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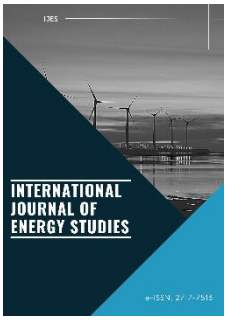

Research Article

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The impact of remote working on Türkiye's energy consumption and greenhouse gas emissions: Learning from the experiences of Covid-19 era

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Highlights

- Covid-19 outbreak provided an opportunity to measure the impact of remote working on energy consumption
- Remote working reduced energy consumption and GHG emissions in Türkiye.
- Türkiye should make use of remote working as an energy efficiency and climate change policy.

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ABSTRACT

Remote working emerged as an important alternative to office working. Türkiye put in force this practice in certain months of 2020 and 2021 during the Covid-19 pandemic that led to serious decline in energy consumption in this period. The aim of this study is to find out the contribution of remote working on reducing fuel consumption in passenger car and electricity demand in case the country's whole potential is used. This article also analyzes the effect of remote working practices on reducing greenhouse gas emissions. Results show that the country can reduce 1.8 million tons of oil equivalent of its' energy consumption which corresponds to 1.66% of the total energy consumption and USD 1.4 billion with 2019 prices. With a total of 7.73 million tons CO_2 eq. emissions mitigation, Türkiye will be able to reduce its transport and electricity related emissions by 3.2% and 3.79%, respectively. Therefore, considering that Türkiye is a net fossil fuel importer country and a party to the Paris Agreement, it is necessary to promote remote working as a complementary energy efficiency and climate change policy. It is beneficial to consider the effect of remote working on energy consumption, including natural gas, during energy crises.

Keywords: Remote working, Fuel and electricity consumption, Emissions mitigation

1. INTRODUCTION

During the Covid-19 pandemic, many countries put in force strict lockdown measures. Many facilities and businesses such as schools, restaurants and fitness centers were shut down where people could have intensive face-to-face interaction. The spread of the outbreak and the lockdown measures affected human mobility, energy consumption and economic activities substantially. According to the International Energy Agency (IEA), the global energy demand declined by 3.8% in the first quarter of 2020 compared to 2019 [29]. Besides OPEC-Russia disagreement on the production amount caused the decline of the crude oil price significantly. In addition, there was a decline in electricity demand by 2.5% [29]. Despite all its negative economic and social effects, the Covid-19 pandemic has revealed important opportunities for the environmental sustainability [31]. Since energy is an emission-intensive sector, the decline in energy consumption and industrial production caused reduction in greenhouse gas emissions (GHG) and atmospheric pollutants. The outbreak has also shown how certain behaviors and practices can change under special circumstances instantly [32]. This transformation has contributed to the widespread implementation of new ways of doing business such as flexible and remote working. During Covid-19 outbreak, remote working has been applied globally out of necessity. This process provided an excellent opportunity to measure the impact of remote working on different areas and the effectiveness of this work arrangement.

Türkiye, as an energy import dependent country, any measure and policy to reduce energy consumption without compromising from the economic output is useful. This study wants to reveal whether remote working can be one of these policies. The main research question of this study is as follows: How can remote working impact energy consumption and GHG emissions in the context of passenger car driving and electricity in Türkiye? This study aims to reveal how remote working can impact Türkiye's energy consumption in passenger car fuel and electricity in a scenario where the country utilizes her full remote working potential. In addition, calculating the amount of reduction in GHG emissions due to a decline in energy consumption will be investigated. This study first reviews the literature. Next, the study describes method and materials and afterwards presents the findings. The discussion section focuses on the drivers for the permanent implementation of remote working. This section is followed by the conclusion.

2. CONCEPT OF REMOTE WORKING AND LITERATURE REVIEW

With the emergence of modern factories and workplaces, the Industrial Revolution was the starting point of the working life as known today [43]. Typically, workdays are from Monday to Friday from 9 AM to 5 PM or 6 PM [11]. The workplace has been the place where the work was performed and the place to go to perform the tasks [11]. With the shift of economies from industry to the service sector and the development of the information and communications technologies (ICT), the situation of going to the workplace has begun to change [11]. For example now, more than 50% of the employees in the ICT sector work remotely in the UK [7].

According to Chartered Institute of Personnel and Development [7], flexible working is a working method that provides a certain level of flexibility in the duration, location and timing of a work performed by an employee. As opposed to the traditional 9 to 5 working, with flexible working employees can have more control over their working arrangement [11]. By having the locational flexibility, employees can work at the different places including in offices, homes, co-working spaces, cafes and even trains [11]. Remote working (teleworking, e-working) is a type of flexible working. It is a working method in which work is carried out partially or completely away from the workplace using technological communication tools [21, 28, 31]. It is also not possible to apply remote working practices in certain areas such as agriculture, forestry, construction [32]. However, the potential is very high in some sectors including information and communication technologies, scientific-technical activities, education and insurance [7, 32]. Each country has a different remote working potential. As illustrated in Figure 1, according to Dingel & Neiman [12], Türkiye's remote working potential is 23% of the total jobs. Benefiting from this study, Crow & Millot [10] takes Türkiye's remote working potential as 23% as well. This can be confirmed by the EBRD [14], which predicts Türkiye's remote working potential between 20-25% of the total jobs.

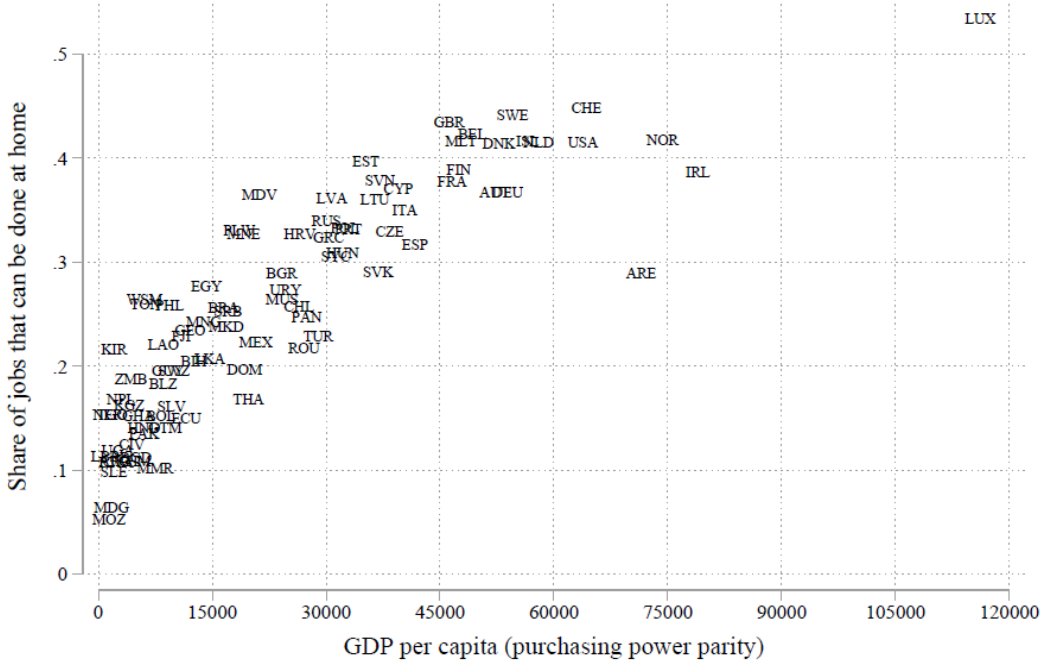

Figure 1. The share of jobs that can be done from home vs. GDP per capita

Source: Dingel & Neiman [12]

There are several studies which assess the impact of remote working, conducted before Covid-19 pandemic. Regarding the effect of flexible working on fuel consumption, Ott et al. [36] researched the implantation of flexible working in a government facility in the USA by providing the employees two alternative working schedules. Their results suggest that flexi-time resulted in 5.8% fuel saving. Besides shorter commute, it has allowed for a better work-life balance. Crow and Millot [10] analyzed the global impact of flexible working on fuel consumption and CO_2 emissions by implementing a scenario where people work from home once a week. According to the results, the savings from remote working are four times higher than the increase in energy consumption in homes. Additionally, one day remote working has the potential to reduce the global oil consumption in road related passenger transport by 1% annually (11.9 million ton oil equivalent-mtoe). After taking into account the increase in energy demand by the households, working from home for 1 day a week can provide an annual saving of 8.5 mtoe and a reduction of 24 million tons CO_2 emissions. Lambrecht et al. [32] focused on the impact of home-office working on reducing transport related GHG emissions in Germany. Their results suggest that Germany can reduce up to 5.8 mt CO_2 emissions. Fuhr & Pociask [22] researched how the widespread provision of internet services and consequently the increase in remote working practices can reduce GHG emissions in the USA. At the time of the study, remote working was applied to 10% of the

employed. According to the results, increasing remote working to 20% has the potential to save USD 96.5 billion and reduce 588.2 tons of GHG emissions in the next 10 years in the USA.

