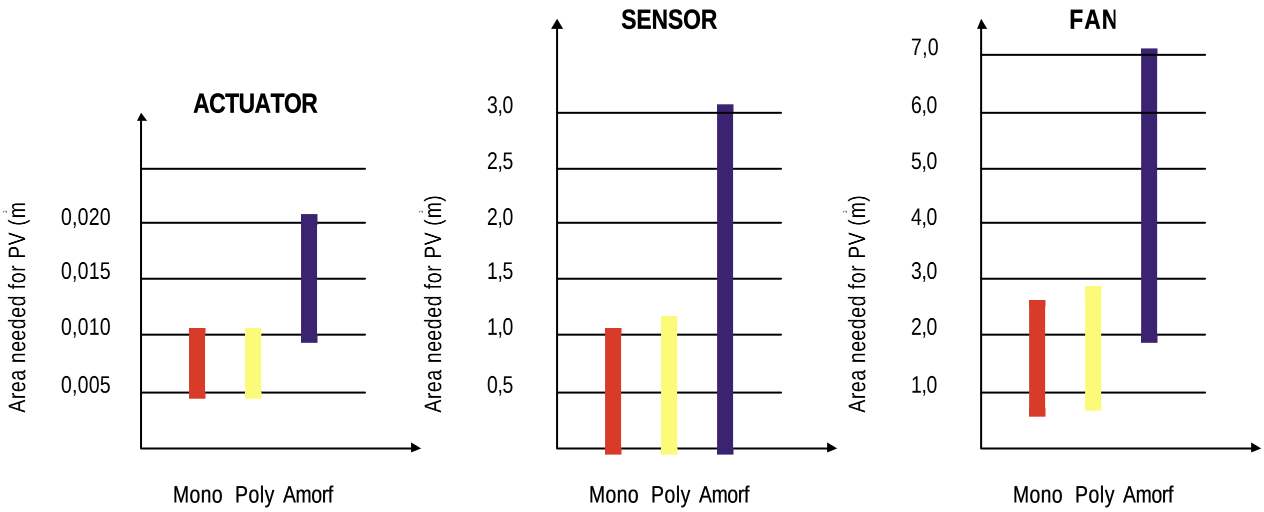

Table 7.4 Area needed for actuator, sensor and fan with different PV cell material

7.6.2 Expected battery sizes

It is very difficult to generalise the required battery sizes. They depend on the ventilation strategy, geography, ambient temperatures, the selected PV size and backup period needed. For each component it is necessary to design the battery bank. However it is clear, that actuators need only small batteries (ordinary AAA size, like the ones used in small electrical appliances) while fans need larger battery banks (between 500-2,000 Wh). Sensors are still under development and different brands and types have different consumptions.

7.7 Conclusion on feasibility of supplying hybrid ventilation system components with PV

It is rather difficult to say anything in general about the feasibility of supplying components of the ventilation system with PV. Therefore detailed information as listed in section 7.2 will be required. A careful review of each component's energy consumption profile is required to establish the feasibility of economic and practical PV use. Under certain favourable conditions (low energy consumption and good insolation) we expect that at least some components may be supplied with electricity through PV systems.

Actuators, as they have been described in the Photovent project, seem fit for supply by PV. They have a small consumption and are close to the exterior. Probably most inlets can be supplied by a rather small PV module and battery. Control units can probably be excluded.

For sensors it is very difficult to say anything in general. It depends on the type, use and brand. There seems to be some development underway that can increase the likelihood of supplying sensors with PV-generated electricity. Some prototyping and testing over a longer period needs to be done.
Fans need more PV power, control units and a battery bank. However, fans are generally placed near the exterior and therefore there is usually more space available for mounting the PV. Other considerations such as environmental issues should also be considered. In general more studies needs to be made in order to make conclusions about the suitability of PV in powering fans.

7.8 Product information on PV systems

Gaia Solar A/S (Denmark)
Dunasolar (Hungary)
Steca (Germany)
Varta (Denmark)
Danionics (Denmark)
MPX Electra (Denmark)
GP batteries (Denmark)

General information on PV:
European Photovoltaic Industry Association (EPIA) (www.epia.org)

7.9 Implementation in Hybrid Ventilation Systems

PV systems can used in a hybrid ventilation system for energy supply for the different components i.e. the inlets (actuator), the damper, the sensors and the fans. Specific information on the implementation possibilities is described in detail in deliverable WPD 3.2 " Specification s of applicable renewable sources for integration in possible prototypes" in the Reshyvent project.

8 PVT collectors

Solar thermal collectors may be combined with PV, into a so called PVT collector (Photovoltaic Thermal). PVT collectors are thermal collectors in which a PV-laminate functions as the solar thermal absorber. In this way, a collector is generated that produces both heat and electrical power. Both air and a fluid can be used as the heat carrying medium for the thermal collector, however for this project the PVT air collectors are the most relevant.

8.1 General description

In general a PVT air collector consist of PV laminates and an air gap in which the fresh air is preheated. This can be both in front of or behind the PV cells. The air inlet is placed at the bottom of the collector and outlet at the top with inlet into the building. The concept is illustrated in the installation presented below.

