VERIFICATION OF ENERGY SAVINGS IN RESIDENTIAL HOUSING

by

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ABSTRACT

Today energy saving rates due to retrofits in residential housing are either measured by experiment on site or predicted by system simulation. In the latter case mathematical models of the components are developed, verified by laboratory tests and combined to represent the thermal characteristics of the investigated system. Then energy demand is calculated before and after adopting the investigated retrofit. There still remains the question, are energy savings precalculated by system simulation: obtained in fact, in other words do they agree with results of field experiments.

Long-term-measurements in 51 residential buildings before and after renewal of the boiler prove, that due to varying occupancy behaviour and weather conditions no reliable results are obtained by such experiments on site. Therefore the correctness of simulation results cannot be confirmed by field measurements.

However, the results measured can be explained by system simulation, calculating the energy consumption before and after renewal of the boiler under uniform boundary conditions. Thereby the strong

INTRODUCTION

A very important criterion to select suitable energy saving retrofits at the structure or heating system of residential buildings are the energy saving rates obtained by such measures. Since they depend on the actual thermal state of the structure and the heating system, on weather conditions and occupancy behaviour and furthermore on the characteristics of the renewed components, they cannot easily be predicted.

Today energy saving rates due to retrofits in residential housing are either measured in field or precalculated by system simulation. There is always asked, are energy savings predicted by system simulation obtained in fact. In other words do they agree with the results of field measurements.

To discuss this question results of field measurements and system simulation obtained in 51 occupied residential buildings, predominant single-family dwellings, are outlined /3/. Thereby the influence of occupancy behaviour on energy saving rate is also demonstrated.

FIELD MEASUREMENT

To determine energy saving rates due to

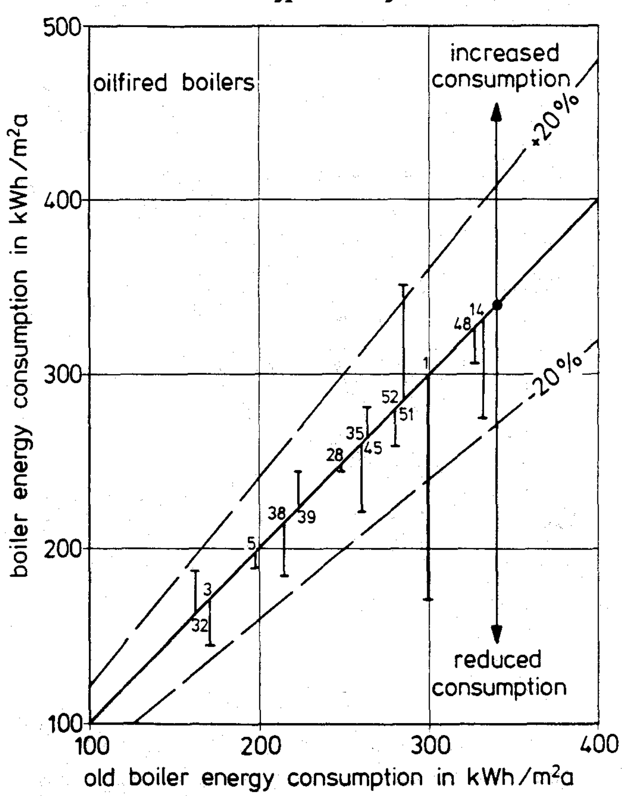

Figure 1: Annual energy consumption of oilfired boilers before and after replacement

retrofits in field, the yearly energy consumption of the heating system is easily measured in field before and after implementation of the investigated retrofit. Since the boundary conditions on site especially occupancy behaviour and weather are changing during the regarded periods of time the energy consumptions measured cannot be compared /2/. This is confirmed by long-term measurements in 51 buildings, equipped with central warm water heating systems, before and after renewal of the oil- or gasfired boilers.

Energy consumption and useful energy of the old and new boilers are measured weekly and monthly during the heating period. Although the measured energy consumption and useful heat are recalculated by the degree-day-method to uniform outdoor temperatures /5/,the energy consumption reduces very differently (figure 1). In some buildings, e.g. building no. 51 the energy consumption increased after renewal of the boiler despite the old boilers have been replaced by very improved new devices.

