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Research and development with full scale research dwellings

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RESEARCH AND DEVELOPMENT WITH FULL SCALE RESEARCH DWELINGS

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ABSTRACT
One of the research programs of the Energy research Centre of the Netherlands (ECN) concerns the built environment. Several facilities to conduct the research activities are at ECN's disposal. One of these facilities, are five research dwellings located on the site of ECN (Petten, Netherlands). Measured data from these facilities together with weather data and computer models of the buildings are used to evaluate performance of innovative energy concepts and components in these systems. The facilities are used for a broad range of research activities as well as product development. This paper explains more about the test facilities and the methods that are used to evaluate performance.

INTRODUCTION
Evaluation of the performance of an energy system or the building envelope can be done using different methods. Simulation with the help of computers has the advantage that one can assess the performance over, for example, a year in a matter of minutes, depending on the speed of your computer. Disadvantage of this method is that the quality of the results depends on the quality of the model and the input. Measurements provide more reliable and practical results concerning energetic performance but are more time-consuming and complicated to execute under controlled and realistic circumstances. The necessity of a large amount of measurement equipment, varying weather and uncertainty in inhabitants' behaviour, are the main complicating factors for successfully executing such measurements.
To combine the advantages of simulation and measurements, ECN has built unique test facilities and developed a data-analysis method.
Measured data from the test facilities and a weather station located near the test facility, combined with the data-analysis method, provide the possibility to produce in relatively short period reliable and practical results on expected long-term performance.

Method The test facilities consist of four full-scale single family dwellings and one rotating facility with four rooms. The four single family dwellings have different bodies but are identical inside (floor area, glass area etc.). The size of the dwellings represents the Dutch average for new dwellings. The bodies differ from full concrete, semi concrete to timber frame. Also different glazing and ventilation systems are applied: triple glazing systems with krypton gas filling to standard double glazing as well as balanced ventilation with heat recovery and natural ventilation are applied. Two dwellings are supplied with automated sun shading systems. Insulation value of the opaque facade and roof is 5 [m2 · K/watt]. The rotating facility is placed in a watertight concrete 'basin'. Filling the basin with water will make the facility, which is built on EPS, float. This allows the facility to be rotated to any orientation. Four facades in the facility can easily be changed, allowing measurements with different facades on any desired orientation. Electricity use of inhabitants, domestic hot water use as well as their influence on humidity, carbon dioxide levels and temperature preferences in a dwelling, are simulated. A control system regulates electrical heaters to simulate heat of the metabolism of people and their electricity use for household appliances. Water vapour and carbon dioxide are injected to simulate evaporation and breathing.

Figure 1: Above the four single-family dwellings

Both test facilities are equipped with an extensive data acquisition system, logging each 10 minutes more than a 100 sensors. Shorter logging intervals (up to 1 second) are also possible. These systems allow registering energy flows such as passive (windows) and active (collector) solar radiation, electricity use but also temperature, humidity and carbon dioxide levels. The data acquisition also allows to measure on component level such as: electricity use of certain pumps or controls, heat supplied by heating systems, temperature and humidity (comfort aspects) etc. Unfortunately it is not possible to directly measure outgoing energy flows (heat) such as ventilation, infiltration and transmission losses. How these energy losses are determined will be discussed in following paragraph.

Simulation and model verification. A computer model helps to determine the energy losses caused by infiltration, transmission and ventilation. The building parameters such as insulation values, window specifications, facade areas, ventilation flow, air tightness etc. are the input for these models as well as the measured data concerning weather, and incoming energy flows. With these inputs, the model is able to calculate heat losses, the solar gains and temperatures inside the dwelling. Comparing the calculated with the measured temperature inside the dwelling verifies the accuracy of the model.

Data Analysis When the heat losses are determined, an overview of all incoming and outgoing energy flows, that is the energy balance, can be made.

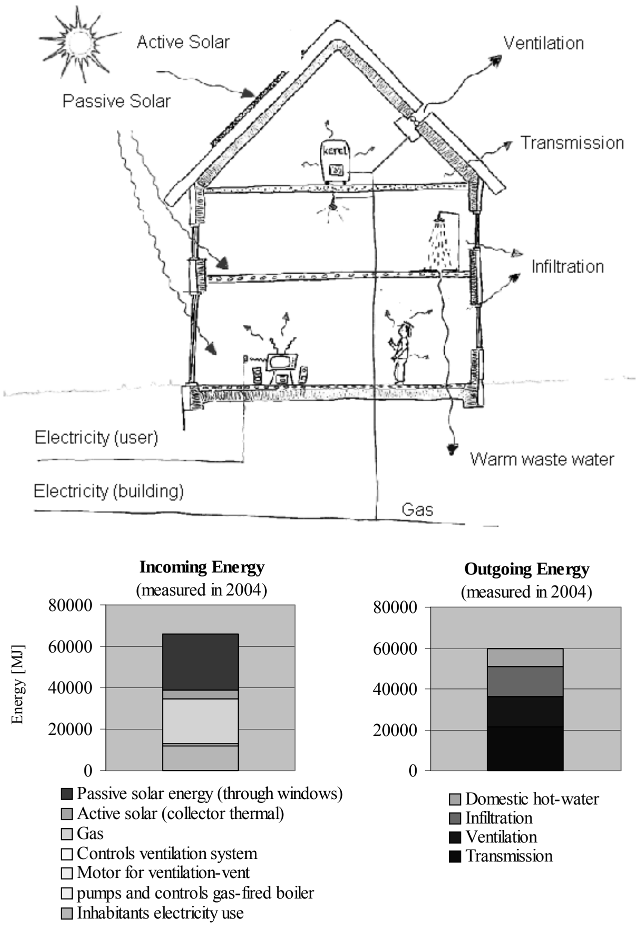

Figure 2: Incoming and outgoing energy flows (energy balance) measured in 2004 from a single-family dwelling with natural ventilation

Figure 2 shows the incoming and outgoing energy flows when the building envelope is assumed as system boundary. In the right graph in the figure, the measured annual energy flows in one of the single family-dwellings are indicated. The graphs show that the 'measured' incoming and outgoing energy are not equal. This is caused by the accumulated uncertainties of the measurement method, measurement errors and data analysis method. For the measurement of the energy balance, assuming the building envelope as boundary, the inaccuracy is less than 10%. Main reason for this inaccuracy is the difficult determination of air change rate due to infiltration and ventilation. For measurements concerning components (for example: heat pump or ventilation device), inaccuracy within 5% is feasible. The validated model can also be used for the extrapolation of measured data, from for example a month, to a longer time span. This way, performance of installation and building envelope components can be assessed over a longer time span or with different weather data (cold winter/warm winter).

Applications Both facilities are deployed for different research activities. The rotating facility is used for measurements concerning the development of active facade components. These facades react (and anticipate) actively on changing conditions (light, air quality, noise, heat, weather). The single family dwellings are used for research activities concerning energy use, comfort and health aspects of innovative energy concepts for houses. Innovative heat pumps, combined heat and power, solar collectors, controls and heat storage are just a few topics that have been investigated. Installation components are tested but also ventilation aspects and the building envelope were topics in research and development for industry. All facilities are available for industrial research and development as well as for research activities.

Conclusion The research facilities together with the data analysis method that is developed provide the opportunity to do controlled testing under controlled and realistic circumstances resulting in reliable and practical results concerning the performance of energy concepts. The facilities together with the data analysis provide the opportunity to;

1. Translate results from 'short' experiments to longer periods
2. Translate results from experiments to other climate conditions or other types of dwellings
3. Analyse the effect of single measures (components) on the total energy concept

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