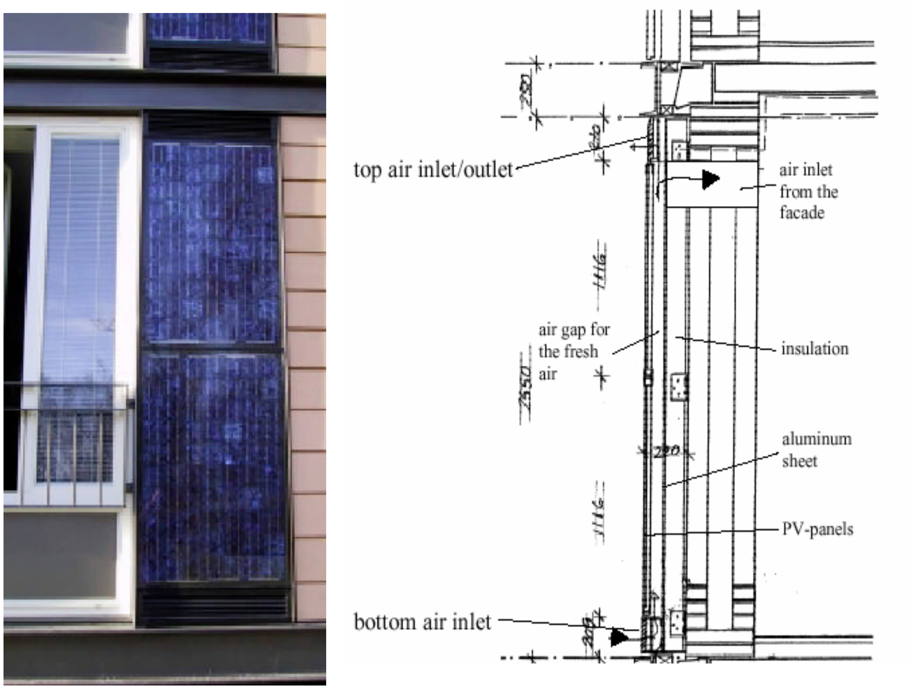

Figure 8.1. Left: Picture of a PVT air facade element, integrated on a residential multifamily building, Lundebjerg (DK) Right: Principle sketch of the PVT air panel at Lundebjerg. (Østergaard 2001)

8.2 The technology

The PVT collector is still a rather new concept in the field. Many pilot projects with different configurations of the collectors are therefore currently being tested, and research to optimise the technology is ongoing.

The PV laminates convert sunlight into electricity with an efficiency of about 10%. Since about 20% of the incident radiation is reflected; the remaining 70% is converted into heat. The temperature of PV panels can reach up to 70°C for high levels of irradiation, and at stagnation even higher temperature can occur. (http://www.ecn.nl)

The largest challenge for the PVT marked is to be able to extract the heat from the panel and to put it to use. A consequence of integrating a PV laminate in a thermal collector is a potential high PV temperature, if the heat is not extracted through the heat-carrying medium (air) at a sufficient speed. High temperatures reduce the efficiency of most PV systems. In research carried out by the Energy Research Centre of the Netherlands it is documented that in the North of Europe the temperature of a standard PVT collector will stay below 130 °C. This is important, since the risk of EVA delamination increases strongly for temperatures over 135 °C. (http://www.ecn.nl)

An example of a promising PVT air collector is the solar roof from Conserval Engineering, Inc. PV cells are mounted over a solar perforated absorber. The PV panels are mounted such that cool ambient air is allowed to pass behind the PV panels in a uniform air flow around each panel and not short circuit some areas and overheat others. Heat generated from the PV cells will be transferred to the air, which then can be used for pre heating of ventilation, a schematic sketch of the collector is illustrated in figure 8.2.

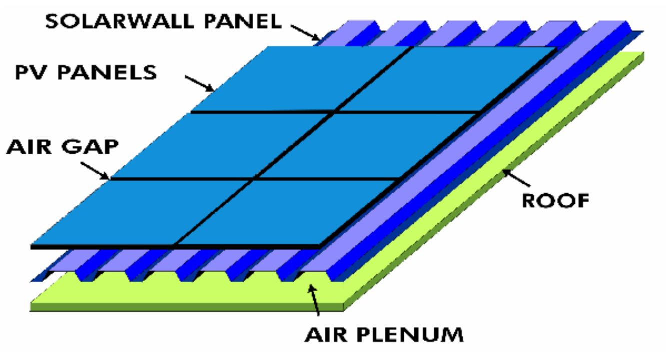

Figure 8.2: Schematic sketch of the PVT collector "Solar Roof" from Conserval Engineering Inc. (www.solarwall.com)

8.3 General design parameters

In choosing what type of PVT system is most suitable, the following demands needs to be considered:

- Needed airflow through the collector
- Temperature and characteristics of the thermal load
- Thermal load (kW)
- Electrical load (kW)
- Suitable mounting locations and building constraints e.g. weight bearing capacity, aesthetics

General comments:

Cooling of the PV panels with ambient air is desirable in order to keep the cell temperature down and thereby the efficiency of the PV panels up. The airflow behind the PV panel is not always enough to ensure the cooling of the PV panel. Therefore in some collector configurations (see figure 8.1) this problem is handled by removing the front cover to the absorber (PV cells). However, by not having a front cover the thermal efficiency of the solar air collector is reduced by approximately half the thermal efficiency of a standard solar air collector.

8.4 Feasibility

As for most renewable systems the feasibility depends on many local factors. The current status of the commercial products is that 10 – 15 % of the incident solar energy is transformed to electricity. The potential heat production from a given surface is thus much higher than the electrical performance, however as mentioned the challenge is to make use of this heat. Still many issues regarding the combination of materials, the dependence of temperature level on the over all yield and the optimum combination of heat and electricity production for various climates and applications are currently being tested. Therefore, the feasibility of the PVT collectors is still unknown.

8.5 Product information

Aidtmiljø (Denmark)
Conserval Engineering, Inc. (Canada)
Grammer (Germany)
Phototronics Solartechnik (Germany)

Millennium Electric (Israel)

Further information about the status of the technology of PVT collectors including an overview of the for the future development is presented in the report “Photovoltaics/thermal Solar Energy Systems – Status of the technology and roadmap for future development” IEA TASK 7 of 2002. This report can be obtained upon request from Esbensen Consulting Engineers A/S.

