Impact of Energy Rating on House Prices and Lending Rates*

Gábor Hajnal – Alexandr Maxim Palicz – Sándor Winkler

The real estate market is a key component of the green transition, and thus it is worth examining the pricing and financing costs of modern residential buildings in Hungary. In our study, we investigate a) whether a significant price premium can be identified for green properties based on new housing projects in Budapest, and b) whether banks finance residential buildings with more advanced energy technologies at lower interest rates. Based on our regression estimation, the green price premium is clearly evident in the Budapest new housing market: on average, homes with an energy rating of BB or better are 5.1 per cent more expensive than homes with an energy rating of CC. Based on our estimate of housing loan interest rates, no significant difference can be identified in the interest rates on loans granted to finance properties with a certificate higher than CC compared to loans granted for properties with CC certificate, i.e. banks do not yet factor energy aspects into the pricing of loans.

Journal of Economic Literature (JEL) codes: C13, G21, R30

Keywords: green financing, new homes, energy rating, housing loans

1. Introduction and motivation

Energy modernisation of the residential building stock in Hungary is crucial for meeting domestic climate change targets, which would also contribute to the security of energy supply. Today, about one third of final energy consumption in Hungary is accounted for by residential buildings (*Government of Hungary 2020*), the vast majority of which are in need of energy modernisation. According to the energy performance certificates issued, environmentally sustainable new housing is gaining ground in the housing market, driven both by the increase in the number of new homes and the previously expected tightening of energy compliance rules (the expected and subsequently delayed introduction of BB or better energy

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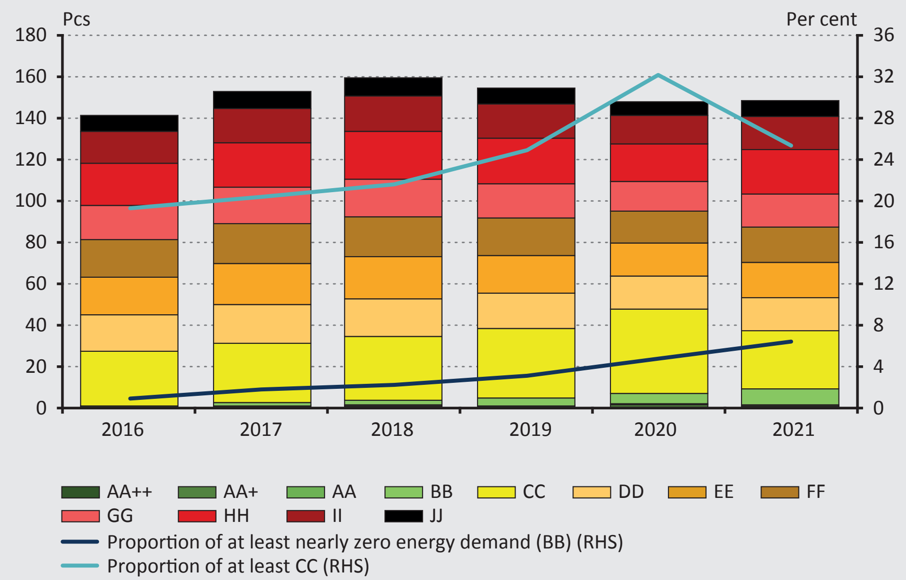
performance requirements for the occupancy of new homes). However, the poor energy performance of the housing stock as a whole is illustrated by the fact that only 3.2 per cent of energy performance certificates issued for residential buildings since 2016 have a rating of nearly zero-energy requirement (BB) or better, and 29.7 per cent have a rating of poor or worse (*Figure 1*).

Figure 1
Distribution of residential buildings with energy performance certificates issued between 2016 and 2021 by energy ratings



Source: Magyar Nemzeti Bank (MNB), e-tanusitas.eu

More energy-efficient homes may be more expensive to build, but demand for these properties may also be higher as sustainability concerns become more important. There is therefore a negative correlation between the improvement in the quality of the residential building stock and the affordability of housing. Consequently, it is important to examine the extent to which green aspects explain the price of properties in the new housing market, i.e. the premium that buyers have to pay for choosing more energy-efficient housing.

Given the increasing proportion of loan-financed home purchases, which accounted for nearly 50 per cent of all housing transactions in Hungary in 2021 (*MNB 2022*), choosing the right financing source is even more important for energetically advanced, newly built properties, the higher price of which may be associated with higher borrowing needs. According to the so-called green hypothesis, loans collateralised by more energy-efficient residential buildings have a lower credit risk due to their long-term stable value and lower maintenance costs, which can ideally manifest in lower financing costs. In our study, we use micro-level loan and real estate statistics to test this hypothesis for the Hungarian lending market using statistical methods.

The study is structured as follows: In the *second section*, we review the theoretical background and domestic experience with green financing. In the *third section*, using data from new housing projects in Budapest, we estimate the impact of better energy ratings on prices of new homes using a regression method. In the *fourth section*, we estimate the partial effect of the energy rating on housing loan interest rates using contract-level data. Finally, we summarise our main conclusions.

2. Theoretical background and domestic experience with green financing

Climate change is one of the major challenges of the 21st century. It has an impact on society, economic activity and inflation trends, as well as on financial stability (*Zöldy et al. 2022*). Direct physical damage can reduce the value of properties and the quality of the living environment (*Kim – Peiser 2020*; *Hirsch – Hahn 2018*), which can even be reflected in loan financing costs (*Nguyen et al. 2018*) and also increase insurance premiums.[1] Over-indebted and low-income households may be particularly vulnerable to the potential economic impacts of climate change. The reason for this is that they have less financial resources for green modernisation and adaptation, and typically spend a higher share of their income on consumables such as heating or electricity that have high greenhouse gas emissions (*Zachmann et al. 2018*). Moreover, a deterioration in labour productivity as a consequence of the negative impacts of climate change may also adversely affect households' income and ability to repay loans (*Gosling et al. 2018*).

Depending on the energy performance of the property, the green transition can shape utility costs and thus property values along different possible long-term paths. It is already being suggested that, as a result of the tightening regulation required by climate policy objectives, the rising costs of fossil energy production could lead to sustained price increases and inflationary pressure (see greenflation, *Schnabel 2022*), which could be further exacerbated by geopolitical risks. By contrast, energy modernisation of real estate can already yield results in the short term, both through an immediate reduction in potential energy use and through the resulting returns from higher property prices (*Zancanella et al. 2018*).

[1] Source: https://www.ft.com/content/5d271251-973d-45e5-8982-2e28bf96f952. Downloaded: 1 March 2022.

