THESIS

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ENERGY EFFICIENCY IN THE RESIDENTIAL SECTOR IN CHINA AND HUNGARY - FROM TRADEMARKS TO THE UPTAKE OF ENERGY-EFFICIENT APPLIANCES

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1 INTRODUCTION

The global energy market shocks have intensified and energy crises was triggered by the outbreak of the Russia-Ukraine conflict. The energy crisis led to an unprecedented sustained rise in the TTF wholesale gas price, and new all-time high of €180.31/MWh in December 2022 (Patrick Heather, 2022).

According to energy research firm Rystad Energy, natural gas is a major input in electricity generation. It accounts for about 20% in the EU (Carlos Torres Diaz, 2022).

Compared to previous years, electricity prices have already risen several times, meaning that the energy required for the three main forms of energy use in our lives: heating, transport and electricity will all become very expensive. Energy is the basis for industrial manufacturing. The European energy crisis has caused the contraction and closure of industrial manufacturing that residential energy use is being hampered (Osička & Černoch, 2022).

According to Josep Borrell, head of EU foreign and security policy, after the Russian-Ukrainian conflict, the EU must reduce its energy dependence on Russia. A high dependence on energy is a great risk for the economic and political development of the country.

In July 2021, the European Commission presented a proposal for a recast Directive on energy efficiency, which makes 'energy efficiency first' an overarching principle of EU energy policy (Brugger et al., 2021).

In EU, Within the building sector, residential buildings have a prominent role by accounting for 75% of the total building stock (Bianco & Sonvilla, 2021a) , thus it is fundamental to promote energy efficiency measures in this sector.

According to the United Nations' Sustainable Development Goal 7, published in 2022, to ensure access to affordable, reliable and sustainable modern energy for all. And to increase the rate of progress in energy efficiency, it is hoped that the annual energy intensity improvement rate will increase from 1.9% to 3.2% by 2030. By 2020, 2.4 billion people still use inefficient and polluting cooking systems (António Guterres, 2022).

China's energy efficiency has improved by 19% since 2000, a huge achievement. Energy consumption in new buildings in urban areas were 20% lower in 2020 compared with 2015.Heating equipment reduced by 20%, cooling and lighting equipment by 10%, and cooking and other equipment by 50% (Li et al., 2020).

A classic example, the Warm Front Home Energy Efficiency Programme in the UK, provided every targeted household a reduction in energy costs about $1000. It also increases the building energy performance (SAP4) rating approximately twice. Replacing traditional biomass cookers with energy efficient cookers significantly reduces fuel costs, and the burden on the environment (Bowen A & Rydge J, 2011).

However, energy-efficient household appliances generate electronic waste (old, discarded devices) and there are more energy-efficient devices (quantity), we use them more than previously the old household appliances.

In addition, they are also expensive. Energy-efficient devices are affordable only to the wealthier, upper classes of society. To make them available for the lower classes, financial support from the state is essential.

With the promotion of energy-efficient devices, energy efficiency labels are increasingly influencing users' purchasing behavior. According to the results of Zainudin et al. (2014a) 's study, most users refer to energy efficiency labels when purchasing appliances, and the level of energy consumption will directly determine whether to purchase the product.

Following that, the aim of this work studies the energy policies of the residential sector in the EU (Hungary) and China and how energy-efficient devices benefit energy efficiency, and analyzes the factors that influence users' purchase of energy-efficient devices after a survey of public awareness in Hungary and China.

2 LITERATURE REVIEW

2.1 Energy Efficiency

According to the first law of thermodynamics, energy does not disappear out of thin air, it is converted from one form to another (Patterson, 1996). Energy efficiency can be defined as using less energy to produce the same amount of services or useful output. broadly defined by the simple ratio:

Useful output of a process / Energy input into a process

The energy crisis of 1979 led to the introduction of energy efficiency. According to the World Energy Council, energy efficiency is the improvement of the efficiency of energy use through technological improvements. It is economically rational and beneficial to the environment and society. The ultimate goal is to reduce energy intensity.

The term energy efficiency came to replace energy saving, and the two concepts are different. According to Inhaber H. (1997) , real energy savings are achieved only when the total energy consumed is reduced. According to Moezzi M. (2000), energy efficiency focuses on how much energy is consumed, that how much energy is used relative to the services required.

Bertoldi P. (2022) , presents the critical view that limiting energy consumption should be about energy sufficiency or conservation, not energy efficiency, which may cause a "backlash" effect.

In EU, Connolly et al. (2014) proposed to expand district heating, which can achieve heat recovery. The use of renewable energy sources as feedstock can save energy and also reduce the environmental burden. This approach can reduce heating and cooling costs by 15%.

Sorrell et al. (2020) showed Energy sufficiency has also been used in policy development as an alternative to energy efficiency and conservation, but most researchers still believe that efficiency and sufficiency can work together to solve the energy crisis.

Thomas et al (2019) define energy sufficiency as “a strategy aiming at limiting the input of technically supplied energy towards a sustainable level.”

Bertoldi, P. (2020) studied the energy savings resulting from energy efficiency policies in the EU member states for the period 1990-2013. The results point out that without energy efficiency policies, energy consumption would have been 12% higher in 2013.

The main ways to reduce the energy consumed directly are: improving energy management; adopting energy efficient technologies. Gordić et al. (2010) said energy management focuses on implementing energy-efficient technologies and eliminating inefficient equipment that can be regularly maintained to ensure proper and efficient operation.

Backlund S et al. (2012) said that the introduction of energy management into future energy policies will play an important role in contributing to the EU's 2020 and 2025 targets.

The Energy Efficiency First Principle means maximizing energy efficiency in the development of energy policies and energy use, especially in the area of sustainable and green development, and contributing to the achievement of the 2030 energy goals.

2.1.1 Energy efficiency standards

Energy efficiency standards are procedures or regulations that specify the energy performance of a product. Energy efficiency standards specify the level of energy efficiency of a product, making it the most efficient so as to obtain higher economic benefits. According to IEA (International Energy Agency) statistics, energy efficiency standards have been implemented in 34 countries (OECD/IEA, 2000).

According to China Energy Efficiency Labeling (CEEL), China has promulgated and implemented 22 energy efficiency standards for energy-using products, such as household appliances, lighting appliances and transportation (Gongyi Zhang et al., 2021).

In the United States, regulations for new light-duty vehicles have increased from 35 miles per gallon to approximately 54.5 miles per gallon by 2025. In addition, federal energy efficiency standards have been proposed for home appliances, residential and commercial buildings.

Currently, the German government uses regulations and subsidies to promote energy efficiency and carbon neutrality. Energy efficiency standards of 50 kWh / m2 /y are required for new buildings and 100 kWh / m2 /y for renovated buildings (Ray Galvin, 2023).

The Ecodesign Directive aims to harmonize energy measures in EU member states. For the energy performance standards of electrical appliances, the Directive sets maximum energy consumption standards for household appliances and takes appropriate energy measures for different households (BMWi, 2014). Over the last forty years, the efficiency of many types of appliances and equipment has improved significantly thanks to energy efficiency standards and labelling (Nadel S., 2019).

2.1.2 Benefits and approaches.

According to the International Energy Agency (IEA), in addition to energy savings, there are broader socio-economic outcomes that can result from energy efficiency improvements.

There are many benefits to improving energy efficiency. Financial/economic, environmental and social. These benefits are also closely related to the prices of different types of energy, energy efficiency measures, technology costs, etc. in a given country (IEA, 2015).

Some of the benefits of improving energy efficiency are shown in Figure 1.

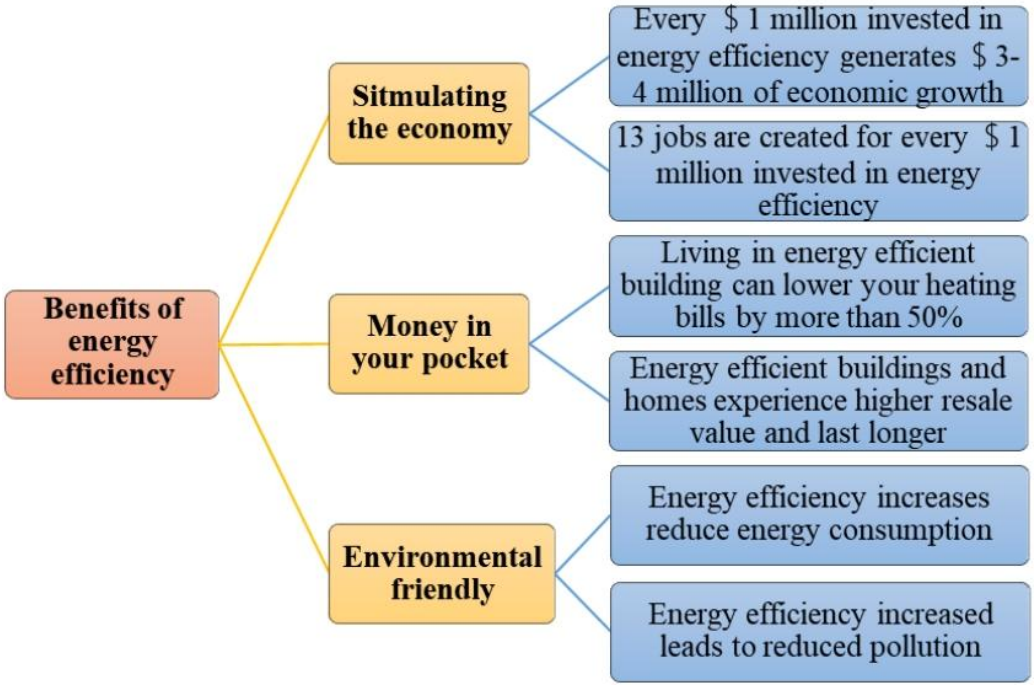


Figure 1. The multiple benefits of energy efficiency

Source: IEA, 2015

Energy-efficient homes and buildings use less energy to heat, cool, and run appliances and electronics, and energy-efficient manufacturing facilities use less energy to produce goods.

Improving energy efficiency in the residential sector can be achieved by retrofitting at the household level to reduce energy consumption through the use of efficient appliances, thereby saving on household energy bills (Annual Report and Accounts, 2011).

Low energy efficiency in the residential sector and inefficient energy appliances lead to higher energy demand. The use of energy efficient appliances contributes to higher energy efficiency and reduced energy demand in the residential sector. But Bouzarovski, S. (2014) said that for low income households, it is hardly affordable to replace new and efficient appliances.

High energy appliances make them spend more money on energy. Therefore, for low-income households, state policy support is necessary.

According to the U.S. Department of Energy (DOE, 2016) estimates, this will result in cumulative energy savings of more than 130 times and nearly $2 trillion in reduced energy bills by 2030.

2.2 Energy Efficiency In the EU and Hungary

Buildings are the largest energy consuming sector in Europe, accounting for 40% of energy consumption and contributing to 36% of energy-related greenhouse gas emissions. Seventy-five percent of buildings in the EU are not energy efficient (European Commission., 2018).Approximately 80% of household energy consumption is used for heating, cooling and domestic hot water and the energy is inefficient.

In the EU, the main use of energy by households is for heating their homes 62.8 % of final energy consumption (Final energy consumption is the total energy consumed by end users, such as households, industry and agriculture) in the residential sector, see Figure 2.

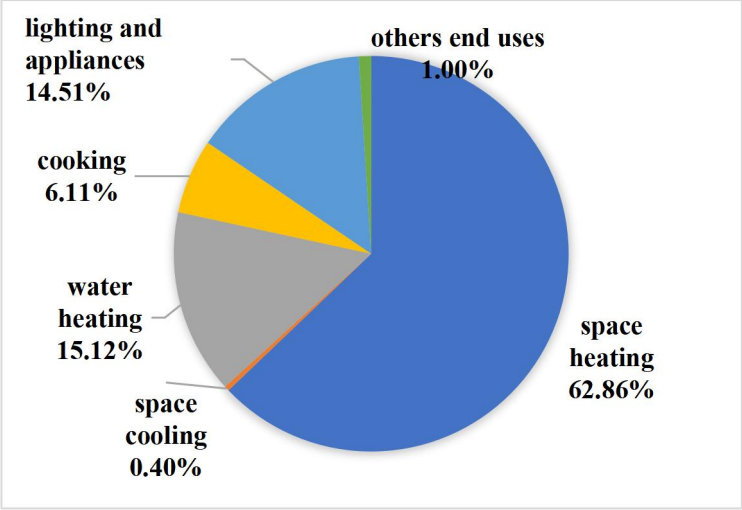


Figure 2. Main use of energy by households in EU

Source: EUROSTAT, 2018

In 2006, the European Union (EU) adopted the Energy Services Directive (ESD), which aims to reduce energy use in the non-tradable part of the EU by 9% by 2016. The primary energy (The total energy demand of a country, it covers consumption of the energy sector itself, losses during transformation and distribution of energy, and the final consumption by end users)

target aims to increase energy efficiency in all sectors of the economy by 20% by 2020 compared to 2005 level (Backlund et al., 2012).

In the 20–20–20 strategy, according to the European Commission's estimates of the technical energy saving potential in various sectors, manufacturing could be improved by 25%, commercial buildings by 30%, and residential by 26%. Backlund et al. (2012) suggest that to reach this goal, the implementation rate of energy efficiency measures needs to be more than 80%.

