Sustainable housing: Analysis of energy performance potential in Turkey with translation of building standards of Austria

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Sustainable housing: Analysis of energy performance potential in Turkey with translation of building standards of Austria

This study aims to investigate the energy-saving potential in the housing sector and encourage the employment of energy-efficient applications in Turkey by adapting the current European building techniques, policies and building standards in the Turkish system. First, the building standards applied in Austria and Turkey were comparatively discussed. Secondly, an energy performance analysis was performed using a PHPP Tool (Passive House Planning Package) and Konya climate data to study a typical detached house in Konya. Several optimisation scenarios that apply the Austrian regulations were conducted to form a base case Scenario. As a result, the energy and greenhouse gas emission reduction potentials, which can be provided using Vienna's building code considering the structural practices and energy techniques, were revealed. The findings shed light on how the building standards and structural practices can contribute to economic and ecological balance. Consequently, the study emphasises revising the Turkish building standards and improving the current policies to ensure high-quality and sustainable housing designs.

Key words:

energy efficiency in housing, construction techniques, housing policy, housing quality, sustainable housing, building standards

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Održivo stanovanje: Analiza energetske učinkovitosti u Turskoj u usporedbi s austrijskim građevinskim standardima

Cilj je ovog istraživanja otkriti potencijal energetske učinkovitosti stanovanja i potaknuti korištenje energetski učinkovitih načina primjene energije u Turskoj prilagođavanjem sadašnjih europskih građevinskih tehnika, politika i standarda gradnje turskom sustavu. U tom kontekstu najprije su uspoređeni građevinski standardi koji se primjenjuju u Austriji i Turskoj. Potom je provedeno istraživanje na slučaju tipične samostojeće kuće u Konyi u smislu analize energetske učinkovitosti pomoću PHPP alata (paket za planiranje pasivnih kuća) uz korištenje klimatskih podataka iz Konye. Nekoliko optimiziranih scenarija u kojima se primjenjuju austrijski propisi izvedeno je prema temeljnom scenariju. Kao rezultat toga, otkriveni su potencijali za smanjenje potrošnje energije i smanjenje emisija stakleničkih plinova, koji se mogu osigurati primjenom građevinskih pravila grada Beča, točnije njegovih strukturalnih praksi i energetskih tehnika. Rezultati objašnjavaju na koji način građevinski standardi i graditeljske prakse mogu doprinijeti ekonomiji i ekološkoj ravnoteži. Slijedom toga, istraživanje naglašava nužnost revizije turskih građevinskih standarda i poboljšanja sadašnjih politika za visokokvalitetno i održivo projektiranje stambenih zgrada.

Ključne riječi:

energetska učinkovitost u stambenom sektoru, tehnike gradnje, stambena politika, kvaliteta stanovanja, održivo stanovanje, građevinski standardi

1. Introduction

The concept of "sustainability", which emerged due to the worldwide energy crisis in the 1970s, has become a concept that is considered in all sectors. Particularly, housing design is considered essential in the construction sector in Turkey. This design process should be addressed with a holistic perspective to ensure liveable environments [1], particularly in western countries where approaches that can nurture this perspective are employed [2-5]. Economic and ecological balances must be taken into consideration as design criterions necessary for this perspective. Although this approach is portrayed as "bad design" by some design trends, it was also envisaged in the first century BC by Vitrivius [6].

Over the last century, the momentum in the energy demand due to industrialisation and population growth has continued to gradually increase along with the adverse side effects like global warming, climate change, and air pollution [7-10]. This occurs as fossil fuels such as oil, coal, and natural gas, also known as limited energy sources, are being rapidly depleted. Energy, the most significant factor that directly affects the balance in the economy, is becoming increasingly important among the importing and exporting countries. The increase in the price of energy resources, depletion of massively-used limited energy resources, and their detrimental effects on the environment, have forced all fields of science to investigate the minimisation of the energy demands and search for alternative/renewable energy resources.

Accordingly, the building sector is responsible for approximately 40 %–50 % of the total energy usage in the world, 30-40 % of all CO2 emissions, and one-third of the greenhouse gas emissions [11-13]. Similarly, the amount of energy used in the HVAC systems in buildings corresponds to approximately half of the total consumption.
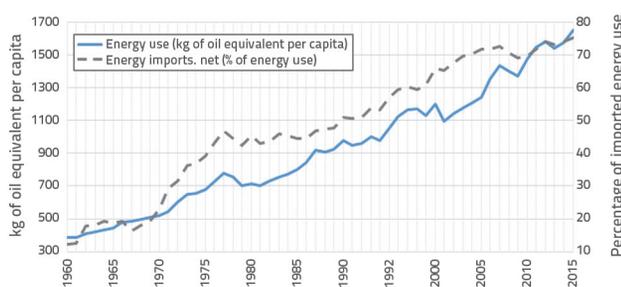

Figure 1. Percentage of energy consumption per capita and demand for energy in Turkey [14]

Turkey's energy dependence on imported raw materials is significantly higher than the average of European countries [15, 16]. The primary source of energy imports constitutes the largest proportion of Turkey's budget deficit. According to Turkish Statistical Institute (TUIK) data, Turkey's 2019 annual energy imports reached approximately $42 billion [17]. As shown in Figure 1, the annual energy consumption per capita

and percentage of energy imports are increasing proportionally in Turkey. In 2015, 75.2 % (1242 kg) of the oil equivalent (koe) per capita (1651 kg) was imported [18]. The issue of energy production and consumption is one of the strategic themes considered in national independence policies of Turkey and should be carefully examined. In addition, the construction sector accounts for a significant share of this consumption. According to data from the Turkey Electricity Distribution and Consumption Statistics [19] the industry sector had the highest energy consumption rate in 2016 (48 %), followed by household (~22 %) and commercial uses (~20 %). It is thus fair to state that when it comes to household and commercial categorisation, electricity is mainly used in the built environment. Moreover, for the total electricity consumption (42 %), an equal quantity of industrial consumption was consumed in the buildings and areas in their vicinity. Among these buildings, housing stood out with an average of ~22 % (Figure 2).
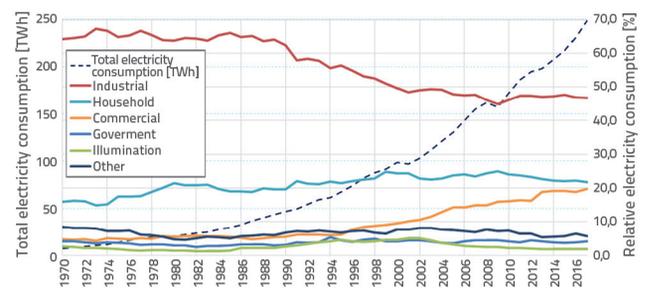

