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Are households living in green certified buildings consuming less energy? Evidence from Switzerland

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ABSTRACT

In this paper, we compare the total energy consumption of households living in green certified buildings with households living in conventional buildings based on the example of the Swiss Minergie label. For this purpose, we estimate an econometric total energy demand model using a panel data set comprised of around 1500 households observed over the years 2010–2015. The empirical analysis provides suggestive evidence that households living in green certified buildings save approximately 25% of total energy. The estimated energy savings are lower than predicted by engineering-based bottom-up models that are not considering energy consumption behavioral factors. Nevertheless, our result suggests that savings in energy use and associated emissions of greenhouse gases (and other pollutants) may benefit from energy policy measures such as public information campaigns or subsidies that promote the construction of green certified buildings. Furthermore, since policy scenarios are usually based on ex-ante energy reduction projections, it is important to consider that the energy savings predicted tend, at least for the building sector, to be higher than they actually are. This difference may therefore impact the scenarios and thus the energy policy measures to be implemented.

1. Introduction

In Switzerland, the building sector accounts for approximately 45% of the total energy consumption. As most of the energy consumed in buildings comes from fossil fuels, the building stock is also responsible for around one third of Switzerland's CO_2 emissions (SFOE, 2021). Furthermore, the residential sector consumes 27.2% of final energy in Switzerland. More than half of the households' final energy consumption was generated using oil or gas (SFOE, 2020b). Therefore, in order to promote a sustainable development as suggested by the Swiss Energy Strategy 2050, it is important to adopt energy efficient technologies in the construction as well as in the renovation of residential buildings. The Swiss Energy Strategy 2050 is based on four pillars: improvements in energy efficiency, promotion of domestic renewable energy, withdrawal from the use of nuclear energy and measures with respect to the electricity grids (DETEC, 2021). In 2019, the Federal Council additionally introduced more stringent greenhouse gas reduction targets, namely zero net greenhouse gas emissions by 2050. In order to reach this objective, the Swiss climate strategy sets specific targets with respect to energy consumption and greenhouse gas emissions by sector. For instance, compared to today's levels private households are expected to reduce their final energy consumption by 15% and their greenhouse gas emissions by almost 100% until 2050 (SFOE, 2020c).

The construction of energy efficient buildings has been promoted through energy policy measures such as up-front subsidies, certification systems and information campaigns. Certification systems and information campaigns are considered to be market based energy and environmental policy instruments for addressing the market failure resulting from asymmetric information. In fact, these instruments reduce the asymmetric information between the actors in the building sector by providing information related to environmental and energy impacts of buildings. As discussed by Newell and Siikamäki (2014), with limited or imperfect information about the energy saving potential, consumers may not be inclined to adopt energy efficient technologies that are often characterized by higher up-front costs than non-energy efficient ones. In this context, as shown in studies by Newell and Siikamäki (2014), Heinzle and Wüstenhagen (2012), Blasch et al. (2017), and Boogen et al. (2020), information campaigns and energy efficiency labels can facilitate households' decision-making by providing information on the energy cost saving potential.

During the last 30 years, innovation in the materials, improvement of the insulation and generally in the building technologies have

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determined an important decrease of the energy consumption per square meter, especially for the so called green certified buildings. Green certification systems guarantee that new and renovated buildings meet environmental and energy efficiency performance standards. The most popular examples of voluntary green building certification systems[1] include schemes such as the *British Building Research Establishment Environmental Assessment Method (BREEAM)* and the American labels *Leadership in the Energy and Environmental Design (LEED)* and *Energy Star*.[2]

Minergie is a voluntary green certification system for energy efficient buildings introduced in Switzerland in 1998 (Beyeler et al., 2009). Minergie certified constructions are characterized by a low energy consumption, use of renewable energy (see Table 4 in appendix), own electricity production and a high living comfort.[3] The Minergie label is given to both new and renovated buildings. Buildings that receive a Minergie certificate or one of its sublabels[4] are entitled to receive an up-front subsidy in most of the Swiss political subdivisions (cantons) (Minergie Schweiz, 2021a).[5] In order to obtain the certificate, buildings must show in the construction permit application an estimated total weighted final energy consumption value per square meter for the overall operation of the building that is lower than a pre-defined limit, which takes into account own electricity production too. The current maximum (engineering-based) value of the final energy consumption per square meter without weighting is 35.7 kWh for newly constructed and completely electrified Minergie buildings (Cozza et al., 2019). This limit is calculated using some technological features as well as assumptions related to the users' characteristics, behaviors and preferences. Hence, the threshold is independent of current inhabitants and their actual usage patterns. For instance, in order to reach the level of energy consumption calculated during the planning phase of the building, the inhabitants of Minergie houses are assumed to behave optimally and use the dwelling and its technologies such as the heating and the ventilation system in a proper way. If a household living in a Minergie certified residence sets the room temperature to 24 °C or opens windows several times a day in winter, the energy consumption per square meter will be higher than initially calculated in the planning phase.

In general, based on ex-ante engineering calculations, the energy saving potential of Minergie certified buildings compared to non-certified buildings, which in any case must comply with the minimum energy standards set by the state, used to be around 60% in the period relevant for the houses considered in our analysis (Beyeler et al., 2009). However, the introduction of more stringent energy consumption standards in the Swiss building sector has reduced the theoretical difference in energy consumption between households living in Minergie labelled and conventional houses over the last years.[6] Nevertheless, Minergie labelled buildings remain interesting beyond the energy efficiency aspect because they offer more comfort through for instance the ventilation system, which is valued by consumers (Banfi et al., 2008; Christensen et al., 2014; Zundel and Stieß, 2011), and provide other benefits like reductions in mortgage rates (Beyeler et al., 2009).

For households it is important to know if living in a green certified house really offers the opportunity to save an important amount of energy. Previous studies have shown that buildings labelled as energy efficient are often characterized by consumption values higher than estimated ex-ante, while the opposite was frequently observed for houses that were initially labelled as energy inefficient (Cozza et al., 2020).[7] Several reasons have been brought up for the deviation of actual and theoretical consumption values ranging from inaccuracies in the planning phase (e.g. about occupants behavior) to the inappropriate implementation and usage of the building technology (Cozza et al., 2021). As these deviations differ across energy efficiency groups, the theoretically calculated energy saving potential does not necessarily correspond to the actual saving potential. However, from an energy policy point of view, it is important to know if the subsidized construction of green certified buildings leads to real energy savings as predicted by engineering projections and therefore are in line with the assumptions taken in the underlying energy policy scenarios to achieve the targets defined.