8.6 Implementation in Hybrid Ventilation Systems

PVT systems can be used in a hybrid ventilation system for preheating of ventilation air and production of electricity to supply the components in the system, the technology is still rather new and needs to be optimised in order to be feasible for implementation.

9 Wind cowls

9.1 General description

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. Because the cowl expels air, no cold air can enter the chimney, when the wind is blowing.

9.2 The technology

The wind cowls are usually divided into two groups, depending on the working principle: Rotating- and stationary wind cowls.

The rotating wind cowls extract the air by slinging it out of the cowl. When the wind hits the cowl, it will rotate which will make the air inside rotate as well. The centrifugal forces acting on the air will hurl it out of the slots in the cowl, creating a low pressure in the cowl.

The stationary cowls use different aerodynamic principals to create a low pressure in the top of the chimney.

Figure 9.1: Examples of wind cowls. Left: a stationary wind cowl ("Colt Top Gas" from "Colt Cowls"). Right: A rotating wind cowl. ("Rotovent" from "Colt Cowls") (www.loftshop.co.uk)

Recently, however, wind cowls designed to rotate with the wind ensuring that the exhaust opening is always shielded are being tested. An example of such a design is the wind cowl produced in framework of the EU project Photovent. This system is designed to minimise the resistance in the out flow of ventilation air and to endure that no wind at any time enters the exhaust opening. The system is illustrated in figure 9.2.

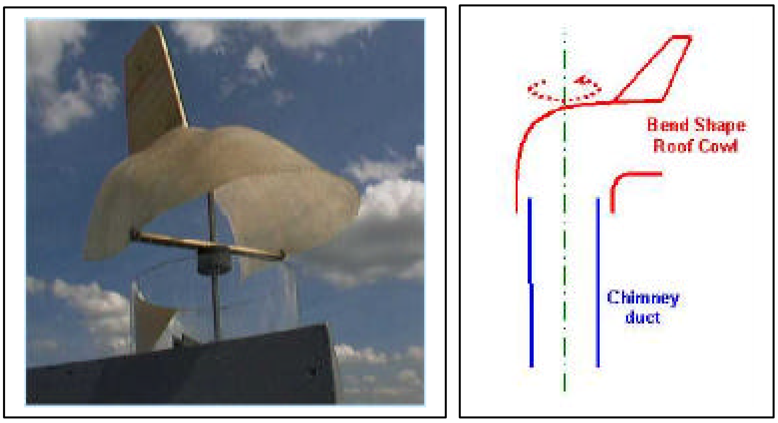

Figure 9.2. Prototype of wind cowl (EU PHOTOVENT)

9.3 General design parameters

Several parameters influence the performance of a wind cowl.

Wind speed

The wind speed is a very important parameter for most wind cowls. Generally the performance of a cowl will increase with increasing wind speed. Therefore, it is important that the cowl is not shielded from the wind.

As an example of the dependence on wind speed, the performance of an ATCO cowl, for various height and temperature differences is illustrated in figure 9.3. The wind cowl is produced by J. Orbesen Teknik Aps, Denmark.

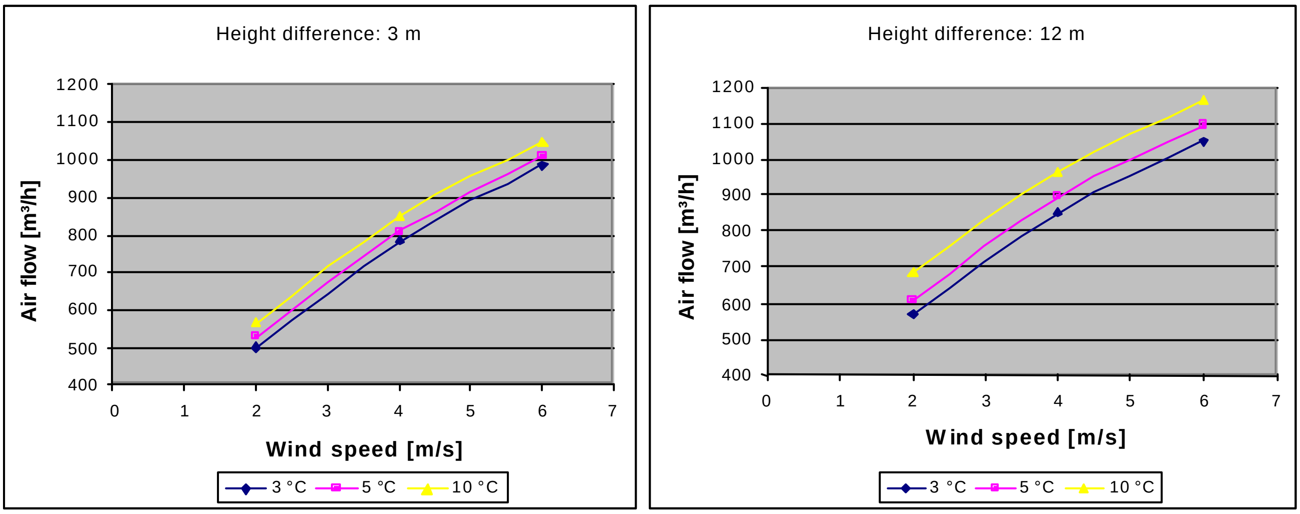

Figure 9.3: The air change for a ATCO wind cowl, produced by J. Orbesen Teknik Aps, Denmark. The curves represent different temperature difference between inside and outside of 3 °C, 5 °C and 10 °C. The difference in height between the intake and exhaust is 3m on the graphs to the left and 12 m for the graphs to the right. The diameter of the duct is 350 mm.

It can be seen from figure 9.3 that even at small wind speeds (down to 2 m/s) the cowl is able to provide a substantial airflow.