In the literature there are studies assessing the impact of Covid-19 pandemic on oil price, consumption and production. Camp et al. [6] researched the impact of the Covid-19 outbreak on the price of crude oil and refined petroleum products. They found that from January to April 2020 the price of oil has declined due to fall in demand and OPEC-Russia disagreement on production and the price began to recover from April to July with ending of the dispute and easing in lockdown measures. Aydin and Ari [3] analyzed how the negative economic impacts of Covid-19 on non-recoverable sectors (e.g. tourism, transportation) can be compensated by the fall of the oil price in Türkiye considering it's high oil dependency. They estimated that the decline of the GDP by 1.16% due to the outbreak can be compensated by the decline of oil imports and under different scenarios, where the price of oil declines by 25% and 50% can increase the GDP by 0.72% and 1.56% respectively. Gürbüz et al. [25] looked at the impact of Covid-19 outbreak and especially the lockdown measures on Türkiye's energy consumption and GHG emissions in road transportation sector. According to their findings; the energy consumption, GHG emissions and their social cost values have decreased in April and May 2020 in Türkiye. Coutellier et al. [9] investigated the impact of homeworking on energy consumption during the curfews in the UK by focusing on transport related fuel, electricity and natural gas consumption. According to the results, during the period of the curfew, weekly electricity consumption increased by 10.4% on average. However, there has been a significant decline in emissions per household due to the change in transportation. Emissions decreased by 33% and they offset the increase in emissions from electricity in the same period.

Considering the importance of social distancing measures during Covid-19 pandemic, Dingel and Neiman [12] researched the rate of jobs that can be done at home for 86 countries. Additionally, the study looked at the relation between wage level and share of home workable jobs. According to the results, the rise in income increases the rate of jobs that can be done at home. As a consequence, there are more home workable jobs in high income countries compared to the developing ones. Results also show that 37% of jobs in USA are home workable which represent 46% of all wages in the country. In addition, 23% of the jobs in Türkiye can be done from home.

3. METHOD AND MATERIALS

The scope of the study covers the effect of remote working on fuel consumption in passenger cars (gasoline, diesel and LPG) and electricity consumption. Therefore, other oil products and energy sources are beyond the scope of this study. In addition, electric-hybrid cars were not included in the study due to their low share (less than 1%) in the total number of cars. While calculating the potential effect of remote working on car fuel and electricity consumption, Covid-19 period of 2020 and 2021 was taken as the basis. However, when calculating the concrete output of this potential (such as fuel saving amount or GHG emission mitigation), data for the year 2019, which did not experience extraordinary events such as pandemics or global energy crisis, was used.

Table 1. Data used in the study

Data	Unit	Source
Workplace mobility	Workplace mobility index	Google [23]
Residential mobility	Residential mobility index	Google [23]
Car driving	Car driving index	Apple [2]
Cars by fuel type	Number of cars	TURKSTAT [48]
Fuel consumption per 100 km	Liters	Otostil [35]
Cost of fuel type	Turkish Lira	EMRA [16], [17]
Annual Turkish Lira to USD exchange rate	USD	OECD [34]
CO_2 Emissions	Kg per gallon	EPA [18]
CH_4 Emissions	Kg per gallon	EPA [18]
N_2O Emissions	Kg per gallon	EPA [18]
GWP of CH_4	CO_2e	IPCC [30]
GWP of N_2O	CO_2e	IPCC [30]
Working days	Number of working days	Hakedis [27]
Remote working potential	Share of jobs that can be done at home	Dingel & Neiman [12]
Türkiye's public electricity and heat production emissions	Kilo tons	UNFCCC [49]
Türkiye's road transportation emissions	Kilo tons	UNFCCC [49]
Türkiye's national emissions	Million tons of CO_2e	TURKSTAT [47]

Türkiye's hourly electricity consumption	MWh	EPIAS [19]
Electricity cost (energy and network cost) in the price	Percentage	EMRA [15]
Price of electricity	Turkish Lira/kWh	TURKSTAT [46]
Türkiye's total energy consumption	Thousand toe	MENR [33]

In order to determine the effect of workplace mobility on car driving, the correlation between the daily car driving index published by Apple and the daily workplace mobility data published by Google in solely working days (excluding non-working and exceptional days) from February 17th 2020 to 31st December 2021 was examined. Apple and Google began to publish mobility data of their users collected from smart phones to help policy makers and scientists make use of real-time data to prevent the spread of the virus [23]. Google collects mobility data from the users which turned on their Location History [24]. The company reports mobility in five categories: Retail and recreation, grocery and pharmacy, parks, transit stations, workplaces and residential [24]. The company set the median values of the dates between 3rd of January and 6th of February 2020 which represent the period where the outbreak has not widely spread [24]. The data tracks how their user's mobility in five categories change compared to the median values of the basis dates [24]. Besides, Apple has a similar approach and set 13th of January 2020 as basis [2]. The company tracks data on three categories: Walking, car driving and public transport [2]. Apple published the relative volume of direction requests in comparison to the basis date [2]. As of April 2022, Apple stopped publishing mobility data publicly and Google does not publish new mobility data since October 15, 2022.

The first Covid-19 case was announced on March 11th, 2020 in Türkiye [45]. As shown in Figure 2, remote working put into force in three periods in the country. Figure 2 also shows workplace mobility in 2020 and 2021. During the periods where flexible working was introduced, there was a decline in workplace mobility. In addition, workplace mobility decreased more sharply in the first period compared to the other the two. It is also worth mentioning that workplace mobility is not only affected by the enforcement of flexible working practices by the government. For example, as shown in Figure 2, the workplace mobility decreased especially in the summer months of 2021, which can be explained by intense annual leave of employees during the summer season.

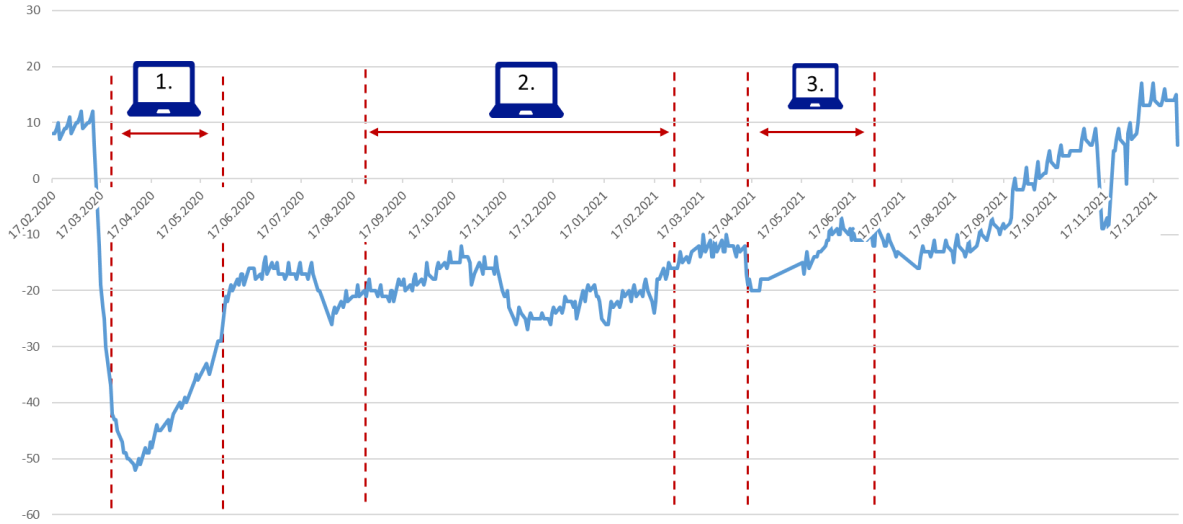

Figure 2. Türkiye's workplace mobility and flexible working periods in the working days of 2020 and 2021

Source: Prepared by the authors based on information from Google [23], Apple [2], Anadolu Agecy [1], Resmi Gazete [37, 38, 39, 40, 41]

As seen in Figure 3, there has been a strong positive relationship between car driving and workplace mobility in working days since the beginning of the pandemic. After the first case seen in Türkiye on March 11th 2020 and the announcement of the Presidential Circular on flexible working, there was a sudden decline in workplace mobility and driving. In general, workplace mobility and car driving changed simultaneously. However, as it can be seen in the figure, the correlation became negative in three periods. The two of these occurred in the summer months of 2020 and 2021. In summer, most employees are on vacation and they do not go to the workplace. That's why the workplace mobility decreases compared to other months. However, due to the increase of travels to other cities, car driving rises. The third exception was the period in between 15-19 November 2021, the school holiday for primary and secondary school students. Many parents were also on vacation, which increased car driving but decreased workplace mobility.

