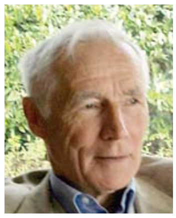
Performance of a nearly Zero House in Belgium

Case study in the frame of IEA ECB annex 58 Research Program







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This case study aims in identifying the best way of verifying the actual performances of a very well insulated building exposed to very significant solar heat gains.

Keywords: nearly zero energy building, nZEB, net zero energy building NZEB, house, energy efficiency.

The method considered is combining measurements with computer simulation; it has already been tested in the frame of the previous IEA ECB annex 53 project "Total Energy Use in Buildings: Analysis & Evaluation Methods": the measured consumption of a dwelling was compared with the simulated consumption on different time bases. The new idea consisted in using the measured indoor temperatures as input data in the simulation.

Satisfactory results were obtained, but this was a relatively "easy" case: a poorly insulated building with negligible solar heat gains and direct electric heating.

The passive house considered in the present case study might be much more difficult to characterize: solar heat gain plays an important role and, even during the so-called "heating season", the net space heating demand is, most of the time of the same order of magnitude as other power demands (sanitary hot water, appliances and lighting).

"Passive" verifications based on a recording of indoor temperatures and energy consumptions without interference with current life of building occupants might require too long periods of observation and produce too inaccurate results.

"Active" verifications will be therefore also considered: they will consist in analyzing the building response to some artificial variation of heating power thanks to some "co-heating" equipment.

The house

The house is built in a very open environment; it's South oriented, with large glazing area on that side (**Figure 1**). Other façades (**Figure 2**) are much less open to sunshine. According to Passive House Planning Package (PHPP) description, the building has the following characteristics:

- Internal volume: 894 m³
- Reference heated floor area: 232 m²
- Windows: 44 m² (with 31 m² South oriented), triple glazing, U=1 W/m²K
- Opaque walls: 244 m², U=0.12 W/m²K
- Roof: 174 m² U=0.1 W/m²K

This gives, for the whole envelope, a total area of 583 m² and an average U value of 0.174 W/m²K. According to the pressure test result, the infiltration is of the order of 0.32 1/h at 50 Pa of overpressure. Per unit of floor area, the nominal heating power and the yearly heating demands are supposed to be equal to 9 W/m² and 14 kWh/m² if the whole house is heated.

Figure 1. South-West corner.

Figure 2. North-West corner.

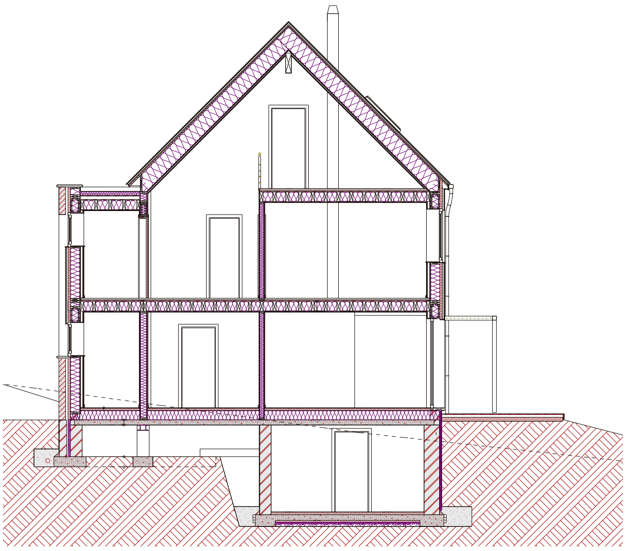

Figure 3. Vertical North-South cross section.