9.3.1 Wind direction

Most cowls are not affected by the wind direction, but it is important to consider the prevailing wind direction, to ensure that no obstacles are present in that direction.

9.4 Feasibility

Many different designs of wind cowls are on the market, however their efficiency is yet not very well documented. Tests of 6 different types of cowls wawere conducted in the project Photo-Vent and 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. However, test conducted over a two-year period by J.Orbesen show that the wind cowl produced by the company Nova Air shows quite good efficiencies with extraction rates ranging from 265 m³/h to 2300 m³/h depending on wind speed, air temperature and duct size.

9.5 Product information

Standard wind huts for exhaust ventilation ducts can be purchased from almost all suppliers. The following is a list of suppliers, which sells more advanced/active wind cowls.

- Klimatbyrån AB (Sweden)
- Nova Air (Denmark)

9.6 Implementation in Hybrid Ventilation Systems

Wind cowls can be used in a hybrid ventilation system to provide an extra driving force for the ventilation; it should be implemented on the exhaust chimney and placed on the highest location on the building.

10 Small wind turbines for building purposes

10.1 General description

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.

10.2 The technology

There are two types of wind turbines: Vertical Axis Turbines (VAT) and Horizontal Axis Turbines (HAT). They can each be divided into two groups, driven by two different forces.

<u>Drag-driven wind turbines</u>

The drag-driven wind turbines are the oldest type of wind turbines, and are driven by the force that is created when the wind hits the blades. The rotor speed on a drag-driven turbine cannot exceed the speed of the wind. An example of a drag driven HAT is a traditional windmill, which utilize the pressure difference created by the blades dragging in the wind.

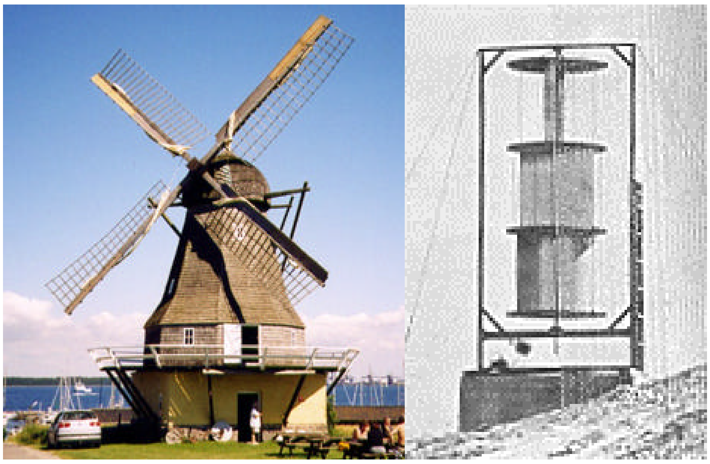

Figure 10.1. Examples of drag driven wind turbines. Left: An old traditional windmill (HAT). Right: A Stacked Savonius rotor (VAT).

The drag-driven wind turbines are rarely used today.

<u>Lift-driven wind turbines</u>

Lift driven turbines have blades shaped like airfoils and use the lift created when the air flows past the blades, to turn the rotor. The rotor speed of a lift driven wind turbine can be larger than the wind speed and thus a lift driven wind turbine can produce much more power with more efficiency than drag driven turbines.

Figure 10.2. Examples of lift based turbines. Left: A HAT 10 kW (at 14 m/s) BWC Excel from Bergey windpower. Right: A VAT Neoga® from Urban Turbines. It consists of a Darrieus type of turbine combined with Savonius blades for start-up.

Small-scale wind turbines can be used to generate electricity needed to run the components in the ventilation system. Some turbines have been designed for running the fan directly, via a drive shaft. Depending on the losses in the bearings, such a system can be very efficient because the energy is converted directly from kinetic to mechanic energy. It is however easier to regulate the fan, using an electric motor than a mechanical system. Therefor this kind of system is only considered useful in regions without electricity and where the ventilation rate is allowed to vary uncontrolled.

A HAT is usually more efficient than a VAT, but needs to be pointed directly into the wind to work efficiently. A VAT on the other hand is independent from the wind direction, and works efficiently in all horizontal wind directions. On rooftops the wind directions vary very much and can change very quickly. Therefore, a VAT is more suitable for rooftops than a HAT.

Another advantage of the VATs is the fact that they utilise the entire height of the wind turbine. Because of this a HAT is usually higher than a VAT with the same power. Therefore, the visual impact of a VAT is usually smaller than that of a HAT.

<u>New promising development of new lift driven wind turbine</u>

In July 2002 the “Vawtex” was voted Innovation of the Year at the Building Services Awards in London. The following announcement concerning this turbine is taken from www.arup.com

“Mike Rainbow and colleagues at the Harare office of the design engineers, Ove Arup, have developed a wind turbine able to rival electricity as a power source for ventilation. The cost of installing the Vertical Axis Wind Turbine Extractor (Vawtex) is similar to that for conventional ventilation. But it is much less noisy, has no fuel cost and causes no pollution. The Vawtex is designed to take advantage of the wind’s lift effect, which takes an aircraft off the ground. This additional force enables it to rotate three times as fast as if pushed by wind-speed alone. Mike Rainbow says it was an exhilarating moment when the prototype spun furiously in a mild breeze. The Vawtex, which is 10 feet tall, will rotate in winds less than 3mph (1,3 m/s) but it is also designed to turn less and less efficiently as the wind becomes dangerously high. Zimbabwe has no tunnel for high-wind testing; so the Arup team tested their turbine by putting it on a lorry and driving it at 75mph down a racetrack.”

The Vawtex is designed with a pair of periscope-shaped wind-cowls that turn in opposition to each other, providing passive supply and extract. The Vawtex is illustrated in figure 10.3.