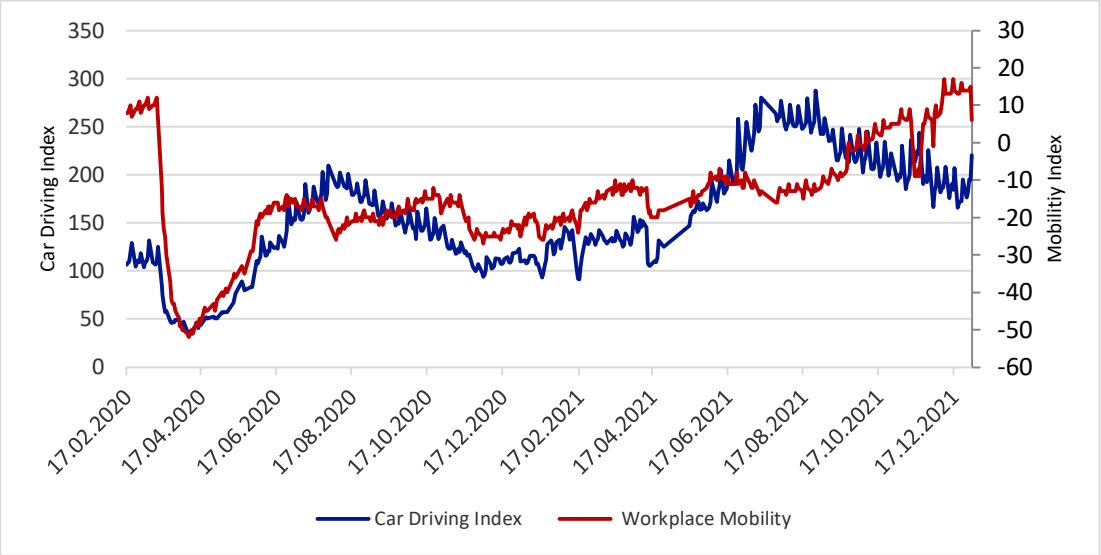

Figure 3. The daily relationship between car driving and workplace mobility in working days in Türkiye

Source: Prepared by the authors based on information from Apple [2], Google [23]

The correlation between passenger car driving and workplace mobility was 0.59 in working days. After determining the correlation, findings of Dingel and Neiman [12] and Crow and Millot [10] on Türkiye's remote working potential (23% of the total jobs) were used. In order to realize this potential, the Covid-19 process has become a trial and test period. In the light of the available data, an empirical potential of 13.51% (23% of 59%) was calculated as a result of the 0.59 correlation between workplace mobility and car driving. It shows that Türkiye could reduce car use during working days by 13.51% in case of utilizing the full potential of teleworking.

Number of cars by fuel type is taken from the TURKSTAT for 2019 [48]. Fuel consumption amount of each car changes according to the fuel type. According to some researches, people in Türkiye drive in average 40 kilometers each day [26, 35]. Based on this, the amount of fuel consumed by cars in 40 kilometers was calculated according to the fuel types. The cost of fuel types is published by the Turkish Energy Market Regulatory Authority's (EMRA) in Turkish Liras and OECD's annual average exchange rates were used to convert Turkish Liras to US Dollars [16, 17, 34]. In this study the cost of the fuel is taken into account instead of the price because the price also includes taxes which have a beneficial role for the public revenue. Thus the study wants to focus on the burden aspect of the energy for the economy. As a result of these calculations, one-day total cost of driving passenger cars in a working day was determined for the Turkish economy. By taking 13.51% of this one-day total fuel cost, the potential daily saving with remote working

was calculated. The annual savings amount is determined by multiplying this amount by the number of working days in 2019. The number of working days in 2019 was found by using an online calculation portal [27].

Concerning the impact of this reduction in fuel consumption on GHG emissions, three main greenhouse gases were taken into consideration: CO_2, CH_4 and N_2O. The amount of emissions that the vehicles will cause by driving 40 kilometers was calculated by using the emission figures of the U.S. Environmental Protection Agency (EPA) for each fuel type [18]. Global warming potential (GWP) calculated by Intergovernmental Panel on Climate Change (IPCC) for 100 years is used to convert CH_4 and N_2O emissions to CO_2 equivalent [30]. By using these data, daily emissions for each gas type was estimated. By taking 13.51% of this emission amount, the emission reduction that can occur with remote working was found. To find the yearly mitigation, one-day emission reduction amount is multiplied by the number of working days in 2019. In order to find the share of this potential mitigation in total emissions, TURKSAT data on national emissions was used [47]. In addition, Türkiye's 2019 CRF table was used to calculate the share of the potential mitigation with remote working in the related sectors, which are "public electricity and heat production" and "road transportation" [49].

In order to find the impact of remote working on electricity consumption, first the hourly electricity consumption data published by Energy Exchange Istanbul (EPIAS) between 17th of February 2020 and 31st of December 2021 was used [19]. Non-working days (weekends, public holidays, exceptional days) were excluded from this data set, and only the electricity consumption data during working hours (08:00 AM-18:00 PM) were taken into account.

Figure 4 shows the relationship between electricity consumption and residential mobility. The inverse relationship is obvious. At the beginning of the outbreak, many employees began working from home, which raised the level of residential mobility to a higher level than ever before. The correlation between the adjusted electricity consumption and the daily residential mobility data published by Google was -0.63 in working days. According to this result, an increase in residential mobility by 100 units reduces electricity consumption by 63 units.

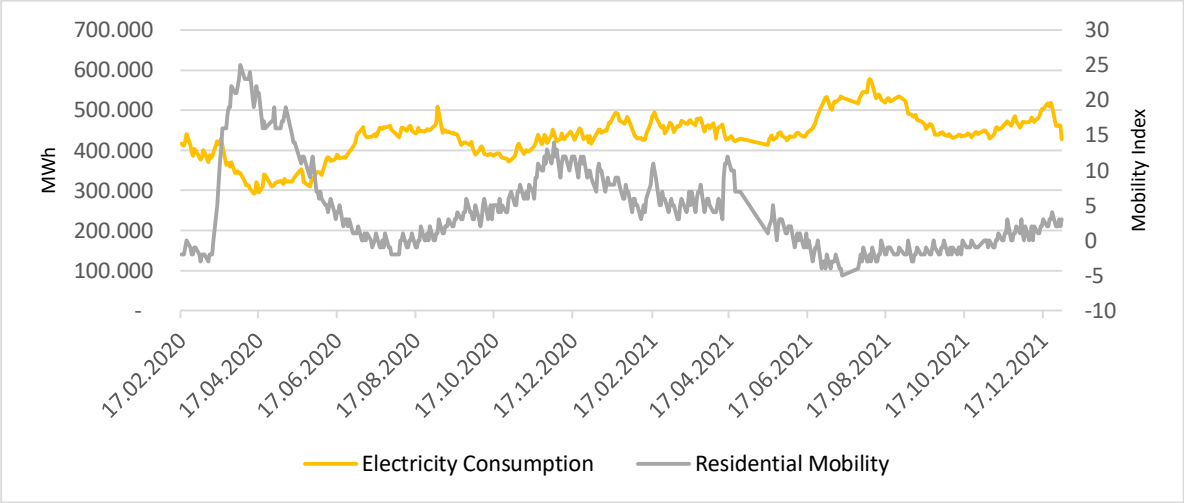

Figure 4. The daily relation between electricity consumption and residential mobility in working days in Türkiye

Source: Prepared by the authors based on information from EPIAS [19], Google [23]

However, not all residential mobility is related to the workplace mobility. Figure 5 illustrates the relationship between residential mobility and workplace mobility. The two variables have almost a symmetric relationship. Their correlation was -0.76 in working days. This means that the negative relationship between workplace and residential mobility is 76%. The rest of the residential mobility is related to the citizens, which are not employed.