In this paper, we want to compare the total energy consumption of households living in Minergie single-family houses with households living in conventional buildings using econometric methods. For this purpose, we estimate an energy demand model using information of a sample of around 1500 Swiss households observed from 2010 to 2015. We expect households living in green certified buildings to consume less energy than households living in non-certified houses. However, this difference may not reflect the expected difference in energy consumption calculated in the planning phase of the building because of behavioral factors (such as higher indoor temperatures set than assumed by the standard) or due to erroneous technical assumptions (e.g. regarding the air change rate).

Few studies in the literature try to quantify the difference in total

[1] We use the terms certification and label as synonyms in this paper.

[2] For a review of the most popular green certification systems see Bernardi et al. (2017).

[3] An important thermal insulation combined with a controlled air exchange system allows to consume little energy and to guarantee fresh and clean air inside the house (Beyeler et al., 2009).

[4] There are three different categories of certifications ("Minerige", "Minergie P" and "Minergie A") that differ in their requirements for renewable own production and weighted energy consumption used for space heating, domestic hot water, and ventilation. All three labels are also available as an "ECO" alternative that additionally takes into account health and ecology in construction. Up to 2021, more than 50,000 buildings received one of the Minergie certifications in Switzerland (Minergie Schweiz, 2021b).

[5] Note that Minergie certified buildings are subject to higher up-front costs compared to conventional houses. The construction cost premium of a Minergie house compared to a conventional building used to be about 5–10% (Salvi et al., 2008). Nowadays, this difference is about 3% as the state has imposed higher insulation standards on conventional houses as well (Minergie Schweiz, 2021a). Salvi et al. (2008) estimated that the market is willing to pay a 7% premium for Minergie certified buildings.

[6] As the latest standard for new construction, we refer to a common standard the cantons have agreed on in 2014 ("MuKEn, 2014" standard). "MuKEn 2014" was completely implemented by 17 out of 26 cantons by September 2021 (EnDK, 2021). This common standard sets a requirement for weighted energy consumption used for space heating, domestic hot water, and ventilation of 35 kWh per square meter for newly constructed single family houses (EnDK, 2018). Minergie adopted this threshold for the two sublabels "Minergie" and "Minergie A" but sets it at only 70% of this value for "Minergie P" buildings in its latest product definition sheet (Minergie Schweiz, 2020). However, note that the MuKEn requirement became much more stringent over time. For instance, "MuKEn 2008" set the limit per square meter at 48 kWh and "Muken 2000" at 90 kWh for weighted energy consumption used for space heating, domestic hot water, and ventilation, while Minergie set this limit at 38 kWh in 2009 and around 42 kWh in 1998 (Beyeler et al., 2009). This is important in our context because the buildings in our sample were constructed before 2010, which is therefore the relevant comparison period in order to answer our research question. Additionally, as opposed to the MuKEn standard, Minergie sets extra limits to the consumption of appliances and lighting and introduces requirements for renewable own electricity production (Minergie Schweiz, 2020).

[7] In the literature it is possible to find several studies that analyze the energy performance gap (EPG) of green certified buildings. These studies are interested to analyze the difference between the ex-ante planned energy consumption and the observed energy consumption. For a review of studies dealing with the EPG related to Minergie certified buildings see Perch-Nielsen et al. (2019) and Cozza et al. (2019).

energy consumption between green labelled and conventional residential buildings. Most of the published studies are interested to make a comparison of the actual consumption of LEED certified buildings to that of non-LEED labelled buildings for the public, commercial and industrial sector.[8] Further, most of these studies are not based on an econometric approach, i.e. on the estimation of an energy demand model that considers socioeconomic explanatory variables.

Jeong et al. (2016) compare the actual energy consumption of 126 multi-family house complexes that accredited an official green building certification – the so called Green Standard for Energy and Environmental Design (G-SEED) – with the observed energy consumption of 321 non-certified ones in South Korea. The results of this study show no significant difference between labelled and non-labelled multi-family houses that belong to the same size class. However, the authors recognize that the results could be imprecise because important factors that influence the level of energy consumption are not considered in the analysis. Examples may include the number of people living in a building or weather conditions.

Li and Carrión-Flores (2017) compare the energy consumption of households living in Energy Star certified homes with households living in non-Energy Star labelled buildings.[9] The comparison is based on the estimation of an econometric energy demand model using information of around 1200 households living in Florida and observed during the period 2000 to 2013. The econometric models control for several household and building characteristics as well as spatial and time fixed effects. The results suggest that, on average, certified homes consume less energy than non-certified ones but more than theoretically predicted in the planning phase of the building. Note that the outcomes of this study could suffer from the presence of an endogeneity problem of the variable indicating that the building is Energy Star certified. Therefore, the analysis presented by Li and Carrión-Flores (2017) provides suggestive evidence and not a causal effect of Energy Star certification on energy consumption.[10]

Regarding the performance of Minergie buildings in Switzerland, Yang et al. (2020) compare the electricity consumption of 217 households living in certified dwellings with 433 households living in non-Minergie labelled houses recently renovated using simple performance indicators and self-reported data. The result of this study shows a statistically significant difference in the mean electricity consumption per square meter but not in the median electricity consumption. Nevertheless, the authors conclude "energy-renovated old dwellings are comparably energy efficient as Minergie-labelled ones." It has to be pointed out that this conclusion is based on the comparison of simple indicators that do not consider that the electricity consumption is also determined by other dwelling and household characteristics as well as preferences.[11] For instance, the houses in the two groups may be characterized by systematically different household sizes or heating systems. Also note, that the Minergie label is based on total energy consumption and not only on electricity consumption.

In our empirical analysis, we are estimating an energy demand function using panel data and econometric methods. In comparison to the paper by Li and Carrión-Flores (2017), which we identified as one of the most relevant studies in the area, we believe to add two important contributions to the literature. First, our model specification is considerably richer. In fact, we are able to take into account a large variety of house and household characteristics as well as variables related to the level of energy services consumed and environmental values. Second, in order to confirm our results, we use an instrumental variable approach to deal with the possible endogeneity issue related to the certification indicator variable. Finally, this is – to the best of our knowledge – the first study that compares the total measured energy consumption of Minergie certified single-family houses with non-certified ones by means of a sophisticated empirical model based on panel data for Switzerland.

