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The drivers of and barriers to energy efficiency in renovation decisions of single-family home-owners

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ABSTRACT

Building renovation is one of the key factors in fostering energy efficiency in the building sector. However with regard to the long-term policy goals such as the Kyoto-Protocol and the IPCC recommendations the past and current rates of such renovations have been too low in most European countries including Switzerland. To identify the relevant factors affecting the renovation decisions of single family home owners three approaches are pursued. The first one consist of an analysis of the exogenous economic, technical and legal frameworks. In the second approach the perception of these boundary conditions by the owners from their subjective point of view is analysed, relying on a survey of owners of single-family homes. Owners were also queried about their motivations and reasons for insulating or not insulating. The third approach consists in the modelling of renovation decision regarding the building envelope based on revealed discrete choice data gained from a survey conducted in the Swiss residential building sector. The model is specified in relation to technical, socio-economic and behavioural hypotheses to test for commonly stated assumptions regarding drivers of and barriers to energy efficiency renovations. From the three approaches it can be concluded that building envelope renovations are affected by technical parameters, and general housing activities such as building extensions and motivations rather than by socio-economic variables such as income, education or age. Finally, findings are used to draw policy implications regarding instruments to promote energy efficiency in the buildings sector.

1 INTRODUCTION

The stock of existing buildings dominates the heating energy demand of the residential sector. In 2005 about two thirds of the heated floor area are in buildings constructed before 1980, i.e. before building insulation had a significant impact (based on data from Aebischer et al., 2002) and the share of these buildings in terms of heating energy demand is almost three quarters, mostly covered by fossil fuels. In view of this relevance and in view of the medium- and long-term energy and environmental policy goals and necessities (Kyoto-Protocol, CO_2-law, 2000 Watt-society, IPCC recommendations) it is indispensable to curb the energy demand of existing buildings, all the more so because energy efficiency (EE) potentials are larger than in new buildings, both on the individual and on the aggregate level.

A key factor of energy efficiency in the sector of the existing building stock is the renovation of the building envelope energy efficiency. For several reasons the building envelope is particularly relevant. Firstly, energy efficiency potentials are particularly large, amounting to about 50% or more if the envelope is renovated comprehensively. Secondly, it determines the level of useful energy requirements which is relevant for both fossil fuelled and renewable energy-based heating systems, since renewables are also scarce or need a scarce input energy (electricity in the case of heat pumps). Thirdly, an energy-efficient envelope facilitates efficient heating systems (particularly heat pumps) and last but not least it generates additional benefits such as improved housing comfort, which are also economically relevant (cf. Banfi et al., 2006), Finally, energy-efficient building envelopes are also a prerequisite for an extensive use of renewable energies whose potentials are limited (cf. Hirschberg et al., 2005, and others).

In Jakob (2006) it has been shown that energy-efficient building renovation is quite cost-effective or even economically viable, at least if regarded from a comprehensive lifecycle point of view which takes into account long-term considerations (e.g. time horizon close to technical lifetime, moderate interest rates, potential energy price risks) and all the more so if co-benefits are evaluated appropriately, cf. Banfi et al. (2006).

However, despite the high relevance of the issue and despite the relatively favourable economics, energy-efficient renovations were and still are only being undertaken at a relatively low rate, as it is shown by Jakob, Jochem (2003) and by Gerheuser (2007).[1] The rates of energy-efficient renovations were and are still quite low. In absolute terms, i.e. relative to the total of the building stock, the average EE renovation rates of the opaque envelope were between 0.4%/a and 0.8%/a during the 1990s and up to 2003. Exceptions are flat roofs and windows, whose rates were between 1.3%/a and 1.7%/a (cf. Jakob, 2006b). Although the rates are higher for some construction periods they are – being equivalent to renovation cycles of 50 to 100 years or more – clearly too low in view of the goals mentioned above.

Table 1 Annual renovation rates for single-family houses (SFH) and multi-family houses (MFH) for the different elements of the building envelope (average renovation rates 1990 to 2000, rates are referred to the building stock of the construction period up to 2000)

	Energy-efficient renovations		Overhauling	
	EFH	MFH	EFH	MFH
Window	1.3%	1.7%	0.1%	0.1%
External wall	0.4%	0.8%	1.3%	1.2%
Flat roof	1.3%	1.7%	0.1%	0.6%
External steep roof including attic floor	0.5%	0.8%	0.6%	0.9%
Ground floor, basement ceiling	0.6%	0.8%	0.0%	0.0%
Overall (area weighted average)	0.6%	1.0%	0.6%	0.6%

Source: Jakob (2006b)

The rates are also low in relative terms, i.e. relative to the total of building envelope measures being undertaken in a given period. For most of the building periods façade insulation were realised only in 10% to 40% of those cases which involved any type of façade measures, the remainder including only overhauling (painting), cf. Jakob and Jochem (2003). Thus, the opportunity of cost-effective energy efficiency improvements was taken only in a minority of the cases.

Similar discrepancies between actual and expected behaviour were reported in other fields of energy use, and particularly in the field of energy efficiency, cf. Sorrel et al., (2004) and Jakob and Madlener (2003) for an overview. The question that arises at this stage is what the actual

[1] Note that the renovation rates surveyed by the ten-yearly conducted "Volkszählung" are not suitable as a measure of energy-efficiency renovations since it records "renovations that increased the value of the building", including both renovation of the building envelope and internal renovations.

causes in the case of existing residential buildings in Switzerland are. To what extent is this observed discrepancy due to the different viewpoints between the private and the societal perspectives (time horizon, interest rates) and to which extent is it due to market failures or barriers? What are the legal, economic, and intrinsic drivers that stimulate energy-efficient renovations and which barriers and inadequate market mechanisms hinder a further diffusion of such renovations? Answers to these questions will be useful in defining a set of policy instruments to stimulate energy-efficient renovations and in taking advantage of the cost-effective potentials to mitigate climate change.

The renovation and overhauling behaviour of building owners is influenced by both exogenous and endogenous explanatory factors (see also overview in Ott, Jakob et al., 2005, p. 85). In this paper the analysis of the current renovation behaviour and of the relevant factors of influence on renovation activities is based on three approaches. The first consists of an analysis of the exogenous economic, technical and legal boundary conditions that impact on the renovation behaviour (section 2). In the second approach the perception of these conditions by the owners from their subjective point of view is analysed, relying on a survey of owners of single-family homes (section 3).[2] The third approach comprises the econometric modelling of the renovation decisions of (single-family house) owners based on a revealed preference approach (section 4), taking into account evidence gained from the previous sections. The modelling is based on data gained from two surveys (cf. Jakob, Jochem, 2003 and Ott, Jakob et al., 2005).

2 TECHNICAL, LEGAL AND ECONOMIC FRAMEWORK CONDITIONS

In this section the technical, legal and economic framework are analysed regarding their impact on energy efficiency in the case of building renovations. The scope includes building and planning regulations, energy, climate policy and clean air regulations, tax law, renovation costs, financial needs, and economic viability considerations, local demand for housing and other general frame conditions (such as energy prices, mortgage interest rates and financing conditions). In each case it is analysed to what extent energy-efficient renovations are rather hindered or rather stimulated. After some short introductory remarks on the technical and physical condition of single-family houses in Switzerland and an analysis of the relevant technical and fiscal codes and regulations, the literature about the cost-effectiveness of building renovation is reviewed, and a discussion of the current market mechanisms and trends is provided. The analysis hereafter focuses on the building envelope which presents particularly

2 The first two sections are based on evidence (and methods used) gained in the context of two research projects about the renovation behaviour, potential barriers hindering a stronger diffusion of energy efficient renovations and potential policy measures to stimulate such renovations (Jakob, Jochem, 2003; Ott, Jakob et al., 2005). The latter reference is the research project "Mobilisation of energy efficiency potentials" co conducted on behalf of the Swiss Federal Offices of Energy (SFOE) and of Housing (BWO)

large challenges. A large proportion of the insights gained can be transferred analogously to building services (such as heating and ventilation) if specific differences are taken into account.

The first questions that was addressed was whether the general physical or technical conditions tend to induce or rather hinder energy efficiency renovations. It was found that in most cases building conditions neither hinder energy-efficient renovation nor urgently call for them. Indeed, from a technical or from a building physics point of view, energy-efficient renovations such as insulations or window replacement can basically be applied to all types of buildings and to most types of building elements. General architectural considerations may restrict renovations, but mostly only external façade insulations are concerned[3]. On the other hand most buildings can be operated and lived in with hardly any restrictions or problems for decades even without additional insulations. Hence, energy efficiency improvements are generally not triggered by technical factors: This would only be the case if residents became more demanding regarding indoor climate or environmental issues can a renovation need possibly be derived from the building's general condition. Exceptions are windows and flat roofs where energy efficiency is stimulated by technical factors. Indeed, new windows that replace existing ones are much more energy-efficient due to the considerable techno-economic progress of the standard market offers (cf. Jakob and Madlener, 2004). In the case of flat roofs it is the shorter technical lifetime (as compared to steep roofs) and construction damages that initiate EE improvements; if the roof membrane is renewed, thermal insulation is usually replaced or enforced and more advanced insulation is applied (cf. Jakob, Jochem et al., 2002).

