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ARAŞTIRMA MAKALESİ RESEARCH ARTICLE

The Impact of Income Level on Household Greenhouse Gas Emissions: A Case Study for Turkey

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Abstract

This study examines the effects of income levels on household greenhouse gas (GHG) emissions. For this aim, the impact of income level on household carbon footprints was analysed. Based on a largescale household survey in Ankara, direct and some indirect GHG emissions at the household level were estimated. Furthermore, the results were examined with the Environmental Kuznets Curve (EKC) Hypothesis which was studied in Turkey. Results showed that there is a significant relationship between household GHG emissions and income level groups. Depending on the level of income, consumption growth, and per capita, energy usage results in an increase in greenhouse gas emissions. Household average emission is found as 6.934 tons of CO_{2e} per capita. Household carbon footprint varied across Ankara's district according to income level. Wealthy districts usually have a higher per capita carbon footprint than poor districts. Besides the wealthiest socio-economic level was found to emit 1.87 times as much CO_{2e} as the lowest. It is identified that emissions from heat production take the larger share of household carbon footprints. It is also determined that the only emission that decreases with higher income levels is indirect emissions from water consumption.

Keywords: ANOVA Analysis, Greenhouse Gas Emissions, Household Income

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Gelir Düzeyinin Hanehalkı Sera Gazı Emisyonlarına Etkisi: Türkiye için Bir Vaka Çalışması

Özet

Bu çalışma, gelir düzeylerinin hane halkı sera gazı emisyonları (SGE) üzerindeki etkilerini incelemektedir. Bu amaçla gelir düzeyinin hane halkı karbon ayak izleri üzerindeki etkisi analiz edilmiştir. Ankara'da gerçekleştirilen geniş ölçekli bir hane halkı araştırmasına dayalı olarak, hane düzeyinde doğrudan ve bazı dolaylı sera gazı emisyonları tahmin edilmiştir. Diğer taraftan sonuçlar Türkiye için çalışılan Çevresel Kuznets Eğrisi (EKC) Hipotezi ile incelenmiştir. Buna göre hane halkı sera gazı emisyonları ile gelir düzeyi arasında önemli bir ilişki olduğu tespit edilmiştir. Gelir düzeyine, tüketim artışına ve kişi başına düşen enerji kullanımına bağlı olarak, enerji kullanımı sera gazı emisyonlarında artışa neden olmaktadır. Hane halkı ortalama emisyonu 6.934 ton CO_{2e} olarak tespit edilmiştir. Hane halkı karbon ayak izi, Ankara ili genelinde gelir düzeyine göre farklılık göstermiştir. Genellikle yüksek gelire sahip ilçeler, düşük gelire sahip ilçelere göre daha yüksek kişi başına karbon ayak izine sahiptir. Ayrıca en yüksek sosyo-ekonomik düzeyin, en düşük sosyo-ekonomik düzeye göre 1.87 kat daha fazla CO_{2e} saldığı tespit edilmiştir. Isı üretiminden kaynaklanan emisyonların hane halkı karbon ayak izi içerisinde en büyük paya sahip olduğu belirlenmiştir. Diğer taraftan gelir düzeyi yükseldikçe azalan tek emisyonun su tüketiminden kaynaklanan dolaylı emisyonlar olduğu da tespit edilmiştir.

Anahtar kelimeler: ANOVA Analizi, Hane Halkı Geliri, Sera Gazı Emisyonları

1. Introduction

There are several articles about Greenhouse Gas (GHG) emissions published for Turkey, from cement manufacturing to fossil fuel consumption. However, there has not been a comprehensive study in the literature that calculates actual household emissions and examines the factors affecting them. Global warming caused by GHG emissions gets more and more important day by day. Environmental concerns have started to put significant pressure on people in recent years (Plassmann, Norton, Attarzadeh, Jensen, Brenton & Edwards-Jones, 2010). The United States Environmental Protection Agency (EPA) defines climate change as a significant change in the measures of climate, such as temperature, rainfall or wind, lasting for an extended period of time – decades or longer. The most important reason for global warming is the increase in the amount of carbon dioxide in the atmosphere. S. Arrhenius is the first to predict climate change as a result of CO_2 accumulation (Türkeş, 2001). As reported by the European Environment Agency (EEA), CO_{2e} emissions from the residential sector accounted for about 27% of the global total CO_{2e} emissions in 2016 (European Environment Agency, 2015). According to the Turkish Statistical Institute (TUIK), Turkey's total emissions in 2018 were 520.9 million tons. 71.6% of the total emissions arise from energy production, followed by industrial processes and product use with 12.5%, agricultural activities with 12.5% and waste, including landfills and wastewater, with 3.4% (Turkish Statistical Institute, 2020a). It is stated that among the largest emitters of greenhouse gases in Europe are Germany, United Kingdom, France, Turkey, Poland, Italy, and Spain (Kijewska & Bluszcz, 2016). Wang et al. analysed the carbon emissions of 170 countries. They reported that energy consumption and urbanization contributed most to carbon emissions (Wang, Shi, 2019). It is determined that non-renewable energy sources had twice the effect on carbon emissions in the European Union region than renewable energy sources (Mert & Bölük, 2016). Cong et al. have demonstrated household CO_{2e} emissions at a community level for Japan. They have prepared map-based emissions by combining the statistical data on households with detailed emission intensities (Cong, Saito, Hirata, Ito, 2019). Barrett et al. have revealed consumption-based emissions results for the United Kingdom and suggested consumption-based emissions as a complementary indicator to the current approach of measuring territorial emissions (Barrett, Peters, Wiedmann, Scott, Lenzen, Roelich & Le Quéré, 2013). It has been explored the interaction effects of income, income inequality, and democracy on Canadian households' emissions using quantile technique with the EKC hypothesis (AbdelHady, 2019). Adriana and Pratama have calculated the GHG emissions associated with household water and proposed ways to reduce emissions (Adriana & Pratama, 2020). Li et. al. have designated household CO_{2e} emissions in Northwest China. They have analysed the relationship between per capita emissions and explanatory factors using spatial econometric models (Li, Huang, Yang, Chuai, Li, Qu d, Zhang, 2016). Mi et al. have studied an environmentally extended multiregional input–output approach to estimate household carbon footprints for 12 different income groups in China's 30 regions. They found that China's households contributed 34% of the national carbon footprint in 2012 (Mi, Zheng & Meng, 2020). Soneja et al. have conducted research to develop field-based estimates of the amount of black carbon and particulate matter that is emitted from households due to the use of traditional cook stoves in Nepal (Soneja, Breyssel & Tielsch, 2013). Vardopoulos and Konstantinou have studied to explore the possible relationship between unemployment rates and their effect on climate change through CO_{2e} emissions from human economic activity (Vardopoulos & Konstantinou, 2017). In the case of China, empirical research was done with the time series data between 1995 and 2010. Consequently, it is found that when increasing 1% of the gross domestic product (GDP) growth index and technology, household carbon emission intensity is lowered by 0.3604% and 0.0412% (Liu, Zeng Qu, Wang Q.H. & Wang L, 2013). It is indicated that gross domestic product, population, and normalized difference vegetation index are all positive driving forces for urban CO_{2e} emissions in China (Wang & Fang, 2018). Intertemporal lifestyle effects on carbon emissions have been studied in China. It was indicated that income and demographic effects contributed only 25.1% of the total household emissions. The remaining 74.9%, is defined as the effect of intertemporal lifestyle changes (Zhang, Shi, Wang, Xue, Song & Sun, 2020). The greenhouse gas emissions of 10 cities were examined by Kennedy et al. Fuel combustion, waste and electricity consumption were included in the calculation (Kennedy, Steinberger, Gasson, Hillman, Havránek, Hansen, Pataki, Phdungsilp, Ramaswami & Mendez, 2010). A similar study was conducted by Long and Fang in Tokyo. According to the results, the first and second emissions sources were found to be electricity and gas consumption, accounting for 22% and 23% of total household emissions, respectively. The four most significant impact factors on household emissions were found to be household residents, household income, house size, and preferred temperature (Zhu, Huang, Chen, 2019). In a study investigating the regional carbon footprint of Germany, it was found that the highest-income households emit 4.25 times as much as the lowest household group (Miehe, Scheumann, Jones, Kammen & Finkbeiner, 2016). In this study, there are theoretical background, methodology, and empirical results. The final section summarizes the conclusions.

