Chapter 58
New Parameters for Reduction of Heating-Based Greenhouse Gas Emissions: A Case Study

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Abstract In this study, the effect of indoor temperature for heating on reduction of carbon dioxide emissions in Turkey is studied under various conditions. Two new parameters are introduced, namely, carbon dioxide emission reduction effect (CO_2 RE) and carbon dioxide emission reduction rate (CO_2RR). The potential heating degree-hour values for Turkey are used in conjunction with the potential average outdoor temperature distribution of the country to calculate/arrive at values for the two new parameters. The average outdoor temperature distributions for Turkey are calculated using this approach. In order to estimate the potential average outdoor temperature distributions and the respective heating degree-hour values, the effects of population and outdoor temperature distribution for each city are considered and included here for comparison purposes. The results show that heating-based carbon dioxide emissions may be decreased by 111 % and 5.6 % for 18 °C and 28 °C indoor design temperatures, respectively. It is considered that these two potential parameters may prove valuable tools for local authorities in identifying cities with significant potential for reductions in carbon dioxide emissions caused by residential heating applications.

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Nomenclature

CAHDH	Country average degree hour values, °C-hours
CO_2RE	Carbon dioxide emission reduction effect, %
CO_2RR	Carbon dioxide emission reduction rate, %
HDH	Heating degree-hours, °C-hours
P	Population

Subscripts

DT	Desired indoor temperature (°C)
RT	Reference indoor temperature (°C)

58.1 Introduction

In the twenty-first century, some of the most significant problems for mankind are climate change, high energy demand, waste management, high water consumption, land management, the conservation of ecosystems, the conservation of endangered species, and issues of public health [1].

Among these, the problem of high demand for energy requires the utilization of different energy sources. It is well known that there is a strong relation between the use of some energy sources, such as fossil fuels, and climate change. Burning of hydrocarbons emits greenhouse gases into the atmosphere, primarily in the form of carbon dioxide, CO_2. Now widely accepted as a greenhouse gas, CO_2 has detrimental impacts on both human health and the global climate. Stabilizing the carbon dioxide-induced components of climate change is an important challenge in the utilization of energy sources [2]. Carbon concentration is predicted to increase to 750 ppm by the end of the century, while the global goal is to keep its concentration at 350 ppm.

Global climate change, it is now generally believed, derives largely from CO_2 emissions, and manifests itself in a range of serious environmental issues such as a 0.6 degree rise in average global surface temperature in the last 100 years, an increase of the global average surface temperature over the last century, a rise in the temperature of the lowest 8 km of the atmosphere, a significant decrease in snow and ice cover, and a general rise in global sea levels and ocean temperatures

[2]. The rapid bulid-up of these problems serves only to make the need for new methods of control and prevention more urgent. Radical changes are required both in the way we use fossil fuels and also in our utilization of energy systems. It is obvious that continued use of fossil fuels at current or increasing rates will have a detrimental impact on the global climate. Stabilization of the amount of fossil fuels used requires effort to reduce energy demand. It also requires new developments in the utilization of primary energy sources which do not emit carbon dioxide into the atmosphere [3].

Revision of indoor temperatures in living areas can reduce heating energy demand and thereby help to reduce heating-related greenhouse gas emissions. Several studies have been undertaken to analyze outdoor temperatures by using degree-hour/day values in order to predict energy requirements for the heating and cooling of buildings [4–8]. Haas et al. [9] investigated the impact of consumer behavior on residential energy demand for space heating in Austria. He states that the thermal quality of buildings, consumer behaviour, heating degree days and building type all have a significant effect on residential energy demand. The result of this investigation provides evidence of a rebound-effect of about 15–30 % due to building retrofit. This leads to the conclusion that energy savings achieved in practice (and consequently the reduction in CO_2 emissions) due to energy conservation measures will be lower than those calculated in engineering conservation studies.

In this study, the effect of variations in indoor heating temperatures on the reduction of CO_2 emissions is examined, and a range of cases are presented for analysis and comparison purposes.