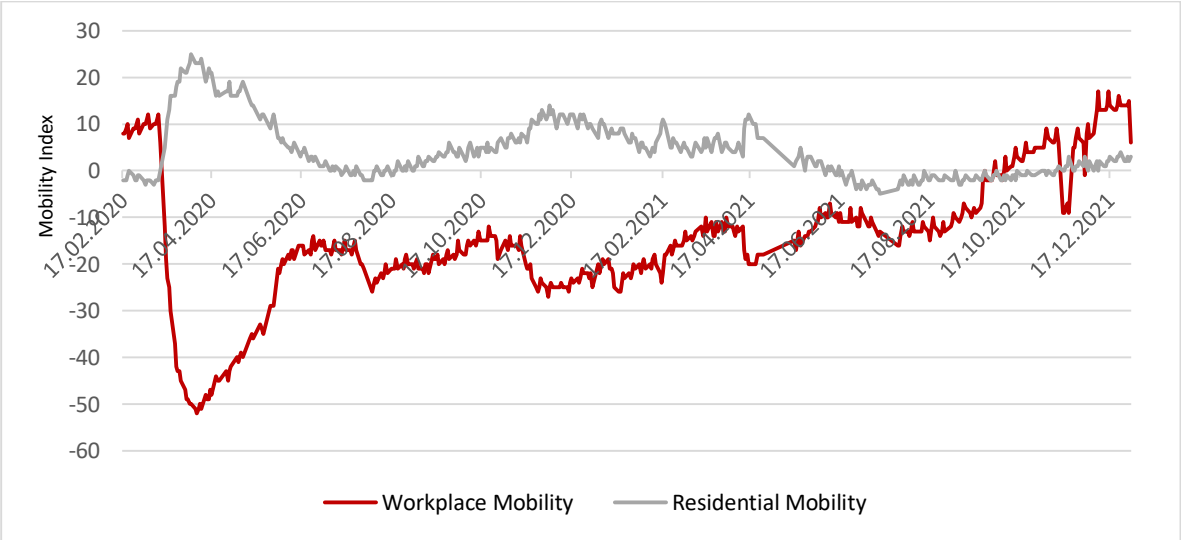

Figure 5. The daily relation between workplace mobility and residential mobility in working days in Türkiye

Source: Prepared by the authors based on information from Google [23]

When these two results are combined, the relationship between electricity consumption and employee-driven residential mobility was found. In this case, if remote working could be applied for all employed, electricity consumption would decrease 48% (76% of 63) in working hours. The same result can also be found by looking at the relationship between electricity consumption and workplace mobility, which can be seen in Figure 6. The correlation between the two data sets was 0.48.

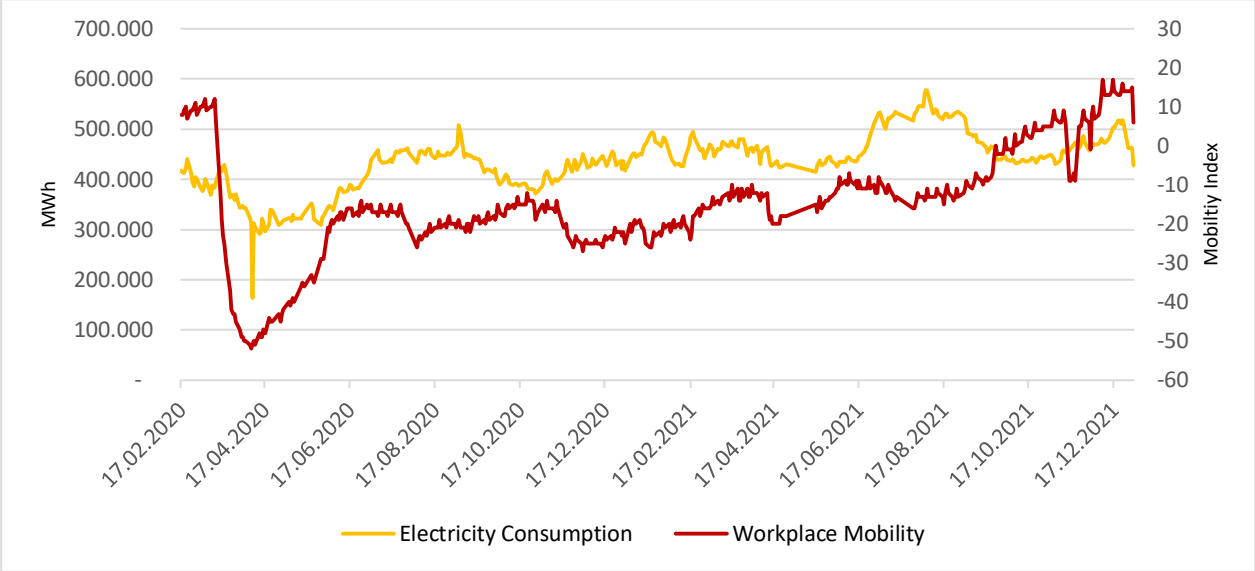

Figure 6. The daily relation between electricity consumption and workplace mobility in working days in Türkiye

Source: Prepared by the authors based on information from EPIAS [19], Google [23]

However, it is not possible to reduce the electricity consumption by 48% during working hours because remote working cannot be applied to all workers but to 23% of the jobs in Türkiye. In this case, if Türkiye utilizes her full remote working potential, the country can reduce the electricity consumption by 10.94% (23% of 48) during working hours.

Based on this result, the amount of saving and GHG emissions reduction potential was estimated by using electricity consumption and GHG emissions data for 2019. Thus the potential annual contribution of remote working was calculated using the data of 2019, which was an ordinary year. All weekends and public holidays were excluded as only working days were taken into account. Consequently, 10.94% of the total electricity consumption between 8.00 AM and 18.00 PM on working days was taken to determine the electricity savings that could be achieved by remote working. EMRA publishes the share of cost components (energy and network cost) within

electricity prices annually [15]. In additional TURKSAT shares the semiannual electricity prices for households [46]. As in the calculation made for car driving, the cost of electricity was taken as the basis for calculating the contribution of remote working to the Turkish economy. The cost of electricity was calculated by taking the average of the semiannual electricity prices and using the share of cost components within the electricity prices. Similar to the calculations made for car driving, OECD's annual average exchange rates were used to convert the cost of electricity from Turkish Liras to US Dollars.

In order to calculate the emission reduction that remote working can provide in the electricity sector, the amount of emissions originating from electricity generation was used in the 2019 CRF table. By using the ratio between the amount of electricity saving with remote working and the total amount of electricity consumed in 2019 published by EPIAS, the potential reduction in electricity-related emissions was determined. According to the results, electricity savings that could be achieved by remote working corresponds to 3.79% of the total electricity consumption in 2019. Hence there is a 3.79% reduction potential in each greenhouse gas emission originating from electricity generation. As a result, the contribution of remote working to the reduction of both electricity sector emissions and nationwide emissions was calculated.

Lastly, after calculating the oil equivalent value of the total savings achieved by remote working, the share of this amount in Türkiye's total energy consumption in 2019 was calculated. Türkiye's total energy consumption data is published by the Ministry of Energy and Natural Resources [33]. As a consequence, the effect of remote working savings in terms of total energy consumption was revealed.

4. RESULTS

4.1. Energy Savings

For calculating the correlation between passenger car driving and workplace mobility, 448 working days of data were used. Although the study examined the working days between 17.02.2020 and 31.12.2021, Apple did not release data for 3 working days[1] during this period globally. Therefore, these three days were not used in the study. As part of focusing solely on

[1] These dates are: 11.05.2020, 12.05.2020, 12.03.2021

working days, all weekends, national holidays[2] and exceptional days were excluded. The exceptional days are administrative leave[3], days between two holidays[4], the full lockdown in 2021[5] and days prior to the full lockdown[6]. As a result, correlation between workplace mobility and car driving was found as 0.59 for working days. This result shows that car driving can decrease by 59% if all employees do not go to work on working days. However, according to Dingel and Neiman [12], 23% of the employees can work remotely in Türkiye. Therefore, 23% of 59 is taken (13.51%) to determine the reduction in car driving in case Türkiye utilizes her full remote working potential. Thus full implementation of remote working has an empirical potential of reducing car driving by 13.51% in working days. Table 2 illustrates the daily cost of car driving in Türkiye for 2019.

Table 2. Daily cost of car driving in Türkiye, 2019

Type of Fuel	Number of Cars (2019)	Consumption in 100 km	Consumption in 40 km	Cost per Liter in 2019 (USD)	Daily Cost (USD)
Gasoline	3,020,017	7	2.8	0.46	3,877,799.76
Diesel	4,769,714	5.5	2.2	0.51	5,315,112.39
LPG	4,661,707	9	3.6	0.22	3,703,074.69
Total					12,895,986.84

Source: Prepared by the authors based on information from EMRA [16, 17], Otostil [35], OECD [34], TURKSTAT [48]

Number of cars according to their fuel type data is taken from TURKSTAT for 2019 [48]. Accordingly, the consumption of cars according to their fuel type in 40 km (daily average driving distance) was calculated. By multiplying the number of cars with consumption per 40 km and cost per liter, daily cost of car driving in Türkiye was calculated, which was USD 12.9 million. By taking 13.51% (remote working' empirical potential to reduce car driving) of the daily cost, daily

[2] The excluded national holidays in working days are: 23.04.2020 (National Sovereignty and Children's Day), 01.05.2020 (Labor and Solidarity Day), 19.05.2020 (Commemoration of Ataturk, Youth and Sports Day), 25.05.2020-26.05.2020 (Ramadan Feast), 15.07.2020 (Democracy and National Unity Day), 30.07.2020-03.08.2020 (Sacrifice Feast), 29.10.2020 (Republic Day), 01.01.2021 (New Year's Day), 23.04.2021 (National Sovereignty and Children's Day), 19.05.2021 (Commemoration of Ataturk, Youth and Sports Day), 15.07.2021 (Democracy and National Unity Day), 19.07.2021-23.07.2021 (Sacrifice Feast), 30.08.2021 (Victory Day), 28.10.2021-29.10.2021 (Republic Day).