As Figure 3 shows, Economidou et al. (2020) counted the energy consumption of residential sector in EU from 1995-2017, that doesn't shows any major changes, and more attention is needed in this area.

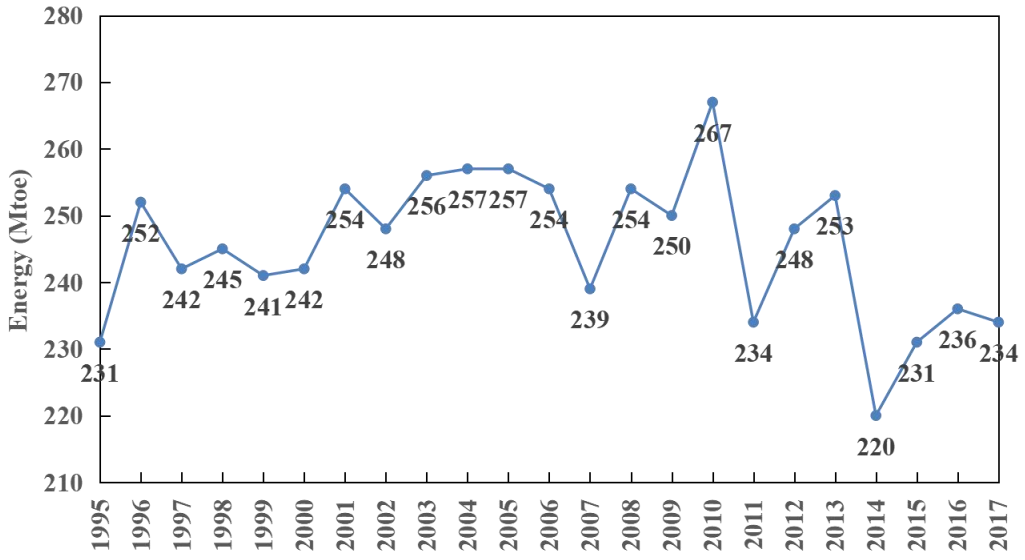


Figure 3. Residential energy consumption in EU-15 (1990–2017).

Source: European Commission，2020

Therefore, as in the case of the Energy and Climate Policy initiative, the implementation of energy efficiency measures is considered paramount to sustain the energy transition and pursue decarbonization.

In 2018, final energy consumption in Hungary was 18.8 Mtoe, 14% higher than in 2000, and the residential sector, which accounts for more than one third of the total consumption, is the largest energy consuming sector.

Hungary has implemented energy efficiency requirements and energy efficiency labels in the industrial sector, adopted energy-efficient equipment and technological innovations. According to ODEX, Hungary's energy efficiency has improved by about 26% from 2000 to 2018. The residential sector, on the other hand, has improved energy efficiency by less than 1%, which is slower progress (Andreas S et al., 2018).

Bianco V. (2021b) mentioned that a large number of relevant policies are currently implemented in EU member states, such as the Energy Efficiency and Services Directive, energy performance indicators for buildings, energy efficiency labels for appliances, etc. Today, an increasing number of policies are targeted at the residential sector, which already accounts for about 1/3 of all measures.

Energy conservation is one of the cheapest and cleanest ways that everyone can participate in reducing energy consumption. Combining personal energy saving actions and energy efficiency directly reduces living energy bills and accelerates the global clean energy transition Najmi et al. (2016).

The Figure 4 shows many ways to save energy in our daily lives.

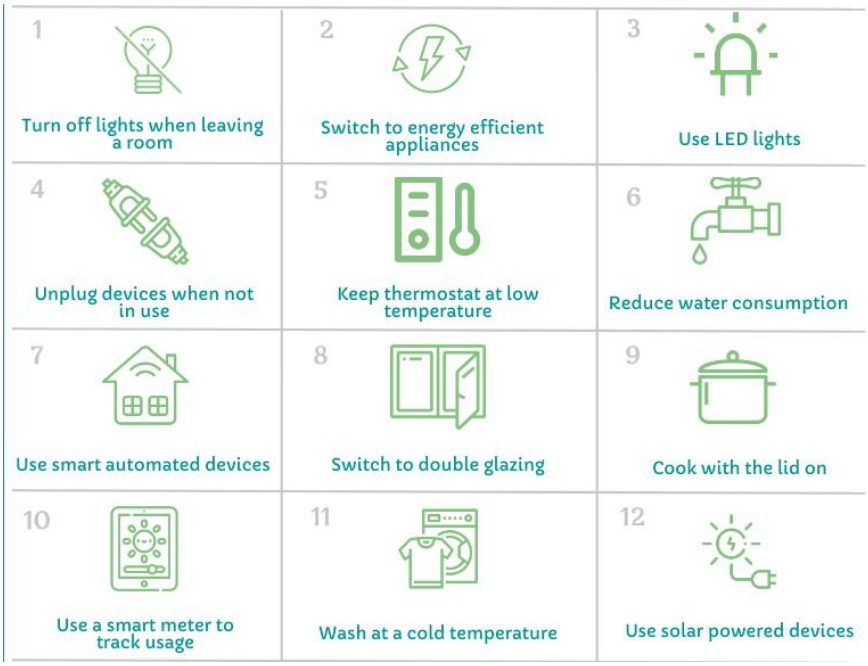


Figure 4. Ways to save energy in our daily lives

Source: GreenMatch,2020

In order to make all users aware of how to save energy, the European Commission, in cooperation with the International Energy Agency and local institutions, launched an energy saving initiative to promote knowledge and allow users to choose more energy efficient and cleaner products when purchasing(Bianco & Sonvilla, 2021a).

The Vienna Climate Change Talks 2007 Report, under the auspices of the United Nations Framework Convention on Climate Change, clearly shows "that energy efficiency can achieve real emission reductions at low cost."

In July 2021, the European Commission presented a proposal for a recast Directive on energy efficiency, which makes 'energy efficiency first' an overarching principle of EU energy policy (Brugger et al., 2021).

The European Commission has proposed a 9% improvement in the EU's energy efficiency target by 2030. In May 2022, the Commission proposed further energy savings in the REPowerEU plan, suggesting an increase in the energy efficiency target from 9% to 13%. And reduce its greenhouse gas emissions to at least 55% below 1990 levels by 2030**.** (EUROPEAN COMMISSION, 2020)

Due to energy efficiency standards, energy-efficient buildings consume 80% less energy than conventional buildings, and energy-efficient buildings emit 30% less CO2. Sun X N et al. (2018) showed that buildings with energy-efficient designs such as energy-efficient lighting, solar panels, etc. can save up to 40% of energy consumption.

In EU, the Zero emission buildings requirement should apply as of 1 January 2030 to all new buildings (Chatterjee S.et al., 2021).The efficient residential construction in Hungary is expected to increase by 4% by 2030 (Carmen et al., 2022).

The European Parliament has proposed the Energy Performance of Buildings Directive (EPBD). By 2030, all new buildings must be Nearly zero energy buildings. by 2050, all buildings must be Zero emission buildings. Timeline for ZEB and NZEB implementation shown in Fig 5.

Fig 5. Timeline for ZEB and NZEB implementation.

Note: Nearly zero energy buildings (NZEBs), Zero emission buildings (ZEBs)

Source: Directive EPBD, 2015

In the EU, the long of life of buildings and the very low rate of demolition make reconstruction and renovation work difficult. According to relevant data, at least 75% of the existing buildings in the EU will still be in use until 2050. In order to achieve the 2030 and 2050 goals, we must invest more energy in the building sector. Overcoming user information barriers and spreading energy efficiency measures are of great importance (Giraudet, 2020).

According to the results of Belaïd & Joumni. (2020)'s study, subjective factors of users, such as perceptions of energy efficiency, concerns about energy-efficient appliances, and purchase behavior can affect the popularity and implementation of conquest energy efficiency policies.

In order to study how user behavior affects the implementation of energy efficiency policies, researchers have done a lot of research and practice to draw the best conclusions for a more rational development of policy measures.

According to the French "Energy Transition Tax Credit (CITE)" policy, French customers who purchase efficient materials can claim a 30% tax credit when implementations are carried out by certified enterprises. In 2018, the 30% was reduced to 15% for window replacement, installation of oil boilers, etc (Andreas S et al.,2018). In 2019, French Environment Minister Nicolas Hulot proposes to grant bonuses to individuals who carry out energy renovation works.

The Energy Performance of Buildings Directive, EU member states are required to carry out energy certification when purchasing or renting, and the certificates need to be provided to occupants. This measure aims to promote energy-efficient housing and to provide incentives for occupants to renovate older, energy-intensive buildings.

In 2011, the U.S. proposed reducing energy and carbon intensity, and in order to achieve its goals, proposed carbon taxes, mandatory standards for more efficient appliances, buildings and vehicles, and subsidies for energy-efficient appliances to reduce the initial cost of energy-efficient equipment (Huntington, 2011).

In December 2014, the German government launched the National Action Plan for Energy Efficiency (NAPE), a policy covering energy efficiency in buildings, energy efficiency in businesses, energy efficiency in appliances, and energy efficiency in transportation. The main measures include energy efficiency targets, building renovation subsidies, and the introduction of tax incentives for building energy efficiency (Schlomann et al., 2016) . Reviewing residential energy efficiency policies in member states, Ugarte et al. found that most policies are aimed at large buildings, businesses, etc., with a few specifically targeting low-income people who use energy-intensive equipment, which means bearing more expensive energy bills (Ugarte et al., 2016).

However, there are not many policies that address how to replace equipment, and this is an important direction for research on subsequent policies.

According to Najmi et al. (2016) the results show that financial incentives have a positive impact on energy efficiency improvements in residential sector. Financial incentives mainly provide support for building energy retrofits, where households can be more active in using energy efficient equipment. In particular, financial support for low-income households has led to an increase in the number of participating households.

In 2003, the European Commission launched the Intelligent Energy for Europe (IEE) program, which runs from 2003 to 2013, with a budget of nearly €1 billion available to fund projects and establish a series of European portals, facilities and initiatives.

For the period 2014-2020, the European Structural and Investment Funds (ESIF) allocated €18 billion for energy efficiency projects. This is a twofold increase in allocations compared to the period 2007-2013.

Ahead of the parliamentary elections in April 2018, the government has decided to provide a further small one-off subsidy of HUF 12,000.

Ahead of the parliamentary elections in April 2018, the government has decided to provide a further small one-off subsidy of HUF 12,000. The main focus is on household heating, such as piped gas, coal and LPG. The subsidy is mainly provided in the form of price compensation, credited to the customer's account.

Hungary's National Energy and Climate Plan (NECP) in2020, the National Energy Strategy (NES) 2030 with an Outlook to 2040 and Hungary's Long-Term Renovation Strategy (LTRS) in 2021 all indicate the future direction of energy development.

More funds will finance energy efficiency in 2021-2027, these funds will mainly focus on public and residential buildings, with energy efficiency and retrofitting of older buildings are important. About 373 billion euros will be the main source of funding for direct investments in energy efficiency (European Commission., 2022).

2.3 Energy Efficiency in China

In China, most of the electricity comes from coal. In recent years, China has invested mainly in clean energy projects to reduce pollution and emissions. As of early 2022, China has about 200 million GW of nuclear power plant capacity (Statista, 2022).

The Fig 6 shows Primary energy consumption by country in 2021. China is the largest consumer of primary energy in the world, using 157.65 exajoules in 2021. According to Jessica Aizarani.(2023), China is the main force in conducting energy saving programs.

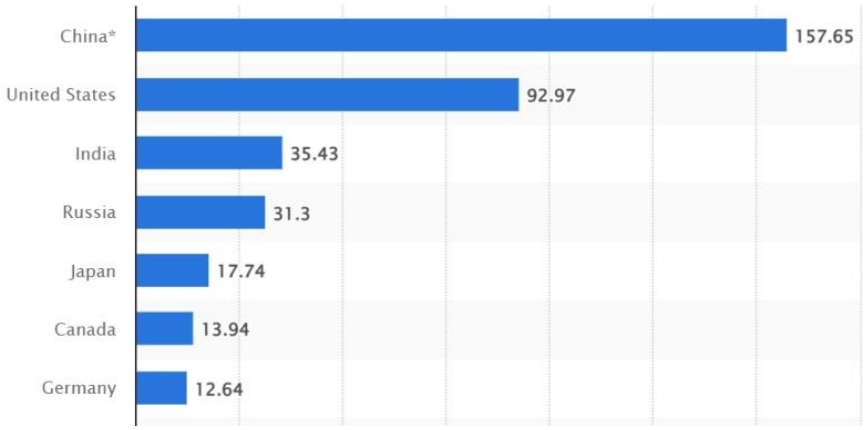


Fig 6. Primary energy consumption by country in 2021.

Source: Statista,2021

In 2013, China incorporated environmental and energy issues into its national policy goals, including improving energy efficiency, which is a key component of its air pollution prevention and control program. China's vigorous pursuit of energy efficiency improvements contributes to the achievement of other Sustainable Development Goals (SDGs).

According to the International Energy Agency IEA's Efficiency Policy Progress Index. China accounted for more than half of the world's total policy progress from 2000-2016.The rate of policy progress from 2011-2015 was extremely high.

The 2016 Energy Conservation Law provides for specific mechanisms to promote energy efficiency and conservation, such as the prohibition of products that do not meet mandatory energy efficiency standards, a phase-out system for obsolete and inefficient products and equipment; and the implementation of energy efficiency labeling management (Wang et al., 2022).