Figure 10.3. Illustration of the Vawtex (www.arup.com)

To date the Vawtex has been made by hand, under increasingly difficult circumstances in Zimbabwe. The design has international patent pending and Arup are currently establishing a fabrication and development base in the UK. To date it is limited in its use to projects where Arup has a direct involvement. However, Arup expect the unit to be available on a broader commercial basis by the summer 2004, and will also be developing units specifically for the domestic market.

10.3 General design parameters

When planning to erect a wind turbine on a rooftop several parameters should be taken into account.

<u>Wind speed and direction</u>

A very important parameter to the performance of the system is the wind speed and direction. If detailed knowledge of this parameter is available it is easier to estimate the performance of the system. It is important to know how the adjoining buildings influence the flow of the wind, so they do not shelter the turbine form the wind.

<u>Sound</u>

Care should be taken not to exceed the maximum allowed sound pressure in and around the building. The sound production from the small-scale wind turbines on the market today varies form 0 to 78 dB(A) at a distance of 1 meter.

Visual impact

As mentioned earlier the visual impact of a wind turbine is often smaller for a VAT than for a HAT. It is difficult to say a anything in general about the visual impact because it is very dependent of individual parameters, such as the dimensions of the building, the architectural design of the building and so on.

Strength of the building

Before erecting a wind turbine it is necessary to investigate if the building structure can support the weight of the turbine. Moreover it should be investigated if the structure can withstand the vibrations from the turbine.

10.4 Feasibility

A wide range of small-scale wind turbines are available on the market today. The prices range form 1,500 € to 20,000 €. //www.bergey.com/. It is not possible to generalise the cost-effectiveness of a small scale wind turbine, because the energy production depends on a range of local factors. E.g. the speed and direction of the wind, the ventilation systems demand for electricity and so on.

10.5 Product information

Most of the small-scale wind turbines available on the market are HATs, but some VATs are available. In addition, special VAT's are made, where the turbine is combined with ducts or diffusers to enhance the performance. The latter have a low visual impact, but are often dependent upon the wind blowing in the correct direction /www.urbanturbines.com/

Specific product information can be obtained at:

Turby (The Netherlands)
Bergey windpower (USA)
Windside (Finland),
Wind Turbines Industries (USA)
Marlec Engineering (United Kingdom)
Proven (United Kingdom)
Vergnet (France)
Ropatec, (Italy)

General information on small wind turbines can be obtained at:

European Wind Energy Association (EWEA), www.ewea.org
American Wind Energy Association (AWEA), www.awea.org

10.6 Implementation in Hybrid Ventilation Systems

Small wind turbines can be used in a hybrid ventilation system to generate electricity needed to run the components in the ventilation system.

11 Solar chimneys

11.1 General description

A solar chimney works as a natural-draft device that uses solar radiation to move air upward, thus converting thermal (heat) energy into kinetic (motion) energy. At constant pressure air density decreases with increasing temperature. Air with a temperature higher than ambient air temperature is driven upwards by the buoyancy force. This physical phenomenon is exploited in passive stack ventilation. Air inside a building has very often a higher temperature than outdoor air, and therefore, it is driven through a stack by the buoyancy force. The buoyancy force (driving force) decreases as the difference between indoor and outdoor air temperature decreases. A solar chimney increases the exhaust air temperature, and therefore increases the "driving" force.

An illustration of a solar chimney is presented in figure 11.1 where PV cells have been mounted on the side of the chimney.

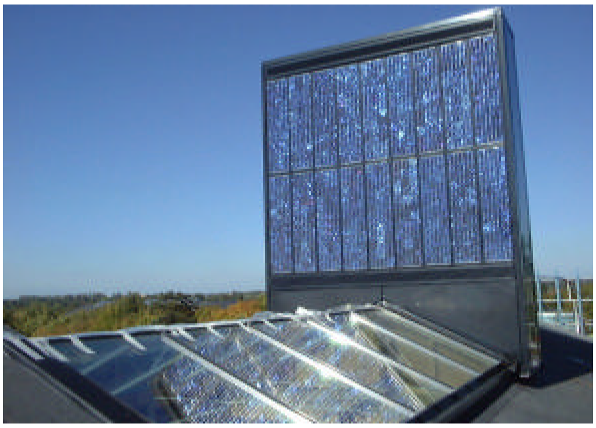

Figure 11.1 Solar Chimney at Lundebjerg, Denmark

11.2 The technology

A solar chimney is a kind of solar air collector, and so the general technology is very simple. As mentioned earlier solar chimneys convert solar radiation (heat) energy into kinetic (motion). Since air is a transparent medium (radiation-transmitting) it cannot be directly heated by solar radiation. Therefore, a solar chimney has to contain a solar absorber, which enables solar heat to be transferred to the air. There are many possible configurations of a solar chimney. The most common configuration is that utilizing the "greenhouse" effect - an air gap with transparent material (glass) on one side and solar absorber on the other side. The example of such configuration is a double facade, which, in some operation modes, also utilizes the solar chimney principle.

The sensitivity of a solar chimney to wind in terms of backflow is generally the same as the sensitivity of other passive stack ventilation systems. The risk of backflow with regard to wind can be minimized by a proper design of a solar chimney. A backflow in a solar chimney can also occur near cold surfaces due to negative buoyancy. The occurrence of such backflow can be eliminated by thermal insulation.

The driving force depends on the difference between mean air temperature in a solar chimney and outdoor temperature. There is a correlation between the solar radiation intensity and the air temperature inside a solar chimney. The decline of driving force, when only indirect solar radiation is available is significant. However, when heat storage is used, the temporary decline of the driving force, when a cloud is going over the sun, can be dampened.