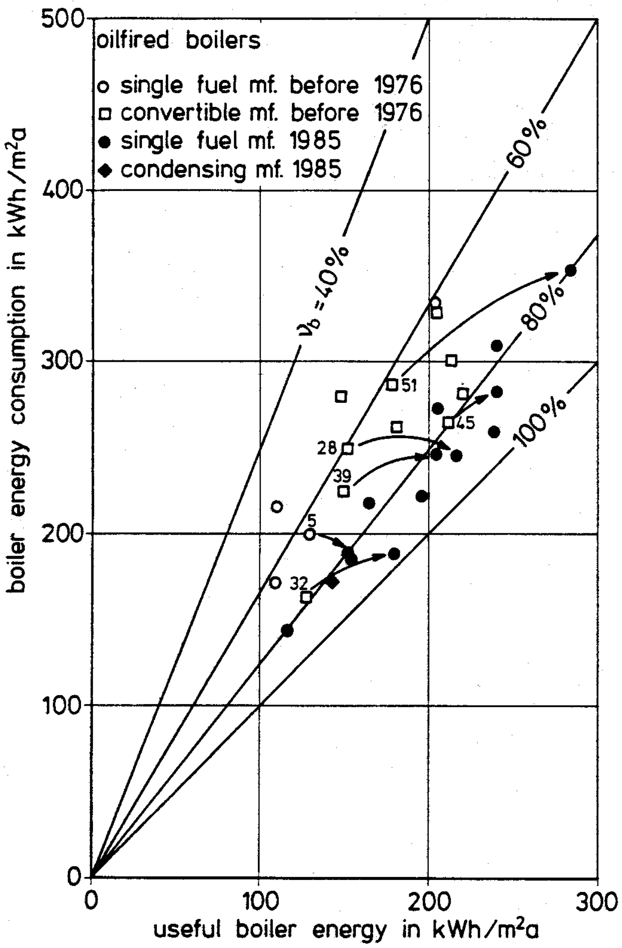

Figure 2: Annual energy consumption and useful energy of oilfired boilers measured before and after replacement

A first explanation is given regarding the measured useful boiler energy before and after renewal of the boiler (figure 2). The useful boiler energy transferred to the network has changed in almost all buildings, in most cases increased. Since no retrofits have been performed at the structure, this effect can only be caused by changing operation of the heat distribution or changing requirements of the occupants.

In most buildings the control of supply temperature by hand is also replaced by automatic supply temperature control due to outdoor temperature with night set back or cut off. Since the controllers are adjusted by experts, reduced supply temperature and therefore less heat losses in the network are to be expected.

All this implements, the requirements of the occupants must have increased. E.g. in building no. 51 the useful energy of the boiler increases about 100 kWh/m²a. Since the efficiency of the boiler has improved about 20 % the energy consumption rises only about 60 kWh/m²a.

In almost each building the energy saving rates due to renewal of the boiler cannot be proved by the energy consumption measured. So the correctness of simulation results cannot be verified by field

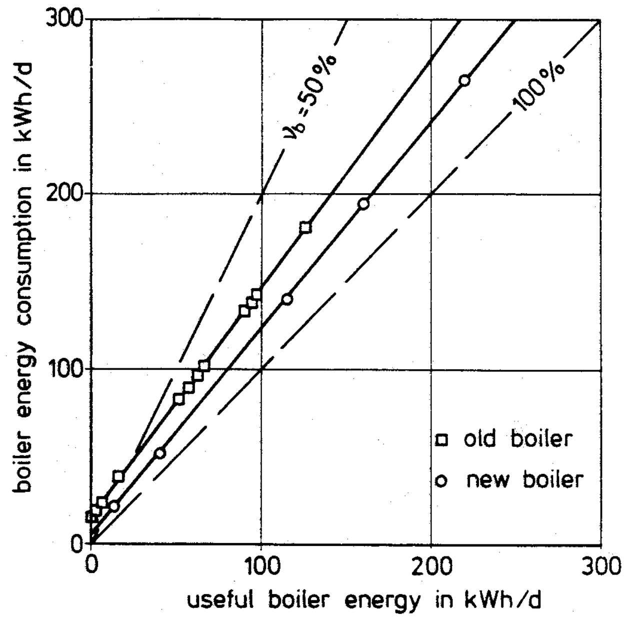

Figure 3: Characteristic curves of the old and new boiler in building no. 51

measurements.

However, the energy consumption and useful heat of old and new boilers measured weekly or monthly describe their thermal behaviour under present operating conditions in each building by linear characteristic curves (figure 3). For instance in building no. 51 the new boiler always consumes less fuel than the old one. Since the curves are not parallel, the energy savings are depending on the load.

SYSTEM SIMULATION

System simulation can be used to predict the energy consumption of heating systems in residential buildings before and after adopting retrofits under uniform boundary conditons, i.e. identical occupancy behaviour and weather. For that purpose the whole system weather, building, occupant and heating system is simulated by a computer code.

Investigating the dwellings above the heat demand of the building is calculated by system simulation for uniform climate /4/, three types of occupancy behaviour (table 1) with respect to the thermal properties of the structure. Internal and solar gains are taken into account. The useful heat of the boiler is obtained by the heat demand of the building and the heat losses of the network. The energy consumption of the old and new boiler can be evaluated by the characteristic curves measured.

occupancy requirements	low	medium	high
daily duration of heating (h/d)	24	24	24
average indoor temperature (°C)	16	19	22
average air exchange rate (1/h)	0,3	0,9	1,5
daily domestic hot water demand (l/person d)	20	50	80

Table 1: Definition of occupancy behaviour

The results of the simulation procedure are characteristic almost linear curves which indicate yearly energy demand of the building and matching energy demand of the old and new boiler (figure 4). The main variable is occupancy behaviour. These curves are used to determine energy consumption of the old and new boiler under identical boundary conditions.