China's differential tariff policy, which raises tariffs for high energy-consuming enterprises that do not meet the minimum energy efficiency standards, helps promote energy conservation in enterprises and plays a role in accelerating energy efficiency improvements.

China started to implement energy-saving projects in 2009. Financial subsidies are used to promote energy-efficient products, energy-saving home appliances, green lighting products, etc. In exception to subsidies, there are energy-saving policies, including government subsidies, tax incentives, pricing policies, etc (Huang et al., 2019). Shan-Shan Y et al. 's study (2022) shows that during the period 2020-2022, the number of energy policies in China continues to rise, supporting energy efficiency improvements and accelerating the achievement of energy efficiency goals.

With "energy conservation as a priority" as an important principle, we emphasize the principle of energy conservation in the whole process of economic and social development and in all fields, and focus on improving energy use efficiency (Yunni T et al., 2023).

The tax incentives significantly improved energy efficiency of firms, the results showed that for every 1% reduction in VAT (Value Added Tax） rate, energy efficiency would increase by 0.58% (Sun C et al., 2020) . China has bilateral cooperation arrangements for energy efficiency with the EU, Laos, the US and Germany.

In 2017, buildings accounted for 18.35% of the country's total energy consumption. Due to the successful implementation of policies and measures, the average annual growth rate of energy consumption in buildings has shown a decreasing trend, from 11.9% to 6% (EPPEI, 2018).

In 2020, the proportion of green building area in new buildings in cities and towns will exceed 50%; the demonstration projects of ultra-low energy buildings (ULEB) and near-zero energy buildings (NZEB) will exceed 10 million square meters (Cao et al., 2016).

The main source of residential energy consumption is the energy consumption of household appliances. About 70% of household CO2 emissions come from household appliances, with air conditioners, refrigerators and televisions accounting for a total of 50%. Therefore, the introduction of energy-efficient appliances can effectively reduce energy consumption in the residential sector (Xiaochun L et al., 2020).

According to Wang J. (2006), if energy-efficient refrigerators were used instead of ordinary refrigerators, the annual energy consumption would be saved by about 20%, and the total national electricity consumption would be reduced by 120 billion KW/h.

In 2009, China released the "Implementation Measures for Trade-in of Home Appliances" to further improve energy use efficiency and reduce environmental pollution. For high energy consumption appliances proposed a trade-in policy. Contains televisions, refrigerators, washing machines, air conditioners, computers, etc. For those involved in recycling old appliances, subsidize the shipping costs and provide a 13% subsidy when purchasing new energy-efficient appliances (China Business Network., 2009).

Because of energy-saving subsidies, factory subsidies, trade-in subsidies and bank subsidies, sales of energy-saving subsidized products at Suning.com increased by 198% over the same period in 2020. Guanwen W. (2022) result shows that primary and secondary energy efficiency Energy-saving home appliances increased from 53% to 79%.

Energy efficiency in the consumer sector is directly related to individual behavior and reflects consumers' awareness of energy efficiency. C. Y. Zhang et al. (2018) said reducing unnecessary energy consumption, or choosing the suitable facilities to reduce energy costs, etc. can help reduce energy consumption based on meeting personal needs. Facilities, like personal behavior, have an important impact on energy savings.

2.4 Energy efficiency labeling and energy-efficient appliances

Energy constraint has become a bottleneck to the economic development of all countries. The implementation of energy efficiency labeling system can effectively improve energy-saving technology, reduce energy consumption and harmful emissions, and play an important role in protecting the environment.

Energy efficiency label as an information label attached to a product or the smallest package of a product to indicate the energy performance of the product in order to provide consumers with the necessary information when they purchase the product.

Many countries have successfully introduced energy efficiency standards and energy efficiency labels. Among them, developed countries have promoted the energy efficiency labeling system relatively early, and Canada first implemented the mandatory energy efficiency labeling (Energy Guide) system in 1978.

Shu He et al. (2015) mentioned Energy efficiency labels enable consumers to choose more energy-efficient product models. Enables electric utilities and government energy efficiency agencies to more easily encourage consumers to purchase energy-efficient products.

2.4.1 Energy efficiency labeling levels

First introduced for a number of household appliances in 1994 and subsequently expanded in 2004 – with a comparative scale from A (most efficient) to G (least efficient).

The following Figure 7 is current EU energy efficiency labels, that clearly shows the marking information, from the representation of the product can know the energy efficiency level, power, etc. For example, the energy efficiency metric of the EU refrigerator label is the consumption per unit volume, and larger refrigerators with smaller surface-to-volume ratios obtain better energy classes.

The EU energy labelling and ecodesign legislation helps improve the energy efficiency of products on the EU market.

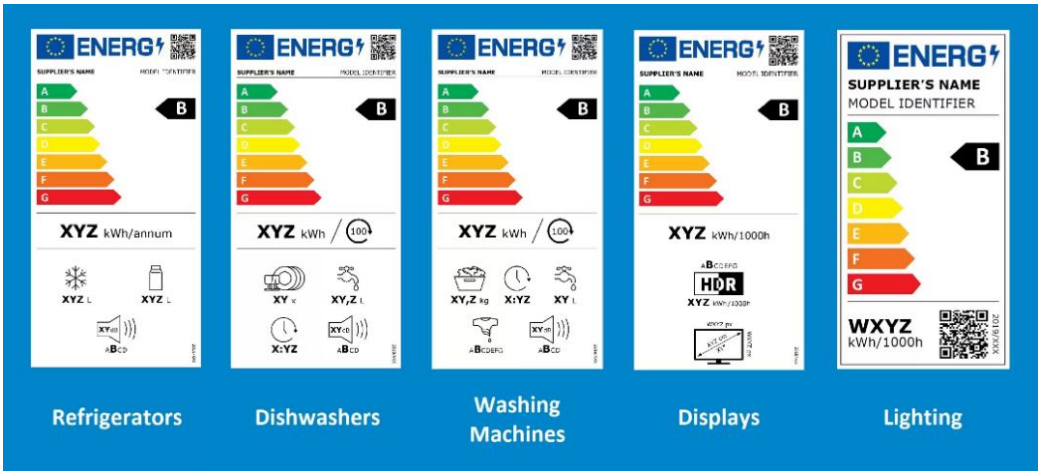


Figure 7. Current EU energy efficiency labels on electrical products

Source: European commission ,2019

In China, products classified into 1-5 levels shown in Figure 8, with level 1 indicating the highest level of energy efficiency and the most energy-saving, and level 5 indicating that it has reached the energy efficiency limit value index and is a qualified product.

Generally speaking, level 1 standard is the goal for general enterprises to strive for, level 2 represents energy-saving products, levels 3 and 4 represent the national average, and level 5 products are products to be eliminated in the future.

Figure 8. The addition of the energy efficiency "leader" logo to China's energy efficiency label

Source: China Energy Lable (CEL),2020

The energy efficiency "leader" is an important measure to promote energy conservation by using the market mechanism. It can promote the improvement of energy efficiency, as well as provide consumers with more energy efficiency information, which is important for promoting energy-efficient products.

2.4.2 Energy Efficiency Label Policy

(1) EU EuP/ErP Directive

In 1992, the EU introduced the first energy label for residential equipment (Directive 1992/75/EEC).

In 1994, the EU started to enforce the energy efficiency rating labeling system for home appliances, and in 2005, promulgated the "Framework Directive on Eco-design Requirements for Energy-using Products" of Directive 2005/32/EC.

In October 2009, the EU revised the Directive (2009/125/EC) "EU Eco-design Directive for Energy-Related Products", expanding the scope of the Directive.

Bertoldi P et al. (2022) mentioned that the combination of eco-design and energy labeling has been successful in significantly improving the energy efficiency of residential facilities and saving energy.

(2) Energy Star USA

In 1980, the U.S. Federal Trade Commission (FTC) implemented a mandatory labeling system for household appliances. In 1992, the U.S. Environmental Protection Agency (EPA) and the Department of Energy (DOE) introduced the Energy Star for industrial and commercial energy-using products. The Energy Star has not only played an important role in the United States, but has also become an international symbol for energy efficiency.

The U.S. ENERGY STAR labeling program has been relatively successful, and Murray & Mills. (2011) 's studied consumers' intentions to purchase refrigerators under the ENERGY STAR policy and found that consumers were willing to pay an additional $250 to $350 for a refrigerator with the ENERGY STAR label.

Businesses can also save money and help protect the environment by making their buildings more energy efficient. ENERGY STAR certified buildings use 35 percent less energy than typical buildings.

(3) China's Energy Efficiency Label

China promulgated the first set of minimum energy efficiency standards for household appliances in 1989, covering eight categories of appliances, including refrigerators, washing machines and air conditioners.

In 1999, China introduced a new Energy Star labeling program, which was first applied to refrigerators, but was eventually abandoned because few models on the market were eligible for the label.

In 2004, "Energy Efficiency Labeling Measures" was promulgated, and since March 1 of the following year, the mandatory energy efficiency labeling system was officially implemented in the home appliance industry.

In 2005, China implemented the energy efficiency labeling system, covering 28 categories of products. In April 2016, the Certification and Accreditation Administration of China (CNCA) issued a document to include 33 types of products into the energy efficiency labeling system. It covers five major fields, including traditional household appliances, refrigeration and air conditioning products, industrial, lighting and office electronic products (Xinyue C et al., 2018).

In February 2016, the Chinese government revised the Measures for the Administration of Energy Efficiency Labeling, and the new version was implemented on June 1, 2016. Although the implementation of the energy efficiency labeling system has achieved remarkable results, there is still room for improvement at the level of the legal system.

The public monitoring system of the energy efficiency labeling system is still not perfect, and there have been cases of false and high labels within the control of the system, and the public awareness of the energy efficiency labeling system is still low.

Lee & Rajagopalan. (2008) proposed a plan to establish an energy efficiency labeling system in Singapore, which features an examination of the overall energy efficiency of buildings based on energy and indoor environmental quality, including not only the efficiency of individual systems, but also strict indoor air quality requirements.

Other countries such as Australia, Japan, Korea, and the European Union have also introduced energy efficiency labeling systems. Some emerging countries are still in the process of implementing energy-efficiency labeling systems.

Liang Wong & Krüger. (2017) summarized the experience of the energy efficiency labeling system in the EU, hoping to provide a reference experience for the RTQ-C system in Brazil.

Shi XP. (2014) attempted to provide Bruneian policy makers with information on how to develop energy efficiency standards and labeling (S&L) regulations by drawing on energy efficiency standards and S&L regulations in the Asia-Pacific region.

He suggested that effective S&L regulations should include four aspects, including clear responsibilities, authoritative management, open principles of technical systems, and enforceable mechanisms.

2.4.3 Energy efficiency labeling applied to electrical appliances.

Brounen & Kok (2011) mentioned Energy efficiency in the residential sector plays an important role in reducing carbon emissions, and in a sample of houses with energy efficiency labels, energy efficiency labels create transparency about the energy efficiency of residences.

In addition to the positive effect, there are related studies in which energy efficiency labels have no significant effect on consumer purchasing behavior: a study by Zainudin et al. (2014b) found that energy efficiency labels are negatively associated with consumer green purchasing behavior and that energy efficiency labels have no effect in encouraging consumers to convey good information in their purchasing decisions.

Brazil & Caulfield. (2017) said Energy efficiency labels provide consumers with awareness of the environmental and energy impacts associated with products and services, and contain a wealth of valid information designed to help consumers compare and choose more energy-efficient products.

Similar to energy efficiency labels are carbon labels, eco-labels, and green labels, which provide consumers with relevant information while also having a significant impact on their purchasing behavior.

According to the results of the study by Abas & Mahlia. (2018) , the energy labeling system for air conditioning systems can improve the energy use efficiency of manufacturers, and the energy efficiency labeling system has a significant impact on reducing energy consumption.

Issock et al. (2018) ’s study found that the level of concern about energy efficiency labels influences the purchase behavior of energy-efficient appliances. Consumers tend to pay more attention to energy efficiency labels when they trust the product's label and when they are willing to purchase energy efficient appliances.

The results of Mills et al. (2010)'s study also suggest that when consumers lack knowledge of energy labels, they may have considerable bias in their choice of energy-efficient appliances.

Mahlia T. (2010) said energy efficiency labeling is one of the key strategies for energy conservation in the household appliance industry and is a common tool for reducing energy use in household appliances in many countries around the world.

Lay Peng T et al. (2016) shows that consumers in Australia and New Zealand prefer to purchase energy efficient appliances with higher energy efficiency ratings.

Sammer K et al. (2006) studied the influence of energy efficiency labels on consumers' choice of washing machines found that Swiss consumers perceive energy-efficient products to have better performance in all aspects. Therefore, they would choose energy-efficient products with higher energy efficiency ratings when purchasing home appliances.

2.4.4 Energy saved through the use of energy efficient equipment.

Energy-efficiency project of nonfluorine refrigerator is the first general consumer product project in China. Approximately 10 million refrigerators are sold each year. Started in 1989 and co-sponsored by NEPA to end the use of CFC-based refrigerators and to improve the energy efficiency of refrigerators in China, the project developed fluoride-free refrigerators that consume 45% less energy.

In china, the promotion of the energy efficiency labeling system has achieved significant energy-saving results, according to estimates, as of 2011, the implementation of the energy efficiency labeling system has saved a total of 205 billion kWh of electricity, equivalent to 7,380 tons of standard coal, equivalent to an emission reduction of 192 million tons of carbon dioxide and 840,000 tons of sulfur dioxide (Kan Wang et al. 2015).

