HEAT RECOVERY VENTILATION WITH CLOSED-LOOP GROUND HEAT EXCHANGE

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ABSTRACT

In this article, it will be shown how heat recovery ventilation with closed-loop ground heat exchange performs in practice, in a residential building in Nijeveen, The Netherlands. A state diagram is presented to explain when heat recovery and/or ground heat exchange is used during the year.
The correlation between ground temperatures and air temperatures shows how the ground preheats the incoming outdoor air from -13°C to 0°C in winter, and precools the incoming outdoor air from 30°C to 23°C in summer. After preheating or precooling, the outdoor air enters the ventilation unit where heat is recovered (only in winter) and the air is distributed to the rooms.
The benefit of heat recovery in winter is expressed in terms of avoided heating relative to ventilation without heat recovery and results in 3899 kWh. The benefit in summer is expressed as free cooling, with reference to the indoor temperature, and results in 950 kWh.

KEYWORDS

residential heat recovery ventilation, ground heat exchange, monitoring, seasonal performance factor, bypass

1 INTRODUCTION

Ventilation of modern residential buildings is often combined with additional technologies to bring fresh air into the building in the most comfortable and energy efficient way. As such, balanced ventilation with heat recovery can be combined with ground heat exchange. Because the ground temperature reacts slower than the air temperature, often the ground can be used to preheat the incoming outdoor air in winter, and precool the incoming outdoor air in summer. In this article, the results will be shown how balanced ventilation with closed-loop ground heat exchange performs in practice, in a residential building in Nijeveen, The Netherlands.

2 TWO TYPES OF GROUND HEAT EXCHANGE

Two variations of ground heat exchange systems exist. First, an open system where outdoor air is led through pipes in the ground, before entering the building and going through the heat recovery unit. For a description of the open system, see the references (Cremers, 2012).

Second, a closed system (see fig. 1) where outdoor air is led through an air-liquid heat exchanger before entering the heat recovery unit. The liquid is a glycol-water mixture that is flowing through a tube. Most part of the tube is horizontally installed in the ground (ground collector) where the liquid picks up the heat (or cold) from the ground (Vollebregt, 2011 and Stege, 2012).

Figure 1: Representation of the ventilation system. Green: outdoor air; Red: supply air; Yellow: extract air; Brown: exhaust air; Grey: the ground collector with glycol-water mixture.

Closed-loop ground heat exchange is preferred, because it is easier to install, and less prone to damage because of natural settling of the ground or digging into the ground after installation. The closed-loop system also avoids potential microbial growth problems. Last, closed-loop ground heat exchange needs less area as it can be installed in a meandering pattern.

3 EXPLANATION OF THE TECHNOLOGY

Balanced ventilation with heat recovery and ground heat exchange is explained using fig. 2. The horizontal axis shows the outdoor temperature. The black line is the desired indoor temperature. For heat recovery ventilation, the green line represents the supply temperature of the fresh air that enters bedrooms and living room via supply air grilles.

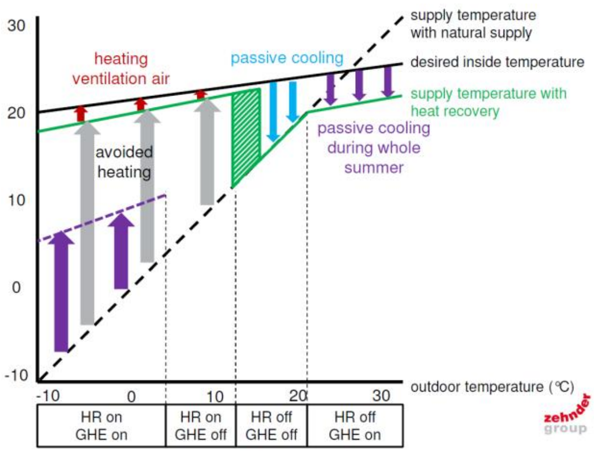

Figure 2: Schematic principle of balanced ventilation with heat recovery (HR) and ground heat exchange (GHE).