[3] Administrative leave for public workers days are: 24.04.2020, 18.05.2020,

[4] 16.07.2021 is a date between Democracy and National Unity Day (15.07.2021) and Sacrifice Feast (19.07.2021-23.07.2021). Therefore many employees took a day off.

[5] Full lockdown dates are: 30.04.2021-14.05.2021, these dates also include Ramandan Feast

[6] Between 27.04.2021-29.04.2021, many people went to countryside and coastal towns before the full lockdown (30.04.2021-14.05.2021).

saving with remote working was found as USD 1.7 million. By multiplying this number with the number of working days in 2019 (248 days), the annual fuel saving can be found as USD 432.1 million. As a result, Türkiye has the potential to save USD 432.1 million annually due to the reduction in car driving with remote working. Figure 7 show the calculation of the potential saving.

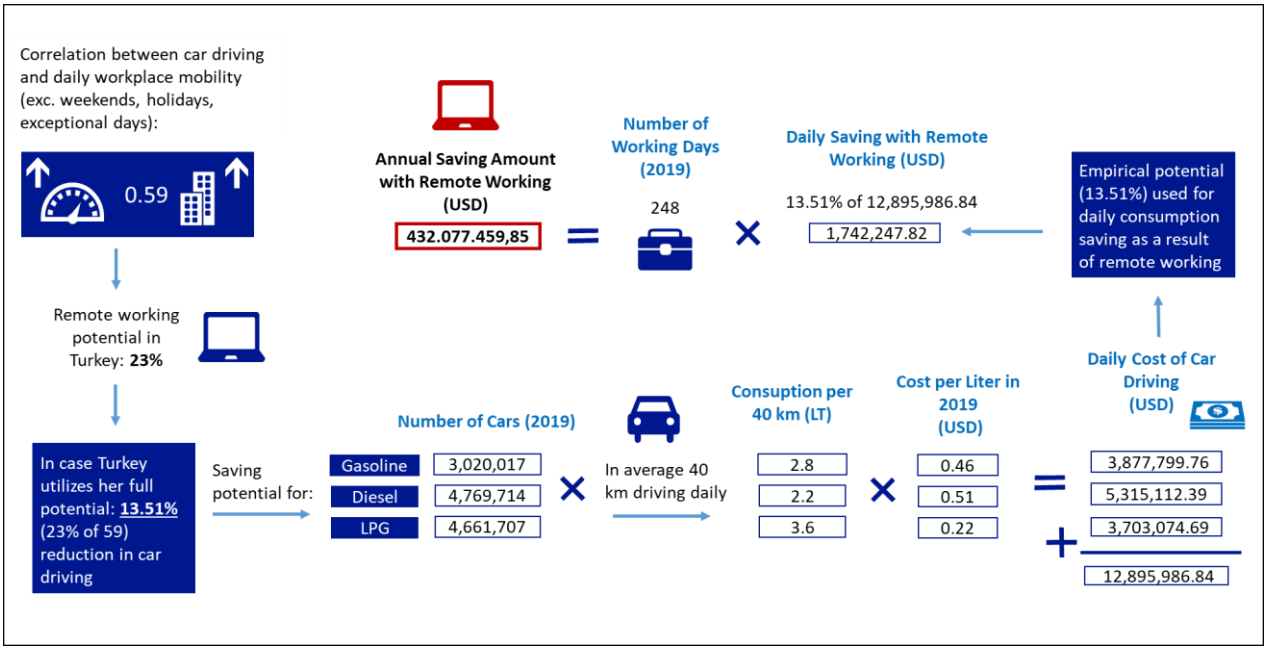

Figure 7. Calculation of the potential annual saving due to reduced car driving with remote working

Source: Prepared by the authors based on information from Apple [2], Google [23], Dingel & Neiman [12], Crow & Millot [10], TURKSTAT [48], Otostil [35], EMRA [16, 17], OECD [34], Hakedis [27]

Similar to the calculation made for passenger car driving, data for 448 working days (17.02.2020-31.12.2021) were used to determine the correlation between electricity consumption and remote working. In order to take into account only working days, the non-working days mentioned in the previous section were excluded from the study. Hourly electricity consumption data are published by EPIAS. Since the working hours are mostly between 8:00 AM-18:00 PM, daily electricity consumption for working days was obtained by summing the electricity consumption between these hours.

A correlation of -0.63 was found between electricity consumption and residential mobility. This result shows that increase in residential mobility decreases electricity consumption. However, not all residential mobility is related to the workplace mobility. People that do not participate in the labor force (e.g. retired, children, disabled) or who are unemployed can be given as an example to

this group of people. For this reason, the correlation between workplace and residential mobility for working days was calculated and found as -0.76. This shows that residential mobility increases by 76% in case all employees do not go to the workplace. When these two relations are combined, that is, in case remote working could be applied to all employees, electricity consumption could be reduced by 48% (76% of 63) during working hours. However, considering that remote working can be applied to 23% of the total employees in Türkiye, remote working can reduce electricity consumption by 10.94% (23% of 48) during working days.

Türkiye's electricity consumption between 8 AM-6 PM on working days in 2019 was found as 101 TWh using EPIAS data. By taking 10.94% of this electricity consumption, the saving with remote working was found to be 11 TWh. Electricity prices are published by TUKSTAT semiannually. Therefore, the average of the semiannual prices for 2019 were taken which was 0.6 Turkish Lira (TL). According to EMRA [15], 81% of the electricity price (0.49 TL) consists of energy and network costs. This cost is converted to USD and found as 0.09 USD. As a result, total electricity saving with remote working was multiplied by the cost of electricity. Thus remote working can save USD 948 million annually from reduction in electricity consumption. The calculations are illustrated in Figure 8.

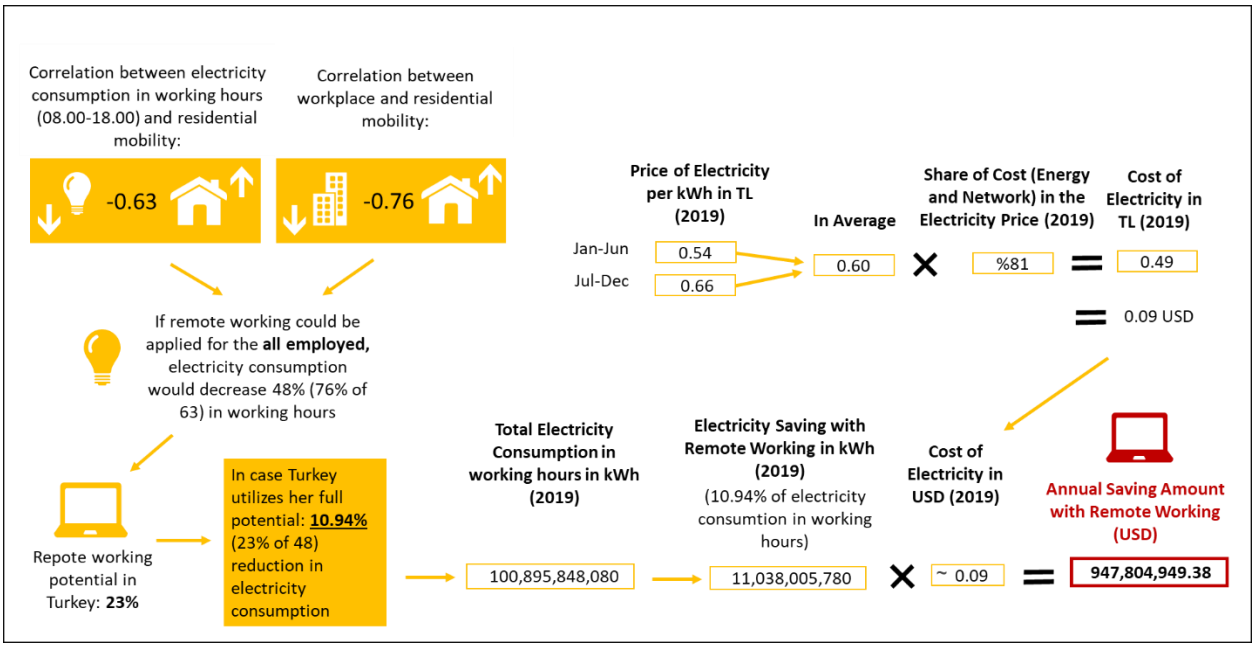

Figure 8. Calculation of the potential annual saving due to reduced electricity consumption with remote working

Source: Prepared by the authors based on information from Google [23], EPIAS [19], Dingel & Neiman [12], Crow & Millot [10], TURKSTAT [46], EMRA [15], OECD [34]

When calculating the effect of remote working on Türkiye's total energy consumption, first of all, the energy saving that can occur as a result of the decline in car driving was found in ton of oil equivalent (toe). Table 3 shows how the annual fuel saving in toe is calculated as a result of the decline in car driving with remote working.

