Room comfort and energy efficiency of an active double skin façade (ADF)

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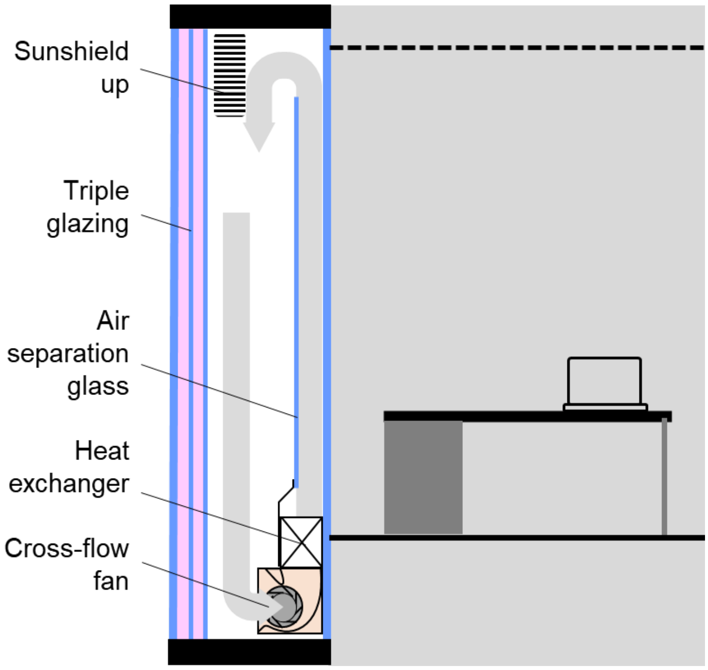
Abstract

Façades with a high portion of glass dominate urban architecture. Despite elegance and flexibility, they only partially meet the energy and comfort requirements of today and tomorrow. HyWin stands for Hybrid Window - in other words, a system in which the "window" is combined with a high-performance cooling and heating function as well as an integrated sunshield protected against wind and weather. The active double facade was developed for high-rise office buildings. However, thanks to minimal maintenance costs, the innovative system is also suitable for residential and hotel building, for exterior skin renovations, and for buildings with lower heights. The advantages of HyWin are evident in extreme weather conditions, and particularly when sustainability and energy efficiency requirements of a site development are high.



1. Design

HyWin is a prefabricated module hermetically sealed against the outside climate with a triple glazing system. Room and Hywin module are separated by a single, openable safety glass. This level is dust tight but not pressure tight. Therefore, if there are different vapor pressures, moisture will be balanced between room and module. Integrated in the module is a highly efficient fan coil unit (heat exchanger and crossflow fan), a customized sunshield based on venetian blinds or textile and an additional air separation glass. The fan coil at the base of the HyWin module is almost invisible and does not affect the window transparency.

