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Thermal upgrades of existing homes in Germany: The building code, subsidies, and economic efficiency

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ABSTRACT

One of the cheapest ways to reduce CO_2 emissions is thermal renovation of existing homes. Germany is a world leader in this project, with a strict building code, generous state subsidies, and an advanced renovation infrastructure. The effects of its policies are here explored in the light of progressive tightening of the building code, and the strict criteria for subsidies. Data on costs and outcomes of residential building renovations are presented from published reports on renovation projects, and cross-checked with projects investigated directly. Comparisons are made in terms of euros invested for every kilowatt hour of heating energy saved over the lifetime of the renovations, for standards ranging from 150 kWh (the lowest standard) to 15 kWh (the highest) of primary energy use per square metre of floor area per year. It is found that the lowest standard is an order of magnitude more cost-effective than the highest, in terms of both energy saved per euro invested, and return on investment over the lifetime of the renovations, regardless of fuel prices. It is argued that this throws into question Germany's policy of progressively regulating for higher renovation standards, and offering subsidies only for projects that go beyond the minimum standard.

1. Introduction

Human activities in existing buildings are the cause of around 40% of the world's total primary[1] energy consumption (IEA, 2006). In the UK this figure is around 30% [1], of which about half comes from space heating [2]. In Germany, where average winter temperatures are some 3 °C lower than in Britain, space heating accounts for over 75% of household energy use [3], and in the EU as a whole around 70% [4]. Total energy used for home space heating in the EU is increasing, mainly due to the increasing number of households and larger size of dwellings [5].

Since much of this energy comes from fossil fuels, energy consumption by households is a very significant issue in attempts to reduce GHG emissions. It has been variously estimated that space heating in buildings accounts for some 25% of EU countries' GHG emissions, about half of which – around 12% – comes from households [6]. Since there is a direct relationship between GHG emissions from space heating, and energy used in space heating, this sector is contributing to the current steady increase in GHG emissions worldwide.

There is great potential for energy savings in household space heating [6,26,27]. Renovating a 1950s German apartment block to the pre-2004 'minimum' standard (see below) can cost less than 3 eurocents/kilowatt hour (kWh) of primary energy saved over the lifetime of the renovations [7]. This compares to the much higher costs of generating energy from renewables such as wind power (8 cents) and photovoltaics (28 cents), and the spot-price of electricity (7 cents), or current heating oil costs (6 cents) [8,9]. Refitting homes can, if planned sensibly, be one of the world's cheapest ways to save energy and reduce GHG emissions.

Of course, this does not take into account subsequent changes in energy use patterns due to the rebound effect [10–12]. For example, in their study of recent home heating upgrades in Britain, Milne and Boardman [13] found that upgrading can form a justification to consume more fuel, even though this costs more, because now the householder is getting better value for money. Hence the uncertainties due to human behaviour changes after thermal refits and other energy efficiency measures offer a caution of the necessarily tentative nature of the findings of studies such as this.

The remainder of this introductory section outlines the relevant issues in the German building code, and how they relate to thermal renovation (TR) of existing homes (EHs) as compared to new builds. It also outlines the system of state subsidies for TR. Section 2 examines case studies of TR projects, developing a mathematical model for comparing the fuel saving economics of various TR standards. Section 3 draws out the implications of this for policy

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[1] 'Primary' household energy consumption includes the energy lost through transportation of useful energy to households. 'End-use' energy refers only to energy consumed usefully in the household.

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Table 1
Energy end use, total costs and energy-saving cost measures for the five standards of thermal upgrade of homes in Ludwigshafen.

Standard	Measures taken	Energy end use (kWh/m^2 a)	Total costs (€/m^2 of floor area)	Costs of energy-saving measures (€/m^2 of floor area)
Render	External wall render only	275	40	0
193 kWh/m^2 a	8 cm external wall insulation	193	76	36 = 36
70 kWh/m^2 a	20 cm external wall insulation	70	87	47
	8 cm cellar ceiling insulation		15	15
	14 cm insulation between spars		17	17
	Double-glazing (U_w: 1.1 W/m^2 K)		50	15
	Simple ventilation system		28 = 197	28 = 122
40 kWh/m^2 a	20 cm external wall insulation	42	87	47
	8 cm cellar ceiling insulation		15	15
	14 cm insulation between spars		17	17
	Double-glazing (U_w: 1.1 W/m^2 K)		50	15
	Heat-exchanger ventilation system		93 = 262	93 = 187
30 kWh/m^2 a	20 cm external wall insulation	28	87	47
	20 cm cellar ceiling insulation		20	20
	14 cm insulation between spars		17	17
	6 cm insulation over spars		6	6
	Triple-glazing (U_w: 0.8 W/m^2 K)		94	59
	Heat-exchanger ventilation system		93	93
	Special measures to prevent heat bridges		72 = 389	72 = 314

Translated from Enseling and Hinz (p. 11) [7].

development and incentives. Section 4 looks at counter-arguments, while conclusions are developed in Section 5.