Table 3. Annual fuel saving as a result of less car driving with remote working

Car Type	The Number of Cars * Fuel Consumption in 40 km	Daily Fuel Consumption (LT)	Daily Fuel Saving (LT)	Annual Fuel Saving (LT)	Kiloliter to Tons Conversion	Tons to TOE Conversion	Annual Fuel Saving (toe)
Gasoline	3,020,017 × 2.8	8,456,048	1,142,412	283,318,184	0.753	1.07	228,272
Diesel	4,769,714 × 2.2	10,493,371	1,417,654	351,578,290	0.843	1.04	306,754
LPG	4,661,707 × 3.6	16,782,145	2,267,268	562,282,418	0.541	1.13	343,740
TOTAL							878,766

Source: Prepared by the author based on information from TURKSTAT [48], Otostil [35], Hakedis [27], Statistics Canada [44]

As presented in Figure 9, first of all, the number of cars in 2019 was multiplied by the consumption per 40 kilometers (in liters) according to the fuel type. Thus daily fuel consumption for each fuel type was calculated. Next, benefiting from the empirical potential between remote working and car driving, 13.51% of daily fuel consumption for each fuel type was taken. Afterwards, the result is multiplied by the number of working days in 2019 and the annual fuel saving with remote working was calculated in liters. Next annual fuel saving is converted to toe by the conversion factors of IEA [44]. As a result, 878,766 toe of energy can be saved as a result of reduced car driving with remote working.

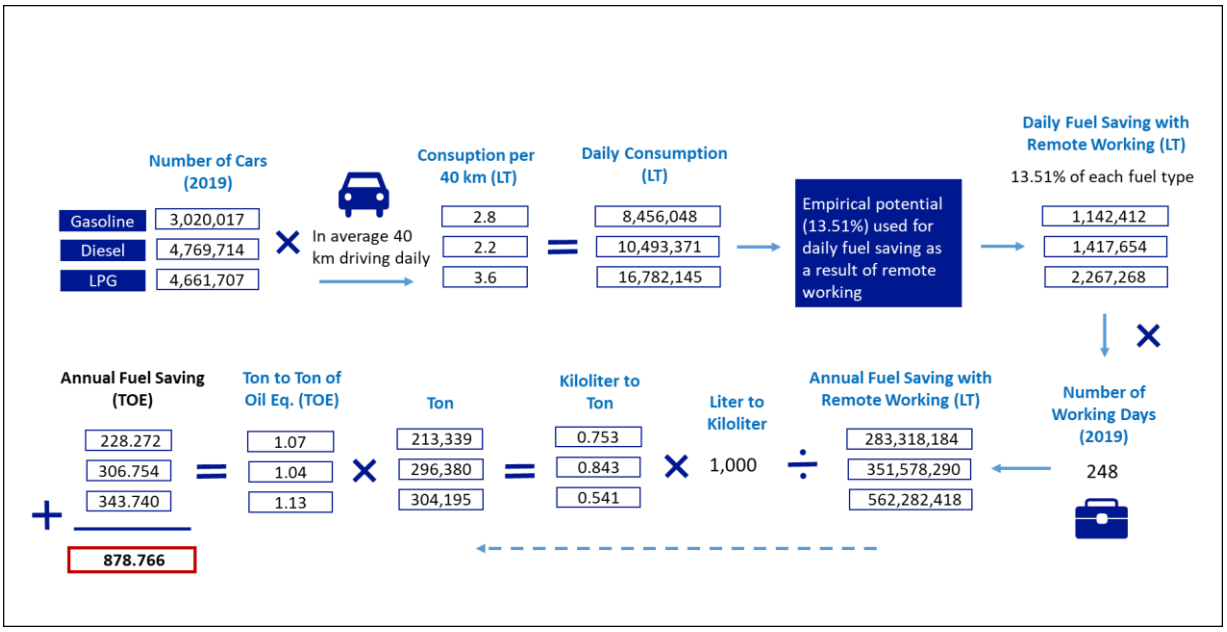

Figure 9. Calculation of the annual fuel saving due to reduced car driving with remote working

Source: Prepared by the authors based on information from TURKSTAT [48], Otostil [35], Hakedis [27], Statistics Canada [44]

In order to find the effect of the reduction in electricity consumption on total energy consumption, the amount of savings that can be achieved by remote working was converted from GWh to toe [20]. The annual electricity saving with remote working was found as 11 TWh, which corresponds to 961,036 toe. As shown in Figure 10, by adding the savings from reduced car driving and electricity consumption, the annual total saving with remote working was found as 1.8 million toe. Türkiye's total primary energy consumption was around 110.6 million toe in 2019 [33]. This means that remote working has the potential to decrease Türkiye's total energy consumption by 1.66%. Thus remote working can help the Turkish economy with reducing its energy intensity.

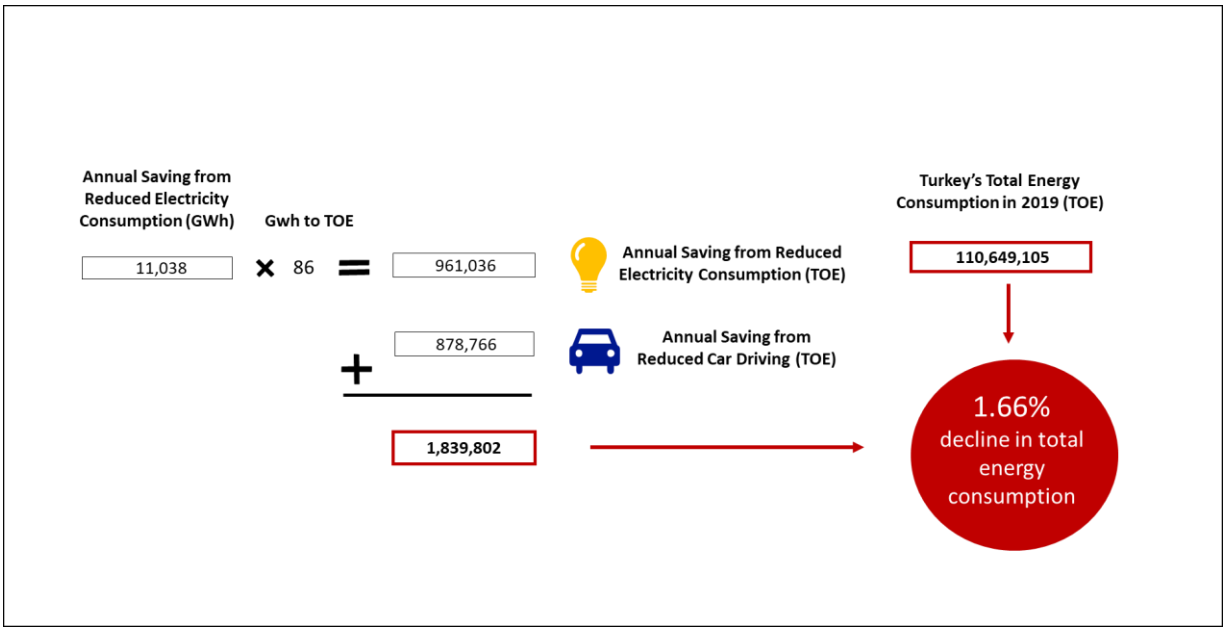

Figure 10. Calculation of the contribution of remote working on reducing Türkiye's total energy consumption

Source: Prepared by the authors based on information from Extra Conversion [20], MENR [33]

4.2 GHG Emissions Mitigation

In calculating the CO_2 mitigation that can occur due to the decrease in car driving, firstly, the number of cars according to fuel types is multiplied by the amount of consumption per 40 km per gallons. Next, the total consumption amount that will occur in 40 km in each fuel type was multiplied by the CO_2 emissions per gallon. Then, the daily total CO_2 emissions was found as 73,049.86 tons, which corresponds to 0.07 million tons (mt). By using empirical potential of 13.51% reduction in car driving with remote working, 13.51% of 0.07 is taken to find the daily CO_2 emission reduction. Finally, by multiplying this result by the number of working days in 2019 (248 days), annual CO_2 mitigation was found. According to the results, remote working has the potential to reduce 2.45 mt CO_2 as a consequence of reduced car driving. The calculations can be seen in Figure 11.