Fig. 1

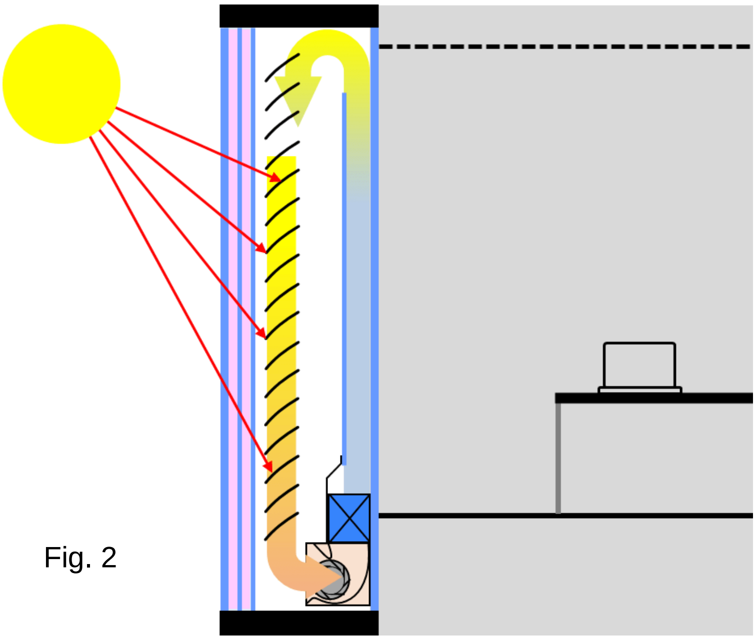


Fig. 2

2. Summer operation

The solar radiation is absorbed by the sunshield and removed by the heat exchanger. The temperature in the closed HyWin module is regulated to a temperature that is several degrees below the desired room temperature. Heat collected by the façade is stored in geothermal probes, most of the time without heat pumps and reused for heating in winter.

The cooling power for room related internal loads is restricted to 80-100 Watt per m2 HyWin surface. The electric energy to drive the fans may be produced by small, façade integrated PV modules. With HyWin the PV production and its use correlate perfectly.

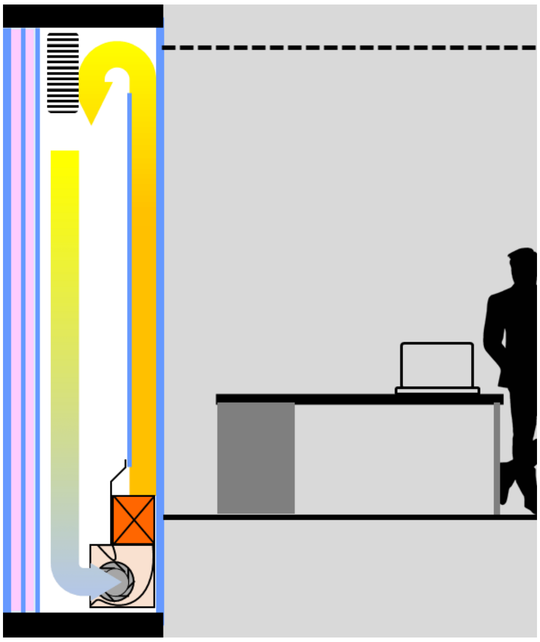


Fig. 3

3. Winter operation

The heat exchanger is supplied with water up to 32°C and ensures a comfortable indoor climate even at extremely low outside temperatures. Conventional floor heating systems as well as the compensation of the cold air drop are not needed. Anergy stored in geothermal probes or energy piles during summer is used and brought to the required temperature level by heat pumps. On cold days any available solar radiation will first be used to heat your office or room. The fan will work at very low speeds or even shut down because the natural convection will drive the air stream.

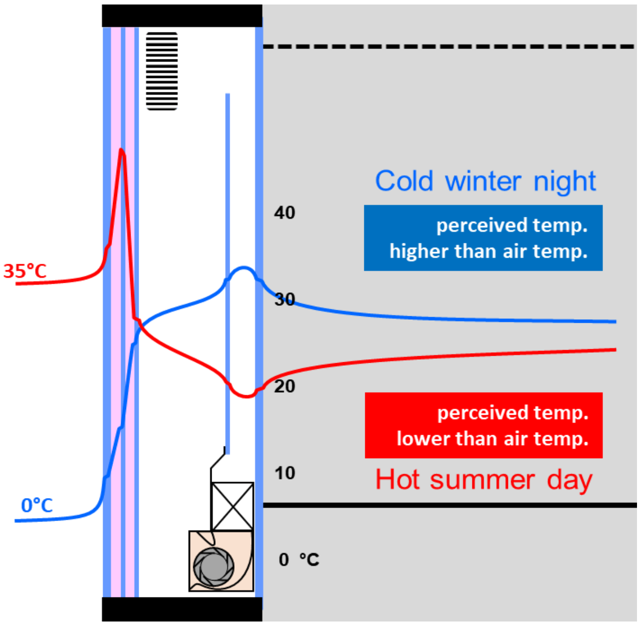


Fig. 4

4. Comfort by radiation

The temperature of the inner HyWin window-pane is lower in summer and higher in winter. Subsequently a major part of the required energy (over 50 %) will be covered by radiation of the room-oriented glass-pane (Stefan Boltzmann), the rest by convection. Compared to conventional facades, the cold radiation in winter and the hot radiation in summer are reversed, thus improving substantially the room comfort. Therefore, workspaces can be placed closer to windows. With internal loads up to 25 W per m2 floor space, HyWin requires no additional cooling or heating.