1.1. The German building code

At the time of writing (August 2009) the rules for building renovations in Germany were given in the *Energieeinsparverordnung für Gebäude* 2007 ([14], 'Energy Saving Regulations for Buildings'). This is a successor to EnEV 2004, and is supplanted again in September 2009 by EnEV 2009 (see [15]). The government has announced its intention of supplanting this once more in 2012 [16].

A crucial point that must be understood at the outset is that EnEV 2004, 2007 and 2009 are designed primarily for new builds, not renovations. They set down the standards of thermal retention which must be achieved in new building design and construction. These standards are driven by the government's commitment to reduce energy consumption in buildings, but are carefully negotiated with the construction industry to take account of its current and future capabilities, so that optimally energy-efficient new buildings can be constructed for reasonable costs—i.e. they must, the legislation declares, be *'wirtschaftlich'* ('economic').

The new regulations (EnEV 2009) raise the standards for whole-building heat retention 'by 30%'. This means that the maximum permitted heat energy consumption per unit floor area is reduced to 70% of that permitted by EnEV 2007 [14]. In 2012 it will be reduced again, to 70% of the EnEV 2009 value, i.e. 49% of the EnEV 2007 [14] value. EnEV 2007 did not upgrade the previous standard, but used the standard set down in EnEV 2004, with minor changes. However EnEV 2004 was a 30% upgrade on the previous standards.

Simultaneously, EnEV 2009 raises the standards for the average heat retention coefficient of a building's outer shell by 15%. This means that the maximum permissible '*U*-values' (see below) are reduced to 85% of the EnEV 2007 [14] values. Again, EnEV 2004 was a 15% upgrade on the pre-2004 *U*-value standards, and these will be raised by a further 15% in 2012.

The core of EnEV 2007 [14] is its (Table 1), an English translation of which is presented in Appendix A. This sets out the maximum permissible primary energy use for space heating and the heating of drinkable water in a new home, using two measures, corresponding to the two parameters outlined above, each of which must be adhered to. One is 'Q_P', the maximum permissible primary energy use per kilowatt hour per square metre of floor area per year (kWh/m^2 a). The other, 'H_T', is the maximum permissible heat transmission loss through the outer surface of the building (i.e. the average *U*-value), measured in watts per square metre of building envelope per degree Kelvin (W/m^2 K). These figures have to be worked out on the basis of keeping an all-round indoor temperature greater than 19 °C.[2]

Further, there is not one absolute figure for each of these two measures. Rather, there is a range given in the table, according to factors calculated from the shape and size of the building. This is because (a) larger buildings retain heat more easily than smaller buildings, as they have a smaller ratio of surface area to volume; and (b) cube-shaped buildings retain heat better than oblong or irregular-shaped buildings, as they, too, have a smaller surface area to volume ratio. The range of values in the table makes allowance for the difficulties of retaining heat in smaller or odd-shaped buildings—yet is nevertheless designed so as to incentivise the construction of the thermo-geometrically more efficient, larger, cubic-shaped buildings.

All this is modified by one further factor: local climate. To work out whether a building will comply with the heat retention rules one has to know the average local temperature. This must be worked out from a further table, in which Germany is divided into 39 postcode districts, each centred on a particular weather station [17]. (As from October 2009 this has been refined, to 8234 weather zones).

Hence, for new builds, EnEV 2007 [14] is an accomplishment of creditable technical sophistication, while the step to EnEV 2009 moves thermal retention requirements for new builds forward.

Questions arise, however, in that the rules for renovating *existing* buildings are based directly on Table 1, which is designed for *new* builds. A mitigating factor – found in EnEV 2004, 2007 and 2009 – is 'the 40% provision': thermal retention standards of renovations of existing buildings are allowed to be 40% more lax than those of new builds. Numerically, this means that Q_P for renovations can be up to 1.4 times Q_P for new builds of corresponding shape and size.

[2] To be strictly accurate, the rules only apply to residential buildings that are heated for more than 4 months of the year. For example, summer houses are not covered by this part of the building code.