Regulations

There are two kinds of regulations to be distinguished: firstly, general building and planning regulations which might pursue very different kinds of goals and could have an indirect, and unintentional effect on the energy efficiency of buildings and their renovations, and, secondly, specific codes and standards that are specifically designed to improve the energy efficiency of buildings. The analysis of codes and regulation of several cantons and communities reveals that neither is of great relevance (cf. Ott et al., 2005).

Indeed, the obstacles from the planning law are limited: deviations from surveying and zoning regulations generally tolerate post-insulation of walls and roofs as exceptions or explicitly permitted them, depending on the regional or municipal regulations. Slightly more relevant in practice are the conflicts of interest between the protection of listed buildings and conservation areas (preservation orders) and the demand for energy-related refurbishments, mainly in the core of small towns and cities. According to experts, roughly estimated at 10% to, at the most, 20% of the buildings are concerned and of these buildings not the whole envelope is affected, but mainly the façades. Finally legal restrictions due to neighbours' rights might hinder external insulation in some cases.

Further, a large part of the building stock is not at all or only sporadically affected by energy-related regulations. Indeed, there are no mandatory renovation requirements and the

[3] Note that renovation in many cases rather improves the architectural expression.

legal regulations only affect conversions, extensions and annexes in the building stock as well as – in some cantons – comprehensive modernisations, but not the existing building stock in general. Further, requirements for these renovation cases are technically and economically sub-optimal, at least from a long-term point of view (cf. Jakob, Jochem et al., 2002). From the perspectives of technological progress and economic efficiency, the legal requirements of thermal insulation are slack and should be tightened, both the performance based (SIA 380/1) and the building element based ones.

Economic, financial and fiscal barriers and drivers

Although other considerations might also impact on renovation decisions, economic determinants such as costs, financial needs, and the outcome of cost-benefit estimations certainly are very relevant. In this section the cost-effectiveness of EE renovations for private building owners is addressed. The effect of the current tax system is likewise demonstrated.

Financial needs and access to capital

As pointed out in Jakob, Jochem et al. (2002), energy efficiency renovations generally call for substantial additional up-front investments, as compared to repairing or overhauling options. The costs of façade overhauling for instance are typically 30 to 40 CHF/m^2 whereas the costs of façade insulations typically amount to 120 to 180 CHF/m^2 or even more, depending on the type of façade chosen. The additional costs of roof insulation are comparable; those for loft floor or basement ceiling slightly lower. The extra upfront costs of window replacement are also considerable if the state of the windows does not call for replacement or if repair and painting is possible (350 to 500 CHF/m^2, depending on the reference case).

Hence, as long as the condition of façades, roofs and windows allows repairing and painting, the additional up-front financial needs for energy efficiency improvements are considerable. In the case of single-family houses the total financial needs might amount to 40'000 to 70'000 CHF or more, depending on the geometrical size and proportions and on the share of building envelope that is renovated, which is 7% to 10% of typical purchase prices of existing SFH. For most single-family house-owners this is not a negligible amount, all the more since achievable energy cost savings are spread over a long time period (30 to 50 years). This need would have to be covered either by one's own savings, perhaps combined with raising the mortgage. In the first case renovations are in direct competition with other expenses (vacation, car) or needs (social security, health, living in the case of retired owners).

The economic viability of energy efficiency renovations from a private perspective

As opposed to the overhauling or doing-nothing option, the life cycle cost structure of energy efficiency renovations is characterised by a very large share of capital costs. As such the gross marginal and average costs of such renovations (as defined in Jakob, 2006) react very sensitively to changes in the assumed interest rates and to the time horizon. The parameter to be compared with, namely the marginal costs of heat generation, in turn depends very much on the assumed or expected energy price, averaged across the time horizon.

As shown in in Jakob (2006), energy efficiency renovations are economically viable if long-term average real interest rates (3% to 3.5%) and lifetime parameters in the order of the technical lifetime of the renovations are assumed. In this case gross average costs (AC) of energy efficiency improvements of usual insulation standards vary between 0.06 and 0.09 CHF/kWh$_{UE}$ on the level of useful energy (UE) and the gross marginal costs of heat generation vary between 0.08 to 0.09 CHF/kWh$_{UE}$, assuming a fuel energy price of 0.06 to 0.07 CHF/kWh.

If building owners assume clearly different parameters, i.e. if they have a shorter time horizon, if they assume nominal instead of real interest rates and if their energy price assumption is guided by the past rather by potential future developments, the outcome of such cost-benefit estimations is altered significantly. Indeed, an interest rate of 5% instead of 3.5% increases the gross marginal costs of energy efficiency by 20% to almost 30% (at constant lifetimes) and a decrease of the time horizon from 40 to 20 years increases the gross MC by almost 40% to 50% (at constant interest rates), resulting in a combined effect of +70%. Moreover, the marginal costs of EE are determined by the actual cost level an individual owner is faced with. Due to the common practice of not inviting tenders, owners might be faced by a high cost level (typically 10% to 20%), especially in the case of advanced EE standards. Finally, the outcome of gross MC estimations is further raised if the substituted overhauling costs are neglected, typically by 30% to 50% or more (remember that the above cited values are based on the assumption that EE renovation are undertaken instead of overhauling measures). If these higher AC are then compared with the low energy price level of the 1990s (about 0.04 CHF/kWh, up to 0.055 CHF/kWh in the case of natural gas), it becomes evident that energy efficiency renovations are not undertaken and if further considerations, e.g. regarding co-benefits, are neglected.

To summarise, the economic viability as such seems not to be a barrier to undertaking energy efficiency renovations if assumptions are based on long-term and forward-looking considerations and if competitive prices are being applied, but it is a barrier if this is not.

Tax incentives

As mentioned above, the economic viability of energy efficiency renovations is rather on the edge, depending on the assumptions. Hence the question is whether the tax system tends to improve or worsen the cost-effectiveness of energy efficiency renovations.

Private individuals can deduct maintenance costs and value-increasing investments from their taxable income. Such deduction possibilities aim to create an economic incentive for both building renovation and energy-related measures, the latter being desirable from an energy policy perspective. The current models of the federal government and the majority of cantons allow special deductions from the taxable income for energy-related investments. However these measures are only specified by their character and not by the energy quality, i.e. no predefined energy-related requirements have to be met. This results in a considerable share of tax incentives being granted for the costs of measures which are compulsory by law and/or would be conducted anyway. This is supported empirically by the statements of interviewees who very rarely listed tax reasons as a motivation for the energy-related measures implemented (cf. Ott, Jakob et al., 2005 and section 3 below), also due to fact that owners only became aware of these incentives after having already renovated. Hence this fiscal measure is characterised by a considerable proportion of free-riders. The tax incentives in their present form are not an efficient way to promote refurbishment activity since they are largely ineffective.

There is a further drawback in the current fiscal incentive system, since it is based on deductions from the taxable income rather than on tax cut-offs or even tax credits. Indeed, due to progressive tax rates the incentives for large investments or more costly options are degressing. Further, the current system provides an incentive to spread the renovation investments over different years to optimise tax payments or tax cuts which creates an incentive to refurbish in stages rather than to do comprehensive modernisations all at once. Moreover, the fiscal incentive is higher for high income households than for low income households due to the progressive tax rates, which is in opposition to presumed incentive needs.

To summarise, the current fiscal arrangement provides some help for renovations, but incentives are not specific to enhanced energy efficiency levels. Furthermore it fosters step-by-step renovations rather than comprehensive renovations.

Current market mechanisms and trends

The diffusion of energy efficiency renovations is also determined by the current structures and the transparency of the marketplace. This applies to the real estate market, and the overhauling and renovations markets. Transactions on these markets are characterised by the fact that they occur only sporadically for most of the actors. This is particularly pronounced in the case of single-family home-owners.[MS2] As such energy-efficient renovations are a credence good (cf. Sorrel et al., 2004) , i.e. its benefits and drawbacks can only be experienced after the investment decision.[4]

Market transparency, certificates and labels in the housing market

In terms of energy costs and energy efficiency the tenancy market is characterised by a considerable lack of transparency. At the moment of contract completion, house purchasers are faced with a considerable information asymmetry, due to the difficulty of estimating potential renovation costs and due to a lack of standardised information about the energy consumption of the building (such as a certified label[5]). As a result there is no specific demand for energy-efficient buildings which could induce owners to improve the EE of their buildings.

Since renovation decisions only occur sporadically, the demand side of the renovation market is characterised by high information and search costs. At the same time, the supply side of the renovation market, namely builders and contractors (tradesmen, roofers, facade and window companies, to some extent also painters and plasterers) also tend to be relatively small. Selecting such small companies as the first point of contact may considerably restrict the scope of consultancy and the range of measures offered early on, all the more as the companies contacted are from the overhauling sector than rather than from planning sector or from the sector of specialised insulation companies (Jakob, Jochem, 2003), which restricts the potential set of renovation options.