2. Methodology

2.1 Study Area and Data Sources

We investigated the relationship between household GHG emissions and socio-cultural level in our study. We used consumption data to calculate household emissions. The survey method was chosen to obtain data, which we put into the calculation of emission. First, we determined the common emission sources for households. According to studies, consumption of fuel, electricity, heat, water, and waste disposal have an important place in the distribution of domestic CO_{2e} emissions (Long, Yoshida, Fang, Zhang & Dhondt, 2019; Hargreaves, Preston, White & Thumim, 2013). In this context, we categorized these sources in accordance with the EN ISO 14064-1 standard. Thus, direct emissions, indirect emissions, and other indirect emissions are included in the content of the study. At this point, as the products consumed or purchased by the households for each part would be varied and would be difficult to identify through a survey; we excluded upstream and downstream emissions from furnishing, equipment/device use, housing, food, clothing, and services such as entertainment, education, and health. Furthermore, the literature on carbon footprint was not adequate to calculate Turkey's total household emissions. We formed questions which contain socio-cultural parameters and then carried out the survey to cover the entire city of Ankara (capital city of Turkey), including urban and rural regions. The survey consists of two parts. The first part includes the questions aimed at obtaining general information and determining the socio-cultural level of the household. In this part, the number of households, their age, and education levels were queried. Moreover, individuals' jobs with their income were also questioned. In the second part, there are questions about the sources of emissions and the factors affecting them, which we considered significant. For example, heating, an important household emission source, could be varying according to the house properties and conditions. Therefore, in the second part, questions about the size, facades, type, and age of houses were included. Furthermore, the types of energy sources used for heating, hot water supply, and cooking were queried. After all, we aimed to reach consumption data in order to calculate the total household emissions. However, as expected, people did not know the quantity of fuel, electricity, water, etc. consumed in a month. At this point, we obtained the average monthly bills of the consumers. Then we determined the household consumption data by dividing the bill total to the current unit price. On the other hand, fuel consumption was identified by questions about the number of cars belonging to the household, the fuel types of the cars, and the annual distances made with these cars. Finally, it was questioned whether the households separated domestic waste and how often they threw it out. Households in Ankara are allocated into five income groups; rich, upper-middle, middle, lower-middle, poor. For this classification, current income level research was made for Ankara (Endeksa, 2020). Survey research was carried out in 25 districts of Ankara.

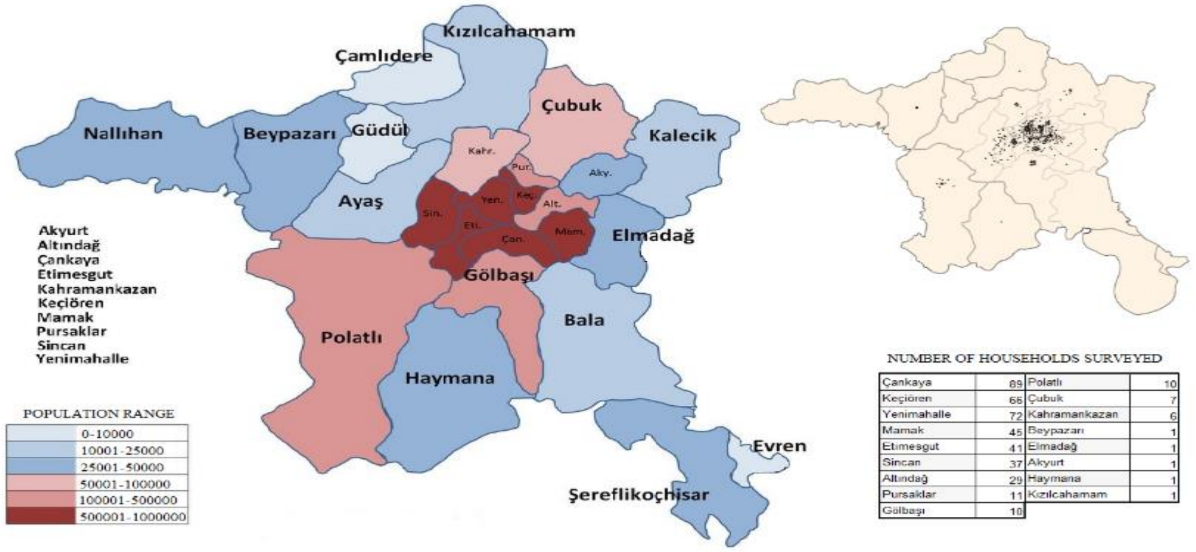

Figure 1. The distribution maps of population density and survey conducted

The total number of surveys according to the district populations of Ankara was distributed according to the stratified sampling method. The numerical representation of the surveys is shown in Figure 1 at the bottom right. The distribution of the surveys by addresses is shown in Figure 1 at the top right. As can be seen, the population density map of Ankara and the survey distribution map are compatible. The surveys conducted in each district were carried out with the simple random sampling method after stratifying according to the population. Then a survey is sent to the relevant households according to the population of the district where the research is conducted. The households were surveyed to ask questions about their socio-cultural level and resources for calculating GHG emissions, respectively. According to the results of the surveys, GHG emissions are calculated and the relationship between the emissions and the socio-cultural level was examined conforming to the statistical methods. Besides the survey research, we searched for the Gini Coefficient for Turkey. As it is known, the Gini coefficient, a widespread measure of income inequality, is a useful indicator for climate change. According to the data (Mi, Zheng & Meng, 2020) the disparity in GHG emissions could be diminished synchronously by increasing the incomes of the poor and changing the lifestyles of the wealthy to decrease the carbon intensity of their consumption patterns. The coefficient takes values between 0 and 1, where higher values correspond to greater inequality. In 2018, the Gini coefficient for Turkey was 0.408 (Turkish Statistical Institute, 2020b). The Environmental Kuznets Curve (EKC) hypothesis tries to explain the relationship between environmental degradation and economic growth, which has been the subject of long-term controversy. The EKC hypothesis states that there is an Inverse-U shaped relationship between environmental degradation and per capita income. A relationship between GHG emissions and per capita income is valid for Turkey (Uzar & Eyuboglu, 2019).