Our results suggest that households living in Minergie certified houses consume around 25% less energy than households living in non-Minergie labelled buildings, ceteris paribus. Even though this is lower than predicted by the theoretical saving potential based on ex-ante engineering calculations, this finding emphasizes the importance and potential of energy policies such as public information campaigns and subsidies that aim at promoting the construction and renovation of green certified buildings in order to achieve energy and climate policy targets.

The remainder of the paper is organized as follows. Section 2 presents the data and section 3 provides a descriptive comparison of households living in Minergie and non-Minergie certified buildings in several dimensions. The econometric model is introduced in section 4 and the empirical results are presented in section 5. Section 6 concludes.

2. Data

For the empirical analysis of this paper, we use a data set created in 2015 by the Center for Energy Policy and Economics (CEPE) at ETH Zurich based on a survey. Detailed information on the questionnaire, on the approach used in the survey design and implementation as well as on the data collected are presented in Blasch et al. (2018). The data set contains information on building and household characteristics, gas and electricity consumption as well as data on behavioral attitudes and energy-related financial literacy (Blasch et al., 2021) of the residents. The original sample represents an unbalanced panel of 8378 unique customers of nine Swiss utilities over the years 2010–2015.

For our empirical analysis, we only consider single-family houses, which represent around 30% of the households in the overall data set.[12] We additionally drop observations that have missing data for electricity and gas consumption. Finally, we exclude the moving-in years as consumption values do not represent annual consumption in that case, as well as households that we observe only once. The final sample consists of 1461 households living in Minergie and non-Minergie certified houses observed over the period 2010 to 2015. Table 1 provides some descriptive statistics of the unbalanced panel data set considered in the econometric analysis ($N = 6570$) for the overall sample and split by certification status (Minergie and non-Minergie labelled buidlings).

The average gas and electricity consumption (*Q_TOT*) in our sample is around 16,700 kWh per year. Households can be very heterogeneous in terms of electricity and gas demand. For instance, dwellings with a gas based space or an electric water heating system would be expected to consume much larger amounts of gas and electricity compared to dwellings using oil or wood based heating. As expected, we also observe a significant difference in average total energy consumption between Minergie and non-Minergie labelled houses. The average annual energy consumption of Minergie buildings is around 14,000 kWh, while non-certified houses in our sample consume almost 17,000 kWh or about

[8] For a review of these studies that in most of the cases do not control for different building characteristics when comparing the energy consumption, see Amiri et al. (2019). Note that the authors of this review highlight the fact that "factors, such as age and size of the building, type of use, climate zone, and occupants' awareness are important factors to consider."

[9] The Energy Star label represents a voluntary energy efficiency label similar to Minergie but is mostly used in the US. In order to be labelled, a building is required to have a 30% lower consumption than a reference home with similar physical dimensions based on engineering projections.

[10] There are several approaches that can be used to identify the causal impact of a variable on an outcome. For instance, a researcher can organize a randomized control trial, use a difference-in-differences estimation or apply an instrumental variable approach. Of course, the use of these methods could be limited by the context and the type of data available.

[11] As discussed in more details in Filippini and Hunt (2011, 2015), the use of simple energy efficiency indicators has several limitations.

[12] Single-family houses are semi-detached, detached as well as terraced houses.

Table 1
Descriptive statistics.

	Overall		Non-Minergie		Minergie		*t*-test
	Mean	*Std. Dev.*	Mean	*Std. Dev.*	Mean	*Std. Dev.*	
Q_TOT	16745.07	*16378.76*	16959.72	*16661.04*	13839.66	*11544.44*	*** (3.91)
invlit	0.68	*0.47*	0.68	*0.47*	0.60	*0.49*	*** (3.59)
enlit	4.60	*3.06*	4.60	*3.07*	4.56	*2.99*	(0.27)
beh_index	2.52	*1.01*	2.50	*1.01*	2.71	*0.98*	*** (−4.32)
envdonat	0.45	*0.50*	0.44	*0.50*	0.50	*0.50*	** (−2.09)
has_young	0.34	*0.47*	0.33	*0.47*	0.44	*0.50*	*** (−4.50)
has_elderly	0.34	*0.48*	0.35	*0.48*	0.29	*0.46*	** (2.35)
hhi6k	0.19	*0.39*	0.19	*0.39*	0.20	*0.40*	(-0.60)
hhi6_12k	0.55	*0.50*	0.56	*0.50*	0.51	*0.50*	** (1.97)
hhi12k	0.25	*0.44*	0.25	*0.43*	0.29	*0.45*	* (−1.71)
univ	0.39	*0.49*	0.40	*0.49*	0.37	*0.48*	(1.21)
univ_partnr	0.20	*0.40*	0.20	*0.40*	0.21	*0.41*	(-0.37)
hhsize	2.89	*1.23*	2.88	*1.23*	3.09	*1.19*	*** (−3.37)
nmeals	9.38	*3.25*	9.42	*3.25*	8.89	*3.30*	*** (3.36)
ndishwcy	3.84	*2.29*	3.82	*2.30*	4.03	*2.16*	* (−1.90)
nwashmcy	3.51	*2.46*	3.48	*2.46*	3.98	*2.40*	*** (−4.20)
ndryercy	1.39	*2.02*	1.39	*2.04*	1.31	*1.88*	(0.88)
nentt	6.88	*5.50*	6.86	*5.51*	7.13	*5.32*	(-0.99)
rmtmp	20.73	*1.27*	20.70	*1.28*	21.10	*1.04*	*** (−6.48)
renov	0.49	*0.50*	0.50	*0.50*	0.45	*0.50*	* (1.84)
has_freezer	0.79	*0.40*	0.79	*0.40*	0.79	*0.41*	(0.47)
has_fr2	0.32	*0.47*	0.33	*0.47*	0.26	*0.44*	*** (3.08)
nosp_appl	0.58	*0.49*	0.58	*0.49*	0.57	*0.50*	(0.50)
sph_distr	0.02	*0.13*	0.02	*0.13*	0.03	*0.17*	** (−2.03)
sph_oil	0.30	*0.46*	0.31	*0.46*	0.15	*0.36*	*** (7.17)
sph_wood	0.06	*0.23*	0.05	*0.22*	0.13	*0.33*	*** (−6.58)
wah_distr	0.01	*0.12*	0.01	*0.12*	0.02	*0.14*	(-1.04)
wah_oil	0.18	*0.38*	0.19	*0.39*	0.08	*0.26*	*** (5.99)
wah_wood	0.01	*0.11*	0.01	*0.11*	0.01	*0.10*	(0.28)
bld1940	0.26	*0.44*	0.27	*0.44*	0.15	*0.36*	*** (5.39)
bld1970	0.24	*0.43*	0.25	*0.43*	0.18	*0.39*	*** (3.11)
bld2000	0.36	*0.48*	0.37	*0.48*	0.22	*0.42*	*** (6.41)
bld2015	0.14	*0.34*	0.11	*0.32*	0.44	*0.50*	*** (−20.40)
is_owner	0.91	*0.29*	0.91	*0.29*	0.91	*0.28*	(-0.23)
sqm	174.20	*62.08*	173.49	*61.92*	183.72	*63.39*	*** (−3.38)
district_1 (Lugano)	0.21	*0.41*	0.21	*0.40*	0.23	*0.42*	(-1.01)
district_2 (Bellinzona)	0.14	*0.34*	0.14	*0.35*	0.08	*0.27*	*** (3.86)
district_3 (Biel)	0.10	*0.30*	0.11	*0.31*	0.08	*0.28*	(1.42)
district_4 (Bern)	0.08	*0.27*	0.08	*0.27*	0.07	*0.26*	(0.40)
district_5 (Luzern)	0.07	*0.26*	0.07	*0.25*	0.10	*0.30*	** (−2.50)
district_6 (Aarau)	0.27	*0.44*	0.27	*0.44*	0.28	*0.45*	(-0.65)
district_8 (Lausanne)	0.03	*0.18*	0.03	*0.18*	0.04	*0.18*	(-0.22)
district_9 (Winterthur)	0.10	*0.30*	0.10	*0.30*	0.12	*0.33*	(-1.62)
N	6570		6118		452		