According to Brown et al. (2002) 's modeling results, the Energy Star program has saved a cumulative 1.5 exajoules of energy between 1993 and 2000, resulting in $10 billion in energy cost savings.

In 2020, the ENERGY STAR residential new construction program helped homeowners save 3 billion kilowatt-hours of electricity, avoid $390 million in energy costs, and achieve 4 million metric tons of greenhouse gas reductions.

The US Department of Energy (DOE 2016) estimates that standards already established (and

therefore included in our AEO 2019 baseline) will, on a cumulative basis, save more than 130 quads of energy through 2030, reducing energy bills by nearly $2 trillion.

Skourtos et al. (2021) estimated that energy labelling will save 230 million tons of energy by 2030, implying an average annual saving of €285 on household energy costs. In addition, energy efficiency measures will generate an additional €66 billion in revenue for European companies.

The EU energy labelling and ecodesign legislation helps improve the energy efficiency of products on the EU market. This makes it easier for consumers to save money on their household energy bills and contribute to reducing greenhouse gas emissions across the EU.

2.5 Summary

Europe and China have announced plans to become carbon neutral by 2050 and 2060, respectively. In the residential sector, energy efficient technologies and behaviors are essential to achieve carbon neutrality.

After reviewing the existing literature, we understand the current residential energy situation, how the government takes measures and how it is applied in daily life. This work studies the energy-related issues in the residential sector in Hungary and China.

1) Verification of the energy consumption and energy efficiency of the residential sector in the Hungary.

2) Verification of energy consumption and energy efficiency in the residential sector in China.

3) Verification of the policies related to the diffusion of energy-efficient appliances and their positive effects.

4) Verification of the mechanism of energy efficiency labels' influence on consumers' purchasing behavior of energy-efficient appliances.

3 MATERIAL AND METHOD

This paper is based on the principle of combining theory and practice, qualitative and quantitative. There three research methods: literature research method, questionnaire survey method and statistical analysis method.

(1) Literature research.

Mainly, we use literature database or online platform to review and organize the existing literature and research results to clarify the current situation of energy efficiency issues, as well as the legal documents and policies of EU government (including Hungarian government) and Chinese government on energy efficiency issues.

(2) Questionnaire survey.

Firstly, according to the research topic of this paper, the questions were scientifically and rigorously designed and the research plan was developed, taking into account the relevant literature. The aim of this paper is to directly participate in the data collection process and to conduct a survey analysis of Hungarian and Chinese citizens. Respondents were asked to answer their perceptions and attitudes towards issues related to energy efficiency in a voluntary and anonymous manner. A questionnaire was administered to the study group individually, thus obtaining authentic and reliable primary data, and the public's responses could be used as research material for a systematic survey.

(3) Statistical analysis

Based on the results of the questionnaire survey, the data were statistically analyzed by Excel. From this, the level of respondents' knowledge about energy efficiency-related policies, as well as the current level of public awareness and methods of energy saving were derived. This will serve as a reference for future energy efficiency policy development and implementation in Hungary and China.

3 .1 Study area

As mentioned before, this work focuses on the development of energy efficiency in the residential sector in Hungary and China. The paper first investigates data on energy consumption in the residential sector in Hungary and China, considering mainly the consumption of electrical energy and natural gas, as well as CO2 emissions in the residential sector.

Second, public surveys were conducted in Hungary and China on issues related to energy efficiency, such as awareness of energy efficiency labels and willingness to purchase energy-efficient appliances, and then the mechanisms by which awareness affects behavior were analyzed.

3.2 Energy consumption and efficiency targets in the residential sector

As shown earlier, the building sector accounts for about 40% of the total energy consumption in Hungary. in 2018, the final energy consumption in Hungary was 13.8% higher than in 2000.

According to the Hungarian National Energy and Climate Plan (2018), Hungary plans to reduce the value of expected energy consumption by about 8-10 % in 2030 without these measures, with a target of not exceeding the value of 27.6 Mtoe.

Under the revised EU Energy Efficiency Directive, 1.5% of final energy consumption must be achieved each year from 2024 to 2030, up from the current level of 0.8%.

Regarding China, under the Sustainable Development Goals, the country needs to reduce its energy intensity by an average of 4.7% per year over the period 2015-2030.

In order to achieve the global sustainable development goals of energy conservation and energy efficiency, specific data collection and statistics on energy consumption in different countries and regions are necessary. These data can be referred to, for example, the World Energy Institute, the International Energy Agency IEA, the Hungarian Central Statistical Office - KSH, the Chinese Bureau of Energy Statistics and the Census of Permanent Population.

3.3 Public Awareness

Achieving energy sustainability and meeting energy efficiency goals depends on a range of factors such as technology, economics, policy environment, and public awareness. The perception of residential customers about energy efficiency is one of the key factors in changing energy efficiency in the residential sector.

Therefore, this paper conducts a public awareness survey in Hungary and China in March and April 2023 to seek public awareness of the research topic of this paper in the target regions in order to analyze and verify the correlation between public awareness of energy efficiency labels and the purchase of energy efficient appliances.

The survey was produced by the Limesurvey of the Hungarian University of Agricultural and Life Sciences and completed by the Hungarian and Chinese public (resident population). A total of 300 questionnaires were collected, with 150 participants from each country.

Theoretically and empirically based research found that individual characteristics of consumers, such as gender, age, education and income, have a significant differential impact on the mechanisms influencing their behavior. The survey focused on citizens over 20 years old and residing in the target countries.

4 RESULTS AND DISCUSSION

4.1 Energy consumption for the residential sector in Hungary

Hungary's electricity and gas consumption in 2020 is shown in Table 1 and Table 2. Hungary consumes 39.37 billion kWh of total electrical energy consumption per year, 4,055 kWh per capita. The total electricity production is 30 billion kWh, which allows for 77% of the electricity production, and the natural gas consumption is 10.39 billion cubic meters, or 1,070 cubic meters per capita, only 17% of which is produced domestically and the rest needs to be imported.

Table 1. Electricity consumption, production, import and export in Hungary in 2020

Electricity	**Total (bn kWh)**	**Hungary per capita (kWh)**
Own consumption	39.37	4054.63
Production	30.22	3112.29
Import	17.95	1848.63
Export	5.24	539.66

Sources：Own work and worlddata

Table 2. Natural gas consumption, production, import, export in Hungary 2020

Gas	**Cubic meters (bn m3)**	**Hungary per capita (m3)**
Own consumption	10.39	1070.04
Production	1.81	186.61
Import	13.37	1376.95
Export	3.52	362.52

Sources：Own work and worlddata

Residential energy consumption is influenced by many factors, such as energy prices, population, dwellings, household income, etc. The residential sector is the largest sector of final energy demand in Hungary and therefore has the greatest potential for energy efficiency.

The government should focus on energy efficiency and energy conservation policies in the residential sector (Eurostat, 2021).

Hungary has one of the highest levels of residential consumption per capita in the EU, and according to the EU Energy Efficiency Data Report 2000-2019, Hungary has made relatively little progress in energy efficiency, with little improvement in the later years (Eurostat, 2021).

According to the October 2022 census, Hungary has a population of 9.604 million people. the first census in 1870 had only 5 million people, and by 1980 the population had reached 10.7 million, but has been steadily declining since then. With the change in population the amount of housing has been increasing and in 2022 there are 4.6 million housing units in Hungary. The changes in population and dwellings in Hungary as shown in In Figure 9.

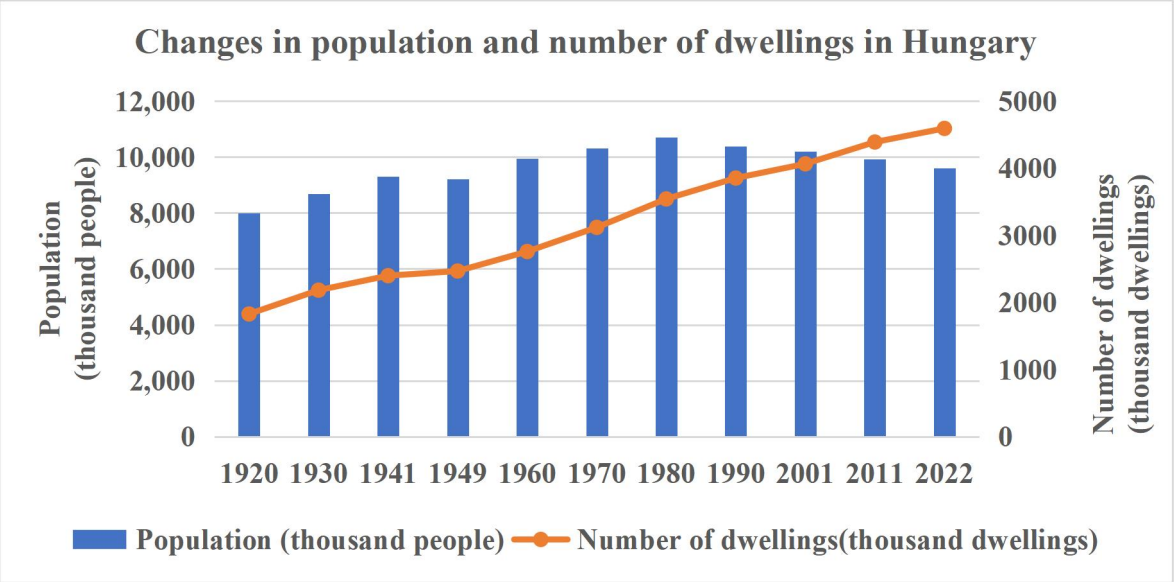


Figure 9. Growth in the number of population and number of dwellings in Hungary

Sources: Own work and Hungarian Central Statistical Office (HCSO)

The residential sector has great potential for energy efficiency, but there is still room for development in energy efficiency. Despite government incentives to invest in energy efficiency, there are still many people who cannot afford it. Since 2014, the proposed Warm Home Program has supported 130,000 households with subsidies totaling HUF 29 billion (ITM, 2018).

The greatest potential for residential energy efficiency lies in the renovation of existing homes. In 2015 the Hungarian National Building Energy Performance proposed an energy saving target of 34.8 PJ per year in 2020 through residential renovation. In Hungary, 80% of homes are not yet modernized and according to the study the buildings built between 1946 and 1980

were found to be the least energy efficient (NFM, 2015) . Figure 10. shows the change in energy consumption from 2000 to 2020, from 2017 onwards the energy consumption decreases and so does the consumption in the residential sector. In 2020, Hungary consumes 1103 PJ of primary energy, 735 PJ of final energy and 249 PJ in the residential sector.

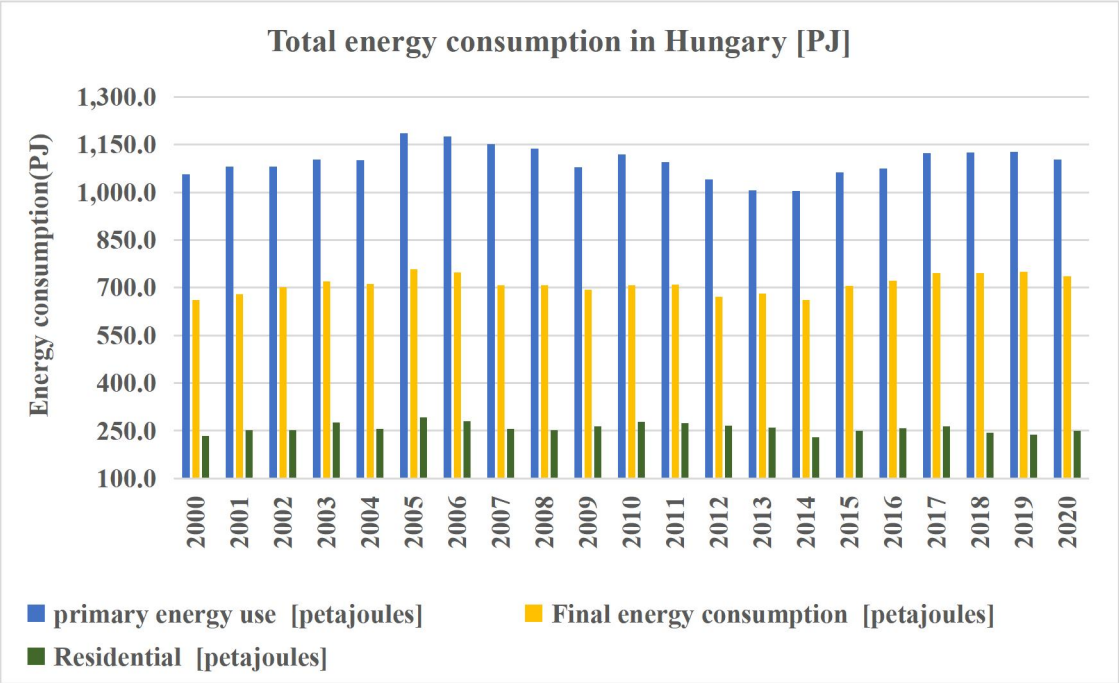


Figure 10. Total energy consumption in Hungary in 2000-2020

Sources: Own work and KSH Hungarian central statistical office

Energy consumption in the residential sector in Hungary, despite its decrease, remains the main sector of energy consumption. According to the data statistics, household electricity consumption is the largest consumption of electrical energy in Hungary. As shown in Figure 11, since 2000, the electricity consumption has been continuously growing and the demand for electricity in households has been increasing. 2021, the total electricity consumption in Hungary is 39799043kWh, and the household electricity consumption is 12294470kWh, which accounts for 31% of the total electricity consumption.