In winter, the necessary heating to bring the incoming fresh air to the desired temperature (red arrows) is low. The avoided heating when compared without heat recovery is shown by the grey arrows. This saves costs for heating the internal climate. Ground heat is used when possible to keep the heat recovery unit free of condensation and ice so that the mass balance is maintained.

Under certain conditions, the bypass is opened automatically to prevent too high supply air temperatures. Now, the fresh air enters the rooms without energy exchange. The green line follows the dashed black line. This is called free cooling as the supply air temperature is below the indoor air temperature (blue arrows).

In summer, the ground temperature is lower than the outdoor air, and even lower than the indoor temperature. Thanks to the ground heat exchange, free cooling is therefore available throughout the summer and this raises the comfort level in every room of the house (purple arrows).

Ground heat exchange is not used for outdoor temperatures between 7°C and 23°C, but these values can be changed according to the location.

4 THE MONITORED HOUSE

In Nijeveen (The Netherlands), the ventilation of a residential building has been monitored for a full year. For the monitoring period, the heat recovery ventilation had a fixed amount of fresh air of 220 m3/h. The closed loop ground heat exchange consists of the unit ComfoFond-L (positioned next to a heat recovery unit) and the ground collector. In this project the ground collector is a 100 m long polyethylene tube with an outer/inner diameter of 25/17 mm. The collector is installed at a depth of 1.20 m in the ground and filled with a glycol-water mixture.

The collector tube is going from the unit in the attic straight down to the basement floor. At the front door of the house it is entering the ground and runs around the house to the backyard. In the backyard it makes a few turns and goes back along the same side of the house and up to the attic again. It is advisable to respect a minimal tube spacing of 60 cm, but in this project the distance is 30 cm in some segments.

Ground heat exchange is automatically switched on/off by a pump in the ComfoFond-L unit. In this project, the pump is running for outdoor temperatures below 7 °C and above 16 °C. The fresh air is distributed throughout the house by round metal ducts branching off to the various rooms. Stale air is returning from kitchen, toilets and bathroom to the heat recovery unit again before being exhausted to the outside.

Flow rates, temperatures and settings of the ventilation system have been collected with an interval of 1 minute, and afterwards 1 hour averages are calculated to give statistical results for July 2011 until August 2012. In spring 2012, some data is missing because of hardware problems with the monitoring equipment.

5 VENTILATION WITH GROUND HEAT EXCHANGE IN PRACTICE

In fig. 3, the ground temperature at 1.20 m depth and the outdoor air temperature are shown. The dampening effect of the ground is visible. At this depth, the ground temperature varies between 5 and 16 °C for outdoor air temperatures between -15 and 35 °C.

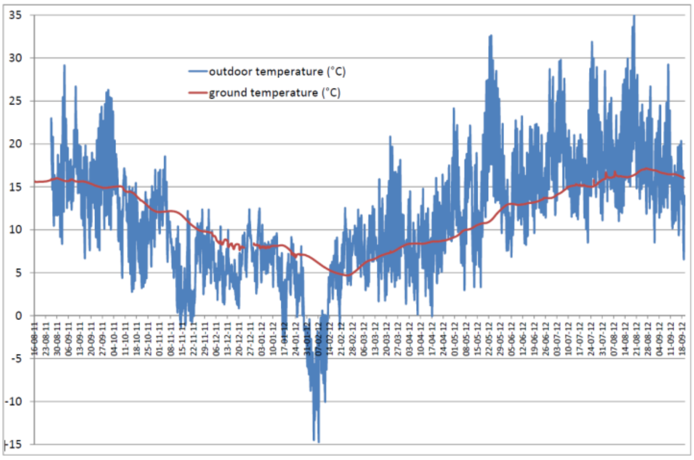

Figure 3: Ground temperature (1.20 m depth) and outdoor air temperature.

There are four possible states for this ventilation system (see also fig. 2), depending on whether heat recovery (HR) is used and/or ground heat exchange (GHE) is used. Fig. 4 shows that in the cold season heat recovery is used, with ground heat exchange whenever the outdoor air was below 7 °C (mostly at night, and during cold days). In the warm season heat recovery is not used (ventilation with bypass open), and for outdoor air temperature higher than 16 °C the ground cools the fresh air even further (afternoons and warm nights). In this project with the mild Dutch sea climate, ground heat exchange is used during 55% of the monitored time.