58.2 Development of New Parameters

In this study, two new parameters are introduced to the literature-CO_2 emission reduction effect (CO_2RE) and CO_2 emission reduction rate (CO_2RR). CO_2RE, and are correlated for each city of the country on CO_2 emission reduction by varying the indoor heating temperature. In fact, CO_2RE is a combination of the total degree-hour value and the population of a city and can be defined as follows:

$$CO_2RE_{city} = \frac{100 \cdot (HDH_{DT} - HDH_{RT}) \cdot P_{city}}{P_{country} \cdot HDH_{RT}} \quad (58.1)$$

where, HDH_{DT} and HDH_{RT} represent the heating degree-hours for desired and indoor temperature; P_{city} and $P_{country}$ are the populations of the city and country considered in the study; and DT and RT represent the desired and reference indoor temperature, respectively.

The other parameter, CO_2 emission reduction rate, shows the contribution of a city to the total effect and can be obtained as follows:

$$CO_2RR_{city} = \frac{100 \cdot CO_2RE_{city}}{CO_2RE_{Tot,\,city}} \tag{58.2}$$

where, $CO_2RE_{Tot,city}$ indicates the total CO_2 emission reduction effect for all cities in the studied country and can be obtained by

$$CO_2RE_{Tot,\,city} = \sum \left[CO_2RE_{city,\,1} + \ldots.. + CO_2RE_{city,\,n}\right] \tag{58.3}$$

This calculation method can be extended to evaluate the contribution of each individual country to overall co_2 emission reduction across the world. For this purpose, the population density-based average heating degree hours for each country should be calculated. In this regard, CO_2 emission reduction rate for a country can be obtained by

$$CO_2RE_{country} = \frac{100 \cdot (CAHDH_{DT} - CAHDH_{RT}) \cdot P_{country}}{P_{world} \cdot CAHDH_{RT}} \tag{58.4}$$

where, $P_{country}$ and P_{world} indicate the population of the country and the world, respectively. The country average degree hour values ($CAHDH_{RT}$) can be calculated for any reference indoor temperature by the following equation:

$$CAHDH_{RT} = \sum \left[HDH^{RT}_{city,\,1} \cdot \frac{P_{city,\,1}}{P_{country}} + \ldots.. + HDH^{RT}_{city,\,n} \cdot \frac{P_{city,\,n}}{P_{country}}\right] \tag{58.5}$$

Note that the population density-based average heating degree hours for Turkey is determined by the following equation:

$$CAHDH_{Turkey}(RT) = 170.85 \cdot 0.97656^{RT} \cdot RT^{2.099} \tag{58.6}$$

The CO_2 emission reduction rate for a country ($CO_2RR_{country}$) and country total CO_2 emission reduction effect ($CO_2RE_{Tot,city}$) can be obtained by using the following equations:

$$CO_2RR_{country} = \frac{100 \cdot CO_2RE_{country}}{CO_2RE_{Tot,\,country}} \tag{58.7}$$

$$CO_2RE_{Tot,\,country} = \sum \left[CO_2RE_{country,\,1} + \ldots.. + CO_2RE_{country,\,n}\right] \tag{58.8}$$

58.3 Results and Discussion

In order to illustrate how to use Eqs. (58.1)–(58.3), two new parameters proposed in this study are calculated for a case study which is carried out for the city of Istanbul. The CO_2 reduction effect for Istanbul by decreasing the reference indoor temperature from 24 to 23 °C can be calculated as

$$CO_2RE_{Istanbul} = \frac{100 \cdot (HDH_{23^\circ\mathrm{C}} - HDH_{24^\circ\mathrm{C}}) \cdot P_{Istanbul}}{P_{Turkey} \cdot HDH_{24^\circ\mathrm{C}}}$$

$$CO_2RE_{Istanbul} = \frac{100 \cdot (67522 - 72528) \cdot (13624240)}{(74724269) \cdot (72528)} = -1.258$$

As seen from the result, there is a 1.258 % decrease in total CO_2 emission in Turkey if the reference indoor temperature in Istanbul is lowered by 1 °C. For this case, CO_2 reduction rate of Istanbul can be calculated as follows:

$$CO_2RR_{Istanbul} = \frac{100 \cdot CO_2RE_{Istanbul}}{\sum CO_2RE_{city,n}} = \frac{100 \cdot (-1.258)}{(-6.644)} = 18.93$$