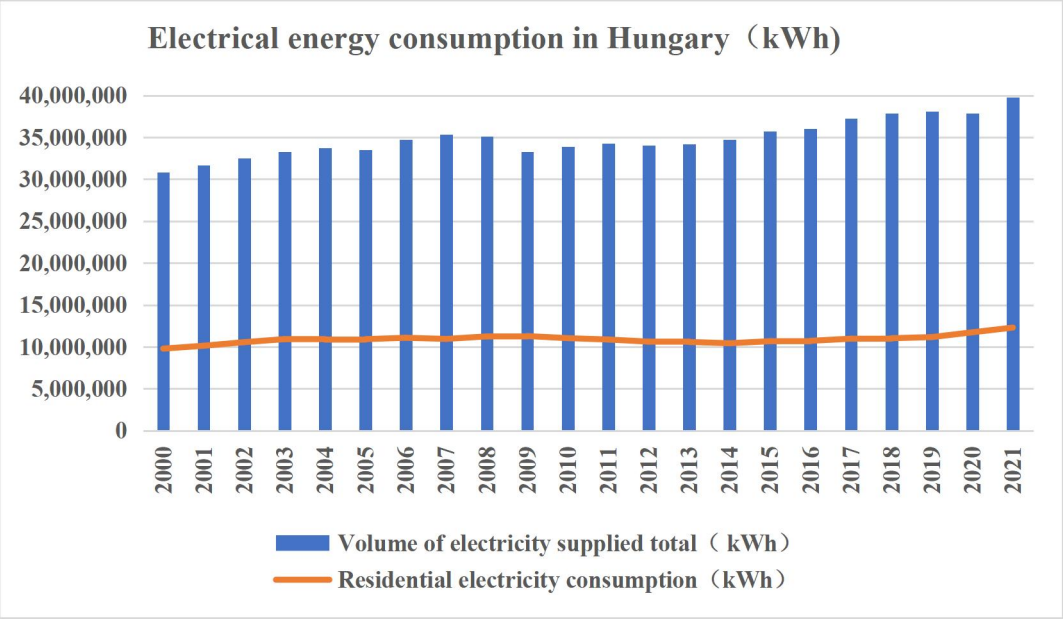


Figure 11. Electricity consumption in Hungary from 2000 to 2021

Sources: Own work and KSH Hungarian central statistical office

CO2 is the main component that contributes to the greenhouse effect and in Hungary, households account for 18% of the total CO2 emissions. As shown in Figure12, CO2 emissions from the residential sector in Hungary 1985-2018. The average reduction of CO2 emissions is about 300kt per year.

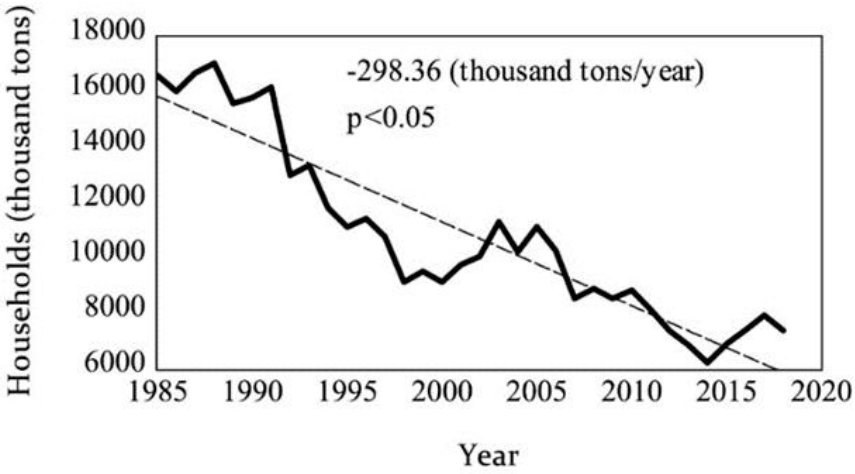


Figure 12. CO_2 emissions in Hungary residential sectors between 1985 and 2018.

Data sources: Own work and worlddata

The Long-term renovation strategies (LTRS) proposes new energy efficiency and emissions targets for residential buildings, achieving 20% energy savings in the residential sector and a 20% reduction in carbon emissions by 2030. However, this target remains controversial.

4.2 Energy consumption for the residential sector in China

According to 2020 statistics, China has a resident population of 141.175 million people, a total housing area of over 50 billion square meters, and 1.49 billion rooms owned by households. the total building stock in China in 2018 was 60 billion square meters, including 24 billion square meters of urban housing, 23 billion square meters of rural housing, and 13 billion square meters of commercial buildings. The residential sector accounts for a relatively large share of the energy consumption, with a total of 1.5 billion square meters. The residential sector accounts for a relatively large share of energy consumption, reaching 60,000 TCE in 2019.

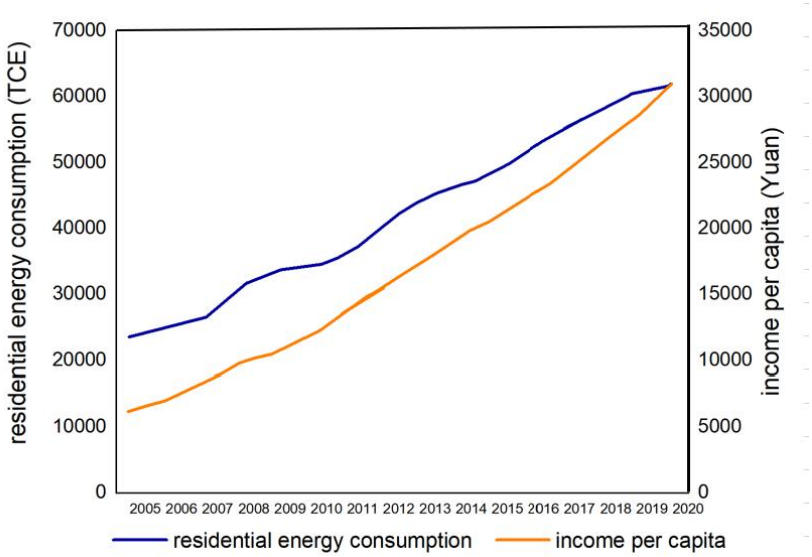


Figure 13. Annual per capita income and residential energy consumption in China, 2005-2019.

Data sources: Own work and China Statistical Yearbook 2021.

Energy consumption in the residential sector is positively correlated with per capita income, the higher the income, the higher the demand for energy, as they can afford higher energy costs and have higher demands on quality of life as the data shows in Figure 13.

According to Zhang M et al. (2022), the results show a significant inverse effect of energy upgrading in the residential sector. An increase rather than a decrease in electricity consumption in urban households reduces energy costs and may increase the frequency and intensity of use of household appliances.

The only reduction in energy intensity is in urban space heating in northern China, where energy intensity is reduced by 17% (from 527 MJ/m2 to 440 MJ/m2). The electrification rate

of urban buildings in northern China is about 47% for urban dwellings, 59% for commercial dwellings, 9.7% for rural dwellings and 3.3% for central heating.

In China, electricity consumption increases by 77% from 2011 to 2022, and in 2022, the national electricity consumption is about 8700 billion kW-h, with the residential sector accounting for 15.3%. The share of electricity consumption in the residential sector is also gradually increasing from 2011. Due to the relaxation of the new crown epidemic policy, experts expect that China's economic operation is expected to generally pick up in 2023, pulling the growth rate of electricity consumption demand up from 2022. Under normal climate conditions, China's total social electricity consumption in 2023 will be about 6% higher than in 2022.

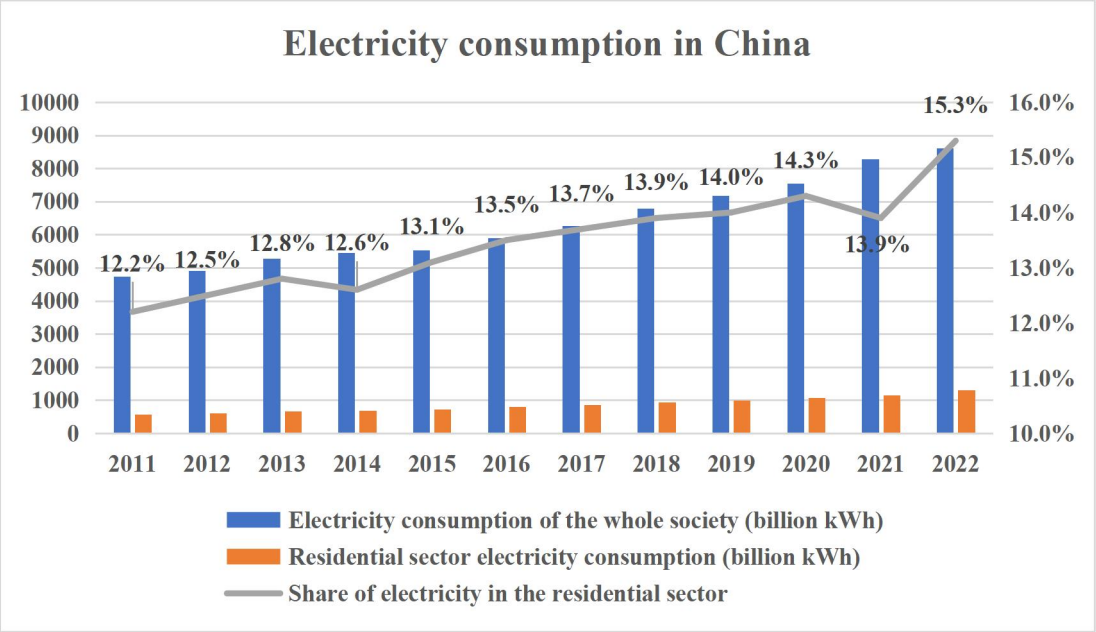


Fig 14. Electricity consumption in China.

Sources: Own work and National Bureau of Statistics

To achieve emission reductions, China needs to control its energy demand growth. Energy growth in the residential sector is directly responsible for carbon emissions as shown in the Figure15. The CO2 emissions from the urban and rural residential sectors in China from 2001 to 2019, with urban residential carbon emissions much higher than rural, due to the large population base and dense carbon emissions in urban areas.

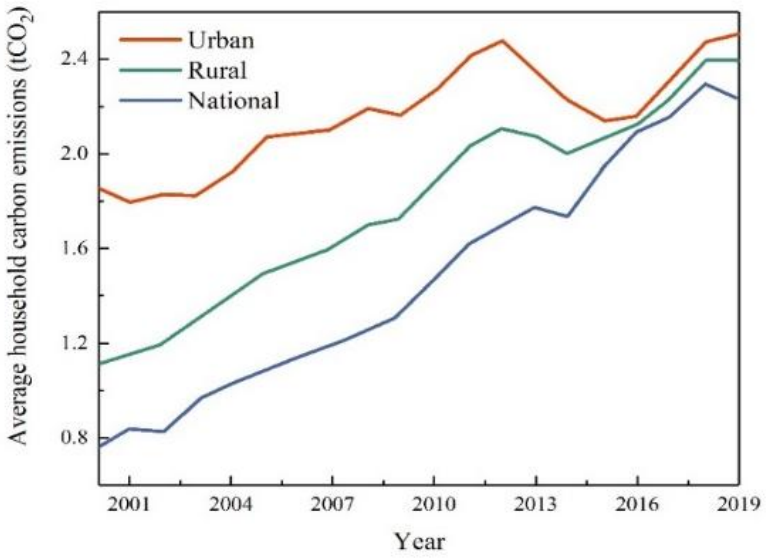


Figure15. CO2 emissions from urban and rural residential sectors, 2001-2019

Sources: Own work and National Bureau of Statistics

China expects that direct emissions of CO2 from the building sector should peak and decline rapidly, with emissions reduced by about 50-95% by 2050 compared to 2015. According to - the conclusions suggest that in 2050 building end-use energy consumption will either be close to today's levels or much higher. This result reflects the paradox of the energy consumption problem in the building sector, where on the one hand there is a need to improve the efficiency of energy use in buildings, and on the other hand urbanization and growth of demand for building energy services raise energy consumption.

4.3 Popular Awareness

In this paper, a survey of Hungarian and Chinese residents was conducted in order to study energy efficiency measures in the residential sector and the contribution of households to energy efficiency. The questionnaire questions were in the form of single choice items. The questions addressed: (1) personal characteristics of respondents - gender, age, education level; (2) economic variables - private monthly income; (3) energy consumption - respondents' personal monthly household energy expenditure; (4) energy conservation awareness - respondents' perceptions of energy efficiency and willingness to save energy; (5) energy conservation measures - the energy conservation programs respondents have adopted or willing to adopt, and the factors that influence these behaviors. The basic profile of the survey respondents shown in Table 3.