The preheating and precooling effect of the ground heat exchange is shown in fig. 5a. For outdoor temperatures lower than 7 °C, the fresh air is preheated by the ground. For outdoor temperatures higher than 16 °C, the fresh air is precooled by the ground.

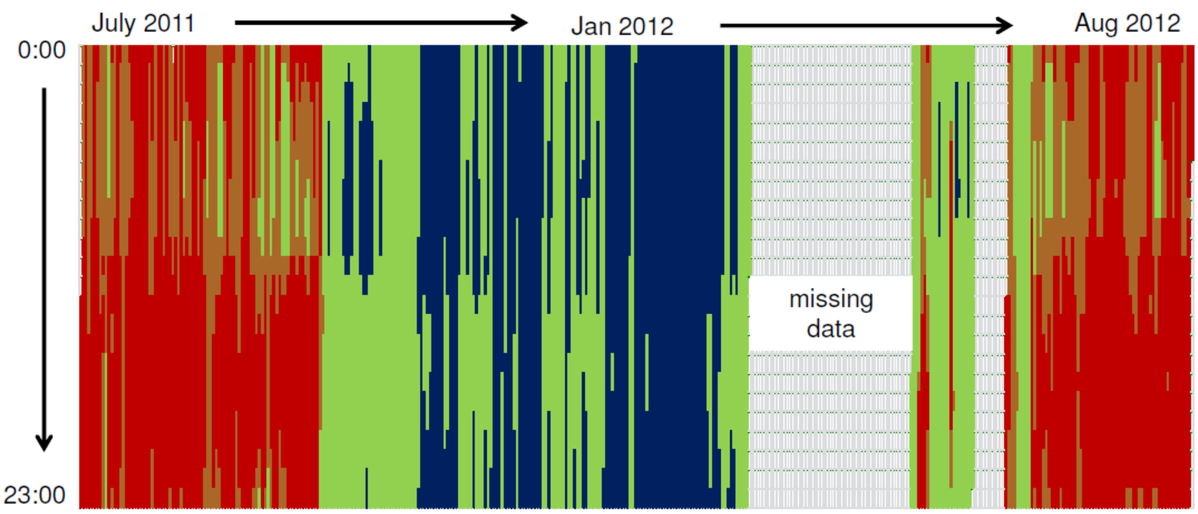

Figure 4: State diagram. Blue: HR on, GHE on; Green: HR on, GHE off; Orange: HR off, GHE off; Red: HR off, GHE on.

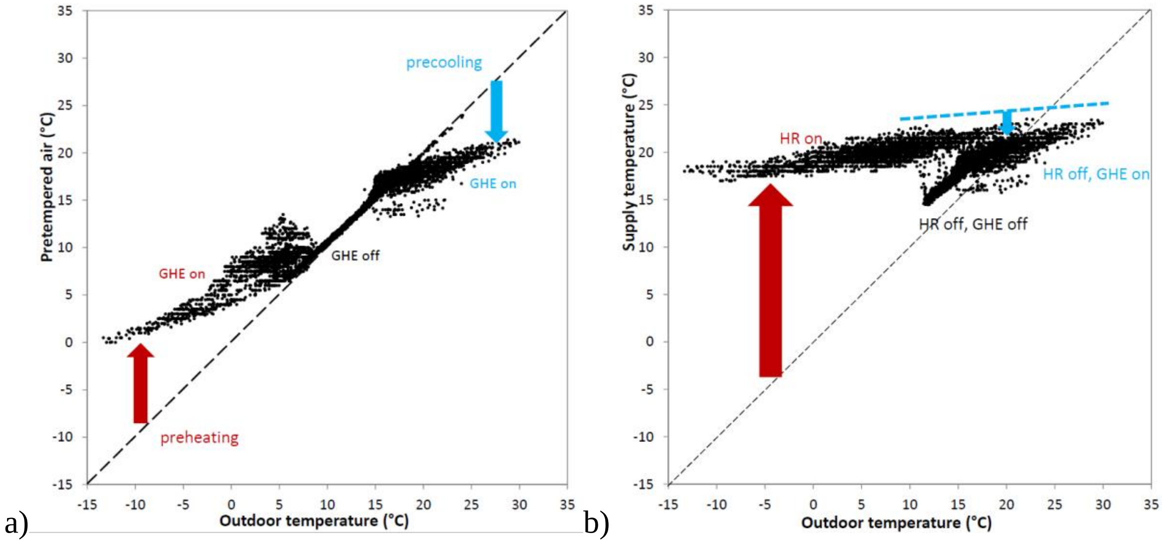

Figure 5: a) Air temperature after ground heat exchange and b) supply temperature as a function of outdoor air temperature.