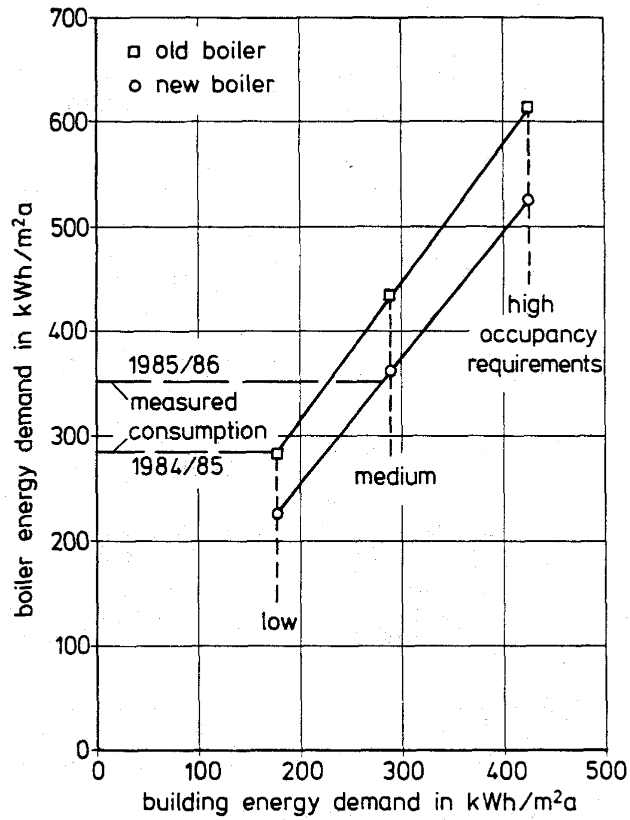

Figure 4: Annual boiler and building energy demand before and after boiler replacement in building no. 51

In building no. 51 assuming low occupancy requirements the energy savings due to renewal of the boiler are about 60 kWh/ m^2a. The measured energy consumption of the old boiler is almost the same as precalculated under low occupancy requirements. After renewal of the boiler the result of field measurement is close to the boiler energy demand supposing medium occupancy requirements. The heat demand of this building has increased due to higher requirements of the occupants, thus boiler energy consumption rised despite an improved heating system. In this way the result of field measurements can be explained by system simulation.

Assuming low accupancy requirements before and after replacement of the boiler energy savings can be proved in all buildings shown in figure 5. They still scatter within a wide range, since the properties of the investigated buildings and their old as well as new heating systems are quite different.

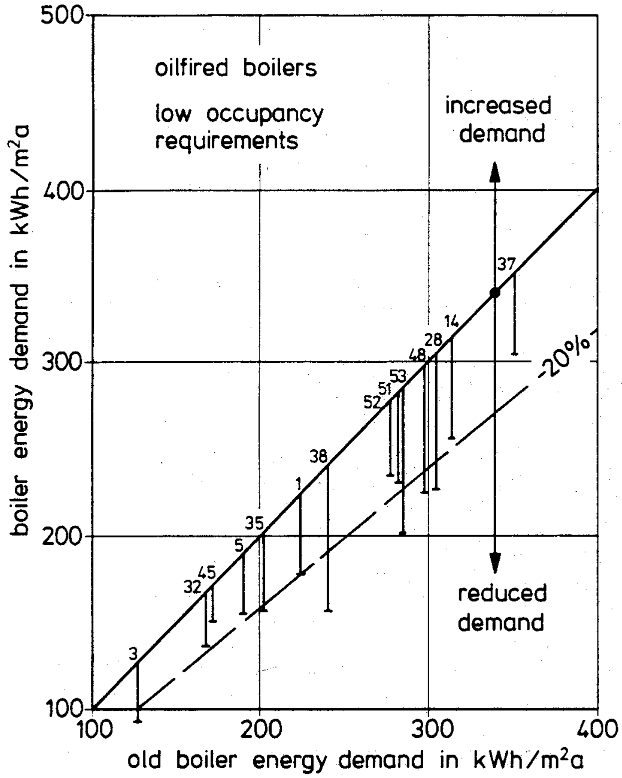

Figure 5: Annual energy demand of oilfired boilers before and after replacement under low occupancy requirements

CONCLUSIONS

Field measurements in occupied buildings do not allow to prove energy saving rates due to retrofits since the boundary conditions occupancy behaviour and weather are varying and can hardly be controlled during the periods of measurement. Therefore the correctness of simulation results cannot be verified by field measurements. Furthermore the results of field measurements are not reproducible.

Energy saving rates due to retrofits can be predicted by system simulation under identical boundary conditions fairly well, presumed the mathematical models used and the necessary data seized are describing the thermal behaviour of the whole system sufficient accurately /1/. Moreover results of field measurement can be explained by system simulation.

The investigations above confirm that energy saving rates due to retrofits in residential housing depend very much on the behaviour of the occupants besides weather and properties of the building and heating system. Therefore they refer only to the investigated building and cannot be easily transferred to others.

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