Table 3. Socio-economic characteristics of Hungarian and Chinese respondents

		Hungary		China	
		Quantity (158)	Frequency	Quantity (152)	Frequency
Gender	Male	76	48.10%	84	55%
	Female	82	51.9%	68	45%
Age	0-20	10	6.33%	1	3%
	21-30	118	74.68%	118	76%
	31-40	24	15.19%	13	8%
	41-50	6	3.8%	17	11%
	＞50	0	0.0%	3	2%
Education	Junior school or below	4	2.53%	10	7%
	High school or junior college	8	5.06%	9	6%
	College	18	11.39%	20	13%
	Bachelor	32	20.25%	76	50%
	Master and above	96	60.76%	37	24%
Income	Below 500€ (＜3k yuan)	38	24.05%	36	24%
	500€-1000€ (3k-5k yuan)	64	40.51%	38	25%
	1000€-2500€ (5k-8k yuan)	30	18.99%	39	26%
	2500€-5000€ (8k-12k yuan)	18	11.39%	25	16%
	More than 5000€ (＞12k yuan)	8	5.06%	5	9%

Sources: Own work

The results of this work show that respondents from different backgrounds have an influence on the answers to the questionnaire, such as education level, income level, and knowledge of energy efficiency. This is in line with the concept of "energy culture" proposed by Stephenson et al. (2010), which affirms that cultural factors influence energy consumption behavior.

The results of the questionnaire also show that some people are somewhat aware of the benefits of energy efficiency in Figure16/b, but nearly half say they are almost completely unaware of them. In Hungary, 72% of respondents believe they are fairly well informed about the benefits of energy efficiency, compared to 53% in China. In addition, 9% of respondents in China were completely unaware of the benefits of energy efficiency, which could be related to the respondents' education level. This could be related to the education level of the respondents, the education level shown in Figure16/a, since the overall education level of the Hungarian respondents is high, with 80% of the respondents having a bachelor's degree or higher. Only 7.5% of Hungarians were at high school level and below, compared to 13% of Chinese respondents.

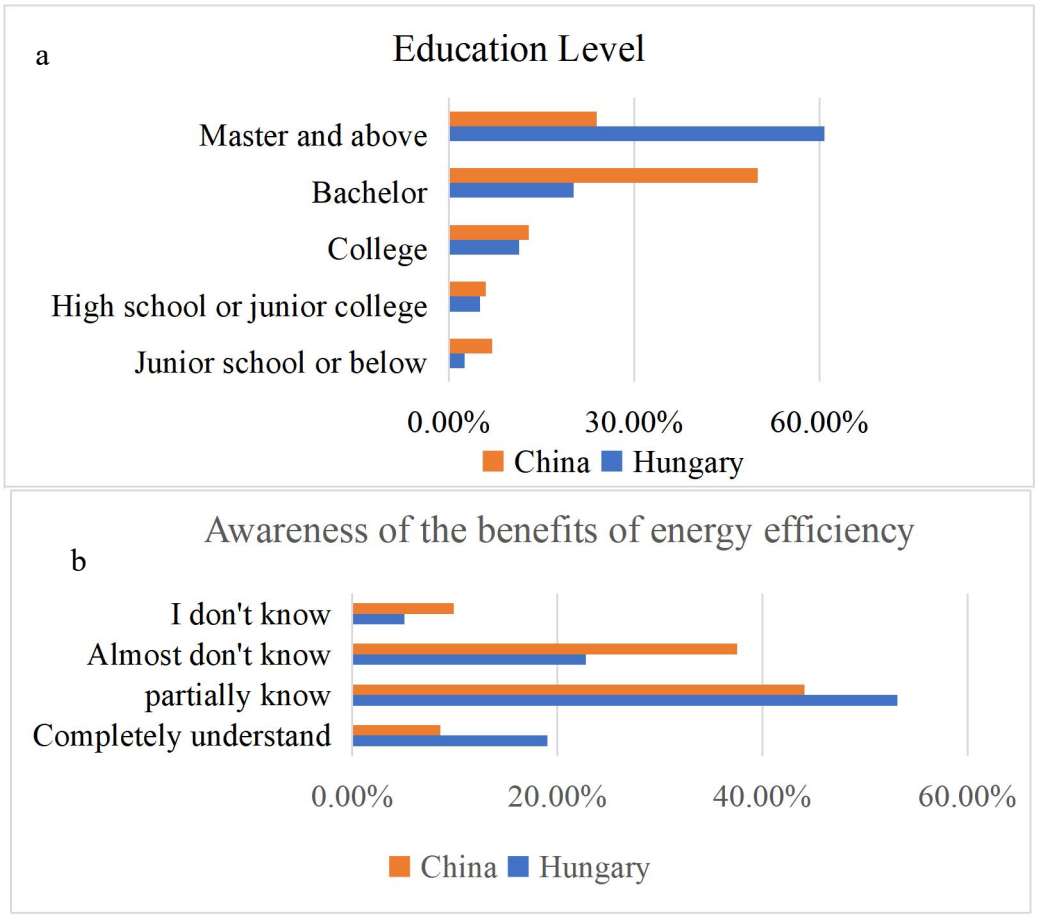


Figure16. The education level of respondents and knowledge of energy efficiency benefits.

Sources: Own work

From the results of the Hungarian and Chinese respondents' knowledge about the benefits of energy efficiency, which still needs to be improved, we need to realize that it is essential to promote and learn about the benefits of energy efficiency, because only a real understanding can lead to a better implementation of energy efficiency improvement measures and encourage social participation. In other words, increased knowledge about energy efficiency, policies, benefits and goals can help the residential sector to reduce energy consumption and improve energy efficiency.

Energy certification for buildings was introduced in Hungary in 2008 and was largely achieved in 2013 and can be registered online and certified electronically. According to statistics, between 100,000 and 150,000 certificates are issued annually, more than 90% of which are for the residential sector.

Under the Energy Performance Certificate (EPC), buildings are assigned an energy rating using an energy efficiency label. The EPC gives an energy efficiency rating from A (most efficient) to G (least efficient), which is currently valid for 10 years.

Since October 1, 2008, all non-residential buildings, sales and rental buildings are required to have a Non-Residential Energy Performance Certificate (NDEPC) and a Recommendation Report (RR). This information will help owners and occupants to make their buildings more energy efficient and allow potential buyers and tenants to compare the energy performance of different buildings.

Figure 17 shows the public awareness of the energy efficiency categories of household dwellings. In Hungary, 60% of respondents said they were aware of their home's energy efficiency category and 40% said they did not know at all, while in China 77% of households were unaware. This may be due to the fact that Hungary certifies buildings and issues certificates.

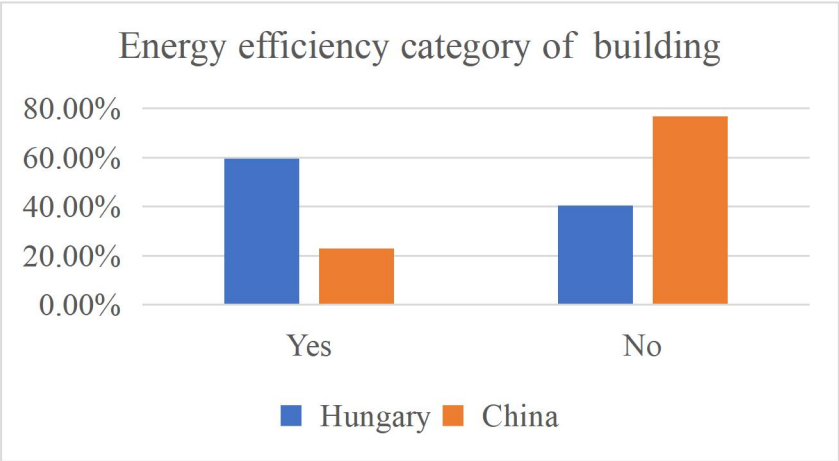


Figure 17. Public awareness of the energy efficiency categories of household dwellings.

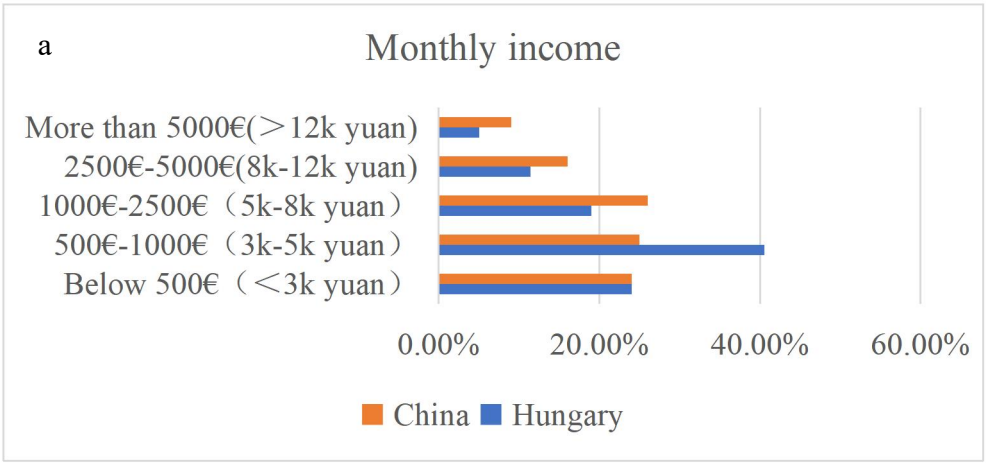
Sources: Own work

The study also investigated the economic income of respondents in both countries, and in both countries, half of the respondents were in the lower and average income levels, 40% were in the middle level, and only 10% were in the higher income levels (Figure 18/a).

As mentioned earlier, the ratio of energy expenditure to total household income is mainly determined by energy prices, the amount of disposable income and the level of energy efficiency of residential buildings, but other factors, such as energy efficiency, also play a role. According to the Hungarian Central Statistical Office (KSH), in 2000, Hungarian households spent only 17.7% of their total expenditures on housing, while in 2010 this ratio was more than 25%.

The EU proposed to phase out electricity price regulation in 2016, but Hungary took an opposing view and insisted on keeping the tariff regulation system, and eventually the EU decided to keep price regulation in exceptional cases and for an exceptional period of time. 2020-2025 continues to follow.

In Hungary and China, more than 40% of respondents said they spend less than 3% of their total income on energy each month (Figure 18/b). And when asked about personal income, China has a higher percentage of middle and high income than Hungary, but 27% of people spend more than 5% of their total income on energy per month in Hungary and only 20% in China, which may be related to the increase in energy prices in Europe in the last two years, but this gap is not very significant because of the different energy policies and prices in the two countries.



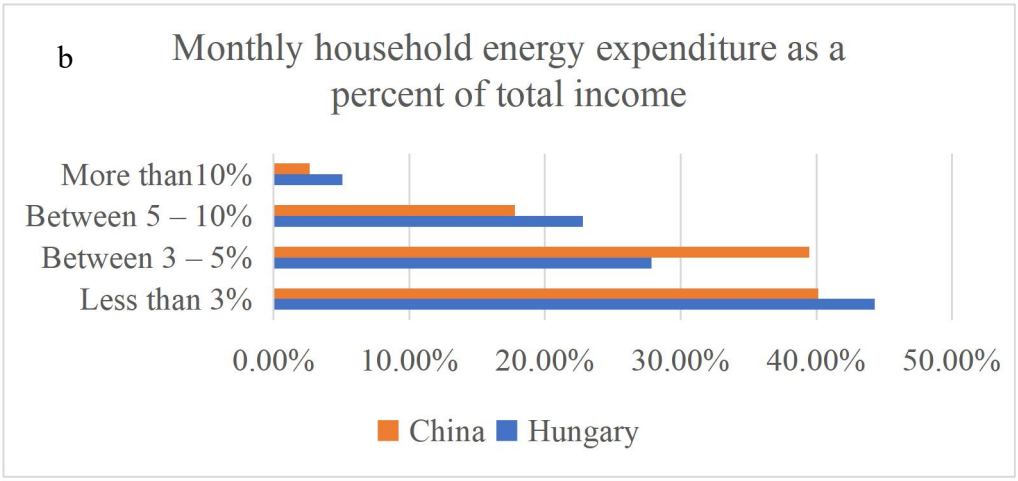


Figure 18/b

Figure 18. Monthly income levels and monthly energy spending of the respondents.

Sources: Own work

According to the Hungarian government's announcement: the average electricity consumption in Hungary is 210 kWh per month (equivalent to HUF 7,750 per month for electricity). The average gas consumption is 144 cubic meters per month (equivalent to HUF 15,833 per month for gas). The part exceeding the average will be paid according to the market price. According to the adjusted tariff, energy consumption below the average value will save nearly HUF 159,000 per person per month compared to the market price, which is equivalent to HUF 1.9 million per year.

Thanks to the electricity price regulation, it makes Hungary one of the few countries where electricity prices have fallen. The Hungarian Prime Minister said that the reduction of utility costs is a good policy and that most Hungarian households consume within the preferential

amount and enjoy low price protection. Under the utility cost reduction program, each Hungarian household receives a monthly subsidy of about 181,000 forints for its utility bills.

With the introduction of "tariffs" for electricity and gas in Hungary, more and more people are adopting various ways to save electricity and gas. The amount and type of energy used in a home is mainly related to the building materials, the energy design system and the economic level of the household. In general, dwellings in developed countries use more energy because they install more appliances. In particular, the full penetration of heating and air conditioning systems is the largest energy use endpoint in the residential sector. In the residential sector, size and energy type, as well as the number of people in the household, are key factors that influence energy spending. Smaller apartments mean fewer people in the household as well and will use less energy because there are fewer areas for energy transfer.

Energy consumption in dwellings and CO2 emissions are positively correlated, and energy scarcity and increasing carbon emissions have become key targets of most national energy policies, such as the European Energy Performance of Buildings Directive (EPBD).