Notes: The statistics refer to 1461 single-family households observed over the years 2010–2015 leading to 6570 observations (unbalanced panel).
*/**/*** indicate statistical significance at the 10, 5, and 1 percent level, respectively.

20% more energy per year. However, as indicated by several highly significant t-tests in the last column of Table 1, certified and non-certified houses differ significantly in many dimensions that potentially influence energy demand. These differences highlight the importance of using an econometric approach for the comparison of Minergie and non-Minergie houses because this allows controlling for several factors in the empirical model.

In our data set we further have information about the level of energy services. More specifically, we have data on the room temperature (*rmtmp*), the number of cooked meals (lunch and dinner) per week (*nmeals*) and the number of hours TVs and computers are running each day (*nentt*) as well as the number of dishwasher (*ndishwcy*), washing machine (*nwashmcy*) and tumble dryer cycles (*ndryercy*) in a typical week. The mean indoor temperature in the houses of our sample is 20.7 °C. On average, participants cook 9 to 10 meals per week. Washing machines and dishwashers are used 3 to 4 times in a typical week and tumble dryers slightly more often than once a week. Around 7 h of entertainment by means of computers and TVs are consumed on average in one day. People living in Minergie buildings prepare significantly less lunches and dinners but enjoy a higher level of indoor temperature. On the other hand, residents of non-certified houses use washing machines and dishwashers significantly less often.

We also have information on the capital stock, i.e. the ownership of certain household appliances. Slightly below 60% of both Minergie and non-Minergie households do not possess large and energy-intensive appliances (*nosp_appl*) such as saunas or Jacuzzis. Separate freezers (*has_freezer*) are present in 79% of the households with no significant difference across groups. Non-certified buildings are significantly more often equipped with a second fridge (*has_fr2*) though (33% vs. 26%).

Furthermore, the data set is rich on variables that describe the household composition and residents' socioeconomic characteristics. The average household size (*hhsize*) in the sample is 2.89, and there is a significantly higher average number of inhabitants in Minergie labelled houses than in non-labelled ones. As a larger number of residents in a household can be expected to lead to an increase in consumption, the gap in total energy consumption of 20% between Minergie and non-certified buildings mentioned above might even increase if we account in the model for household size. Two binary indicators capture the age structure within a residence, namely the presence of children/teenagers below 20 years (*has_young*) or elderly people above 64 years (*has_elderly*). A significant higher fraction of households has children in the Minergie group (44%) than in the non-certified group (33%) while the opposite is the case for elderly residents (29% vs. 35%). More than half of the households in the sample have an income between 6000 CHF and 12,000 CHF (*hhi6_12k*), 19% below 6000 CHF (*hhi6k*) and 25% above 12,000 CHF (*hhi12k*). Significantly more non-Minergie certified houses are contained in the middle category but significantly less in the high income class, while there is no significant difference between labelled and non-labelled residences in the low income group. With respect to education, we use two dummy variables indicating if the respondent (*univ*) or the respondent's partner (*univ*_partnr) has a university degree, which is true for 39% and 20% of the households in the sample, respectively. These variables are not significantly different between Minergie and non-Minergie households.

We account for a number of dwelling characteristics in our econometric analysis too. The average living area (*sqm*) in the sample is 174 sqm and substantially larger for Minergie than for non-certified buildings. Construction and renovation options available to renters are very different compared to owners. In our sample, 91% of the single-family houses are owned (*is_owner*) by the residents occupying both labelled and non-labelled buildings. As expected, significantly more non-Minergie residences rely on oil fired water (*wah_oil*) and space heating (*sph_oil*), while more Minergie houses use wood-based systems (*sph_wood*) and district heating (*sph_distr*) for space heating. District heating (*wah_distr*) and wood (*wah_wood*) for water heating is not very frequently observed in the sample. The dummies for the periods when a building was originally constructed (*bld1940*, *bld1970*, *bld2000*, *bld2015*) indicate that Minergie houses are newer on average, with a great majority being originally built between 1970 and 2015. The differential age structure is probably also the reason for the higher share of renovated buildings (*renov*) in the non-labelled group. From the utility binary variables (*district_1-district_9*) we can see that most of the respondents in the sample considered are located in Aarau (27%), Lugano (20%) and Bellinzona (14%) and that the fraction of Minergie certified buildings can vary significantly across regions.