According to the green hypothesis, residential real properties with better energy efficiency have higher and more stable values and their lower utility costs also reduce the cost of living, which can have an overall positive impact on the loss given default (LGD) and probability of default (PD). The potentially lower default probability of green mortgages may result on the one hand from the more favourable credit risk characteristics of the clients choosing such properties (higher income, more environmentally conscious buyers) and on the other hand from the higher income of the borrowers that can be used to repay the loan due to the lower maintenance costs of the properties. Looking at data from four EU countries, *Baccega et al.* (*2019*) find a robust, statistically significant negative correlation between the energy performance of financed properties and default for Belgium and the Netherlands. *Billio et al.* (*2021*) found a lower risk of default based on data from Danish mortgage transactions, while *Guin and Korhonen* (*2020*) and *Guin et al.* (*2022*) found a lower risk of default on micro data from the UK. *Schütze* (*2020*) found lower expected losses for green mortgages using data for Germany. The results suggest that the energy efficiency of buildings has significant explanatory power for the probability of default of clients, even when examining a wide range of control variables. Overall, therefore, loans financing green properties may have a lower credit risk compared to less energy-efficient properties.

The lower credit risk may justify, *ceteris paribus*, a lower risk premium, and thus lower interest rates for green housing loans. However, little empirical research has been conducted on the relationship between energy efficiency and loan pricing. *An and Pivo* (*2018*) examined the default risk and loan terms of loans for energy-certified buildings in the US office building market. They found that with regard to loans granted for buildings that were already green-certified upon loan origination, banks set interest rates that were 15 basis points lower on average than for buildings that were green-certified only after the loan was granted. According to the authors, the difference in loan pricing is not economically significant compared to their estimate that the default risk for green buildings is 34 per cent lower on average than for other office buildings. *Giraudet et al.* (*2021*) studied the impact of energy efficiency on loan pricing in the French personal loan market. In their analysis, they looked at both home renovation loans and car loans, classifying loans for improving the energy efficiency of a property as "green" in the case of the former and loans for the purchase of a new energy-efficient car in the case of the latter. They found that, on average, the interest rate on loans for green car purchases is lower than on loans requested for other vehicles, while the result for loans for home renovation was counter-intuitive: loans for improving the energy efficiency of buildings are financed more expensively on average by institutions than loans for other renovation. The authors explain the latter result by a phenomenon identified in a previous study

(*Giraudet et al. 2018*), namely that banks' pricing practices reflect the low quality of energy efficiency renovations.

The lower risk of green mortgages is also underpinned by the potentially higher stability in the value of energy-efficient properties today. Demand for green properties is rising due to lower maintenance costs, sometimes higher comfort levels, possible energy efficiency regulations (*Ferentios et al. 2021*) and the gradual incorporation of energy performance data into purchasing criteria (*Hartenberger et al. 2017*), suggesting that these properties may exhibit a green price premium (*Hyland et al. 2013*; *Cajias – Piazolo 2013*; *Stanley et al. 2015*; *Fuerst et al. 2020,* etc.). Looking at domestic studies, *Ertl et al.* (*2021*), analysing data on detached house transactions in 2019, found that there is a significant premium in the price of detached houses as a result of a higher energy rating. Compared to the FF energy rating considered as average, a discount of around 20 per cent was identified for properties with worse energy performance, while a price premium of 10–15 per cent was identified for properties with higher energy ratings. The authors also found that family houses with a BB or higher energy rating are about 13 per cent more expensive than those with a CC energy rating. This suggests that the value of green properties may remain higher even during periods of real estate market stress, and thus the green housing market may be less volatile, meaning that green mortgage collateral may offer higher returns for lenders in the event of default.

Table 1
Overview of the credit risk characteristics of green mortgage lending

Author	Sample (geographical scope)	Property value/Loss given default	Default risk
Hyun et al. (2013)	*Ireland* data on 260,000 real estate transactions	*Significant* real estate price premium	*Not examined*
Cajias – Piazolo (*2013*)	*Germany* data on 2,630 real estate transactions	*Significant* real estate price premium	*Not examined*
Stanley et al. (*2015*)	*Ireland* data on 2,792 real estate transactions in the surroundings of Dublin	*Significant* real estate price premium	*Not examined*
Fuerst et al. (*2020*)	*United Kingdom* micro-data on real estate transactions	*Significant* real estate price premium	*Not examined*
Ertl et al. (*2021*)	*Hungary* real estate transaction data for 2019 (detached houses)	*Significant* real estate price premium	*Not examined*
Baccega et al. (*2019*)	*Four EU countries* aggregate data: UK, IT microdata: BE, NL	*Not examined*	IT, UK: data suggesting lower risk BE, NL: robust negative correlation
Schütze (*2020*)	*Germany* aggregate data	*Significant* lower expected losses for modern properties	
Guin – Korhonen (*2020*)	*United Kingdom* microdata	*Not examined*	*Significant* green housing loans are less likely to default
Billio et al. (*2021*)	*Denmark* 120,000 properties period between 2014–2018	*Not examined*	*Significant* greater impact for lower income clients
Guin et al. (*2022*)	*United Kingdom* microdata	*Not examined*	*Significant* green housing loans are less likely to default

Overall, the above studies suggest that, by taking into account the energy performance of properties, lenders can make more accurate lending decisions compared to institutions that ignore these characteristics. The potentially lower credit risk of energy-efficient properties could therefore have a significant impact in the future on lenders' risk management, regulatory requirements and the potential for the use of green financing instruments. Incorporating the energy performance of real estate collateral into lending and pricing may allow for lower interest rates for more energy-efficient properties and the development of dedicated green loan products, due to the lower risk premium. However, the picture is complicated by the fact that the studies examined (*Table 1*) only looked at relatively short time horizons and only found a correlation between energy rating and real estate price and probability of default for certain countries or sub-markets. Further research is therefore needed to provide general support for the green hypothesis, which will require the development of widespread access to energy data.

3. The link between the energy performance of residential buildings and prices

3.1. Data used for the estimation

To answer the question of how more advanced energy features affect the price of newly built homes, we use data from new housing projects in Budapest to make our statistical estimates. The database is the Budapest Housing Market Report,[2] compiled by the Eltinga Real Estate Market Research Centre, which covers new housing projects in Budapest that are larger than four residential units and are currently under development and for sale, on a quarterly basis. The database contains detailed information on the energy performance of buildings since Q1 2019, which can be either the energy performance certificate or the type of building engineering, or both.