5. Maintenance and lifetime

As with conventional façades, only one exterior surface and the inner safety-glass require cleaning. All components can be serviced or replaced via the openable interior safety-glass and a service flap below the intermediate floor. All components of the HyWin module are based on long established and proven technologies with reliability track records. The MTBF (meantime between failure) of the cross flow fan is specified with 50'000 hours. An optimal design of the fan coil (combination of crossflow fan and heat exchanger) will limit pressure drop at full speed below 20 Pa and therefore keep the fan noise minimal. The temperature and humidity cycles are compared to CCF solutions significantly lower and will enhance the lifetime of all integrated elements and reduce maintenance cost.

6. Air exchange

The necessary air exchange to keep the CO_2 level in the room on a specified level is not integrated in the HyWin system. Without considering openable windows, there are two possible designs:

a) Centralized In- and Outlet channels (parallel to the elevators) in the middle of high-rise building. This may be of interest: Optimized inlets shown in Fig. 6 and outlets in the depth of the room may improve cooling power by 50 % (by increasing the heat transfer coefficient).

b) Air exchange units with small integrated heat recovery systems and related, small in- and outlets below or besides the HyWin modules. We don't recommend this solution.

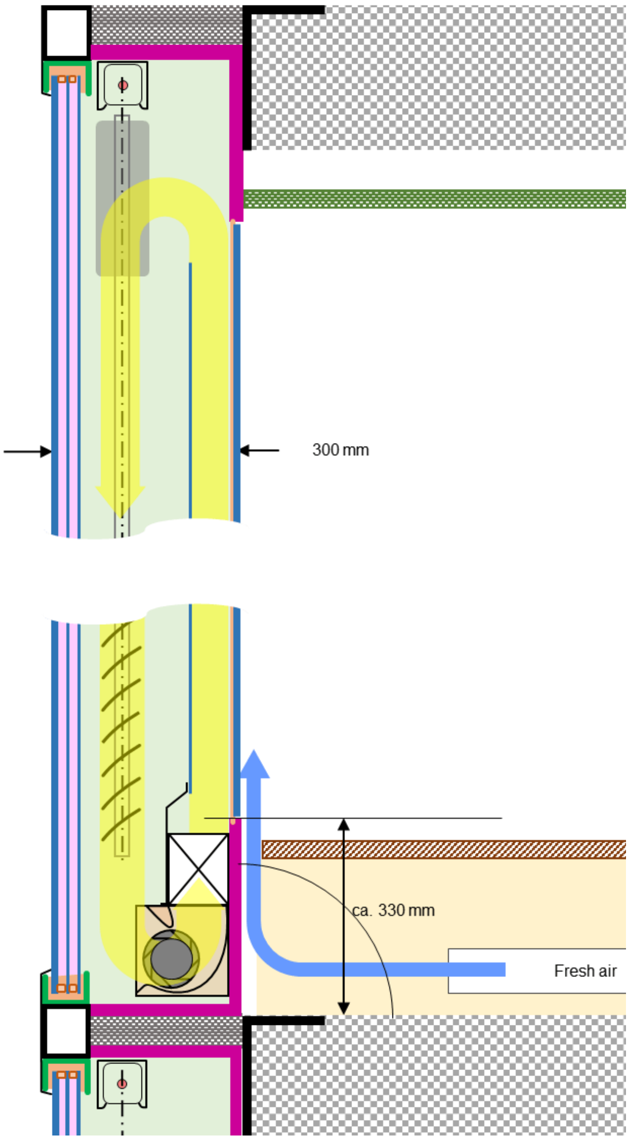


Fig. 5

7. Energy management

Today, areas with hundreds of apartments and one or more high-rise buildings are usually supplied by local "heating" networks. To avoid CO_2 production (oil and gas burners) and to save electric energy is becoming more and more important. Therefore, architects and engineers try to provide the necessary energy for heating, cooling and hot water supply by heat pumps and seasonal energy storages (hundreds of geothermal probes). Many of these systems have a problem after two or three years. Because the network consumes too much energy, the seasonal storage undercools. The solution is: Regeneration of the geothermal probes with hybrid collector-fields (photovoltaic electricity and warm water) on hot days. To collect sufficient energy requires a large area on the roof. In high-rise buildings – the roof size is small related to the building volume. The ratio gets smaller with every additional floor.

With HyWin, the challenge related to local "heating" networks is different. HyWin produces, if all sun-oriented facades are equipped by such modules, too much energy and will eventually overheat the seasonal storage. To keep the temperature of seasonal storage within limits the planners need first to know the behavior of their geothermal probe field. In a second step they need to optimize the energy balance:

a) selection of a low triple glazing g Value (usually 0.3)

b) design of the façades with an optimal distribution between transparent and opaque elements

c) shadowing the façades with horizontal and vertical elements (mullion/transom)

d) identify consumers in the same area they need anergy or process energy also at summertime.