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4 As opposed to search goods where much more frequent purchases allow for corrections.

5 Building certification and labelling is part of the European Directive of Building Performance (EPBD) and is also being discussed in Switzerland, cf. Baumgartner et al. (2004) and Rieder et al. (2006).

Pioneer surcharges in the renovation market

In terms of pricing energy efficiency renovation, there is obviously a large difference between the established renovation standards and more advanced energy efficiency standards, as pointed out in Jakob, Jochem et al. (2002) and in Jakob and Madlener (2004), pp. 160 – 161. It can be concluded that advanced energy efficiency standards are still in a pioneer phase. Indeed, both renovation companies and owners have as yet had little experience in advanced standards. Due to limited experience, renovation companies are still in a phase of learning, both on the technical and on the price setting level (cf. Jakob and Madlener, 2004).

Since most companies are small and medium sized enterprises (SME), which in addition are often operating at the margin of profitability (as stated by experts from the sector), product development cannot be financed by their own resources (seen as an investment), but costs have to be covered by (pioneer) clients. Thus, pioneer clients are currently financing the process of development and learning. This– in combination with the long life cycles and the low rates of application – hinders a rapid diffusion of advanced standards.

Demographics and the socio-cultural development trend

Demographic development in the future will result in an increase in the turnover of older SFH. In principle an increased turnover offers more frequent occasions to assess the specific qualities of the buildings and the opportunities for renovations and modernisations, particularly in the case of single-family houses. In addition, according to Ott, Jakob et al. (2005), altered requirements for dwellings could be expected from an ageing (on average) residential population with higher standards of living comfort, increasing individualisation and the future development of the workplace by portfolio workers and employees with a part-time job at home. These trends potentially lead to renovations and adaptations of dwellings, which will offer an opportunity for energy-related renovations if the modernisation follows an overall concept and reaches a certain level of intervention. Yet it remains to be seen whether these opportunities are recognised by the stakeholders and whether other barriers can be overcome (e.g. financial barriers of young families taking over older SFH).

3 BARRIERS AND INCENTIVES AS PERCEIVED BY THE BUILDING OWNERS

The survey covered owners' past renovation works, their main motivation and their perception of the exogenous factors, including their subjective relative weighting, motivations, building-related goals and strategies, knowledge, as owner type and age, and others. Owners who have realised energy efficiency renovation were distinguished from owners who only conducted overhauling or renovations with energy relevance or did not renovate

The goal of the survey conducted in the framework of the research project (Ott, Jakob et al., 2005) was to complement the exogenous analysis and to counterbalance the findings of the background analysis (section 2) with the subjective view of the building owners. The survey results should allow the weighting of potential barriers according to their relevance and the identification of drivers and possible further barriers that cannot be detected by purely theoretical analytical means. Thanks to the availability of pre-information about past envelope renovations,[6] some questions were tailored to individual cases. A distinction was made between those who did not perform an energy efficiency renovation and those who did. The former were queried about reasons and barriers and the latter about motivations and drivers. This approach revealed some quite interesting insights, as is shown in the following sections. Further it was assumed that the socio-economic characteristics of owners, but also motivations and goals, have an impact on the attitude owners have towards their building and finally on renovation behaviour.

The following findings are mostly based on the samples of the survey conducted in Ott, Jakob et al. (2005) consisting of 360 SFH, in some cases on the complete samples of Jakob, Jochem (2003), consisting of 1046 SFH, mostly from the cantons of AG (17%), BE (21%), BL (15%), TG (9%) and ZH (33%). 72% of the buildings are located in an agglomeration, 64% in a community with natural gas supply and 32% in a community with the label "energy city".

Almost three quarters of buildings in the sample were constructed in 1975 or before, that is during the period when building insulation was neither mandatory nor common. Slightly more than a third of buildings date from 1946 or before (cf. Table 2). Note that buildings constructed after 1985 are intentionally underrepresented in the sample, since these buildings are much less relevant regarding the scope of the study, since they were built more energy-efficiently and are therefore less relevant from an energy policy point of view. Façades and walls of single-family houses were insulated at a rate of 0.4%/a to 0.8%/a between the mid 1980s and 2000 (cf. Table 1). General building conversions and extensions was conducted in 42% of the SFH during the assessment period (Table 2), and in 10% of the buildings a roof extension was undertaken.

Socio-economic variables include family situation, income, education, occupation and age (cf. Table 2). Notably 40% of the owners of the sample were more than 64 years old and that only 12% were younger than 45 years old.[7] The majority of SFH owners in the sample (n=360) are older than 50 years, with an average of 60 years. The age distribution of the owners of the buildings to be renovated (constructed before 1970) is even more skewed towards older people (cf. Table 2). In Switzerland as a whole 23% of the owners of these buildings are between 55 and 64 years old and 36% more than 64 years while only 23% younger than 45 years (based on data from census "Volkszählung 2000", Swiss Federal Office of Statistics).

Another interesting fact is that the age of the owners is quite strongly correlated to the age of the building; young buildings are the property of young owners and middle-old buildings are the property of older owners and only buildings constructed before the 1960 have a larger age distribution (cf. Jakob, 2004 or Ott, Jakob, 2005, p. 46). This suggests that owners construct their SFH at the age of 30 to 40 years and then own them for quite a long period. Respondents have on average owned their home for 24 years . About one third of the buildings in the sample have

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6 The people and buildings surveyed is a sub-sample of the sample of people and buildings surveyed in Jakob, Jochem (2003).

7 With respect to the Swiss owners of SFH constructed before 1980 the distribution is biased towards older owners; according to the population census of 2000, the share of owners who are younger than 45 years is 23% and the share of owners who are older than 64 years old is 32%.

been the owners' property since the year of construction, i.e. they are the first owner of the building (this share is higher in the case of younger buildings), and about half of the buildings have been purchased (particularly those which were constructed before 1960).

Table 2 Descriptive statistics, mean and standard deviation (in parenthesis, only for non-dummy variables), N=360

	Cat 1	Cat 2	Cat 3	Cat 4
Construction period (1946 or before | 1947-1975 | 1976 or later | NA)	0.342	0.386	0.272	
Building with flat roof	0.067			
Size of single-family house (small | medium | large)	0.461	0.425	0.114	
Annual income tax burden (labour income 100 kCHF, 2 children) in community of building location, given in kCHF	10.282 (2.584)			
Building extension or general conversion	0.419			
Façade or roof at the end of life time (as perceived by the owners)	0.336			
Motivation energy saving or environment	0.211			
Motivation extension of roof space	0.103			
Motivation aesthetics of façade	0.175			
Envelope strategy (comprehensive | step by step | overhaul. | minim.)	0.072	0.297	0.422	0.178
Visited at least 1 information event	0.247			
Profession (Arch., planer | builder| build. mang. mercantile | oth., NA)	0.111	0.086	0.231	0.617
Occupation (Arch., planer , builder, build. mang. | retired | other, NA)	0.194	0.231	0.617	
Education (mandatory school, apprenticeship | high school, univ. | NA)	0.528	0.389	0.092	
Age of respondent (less than 45 | 45 to 64 | more than 64 years | NA)	0.122	0.450	0.400	0.028
Family situation				
Monthly household income kCHF (< 6 | 6 to 10 | > 10 |NA)	0.303	0.406	0.169	0.122

Financing or building professionals or owners with an occupation in the building sector comprise about 20% of the respondents. About half of them have a technical profession or an occupation related to building or construction issues. Almost 40% of the sample stated that they have a high education.[8] About 25% of the respondents visited at least one information event or a specialised fair or tradeshow, which was assumed to have a positive impact on insulation renovation modes.

Goals, strategies and motivations

Since it was assumed that intrinsic goals, strategies and motivations would have an impact on the renovation behaviour, several questions about these were included in the survey.

Regarding the closed question what is most important to them regarding their building, 63% of the respondents stated "aiming for or maintaining a high level building quality" and 33% stated "maintaining the value of their building in the long run". Two thirds of the latter aim simultaneously at low maintenance and retrofit cost. Less than 5% stated that minimal maintenance was most important to them. Regarding the building envelope strategy (half-open question), only 7% stated that they follow a top level strategy including comprehensive

[8] With respect to high education, the sample is over-represented compared to the Swiss population

renovations and modernisations; about 30% stated that they follow a strategy of step-by-step renewal, while a relative majority of 42% opted for a strategy of ongoing overhauling and 18% follow a strategy of minimal maintenance (4% did not specify their strategy). Hence there is a certain discrepancy between general goals and the strategy regarding the building envelope.

The most important reasons (triggers) for conducting energy measures are the lifespan of the building elements affected and reasons affecting specific components (aesthetics, noise, loft conversions etc.). Slightly more than 20% of the owners stated that their façade or roof renovation was motivated by environmental or energy saving considerations and slightly less than 20% by aesthetic reasons (cf. Table 2). In about 10% of cases, the motivation was an extension of the roof space.