For the period between Q1 2019 and Q4 2021, our database contains a total of 5,371 project observations, where an observation covers the characteristics of a housing project for a given quarter (e.g. construction status, planned completion, average square meter supply price). Adding up all the individual projects monitored over the three-year period, this represents some 41,501 new homes in Budapest. For 76 per cent of the project observations (4,090 observations), information on the energy performance certificate was available, and for 68 per cent (3,668 observations), the database included the average square meter supply price per vacant home, in addition to the certification information. Energy performance certificates are not yet available during the construction of buildings, as they can be issued for buildings that are already completed and awaiting occupancy permits; in many cases, however, developers already provide a projected certificate value based on the construction plans. Finally, the certificate values given in the first case of completed buildings were imputed to observations for previous quarters of the project, when the project was still pending or under construction.

[2] https://eltinga.hu/en/housing-report

The energy performance certificate shows the energy performance characteristics and efficiency of the building, as determined by a calculation method[3] according to the legislation. In Hungary, an energy performance certificate is required for the occupancy permit for new residential buildings and for the purchase of second-hand residential buildings, and is valid for 10 years afterwards. The current Hungarian system of energy performance certificates has been in place since 2016 and divides the overall energy performance of buildings according to a 12-grade scale *(Table 6 in the Annex).* In our study, we look at the impact of energy ratings and, in relation to the energy performance of buildings, the existence of renewable energy utilisation in buildings.

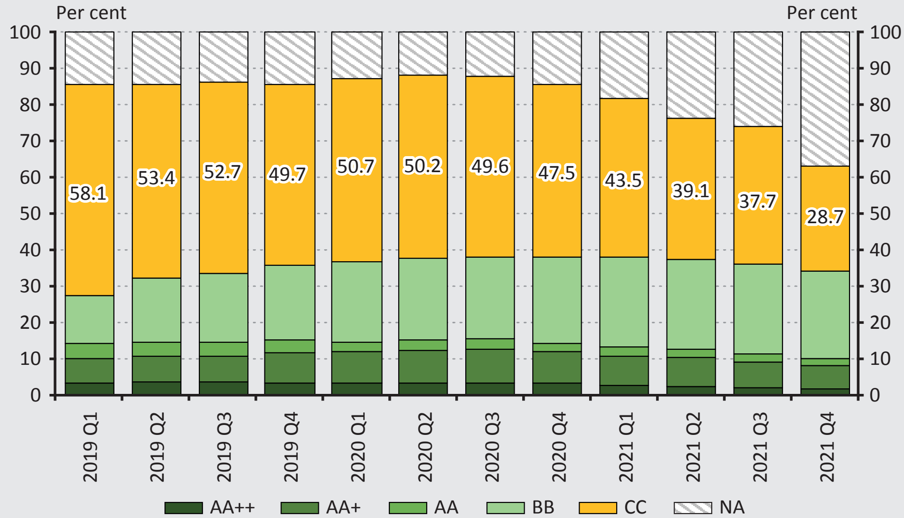
According to the requirement laid down in EU taxonomy,[4] the primary energy demand determining the energy performance of a building should be less than or equal to the threshold for nearly zero-energy demand (hereinafter "NZE") buildings set in national measures implementing Directive 2010/31/EU of the European Parliament and of the Council,[5] which in the Hungarian legislation is 100 kWh/m^2/year. The introduction of the NZE requirement for newly built residential buildings in Hungary was originally set for 1 January 2021, which the regulatory authority first postponed by half a year, then by another year, and then by two more years in the summer of 2022. Therefore, the period between 2019 and 2021 examined in our study is an appropriate period to examine the transition towards the NZE requirement in the supply of new homes and the impact of these more stringent requirements on the new housing market, because, in response to the anticipated tightening of regulations, developers have gradually adapted, and an increasing proportion of buildings have been built to meet the NZE requirement.

Based on the new housing developments in Budapest in our database, it can be seen that in 2019 the majority of residential buildings on the market (planned, under construction or completed but still with vacant units) did not yet meet the NZE requirement. In Q1 2019, 58.1 per cent of new residential units under development and for sale in Budapest had a CC energy rating, and, considering only known certificates, 68.1 per cent of homes did not meet the NZE requirement (*Figure 2*). In many cases, the database does not contain data on the energy

[3] The Hungarian certification system is set out in Government Decree No 176/2008 (VI. 30.).
[4] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R0852 Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM:C(2021)2800
[5] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32010L0031&from=EN

performance certificate, but does contain data on the building engineering. The missing certificates were substituted in according with the following principle: a BB certificate was assumed if renewable energy was used in the building engineering, and a CC certificate was assumed if not, which is referred to as the estimated energy performance certificate. Our rating is based on the principle that, according to the regulations, a property can only be rated BB or higher in Hungary if it uses at least 25 per cent renewable energy.

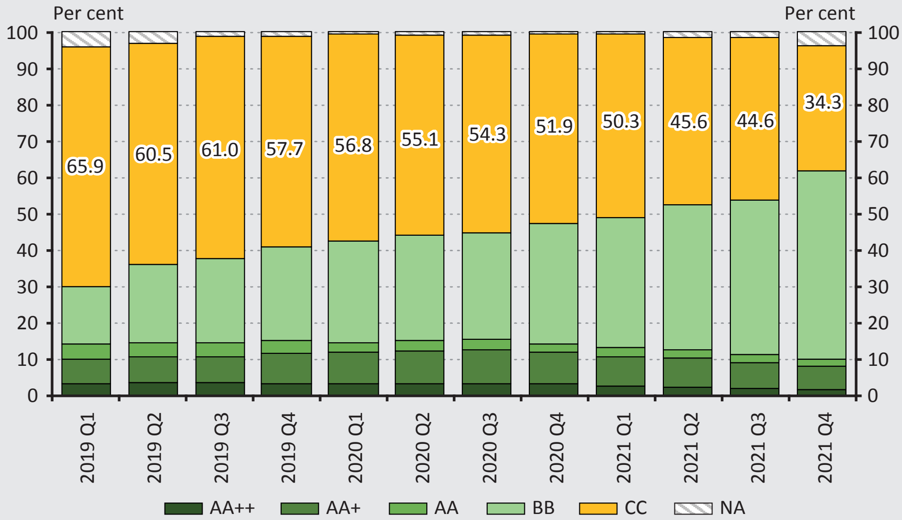
Figure 2
Distribution of the number of residential units in condominium projects under development and for sale, based on known energy ratings



Source: Calculations based on Eltinga–Housing Report data

Looking at the temporal distribution of residential units under development and for sale by estimated energy performance certificates, the "green" transition in the new housing market is clearly visible, i.e. buildings meeting the NZE requirement are gaining ground as we approach the previously expected entry into force of the NZE requirement (*Figure 3*). In Q1 2019, 65.9 per cent of the new residential unit supply in Budapest did not meet the NZE requirement (i.e. had a CC rating), which fell to 34.3 per cent by Q4 2021.