2.2. Calculation of GHG Emission

2.2.1 Heating and Transportation

Greenhouse gas emissions from transportation and heating primarily come from the burning of fossil fuels. According to the EN ISO 14064-1 standard, these emission sources are considered as direct emissions, owned or controlled by a household. In general, emissions of each greenhouse gas from the sources are calculated by multiplying fuel consumption by the corresponding emission factor. In the study, the IPCC 2006 Tier 1 method was applied to calculate direct emissions (Mi, Zheng & Meng, 2020). In the Tier 1 method, emissions of CO_2, CH_4 and N_2O are calculated by multiplying the amount of fuel consumed and the emission factor (IPCC, 2006). The following equation is used:

$$\mathrm{Emissions}_{\mathrm{GHG\,,fuel}} = \text{Fuel Consumption x Emission Factor}_{\mathrm{GHG,fuel}} \quad (1)$$

where;
Emissions $_{\mathrm{GHG\ fuel}}$ is emissions of a given GHG by type of fuel (kg GHG),
Fuel Consumption is amount of fuel combusted (TJ),

Emission Factor $_{\mathrm{GHG\ fuel}}$ is default emission factor of a given GHG by type of fuel (kg gas/TJ).

For CO_2, it includes the carbon oxidation factor, assumed to be 1.
Moreover, CO_2, CH_4, N_2O and other gases are converted to tons CO_{2e} by using the last updated global warming potential values. To calculate the total emissions by gas from the source, the emissions as calculated in Equation 2 are summed over all fuels: (IPCC, 2006)

$$\mathrm{Emissions}_{\mathrm{GHG}} = \sum\nolimits_{\mathrm{fuels}} \mathrm{Emissions}_{\mathrm{GHG,fuel}}$$

2.2.2 Electricity

Emissions from electricity consumption occur where electricity is generated (EN ISO 14064-1, 2019). The amount of CO_2 emissions resulting from fossil fuels in electric power generation varies depending on the type of fossil fuel. A significant portion of the greenhouse gas emissions in Turkey stem from electricity generation (Özcan & Öztürk, 2015). We preferred Tier 2 for electricity emissions. In the Tier 2 approach, default emission factors (Tier 1) are replaced by country-specific emission factors. There are some grid electricity emission factors for countries documented in some international publications. When analysing data for Turkey, we found big differences, up to 50%, between values. This would cause inconsistency. Therefore, we used emission factors from our previous study for this paper (Yatarkalkmaz & Özdemir, 2019). Electricity emission factors were developed using country-specific data such as the carbon content of the fossil fuels used in national electricity production, the quality of the fossil fuels, and the state of technological development. Equation 3 is used to calculate electric emission factor.

$$\mathrm{Emissions}_{\mathrm{Electricity}} = \text{Electricity consumption (kwh) x Emission Factor}_{(\frac{\mathrm{kgCO2}}{\mathrm{kwh}})} \quad (2)$$

where;

Emissions $_{\mathrm{Electricity}}$ is emissions of a given GHG (kg GHG),
Electricity consumption is amount of electricity (kwh),
Emission Factor $_{\mathrm{Electricity}}$ is country-specific emission factor of a given GHG (kg CO_2 /kwh).

2.2.3 Domestic Waste and Water Consumption

An effective greenhouse gas inventory requires detailed understanding of a household's greenhouse gas emissions. Therefore, we have focused on other indirect emissions as well as direct emissions and energy-indirect emissions. At this point, we delved into waste volume and water consumption because they have a significant effect on household GHG emissions. Different types of waste generate various quantities of greenhouse gases. Depending on the type of waste, CO_2 is formed from the degradation of fossil fuels while CH_4 is formed from the decomposition of biogenic materials in landfill (GHG Protocol, 2001). We used the average-data method to calculate emissions from domestic waste. This method involves estimating emissions based on total waste according to the landfill method and using average emission factors (GHG Protocol, 2021). Equation 3 is used to calculate waste generated in housing.

$$\text{Emissions}_{\text{Waste}} = \text{Waste generated (kg) x Emission Factor}_{(\frac{\text{kgCO2e}}{\text{tonne}})} \tag{3}$$

where;
Emission $_{\text{Waste}}$ = Emissions of a given GHG by type of waste (kg GHG),
Waste $_{\text{Generated}}$ = Amount of waste (kg)
Emission factor = Default emission factor of a given GHG by waste ($kgCO_{2\text{-}Eq}$/tonne).

Equation 4 is used to calculate emissions from water consumption:

$$\text{Emissions}_{\text{Waste}} = \text{Water consumed (kg) x Emission Factor}_{(\frac{\text{kgCO2e}}{\text{tonne}})} \tag{4}$$

2.3. Statistical Analysis

To apply ANOVA analysis, data must be normally distributed in each of the groups. This assumption is checked before statistical analysis. The following hypotheses are used for this purpose.
Normality assumption hypothesis group 1:
H_0: In the poor income group, GHG emissions are normally distributed.
H_1: In the poor income group, GHG emissions are not normally distributed.

Normality assumption hypothesis group 2:
H_0: In the lower-middle income group, GHG emissions are normally distributed.
H_1: In the lower-middle income group, GHG emissions are not normally distributed.

Normality assumption hypothesis group 3:
H_0: In the middle income group, GHG emissions are normally distributed.
H_1: In the middle income group, GHG emissions are not normally distributed.

Normality assumption hypothesis group 4:
H_0: In the upper-middle income group, GHG emissions are normally distributed.
H_1: In the upper-middle income group, GHG emissions are not normally distributed.

Normality assumption hypothesis group 5:
H_0: In the rich income group, GHG emissions are normally distributed.
H_1: In the rich income group, GHG emissions are not normally distributed.

After obtaining all p values, since the smallest p value is greater than 0.05, the null hypotheses for normality is accepted for each income group. After confirming that the depended variable representing greenhouse gas emissions showed a normal distribution, whether the mean consumption differs between the average emissions between 5 income groups was investigated. For this purpose, one-way analysis of variance (ANOVA) was used to reveal any significant differences between income groups. During these analysis, the SPSS 22.0 program was used. The following hypotheses were used for the ANOVA analysis:

H_0: There is no difference in average emissions between income groups.
H_1: At least two of the average emissions between income groups differ.