There is a possibility to have a solar chimney assisted with wind catchers for both air supply and air exhaust. A wind scoop enables to catch breeze and supply air into a ventilated space. A small overpressure inside a ventilated space, caused by the wind scoop, would increase the flow rate through a solar chimney. A solar chimney could also be fitted with a kind wind cowl. The problem is a shape of a cross-section of a solar chimney, which is usually rectangular with a high aspect ratio. A contribution of a wind cowl to the solar chimney performance would significantly depend on the wind direction.

11.3 General design parameters

It is important to distinguish between the performance of a solar chimney and the performance of a solar chimney ventilation system. The performance of a solar chimney depends on many parameters (configuration of a chimney, geometry of a chimney gap, tilt angle, latitude, sunshine time, etc.). It is possible to optimize a solar chimney to achieve the highest performance for a specific season.

As far as the solar chimney ventilation system goes, a solar chimney contributes to the stack effect created by the difference between indoor and outdoor air temperature. In winter, when the indoor-outdoor temperature difference is high, a contribution of a solar chimney to the overall stack effect is lower than in summer, when this temperature difference is small. It is, therefore, desirable to have the highest performance of a solar chimney in summer.

11.4 Feasibility

The main asset of utilization of solar chimneys in ventilation is improvement of the performance of passive stack ventilation on hot sunny days, when there is a small difference between indoor and outdoor air temperature. Solar chimneys used for passive cooling, in countries with hot climate, could avoid mechanical cooling, and therefore to save significant amount of energy.

Even though the principle of solar chimney ventilation has been known for centuries, there are many possibilities how to employ modern technologies in the solar chimney design. One option is to replace glass with semi-transparent photovoltaic cells, which would power a DC fan. Such combination represents a fan assisted natural ventilation system, which could operate without an access to the power grid. The photovoltaic panels, in this case, could also feed a control system, including motorized dampers.

11.5 Product information

The solar chimney is usually fitted to the individual building situation and is designed by architects and engineers working on the specific project. Therefore, there is no general product information available at the moment.

11.6 Implementation in Hybrid Ventilation Systems

A solar chimney can be used in a hybrid ventilation system to increases the exhaust air temperature, and therefore increases the “driving” force in the ventilation system.

12 Integration of renewable energy in urban canyons

The urban environment is characterized by large variations in the density of buildings affecting the spacing between buildings and the height of buildings in cities i.e. canyon effect. This leads to large variations in the potential for integrating renewable energy in the built environment of urban areas and especially in the integration of renewable energy technologies in the facades and roofs of buildings. Wind cowls and wind turbines are normally placed on top of the roof, and are not affected much by the conditions in an urban canyon. However, solar energy applications may be placed at facades and are therefore largely effected by surrounding circumstances such as shade from buildings and trees. Solar chimneys should be placed on top of the roof and will therefore not be affected by shades from trees, however shades from other buildings higher than the buidling on which the chimney is placed could affect the performance.

It is difficult to generalize the effects of urban canyons on solar renewables, except that it is important to consider the sun/shade conditions before setting up a solar application. The following sections shortly describes the parameters to consider and which constrains are attached when integrating solar renewable energy in an urban canyon environment.

12.1 Sun/shade conditions in urban canyons

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.

In the following is illustrated an example a sunshade condition for a solar panel placed on the facade in an urban canyon. The chosen situation is illustrated in figure 12.1.

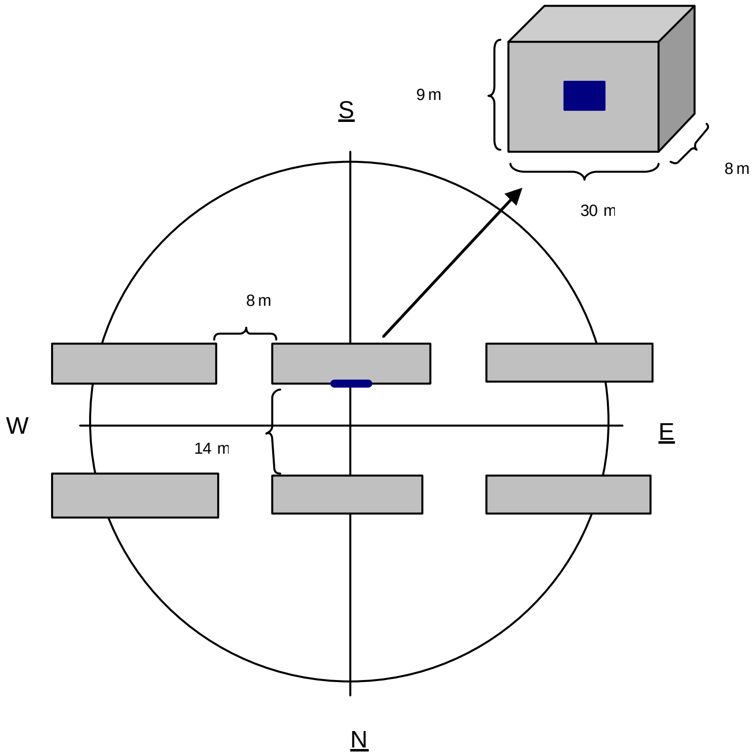

Figure 12.1. Illustration of the orientation and dimensions of the urban canyon to be analysed.

The canyon is oriented east/west with building blocks of 9 m in height and 30 m in width. The building blocks are placed on each side of a 14 m wide road. The solar panel is placed on the facade of the middle block oriented south.