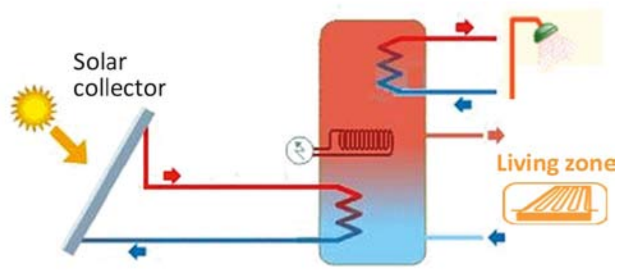

Figure 4. Boiler equipped with electric resistance and solar thermal collectors, supplying heat to the living zone heating floor and providing domestic hot water.

Energy systems

The large South-oriented glazing is protected from outside by motorized blinds.

The house is ventilated thanks to a dual-duct mechanical system with fresh air pre-heating through both ground-connected heat exchanger and air/air recovery (effectiveness estimated to 65%).

The house ground floor is equipped with a water floor heating system.

Electric floor heating is used in both bath rooms (installed powers: 250 and 150 W in the large and small bath rooms respectively).

The office room of the second floor is occasionally heated by an electrical convector.

Ground floor space heating and sanitary hot water systems are supplied from a common hot water tank heated by an electrical resistance of 4 kW and by 4 m² of evacuated tubes solar collectors installed on the roof.

The solar heat exchanger, the electrical resistance and the (space and sanitary) heat use connections are located at the bottom, at the middle and at the upper part of the tank, respectively (**Figure 4**).

The electrical resistance is controlled in such a way to maintain a temperature of 55°C in the upper part of the water tank. 22.5 m² of PV collectors are also installed on the roof; their nominal power is of the order of 4500 W. They are expected to produce a total of the order of 4200 to 4800 kWh/year.

Control strategy

In order to reduce the overheating risk in the living room, external blinds openings are automatically adjusted every half hour according to the indoor temperature, provided the heating system and the indoor lighting are switched OFF.

The mechanical ventilation is sized for a nominal air flow rate of 350 m³/h. Electric fan provides thee rotation speeds. Occupants usually impose the middle rotation speed corresponding to 45% flow rate reduction factor.

The outdoor air is supplied through 8 outlets (**Figure 5**):

- Ground floor: 3 in the living room
- First floor: 1 in each of the three sleeping room and 1 in the office room

- Second floor: 1 in the west room

Extractions are realized through 9 inlets:

- Ground floor: 2 in the kitchen, 1 in the toilet and 1 in the technical room
- First floor: 1 in each of the two bath rooms, 1 in the washing room and 1 in the toilet
- Second floor: 1 in the east room.

In nominal conditions, the air should be distributed as follows:

- Ground floor: supply 150 m^3/h, extraction 130 m^3/h
- First floor: supply 200 m^3/h, extraction of 185 m^3/h
- Second floor: supply and extraction of about 35 m^3/h

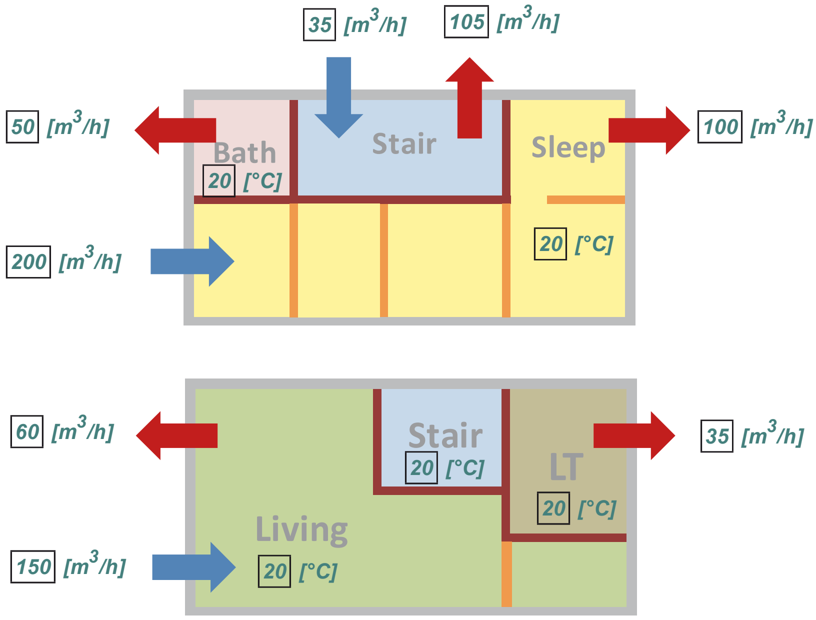

Figure 5. Simplified scheme of the house floor building zones with nominal outdoor air flows.