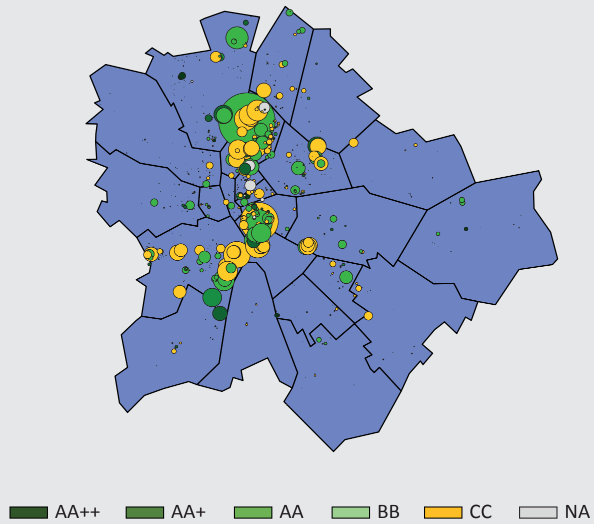
Figure 3
Distribution of the number of residential units in condominium projects under development and for sale, based on estimated energy ratings



Source: Calculations based on Eltinga–Housing Report data

The spatial distribution of new residential units on the market in the last three years is highly concentrated. 29.3 per cent of the residential units are located in one district (District 13) out of the 23 districts in Budapest (*Figure 4)*. 57.6 per cent of the residential units are located in three districts (13th, 11th and 9th) and 90.4 per cent in 11 districts. The high spatial concentration of new condominium developments is explained on the one hand by the availability of development sites and the location of marketable areas that are closer to the city centre or have good public transport connections. As shown in *Figure 4*, most of the condominium development projects are located in the central part of Budapest, along a north-south axis. The Budapest public transport network is particularly favourable in these areas, with several metro connections, which significantly increases the value of residential buildings. However, the proportion of environmentally sustainable, new homes meeting the NZE requirement is not highest where most homes are built. The share of new homes with at least a BB rating is highest in Districts 12, 17, 3 and 1 (over 80 per cent), while in District 13, where most new homes are built, only 33.9 per cent of homes met the NZE requirement between 2019 and 2021.

Figure 4
Location, number of homes and estimated energy performance certificates of new housing projects in Budapest for sale between Q1 2019 and Q4 2021

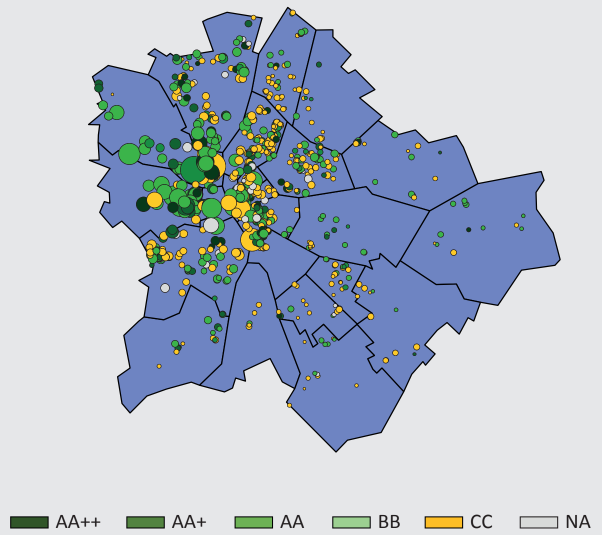


Note: Based on estimated energy performance certificates where not known; BB if renewable energy use is known, otherwise assuming a CC rating. The size of the circles in the chart is proportional to the number of homes (the largest circle represents 790 homes).

Source: Calculations based on Eltinga–Housing Report data

There is considerable variation in the average square meter supply price of housing projects. In Q4 2021, the average square meter price of a new residential unit in the most expensive building was HUF 3.9 million, while the average price of a new residential unit in the cheapest building was HUF 616,000. The average square meter supply price of a new residential unit in Budapest as a whole was HUF 1.1 million. *Figure 5* shows the importance of location in the pricing of residential buildings. The central areas of the capital and the 12th District are the most expensive in terms of average square meter price.

Figure 5
Location, average square meter price and estimated energy performance certificates of new housing in Budapest for sale between Q1 2019 and Q4 2021



Note: Based on estimated energy certificates where not known; BB if renewable energy use is known, otherwise assuming a CC rating. The size of the circles in the figure is proportional to the square meter price of the apartments (the largest circle represents 3.9 million HUF/m^2).

Source: Calculations based on Eltinga–Housing Report data

The distribution of projects meeting and not meeting the NZE requirement by number of homes and square meter price differs, especially for the latter. 55 per cent of housing projects with CC energy performance certificates are condominiums of 25 units or less, while 61 per cent of homes with BB energy rating fall into this category. 31 per cent of housing projects not meeting the NZE requirement had an average square meter supply price of HUF 750,000 or less, while the same proportion for projects meeting the NZE requirement was only 13 per cent. Overall, relatively cheaper housing projects with 25–100 homes are over-represented among those with a CC energy performance certificate (*Table 2*).

Table 2
Distribution of individual projects in the database by square meter price and number of homes broken down by category of estimated energy performance certificates

	Less than 25 units	25 – 50	50 – 100	100 – 200	Over 200 units	Total
	CC					
Below HUF 0.75 mn	18.6	4.2	3.3	3.1	1.4	**30.6**
HUF 0.75 – 1.0 mn	23.9	7.2	6.9	5.0	3.1	**46.1**
HUF 1.0 – 1.25 mn	7.8	1.7	2.2	1.4	1.7	**14.7**
HUF 1.25 – 1.5 mn	2.8	0.8	0.6	0.3	1.1	**5.6**
HUF 1.5 – 1.75 mn	0.8	0.0	0.0	0.0	0.0	**0.8**
HUF 1.75 – 2.0 mn	0.0	0.0	0.3	0.0	0.0	**0.3**
Above HUF 2.0 mn	0.8	0.3	0.8	0.0	0.0	**1.9**
Total	**54.7**	**14.2**	**14.2**	**9.7**	**7.2**	**100.0**
	BB or higher					
Below HUF 0.75 mn	9.1	1.0	1.8	0.5	0.5	**13.1**
HUF 0.75 – 1.0 mn	17.8	4.7	6.3	3.9	1.6	**34.2**
HUF 1.0 – 1.25 mn	11.5	4.2	2.9	3.4	2.1	**24.0**
HUF 1.25 – 1.5 mn	8.6	0.8	1.0	0.5	0.8	**11.7**
HUF 1.5 – 1.75 mn	5.0	0.0	0.3	0.5	0.0	**5.7**
HUF 1.75 – 2.0 mn	2.6	0.3	0.3	0.8	0.0	**3.9**
Above HUF 2.0 mn	6.0	0.8	0.3	0.3	0.0	**7.3**
Total	**60.6**	**11.7**	**12.8**	**9.9**	**5.0**	**100.0**