Whereas the lifespan motivation applies for both renovation modes, the other motivations are more specific: those who insulated mostly stated environmental and energy saving reasons as relevant, whereas those who only conducted an overhauling measure did not refer to this argument at all (cf. Figure 1). Qualitatively similar findings are observed in the case of roofs, windows, and internal renovations (cf. Jakob, Jochem, 2003 or Ott, Jakob et al., 2005, pp 94 – 96).

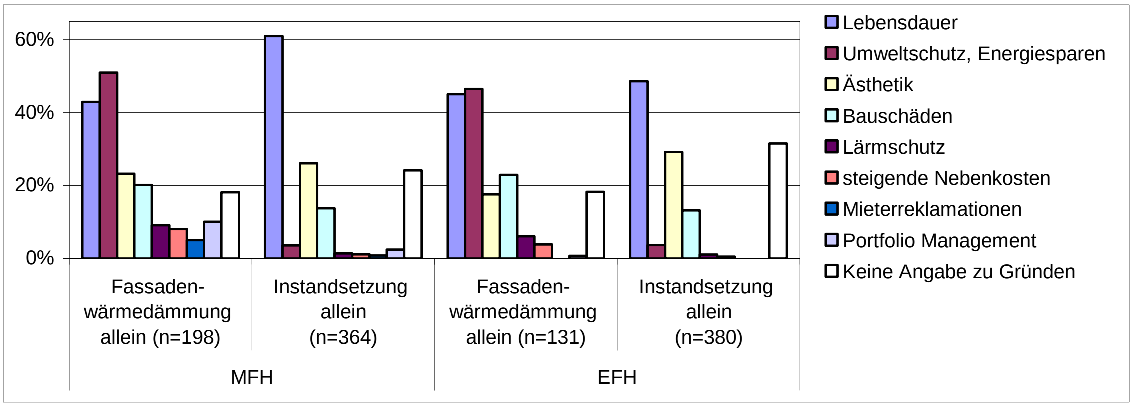

Figure 1 Share of motivational reasons stated by the owners (or managers), differentiated according to the façade renovation mode for the cases of single and multi-family houses. More than one motivation could be stated (source: Jakob, Jochem, 2003)

Hence, in the case of insulation, environmental and energy considerations are mostly cited as the second most important reason (after the end-of-lifespan argument), together with other reasons such as roof space extensions or noise protection (in the case of windows). In contrast, overhauling is rather motivated by other, building-element-specific considerations such as aesthetics or construction damages, or is not specified.

The analysis regarding the impact of the age indicates that middle-aged owners (45 to 64 years) more frequently put more emphasis on general building quality. High building quality is still frequently emphasised by retired persons, but this group also states low maintenance costs as being an important element. There is also a stratification in terms of building envelope renovation strategy; up to retirement owners tend to more and more comprehensive strategies instead of step-by-step low-level approaches, which is more frequently given by retirees (cf. Jakob, 2004 for details). Decision-finding and -making also depends on age: young owners (less than 45 years) tend to consult architects and planners more frequently whereas elder respondents tend to determine the measures directly. However, despite these impacts of the owners' age on goals, strategies and decision making, no impact on the actual average renovation rates over the period 1986 to 2000 could be detected by the renovation choice model (cf. section 4 below). Apparently different influencing factors balance each other out (or the data set is too small and/or not specific enough).

Information and decision making

Policy analysts and energy efficiency promoters often deplore a lack of information preventing a more prominent diffusion of energy efficiency in the building sector. Therefore the state of information and the information process was queried in the survey, based on different indicators such as the attendance at information events or visits to fairs, the type of profession or occupation, the type of consultancy, and method of defining orders and selecting contractors. The impact of each of the indicators on the relative share of renovation rates was checked.

Over 70 % have never attended an organized information or further education event and only 25% attended one or several of such events. What is interesting to note in this context is that owners state "more information" only very rarely when asked about additional incentives which would be useful from their point of view (cf. Ott, Jakob et al., 2005).

Finally, at the end of the decision-making chain is formulating an order and finding or choosing contractors, these steps often being interlinked with each other. This process can be characterised as traditionalist and informal: 60 % choose companies they have had before for renovations and 37 % take up the recommendations of friends. In contrast, to the findings above, the general process of measure defining and contractor selecting does have an impact on the decision outcome[9]: the buildings of the minority of owners who stated having contracted an architect or planner were insulated significantly more frequently (almost fifty percent) than those of the rest of the sample. On the other hand the insulation rate was below average if a contractor was selected to suggest measures[10] and it was also below those who defined the measures themselves before selecting a company[11].

Although there is some good reason to assume that selecting a company is somewhat endogenous to precedent motivations or decisions (those who decided to insulate might rather contract an architect than others) and that it cannot be directly seen as the origin of an insulation measure, such a selection seems nevertheless have an impact on the decision outcome. This specially applies for the case of yet undecided owners, who finally renovate less often than the average.

Drivers and barriers as seen by those who conducted EE renovations

The owners who conducted a façade or roof insulation between 1986 and 2000 were asked regarding their motivations, pointing to the fact that overhauling would have been much less

9 Note that the question regarding measure defining and company selecting was not specifically related to a certain measure type, but referred to renovation/renewal measures in general

10 This pattern was followed by one third of the owners

11 This pattern was followed by about 40% of the owners

costly (in terms of up-front costs). The responses of the single-family house-owners to these half-open questions revealed not one or two very important reasons, but a broad distribution of reasons. The three most frequently stated reasons are environmental and energy-saving considerations, building extensions and/or alterations, and increasing comfort of living (cf. Table 3). Remarkably a favourable cost-effectiveness or fiscal incentives were only rarely a reason for insulation measures.

Most of those questioned regarding barriers experienced no financing problems during their modernisation plans (>80 %) and legal regulations have not hindered the majority doing their modernisations (92 %). This is in line with the fact that only 2.2 % of single-family house-owners admitted to staggering renovations in order to avoid having to provide an energy certificate (an energy certificate is needed in the case of major conversions, extensions, alterations or renovations impacting on the envelope, but not in the case of overhauling).

Table 3 Rationale for façade or roof insulation, although overhauling would have been less costly. Share of stated selections of those single-family houses (SFH) and multi-family buildings (MFB) where such insulation was implemented between 1986 and 2000

	SFH		MFB	
	Façade	Roof	Façade	Roof
Insulation was necessary (building physics, moisture, damages)	16%	6%	32%	22%
Insulation was cost-effective, i.e. investment could be paid back	11%	13%	13%	10%
Insulation was installed due to environmental and energy saving reasons	39%	39%	38%	31%
Insulating instead of overhauling is part of the owner's basic strategy	21%	26%	38%	34%
Insulation was made in connection to building extension / alteration	30%	29%	23%	37%
The insulation measure yielded fiscal advantages	2%	0%	5%	0%
Insulation was made to improve housing comfort / comfort of living	31%	31%	Not applicable	
Insulation allowed for rent price increase	Not applicable		7%	1%
Insulation is demanded by tenants	Not applicable		5%	7%
Other reasons	7%	6%	11%	2%
No indication	5%	6%	2%	0%
Total (Multiple selections were permitted)	162%	156%	173%	144%
N (number of buildings with façade or roof insulation measure '86-2000)	61	108	56	91

Source: Jakob (2004), see also Ott, Jakob et al. (2005), p. 71 and p. 81

Barriers as seen by those who conducted EE renovations

A considerable majority, namely about three quarters, of those who did not implement a façade or roof insulation between 1986 and 2000 answered that they did not even seriously consider doing so. Overall it is again a broad spectrum of reasons which were indicated for being the cause of not insulating cf. Figure 2.

About 30% did not see a necessity of insulating or stated that an insulation is already in place (e.g. in the case of cavity walls or roof floors). It should, however, be noted that most of the buildings in the sample are from the construction periods of the 1980s and before when insulation was not common and that Figure 2 reports on the sub-sample of owners who indicated not having insulated since 1985. Further obstacles are architectural or technical (10% to 20%) or economic reasons (about one quarter of the owners). More than one third did not specify a reason. Only about one quarter explicitly stated economic or financial barriers..[12] Within this quarter, both reasons are of about equal relevance. The policy implication of these findings is that awareness and consciousness have to be raised among a large proportion of owners. This might be done by different instruments, economic incentives being one of them.[13]