In winter time, the water temperature of the floor heating system is usually maintained between 28 and 30°C.

The building is occupied by a four people family (two parents and two children). All of them are out (for work and school) during week days. The hot water consumption is estimated to 200 l and 7 kWh per day. This heat demand is almost completely covered by the solar system in summer time.

Measured and estimated consumptions

Electrical consumption was manually recorded on a two year period (**Figure 6**). It corresponds to the integration of the total electricity consumption of the building. Negative slopes along this curve corresponds to time periods during which the PV collectors are producing more electricity than required and sending back energy to the network.

The total electricity consumption and the PV cell production recorded from 1st January to 31st December 2012 are plotted on **Figure 7**. The difference is provided by the grid.

The corresponding measured electricity consumptions devoted to the boiler, bath rooms electric floor heating and fans are plotted in **Figure 8**. The electricity consumptions devoted to other uses (lighting, appliances and pumps) are deduced from the energy balance.

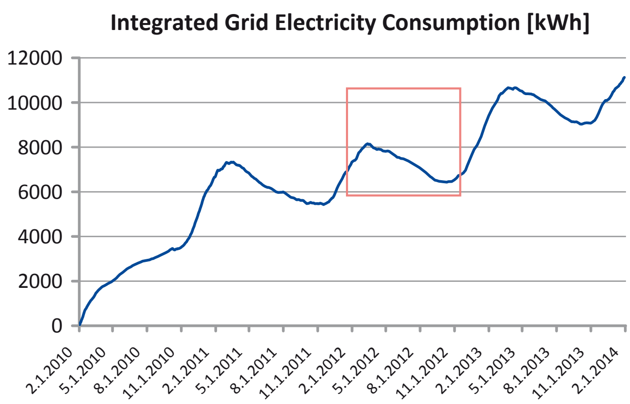

Figure 6. Integrated total electricity consumption (electricity counter).

The "fans" curve corresponds to the consumption of the fans of the mechanical ventilation system. This consumption (173 kWh/yr) is marginal (it's even null in some periods during which the ventilation was not operational).

An energy balance of the measured electricity consumption is provided in **Figure 9**.

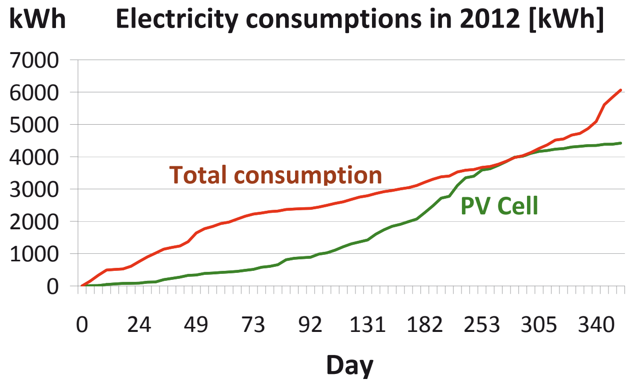

Figure 7. Measured total electricity consumption W_{total} and PV cell production W_{PV} for a year.