Note: Based on the latest price information for each project.
Source: Calculations based on Eltinga–Housing Report data

3.2. Estimation results: The link between the energy performance of residential buildings and prices

In the following, we look at the impact of the buildings' energy performance certificates, i.e. their energy efficiency, on the average square meter supply price of new housing projects. We examine this using a linear regression model, where the dependent variable is the average square meter supply price of new housing projects in each quarter and the explanatory variables are the different characteristics of the projects, including their energy performance. The explanatory variables of the model include a binary variable identifying the quarter of sale, which, in addition to including other explanatory variables, essentially captures the average "pure" price variation of the housing market.[6] Location is a significant driver of property values, which we controlled for in our model using several variables. First, we divided Budapest into 19 different relatively homogeneous areas based on postal codes. These areas were delimited by means of a regression method so that each area was as homogeneous as possible in terms of, inter alia, price and property type, and the postal codes

[6] This approach is essentially in line with the hedonic regression methodology used to calculate house price indices, which is also followed inter alia by the MNB house price index. (*Banai et al. 2018*).

constituting the areas were close to each other. In terms of location, two additional variables were created using the geocodes of the projects: (i) the straight line distance of the projects from Deák Ferenc Square, as the largest downtown public transport hub in Budapest, and (ii) the straight line distance of the projects from the nearest metro station, which is intended to control for the "quality" of public transport. The price of housing in our model is thus determined, on the location side, by the neighbourhood in which it is located (less expensive or more expensive) on the one hand and by the quality of public transport in the area, on the other.

Other characteristics of the projects are captured in the modelling with the following variables: the number of units in the project, the pre-sales rate in the given quarter, the rate of housing tax and the size of the developer. The number of housing units in a project captures the complexity of the development. The pre-sale rate is a control for the fact that, during the initial period of sale, it is likely that units with smaller floor areas which are thus more marketable but with higher square meter prices will be sold quickly, and therefore, in case of a higher pre-sales rate the project is likely to cover less marketable units and therefore with lower unit prices. The VAT rate on housing changed several times during the period of our analysis, between 2019 and 2021. Developers may price in a higher tax burden into the price of residential units that can be sold at a higher VAT rate. Finally, the size of developers was determined based on whether they develop more or fewer than 250 residential units in a given quarter. Larger firms may offer buyers a more competitive price due to economies of scale, better market knowledge and longer-term contractor relationships.

We included the energy performance of housing projects in our estimates in three ways. First, with energy performance certificates known with certainty. Secondly, with energy performance certificates supplemented by estimation, where we assumed a BB certificate for the use of renewable energy in the case of certificates that are not known, and otherwise a CC certificate. In our third approach, we used exclusively the information on whether a building uses renewable energy. We expect that properties with more advanced energy systems may be more expensive compared to less advanced properties, which may be mainly due to lower maintenance costs and stability of value. The higher price may also be due to the higher cost of the engineering and building materials needed for more advanced energy systems.

The main results of our estimation are shown in *Table 3*. In our main model (Model 1), we control for the energy performance of new housing projects using the energy performance certificate data that is known with certainty; thus, our estimate is based on 3,659 observations and has an explanatory power of 74 per cent. The explanatory variables included in the main model all significantly explain our target variable. Based on the quarterly coefficients of advertising, the average square meter supply price of new homes increased significantly between Q1 2019 and Q4 2021, rising by 33.1 per cent overall and by 2.6 per cent on average per quarter, simply due to the lapse of time, i.e. such a large increase in the price of new housing can be measured in the Budapest new housing market. According to the MNB's housing price index, housing prices in Budapest rose 21.2 per cent between Q1 2019 and Q3 2021, while the model shows that new housing prices in Budapest rose 26.6 per cent over the same period. Price indices for new and pre-owned homes from the Hungarian Central Statistical Office (HCSO) also show a similar picture, i.e. indicating higher price increases for new homes. The former rose by 31.3 per cent and the latter by 25.2 per cent over the period, but the HCSO only publishes price indices for the country as a whole, and therefore we cannot directly compare our results for the Budapest housing market with the price increases published by the HCSO.

In the model, the energy performance of the buildings was controlled for using the known energy performance certificates, where the CC-rating certificate was taken as the benchmark. Buildings with AA or better rating were aggregated into one category, due to the lower number of elements compared to CC and BB-rated buildings. Our results show that buildings with a BB energy performance certificate (compliant with the NZE requirement) have a significantly higher average square meter supply price per home, by some 5.1 per cent, compared to those with a CC certificate. The partial price effect of buildings with AA or better rating, which is more favourable than the NZE requirement, is slightly higher, at 6.1 per cent, compared to those with CC rating. The model is also estimated with the BB category as the benchmark. Based on the results of this model, there is no significant price difference between BB and AA or better rated buildings, the latter being only significantly more expensive than buildings with CC rating. Our results show that the price of new homes meeting the NZE requirement differs significantly from those with CC rating, while there is no statistically significant premium for buildings with better energy performance certificate than the NZE requirement in the metropolitan market for new residential units.

Most of the other explanatory variables in the regression have significant intuitive signs (*Table 3*). A higher number of residential units increases the average square meter supply price of the project, which is probably due to the fact that developers seek to build and sell as many residential units as possible in an area that offers better business opportunities for them. In line with our preliminary expectation, higher pre-sale rates are negatively correlated with the average square meter supply price, meaning that lower-priced residential units, such as those with larger floor areas or less favourable locations, are sold at the end of the project sales period. The distance of a project from the nearest metro station also has a significant explanatory power on the square meter price: an extra kilometre reduces the average square meter supply price by 1.4 per cent. A dummy variable defined for 19 different areas of Budapest was also found to be significant. The VAT on housing was insignificant in our estimations and was therefore not included in our final model. This is presumably also due to the fact that when the reduced housing tax was phased out at the end of 2019, the rules still allowed the majority of new homes to be sold at a 5 per cent VAT rate, and the 5 per cent housing tax returned in general from 2021. We also eventually removed the size of developers from our estimates, as the variable's inclusion no longer materially improved our model.