Figure 2. Turkey's annual electricity consumption by sector [19]

According to data from Republic of Turkey's Ministry of Energy and Natural Resources, the highest final energy consumption rate in 2015 (32.8 %) was in the building sector [20]. Within the scope of the Climate Change Action Plan 2011-2023, various targets were defined by the Ministry to enhance the energy efficiency and increase the rate of renewable energy electricity generation. There are various actions outlined in the Energy Efficiency Strategy Document for turning at least one-quarter of the building stock in 2010 into sustainable buildings before 2023. Moreover, there are also actions for the inclusion of sustainability-themed qualifications in the requirements for building permits and promotion of sustainable reproduction in mass housing projects [20].

According to the data from TÜİK "Building use permits given between 2014-2018 for housing in Turkey," the number of detached houses iS101405, covering a total net area of 19,729,501 m² [21]. The energy usage and energy-saving potential per unit area are higher in detached houses compared to apartments. Thus, an improvement in the energy-saving methods reflects on a broader aspect than that in other residential building types. In contrast, having a guideline for smaller units such as detached houses also has the potential to create discussion platforms and encourage following firmer steps when revising the building standards. Moreover, new standards for larger residential units can be enhanced,

followed by offices, educational buildings, health centres, and industrial buildings.

Several proven methods have already been successfully applied in areas like Europe, where they conduct strategic plans at both the national and state or regional levels by enforcing their plans using laws and incentives [22, 23]. Among the European countries, Austria has become a reference country due to its sustainable building approach, which was formed by following the EU standards, measures, and sanctions regarding the energy efficiency and liveability for the next 30 years [24-27]. In Austria, the "Energy performance of buildings directive (EPBD)" was approved in 2002 and was implemented in 2003 [28, 29]. The aim of this directive is to increase the energy performance of buildings in countries within the European Union using cost-effective measures. It was created to adapt the EU Energy Performance Certificate to national laws within the regulation of "Directive 6: Energy saving and thermal insulation", which is under the responsibility of the Austrian Technical Institute. The period between 2005 and 2009 marked the beginning of the implementation of the EU energy and climate targets in Austria with a focus on sustainability, where many positive measures were implemented to achieve the intended energy policy goals [27, 30]. Austria set itS2020 targets in line with the EU's Climate and Energy Policy 20/20/20 [28] targets of 2008, and the strategic measures were collaboratively developed in cooperation with the states and experts in April, 2009. In this strategy, 20 % more energy efficiency, 34 % higher renewable energy shares, and 39 % less greenhouse gas emissions compared to 2005 are targeted [31]. Figure 3 shows the greenhouse gas emission in Austria between 2005 and 2020. As shown in Figure 4, improvements in energy efficiency, particularly in the housing sector, are required. These developments, which increase energy performance through various initiatives and employed strategies and policies, show that considerable progress has been made to achieve sustainability.
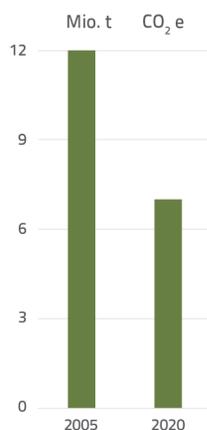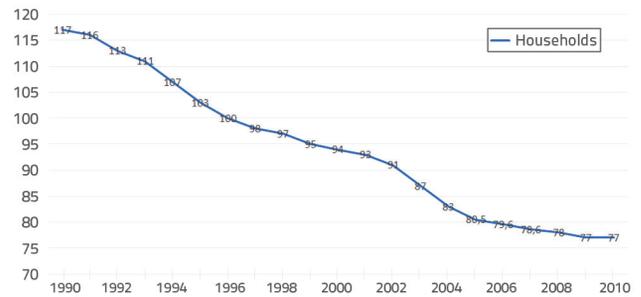

Figure 4. Austria's housing sector energy efficiency index between 1990 and 2010. (The energy efficiency in 1996 was taken as 100 % and the percentage of changes in the other years were determined accordingly) [31]

As a result, the building regulations aimed at improving the energy efficiency in the housing sector resulted in positive developments in European countries. For the reasons stated above, the development of these regulations in Turkey can potentially reduce the building energy demand. This study aims to determine whether an increase in the energy efficiency potential in Turkey can be achieved by adapting the current construction techniques, energy efficiency technologies and building standards of Europe to the Turkish system. The strength of this study comes from adapting the aforementioned standards to a detached house model in Konya, which is used to demonstrate the potential for energy efficiency and provides a guideline for the construction and refurbishment of new detached houses. Furthermore, arguments and suggestions based on the building standards and policies are made using alternative scenarios to simulate the minimum requirement cases, optimum cases, and enhanced cases.

Although the use of only the building standards has the potential to gradually enhance the energy consumption levels, the effect was limited to an extent. This limitation is subjected to a more social issue which is in this case: public participation. Building standards can be overlooked without public consent and construction can be conducted to a lower standard. In addition, constant construction inquiries are required. Therefore, this results in poorer improvements, even for the minimum requirement case. In summary, public participation can only be achieved by encouraging the adoption of building standards. Therefore, incentives supported by governmental bodies become useful in this case. Incentives play a large part in the strategic plan by showing that the national, regional, and local policies can sustain energy-efficient applications.