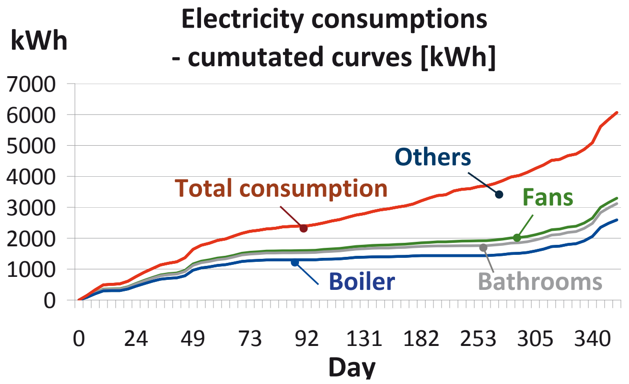

Figure 8. Measured total electricity consumption including the boiler resistance for space heating and DHW, the electric floor heating in the bathrooms, the fans and the other uses (lighting, appliances and pumps) for year 2012 (cumulated curves).

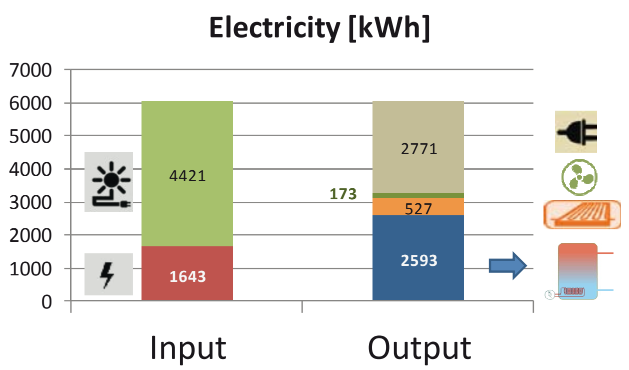

Figure 9. Breakdown of electricity consumptions for year 2012.

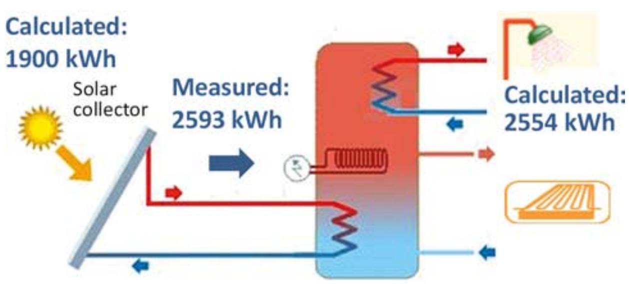

Figure 10. Energy balance of the boiler for year 2012.

If not taking the lighting and appliances consumptions, this house can be considered as a "nearly zero energy building": the thermal and PV collectors are roughly covering the whole (space and sanitary water) yearly heating demand.

Space heating and sanitary hot water consumptions provided by the boiler are not actually distinguished in these records (only the total is actually measured). **Figure 10** provides a balance of the boiler energy inputs (solar thermal collectors, electric resistance) and outputs (domestic hot water production and floor heating in the living zone).

The sanitary hot water consumption (2554 kWh) on Figure 10 corresponds to an extrapolation from records having been taken before the installation of the solar system (7 kWh per day). The production of the solar thermal collector is expected to reach 2000 kWh per year. The heating demand of the living zone computed through a dynamic simulation with EES solver, on the basis of 2012 weather data, reaches 513 kWh. It seems to be strongly underestimated. This is probably due to a stack effect occurring in the staircase that provides heat from the living zone to the upstairs.

Conclusion

The analysis of measured electricity consumptions in this passive house inhabited by occupants who are very motivated for energy saving purposes shows, that the house can be considered as a "nearly zero energy building": the thermal and PV collectors are roughly covering the whole (space and sanitary water) yearly heating demand. They do not cover the whole lighting and appliances consumptions.

It is difficult to provide an accurate energy balance of the house on the basis of the available data, as the effective heat production of the solar thermal collectors is not recorded. Heat production of the solar thermal collectors should be measured in order to provide a complete balance of the system.

Dynamic simulation of the building provided with a floor heating systems at the ground floor seems to underestimate the ground floor heating demand, probably because of a stack effect occurring in the staircase and providing heat from the living zone to the upstairs.

Acknowledgments

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