Optimal performance would be that the air temperature is preheated in winter to 5°C (minimal ground temperature) and precooled in summer to 16°C (maximal ground temperature). In this project the air temperature is minimally 0°C and maximally 21°C. Detailed analysis has shown that the performance of the ground heat exchange could be improved with better positioning of the ground collector. The collector should be laid out more evenly in the ground, respecting a minimum distance between two tubes of 60 cm.

After the heat recovery unit, the fresh air is increased in temperature when the heat recovery is on (see fig. 5b). Even with outdoor temperatures as cold as -13 °C, the fresh air is brought to the living rooms at a comfortable 17 °C. This reflects the huge energy saving capacity, as the heat demand for ventilation is decreased enormously. In fact, the average heat recovery efficiency is measured as 92% over the entire heat recovery season.

If the heat recovery is off, the ground heat exchange helps to keep the fresh air temperature low, so that the supply temperature is always lower than the indoor temperature. This means free cooling for the whole warm season, and not only during cool summer nights. The free cooling helps to keep the cooling load of the house low in summer, in the same way as proper shading equipment.

6 ENERGY SAVING

The performance of the ventilation system in terms of energy is given in table 1. The seasonal performance index SPF is calculated as the energy gain divided by the energy consumption, both inside and outside the heat recovery season.

The energy saving of the heat recovery is calculated in terms of avoided heating. The reference situation is that fresh air comes in at the same temperature as the outdoor air. The avoided heating thanks to heat recovery is calculated using the difference between supply air and outdoor air and the actual air flow rate. This saving is achieved using electrical energy by the fans of the heat recovery unit and the pump of the ComfoFond-L ground heat exchanger in the heat recovery season.

With heat recovery off, the free cooling for the house is calculated using the difference between indoor temperature and supply temperature and the actual flow rate. This free cooling is again achieved using electrical energy by the fans of the heat recovery unit and the pump of the ComfoFond-L ground heat exchanger outside the heat recovery season.

For this monitored installation, the values of the SPF inside en outside heat recovery season of 7 and 2 respectively are quite low compared to the reported 17 and 8 (Cremers, 2012). This is because the fans and the pump take more energy. The first due to from resistance in the air distribution system and the second due to a higher pump speed setting than necessary.

Table 1: Annual energy benefit of heat recovery ventilation and seasonal performance factors

	Energy gain	**Electrical consumption**	**Seasonal Performance Factor SPF**
Avoided heating load	3899 kWh	593 kWh	7
Free cooling load	950 kWh	408 kWh	2

7 CONCLUSIONS

The combination of a balanced ventilation unit with heat recovery and ground heat exchange can provide ventilation which is both energy efficient and comfortable.

In the cold season, the ground heat exchange in combination with heat recovery ensures that fresh air is brought into the rooms in a stable and comfortable way, whilst keeping the heating demand for ventilation low. In the warm season, the ground heat exchange ensures free cooling for the whole summer (not only cool summer nights), keeping the cooling load of the house low. Along with proper shading measures in the house, the ventilation system with ground heat exchange also prevents overheating of the house.

8 REFERENCES

Cremers, B.E. (2012). Long term monitoring of residential heat recovery ventilation with ground heat exchange, REHVA Journal, August 2012, 41–46.

Stege, C. ter (2012). Geen bevriezing of oververhitting bij ventileren met aardwarmte (in Dutch), *Gawalo*, November 2012, 14–17.

Vollebregt, R. (2011). Koelen zonder energiegebruik door zomernachtventilatie (in Dutch), *Verwarming & Ventilatie*, May 2011, 268–271.