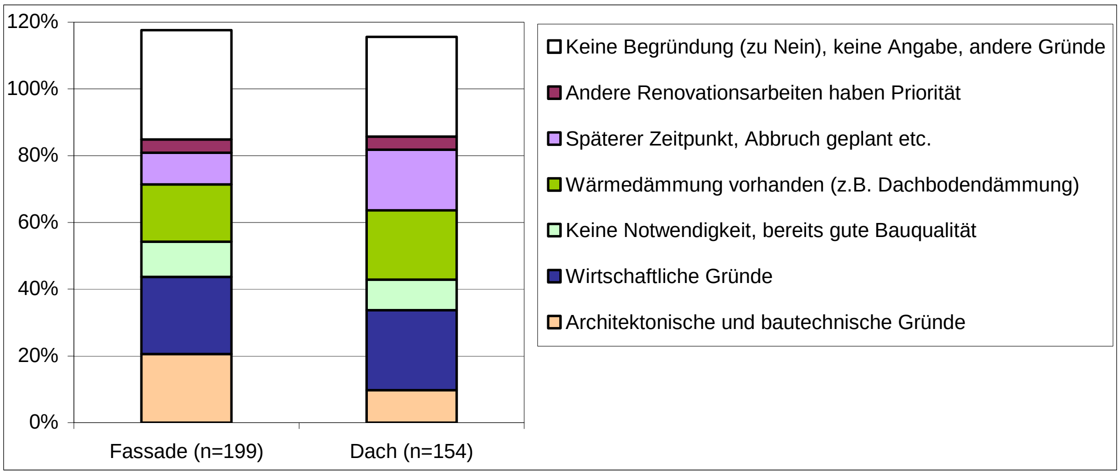

Figure 2 Share of barriers as stated by SFH-owners who did not conduct an insulation of façade or roof between 1986 and 2000. Half-open question, multiple selections were permitted (source: Jakob, 2004, cf. also Ott, Jakob et al., 2005)

Finally, owners were asked about regarding additional incentives or changes in the framework conditions that would facilitate EE renovation from their perspective. Owners did not call at all for more information and only rarely for subsidies. They rather wanted fiscal incentives instead, which contrasts with the actual situation. Indeed fiscal advantages for building renovation are already in place in most cantons. Here the question arises whether they are not informed about existing incentives or whether they wanted incentives in addition to the existing ones.

Comparative analysis

At this stage it is interesting to compare the outcome of the background analysis (section 2) with the analysis of the owners' perspectives and to check to which extent the results are congruent or eventually different from each other. This comparison is however not possible regarding all of the individual research questions and regarding each specific hypothesis; hence, to a certain extent the two approaches are complementing each other..

The overall picture of the topics where a comparative analysis is possible is characterised by some congruencies, but also by some relevant differences between the outcome of the two approaches (cf. synoptic overview in Table 4).

12 This share is higher for the (small) group of those who were considering the issue of insulation: apparently economic barriers become more important if examining the subject more closely.

13 It can be assumed that (strong) economic incentives would also overcome the owners' lack of awareness.

Table 4 Synopsis of barriers and drivers from the analysis of the technical, legal and economic framework conditions (background analysis) and as perceived by the surveyed SFH-owners.

Barrier and or driver	**Background analysis**	**Perception by owners**
Building context		
- Physical or technical condition of façade or roof	General driver, but not specifically for EE (insulation is in most cases not essential for building operation, only "nice to have").	Strong driver (trigger) for taking action, but not necessarily for EE. In some cases also barrier to EE, particularly in case of façade.
- General renovation activity (extensions, alterations)	Extensions have significant positive impact (legal requirements).	Extensions stated as drivers (especially in the case of roof). Other renovation priorities are <u>not</u> stated as concurring barrier.
Regulations		
- Planning and construction	Generally no barrier except in some few cases (distances to neighbours, listed buildings or historical, valuable façades in city centres).	Not perceived as a barrier.
- Energy codes and standards	Could be a barrier (minimal standard required and/or energy certificate need in case of large renovations: risk of contour).	Not perceived as a barrier.
Economic, financial, fiscal		
- Economic viability	No barrier in case of long-term consideration, barrier otherwise (in case short time horizons, low energy prices, if compared to do nothing option).	Weak driver, weak to moderate barrier (generally, between 10% and 15% stated a lack of economic viability as reason for not having insulated (*)
- Financial need, access to capital	Upfront capital need is large. Basel II: still unclear. Could provide incentives (differentiated interest rates), but could also be a barrier (restricted access to capital for some owners).	Financial needs stated as barrier by some owners (between 10% and 15%) (*).
- Tax incentives	Driver: costs of EE renovations may be deducted from taxable income in most cantons and on federal level.	Not perceived as barrier nor driver, often unknown or only known after renovation (free rider effect).
Information, knowledge, other		
Information and know-how	(Technical) information in terms of brochures, websites and public consulting was available (especially in the 1990s). Economic information, short lists of companies, labels were missing.	No lack of information stated by owners (note: purchasers and tenants were not queried); only few visited information events or specific fairs, consulting sources are friends or known companies.
Choice of company		Impact on renovation mode.
Awareness, attitude, strategy		Strong driver <u>and</u> strong barrier.
Socio-economic		
- Education	Impact was assumed	No sign. impact on renovation.
- Age	Impact was assumed	Impact on goal and strategy, but no sign. impact on actual renovation.
- Income	Impact was assumed	No sign. impact on renovation.
Within the minority group of those who examined the subject more closely these proportions are about one and a half time as high		

Source: own representation, based on findings of this section and of section 2.

A fairly good congruence can be observed in terms of general renovation activity as triggering factor and in terms of regulations which are not unanimously identified as relevant barriers. Further, resemblance is observed in terms of the impact of socio-economic variables: no significance impact could be detected by the econometric model and also respondents stated such factors (e.g. too advanced age, too low income) only rarely as barriers.

To a certain extent congruence is also observed in terms of economics. From a techno-economic analytical point of view the cost-effectiveness depends on some decisive parameters such as time horizon, interest rate, and future energy prices. In some cases the outcome of the analytically calculated cost-effectiveness is positive, and in some cases negative. Taking into consideration that the mentioned parameters certainly vary between the heterogeneous owners the finding is in accordance to the outcome of the survey responses: cost-effectiveness is only quite rarely stated as driver and also only a (larger) minority stated it as a barrier.

In contrast there is a larger discrepancy regarding tax incentives. Although tax incentives may be quite considerable, particularly in the case of owners faced with a high marginal tax rate, these tax incentives are not perceived by the building owners as incentive.

4 ECONOMIC MODELLING OF RENOVATION BEHAVIOUR

The economic modelling of renovation behaviour allows the testing of hypotheses on the drivers and barriers of energy efficiency in the case of existing buildings. Such hypotheses are either derived from theory or are commonly stated by researchers and stakeholders in the field. The motivation for modelling renovation behaviour is that it provides potentially useful insights regarding the design of policy instruments which stimulate energy-efficient renovation

Theoretical background and modelling approach

The decision whether or not to retrofit the building or whether to opt for an overhauling or a retrofit that improves the energy efficiency of the building is a typical example of a discrete choice. The choice of a specific renovation type is a typical discrete decision, since homeowners have to decide for one specific type of renovation (e.g. either overhauling/painting or insulating): a linear combination of different renovation modes is not realisable. Thus, an important proportion of the models used in the literature belong to the category of discrete choice models (see for instance Sadler 2003). In the case of façade or roof, for instance, there is a quite limited number of actions that can be taken. The (reasonably) feasible set of options and its economics depend on circumstances. Some of the measures could be taken at any point in time and some of the measures are triggered by exogenous factors, typically by technical ones (need of repair or replacement).

The econometric estimation of the choice behaviour can be based on two different methods: the revealed and the stated preference method. The first method is based on the observation of the actual renovation decisions of house-owners (thus, actual market data are collected), the second method is based on information respondents give through interviews or experiments about hypothetical situations. Thus, the first method is mainly suitable for understanding the past and present behaviour, which is useful for policy or product designs that are not too far away from the set of past and present boundary conditions. The second is particularly suited to forecasting the potential behaviour of economic actors regarding new products or new boundary conditions that have not been experienced yet. Both methods have advantages as well as drawbacks (cf. for example Verhoef and Franses 2002 or Louviere et al. 2000 for further insights of the strengths and weaknesses of the two approaches).

The understanding of the past (revealed) renovation behaviour, for instance through economic modelling of the renovation decisions, is also useful regarding the drafting of future policies which appeal to new policy instruments and involve new technologies. The impact of such policies would typically be estimated using stated preference methods. Modelling revealed behaviour helps to validate stated preference models and to check the plausibility of their results. In the ideal case both model types are combined by analysing revealed and stated preferences simultaneously .

Regarding the theoretical embedding, two basic owner-types have to be distinguished, firstly the owner-occupier who experiences her or his decisions directly in terms of costs and (qualitative) housing benefits, and secondly the case of an owner-landlord, in whose case costs and benefits are transferred to and from tenants through monetary flows, depending on the tenants' willingness to pay for the respective quality impacts. In this latter case an investment decision model, perhaps including uncertainties, would be an appropriate approach (cf. Hirshleifer, 1965; Decanio and Watkins, 1998; Ford, Fung and Gerlowski, 1998).

In the basic case of an owner-occupier, i.e. in the case of a single-family house-owner (excluding the case co-property of buildings in terms of freehold flat), the renovation decision can be modelled based on random utility theory, assuming that homeowners evaluate each renovation mode (e.g. maintenance without or retrofit with an energy efficiency improvement) and then choose the mode which leads to the highest expected utility (cf. Louviere et al. 2000; Banfi et al. 2006). The utility can be decomposed into a deterministic and a stochastic part. The choice set and the deterministic part of each renovation mode and of possible further action alternatives (including the do-nothing option), depends on its attributes (costs, lifetime, aesthetics, impact on energy efficiency and thermal comfort), on the current building situation, the current local market situation, and on socio-economic characteristics such as income, age, education, and, importantly, attitudes and expectations. Using econometric methods it is possible to identify the contribution of each attribute and of socio-economic variables on the overall choices.