These hypotheses can also be expressed mathematically as:
H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$
H_1: At least one $\mu_k \neq \mu_l$ (k≠l and k, l=1,2,3,4,5)

The ANOVA model used is given below.
$y_{ij} = \mu + \mu_i + \epsilon_{ij}$ i=1,2,3,4,5 (income levels) (5)

This notation represents the independent one-way ANOVA analysis on 5 income level group. While applying separate one-way ANOVA analysis, we have assumed that there is no interaction between explanatory variables and we have just focused on one categorical variable to explain the dependent variable, ignoring all other explanatory categorical variables at each step. In general, the ANOVA table for the one-way case is indicated in Table 1:

Table 1. ANOVA table for the one-way case

Source	Sum of Squares	df	MS	F
Factor	$SS_F = J\sum(\bar{y_i} - \bar{y}_{\dots})^2$	I-1	$MSF = SS_F/(I-1)$	MSF/MSE
Residual	$SS_E = \sum\sum(y_{ij} - \bar{y_i}_{\dots})^2$	I(J-1)	$MSE = SS_E/(I(J-1))$	
Corr. Total	$SST = \sum\sum(y_{ij} - \bar{y}_{\dots})^2$	IJ-1		

3. Results And Discussion

3.1. Data Analysis

447 people participated in the survey. Data was examined according to normal distribution analysis. In the study, since the relationship between the GHG emission of the household and the socio-cultural level was examined, the average of the survey results was calculated on household basis. When the results of the first part of the 447 questionnaires were analysed, there were 1413 people in these households.

The most important assumption of ANOVA is that the dependent variable is normally distributed in each subgroup of the explanatory variable. The explanatory variable is a 5-level categorical variable. Income group with 5 levels was used as the explanatory variable. From this point of view, analysis of normality was performed in each of the 5 groups. Since p>0.05 was found in all 5 tests, the H_0 hypothesis was accepted. That is, the dependent variable was normally distributed in the subgroup (j=1,2,3,4,5). Normal distribution test results for p values are 0.1783, 0.3153, 0.4855, 0.5458, 0.6581, respectively, from poor to rich according to the income groups.

Table 2. The ANOVA test results

Source of variance	SS	df	MS	F	p-value
Between groups	4E+10	4	9E+09	1384	<0.001
In groups	1E+10	2135	6E+06		
Total	5E+10	2139			

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$

H_1: At least one $\mu_k \neq \mu_l$ (k≠l and k, l=1,2,3,4,5)

The consistency of the remaining data within itself was checked. According to the ANOVA test results (Table 2), the p value between groups was found very closed to zero. Since the p-value was less than 0.05, the H_0 hypothesis was rejected.

At least one of the groups has been inferenced to have different mean at the %0.05 significance level.

3.2 Carbon Footprint

We calculated the household carbon footprints of five groups based on their income distributions. When the emissions were examined, it was found that the emissions were high for upper income groups. Thereafter, household emission averages (tCO_{2e}) were determined as 5.07 for the poor group, 4.82 for the lower-middle group, 5.96 for the middle group, 7.96 for the upper-middle group, and 9.49 for the rich group. Contrary to expectations, the emissions of the lower income group were not the lowest. A closer look would reveal that at lower income level, the lowest emissions were observed (Figure 2). This decrease has been caused by the heavy use of non-clean fossil fuels (coal and fuel oil). At a poor level, 37.5% of the respondents get heated using non-clean fossil fuels. While this rate is 11% in the lower middle level, it has decreased to 0.5% in the middle. No non-clean fossil fuel use has been found in the upper middle and rich levels.

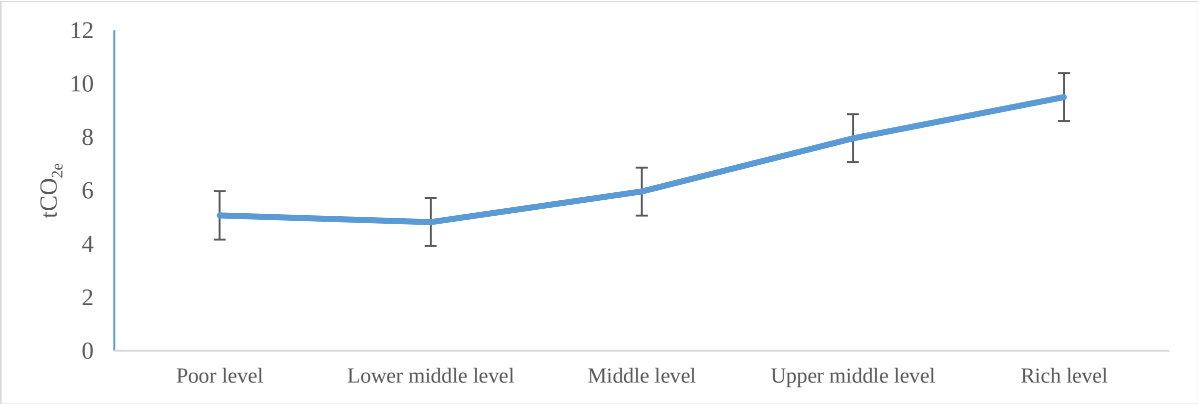

Figure 2. Average emissions (tCO_{2e}) according to income levels.

Whereas emissions have considerably increased between the lower middle income and rich income levels.

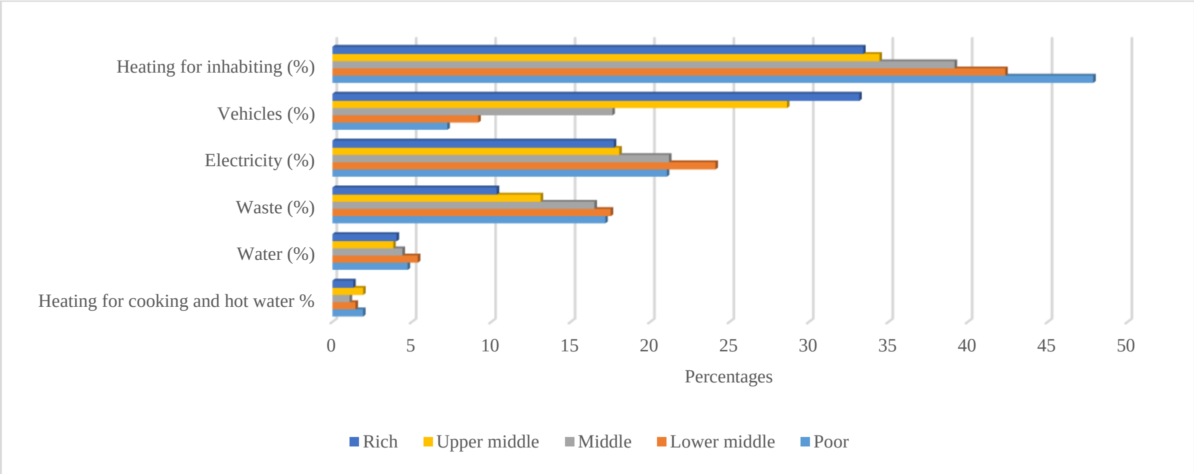

Figure 3. Percentages of household emissions sources

Heating accounts for 39% of emissions (heating for living + hot water supply and cooking) in the middle level. This is because the largest share of household emissions for all income levels belongs to heating. While this share is higher in the poor level (47.385%), it decreases by 33% in the rich level due to low carbon fuel use and vehicle emissions occupying an important place. This shows us the importance of the facade of houses and insulation. It can be said that, in total, 61% of emissions are direct emissions. On the other hand, 20% of emissions come from electricity use, which is an energy-indirect emission. In addition, 19% of emissions are from waste disposal and water supply, which is an indirect emission (Figure 3).