As an example the shading of this solar panel is analyzed for a location of the canyon in Copenhagen Denmark i.e. latitude 55.5 and longitude 12.5. The shading has been analysed using a Danish shade programme, Soldia for Windows, developed at the Technical University of Denmark. The shading condition of the solar panel, viewed over a full year, is illustrated in figure 12.2

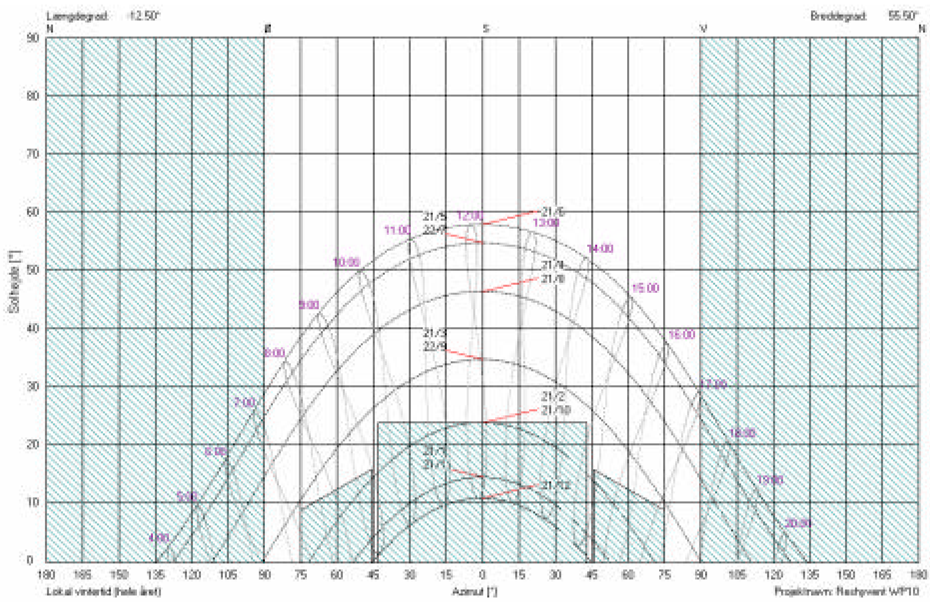

Figure 12.2. Shading condition for a solar panel placed in the canyon illustrated in figure 12.1.

From figure 12.2 it can seen that the solar panel is fully shaded in the winter months from November to February, however during spring, summer and autumn, from February to November, the panel will not be effected by shade from opposing buildings in the canyon. The two large shadows to the far right and left is due to the vertical position of the panel. At vertical position (tilt angle is 90 degrees) it is only possible to receive direct sunlight in a circumference of 180 degrees. This means, that when the sun is positioned to the north of east and west, as it will be in early mornings and late evenings in the summer, the solar panel will be shaded.

When dimensioning solar applications, the specific shade situation must be taken in to consideration, i.e. a solar shade analysis like the one illustrated above must be carried out.

<u>PV systems</u>

PV systems are very sensitive to shadow. If only a small fraction of the PV panels 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 eliminated 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 be mounted facing north.

If the location of the panels is close to the equator, the sun will rise close to the east and be at a large angle over the horizon in the middle of the day. This means that the surrounding buildings can be relatively high without casting shadow on the PV panels. If the PV system is located in the northern countries the sun rises in the north-east in summer and south-east during the winter, and is positioned much lower in sky than in southern countries. Especially in the winter the sun will be at a low angle over the horizon. This means that even small surrounding buildings can eclipse the sun from the panels in the winter, especially if the panels are facing east or west.

<u>Glazed balconies, solar air collectors & solar walls</u>

Solar renewable energy technologies used for heating (e.g. glazed balconies, solar air collectors & solar walls) are not as dependent on direct sunlight as PV systems are. These technologies will still function relatively well if a fraction of the collector is eclipsed from the sun.

Nevertheless, it is important to consider the sun/shade conditions before implementing the technology. When shading occurs the collector can only utilize diffuse and reflected radiation. Direct solar radiation carries larger amounts of energy than diffuse and reflected radiation and it is therefore still important to minimize the amount of shading on the collector surface in order to optimize the efficiency of the collector.

When considering the sun/shade conditions in urban canyons with respect to a solar thermal technology the same considerations as for the PV system are valid.

12.2 Geographical position

In order to estimate how the geographical position affects the yield of renewables, simple simulations has been carried out for cities in the four climate zones.

It is estimated that the wind direction and speed on rooftops in the urban environment is much more dependent on the geometry of the adjoining buildings than on the geographical position. Because of this, only renewables based on solar energy will be investigated.

Analyses have been carried out by simulating PV systems located in four specific locations in Europe. It is expected that solar thermal renewables will have approximately the same dependency of geographical position as PV systems. All the simulations have been carried out in the simulation program Bsim2002.

The locations are:

- Severe - Tromsø, Norway (latitude: 69.4°, longitude: 19.0°)
- Cold - Stockholm, Sweden (latitude: 59.3°, longitude: 18.0°)
- Moderate - Amsterdam, The Netherlands (latitude: 52.3°, longitude: 4.8°)
- Mild and warm - Nice, France (latitude: 43.7°, longitude: 7.3°)

In each simulation five (5) polycrystalline PV modules of 1 m² have been used. Four (4) of these have been mounted vertically and pointed to the west, north, east and south. The last one has been mounted horizontally. The power is calculated using the formula:

$$Q = e \cdot \left(I_{diffuse} + I_{direct}\right) \cdot A$$

Where

Q: The power of the PV module

ε : The efficiency of the module (10 %)

I: The solar radiation provided in the climate data[1]

A: The area of the PV module.

To obtain the annual yield, the power has been integrated over a year, using a time step of ½ hour.

[1] Climate data for Stockholm, Amsterdam and Nice is International Weather for Energy Calculations (IWEC) from ASHRAE and climate data for Tromsø is generated artificially.