We furthermore include indicators for the respondents' level of energy (*enlit*) and investment literacy (*invlit*) as well as their energy-saving behavior (*beh_index*). Investment literacy is measured by a dummy variable that takes the value of one if the participant could solve a compound interest rate exercise. Around 67% of the respondents in our sample got this question right. The two sample *t*-test indicates that investment literacy is significantly lower for inhabitants of Minergie buildings. The index for the energy literacy can take values from one to eleven and was created by aggregating the number of correctly answered questions on energy-related knowledge such as the price of electricity in Switzerland or the consumption values of different appliances. The mean energy literacy score is 4.60 out of a maximum of 11 points in our sample. Furthermore, we measure the participants' energy-saving behavior by means of four specific questions regarding energy services consumption at home such as completely switching off appliances instead of leaving them in stand-by mode or choosing a dishwasher program depending on the dirtiness of the dishes. If such a question was answered with "always" or "very often", the participant was assigned one point. The behavior index represents the sum of points received by the respondent. The average behavior index in our sample is around 2.5, but significantly higher for inhabitants of Minergie dwellings. Moreover, a dummy taking the value of one if a participant has donated to an environmental organization in 2014 (*envdonat*) is measuring the green attitude of the respondent. On average, 45% of the participants in our sample did such donations, but a significantly higher share of Minergie households did so compared to households living in non-certified dwellings.

3. Model specification

The residential energy demand model used in the empirical part of this analysis is based on the household production theory. As shown in Alberini and Filippini (2011), using this theoretical framework, it is possible to derive the optimal demand function for energy. Based on this previous literature, we specify the following residential energy demand model:

$$E = f(P_E, P_K, ES, Y, H, M) \tag{1}$$

where total energy demand (E) is assumed to be a function of energy prices (P_E), capital price (P_K), level of energy services consumed (ES), income (Y), some household and building characteristics (H) and a binary variable reflecting the Minergie certification status of a building (M).

For the econometric analysis, we should keep in mind that the energy price is the same for households served by the same utility. Therefore, considering that we are using data from only eight utilities, the variation of this variable is very small. Further, in our data set we do not have information on the capital price of the appliances and the heating systems. However, it is reasonable to assume that the capital price (the annual depreciation cost of durables used to produce energy services and the annual opportunity cost of capital) is constant within the service area of a utility. Hence, in order to capture the possible impact of these two prices in the empirical model, we introduce three types of dummy variables in the econometric specification: utility-specific dummies and time dummies as well as their interactions. Of course, we should point out that these binary variables are also capturing other time-invariant institutional and regional differences that influence total energy demand.[13]

For the econometric analysis we decided to use a log-log functional form.[14] Therefore, starting from equation (1) we specify the following empirical model:

$$\ln E_{it} = \beta_0 + \beta_M M_i + \beta' X_{it} + \gamma_t + \gamma_r + \gamma_{rt} + a_i + u_{it} \tag{2}$$

$\ln E_{it}$ Natural logarithm of total energy consumption of household i in year t
M_i Dummy variable indicating that a house has a Minergie certification
X_{it} Vector of house and household characteristics, level of energy services and income
γ_t Year fixed effects
γ_r Region-specific fixed effects
γ_{rt} Region-year fixed effects
a_i Random household effect
u_{it} Idiosyncratic error

The use of a log-log functional form implies that some continuous variables included in X_{it} such as the living area or the energy services consumed are ln-transformed whereas the dichotomous variables are introduced in the model as dummies. Energy literacy and energy-saving behavior enter the model as binary variables taking the value of one if the respondent's index level is higher than the median index level. The indoor room temperature as well as the household size are considered through several binary indicators representing different levels of the underlying variables.

To estimate the empirical model given by equation (2) we use panel

[13] In a preliminary analysis, we estimated equation (2) by including the energy price and leaving out the interaction between the time and the utility dummies. As expected, due to the low variation of the energy price across the utilities, the coefficient of this variable, although negative, was not significant.

[14] We decided to use a log-log function form for two reasons. First, the estimated coefficients can be directly interpreted as elasticities, whereas for the interpretation of the coefficients of the dummy variables on total energy demand, such as the Minergie variable, we should use the following expression: $\exp(\beta) - 1$. Second, the distribution of total energy consumption is skewed to the right. Therefore, following Fox (2015, p. 59), we use the log-transformation to get a more bell-shaped distribution.

data and a random effects (RE) estimator. This estimator assumes that the random effects are uncorrelated with the observed variables included in the energy demand function. To control for the potential correlation of household-specific effects with explanatory variables, we applied Mundlak's formulation to the RE model (Mundlak, 1978).[15] The correlation of household-specific unobserved effects with explanatory variables are captured in an auxiliary equation given by:

$$a_i = \gamma \overline{X}_i + \delta_i \quad (3)$$

where $\overline{X}_i = \sum_{t=1}^{T_i} X_{it}$ and $\delta_i \sim iid(0, \sigma_\delta^2)$. X_{it} is the vector of all explanatory variables and γ is the corresponding vector of coefficients.

From an econometric point of view, the coefficient β_M in equation (2) related to the most important explanatory variable for this study can only indicate a causal effect under a set of identifying assumptions. First, the model given by equation (2) does not suffer from the excluded variables bias. Secondly, there is no simultaneity between Minergie certification and total energy demand. Third, Minergie certification is measured without systematic error. The inclusion of several explanatory variables in model given by equation (2), the use of a Mundlak version of the random effects estimator and the inclusion of temporal and spatial fixed effects at the regional level should exclude the presence of an unobserved heterogeneity bias. Given our information, the variable Minergie should be measured in a precise way. Finally, we think that we can exclude the presence of reverse causality, i.e. in our case a situation where households that have strong preferences to consume a low amount of energy tend to live in Minergie houses. As a robustness check, we also apply an instrumental variable approach in the estimation of equation (2). Of course, as we know from the literature, it is not always easy to find a good instrument that satisfies the following conditions: a) it is correlated with the endogenous variable; b) it is independent of the unobserved error; c) it affects total energy consumption only through the endogenous variable. After trying several possible instruments such as results of referendum votes related to environmental issues, we considered two variables as valid instruments. The first is the share of residential area at municipality level (zone1_rel), measured as the ratio of total residential area to total land area. The second is the municipality-specific "land to building ratio" (AZ_zone1), i.e. the ratio of the size of the building to the land. This number reflects the type of building that can be constructed in a municipality. Minergie buildings are allowed to utilize a higher fraction of land for construction purposes than non-labelled houses in certain municipalities.

As our endogenous explanatory variable of interest is binary, we follow the procedure recommended by Wooldridge (2002). We first estimate a panel probit model by maximum likelihood. The fitted probabilities from this first step are then used as instruments in a random effects instrumental variable regression. We use robust standard errors clustered on the household level.