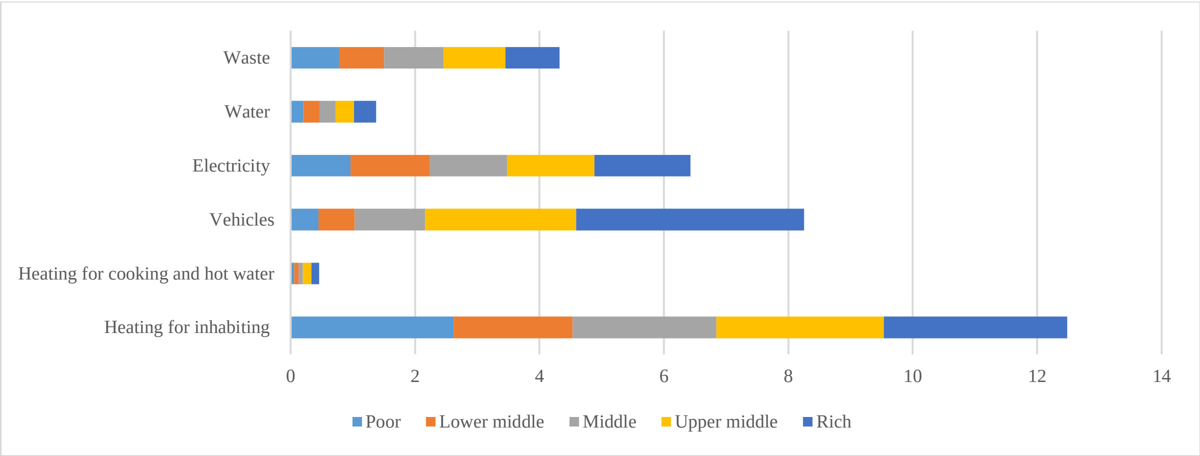

Figure 4. Average values (tCO_{2e}) of household emission sources

It is seen in Figure 4 that emissions from heating for habitation take the larger share of household carbon footprints, independent of income level. The city of Ankara is located in a continental climate. While the average temperature is 24 ºC in the summer months, it decreases to -1 ºC in the winter months (Climate Data, 2022). So, heating of the buildings in Ankara comes with a huge carbon footprint. We have stated factors affecting emissions from heating, that is the facade and the condition of the house. As can be predicted, much, little or no exposure to the sun will affect the amount of energy needed for heating. Accordingly, the least energy need for heating was seen in houses facing south, and the highest energy need was seen in houses facing north (Figure 5). Emissions due to occupied heating were highest in north and northwest facing houses. Values (kg CO_{2e}/per m^2) were found to be 21.91 and 19.01, respectively. West and south-facing houses had the lowest emissions, with 17.45 and 17.36 emissions, respectively.

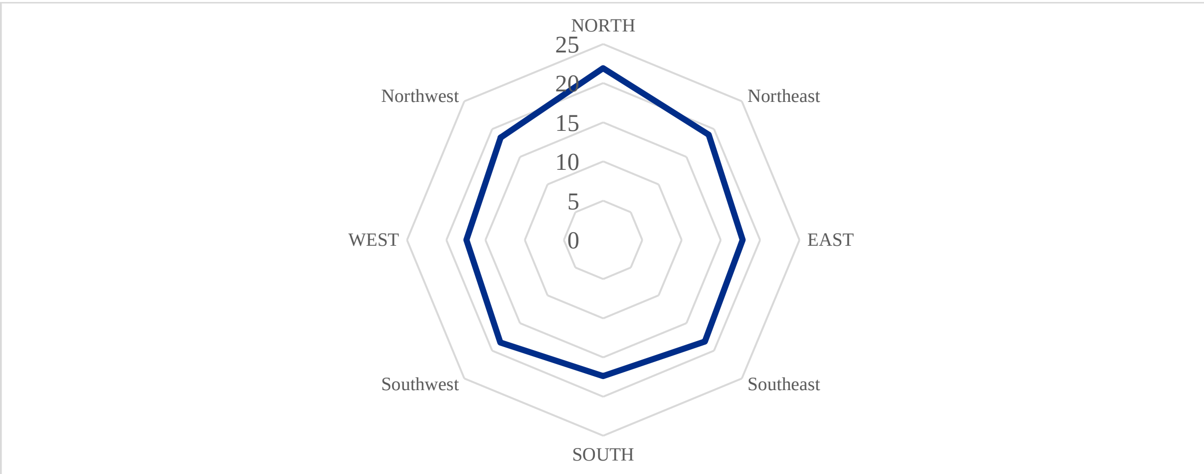

Figure 5. Facade and average heating emissions (kg CO_{2e}/per m^2) of houses using natural gas

Another factor, when we compare the age of the houses with the emissions from heating (Figure 6), the emission values of the older houses come out higher. In the research, 44% of the houses were between 0–10 years old, and the lowest average heating emission value (kg CO_{2e}/per m^2) was found to be 17.14 in this age group. While the average energy (Tj/kg) required for heating houses aged 0–10 year was 0.19, this value was determined as 0.30 for houses aged 40–50 years. It is obvious that as the ages of the houses increase, so does the energy required to heat the building.

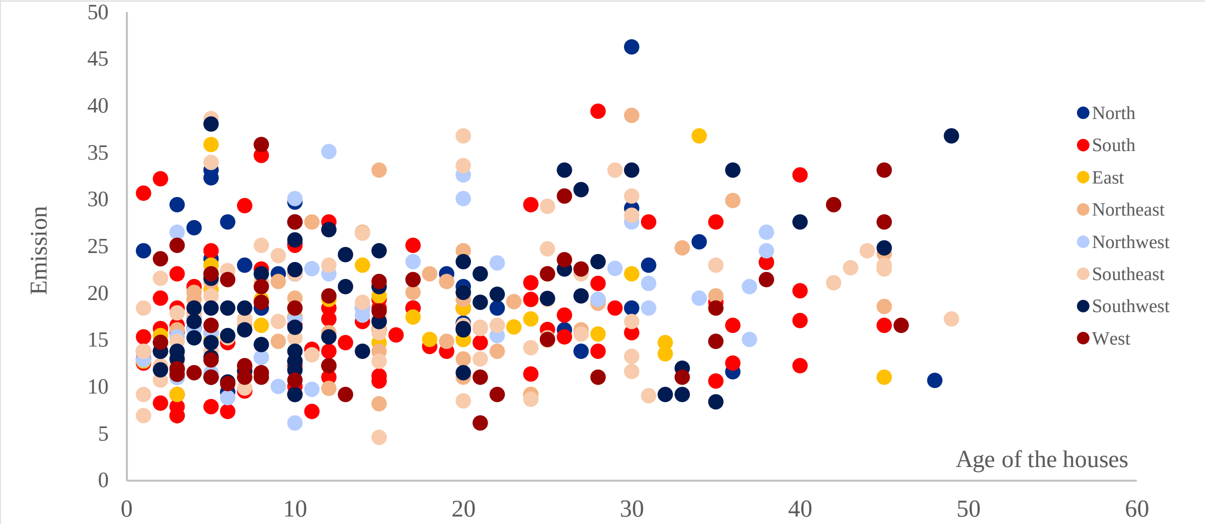

Figure 6. House age - average heating emissions (kg CO_{2e}/per m^2) of houses using natural gas