Similarly, the building standards regarding thermal insulation in Turkey have been in development since 1989. However, the standards were not effectively supported by policies. Another issue is that the current standards are significantly inferior compared with the EU standards. This study used a detached house model to analyse a comparative analysis. The baseline was the current Turkish Standards for detached houses which was in use between 2014 and 2018. The alternative scenarios

Figure 3. Austria's building sector total greenhouse gas emissions between 2005 and 2020 [31]

were formed according to the Austrian standards and policies. A similar study comparing the TS 825 [32], EN 832, and German thermal insulation standards was conducted by Dilmaç and Kesen in 2003 [33]; however, an updated version of TS 825 was formulated in 2008 and 2013 [32, 34, 35]. EU standards have also evolved, particularly in the last 20 years. Various improvements have been introduced to reduce the energy demand in buildings. In this sense, comparing the TS 825 standards applied in Turkey with the European standards using an exemplary structure paves the way for suggestions that can be made for the national standards and building policies.

In line with these targets, the scenarios for the detached house project model were generated. The baseline Scenario was formed according to the laws and regulations in Turkey, the alternative scenarios were set in accordance with Austrian laws, regulations, and policies. As a result, the potential for energy savings and reduction in carbon emission was achieved when the improvement scenarios for the structural and technical equipment and fittings were determined. In addition, by considering the amount of total residential usage areas for all detached housing units built between 2014 and 2018 in Turkey, the potential for reducing the energy demand and carbon emissions from all the detached houses built within these years was determined.

2. Building insulation standards in Turkey and Austria

Energy efficiency in buildings is primarily related to the building envelope. Therefore, maintaining the comfort conditions created in the interior spaces directly depends on the thermal performance of the building envelope. For the envelope to perform optimally, openings (cracks, application errors, or any planned non-operable openings) should be avoided. Moreover, the thermal transmittance values (U-value [W/m^2K]) of all building elements associated with the envelope, namely the foundation, walls, slabs, windows, doors, and roof, should be reduced as much as possible. If the difference in the U- values of two of these elements is high, this results in the creation of heat transfer routes through the building element in thermal bridges. Here, structural distortions were observed, and the thermal performance of the structure was

defined using the element with the highest U-value [36]. To ensure energy efficiency, accurately calculating and selecting the materials that compose the building elements and setting these calculations to a standard will provide benefits in terms of the energy consumption. In summary, it is important for the elements forming the building envelope to have a homogeneous U-value distribution, which improves the energy performance of the building [37-39].

Over the past 15 years, Austria has been formulating a series of regulations on the energy policy in the housing sector in accordance with the European Parliament Regulations. Although Austria's ratio of dependency on exports in energy was 65 % in 2000, this ratio decreased to 64 % in 2017. In Turkey, this ratio was 64 % in 2000; however, the data from 2017 shows that it exceeded 77 %. Given the increasing population and accelerating industrial and residential development in Turkey, these ratios will likely reach much higher levels soon. In addition, as a result of the incentives and support given to the housing sector with regard to the energy policy formulated by the Austrian government, the ratio of housing benefiting from renewable energy sources increased from 1.2 % to 3.8 % in 2016; whereas the ratio of the housing benefiting from renewable energy sources to all the residential buildings with building permits in Turkey was 0.14 % as of 2017 [21].

The ÖIB 6 regulation published by the Austrian Building Application Institute (Österreichische Instituts für Bautechnik), which emphasises energy efficiency in the planning of new houses in Austria, indicates the limits for the energy efficiency of buildings and maximum U-values for building elements. This regulation outlines the maximum heating and domestic hot water demand [kWh/m^2.year], maximum primary energy demand [kWh/m^2a], total energy efficiency factor, and greenhouse emission values per living area in a holistic perspective. Moreover, the maximum heating energy requirement in this regulation is limited to 54.4 kWh/m^2.year for new residential buildings designed from 2016 in accordance with the European Parliament's regulation 2010/31/EU. Considering that the detached house project model was designed in 2016, the maximum values in the ÖIB 6 regulation were used in the calculations (Table 1) [40].

Transparent architectural elements provide passive gains from the solar energy to the building. These transparent architectural

Table 1. Energy performance values for newly-built houses according to the ÖIB 6 Regulations

Need for energy		For new building projects	For major refurbishment projects
Heating and domestic hot water energy requirement [kWh/m^2 year]	until 31.12.2016.	16 x (1 + 3.0 / lc*)	23 x (1 + 2.5 / lc*)
	as of 1.1.2017.	14 x (1 + 3.0 / lc*)	21 x (1 + 2.5 / lc*)
Max. heating and domestic hot water energy requirement [kWh/m^2 year]	until 31.12.2016.	54.4	-
	as of 1.1.2017.	47.6	-
lc = Gross building volume / Total area of the building envelope			

Table 2. Comparison of Austria's and Turkey's maximum U-values [W/m²K] for the building elements

Building element	Austria	Turkey Region 1	Turkey Region 2	Turkey Region 3	Turkey Region 4
Wall (outside contact)	0.35	0.70	0.60	0.50	0.40
Roof	0.20	0.45	0.40	0.30	0.25
Floor	0.40	0.70	0.60	0.45	0.40
Window	1.40	2.40	2.40	2.40	2.40

Table 3. Calculation of the annual net heat requirement (Q [kWh/m².year]), which is limited depending on the region and intermediate value A_{net}/V_{gross} ratio [32]