If the characteristics of a given renovation mode are the same for all the individuals in the data set or where no information on the renovation modes is available, it is obviously not possible to identify the impact of such characteristics on the renovation decision. However it is still possible to model the impact of exogenous or endogenous factors on the choices made. Exogenous factors typically include building characteristics or location-specific characteristics (proxies for the local market situations) and endogenous factors typically include the socio-economic characteristics of the deciding actor, including attitudes and expectations. Thus, the utility of a certain type of renovation mode j for an individual q can be expressed as:

$$U_{qj} = U_{qj}(X, Z, H)= V_{qi}(X, Z, H) + e_{qi}$$

where X is a vector of housing characteristics (such as construction period, technical state of building elements, type and size of building etc.), Z a vector of location characteristics (such as canton, fiscal charge, type of agglomeration etc.), and H a vector of person specific characteristics (such as age, education, income, savings). H might also include a vector of attitude such as interest in housing quality, environmental issues, and others. The utility is decomposed into a deterministic part V_{qi} that depends on observable components (X, Z, H) and in a stochastic element e_{qi} (Louviere et al. 2000).

The probability of choosing renovation mode j can be written as

$$P\left(j \mid j,k \in A\right) = P\left[\left(v_{qj} + e_{qj}\right) > \left(v_{qk} + e_{qk}\right)\right]$$

House-owners are assumed to choose the alternative with the highest utility. That means that renovation mode j is chosen if the utility of this alternative is higher than the utility generated by all other alternatives in the choice set A.

It is assumed that the observable components X, Z, and H impact differently on each renovation mode. Hence the econometric analysis of the data can be carried out using a conditional multi-nominal logit model (Greene 2003) or a multi-nominal probit model. In the case of more than two alternatives (feasible choices) modelling should be related to the decision structure, and in the case of the logit approach the assumption of the independence from irrelevant alternatives has to be verified. Indeed, in the case of buildings, structured decision patterns, i.e. hierarchical decisions, are quite likely. The first decision could for instance include the decision whether or not to renovate the building envelope and the second whether an overhauling or an energy efficiency renovation is chosen. Such a case is typically modelled by a tree structure .

Data description and model specification

The data used for the modelling of revealed choice was obtained from two surveys The goal of the first survey was to estimate the annual rates of the different renovation modes of the building envelope and the heating systems and to collect some first information about drivers and barriers of energy efficiency from the viewpoint of the owners (cf. Jakob, Jochem, 2003). At this stage only very few socio-economic data were gathered, since an economic modelling was not the goal of this survey. The goal of the second survey was to reveal more precisely the drivers and barriers of energy efficiency, by specific questions that were related to the renovations as indicated by the first survey (cf. Ott, Jakob et al, 2005 and Jakob, 2004). The first survey was conducted at the end of 2001 and the beginning of 2002 and the second survey in spring and summer 2004. The estimation sample includes 360 single-family houses. Descriptive statistics of the sample of single-family home-owners are displayed in Table 2, section 3, p. 10).

Due to the relatively low number of buildings and due to the low rate of energy efficiency renovations the choice variables covered a period of several years, namely 1986 to 2000. This period might seem quite long, but it should be noted that this period was quite stable in terms of framework conditions (energy prices did not vary much after 1986). Further, some renovation modes were aggregated to restrict the number of coefficients to be estimated and only the one of highest interest, namely the opaque building envelope, was kept. In 22.5% of the single-family houses in the sample an insulation of the roof, the roof space or the façade was performed and in 25% an overhauling without any insulation (cf. Table 5). In the remainder of the buildings, other types of renovations such as window replacement or internal renovations or no renovations were performed.

Some of the buildings with outcome 3, i.e. buildings whose façade or roof was neither insulated or overhauled during 1986 and 2000, include façade or roof insulation or overhauling before 1986. For clarity, i.e. to obtain a clear-cut observation period, and to avoid noise (respondents might have confused renovation insulation with insulation at the construction of the buildings) the corresponding 37 observations were dropped from the estimation sample.

Table 5 Choice of renovation mode choices of single-family house-owners between 1986 and 2000

Outcome	Description	Count	Share
Outcome 1	Insulation of façade and/or roof	81	22.5%
Outcome 2	Overhauling of façade and/or roof, but none of them with insulation	91	25.3%
Outcome 3	Other kinds of renovation or no renovation	188	52.2%
Total		360	100.0%

Before designing the survey questionnaire we worked out several hypotheses about potential impacts on renovation choices. The drivers of the insulation mode can be grouped into the following categories: technical, attitude/motivational, socio-economic, and locational.

The age and the state of the building and its components presumably have a strong impact on the renovation activity of the owners. As compared to younger buildings which were insulated during their construction, one can expect increased rates of the insulation mode for buildings from the whole construction period 1975 and before, and possibly particularly high rates for the boom period 1946 to 1975 which was characterised by a particularly low construction quality in terms of thermal comfort, thus creating a corresponding need to catch up. Due to assumed heterogeneity and possible former renovations the objective variable “construction period” was complemented by a subjective variable “element has reached end of its life time”, as perceived by the owners.

Further, it can be expected that other types of renovation and housing activity, typically inside the building, impact on the renovation or overhauling of the building envelope. This impact could be negative or positive: either insulation is in competition (financially and economically) with other (large) renovation projects, or it is triggered by other types of renovation or building works. Indeed building experts put emphasis on the fact that insulation is not a primary motivation for initiating renovations (due to the lack of cost-effectiveness if solely undertaken with the aim of energy saving), but that renovation activity tends more often to be induced by needs such as additional or altered space.

Building insulation is a quite specific type of renovation due to its typical add-on character. Thermal insulation is rarely indispensable to the running of a building, except for some cases of the boom construction period. Although it provides other important benefits (such as thermal comfort, see Banfi et al, 2006), insulation is primarily seen as an energy efficiency measure, reducing energy costs and improving environmental performance. Hence it can be assumed that owners that are environmentally concerned or intrinsically convinced that individual action is needed would insulate more frequently than the rest of the population. Accordingly, we queried owners regarding their specific motivations. In addition, we assumed that owners with high education tend to be more environmentally concerned and that they could better estimate the potential benefits of building insulation.

Regarding further socio-economic variables, it was assumed that financing or building professionals or an occupation in the building sector would have a positive impact on renovation activity. Furthermore, visits to information events or specialised fairs or tradeshows was assumed to have a positive impact on the insulation renovation mode.

Building insulation renovations are characterised by a considerable upfront financial demand, which is then amortised over a long period of time. Therefore it can be assumed that owners with high income choose this type of renovation more frequently than those with low income. Further, due to the long time horizon we assumed that aged and/or retired owners would chose the insulation mode rather less often, firstly because of the irreversible character of the investment and secondly because monetary pay-back flows are delayed too long.

Finally it was assumed that the location of the building impacts on the renovation choice. A distinction was drawn between the cantonal and the communal level. In Switzerland, cantons have a large independence in terms of general fiscal policy and energy policy in the building sector. There are different rules in various cantons regarding deductions for renovation and overhauling costs from the taxable income, and cantons may define individual mandatory standards and – more relevant for the case of renovation during 1986 to 2000 – may define their own subsidy programs. Further, the income tax burden varies between cantons and communities. To test for these factors, we defined dummy variables for cantons and included the income tax burden for a typical owner (annual household income 100'000 CHF, 2 Children) as a community-specific variable.

Two models are specified. The full model includes the same variables as the reduced model, but additionally specific "event-type" variables for the building elements considered (e.g. roof space extension, damage) and attitude and motivation variables (e.g. general regarding goals and strategies, end of lifetime of the building element as perceived by the owner). The reduced model includes only general and "objective" variables, that is, general characteristics of the building and its location (community and canton) and of the owners. This approach was chosen to test the robustness of the model results by omitting event-based and subjective variables (and to test for endogeneity).

To use a simple multi-nominal logit model rather than a probit model, a nested structure or an error correlation approach, the IIA assumption, that the relative odds of any two outcomes are independent of the others (in the case of three of the others), has to be tested. This was verified for all models with the Hausman and the Small-Hsiao test of STATA. Omitting outcome 1 or outcome 2 did not change the relative odds in a statistically significant way, which means that the IIA assumption holds. For model 1, for instance, $Chi^2(df=11)$ of omitting outcome 1 = -3.26 and $Chi^2(df=11)$ of omitting outcome 2 = -1.3.

Estimation results and discussion

The estimation results for outcome 1 (façade and/or roof insulation) are displayed in the upper part of Table 6 for two different multi-nominal logit models and in the lower part for outcome 2 (façade and/or roof overhauling). The reference case (outcome 3) is for other kinds of renovations or no renovation during the considered period (1986 to 2000).