Table 3
Regression results showing the factors explaining the average square meter supply price of new housing projects

Dependent variable: Logarithm of the average square meter supply price of the project	Model 1		Dependent variable: Logarithm of the average square meter supply price of the project	Model 2	
	Coefficient	p-value		Coefficient	p-value
Advertising quarter			**Advertising quarter**		
2019 Q2	0.051	0.000	2019 Q2	0.056	0.000
2019 Q3	0.081	0.000	2019 Q3	0.082	0.000
2019 Q4	0.100	0.000	2019 Q4	0.102	0.000
2020 Q1	0.130	0.000	2020 Q1	0.131	0.000
2020 Q2	0.140	0.000	2020 Q2	0.146	0.000
2020 Q3	0.152	0.000	2020 Q3	0.151	0.000
2020 Q4	0.161	0.000	2020 Q4	0.166	0.000
2021 Q1	0.181	0.000	2021 Q1	0.193	0.000
2021 Q2	0.207	0.000	2021 Q2	0.221	0.000
2021 Q3	0.235	0.000	2021 Q3	0.236	0.000
2021 Q4	0.286	0.000	2021 Q4	0.295	0.000
Energy performance certificate			**Advertising quarter * use of renewable energy**		
BB	0.050	0.000	2019 Q1	0.056	0.001
AA, or higher	0.059	0.000	2019 Q2	0.051	0.001
			2019 Q3	0.062	0.000
			2019 Q4	0.057	0.000
			2020 Q1	0.065	0.000
			2020 Q2	0.055	0.000
			2020 Q3	0.067	0.000
			2020 Q4	0.052	0.001
			2021 Q1	0.044	0.004
			2021 Q2	0.053	0.001
			2021 Q3	0.077	0.000
			2021 Q4	0.067	0.000
Number of units	0.0002	0.000	**Number of units**	0.0001	0.000
Pre-sale rate	–0.114	0.000	**Pre-sale rate**	–0.109	0.000
Distance from metro	–0.014	0.000	**Distance from metro**	–0.018	0.000
Areas in Budapest	Based on postcodes, 19 homogeneous areas with significant coefficients.		**Areas in Budapest**	Based on postcodes, 19 homogeneous areas with significant coefficients.	
Constant	14.447	0.000	**Constant**	14.377	0.000
Number of observations	3,659			4,271	
R^2	74.30			75.18	
Adjusted R^2	74.06			74.92	

We tested the robustness of our model in several ways. For instance, the model calculation was performed with energy performance certificates supplemented by estimation, bringing the total number of observations to over 4,500. We obtained very similar results for the partial effect of energy performance certificates on average square meter prices. Buildings with BB certificates were on average 5.7 per cent more expensive than buildings with CC certificates, while the partial effect of AA or better certificates increased slightly to 6.5 per cent. The model estimation was also conducted including only the binary variable of whether or not the building uses renewable energy, instead of the energy performance certificates. According to our estimates, the use of renewable energy increases average square meter prices by 6.0 per cent, which is also consistent with the results of our main model. We also extended our model to include interactions between renewable energy use and sales quarters to assess whether the partial effect of more advanced energy use changed over time (*Table 3, Model 2*). Based on this estimate, the price premium for buildings using renewable energy ranged from 5.3 to 6.9 per cent until Q4 2020, declined to 4.5 per cent in Q1 2021, and then was 8.0 and 6.9 per cent in Q3 and Q4 2021, respectively. The latter value may also reflect the demand stimulus effect of the FGS Green Home Programme. Finally, as part of the robustness analysis, we estimated our model by eliminating buildings with over 250 units. This reduced the number of items in the sample by just over 100 observations, and the price premium for buildings rated BB and AA or better increased slightly by approximately one percentage point compared to those rated CC.

Overall, the results are in line with previous findings in the national and international literature, suggesting that residential buildings with more advanced energy systems exhibit a significant price premium. *Ertl et al.* (*2021*) found that detached houses with a BB or better energy rating are about 13 per cent more expensive than those with a CC energy rating, suggesting that the green price premium for detached houses in Hungary may be higher than for new-build condominium units. Comparisons with the results of the international literature are, however, complicated by the fact that the energy scales studied are diverse. Nevertheless, our results fit with the general findings whereby better energy efficiency increases the value of residential buildings (see, for example, *Hyun et al. 2013*; *Stanley et al. 2015*).

4. Identifying the impact of energy efficiency on interest rates

In the next section of our study, we use linear regression to investigate the impact of energy performance certificate on the interest rate of newly contracted housing loans, i.e. whether banks take energy efficiency into account, *ceteris paribus*, when pricing loans.

4.1. Data used and descriptive statistics

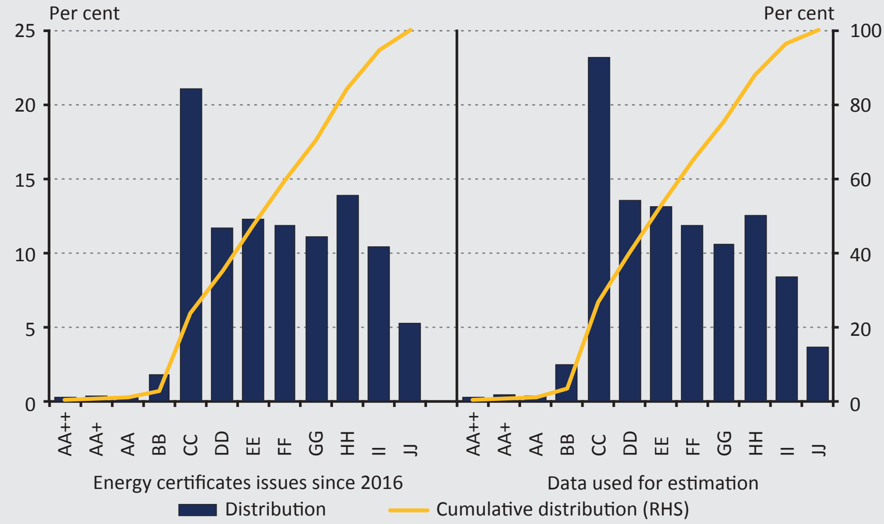
Our analysis is based on the information content of two databases:

- The central bank's credit register (HITREG) database, which contains anonymised, transaction-level data on the contractual details of retail loan contracts on the balance sheet of credit institutions;
- and the Real Estate Transaction (ING) report, which also contains anonymised, transaction-level data on the characteristics of the real estate, as the subject matter of the sale and included as collateral in the loan or lease contracts concluded during the reference period.

As the latter data set only contained data for 2021 and Q1 2022 at the time of the analysis, from the former database we only kept the observations contracted during this period, and thus the estimation results relate primarily to this period. In the HITREG database 85,165 and in the ING database 71,162 individual observations on the purchase of new or second-hand homes are available for 2021 and 2022 Q1, but for 28,326 observations from the latter population the energy performance certificate is unknown and these observations were dropped. In total, by combining the databases, we have a micro-level database containing 38,194 observations by loan contract, which anonymously contains the most important characteristics of the borrower, the loan contract and the collateral for new housing loan contracts.