Region	Q' – godišnja potreba za energijom za grijanje [kWh/m² godišnje]
1st region	$Q'_{1.DG} = 44.1 \times A/V + 10.4$ [kWh/m² year], calculated using A_{net}
	$Q'_{1.DG} = 14.1 \times A/V + 3.4$ [kWh/m² year], calculated using V_{gross}
2nd region	$Q'_{2.DG} = 70 \times A/V + 24.4$ [kWh/m² year], calculated using A_{net}
	$Q'_{2.DG} = 22.4 \times A/V + 7.8$ [kWh/m² year], calculated using V_{gross}
3rd region	$Q'_{3.DG} = 76.3 \times A/V + 36.4$ [kWh/m² year], calculated using A_{net}
	$Q'_{3.DG} = 24.4 \times A/V + 11.7$ [kWh/m² year], calculated using V_{gross}
4th region	$Q'_{4.DG} = 82.8 \times A/V + 50.7$ [kWh/m² year], calculated using A_{net}
	$Q'_{4.DG} = 26.5 \times A/V + 16.3$ [kWh/m² year], calculated using V_{gross}
A_{net} - building net total area [m²]; V_{gross} - building gross total volume [m³]; Q' - annual need for energy for heating [kWh/m² year]; DG - region	

elements cause significant heat losses at night and during the winter if the expected potential energy from solar energy is obtained. Therefore, the size and direction of building elements such as windows are factors to be considered at the planning stage. Window systems consist of frames and glass modules, and the U-values of these two materials differ from each other. According to ÖIB Directive 6, the total thermal transmittance (U) of the window systems should not exceed 1.4 W/m²K. In addition, windows in Austria are produced using triple-glazed panels, insulation, and wood/aluminium framing to provide low-energy homes, with a total U-value of approximately 1.0 W/m²K. Using the new window systems, it is possible to reduce the U-value indicated in the ÖIB Directive 6 for passive houses from 0.8 W/m²K to 0.6 W/m²K.

In addition, according to Article 3 of the Vienna Zoning Law, new buildings have to utilise alternative energy systems that will provide high energy efficiency [41, 42]. In Article 4.4. of the ÖIB regulation dated 12.04.2019 [40], the maximum U-values for building elements are indicated in the tables. Table 2 shows a summary of the U-values obtained from the ÖIB regulation and the 4 different climatic regions in Turkey according to the "Thermal Insulation in Buildings Directive" published by the Ministry of Environment and Urban Planning. The monthly average temperature values by region are also given in Figure 5. Based on this, the city of Konya was located in the 3rd region. The maximum U-values recommended for the different climatic regions based on the building envelope elements are comparatively shown for Austria and Turkey in Table 2.
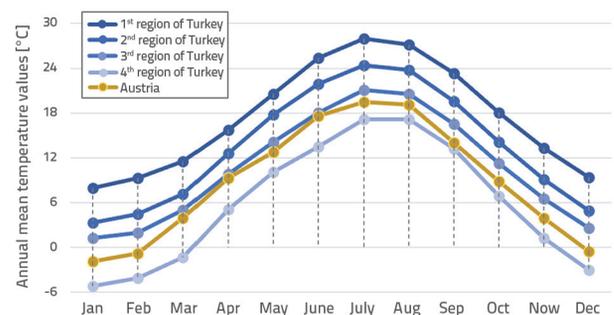
Figure 5. The annual average temperatures of Austria and different climatic regions in Turkey [32]

The U-values stated in the Thermal Insulation Regulation for Buildings are the recommended values. The annual heating energy demand calculations are, however, obligatory. These limit values vary by zone and total area / gross volume [A/V] ratio and are presented in Table 3.

3. Materials and methods

In Austria, building energy certificates are provided through GEQ Energieausweis, a national building energy simulation program. This program contains pre-defined climate data for each region in Austria, and editing the data is impossible. In addition, determining the local standards within the program and presenting these standards directly to the user facilitates usage and accelerates the registration building process.
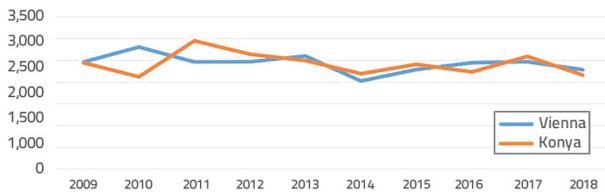
Figure 6. Heating degree day for the cities of Vienna and Konya between 2009 and 2018
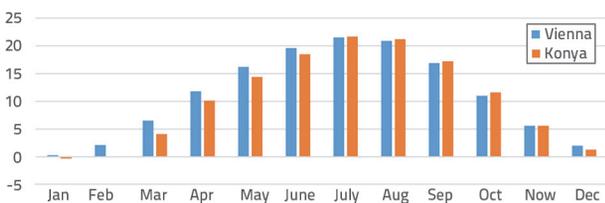

Figure 7. Average monthly outdoor temperature distribution for the cities of Vienna and Konya

Although the monthly lowest, highest, and average temperature values for Konya and Vienna were similar in 2019 (Figures 6 and 7), there were differences in the radiated energy of the global radiation. Since buildings with the same geometry and building materials may exhibit different energy performances depending on the climate in the different geographical regions, the GEQ programme, which is limited to only Austrian climate data, could not be for the selected case in Konya. Therefore, the energy performance calculations were conducted using the PHPP 9.6 tool developed by the Passive House Institute, which allows the editing of the climate data for Konya [44].

For the climatic regions, only thermal performance analyses were conducted for the regions indicated in Table 2, and the amount of precipitation and precipitation type were neglected. Thus, the energy performance of a detached house with a heating area of 255 m² in Konya, which was designed in 2016 and built in 2018, was chosen as the model house, and calculations were conducted on the climatic data of Konya using the PHPP Tool. PHPP, introduced 1998, produced output in the xlsx/xlsm format. The main features of these tools are space heating and cooling (annual and monthly methods); heat distribution and supply; electricity and primary energy demand determination; calculation of the characteristic values of windows, shading, heating load, cooling, and dehumidification demand; ventilation for large objects and non-residential buildings; accounting for the renewable energy sources; and EnerPHit certification (retrofitting of existing buildings). This program is verified and employed internationally in numerous academic and commercial projects to analyse and improve the building energy performance [45-47]. Scenarios in which the existing house model was adapted to Austrian standards in terms of the structural and energy techniques were created to ensure minimum compliance with the Vienna Zoning Laws with regard to the limit values of the ÖIB 6 Regulation. First, the building elements were arranged in accordance with the ÖIB

6 Regulation by considering the U-value limits. Subsequently, a heat pump and solar panels, which are efficient heating technologies, were adapted in accordance with the Vienna Zoning Laws. Consequently, the total energy savings and carbon emission values achieved in the improvement scenarios were determined. The approximate quantity of the energy-saving potential and carbon emission reduction that can be achieved if the ÖIB Regulation was to be implemented all over Turkey was then obtained by considering the usage areas of all the detached single-family houses that have received permits between 2014 and 2018 in Turkey.