Improving energy efficiency and reducing residential energy consumption can start with the design of building energy systems on the one hand, and individual occupant energy saving behaviors on the other hand have a big impact. Proactive conservation of energy use and the use of energy efficient equipment are the main ways in which individual households can reduce their household energy expenditure. Figure 19 shows the willingness to adopt energy-saving methods. In this survey, 95% of Hungarian respondents said they would reduce their home energy consumption through personal behavior, while another 5% said they never pay attention to energy efficiency. In China, 90% of respondents indicated that they would take energy saving measures, and it is worth mentioning that almost half of the respondents would use both ways of saving energy, and that a combination of both ways would produce greater energy savings.

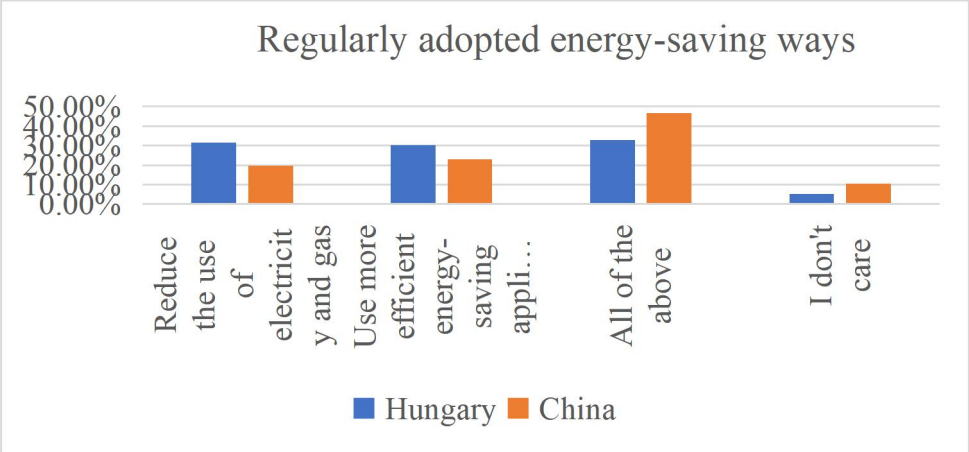


Figure 19. Respondents' willingness to adopt energy-saving methods

Sources: Own work

According to the results of the Hongguang N et al. (2023) 's study, for technical measures taken in China, the prevalence of improved building insulation is 68%, efficient heating systems 67%, and the use of LED lights 87%. For behavioral energy saving measures, 43% turn on the heat at night, 73% turn off the windows when the heat is on, and 82% turn off the lights with their hands. This indicates that most people in China prefer technical energy efficiency, which is consistent with the finding in this paper that a high percentage of respondents use energy-efficient equipment. In contrast, people in Hungary may be more likely to prefer behavioral energy efficiency.

The cross-country study of technical and behavioral energy efficiency is complex in terms of influencing factors and requires more in-depth analysis. In terms of policy, direct energy efficiency subsidies provide incentives for households to adopt technical energy efficiency, while relatively reasonable energy tariff systems in Europe promote behavioral energy efficiency among households.

Further clarify the application of energy systems in the residential building sector and improve building energy efficiency design standards. Currently, China has five building energy efficiency design standards, three of which are for residential buildings in different climate zones (i.e. JGJ 26, JGJ 75 and JGJ 134), one for rural residential buildings (i.e. GB / T 50824), and one for commercial buildings (i.e. GB 50189). These codes are updated periodically as relevant technology advances, particularly with respect to wall insulation, replacement of more efficient windows, and more effective heating systems.

In some ways, technical energy efficiency is more influential than behavioral energy efficiency, and can be spread more quickly when there is policy support. Currently, households have the most direct access to home energy efficiency devices, and improving appliance efficiency standards and labeling programs to incorporate smart technologies to achieve systemic energy savings is one possible measure.

Existing energy efficiency standards and labeling programs (EES&L) already cover many of the key energy-using devices in buildings, including air conditioners, televisions, washing machines, lamps, chillers, copiers, fans, printers, water heaters, range hoods, and induction cooktops.

Regarding the level of awareness of energy efficiency labels, the questionnaire surveyed households in Hungary and China, and the results were not very positive. Figure 20 shows the respondents' knowledge of energy efficiency labels. In both countries, 50% of the respondents said they were hardly aware of energy efficiency labels or had never even heard of them. Although the appliance industry has classified products for energy efficiency, publicity and public awareness are insufficient. The survey also found that even though many people are using less energy-efficient devices in their homes, they seem to be unaware of them. Therefore, the popularity of energy efficiency labels is paramount in promoting the purchase of energy-efficient appliances by households.

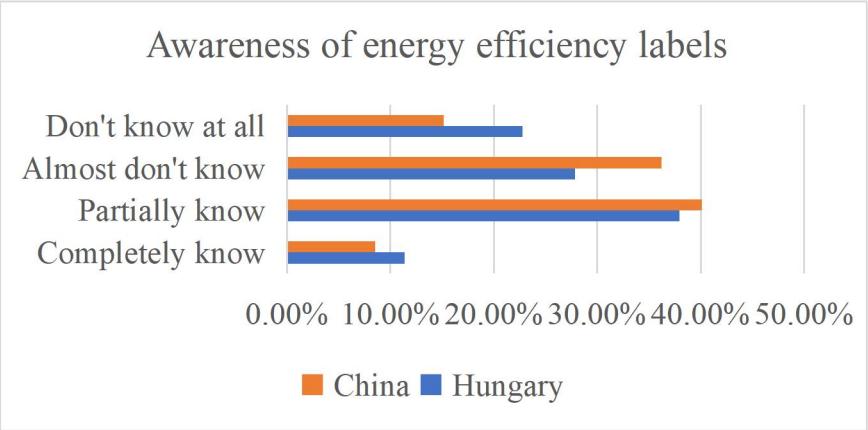


Figure 20. Respondents' knowledge of energy efficiency labels

Sources: Own work

From March 2021, only appliances with the new energy label can be sold in Hungary. According to previous studies, when purchasing appliances, users consider price first and energy efficiency second. Therefore, the energy label is an effective way to provide information on energy efficiency. When purchasing washing machines, refrigerators and

dishwashers, the energy consumption of the machine, the noise index, and the ABC label can be obtained from the label. The new energy efficiency label currently has only an A rating, as the previous A+ was difficult to truly distinguish. Therefore, the EU has introduced stricter standards for classifying appliances.

Data from the Hungarian Central Statistical Office (KSH) shows that in 2010, only 10 out of every 100 Hungarian households had a dishwasher, a figure that rises to 27 by 2020. Dishwashers can help users save a lot of time, water and energy compared to hand washing.

In China, the new national standard for energy efficiency of air conditioners, which will be implemented in July 2020, significantly raises the level of energy efficiency standards. In 2021, the percentage of sales of new Grade 1 energy-efficient products in the domestic offline market for refrigerators, TVs and air conditioners will be 71.5%, 5.7% and 66.4% respectively, while the percentage of new Grade 2 energy-efficient products will be 27% and 66.4% respectively. products will account for 27%, 50.4% and 1.5% respectively.

The promotion of energy-efficient home appliances means that households have to replace their original equipment. The questionnaire surveyed respondents on the frequency of replacing home appliances. The results show that most people replace washing machines, refrigerators, etc. with a frequency of 5-10 years, which is consistent with the reactions of the respondents in Hungary and China as shown in Figure 21. Although their behavior is more friendly from the environmental point of view and reduces the number of obsolete appliances eliminated. However, with the development of technology, electrical equipment is updated very quickly, which means that new electrical equipment has lower energy consumption.

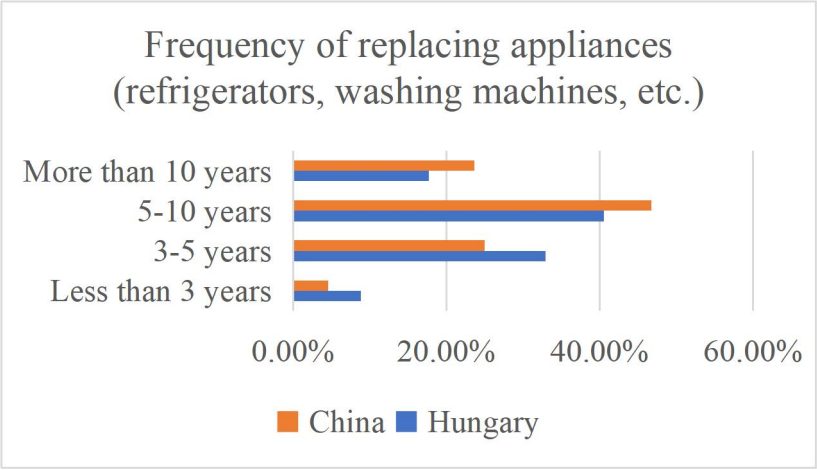


Figure 21. Statistics on the frequency of replacing household appliances by respondents.

Sources: Own work

Jiang Feng, executive director of the China National Electrical Appliances Association, said that according to the series of standards for the "safe use of household appliances", the safe use of refrigerators, air conditioners, washing machines, range hoods, electric water heaters and other products are no more than 10 years. "Urban and rural households have a large number of appliances that have been in use for more than 10 years are still in operation, and there is a huge potential for replacement demand."

For air conditioners, refrigerators, washing machines and televisions, Midea provides "green recycling + Trade-in subsidy " for 4 types of large home appliances, regardless of brand, as well as a convenient service of dismantling, delivering and installing.

By installing efficient household appliances, such as washing machines, dishwashers and lighting, electricity consumption is greatly reduced compared to ordinary housing, without compromising the comfort and convenience of the residents. All building services are designed to operate at maximum efficiency. High-efficiency appliances are usually no more expensive than regular appliances and can also offset the cost of purchasing new appliances by saving electricity (Schnieders et al. 2006).

The paper also investigated the public's willingness to consider energy-efficient appliances when purchasing appliances. The results of the questionnaire show that more than 95% of the respondents in both Hungary and China said that they would buy energy-efficient appliances, but there are differences in the degree of willingness. In China, 47% of respondents said they would always buy energy-efficient appliances, while this willingness appears to be less strong among Hungarian respondents, as 44% said they would only occasionally buy energy-efficient appliances (Figure22/a).

Among respondents who actively buy energy-efficient appliances were also surveyed to see if they would recommend others to buy them, with 95% of respondents in Hungary saying they would recommend them, and 92% in China also mentioning that they would recommend them (Figure 22/b). The conclusion shows that people who are more aware of active purchase, they are also more willing to recommend others to buy, therefore, public awareness is also a major way to popularize energy efficient appliances.