4. Empirical results

Table 2 presents the results of the random effects (RE) along with the instrumental variable (IV) regressions as discussed in section 3. In our final sample, 1461 households are observed in two to five years leading to a total number of observations of 6570. Column (1) shows the coefficients and the corresponding clustered standard errors for the random effects model. Column (2) presents the results for the instrumental variable regression. The dependent variable in both specifications is the natural logarithm of the sum of annual gas and electricity consumption.

Table 2
Results.

ln(Q_TOT)	RE	IV
	(1)	(2)
minergie	−0.254*** (0.075)	−0.795* (0.410)
invlit	−0.040 (0.038)	−0.053 (0.042)
enlit_dummy	−0.060 (0.038)	−0.052 (0.039)
beh_dummy	−0.022 (0.038)	−0.005 (0.039)
envdonat	0.008 (0.038)	0.003 (0.040)
has_young	−0.092* (0.051)	−0.113** (0.051)
has_elderly	0.075 (0.046)	0.068 (0.046)
hhi6_12k	−0.012 (0.051)	−0.019 (0.054)
hhi12k	0.019 (0.075)	0.043 (0.073)
univ	−0.047 (0.045)	−0.031 (0.045)
univ_partnr	−0.057 (0.051)	−0.083* (0.049)
hhs2	−0.031 (0.025)	−0.030 (0.025)
hhs3	0.028 (0.028)	0.028 (0.029)
hhs4pl	0.100*** (0.027)	0.103*** (0.027)
lnMEALS	0.007 (0.058)	−0.021 (0.055)
lnDISH	0.141*** (0.043)	0.123*** (0.040)
lnWASHIN	0.127*** (0.031)	0.132*** (0.032)
lnENTT	−0.006 (0.031)	0.013 (0.031)
temp2021	0.156** (0.067)	0.133** (0.064)
temp21p	0.179** (0.073)	0.182** (0.075)
renov	−0.014 (0.039)	0.013 (0.041)
has_freezer	0.140*** (0.051)	0.142*** (0.050)
has_fr2	0.068* (0.039)	0.051 (0.041)
nosp_appl	−0.157*** (0.039)	−0.148*** (0.037)
sph_district	−0.807*** (0.197)	−0.740*** (0.243)
sph_oil	−1.092*** (0.063)	−1.099*** (0.065)
sph_wood	−0.891*** (0.082)	−0.824*** (0.093)
wah_district	−0.328 (0.210)	−0.366 (0.255)
wah_oil	−0.232*** (0.068)	−0.240*** (0.071)
wah_wood	−0.278* (0.157)	−0.346** (0.170)
bld1970	−0.0658 (0.053)	−0.067 (0.054)
bld2000	−0.245*** (0.056)	−0.251*** (0.055)
bld2015	−0.509*** (0.072)	−0.420*** (0.116)
is_owner	0.325*** (0.080)	0.331*** (0.083)
ln_sqm	0.267*** (0.059)	0.280*** (0.060)
constant	7.614*** (0.332)	7.610*** (0.329)
Utility FE	Yes	Yes
Year FE	Yes	Yes
Utility-Year FE	Yes	Yes
N	6570	6363

Notes: Column (1) represents the random effects model with Mundlak correction terms (not reported). Column (2) is an instrumental variable variation of the model in column (1).
Robust standard errors are reported in parentheses. */**/*** indicate statistical significance at the 10, 5, and 1 percent level, respectively.

Generally, we observe similar signs and magnitudes of the coefficients in the two models. Moreover, most of the associations point to the expected directions. For instance, there is a significant positive correlation of electricity and gas consumption with building size. More specifically, a 1% increase in living area is associated with an approximate 0.25% increase in total energy consumption. Additionally, there is also a significant correlation of the age of the houses with total energy consumption. Houses built between 2000 and 2015 and between 1970 and 2000 are estimated to consume around 50% and 25% less than buildings built before 1940, respectively. Note that we do not find a significant difference in total energy consumption between houses built from 1940 to 1970 and the reference category.

Furthermore, the results suggest that two and three person households are not associated with significantly higher electricity and gas consumption values than one person households, but dwellings with four or more inhabitants are, ceteris paribus. Not only the number of

[15] Equation (2) can also be estimated using a fixed effects estimator. The main advantage of the fixed effects specification is that the estimated coefficients are unbiased even if explanatory variables are correlated with household-specific dummies. The main drawback is that time invariant variables such as the Minergie indicator are captured by the fixed effects and cannot be included in the model. Therefore, using a fixed effects estimator it is not possible to obtain the coefficient of the Minergie variable. The Mundlak correction is an interesting approach that should solve the correlation issue while allowing the inclusion of time invariant variables in the model.

residents may be important but also their age structure. We find a negative coefficient for the presence of children and teenagers in a household and a positive one for the presence of elderly inhabitants over 64 years. However, only the former is significant (at the 10% level) while the latter is not.

There is also heterogeneity with respect to the ownership status in the sense that renting correlates negatively with consumption values. Particularly, we estimate that rented buildings consume around 30% less than owned ones. This might reflect the fact that the energy consumption of shared facilities in rented buildings is included in the rental rate and thus runs on a separate account or meter.

As expected, households relying on oil, wood or district water and space heating are associated with significantly lower consumption of electricity and gas as alternative energy sources are exploited that we do not include in our dependent variable. Additionally, the ownership of certain household appliances exclusively correlates positively with consumption values. For instance, we estimate that households owning a separate freezer consume around 14% more energy.

There is heterogeneity in the importance of different energy services with respect to electricity and gas consumption. On the one hand, higher numbers of dishwasher, washing machine and tumble dryer cycles as well as warmer indoor temperatures are associated with a significant increase in energy consumption. On the other hand, we do not find the same result for the number of TV and PC hours or the number of warm meals prepared. The reason for the heterogeneity in significance might be the differences in energy requirements of the energy services considered.

Surprisingly, we do not find a significant association between total energy demand and either energy and investment literacy, energy-saving behavior, environmental attitude and education as well as renovations after controlling for all other factors in this model.

Our primary goal of this empirical analysis is to estimate the difference in total energy consumption of households living in Minergie dwellings and households occupying non-Minergie buildings. The general idea is that by controlling for several household characteristics we are able to identify the role of Minergie building certification with respect to total energy consumption. The results in column (1) show that Minergie buildings are associated with lower consumption of around 25% compared to non-certified houses, ceteris paribus. This effect is highly significant and even larger than the one calculated in the simple comparison of mean consumption presented in section 2.