3.1. Climate data information and energy performance calculation method

The national building energy simulation program (GEQ) is a software specific to Austria and was created in collaboration with the Austrian Building Institute. Climatic data from all the states and cities in Austria are predefined, and the user is not allowed to interfere with this data. Climatic data is defined automatically by the user by entering the address information. The software also has an interface to automatically transmit the final calculations to the relevant institution. For this reason, the GEQ is one the few reliable software used by both the central government and local governments throughout Austria. This serves as an important contribution to the current practices and success of implementing regulations on energy efficiency. However, due to the limitation that exists in the GEQ program, which hinders the editing of the climatic data, the PHPP tool was used to assess the energy performance.

There are two important climatic data used in energy identity calculations: "heating degree day" and "outdoor temperature". Austria's and Turkey's climatic data were classified based on these two properties to produce clustered cities in 4 climatic regions according to TSE 825, which were grouped using similar degree-day numbers. Considering this situation, it can be seen that the similarities between the cities of Konya and Vienna coincide with the climatic classification based on both the average outdoor temperature and heating degree day. Therefore, comparing these cities according to the energy performance calculations and integrating the building codes to Konya would be meaningful due to their similar features.

3.2. Simulation setup

A detached house in Meram, a district of Konya (Figure 8 and 9), was selected to serve as the model house. It was designed in 2016 and construction was completed in 2018. The residence consists of a ground floor and attic, which is not used due to the roof's slope. The height of the upper floor of the house is limited to 3.5 m in accordance with the Zoning Regulation. The house had a total construction area of 355 m² and a gross volume of 1215 m³, has a building surface of 877 m². Its A/V ratio is 0.72 [1/m] and V/A ratio iS1,39 m.

Ground floor
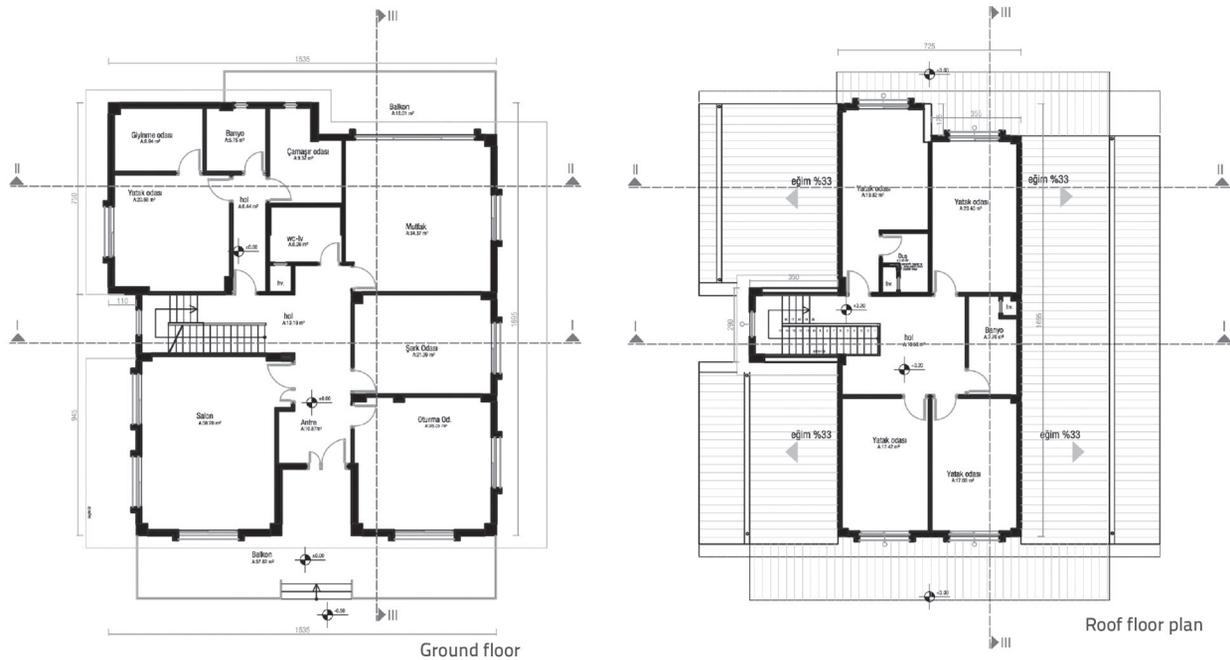
Roof floor plan

Figure 8. Floor plans for the model house in Konya (retrieved from Promim Architecture)


Section III-III

Section II-II
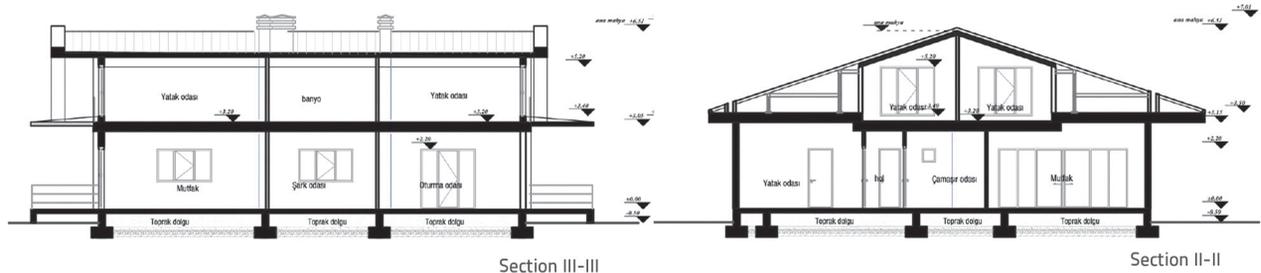
Figure 9. Cross sectional plans for the model house in Konya (retrieved from Promim Architecture)

Airtightness (Pressurisation n50 1/h) value is taken as 1.0 in the simulation setup. Since the ventilation standard DIN 1946-6 is used in new builds and renovations – apart from expert opinions in problem cases – the value has little practical relevance for existing buildings. Construction practice in new buildings and renovations shows that in multi-storey apartment buildings, a higher level of tightness is often achieved on the standard floors. Air exchange rates at 50 Pascal below 1 h^{-1} are not uncommon.