The results of both models are generally plausible. Many, but not all, coefficients vary from 0 to a statistically significant degree. Let us first focus on outcome 1, which is the outcome of particular interest from an energy policy point of view. In model 1 the estimated coefficients of building characteristics have the expected sign and they are – with a single exception – statistically significant. The exception is the construction period 1947 to 1975, which, however, is plausible in the sense that the construction period before the mid-seventies can be considered as rather uniform. Buildings with a flat roof were insulated more frequently. Hence the opportunity of the repair of these roofs was used to improve the insulation.

The coefficients of the more specific building-specific variables introduced in model 2 generally show a (highly) significant impact on the renovation modes: insulation is installed more frequently in the case of roof space or building extensions or alterations, if the building element reached the end of its lifetime (from the owner's viewpoint), and if construction damage at façade or roof had occurred. Finally, and important to note, intrinsic variables of a more general character such as building envelope strategies or general building quality goals[14] do not show a significant impact on the renovation modes.

The assumption that socio-economic variables such as income, age and education would have an impact on the renovation modes could not be confirmed by the estimations. Hence owners with high income or high education or owners following a top-level quality strategy did not insulate more frequently[15], and elderly persons did not insulate less frequently, as one could assume. Eventually this latter finding could result from a data artefact (during the assessed period of 15 years many of the respondents were still younger than 65 years old). The same applies for further indicator variables such as the general quality goal that owners have regarding their building, their building envelope strategy, or whether they have visited energy information events or not. Apparently more specific variables such as perceived lifetime overruled the impact of more general variables such as goals and strategies.

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[14] The variable regarding general quality goals was tested, but not included in the models displayed in Table 6.

[15] This could be due to the discrepancy between stated general goals and the stated strategy regarding the building envelope (cf. data description sub section).

Table 6 Estimation results of the multi-nominal logit models of revealed renovation mode choices of single-family house-owners (N=323)

	Model 1			Model 2		
Outcome 1: Façade or roof insulation	Coeff.	(SE)	Sig.	Coeff.	(SE)	Sig.
Outcome 1: Façade or roof insulation						
Construction period 1947-1975	0.22	(0.34)		0.82	(0.42)	**
Construction period 1976 and later	-2.06	(0.46)	***	-0.81	(0.57)	
Building with flat roof	1.85	(0.61)	***	1.20	(0.71)	*
Large single-family house	0.89	(0.47)	*	0.71	(0.56)	
Income tax burden (100 kCHF, 2 children)	-0.05	(0.06)		-0.04	(0.07)	
Building extension or conversion	n.i.			1.39	(0.39)	***
Extension of roof space	n.i.			2.33	(0.65)	***
Construction damages at roof or façade	n.i.			2.41	(0.56)	***
Façade or roof at the end of life-time (perceived)	n.i.			1.67	(0.39)	***
Comprehensive strategy regarding envelope	n.i.			-0.08	(0.72)	
Age of respondent more than 64 years	-0.05	(0.34)		0.34	(0.40)	
Household income	0.00	(0.43)		-0.01	(0.51)	
Education University or High School	0.05	(0.32)		-0.01	(0.38)	
Respondent visited at least 1 information event	0.35	(0.35)		0.45	(0.43)	
Occupation arch., planner , builder, build. mng.	-0.49	(0.44)		-0.72	(0.53)	
Constant	0.07	(0.75)		-2.43	(0.95)	**
Outcome 2: Façade or roof overhauling (painting)						
Construction period 1947-1975	0.91	(0.35)	***	1.27	(0.40)	***
Construction period 1976 and later	-0.49	(0.38)		0.40	(0.47)	
Building with flat roof	0.65	(0.68)		-0.12	(0.75)	
Large single-family house	0.46	(0.49)		0.52	(0.52)	
Income tax burden (100 kCHF, 2 children)	-0.12	(0.06)	**	-0.14	(0.06)	**
Building extension or conversion	n.i.			0.23	(0.36)	
Extension of roof space	n.i.			1.23	(0.72)	*
Construction damages at roof or façade	n.i.			1.78	(0.56)	***
Façade or roof at the end of life-time (perceived)	n.i.			1.78	(0.37)	***
Comprehensive strategy regarding envelope	n.i.			0.20	(0.71)	
Age of respondent more than 64 years	0.46	(0.32)		0.64	(0.36)	*
Household income	0.36	(0.40)		0.32	(0.44)	
Education University or High School	-0.84	(0.32)	***	-0.77	(0.35)	**
Respondent visited at least 1 information event	-0.19	(0.36)		-0.18	(0.40)	
Occupation arch., planner , builder, build. mng.	0.01	(0.40)		-0.03	(0.44)	
Constant	0.57	(0.69)		-0.59	(0.83)	
Pseudo-R^2 | Log likelihood | Chi^2(df)	0.11 | -303.2 | 77.9(20)			0.25 | -2510 | 174.2(30)		
Significance levels: ***=1%, **=5%, *=10% n.i.: not included in the model						
Reference Outcome: No renovation or renovation, window renovation or internal renovation						
Reference construction period: before 1947						

Comparing the estimation results between outcome 1 (insulation) and outcome 2 (overhauling) also quite yields plausible results. Damage and lifetime considerations of the building elements are relevant for both outcomes, since both modes allow for a corresponding repair and improvement; see the section regarding the marginal effects of evaluating the relative intensity of the impact on the choice. The community-specific income tax burden has a negative effect on outcome 2 (the coefficient for outcome 1 is also negative, but not significantly different from 0), which means the renovation activity lowered by the community tax burden; interestingly, the overhauling mode is more affected than insulation mode. Note that this is in line with other findings concluding from the model presented here or from additional questions of the survey (cf. Ott, Jakob et al, 2005): insulation is not so much motivated or hindered by economic factors as by technical (damage, lifetime of components), personal (attitudes such as environmental concerns) or occasional factors (building extensions).

The canton of the building location was also tested. In the models with intrinsic variables, none of the dummies for the main canton was significantly different from 0 (only the dummy for other cantons was, but less than 5% of the sample are in those cantons) and in the models without intrinsic variables in only one exception (SFH in the canton of TG were less frequently insulated). Also other location-specific variables on the community level such as tax revenues per inhabitant, community type (agglomeration or not), energy city, and others, did not show a significant impact on the renovation choices.

Comparing the actual versus the predicted outcomes allows for a characterisation of the predictive power of the estimated models. The share of correct predictions is quite low in the case of the first model without specific and intrinsic variables, in particular for outcome 1 (insulation). Indeed, it only predicts 28% of the outcome 1 correctly (cf. Table 6), which is even less than a model that contained only a constant (in this case about 33% would be predicted correctly). The predictive power of model 2, which includes specific and intrinsic variables, is much higher, not only for outcome 1, but also for outcome 2. The predictive power of model 2 can be characterised as quite good, given the relatively few observations and relatively few and rather general variables (particularly, no specific information on the renovation modes such as costs was available). Finally, model 2 also performs much better in terms of Chi^2 and in terms of pseudo R^2 (it is 2.5 times higher than model 1).

Table 7 Actual outcomes vs. predicted outcomes

		Model 1				Model 2			
Actual		Outcome 1	Outcome 2	Outcome 3	Share correct	Outcome 1	Outcome 2	Outcome 3	Share correct
Outcome 1	81	23	12	46	28%	45	17	19	56%
Outcome 2	91	7	37	47	41%	17	42	32	46%
Outcome 3	151	14	21	116	77%	10	15	126	83%
Overall	323	44	70	209	54%	72	74	177	66%

In the case of dummy variables the marginal effects are defined as the difference of the predicted probabilities of the two states of the corresponding dummy variable (0 or 1). This difference is estimated at the sample mean, i.e. all the other variables are set equal to the sample mean. In Table 8 the marginal effects (ME) are given for outcome 1 and outcome 2; the ME of outcome 3 can easily be calculated due to the fact that the ME of all three outcomes sum up to 1 for a given variable.

Table 8 Marginal effects (ME) of significant variables (p<0.1, cf. Table 6) on choice probabilities of outcomes 1 and 2, at the sample mean

	Model1				Model2			
	Outcome 1		Outcome 2		Outcome 1		Outcome 2	
Outcome 1: Façade or roof insulation	ME	(SE)	ME	(SE)	ME	(SE)	ME	(SE)
Construction period 1947 to 1976			0.18	(0.07)	0.04	(0.06)	0.22	(0.08)
Construction period 1976 and later	-0.27	(0.05)						
Building with flat roof	0.35	(0.12)			0.26	(0.14)		
Large single-family house (more than 180 m^2)	0.14	(0.09)						
Income tax burden (100 kCHF, 2 children)			-0.02	(0.01)			-0.03	(0.01)
Building extension or conversion	n.i.		n.i.		0.23	(0.06)		
Extension of roof space	n.i.		n.i.		0.36	(0.11)	0.00	(0.11)
Construction damages at roof or façade	n.i.		n.i.		0.14	(0.06)	0.25	(0.07
Façade or roof at end of life-time (perceived)	n.i.		n.i.		0.29	(0.09)	0.12	(0.09)
Age of respondent more than 64 years							0.12	(0.07)
Education University or High School			-0.17	(0.05)			-0.16	0.06
n.i.: not included in the model								

The probability of renovation is strongly increased in roof and building extensions and conversions and by lifetime considerations (+14% up to +36%), cf. Table 8. With one exception, these variables impact more strongly on outcome 1, i.e. on the insulation mode, the exception being construction damage, which impacts more on the overhauling mode. Hence the end of the lifetime of a building element stimulates renovation, but not exclusively energy-improving renovation. The probability of overhauling renovation without energy improvement is also increased in the case of the middle-aged buildings constructed between 1947 and 1975 (+22%), except for those with a flat roof.