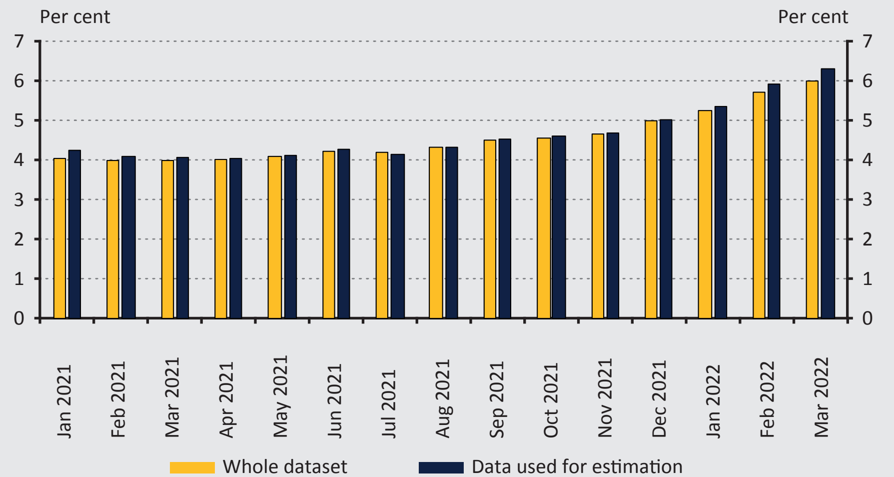
The representativeness of the data for the whole population was tested from two perspectives. On the one hand, the distribution of energy performance certificates of the properties in the database is almost identical to the distribution of energy performance certificates of the national residential building stock (*Figure 6*), indicating appropriate representativeness in terms of energy ratings. On the other hand, with respect to the average interest rates describing the dependent variable of our estimation, it can be observed that the weighted average interest rates used in the estimation are typically higher than for the whole population, but the difference does not exceed 30 basis points in any of the months considered (*Figure 7*).

Figure 6
Distribution of energy performance certificates of the properties



Note: FGS GHP-transactions were eliminated from the database.
Source: e-tanusitas.eu, calculations based on MNB data

Figure 7
Weighted average interest rate on the housing loan contracts used in the estimation



Note: FGS GHP-transactions were eliminated from the database.
Source: Calculated based on MNB data

Based on the descriptive statistics, an intuitive picture emerges with respect to the average year of construction and the average square meter price of the properties used as collateral: properties with higher energy ratings were on average built later and are more expensive (*Table 4).* As regards the distribution of average interest rates by energy performance certificate, which describes the dependent variable of our estimation, it can be observed that banks typically lend at lower average interest rates for contracts secured by properties with higher rated energy performance certificates. This leads us to conclude that institutions do take into account the energy performance of the property when pricing loans, but the difference in average interest rates may capture other characteristics strongly related to the energy performance certificate, such as the quality of the property or the riskiness of the borrower. Therefore, in the next section of our study, we use a linear regression method with control variables to examine the partial effect of energy rating on interest rates.

Table 4
Descriptive statistics of loan contracts in the database by energy rating

Energy rating	Number of observations	Average construction year	Average square meter price (HUF)	Average interest rate (%)
AA++	93	2018	816,727	4.40
AA+	140	2012	775,024	4.35
AA	120	2010	662,083	4.54
BB	933	2013	677,194	4.64
CC	8,836	1997	560,124	4.70
DD	5,154	1985	489,723	4.78
EE	5,012	1977	444,570	4.87
FF	4,517	1970	418,576	4.97
GG	4,028	1965	372,750	5.18
HH	4,786	1962	305,363	5.45
II	3,198	1961	294,425	5.63
JJ	1,377	1960	270,905	5.65

Source: Calculated based on MNB data

4.2. Estimation results: The link between energy performance certificates for residential buildings and interest rates

The methodological implementation of our analysis, which focuses on the impact of energy efficiency on interest rates, is based on the previous studies in the Hungarian literature in which the authors aimed to identify factors explaining lending rates (see, for example *Aczél et al. 2016*; *Dancsik – El-Meouch 2019*). In addition to the explanatory variables used in the literature, we also include variables controlling for the location and quality of the property, based on the ING database, in order to accurately estimate the partial effect of the energy performance certificate. The explanatory variables used in the model are:

- Property characteristics[7]
  - Energy performance certificate of the property used as collateral
  - Square meter price, expressed as the ratio of the sale price of the property to the useful floor area of the property, in thousand HUF

- Contract characteristics
  - Age of the borrower
  - The net monthly income of the borrower, recorded at the time of the loan contract and taken into account in the debt-service-to-income ratio, expressed in thousand HUF, categorised; in the case of multiple borrowers, the variable includes the aggregated income of the debtors
  - Debt-service-to-income (PTI): the monthly repayment as a proportion of the borrower's net monthly income
  - Loan-to-value (LTV): loan amount as the proportion of the collateral value (value of property)
  - Size of the contracted loan amount, expressed in million HUF, categorised
  - Contracted length of the interest rate period, categorised

- Other, binary variables
  - HPS-loan dummy: Is the loan a subsidised housing loan under the Home Purchase Subsidy Scheme for Families (HPS)?
  - CCHL-loan dummy: Is the loan a Certified Consumer-friendly Housing Loan (CCHL)?
  - Time dummy: the month in which the housing loan contract is signed, controlled for changes in the yield curve and the funding costs
  - Bank dummy: bank disbursing the loan[8]

In our model, properties with better than BB energy performance certificate were grouped into one category, which was mainly justified by the low number of observations available in the database. In the model, properties with the largest number of observations in the database and a CC energy performance certificate were taken as the benchmark. To identify partial effects, the following linear regression (OLS) was estimated:

$$\begin{aligned} &\mathit{INTEREST\ RATE}_i = \beta_0 + \beta_1\, \mathit{PROPERTY}_i + \beta_2\, \mathit{CONTRACT} \\ &+ \beta_3\, \mathit{HPS\ LOANdummy}_i + \beta_4\, \mathit{CCHL\ LOANdummy}_i + \beta_5\, \mathit{BANKdummy}_i + \beta_6\, \mathit{TIMEdummy}_i + \varepsilon_i \end{aligned} \quad (1)$$

[7] We included the year of construction among the explanatory variables during the model construction, but it did not prove to be significant, therefore it is not included in the model presented here.
[8] Banks with fewer than 400 observations were dropped from the estimation, reducing our database to 37,907 observations.

where $INTEREST\ RATE_i$ is the annualised interest rate on the i-th contract. *PROPERTY* is a vector containing the property characteristics, *CONTRACT* is a vector containing the contract characteristics, and dummy variables are included for *HPS*- and *CCHL*-loans, as well as for the disbursing bank and the date (month) of the contract. β_0 is a constant, β_1, β_2, β_3, β_4, β_5 and β_6 are vectors of coefficients associated with each set of variables.