All simulations in the scenarios were carried out using the climate data of the city of Konya and PHPP Tool. Evaluation of the current situation was determined based on the design documents which were permitted by the municipality in accordance with TS 825 and Thermal Insulation in Buildings Directive published by the Ministry of Environment and Urban Planning.

The model house was calculated using the PHPP tool and three alternative scenarios: Scenario 1a, Scenario 1b and Scenario 2; which were conducted under different implementations following the regulations, policies, and implementations in Vienna (Figure 10; Tables 4 and 5). In Scenario 1a (S1a), improvements to ensure the minimum conditions were met in accordance with the Vienna Zoning Laws and ÖIB 6 Regulations were observed. The calculations are shown in Tables 4 and 5 and Figure 10. In this Scenario, optimisations were carried out for the building elements according to the minimum requirements in the ÖIB Regulation. The thermal insulation thicknesses were determined by taking into consideration the limitation of the maximum heating energy requirement value in this regulation (54.4 kWh/m^2 year). For example, although an 8 cm EPS thermal insulation is sufficient for a U-value of 0.35 W/m^{2}K, which corresponds to the limitation requirement value for the exterior wall, the thickness of the material was revised to 16cm to provide 54.4 kWh/m^2 year. Otherwise, even if the U-values requirements of the building elements in the regulation were provided; the house would not have been designed according to the regulation because of the maximum heating energy demand was ignored.

The optimisations in Scenario 1b (S1b) were carried out to provide another requirement for the Vienna Zoning Law Article 3,

Table 4. U-values used in the current situation and improvements made to the different scenarios

Building elements	Current situation	Minimum values according to the ÖIB 6 regulation	Scenario 1a-1b	Scenario 2
Exterior brick wall	0.50 [W/m²K]	0.35 [W/m²K]	0.21 [W/m²K]	0.17 [W/m²K]
Exterior concrete- reinforced wall	0.61 [W/m²K]	0.35 [W/m²K]	0.23 [W/m²K]	0.18 [W/m²K]
Attic partition wall	1.22 [W/m²K]	0.35 [W/m²K]	0.21 [W/m²K]	0.17 [W/m²K]
Attic slab not used	0.24 [W/m²K]	0.20 [W/m²K]	0.18 [W/m²K]	0.15 [W/m²K]
Floor in contact with earth	0.45 [W/m²K]	0.40 [W/m²K]	0.27 [W/m²K]	0.14 [W/m²K]
Roof slope used	0.30 [W/m²K]	0.20 [W/m²K]	0.19 [W/m²K]	0.13 [W/m²K]
Cantilever slab	0.45 [W/m²K]	0.20 [W/m²K]	0.17 [W/m²K]	0.12 [W/m²K]
Window	2.80 [W/m²K]	1.22 [W/m²K]	1.22 [W/m²K]	0.71 [W/m²K]
Door	2.50 [W/m²K]	1.70 [W/m²K]	1.10 [W/m²K]	0.63 [W/m²K]

Table 5. Energy sources used in the current situation and improvements made in the different scenarios

POWER SUPPLY				
Need for energy	Current situation	Scenario 1a	Scenario 1b	Scenario 2
HEATING AND DOMESTIC HOT WATER	Condensing natural gas combi boiler	Condensing natural gas combi boiler	Air source heat pump + heating recovery ventilation	Air source heat pump + photovoltaic panels (16 m²) + heating recovery ventilation

which entails the application of alternative energy systems that provide high energy efficiency in newly-constructed buildings. Within the scope of alternative energy systems, at least one system among the heat pump system, district heating system, cogeneration energy system, and systems that benefit from decentralised renewable energy sources should be adopted [33]. Therefore, a heat pump and heating recovery ventilation was used as an alternative energy system in S1b due to its convenient installation cost and prevalence in detached houses. Consequently, full compliance with the ÖIB 6 Regulation and Vienna Zoning Laws was ensured within the energy efficiency framework.

In Scenario 1a, the building's energy source was maintained as natural gas and optimisations were only made on the building elements features. In this case, the savings in the carbon emission values and energy efficiency potential were only determined when the building elements of the house improved. In addition to this improvement, in Scenario 1b, an air source heat pump with heating recovery ventilation was replaced with a condensing natural gas boiler. In contrast, in Scenario 2, materials with higher thermal performances were used instead of the insulation materials employed in S1a and S1b. Thus, the thermal conductivity values of the insulation material (EPS) used on the brick walls in scenarios 1a and 1b were 0.040 W/mK, and that in Scenario 2 (EPS F+) was 0.031 W/mK. These insulation materials are frequently applied in Vienna, particularly in the detached housing sector. Furthermore, the thicknesses of the thermal insulation materials were partially changed, and renewable energy

sources were employed to demonstrate a comparison with the previous scenarios (Table 5). In S2, an air source heat pump and heating recovery ventilation similar to that in Scenario 1b were used. The windows glazing types were also changed accordingly. For instance, in the current scenarios, a 4x12x4 clear glazing with a metallic frame was employed and resulted in a U-value of 2.80 W/m²K. In Scenario 1a and 1b, the window was changed into an argon-filled, low-e triple glazing. In contrast, xenon-filled, very low-e glazing was employed in Scenario 2. The g value for all windows in the given scenarios was taken as 0.50. Additionally, photovoltaic panels with an area of 16 m² were placed on the roof.