As discussed in section 3, we cannot exclude that the coefficient of the Minergie indicator variable is biased because of endogeneity. Therefore, as a robustness check we present the results obtained using an instrumental variable regression approach in column (2). The outcome confirms the results of our main specification.[16] As in the previous model of column (1), we find a negative effect of Minergie certification on total energy consumption. However, the IV estimate is substantially larger than the one in the random effects model. More specifically, we find that Minergie labelled residences consume about 55% less electricity and gas than their non-certified counterparts do, significant on the 10% level.[17] This is more than twice the effect we reported in first column. However, we have to recognize that the first stage of our instrumental variable specification is not completely satisfactory (see Table 3) leading to standard errors of the instrumental variable estimate that are more than five times as large as the standard errors in the random effect model. This is why the IV confidence interval actually contains the random effects estimate, despite the large differences in the coefficients estimated by the two models. Hence, we cannot say that the difference between the two coefficients is statistically significant, even though it is practically very large. Therefore, we prefer the results obtained with the main model specification presented in column (1) that provide suggestive evidence that Minergie certification leads to a reduction of at least 25% in total energy consumption.

5. Conclusion and policy implications

The building sector is responsible for a high share of total energy consumption and greenhouse gas emissions. During the last decades, households have become more aware about the importance of reducing energy consumption in the building sector in order to diminish the negative effects of climate change. However, with limited or imperfect information about the energy saving potential, households may not be so inclined to construct energy efficient buildings that are usually characterized by higher up-front cost than conventional ones. In this context, information campaigns and green certification systems have the goal to facilitate households' decision-making by providing information on the energy cost saving potential. For instance, the voluntary Minergie certificate aims to reduce the information asymmetry in the real estate market and to guarantee buyers a standard of energy efficiency and living comfort. One of the limitation of energy efficiency labels and green building certification systems is that they reflect theoretical consumption values based on ex-ante engineering projections and behavioral assumptions. For households it is important to know if living in a green certified house really offers the opportunity to save an important amount of energy, and therefore to reduce the energy cost.

Our study attempts to compare the total energy consumption of households living in green certified buildings with households living in conventional buildings. We find suggestive evidence that households living in green certified buildings carrying the Swiss Minergie label consume around 25% less energy. This is lower than the theoretical saving potential based on ex-ante engineering calculations. The literature has frequently found that buildings characterized by a high energy efficiency rating consume more than estimated in the planning phase, while the opposite was observed for low energy efficiency score buildings. Hence, the estimated difference between theoretical and actual saving potential of Minergie certified houses might be a result of Minergie houses performing worse than predicted, conventional buildings performing better, or both.

One objective of the Swiss Energy Strategy 2050 is to increase energy efficiency across several sectors. In this context, it aims at reducing the annual energy consumption in buildings from 100 TWh to 55 TWh by 2050 (SFOE, 2021). For this reason, several cantons are subsidizing the construction and renovation of buildings according to energy efficiency standards such as Minergie. The subsidy is intended to reduce an initial financial barrier for certified homes that are typically more expensive to construct. The construction cost premium of a Minergie house compared to a conventional building was about 5–10% until 2014 (Salvi et al., 2008). Nowadays, this difference is about 3% as the state has imposed higher insulation standards on conventional houses as well (Minergie Schweiz, 2021a).[18] From an energy policy perspective, it is important to ask whether the measures taken to encourage the adoption of Minergie certified homes are effective and justified. As mentioned at the beginning of this paper, the reduction in energy consumption of a Minergie labelled house compared to a conventional building was estimated to be around 60% from an engineering point of view (Beyeler et al., 2009). In this study we have shown that this saving does not occur in reality and is about 25%, which is in line with the findings of Li and Carrión-Flores (2017) for the Energy Star certification. However, even though the theoretical saving potential was not confirmed, our results show that the

[16] The first stage panel probit model results are presented in the Appendix. Both instruments correlate significantly with our Minergie indicator and exhibit the expected sign.

[17] $e^{-0.795} - 1 = -0.55$

[18] To reach the goals of the climate strategy 2050, additional investments of 23 billion Swiss francs are expected for private households. However, both the operating and maintenance costs as well as the energy costs are projected to become lower (SFOE, 2020c).

total energy consumption in the building sector can still be substantially reduced by constructing more houses that carry the Minergie label. Considering our estimated significant energy saving potential for Minergie certified buildings, the consumption reduction targets of the Swiss Energy Strategy 2050 for this sector mentioned above could be supported by building new houses or retrofitting existing dwellings according to the Minergie standard.

Nevertheless, the difference between theoretical and actual energy savings could call into question the appropriateness of a subsidy for Minergie certifications. However, it should not be forgotten that, in addition to contributing to the reduction of energy consumption, Minergie houses emit much less CO_2 than conventional houses because they are equipped with efficient heating systems based on electricity and often rely on renewable energy sources (see Table 4 in appendix). This is important because the Swiss Federal Council introduced a zero net greenhouse gas emissions target by 2050. In this context, private households are expected to reduce their emissions from 7.7 mt CO_2-eq to almost zero in 2050 (SFOE, 2020c). Our sample shows that a typical non-Minergie certified house with a gas-based water and space heating system is responsible for approximately 5000 kg CO_2-eq emissions annually. On the other hand, a typical Minergie house relying on a heat pump for both water and space heating that uses electricity produced with the representative energy source mix for Switzerland emits only around 1000 kg CO_2-eq per year.[19] For this reason, we believe that even if the reduction of energy consumption is actually lower than the one calculated ex-ante on engineering basis, the subsidy for green certification should be maintained in order to reach the greenhouse gas emissions target as defined by the Swiss Federal Council.

Parallel to the Minergie certification system, there is the voluntary Swiss Cantonal Energy Certificate for Buildings (CECB), which categorizes buildings into energy efficiency classes from A (very efficient) to G (very inefficient). Some cantons subsidize marginal improvements in CECB classes regardless of the initial energy efficiency class of the building. However, as shown by Cozza et al. (2020) a large drop in terms of kg CO_2-eq/kWh is only observed if buildings are constructed or improved to class A or B, while upgrading within classes G to C does not lead to a significant reduction in greenhouse gas emissions. Hence, policies supporting marginal improvements in CECB classes run into the risk of subsidizing ineffective measures that do not contribute significantly to the climate targets of the Swiss Federal Council. This risk does not occur when supporting Minergie certifications, since buildings constructed according to Minergie standards can be considered to belong to the top CECB classes and therefore deliver accordingly in terms of greenhouse gas emission reductions.