High education has a negative impact on the probabilities of the overhauling mode; the probability is lowered by 16%. Since the corresponding variable of outcome 1 was not significantly different from 0 (and the coefficient is almost 0), it can be concluded that this lack of overhauling is not compensated by more frequent insulations but by other types of renovations (windows, internal etc.) or by the doing-nothing option (outcome 3). As mentioned earlier, the remaining socio-economic variables do not impact on the envelope renovation modes. Apparently, education, income, and occupation do not stimulate energy efficiency renovations. Note finally that the marginal effects of the additional models that include the canton dummies (not presented here) are similar to the ones in Table 8.

The model presented in this section is a first attempt to model the renovation choices of SFH-owners in Switzerland. Due to limitations in the data set further research is needed to deepen the understanding of the renovation behaviour. Further variables such as other large expenses and energy prices should be made available and some of the existing variables should be clarified. It should also be investigated to which extent some of the variables used are endogenous.

Unfortunately no energy price impact could be detected with the available data set. Indeed, between 1986 and 2000 the consumer price level of heating oil and natural gas was quite constant. Price increases, e.g. due to the first gulf war, were of quite short period and did not have a lasting impact on the beliefs of the private single-family owners. In addition there was no distinct signal towards energy price measures, for instance a CO_2 tax, during that period. Since 2000 the situation is somewhat different, due to a strong increase of the oil price, due to an emerging debate on resources and extraction/refinery capacities and due to a more intensive climate change debate. It is planned to conduct a similar study as presented here for the case of multi-family buildings including the period as from 2000.

5 Summary, discussion and conclusion

In this paper the barriers and drivers of energy efficiency in the case of single-family house (SFH) renovations were addressed by three approaches, namely by an analysis of the technical, legal and economic framework conditions, by a survey that gathered the subjective perceptions of these framework conditions as well as the motivations of the SFH-owners, and by the econometric modelling of the revealed renovation choices. Consistency between the three approaches was observed in terms of some, but not all barriers and drivers.

The analyses consistently revealed that building envelope renovation is triggered by general renovation activity such as building extensions or alterations, by the end of the lifetime of the element and by energy saving and environmental concerns. It is only the latter that leads to significantly more energy-efficient renovations. Consistency was also observed in terms of regulations, which are unanimously not identified as relevant barriers, and in terms of information; during the period considered technical information in terms of brochures, websites and public consulting was available (especially in the 1990s) and owners did not criticise a lack of information.

Regarding economic, financial and fiscal factors some consistency, but also some discrepancy can be recorded. The finding from the survey responses that economic viability is only quite rarely stated as a driver and also only by a minority as a barrier is more or less in accordance with the cost-benefit analysis using empirical data from the literature (Jakob, 2006). Consistency is given especially if it is taken into account that some decisive parameters such as time horizon, interest rate, and future energy prices certainly vary between the heterogeneous owners. Indeed, the variation of these parameters leads either to a negative or a positive outcome of a cost-benefit analysis which explains why some owners stated economic factors as a barrier and other did not. Remember that owners stated the high financial demand as a barrier to EE about equally often as the economic viability.

A discrepancy between the different approaches is observed regarding tax incentives. The analysis of the fiscal ordinance revealed large incentives but these incentives were perceived by the survey owners only to a very limited extent and often only after renovation decisions. A discrepancy was also observed in terms of the impact of socio-economic variables: such impacts were expected from the theoretical background, but no significance impact could be detected by the econometric model and also respondents stated such factors (e.g. too advanced age, too low income) only rarely as barriers. Apparently, other considerations that are not directly correlated with these basic socio-economic variables overrule their impact.

Indeed, the survey revealed a very relevant outcome, namely regarding awareness, attitudes, motivations, goals and strategies. A remarkably large majority of the owners did not even address the question whether to insulate or not. This applies not only to those who did not undertake any type of renovation, but remarkably even to those who actually undertook some envelope measure.[16] Renovation behaviour is quite strongly determined by the fact whether owners see a need for insulation or not (if they addressed the question at all) and by environmental and energy saving and by comfort of living considerations. Either the necessity for modernisation is derived from these factors or, alternatively, the need is not perceived; owners stated that the building is in good condition, that thermal insulation exists (although on a low level), or that insulation is "not necessary".[17] Economic reasons such as energy cost savings or fiscal advantages were stated much less frequently as a reason to insulate. These findings reveal a considerable lack of awareness and imply that awareness raising is very relevant and must be one of the first serious steps of policy actions.

Overall, the variety of obstacles and motivations stated by the owners is quite broad, including environmental/energy saving, technical and economic reasons. Opportunities and occasions such as building and space extensions and internal motivations are relevant drivers of EE renovations rather than information, education or high income which do not show a significant impact on the renovation choice. To summarise concisely: it is conviction rather than economics that have driven building insulation so far, and it is a lack of consciousness and partly economics that have hindered building insulation in the past.

In view of the market structures observed and the common practice of decision making, renovation behaviour can be described as being strongly oriented on previous experiences. Innovations tend to diffuse via personal, word-of- mouth recommendations.

The renovation choice modelling reveals that technical building characteristics such as building age, damages to building elements and triggering events (such as building alterations and extension) have a very strong impact on the choice of renovation modes. Their impact is much more relevant than those of socio-economic variables such as income, age, education, professional occupation, general quality goals or information indicators whose impact on the renovation modes could not be confirmed by the estimation results. Hence owners with high income and high education, or owners following a top-level quality strategy seem not to insulate more frequently and older people did not insulate less frequently, as one might have assumed. These findings from the modelling of the renovation choices are quite consistent with the conclusions that can be drawn from other survey questions. On the one hand, energy-efficient renovations were motivated by environmental and energy-saving considerations or by building extensions/alterations rather than by economic or fiscal advantages. On the other hand, in terms of the non-adoption of EE renovation, the lack of awareness or necessity played a more relevant role than the lack of cost-effectiveness or the lack of financial resources or other barriers.

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16 This may also explain the (unexpected) result that owners did not perceive a lack of knowledge and information, apparently they did not give a great deal to the subject.

17 Although their buildings were constructed before the mid 1970s and they had not insulated since then.

Policy implications and recommendations

A lack of information was not revealed from the survey answers nor from the econometric modelling. Note however that economic information, short lists of certified products companies, and labels was missing during the considered period. Hence there is not a lack of information in terms of quantity and even not in terms of quality, but rather in terms of the adequate type of information to increase market transparency and to reduce transaction costs.

Hence, owners and even more building purchasers must be provided by simple, but a timely and highly credible information about the EE level of the building, typically provided by energy certificates, (categorising) labels[18] or information about standardised annualised future energy costs. Useful and adequate information is also generated by lists of EE buildings or by short lists of certified companies and professionals (as for instance realised to a certain extent by the Minergie-association). Such information is particularly valuable since private owners only very rarely are in a decision situation (due to the long lifetime of building components and due to the low change rate of ownership). The builders and contractor companies as first contacts and multiplicators therefore have also to be incorporated as a target audience in campaigns for sustainable renovations in the building sector. Public involvement in the field of information and market transparency is justified among others due to the ancillary and external benefits provided by such efforts (cf. Sorrel et al., 2004).

Finally, regarding economic incentives, two barriers have to be addressed, namely the economic viability that is not given for all the owners in their perspective, and the high upfront financial demand. These barriers can be addressed simultaneously either by subsidies or by fiscal incentives. Although a CO_2-tax or energy taxes would address only the economic viability barrier, it is recommended to implement such a tax in combination with the subsidy and the fiscal incentives. Indeed, such a tax ensures owners regarding their long-term investments and tax revenues can be used (partly) to finance subsidy or fiscal incentive programmes. To lower free-rider effects such programmes should require minimal energy efficiency standards.

Regarding the current tax incentive system adjustments are needed if such tax incentives should play a role as a EE policy instrument, for instance as a surrogate for subsidies, if such are judged to be necessary. It is indispensable to make such incentives more known so that owners can include them in decision making. It is recommended to implement a tax credit system rather than a system of deductions from the taxable income. In a tax credit system, the fiscal incentive is provided by a reduction of the tax due. If the tax due is low or even zero, the incentive is spread over several years or even paid as a cash contribution. Such a system overcomes the considerable disadvantage from deductions of the taxable income, in which incentives increase with high income and decrease with low income. In contrast, with a tax credit system the incentive is – at least in absolute terms - constant for all income groups (tax credit systems are in place in France, the US, and in other countries.

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18 A label such as Minergie or Passivehouse is helpful, mainly in the case of new buildings, but due to its top-level target not suited to covering the whole housing market.

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