4. Results and discussion

As a result of the analysis made using the PHPP tool, the energy demand and carbon emission values for the current situation and three additional scenarios on the energy performance and energy balance of the house were comparatively determined. The heating and domestic hot water requirement, which is currently at 43,523 kWh/year, was reduced to 16,401 kWh/year in S1a, a 62 % reduction in energy. Here, the same materials as those in the current situation were used. However, the thicknesses of the materials were improved in accordance with the Vienna Zoning Law and the ÖIB 6 regulation. Therefore, it was determined that the total demand for heating and domestic hot water was reduced from 122,6 kWh/m² per area to 46,2 kWh/m², which reduces the current value by 62 %of. In this Scenario, the annual greenhouse gas emissions were reduced

HEAT INSULATION MATERIAL TABLE				
Building elements	**Current situation**	**Scenario 1a**	**Scenario 1b**	**Scenario 2**
Exterior wall brick	EPS 5.0 cm	EPS 16.0 cm	EPS 16.0 cm	EPS F+ 16.0 cm
Exterior wall reinforced concrete	EPS 5.0 cm	EPS 16.0 cm	EPS 16.0 cm	EPS F+ 16.0 cm
Attic partition wall	–	EPS 16.0 cm	EPS 16.0 cm	EPS F+ 16.0 cm
Attic slab not used	Stone wall 10.0 cm	Stone wall 15.0 cm	Stone wall 15.0 cm	Stone wall 20.0 cm
Floor in contact with earth	XPS 5.0 cm	XPS 10.0 cm	XPS 10.0 cm	XPS 20.0 cm
Roof sloped used	Stone wall 10.0 cm	Stone wall 20.0 cm	Stone wall 20.0 cm	Stone wall 30.0 cm
Cantilever slab	EPS 5.0 cm	EPS 16.0 cm	EPS 16.0 cm	EPS F+ 16.0 cm
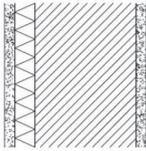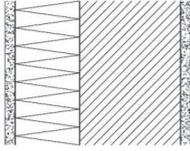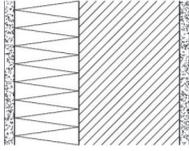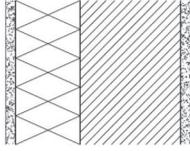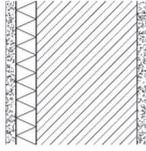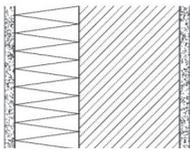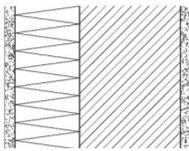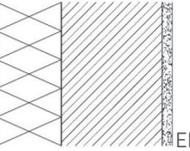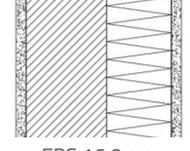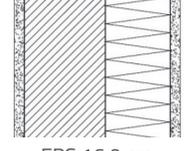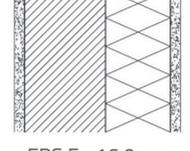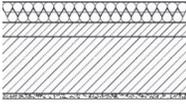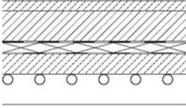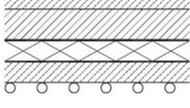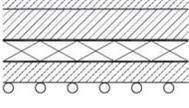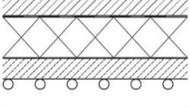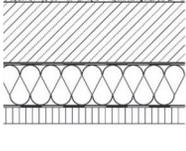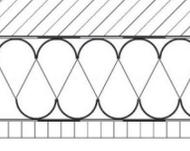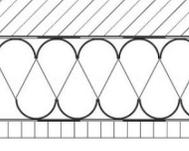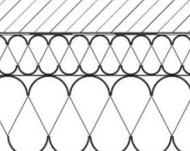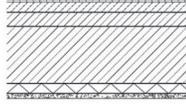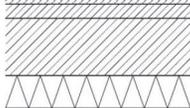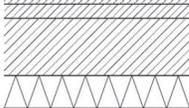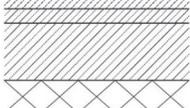
Figure 10. Thermal insulation materials and their thicknesses for the current situation and optimised scenarios

Table 6. Energy demand and carbon emission values according to the current and alternative scenarios

	ENERGY DEMAND AND CARBON EMISSIONS				
355 m² detached house A/V = 0.73 [1/m]	Heating and domestic hot water energy requirement [kWh/year]	Heating and domestic hot water energy requirements per area [kWh/m² year]	Greenhouse gas emission value [CO_2/year]	Greenhouse gas emission value per area [CO_2/m² year]	Primary energy demand [kWh/year]
Current situation	43.523	122.6	13.809	38.9	84.845
Scenario 1a	16.401	46.2	7.064	19.9	38.340
Scenario 1b	8.931	25.3	7.029	19.8	18.815
Scenario 2	3.692	10.4	4.721	13.3	10.650

Table 7. Energy demand and carbon emission values according to the current and alternative scenarios [%]

	ENERGY DEMAND AND CARBON EMISSION VALUES				
355 m² detached house A/V = 0.73 [1/m]	Heating and domestic hot water energy requirement [kWh/year]	Heating and domestic hot water energy requirements per area [kWh/m² year]	Greenhouse gas emission value [CO_2/year]	Greenhouse gas emission value per area [CO_2/m² year]	Primary energy demand [kWh/year]
Current situation	0 %	0 %	0 %	0 %	0 %
Scenario 1a	62 %	62 %	48 %	48 %	54 %
Scenario 1b	79 %	79 %	49 %	49 %	78 %
Scenario 2	91 %	91 %	65 %	65 %	87 %

Table 8. Energy balance in the current situation and alternative scenarios

	ENERGY BALANCE		
355 m² detached house A/V = 0.73 [1/m]	Heat loss by building elements [kwh/m² year]	Solar energy gain from windows [kWh/m² year]	Heat gain by photovoltaic panels [kWh/m² year]
Current situation	144.4	50.9	–
Scenario 1a	56.4	36.3	–
Scenario 1b	56.0	30.9	–
Scenario 2	34.9	24.3	4.81

Table 9. Annual heat losses/gains and demands in the current and alternative scenarios

	Heat losses/gains/demand				
355 m² detached house A/V = 0.73 [1/m]	Total heat losses Q_L	Available solar heat gains Q_s	Internal heat gains Q_I	Heat gains Q_G	Heating demand Q'
Current situation	173.9	50.9	16.3	51.3	123
Scenario 1a	85.3	36.3	14.7	39.1	46
Scenario 1b	60.5	30.9	13.1	35.2	25
Scenario 2	38.6	24.3	11.4	28.2	10

to 48 % and the annual primary energy demand was reduced to 38,340, 54 % from the current 84,845 kWh.