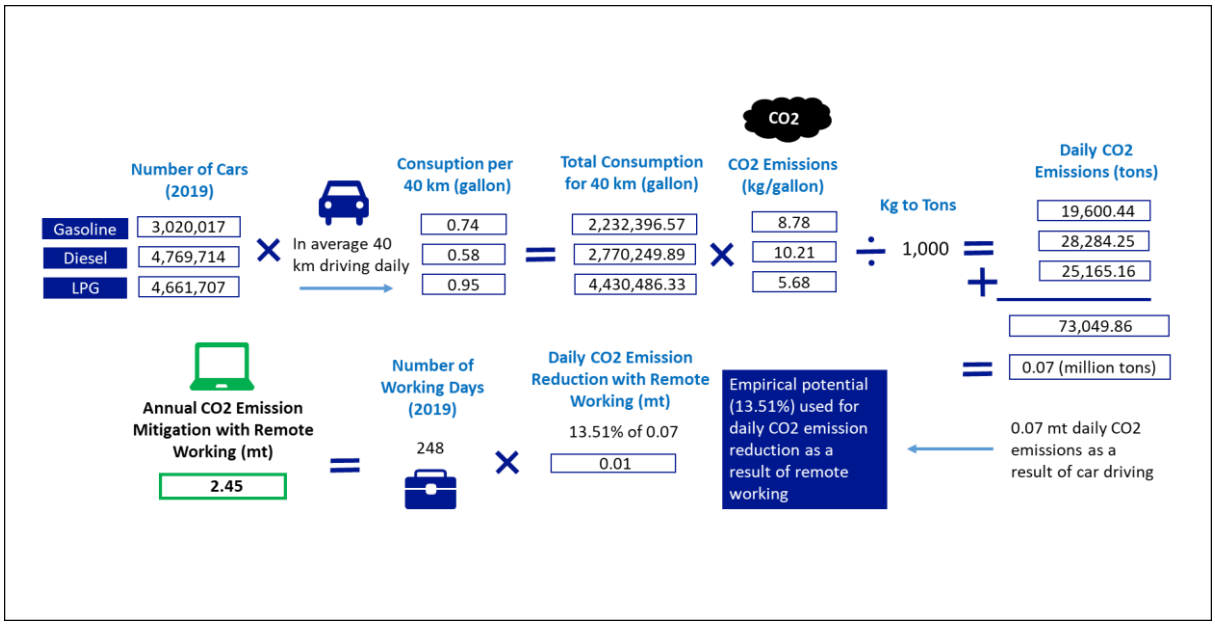

Figure 11. Calculation of the annual carbon dioxide emission mitigation due to reduced car driving with remote working

Source: Prepared by the authors based on information from Apple [2], Google [23], Dingel & Neiman [12], Crow & Millot [10], TURKSTAT [48], Otostil [35], Hakedis [27], EPA [18]

As illustrated in Figure 12, similarly the total amount of methane emissions for each fuel type was added up and according to the result 80.6 tons of CO_2e of CH_4 emissions per day are caused by driving, which is equal to 0.0008 mt CO_2e. Considering the empirical potential of 13.51%, annual CH_4 emission mitigation of 0.003 mt CO_2e was found as a result of reduced car driving.

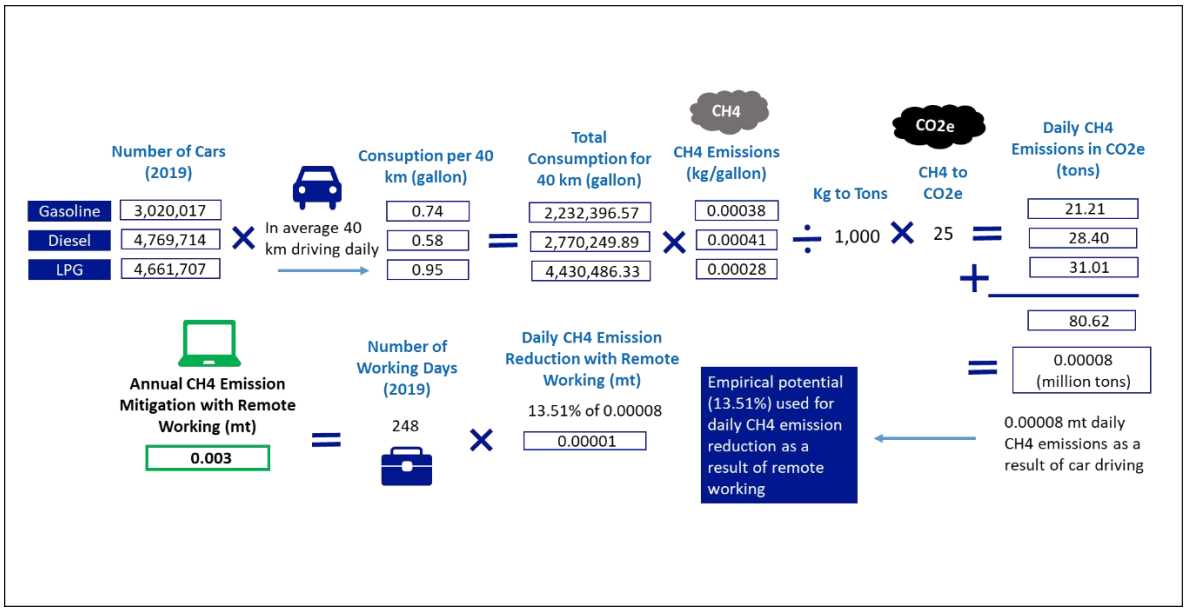

Figure 12. Calculation of the annual methane emission mitigation due to reduced car driving with remote working

Source: Prepared by the author based on information from Apple [2], Google [23], Dingel & Neiman [12], Crow & Millot [10], TURKSTAT [48], Otostil [35], Hakedis [27], EPA [18], IPCC [30]

In a similar manner, the annual N_2O emission mitigation with the implementation of remote working was calculated as 0.01 mt CO_2e (Figure 13).

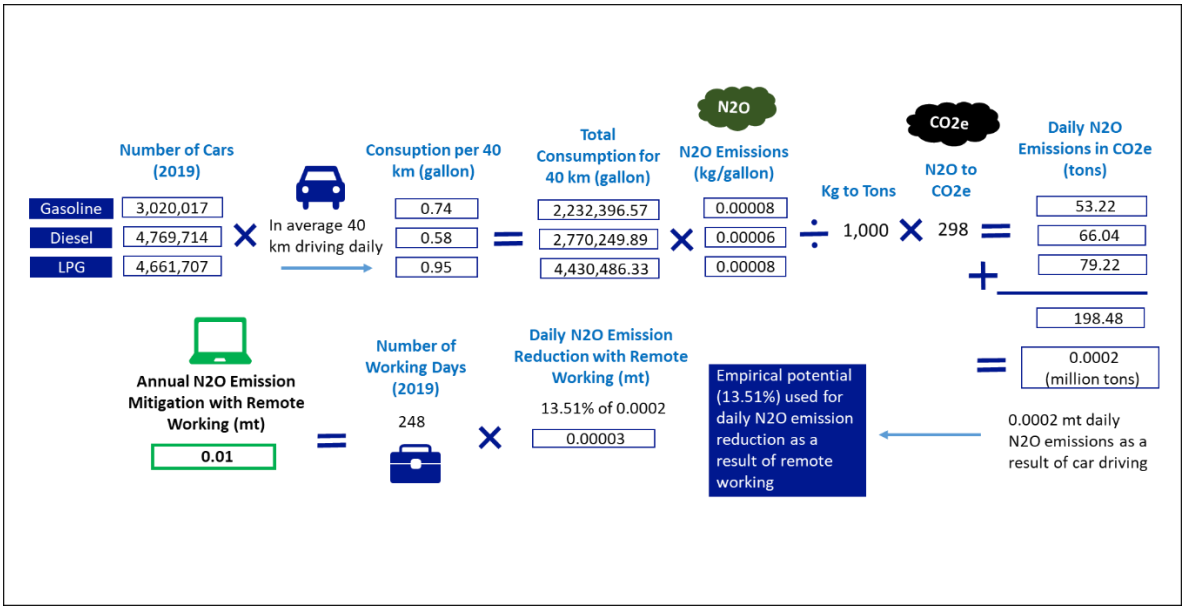

Figure 13. Calculation of the annual nitrogen dioxide emission mitigation due to reduced car driving with remote working

Source: Prepared by the author based on information from Apple [2], Google [23], Dingel & Neiman [12], Crow & Millot [10], TURKSTAT [48], Otostil [35], Hakedis [27], EPA [18], IPCC [30]

By summing all of the mitigation potential of the greenhouse gases, 2.46 mt CO_2e can be found as a result of less car driving (Table 4). The total emission mitigation potential corresponds to 3.2% of the total emissions in the transport sector in 2019.

Table 4. GHG emission mitigation potential of remote working as a result of the reduced car driving

	Mitigation Potential (mt CO_2e)
CO_2	2.45
CH_4	0.003
N_2O	0.01
TOTAL	2.46

Remote working has an empirical potential for reducing 11,038 GWh of electricity consumption in Türkiye, which corresponds to %3.79 of the total electricity consumption (291,069 GWh) in

2019. Thus it is assumed that each GHG emission from electricity generation can be decreased by 3.79% by putting in force remote working practices. By adding CO_2, CH_4 and N_2O emission mitigation potentials with remote working, in total 5.3 mt CO_2e can be found. This means that remote working has the potential to decrease 5.3 mt CO_2e GHG emissions annually as a result of reduced electricity consumption. The calculations can be seen in Figure 14.