8. Test Unit (Location: Rifferswil, ZH, Switzerland)

Fig. 6

Fig. 7

Fig. 8

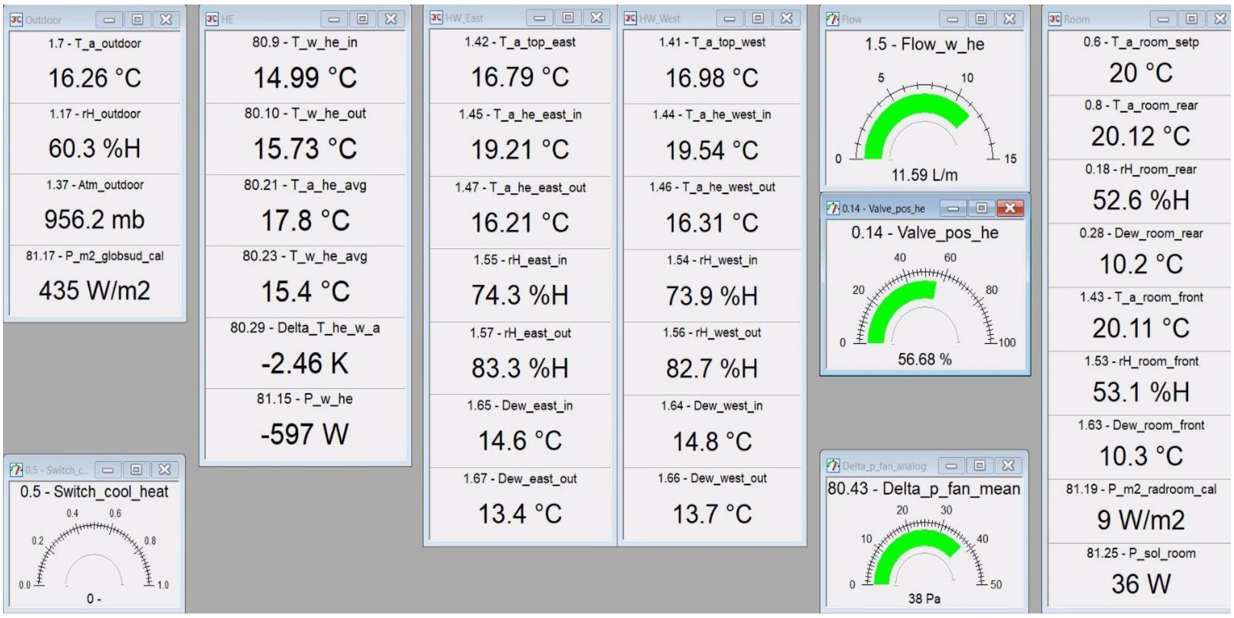


Fig. 9

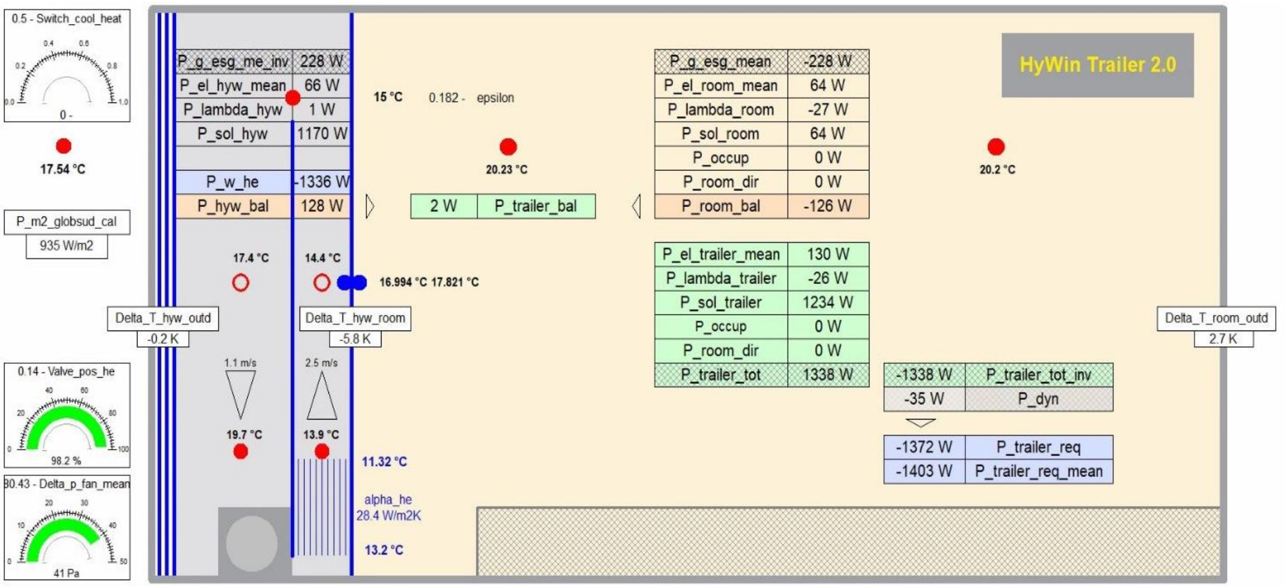


Fig. 10

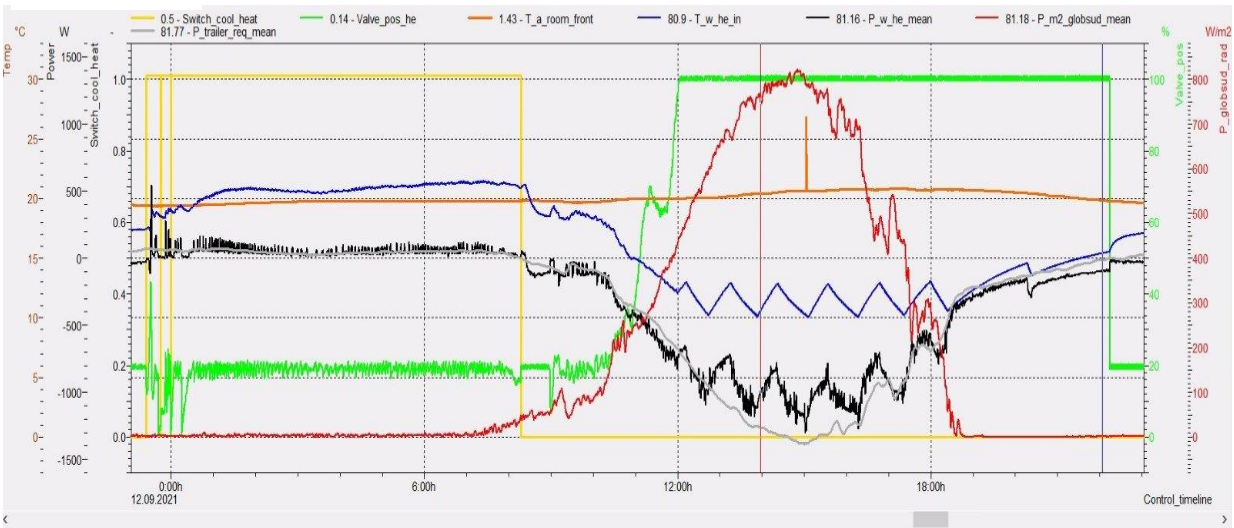


Fig. 11

9. Concept Validation with a Test Unit

With the help of Swiss Climate Foundation we could design and build a Test Unit (Fig. 6) which has a big HyWin Module (2.0 by 2.5 m). The volume of the testroom is about 25 m^3 and is equipped with a datalogger (Almemo 5690), about 50 sensors and a control unit (Dolder eNet 1). At this location there is no geothermal probe. Therefore a second trailer simulates a geothermal probe and supplies cold (with an air/water heatpump) or warm water, whatever is needed. The temperature level of this supplies is controlled by the outdoor temperature.

Fig.7. shows the HyWin Module with “venetian blind sunshield”, Fig. 8 our “back office” with the Almemo controller (right), a second laptop and a bigger monitor on the left side. The “room controller” and all necessary installations are installed on the back wall. One of the most important measurements is the thermal power supplied/removed by the heat exchanger. This measurement is based on a magnetic-inductive massflowmeter and a