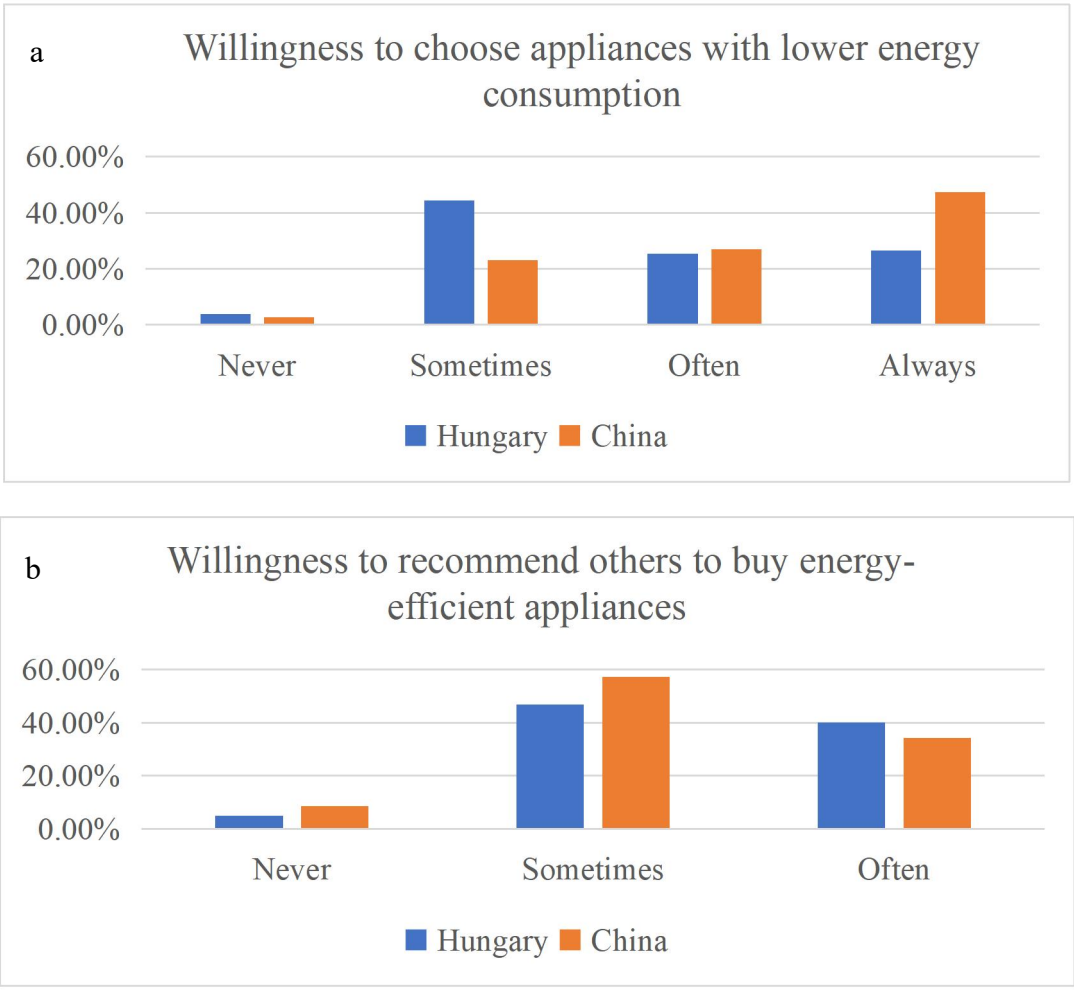


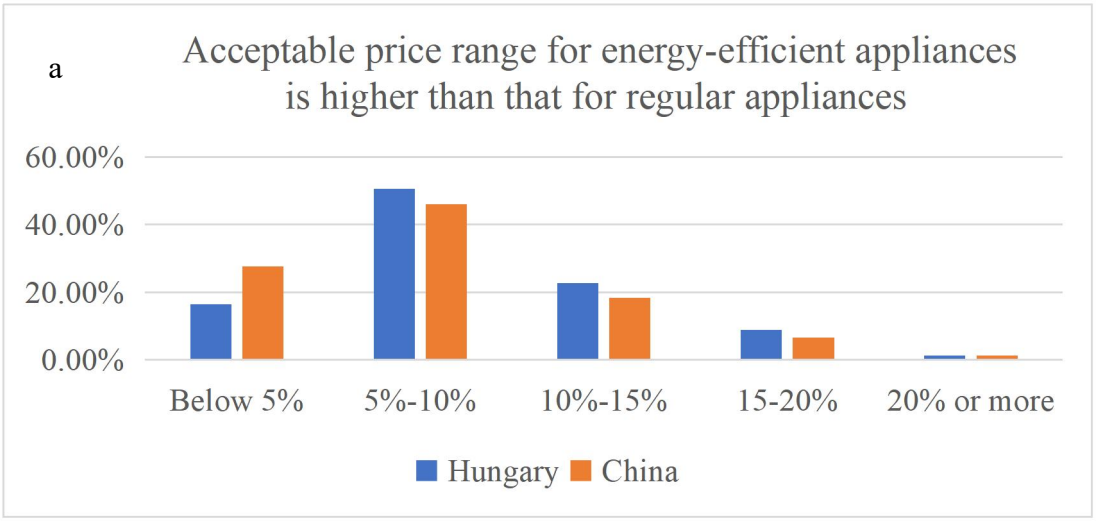
Figure 22. The public's willingness to buy low-energy appliances and to recommend others to buy them.

Sources: Own work

The survey also interviewed users about the acceptable price of energy-efficient appliances. Most users could accept a price range of 5%-10% higher for energy-efficient appliances than for regular appliances, and almost everyone was reluctant to accept when the price range was 20% higher (Figure 23/a). But when asked if they would choose to replace their old appliances if given a government subsidy, even though the old appliances were still available, more than 90% of people in both countries said they would probably or definitely buy them (Figure23/b).

Although the price of energy-efficient appliances is higher compared to regular appliances, appliances that consume less energy will save more energy costs. For example, a dishwasher with an energy efficiency label with an E rating, when used in energy saving mode (ECO), consumes 95 kWh per 100 uses, which is about HUF 7,100 a year based on 4 uses per week.

However, when choosing a more expensive, more energy-efficient C-rated dishwasher, the annual electricity bill would be under HUF 5,700.



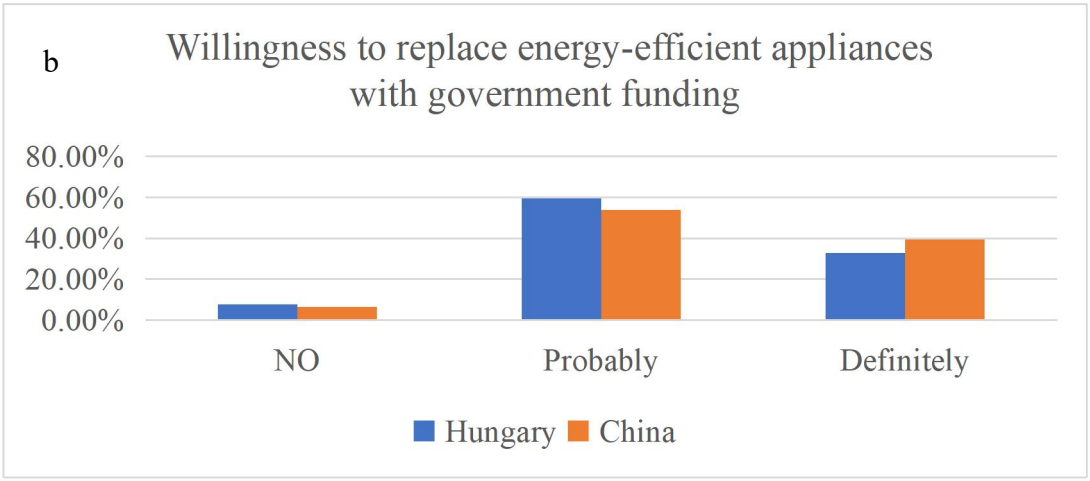


Figure 23. Public concern about the price of energy-efficient appliances, and government subsidies

Sources: Own work

In order to stimulate the market of energy-saving washing machines and refrigerators, the Hungarian government has implemented a series of policies to encourage people to buy energy-saving appliances in order to phase out old ones. Customers who purchase energy-efficient appliances usually receive a subsidy of 30%-50%.

In September 2017, Hungary began accepting applications for gas heater replacement subsidies of up to 100,000 forints. The government has allocated 1.5 billion forints for the replacement of old gas and installation of new energy-efficient products in Hungary's "Home Warmth Program", with Budapest and Pécs as the main pilot cities.

"This is the largest subsidy for the Home Warmth Program since its inception, and the government hopes that it will stimulate the modernization of Hungary's home heating systems. The Home Warmth Program has received nearly 50,000 applications for the replacement of large household appliances, half of which are refrigerators and half of which are washing machines.

China promulgated the "Implementation Plan for Promoting Green Consumption", which proposes to encourage and guide consumers to use green energy-saving home appliances, environmentally friendly furniture and other household products. Encourage regions with the conditions to carry out energy-saving home appliances and intelligent home appliances to the countryside action. In order to speed up the elimination of high energy consumption home appliances, subsidies for trade-in of designated categories of home appliances, such as air conditioners, television and washing machines, will be offered to consumers at a 20% price discount. From the feedback of consumers, through the preferential policy and consumer concept guidance, the awareness of green consumption and consumer demand has increased.

Household appliances are the second largest source of energy consumption for residents, and about 30% of the residents' carbon emissions come from household appliances. Liu Ting, president of China Household Electric Appliance Research Institute, said that China is the world's largest home appliance production base and home appliance consumption country. Strengthening technological innovation and accelerating the transition to green and low-carbon in the appliance industry is an inevitable choice to achieve healthy and sustainable development.

5 CONCLUSION

According to Jonas Grafström. (2018), energy and environmental issues are among the most sensitive topics of our time, which are globally universal. Energy efficiency is the key to reduce energy consumption and environmental problems. Improving energy efficiency necessitates the development of new energy-efficient technologies, and the widespread dissemination of technologies requires the diffusion of relevant knowledge.

After the current global energy policies, laws and regulations, as well as the presentation and continuous improvement of strategic energy goals, the issue of energy efficiency has made some progress, with the residential sector accounting for a larger share of energy consumption. The research analysis of this work shows that there is a lot of room for improving energy efficiency in the residential sector in Hungary and China. This is because 90% of the respondents indicated that they would be very willing to participate in home energy efficiency improvement programs if the government provided energy subsidies. Based on the respondents' feedback, it is clear that there is a great interest in improving energy efficiency, but little seems to be known about specific legislation, policies, and measures.

From the findings of this work, it is important for the government to recognize the lack of communication of energy efficiency policies. Using appropriate methods to effectively disseminate energy efficiency-related information and encourage public participation makes energy efficiency issues a topic of general interest. This is because those who are energy conscious among the respondents will also be willing to recommend others to adopt energy efficiency measures. Behavioral and technical energy efficiency are the two main ways to improve energy efficiency in the residential sector, and in the survey it was found that a combination of the two technologies seems to be the measure that most people are willing to take, which is a good sign because this will make a significant contribution in the reduction of energy consumption.

This paper also examines the popularity and policies of energy efficiency labels and energy efficient appliances. Respondents were surveyed about their awareness of energy efficiency labels and their willingness to purchase energy-efficient electric heaters. The results show that in Hungary and China, energy consumption is not the primary consideration for users when purchasing appliances, but price is. Moreover, most people have little understanding of energy efficiency labels and do not pay attention to them at all when purchasing appliances. The survey results also show that the number of people buying energy-efficient appliances has

increased with government price subsidies. However, there is a big difference between Hungary and China in terms of subsidies for energy-efficient appliances. In Hungary, government subsidies are mainly centralized for replacing old gas appliances, installing new energy-saving products, and for households participating in the Home Warmth Program, they can apply for subsidies. In China, there are mainly government incentives and incentives for the home appliance industry, such as the government's Home Appliance Rural Campaign and the Home Appliance Industry Trade-In Campaign.

While there are many barriers to improving energy efficiency in the residential sector, investing in education and energy-related knowledge, technological innovation in energy efficiency, optimizing home energy systems, and incentivizing the appliance industry are viable ways to promote reduced energy consumption, increased efficiency, and carbon emissions in the residential sector. Thus, alleviating the energy crisis in both countries and making sufficient, efficient, and affordable clean energy available to the public.

This paper demonstrates the need and feasibility of implementing energy efficiency improvements in the residential sector in Hungary and China by analyzing data on energy consumption in both countries, combining relevant literature studies, and analyzing the public's willingness.

6 SUMMARY

Energy efficiency improvements in the residential sector can help reduce energy demand and contribute to the environmental goal of zero carbon emissions. However, inadequate energy efficiency policies and public awareness of energy conservation have led to low energy efficiency and high energy consumption in the residential sector. This study examines the current state of energy efficiency in the residential sector based on existing energy efficiency policies and energy efficiency targets in the EU and China, which contribute to the achievement of "safe, clean, and efficient energy".

Drawing on two case studies from the residential sector in Hungary and China, this paper assesses the development of energy efficiency in the residential sector in terms of policy measures, the diffusion of energy efficiency labels and the use of energy-efficient appliances. A literature research, questionnaire survey and statistical analysis were used. The study shows that the Hungarian and Chinese governments have implemented a series of better policies that, together with the increased awareness of energy efficiency among households, have significantly reduced energy consumption. Despite the improvements in energy efficiency, financial and fiscal incentives may be of greater use due to the large volume of older buildings in Hungary and the low renovation rate, which makes it difficult to make further improvements. In addition, the findings of this study may help policy makers to make effective policy decisions for energy efficiency improvements in both countries.

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9 APPENDIX

Appendix 1 – Survey with countries populations in English

1. Your gender is? ( )

A. Male

B. Female

2. Your age is? ( )

A. Under 20 years old

B.21-30 years old

C.31-40 years old

D.41-50 years old

E.50 years old or above

3. Your education level is? ( )

A. Junior high school or below

B. High school or junior college

C. College

D. Bachelor

E. Master and above

4. Which category does your monthly income belong to? ( )

A. Below 500€ （< 3k yuan）

B.500€ - 1000€ （3k-5k yuan）

C.1000€ - 2500€ (5k-8k yuan）

D. 2500€ - 5000€ (8k-12k yuan)

F. More than 5000€ (> 12k yuan)

5. What percentage of your monthly income do you spend on electricity and natural gas? ( )

A. Less than 3%

B. Between 3–5%

C. Between 5–10%

D. More than 10%

6. Are you aware of the energy efficiency category of your building? ( )

A. Yes

B. No

7. In your opinion, how much do you know about the benefits of energy efficiency? ( )

A. Completely understand

B. Partially know

C. Almost don't know

D. I don’t know

8. Which type of energy saving do you often take? ( )

A. Reduce the use of electricity and gas

B. Use more efficient energy-saving appliances

C. All of the above

D. I don't care

9. Do you know about energy efficiency labels? For example, Energy Star. ( )

A. Completely know

B. Partially know

C. Almost don't know

D. Don't know at all

10. How often would you consider replacing your refrigerator, washing machine, etc.? ( )

A. Less than 3 years

B. 3-5 years

C. 5-10 years

D. More than 10 years

11. Faced with two appliances with the same function, would you choose to buy energy-saving appliances that consume less energy? ( )

A. Never

B. Sometimes

C. Often

D. Always

12. What is the price range you can accept for energy-efficient home appliances over ordinary home appliances? ( )

A. Below 5%

B. 5%-10%

C. 10%-15%

D. 15-20%

E. 20% or more

13. Would you replace your appliances with new, more energy-efficient ones if the government subsidized part of the cost? ( )

A. No

B. Probably

C. Definitely

14. Would you recommend others to buy energy-saving household appliances? ( )

A. Never

B. Sometimes

C. Often

D. Always

DECLARATION

on authenticity and public assess of final mater's thesis

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Title of the document: Energy efficiency in the residential sector in China and Hungary - from trademarks to the uptake of energy-efficient appliances.

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