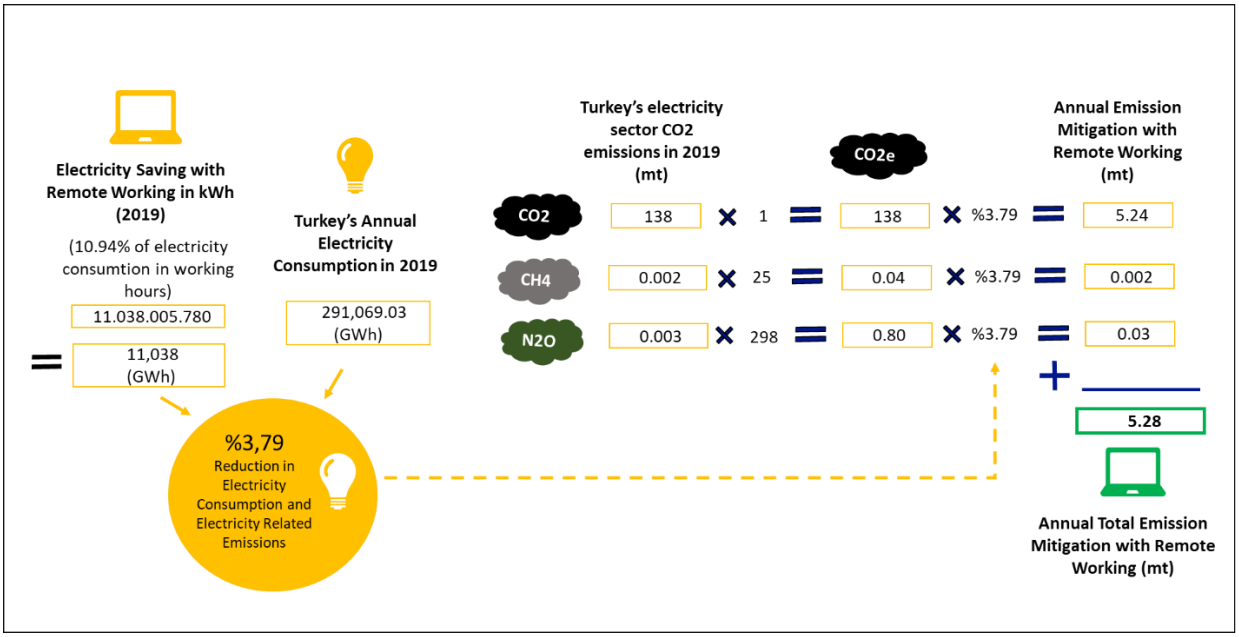

Figure 14. Calculation of the annual GHG emission mitigations due to reduced electricity consumption with remote working and it's share in the total electricity related GHG emissions

Source: Prepared by the author based on information from Google [23], EPIAS [19], Dingel & Neiman [12], Crow & Millot [10], UNFCCC [49], IPCC [30]

5. DISCUSSION

Some jobs cannot be done remotely due to their nature. However, for some jobs remote working increases the efficiency. According to an experiment done in a travel agency company, home working increased the performance of call center employees by 13% while increasing work satisfaction and decreasing the turnover [4]. After the success, the company has enabled remote working to all employees. As a result, with most of its employees switching to remote working, there has been a 22% increase in employee performance [4].

First of all, computer and internet services became a precondition for remote working [7]. However, even though all the internet infrastructure and technological facilities are available, Türkiye went back to office working for public employees since 1st of July 2021. For this reason,

it has been understood that technology is not the only factor to bring remote working permanently and there is a need for new norms and change in the work culture [7].

Having realized the gains of remote working during the Covid-19 pandemic, many technology companies such as Twitter, Spotify and Square announced that they are going to implement remote working permanently [5]. On the other hand, many Wall Street Banks such as Goldman Sachs insist that remote working was applied temporarily [8]. According to the regular way of doing business, employers mostly evaluate the performance of their employees according to the time spent in the workplace rather than output [7]. However, it is much more productive for both employees and employers to create a culture of trust by looking at the productivity of the employees [7].

Remote Working Regulation entered into force on March 10, 2022 in Türkiye, which set framework of the main principles and processes of the working method [42]. Even though it was a necessary step to protect employee and employer rights, the legislation lacks incentives to promote remote working. According to a research by Aon on multinational and local companies in Türkiye, only 3% of companies provide full scale remote working arrangements for their employees after the Covid-19 normalization period [13]. Considering that 23% of jobs can be done remotely in Türkiye, it is important the Turkish government to promote flexible working, in particular remote working and hybrid working practices, in the "new normal" era for private workplaces. In addition, it is important the Turkish government to make use of flexible working in public institutions permanently, as this study confirms its benefits as an effective energy efficiency and climate change policy.

As Dingel and Neiman's [12] research shows, remote working potential rises as countries' GDP per capita increases. For this reason, if Turkish economy could maintain stable and high growth, this will raise the country's remote working potential to the level of developed countries in the future. In addition, the development of technological and digital infrastructure are other factors that increase the potential [32]. Therefore, increasing investments in these areas will enable Türkiye to benefit more from remote working opportunities.

Electric-hybrid cars were not included in the study due to their negligible share (less than 1%) in the total number of cars in Türkiye. However, it is expected the electric cars to replace internal

combustion engine cars in the near future. Therefore, it would be beneficial to include them in future studies.

6. CONCLUSION

The Covid-19 pandemic has been an important testing period for measuring the wide-ranging effects of remote working. According to the findings of this study, with the full utilization of remote working potential, Türkiye can save annually USD 432 million due to the reduction in car driving and USD 948 million from the decline in electricity consumption with 2019 prices. Thus the total saving amount was found to be USD 1.4 billion with 2019 prices. Although it is expected that working remotely will lead to a decrease in car driving, this study revealed that remote working also contributes to the reduction of electricity consumption. Less electricity consumption due to remote working might have occurred as individuals are more careful about their electricity consumption when they pay the bills by themselves. This subject can also be a research area for further studies.

In terms of GHG emissions, Türkiye can mitigate 2.46 mt CO_2e GHG emissions from reduced car driving which corresponds to 3.2% of the annual emissions in the transport sector. In addition, remote working has the potential to decrease 5.28 mt CO_2e GHG emissions annually as a result of reduced electricity consumption and this represents 3.79% of the electricity-related emissions in Türkiye. As a result, a total of 7.73 mt of CO_2e emission mitigation potential was found. This corresponds to 1.53% of the total GHG emissions in Türkiye. As a party to the Paris Agreement, Türkiye has to decrease it's GHG emissions and plans to reach net zero emissions by 2053. As the findings of the study show, remote and hybrid working can also be implemented as a complementary climate change policy to decrease the country's GHG emissions without compromising from economic growth.

The total energy saving that can be achieved by remote working was found to be 1,839,802 toe. Türkiye’s total energy consumption was 110,649,105 toe in 2019. Consequently, remote working has the potential to reduce Türkiye's total energy consumption by 1.66%.

For the permanent implementation of remote and hybrid working, it is important that the economic, social and environmental benefits of this work arrangement are well understood by the policy makers and the society. Besides, it is necessary the Turkish government to put in force flexible

working practices in public institutions and promote such working arrangements for private work places. While this study reveals the benefits of working remotely under normal conditions in terms of petroleum products and electricity consumption, the contribution of remote working during energy crises should be investigated in future studies especially for energy import dependent countries such as Türkiye.

NOMENCLATURE

CH_4: Methane

CO_2: Carbon Dioxide

CRF: Common Reporting Format

EMRA: Turkish Energy Market Regulatory Authority

EPA: U.S. Environmental Protection Agency

GDP: Gross Domestic Product

GHG: Greenhouse Gas

GWh: Gigawatt Hours

GWP: Global Warming Potential

ICT: Information and Communications Technologies

IEA: International Energy Agency

IPCC: Intergovernmental Panel on Climate Change

Km: Kilometer

LPG: Liquefied Petroleum Gas

MENR: Ministry of Environment and Natural Resources

MT: Million ton

MTOE: Million Ton of Oil Equivalent

MWh: Megawatt Hours

N_2O: Nitrous Oxide

OECD: Organization for Economic Co-operation and Development

OPEC: Organization of the Petroleum Exporting Countries

TOE: Ton of Oil Equivalent

TURKSTAT: Turkish Statistical Institute

TWh: Terawatt Hours

DECLARATION OF ETHICAL STANDARDS

The authors of the paper submitted declare that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

İzzet Arı: Supervised the reseach and wrote the manuscript.

Mustafa Kaya: Conducted the data analysis and wrote the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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