precise ΔT measure-ment with Platin resistors. Other input signals are: outdopor solar power on the vertical, south oriented HyWin module (Thermopile protected with quartz glass), the thermal power which is transferred between HyWin module and room, many temperatures and relative humidities, all electric consumers and the Δp of the crossflow fan. A data link allows to monitor all values remotely as well as to adjust constants and parameters.

Fig. 9 Shows the majority of the measured parameters.
From left to right: outdoor values, heat exchanger, right and left half of the HyWin module, some analog indicators and room sensors.

Fig. 10 Shows the processchart with the current energy balance of the HyWin module (grey), the energy balance of room (ocher) and the energy balance of the whole trailer (green).

Fig. 11 Shows a typical timeline depiction on a nice sunny day:
Solar power (red) - heat exchanger inlet temperature (blue) - position of mixing valve (green) - required and real cooling power (grey and black).

10. Summary

- HyWin solves the problem where it starts. HyWin separates the outer climate from the room climate. Changing outdoor conditions are quickly compensated. Temperature control will be much easier.

- HyWin will replace todays heating and cooling systems. Compared to CCF there is no need for dry air to prevent condensation inside the cavity. This saves tubing, compressors, air dryers but also protects the integrated sunshield from damages through aging and outgassing. HyWin allows better use of the given building volume. All installations including air exchange may be integrated in a intermediate floor with a height of ~ 25 cm. Investment and life cycle cost should be, compared to CCF or Double Skin Façades (DSF), similar or lower. Because HyWin integrates all heating/cooling functions in the façade and requires less valves, tubing and controllers, it will become a low-tech solution.

- “Stefan Boltzmann” radiation will improve comfort.

- HyWin works with high efficiency heat exchangers (alpha bout 30….40) – therefore with bigger ΔT than free cooling and floor heating systems. The electric pump energy to keep the mass flow on a necessary level is smaller.

- As long as the heatpumps run exclusively by renewable energy (electricity produced by hydroelectricity, photovoltaic, wind or biomass) and a good design of the local heating network, the development can be labeled “green and sustainable” and will be less sensitive to future climate changes.