Almost every household's emissions have been increased from a poor level to a rich level. There have been notable increases in two sources: vehicle use and meeting hot water and cooking needs. Because electricity is commonly used instead of natural gas for cooking and hot water in low-income households, emissions from this source were found to be lower than in higher-income households. When emissions from private vehicles are examined closely, not only the number of vehicles but also the distance travelled by these vehicles show a big difference (Figure 7). Vehicle owners in low-income areas travel an average of 3000 km per year. This figure was 19600 km at the rich level. It was seen that the use of vehicles has made a significant contribution to these increases. It was discovered that using private vehicles for transportation was very rare at the poor level (only 25% of respondents have their own vehicle). At the richest level (with the highest emissions), 95.45% of respondents own a vehicle, with a second owned by 25.75%.

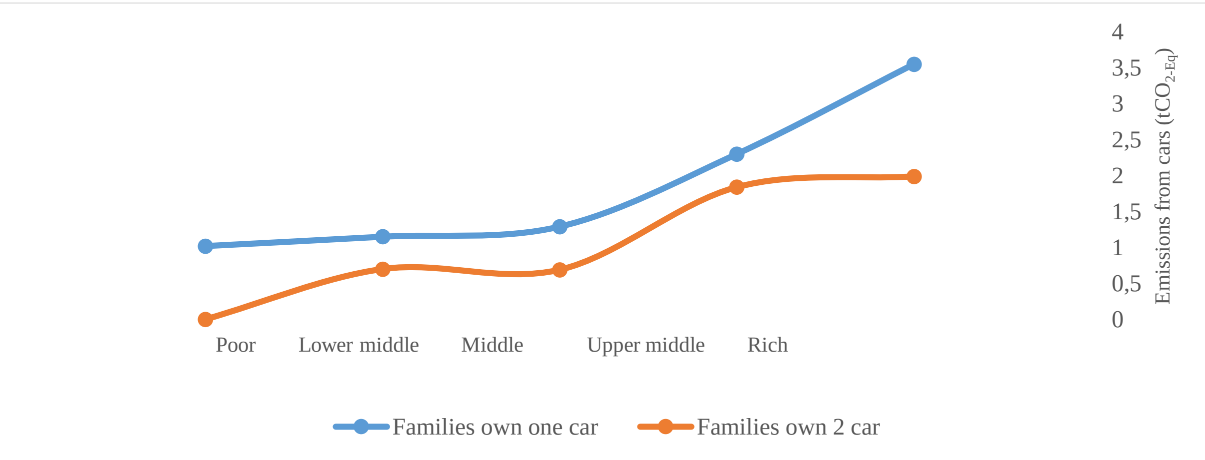

Figure 7. House age - average heating emissions (kg CO_{2e}/per m^2) of houses using natural gas

3.3 Per Capita Carbon Footprint

One of the important parameters according to per capita carbon footprint is how many people the family consists of. As expected, when the family population is asymmetric across income levels, the per capita carbon footprint could be higher or lower than it needs to be. Therefore, it is important to determine the family population so that the survey results are not misleading. This situation did not affect per capita emissions as the average number of people per family varied between 3.5 and 3.7 (Figure 8) among income groups.

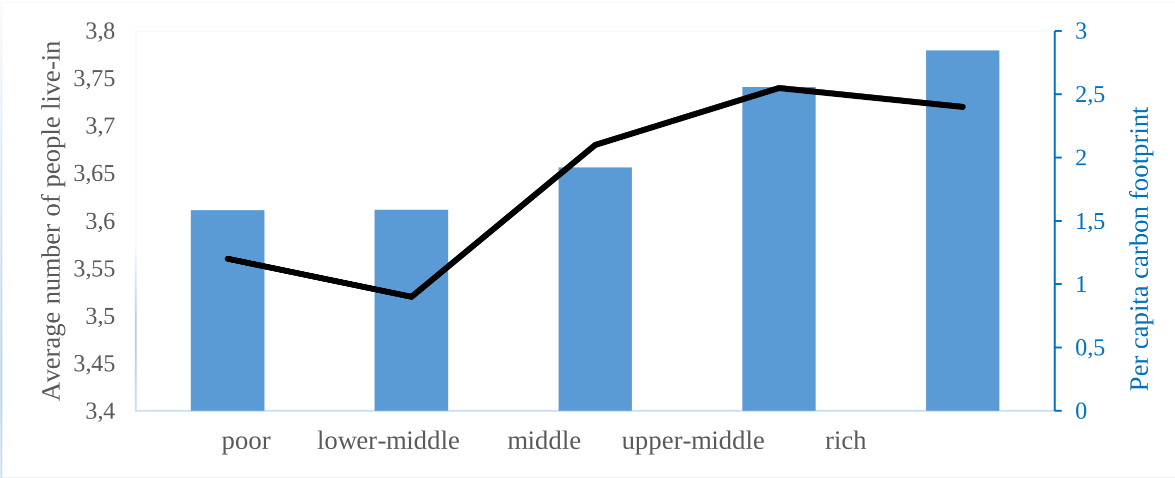

Figure 8. Per capita carbon footprint tCO_{2e} - average family population

The difference between the income groups was found to be high (up to almost 10 times). While the per capita carbon footprint (ton/CO_{2e}) in the poor level was 1.585, it was 2.104 in the upper-middle level, 1.922 in the middle level and 2.848 in the rich level. The ability to use more energy with an increasing income level reveals that there is a direct proportion between per capita emissions and income level. Although the per capita emissions in the middle group were found to be lower than the lower middle level, the values of the two levels were found to be close to each other. This decrease can be explained by the distribution of the survey data, its inherent uncertainty and other environmental factors. As a result (Figure 9), it has been clearly determined that the higher the income, the higher the per capita carbon foot print.