Based on the R^2 statistic, the explanatory power of the model reached 75 per cent. All explanatory variables significantly explain the interest rate on housing loans at the 5 per cent significance level. For the question that is most relevant to this stage of our analysis, the model provides the following result: for properties with an energy rating of BB or better than BB, there is no negative partial effect on the contract rate, even at the 10 per cent significance level (*Table 5*). This result shows that for properties with the best energy performance, banks do not factor energy considerations into the pricing of loans. However, a significant positive effect can be measured on the pricing of loan contracts for properties with energy performance certificates significantly lower than CC, such as FF, GG, HH, II and JJ. With regard to the latter result, it is conceivable that the low energy rating, in addition to the effect captured through other control variables, captures the poor quality of the property, which banks take into account in the terms of the loan contracts.

A significant negative partial effect can be measured for the square meter price variable controlling for the quality of the property, but the magnitude of the effect is negligible. The results on the characteristics of the contract are also in line with our preliminary expectations: institutions tend to lend at increasingly lower interest rates on average to clients in the higher income category and to clients requiring higher loan amounts.[9] In addition, a longer interest period, a higher payment-to-income and loan-to-value ratio on average increase the level of the interest rate, although the latter variables have a low partial effect. We also controlled for the type of loan: the partial effect of Certified Consumer-Friendly Housing Loans is significantly negative and that of HPS loans is significantly positive.[10] Finally, we also included in the estimation the disbursing bank and the month of disbursement, controlling for different pricing behaviour of banks in the former case and for the rising yield environment in the latter.

[9] As a reflection of typical pricing practices of banks, the contract amount and income variables were included as category variables in the model.

[10] *Dancsik et al.* (*2022*) also found that banks typically price *overall* subsidised HPS-loans at a higher rate than market loans (taking into account the interest paid by the client and the interest subsidy paid by the state), which may be due to the statutory fixed client interest rate and the resulting low intensity of competition.

Table 5
Result of the estimated OLS-regression

Dependent variable: annualised interest rate of the contract	**Coefficient**	**p-value**
Energy performance certificate (compared to CC)		
higher than BB	0.009	0.832
BB	–0.008	0.742
DD	0.012	0.363
EE	0.032	0.015
FF	0.051	0.000
GG	0.072	0.000
HH	0.103	0.000
II	0.119	0.000
JJ	0.155	0.000
Square meter price	–0.000	0.003
Age	0.001	0.004
Income category (compared to an income of up to HUF 250,000, in thousand HUF)		
250–500	–0.252	0.000
500–750	–0.360	0.000
More than 750	–0.443	0.000
PTI	0.004	0.000
LTV	0.002	0.000
Contract amount category (compared to a maximum contract amount of HUF 5 million, in million HUF)		
5–10	–0.519	0.000
10–15	–0.834	0.000
15–20	–1.068	0.000
over 20	–1.491	0.000
Length of interest rate period (compared to an interest rate period of at least 1 but not more than 5 years)		
5–10 years	0.664	0.000
over 10 years	1.048	0.000
HPS-loan	1.218	0.000
CCHL-loan	–1.088	0.000

Table 5
Result of the estimated OLS-regression

	Coefficient	p-value
Date of disbursement (compared to January 2021)		
February 2021	–0.043	0.146
March 2021	–0.067	0.013
April 2021	–0.137	0.000
May 2021	0.010	0.741
June 2021	0.048	0.060
July 2021	0.223	0.000
August 2021	0.300	0.000
September 2021	0.346	0.000
October 2021	0.443	0.000
November 2021	0.592	0.000
December 2021	0.929	0.000
January 2022	1.325	0.000
February 2022	1.90	0.000
March 2022	2.196	0.000
Bank disbursing the loan	9 banks with significant coefficients	
Constant	6.077	0.000
Number of observations	36,072	
R^2	0.747	
Adjusted R^2	0.747	

Note: We also ran the regression with the elimination of HPS-loans and found no significant change in the estimated coefficients. HPS-loans are included in the sample at the full interest rate, i.e. they also include state subsidy, and thus the principles generally applied in bank pricing to the full price are valid. Moreover, we control for potential pricing discrepancies of HPS-loans with an HPS binary variable in the original regression.

Source: Calculated based on MNB data

5. Conclusions

According to the green hypothesis, residential buildings with more modern, environmentally sustainable energy performance are more stable in value and have a lower credit risk. The construction costs of homes with more advanced energy systems are higher, but the lower credit risk of home loans for these properties justifies, *ceteris paribus*, a lower interest rate, which may partly offset the higher transaction price. In our study, we used statistical methods to examine the existence of sustainability considerations in the domestic new housing and housing finance market.

One of the main conclusions of our study is that housing developers in the Budapest new housing market offer environmentally sustainable properties at significantly higher prices. We estimate that the average square meter supply price of homes in buildings with BB energy performance certificate is significantly higher, by about 5.1 per cent, compared to those with CC certificate. Furthermore, the average square meter price of buildings rated AA or better was not found to be significantly higher compared to those rated BB.

Looking at the credit market implications of the green hypothesis, we found that banks do not finance residential buildings with environmentally sustainable energy more cheaply: the interest rate on loans for properties with a BB or better energy rating is on average no different from the interest rate on loans for properties with a CC energy rating. This result shows that banks do not yet factor energy considerations into pricing of loans. In the current banking practice, amongst other things, the risk parameters of the borrower and the loan contract as well as other qualitative features of the property play a key role in determining the interest rate.

Overall, in the domestic market for new housing, developers already offer homes with more advanced energy systems at higher prices, but there is currently no bank product on the market offering better terms for the purchase of environmentally sustainable residential buildings financed by a loan. The latter finding points to the need for the uptake of green credit products, which would contribute significantly to accelerating the sustainable economic transition in the Hungarian housing market by stimulating the demand side.

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Annex

Table 6
Classification of buildings according to their overall energy performance and their relative percentages

Energy rating	Textual description of energy rating	Percentage ratio by aggregate energy indicator (%)
AA++	Minimum energy demand	<40
AA+	Outstandingly high energy efficiency	40–60
AA	Better than nearly zero-energy buildings requirements	61–80
BB	Meets the requirements for nearly zero-energy buildings	81–100
CC	Modern	101–130
DD	Nearly modern	131–160
EE	Better than average	161–200
FF	Average	201–250
GG	Close to average	251–310
HH	Poor	311–400
II	Bad	401–500
JJ	Extremely bad	500<

Source: e-tanusitas.eu