Result of Bsim2002 simulation

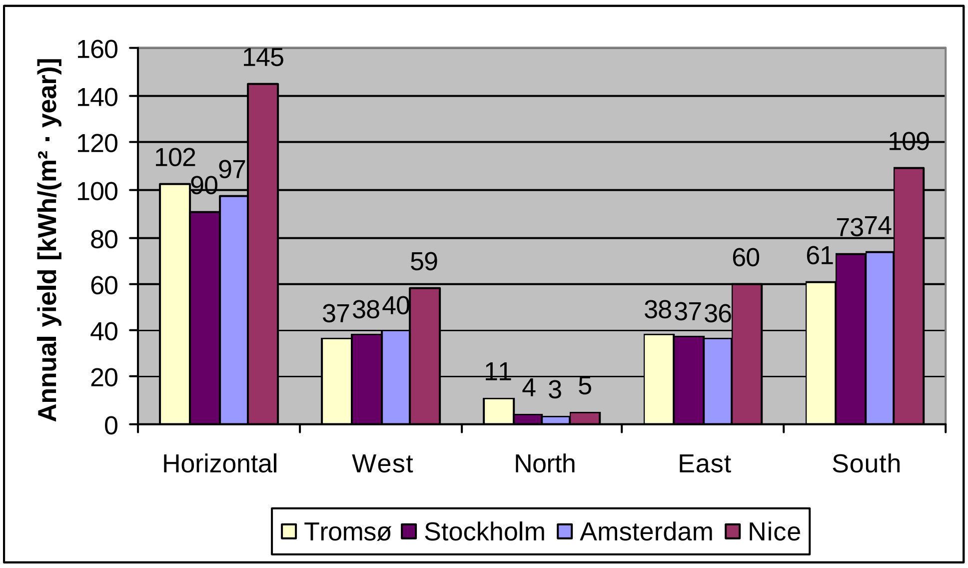

Figure 12.3: The result of the simulations. The PV modules are polycrystalline, with an efficiency of 10 %. The results for Tromsø are uncertain because the climate data used in the simulation is generated artificially, based on measurements.

In all four (4) locations, the PV modules produce more electricity, when mounted horizontally than when mounted vertically. This is because a PV module will be shaded some of the day when mounted vertically. But if the PV module is mounted horizontally no shade will fall on it during the day.

If the PV modules are mounted vertically the annual yield is largest if they are orientated to the south. Furthermore, it can be seen that the annual yield is almost the same weather the PV modules are oriented to the east or west.

If the modules are oriented to the east, south, west or mounted horizontally the annual yield is largest in Nice. The reason for this is that the energy in the solar radiation is more intense at low latitudes than at high latitudes. If the modules are pointed to the north, the annual yield is largest in Tromsø, while more direct solar radiation hit at high latitudes than close to equator.

If the modules are mounted horizontally, the annual yield is larger in Tromsø than in Stockholm and Amsterdam. It is assumed that the reason for this is that there are more clouds over Stockholm and Amsterdam than in Tromsø. This last phenomenon emphasises the importance of analysing each case independently when installing solar renewable technology.

The optimal tilt for a PV system will usually be in between vertical and horizontal, for mid European location (i.e. Amsterdam the optimal location is around 40 degrees facing south).

13 Summary and recommendations

The integration of renewable energy technologies in the RESHYVENT project focuses on solar and wind applications to substitute fossil fuel in the operation of hybrid ventilation systems. On the basis of existing renewable technologies this report gives an overview of the possibilities for integration of renewable into hybrid ventilation components.

When integrating renewables in a 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 remaining energy is supplied by renewable energy and third the remaining energy demand, if any, is supplied by conventional energy sources (fossil fuels). The third step includes optimisation of the efficiency of the conversion of fossil fuels. This report is focusing on step two the integration of renewable technology in hybrid ventilation systems. The following renewable applications have been described:

- Glazed balcony and sunspaces
- Solar air collector and solar wall
- PV systems
- PVT systems
- Wind cowls
- Wind turbines
- Solar chimneys

The described applications are all suitable in combination with a hybrid ventilation system, however whether the applications are feasible very much depends on the specific ventilation concept, location and urban environment.

A rough overview of the characteristics, urban constraints and recommendations for the use of the different applications are shown in table 13.

Concept	Description	Urban constraints	Recommendations
Glazed balconies	Existing or new balconies glazed for increase of the living area. Reduction of noise and for preheating of inlet air	Shadows and shelter in canyons	Recommended in open courtyards or at free exposed facades
Solar walls	Existing or new facades with glazing to improve the insulation level and for preheating of inlet air	Shadows and shelter in canyons	Recommended in open courtyards or at free exposed facades
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
PVT systems	Integration in facade for production of auxiliary electricity and thermal energy for preheat of ventilation air	Very sensitive to shadows and shelter in canyons	Recommended in open courtyards or at free exposed facades
Wind cowls	Increase of wind induced flows in extracts	No constraints	Recommended at roofs
Wind turbines	Auxiliary electricity for fans and controls in the ventilation system	No constraints	Recommended at roofs
Solar chimneys	Increase of stack driven flows in extracts	No constraints	Recommended at roofs

Table 13.1 Characteristics of solar and wind applications in urban areas.

14 Simulation tools

Software tools available for PV simulation

- PVS for Windows (Fraunhofer Institute for Solar Energy Systems - Germany)
- PV SYST (CUEPE / University of Geneva – Switzerland)
- PV F-Chart (F-Chart Software)
- PV*Sol (Dr. Valentin Energie Software GmbH – Germany)
- BSIM 2002 (Danish Building Research Institute, Denmark)

Software tools available for solar preheating simulation

- TRNSYS (thermal systems, fluids)
- TRNSAIR for windows 95/ NT(thermal Solar air systems) (Transsolar energietechnichnik GmbH - Germany)
- SimCAD (controls)
- THERM (two dimensional heat flow)

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