Finally, we know that policy makers define and implement energy policy measures in order to achieve medium-to long-term energy savings and greenhouse gas emission reduction targets defined under various scenarios. The results of this study indicate that in developing these scenarios that are usually based on engineering projections, it is important to consider that the energy savings predicted tend, at least for the building sector, to be higher than they actually are. This difference may therefore imply an overestimation of the long-term energy-saving potential that can be reached with the planned energy policy measures. As mentioned above, the Swiss government plans to reduce the energy consumption in the building sector from 100 TWh to 55 TWh by 2050, assuming that the buildings will satisfy a pre-defined energy consumption standard per square meter (SFOE, 2020a). Given the results of our study, it will be difficult to reach this goal with the planned policy measures. Therefore, policy makers should on one side promote the level of precision of the engineering based energy consumption estimates and on the other side define and implement new stringent policy measures with respect to observed energy consumption values.

Cozza et al. (2021) summarized several solutions to close the gap between ex-ante calculated and observed consumption values. These solutions may also be supported by policy measures in order to improve the engineering based estimation of the energy saving potential of green certified houses. For instance, it is important to enforce good practices in construction in order to prevent low quality work that results in a higher than predicted total energy consumption. Currently, the check if a building satisfies the theoretical energy consumption standard is usually only done during the approval phase of the project before construction. Therefore, there is a risk that the constructed building, due to low quality work, does not satisfy the standard. The government could solve this problem by introducing some random checks right after construction in order to identify buildings that are not fulfilling the energy consumption standard from a technical point of view.[20] In case the buildings are far from the standard, the state could introduce a penalty. If a subsidy has been granted, part of it may only be paid if proper execution and performance has been demonstrated right after construction. However, this approach might lead to additional cost that are higher for green labelled buildings than for conventional buildings that do not receive a subsidy and therefore increase the premium for certification. Additionally, the lower subsidy in the beginning might hinder people to certify in the first place.

Policy measures may not only be used to ensure that the theoretical values are obtained but also to improve the observed energy consumption values. One way to mitigate the risk of differential target and observed outcomes is to base energy policies such as labels and certificates on observed consumption values instead of theoretical projections. Subsidies for energy efficient and green certified buildings could be given continuously if standards are kept over the lifetime of the building and not as a one-time up-front amount in the construction phase. Again, there is a risk of additional monitoring cost though and the lower upfront subsidy might prevent people to certify at all but having more certified homes that do not deliver in terms of energy savings does not help to achieve the energy policy goals anyway.

CRediT authorship contribution statement

Massimo Filippini: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Adrian Obrist:** Methodology, Software, Formal analysis, Data curation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[19] We use the life cycle assessment database for the building industry (KBOB, 2016) that indicates greenhouse gas emissions of 0.102 kg CO_2-eq/kWh for the average electricity mix consumed in Switzerland and 0.228 kg CO_2-eq/kWh for gas.

[20] In order to achieve high quality work, Minergie already relies on a list of accredited construction companies (Minergie Schweiz, 2019) and performs random checks for at least 20% of the buildings up to five years after certification issue date in order to confirm the compatibility with the standard (Minergie Schweiz, 2020).

Appendix

Instrumental Variable Approach: First-Stage Results

Table 3
First stage results (panel probit regression)

Minergie	(1)
AZ_zone1	−2.329** (1.134)
zone1_rel	2.356* (1.278)
invlit	−0.825** (0.359)
enlit_dummy	0.250 (0.338)
beh_dummy	0.559* (0.322)
envdonat	0.484 (0.323)
has_young	−0.001 (0.455)
has_elderly	0.235 (0.394)
hhi6_12k	−0.785* (0.449)
hhi12k	−0.741 (0.565)
univ	−0.120 (0.389)
univ_partnr	−0.070 (0.450)
hhs2	0.132 (0.534)
hhs3	0.106 (0.614)
hhs4pl	−0.098 (0.683)
lnMEALS	−0.725* (0.390)
lnDISH	0.075 (0.305)
lnWASHIN	0.112 (0.273)
lnENTT	0.295 (0.255)
temp2021	1.235* (0.665)
temp21p	1.946*** (0.693)
renov	0.779** (0.358)
has_freezer	−0.159 (0.407)
has_fr2	−0.360 (0.359)
nosp_appl	−0.336 (0.326)
sph_district	3.913 (2.769)
sph_oil	−0.641 (0.560)
sph_wood	4.554*** (0.594)
wah_district	−3.150 (2.991)
wah_oil	−1.083 (0.688)
wah_wood	−6.108*** (1.979)
bld1970	0.661 (0.494)
bld2000	0.323 (0.486)
bld2015	6.410*** (0.579)
is_owner	−0.462 (0.580)
ln_sqm	0.387 (0.501)
_cons	−11.61*** (3.241)
Utility FE	Yes
Year FE	Yes
Utility-Year FE	Yes
N	6363

Notes: Standard errors are reported in parentheses. */**/*** indicate statistical significance at the 10, 5, and 1 percent level, respectively.

Additional Tables

Table 4
Energy sources for water and space heating in conventional and Minergie single family houses for two construction periods

Energy Source	Water Heating				Space Heating			
	2001–2005		2006–2015		2001–2005		2006–2015	
	Conv	Minergie	Conv	Minergie	Conv	Minergie	Conv	Minergie
Biomass	1.48%	9.70%	2.63%	5.90%	3.52%	23.22%	5.34%	10.77%
District heat	2.45%	0.54%	2.76%	2.65%	2.86%	0.61%	2.73%	2.87%
Electricity	32.50%	12.05%	26.41%	14.03%	3.36%	6.12%	2.58%	10.76%
Gas	25.99%	3.70%	13.17%	1.86%	30.05%	6.33%	16.66%	2.98%
Heat pump	15.26%	50.77%	41.37%	59.06%	31.50%	56.80%	65.98%	66.40%
Oil	19.21%	0.47%	3.78%	0.10%	27.26%	0.74%	5.18%	0.30%
Solar	2.04%	22.63%	9.02%	15.79%	0.31%	5.99%	0.58%	4.96%
Other	0.80%	0.13%	0.81%	0.61%	1.05%	0.20%	0.92%	0.97%

The data was obtained from the Swiss Federal Statistical Office (FSO, 2016) for conventional single family houses and a data set on all Minergie certified buildings constructed between 1998 and 2018 provided by the Minergie Schweiz institution.

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