In Scenario S1b, which aims to execute the "addition of high-efficiency renewable energy systems" requirement of Article 118 of the Vienna Zoning Regulation, "heat pump" and heating recovery ventilation were conducted similar to those in Scenario S1a, where the material thicknesses were conveniently improved. In this case, the annual heating and domestic hot water demand (16,401 kWh), which was reached in Scenario S1a, was reduced to 8,931 kWh, and the heating and domestic hot water energy requirement per unit area (46,2 kWh/m²) in the S1a was reduced to 25.3 kWh/m². As a result, it was

determined that in the S1b Scenario, the energy was reduced by 79 % compared to the current situation. The S1b greenhouse gas emissions were also reduced by 49 % compared to the current situation. In this Scenario, the primary energy requirement, which was 38,340 kWh per year in S1a, was reduced to 18,815 kWh per year. In S1b, the building's energy was reduced by 78 % compared to the current situation (Tables 6 and 7).

In Scenario S2, the materials in S1a and S1b were replaced by a higher-performance thermal insulation material that is commonly used in the Vienna detached housing sector, making changes to their thicknesses and photovoltaic panel area (16 m^2) that is applied on the roof as the renewable energy source. As a result of these improvements and optimisations, the annual heating and domestic hot water energy demands were reduced to 3,692 kWh, representing a 91 % reduction in the energy compared to the current situation, and the heating and domestic hot water energy requirement per unit area was reduced to 10.4 kWh/m^2 from the 25.3 kWh/m^2 in S1b. Moreover, when the greenhouse gas emission was reduced by 65 % compared to the current situation, the primary energy demand was reduced to 10,650 kWh per year, an 87 % reduction in the energy compared to the current situation. Consequently, it was concluded that the S2 Scenario has the highest energy performance (Tables 6 to 9). As shown in Tables 8 and 9, the annual values for each area in terms of the heat losses/gains, and heating demand drop significantly in the applied scenarios.

5. Conclusion

This study addressed the relationship between the energy performance and construction quality, as well as the importance of well-structured building standards/regulations to encourage this quality. Several scenarios were applied to a case study in Konya, Turkey, following the building regulations and prevalent applications in Austria to reveal the energy-saving potential for buildings in Turkey. A gradual increase in the building energy performance was observed in the simulation results performed on the scenarios of the model house. This shows that in Vienna, the energy demand of buildings is controlled by the building standards and regulations and is not left to the initiative of the various actors like building owners, contractors, or construction firms. Building policies where the actors are encouraged to improve their building envelope or employ alternative energy sources maintains the sustainability of energy-efficient approaches.

Moreover, it can be clearly stated that building standards should not only define the material properties like the thermal conductivity value or material thickness ranges, but also give a more holistic approach such as the annual energy demand, carbon footprint, cost analysis, energy monitoring or even wastewater recycling.

An energy savings of up to 62 % was achieved in the S1a Scenario, which only met the regulation requirements,

comprised of reducing the amount of heat lost by only changing the thicknesses of the existing building elements in the model house, and emphasising using sanctions how easily a substantial decrease in energy use can be achieved. In addition, S1b was formed around a regulation where at least one of the traditional systems has to be replaced with a high-efficiency system. Then again, the 79 % gain compared to the current situation shows that even a specific rule can minimise energy consumption and dependency. Furthermore, building policies in Vienna that offer economic incentives to employ renewable energy resources and further improve their building systems with higher efficiency rates and building envelopes resulted in the adoption of energy-efficient approaches in a wider spectrum. With these improvements applied to the model house in Scenario S2 (materials with a lower thermal conductivity and more efficient applications, increasing the use of renewable energy sources, etc.), a decrease in energy demand of up to 91 % was observed. These research processes and results affect how several construction methods could be efficiently employed in buildings in Turkey. Moreover, the outcomes should not be considered from an energy-savings perspective alone. They were correlated with the greenhouse gas emissions and directly impact the buildings' carbon footprint, reflecting on a more "sustainable built environment". Considering the large number of detached houses in Turkey, this will also positively affect the economy. To realise these improvements in Turkey, the current standards should not be limited to material properties alone. Moreover, a holistic approach needs to be employed where values like the annual energy demand per unit area and gas emissions are included, or zoning methods are proposed. The existing energy certification system should be encouraged through sanctions and financial support systems. Considering the influence of the building policies on the public adoption of such approaches, similar methods to the EU policies need to be adopted [48].

Notably, using only the building regulations results in a saving potential of up to 62 % even with easy-to-apply arrangements and without changing the materials used by only setting a limit on the U-values and annual energy requirement per unit area. Considering that the housing sector ranks second in the basic electricity consumer sector after the industry sector, a considerable improvement in energy savings can be achieved in Turkey. Thus, this study emphasises the necessity of using efficient techniques and technologies encouraged in various building standards in a holistic perspective to achieve high-quality and sustainable housing designs. Moreover, the demonstration of these techniques and standards in a case study has provided a base/guideline for the studies in this context, as well as for the policy developers.

For future study, there are a few potentially interesting directions that could be derived from this study. First, several typologies in Turkey can be conducted as a case study to verify the results. Second, the study can be expanded by considering the cost through a comparative analysis of the current and applied scenarios.

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