EFFECTS OF ENERGY CONSERVATION MEASURES: RESULTS FROM A SWEDISH BEFORE-AFTER STUDY

Gunnar Anderlind, Leif Bengtsson, and Hans-Olof Karlsson,
Lund Institute of Technology,
Peter Rundberg, Chalmers Institute of Technology,
Lars-Olof Höglund, and Conny Rolén,
the Royal Institute of Technology, Stockholm,
Christer Hjalmarsson, and Urban Norlén,
the Swedish Buildning Research Institute,
Jan-Åke Jonsson, and Jan Nordlander,
Building Centre of Northern Sweden and
Håkan Johansson, University of Luleå
(all together called the H II-group)

INTRODUCTION

To estimate the average savings of a number of energy conservation measures a before- after study in 306 randomly selected single family and multifamily houses from four different parts of Sweden was performed. The field work was carried out during two to three heating seasons including weekly measurements of energy consumption, indoor and outdoor air temperatures, wind speed and insolation. The houses were also inspected at site.

METHODOLOGY

The energy signature model is a relation between average heating load and climatic load by means of a linear regression model with one or more parameters. The (energy) parameters express the resistance and benefits of the house to different climatic strains.

The calculation model used is based on the assumption that the weekly energy consumption for space heating and domestic hot water in a building is linear in the weekly average indoor/outdoor temperature difference during the heating season and is independent of temperature during the nonheating season. On the basis of these assumptions, the energy signature of a building can be determined from weekly mean values of energy consumption and temperatures indoors and outdoors. The equation of the energy signature is determined by the least-squares method. The slope of the fit is the heat loss factor of the building, i.e., the amount of increase in energy consumption for a one-degree Celsius increase in the indoor/outdoor temperature difference. The intercept - the "energy consumption" at zero indoor/outdoor temperature difference - is the winter factor. Similarly, a summer factor is defined as the average energy consumption for hot water heating in the non-heating season. The consumption of the building for an average year is given by:

$$W = bQ + cT + dP$$

where

W = the annual energy consumption per dwelling for the average year (kWh/dwelling, year)

Q = the number of degree hours, to the base temperature of the individual dwelling, during the average year (^{o}Ch/year)

T = the length of the heating season in the average year (h/year)

P = the length of the nonheating season in the average year (h/year)

b = the loss factor of the building, as obtained from the least-squares fit (kWh/h, dwelling, ^{o}C) of the energy signature

c = the winter factor, as obtained from the least-squares fit, (kWh/h,dwelling) of the energy signature

d = the summer factor for the building (kWh/h,dwelling).

In electrically heated houses, where household energy consumption is included in the metered space-heating consumption, we used handbook values of household energy consumption to estimate consumption for spaceheating and preparation of hot tap water. Handbook values were also used in cases where the energy consumption for preparing hot tap water was not included in the energy measurement. The energy consumption is normalized for both the pre- and post-retrofit periods. The energy saving is calculated as being the difference between these two normalized values.

RESULTS

Table I. Average expected and measured energy savings. Standard deviations for measured energy savings (MWh/dwellings, year). Measured savings in percent of previous consumption (%)

Conservation Measure	Number of houses	Expected savings average	Measured savings average	std.dev.	%
Single family houses					
Triple glazing	19	3.36	1.63	2.44	5
Wall insulation package	29	10.74	5.72	5.89	16
Retrofit package	4	11.51	8.76	5.15	25
Conversion to el heat	35	9.82	8.16	5.74	22
Heat pump	59	-	-	-	52

Multifamily houses					
Triple glazing	27	1.66	1.32	2.01	7
Attic insulation	29	.76	.63	.94	4
Regulation package	19	.54	.66	2.06	3
Retrofit package	39	2.32	2.11	1.78	13
Conversion to distr heat	26	2.75	4.71	4.50	21
Heat pump	20	-	-	-	48

For comparison expected savings were calculated on the basis of U-values as obtained from inspection at site.

Triple glazing

Replacement by or upgrading from double- to triple-glazed windows has not given the expected saving. In an earlier study (H I) higher savings were obtained, 2-3 MWh/dwellings, year for single family houses.

Wall insulation

The typical case of additional insulation is about 10 cm external mineral wool. The average saving are substantial.

Insulation package

This package consists of both wall and attic insulation. The energy saving are more significant than for the group where only wall insulation was added.

Conversion to electric heating

There are three kinds of retrofits, the "Elkassett", an electric resistance boiler in the existing hydronic heating circuit, the "Elpanna", a rather larger electric resistance boiler and the "Elpatron", a smaller electric heater of the water in the existing boiler. On the average the energy consumption decreased 22%, which of cause is substantial. The expected decrease in energy consumption will be of this size if the losses in the boiler with oil heating is about 20%.

Installation of a heat pump

A large number of heat pumps have been installed in Sweden, with expectation that they would give great energy savings. For this reason it was important to include this type of retrofit in the study. There are both ground-source and air-source heat pumps in the study. To estimate the savings for this retrofit we have used a separate model, which means that we compare the actual energy consumption after installation of the heat pump with the energy consumption estimated using weather data for the after-heat pump period and the energy signature calculated from the pre-heat pump period.

Table II. Designed and measured values of the Seasonal Performance Factor (SPF). Measured values were obtained to the year 1985.

	SPF	
	designed	measured
Single family houses	2.60	2.30
Multifamily houses	2.74	2.95

Attic insulation

In multifamily houses the attic insulation gave the expected savings.

Regulation package

Most common this package is adjustment of the heating system and installation of thermostatic radiator valves.

Retrofit package

The most common retrofits in this package are installation of attic insulation and thermostatic radiator valves, and adjustment of the heating system. We can see that this package gives a greater energy saving compared with the sum from attic insulation and a regulation package.

Conversion to district heating

Many multifamily houses has converted from separate oil heating to district heating and as with electric conversion we expect to decrease the energy consumption with the losses in oil heating. The savings are the expected, 15-20%.