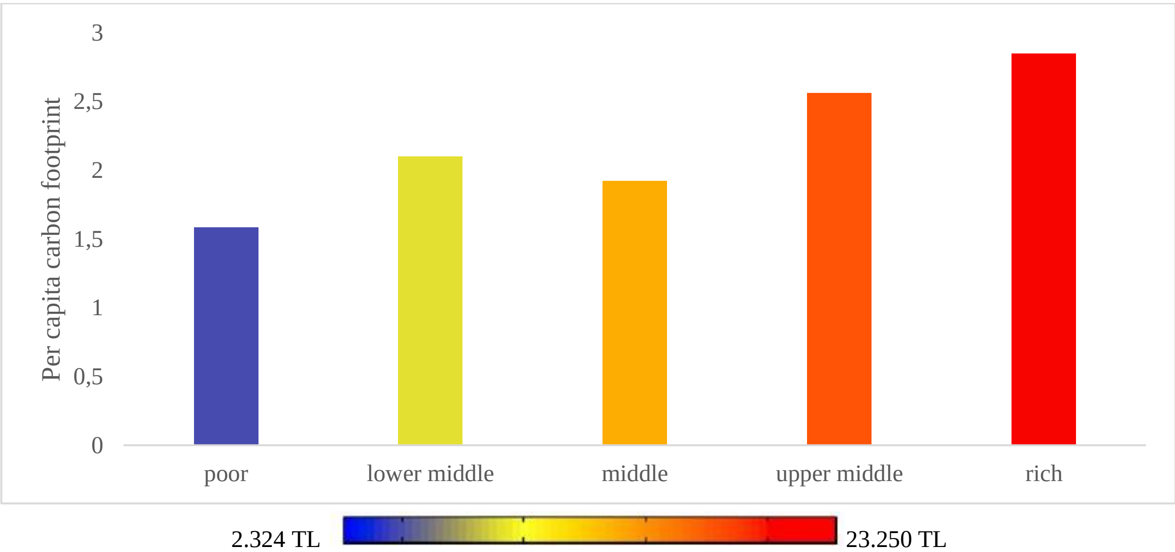

Figure 9. Per capita footprint (tCO_{2e}) according to amount of income

When the emissions related to electricity consumption are examined, a considerable increase (60.41% from poor to rich) has been observed. Grid electricity is being used within the boundaries of Ankara province, where the study was conducted, and all types of electricity are the same (no use of renewable energy). Keeping in mind family populations, which are close to each other, this increase in electricity emissions can be explained by lifestyle. Per capita electricity consumption has increased with the improvement in living conditions and welfare paralleled with industrialization. The fact that families with a higher income have more electrical devices means they increase their electricity consumption and emissions. On the other hand, regardless of their income, families with a high population did not have emissions from electricity consumption. The number of toddlers in the family can explain this situation.

There has been a significant increase (up to 75%) in water consumption at lower income levels. This indicates that water consumption for personal use has increased. As the education level increases, it was seen that water consumption decreases in line with the awareness of individuals caring about the sustainability of natural resources.

Within the scope of the research, the origin of the domestic waste was examined. A study conducted in Turkey looking at the components of municipal solid wastes figured out that kitchen wastes have a significant place with 48.70%. Paper waste constitutes the second place with a rate of 19.10%. Plastic and glass waste are the third and fourth highest components, with 14.80% and 11.50%, respectively (Gökpur, Zıba & Dolaz, 2019). Accordingly, the reason for the high emissions from waste in the higher income group can be explained by the fact that it is related to more food consumption. When we evaluate waste generation and water consumption according to education levels regardless of the amount of income (Figure 10), we can say that the average amount of waste emissions did not differ from each other (low correlation; 0.033 stated in Table 2). In other respects, higher education levels come with lower water consumption. This situation (together with those described above in water consumption) can be explained by the increase in education levels contributing to water awareness.

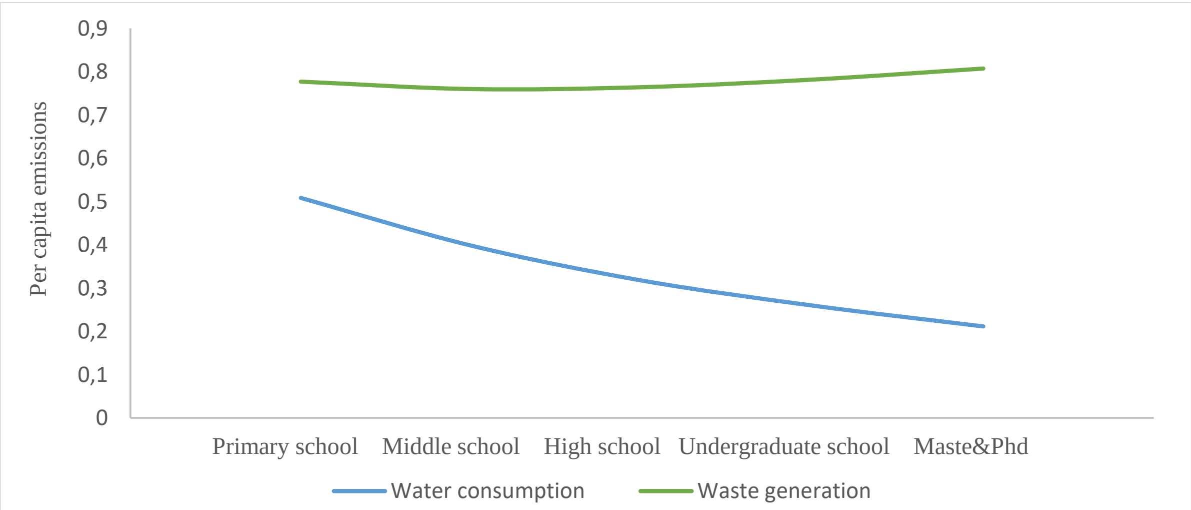

Figure 10. Per capita emissions (tCO_{2e}) from water consumption and waste generation

Another significant factor influencing emissions is whether the family lives in an apartment or a single-family home. While the average emission (tCO_{2e}) of those who live in a single house is 9.973, this number falls to 6.779 for those who live in apartments. The most important factor causing this difference is the heating for the inhabitants. Heating emissions (tCO_{2e}) constituted 2.426 (37.33% of total) for apartment residents and 3.775 (42.54%) for families living in a single house. The largest share of household emissions is sourced from heating. It was determined that as the income level increases, the energy used for heating also increases. Parallel to economic growth, the use of natural gas has scaled up rapidly in recent years. It is used extensively owing to its being a clean resource and ease of use. Natural gas is widely used in the districts where the survey was conducted. Therefore, there can be dramatic results for other regions, especially underdeveloped and rural ones, using non-clean sources. It has been determined that electricity consumption has increased at higher income levels. Lighting and refrigerators account for the majority of Turkey's electricity consumption (gazelektrik.com, 2020). As the amount of income increases, people want to live in larger houses. Big houses with more rooms need more enlightenment.

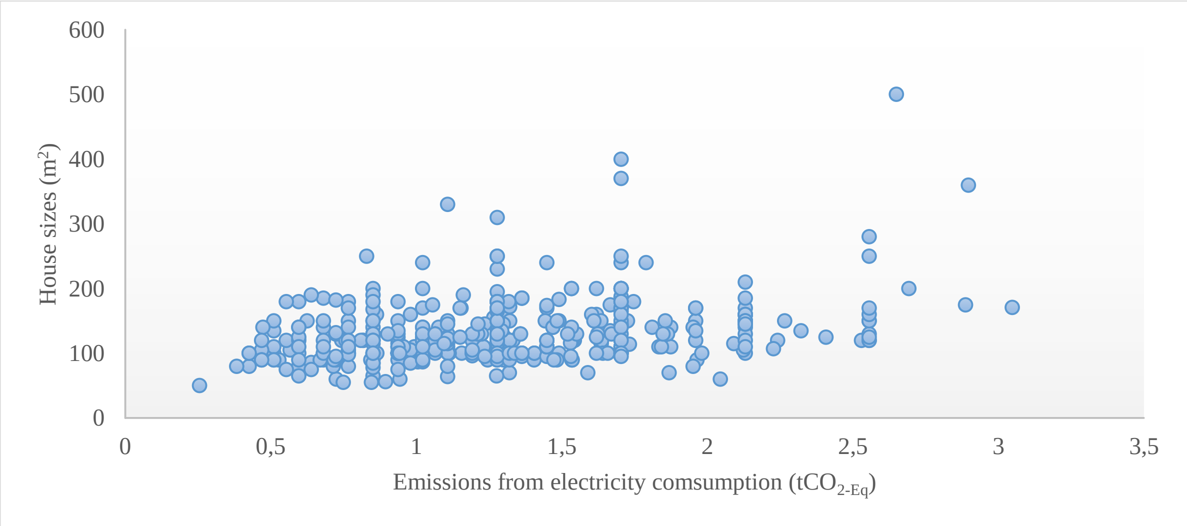

Figure 11. Emissions according to house sizes

Devices that work non-stop due to the constant need for electricity are used more in high-income families as seen in Figure 11. For example, some families may use deep freezers to store more food together with their refrigerator. Television has the second largest place in electricity consumption. In recent years, the number of televisions in families has increased due to the changes in watching habits and the fact that people have more private spaces. This increase is reflected in the amount of electricity-related emissions. Another important source of emissions was seen in vehicle use. As the income group increases, people do not prefer public transportation and prefer to travel in their own personal vehicles. Cars with LPG conversion systems and gasoline-powered cars are mainly used in lower income groups. These cars have lower emission values when compared with diesel cars. Diesel vehicles (lower fuel consumption) are mostly used at higher income levels. Since the prices of diesel vehicles are higher, these cannot be purchased by those with lower income levels. Food generates greenhouse gases while reaching to the plates and then for disposal. Approximately one-third of the food purchased from the market in developed countries is wasted as household waste (Premanandh, 2011). So, consuming as much as needed will reduce emissions from waste generation. The only emission source that decreases with the higher income level is emissions due to water consumption. Increasing income levels affect water consumption in two different ways. One of them is improving the living standards (spending more time outside, using a dishwasher, being able to pay for some cleaning tasks such as dry cleaning, carpet washing, etc.); and the other is conscious use thanks to education. While the emission from water consumption per capita in the poor level was 0.35 tons of CO_{2e}, it was 0.20 tons of CO_{2e} in the rich level. According to a study conducted in Balıkesir, Turkey, it has been observed that as the income level decreases, water consumption increases (Aliağaoğlu & Mirioğlu, 2019).

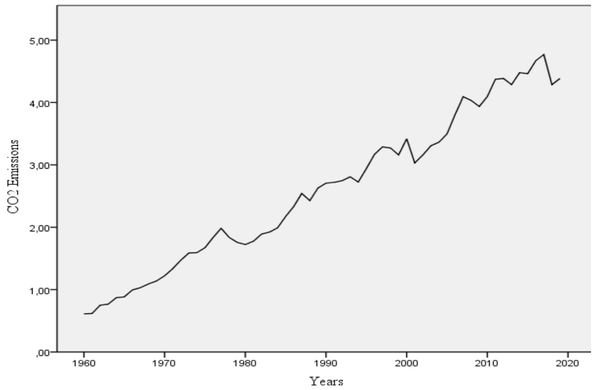

Figure 12. CO_2 emissions (ton per capita) of Turkey between 1960-2020 (World Bank Data, 2020)

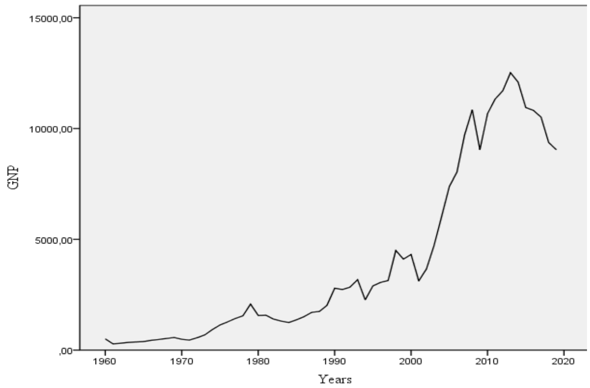

Figure 13. Gross national product ($) of Turkey between 1960-2020 (World Bank Data, 2020)

Turkeys' last 60 years' development (Figure 12 and Figure 13) has meant that more growth and more enrichment comes with more energy use. Need for energy has continuously gone up due to the increasing urban population, developing technology, high level of industrialization and the rise in the information sector. A large part of the energy obtained from the use of fossil fuels has negatively affected the environment. We compared our result that economic growth affects positively the level of CO_{2e} emissions with the previous Environmental Kuznets Curve (EKC) hypotheses studied for Turkey. According to papers, with the increasing income level, a positive and significant role of energy consumption on CO_{2e} emissions has figured in Turkey (Lebe, 2016; Kemal & Hizarci, 2017; Dam, Karakaya & Bulut, 2014; Turkish Statistical Institute, 2020c). A study done by Turkish Statistical Institute (TUIK) shows that annual emission of a person in Turkey in 2018 is calculated as 6.4 tons CO_{2e} (Turkish Statistical Institute, 2020d).

4. Conclusion

In this paper parameters on household emissions are studied. By reducing the use of fossil fuels in energy needs, fore and most household GHG emissions can be reduced. For this purpose, much attention can be paid to social policies.

In this context, public transportation can be encouraged and energy management of buildings may be supported. Policies that neglect fuel efficiency considerations by reducing the fuel consumption of vehicles are no longer sustainable. Also some obligations could be adopted to electricity generating companies such as certain proportion of total production, given to grid, should be supplied from renewable sources rather than using fossil fuels. That's because these plants provide consistent electricity over long periods of time and are relatively inexpensive to construct. Carbon-based fuels, on the other hand, emit large amounts of CO_{2e}, which contributes to climate change. Other pollutants, such as sulphur and nitrogen oxides, are produced by these plants, resulting in acid rain. Giving more importance to recycling will have a huge recovery on amount of emissions. As we gain more technical and management competencies, we can build an increased capacity to use cycles in the end to end material production. Recycled resources will replace newly mined or manufactured materials in an increasing number of new products. These energy-intensive recycling procedures will have a decreasing impact on greenhouse gas emissions as our economy decarbonizes. To make this happen, we'll need technology, organizational capacity, human innovation, and political will. Additional government regulation, as well as financial incentives and disincentives, are needed to hardwire sustainability management into organizational activity in order to steer a large economy away from behaviours that degrade environmental quality. Besides it would be more accurate to say that, consuming as much as needed will strengthen the efforts done against climate change.

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