The result points out that the contribution of Istanbul within Turkey on decreasing the heating based CO_2 emission when the reference indoor temperature is lowered by 1 °C is 18.93 %. Similar to this, the average CO_2RR for each city in Turkey was calculated for 18–28 °C reference indoor temperatures and given in Table 58.1. Meanwhile, the 15 cities with highest CO_2RR values are given in Fig. 58.1. These cities are Istanbul, Izmir, Adana, Ankara, Mersin, Antalya, Bursa, Antakya, Şanlıurfa, Kocaeli, Manisa, Gaziantep, Konya, Samsun, and Aydın. As seen in the figure, these cities have 65.6 % contribution to the total CO_2RR. It should be noted that ordering in these cities is not directly related to their population.

It is apparent that outdoor temperature distribution is another factor effecting both CO_2RR and CO_2RE. Annual outdoor temperature distribution for each city in Turkey was determined and used to calculate the average annual outdoor temperature distribution for Turkey. Here, the reference is taken as the population of each city. Average outdoor temperature distribution for Turkey was calculated and given in Fig. 58.2.

Furthermore, the population density-based average heating degree hours for Turkey is calculated by using average outdoor temperature distribution and given in Fig. 58.3. The effect of variation in indoor temperature between 18 and 28 °C on the heating-based CO_2 emission is investigated and given in Table 58.2. As can be seen from Table 58.2, the heating-based CO_2 emission reduction for 1 °C indoor temperature difference changes between 5.3 % and 9.3 % respectively.

Table 58.1 Average CO_2 reduction rate of each city in Turkey

No	City	CO_2RR (%)	No	City	CO_2RR (%)
1	İstanbul	18.355	41	Erzurum	0.502
2	İzmir	7.634	42	Çorum	0.494
3	Adana	6.407	43	Rize	0.478
4	Ankara	4.536	44	Edirne	0.447
5	Mersin	4.261	45	Isparta	0.444
6	Antalya	4.034	46	Yozgat	0.425
7	Bursa	3.351	47	Kırklareli	0.395
8	Antakya	2.865	48	Amasya	0.382
9	Şanlıurfa	2.464	49	Düzce	0.379
10	Kocaeli	2.120	50	Siirt	0.376
11	Manisa	2.105	51	Aksaray	0.372
12	Gaziantep	1.957	52	Uşak	0.370
13	Konya	1.896	53	Kastamonu	0.327
14	Samsun	1.877	54	Kırıkkale	0.308
15	Aydın	1.750	55	Muş	0.306
16	Diyarbakır	1.749	56	Sinop	0.300
17	K.Maraş	1.492	57	Burdur	0.285
18	Balıkesir	1.486	58	Yalova	0.277
19	Denizli	1.278	59	Nevşehir	0.265
20	Sakarya	1.187	60	Bitlis	0.261
21	Trabzon	1.186	61	Bolu	0.260
22	Ordu	1.083	62	Karabük	0.251
23	Kayseri	1.048	63	Ağrı	0.239
24	Muğla	0.997	64	Bilecik	0.231
25	Tekirdağ	0.988	65	Karaman	0.228
26	Mardin	0.981	66	Bingöl	0.224
27	Osmaniye	0.946	67	Bartın	0.223
28	Zonguldak	0.863	68	Kırşehir	0.217
29	Adıyaman	0.850	69	Hakkâri	0.203
30	Van	0.821	70	Artvin	0.203
31	Malatya	0.777	71	Kars	0.197
32	Eskişehir	0.751	72	Kilis	0.191
33	Çanakkale	0.720	73	Erzincan	0.191
34	Afyon	0.690	74	Iğdır	0.172
35	Tokat	0.688	75	Çankırı	0.160
36	Giresun	0.661	76	Gümüşhane	0.113
37	Batman	0.608	77	Tunceli	0.081
38	Kütahya	0.569	78	Ardahan	0.065
39	Elazığ	0.548	79	Bayburt	0.053
40	Sivas	0.527			

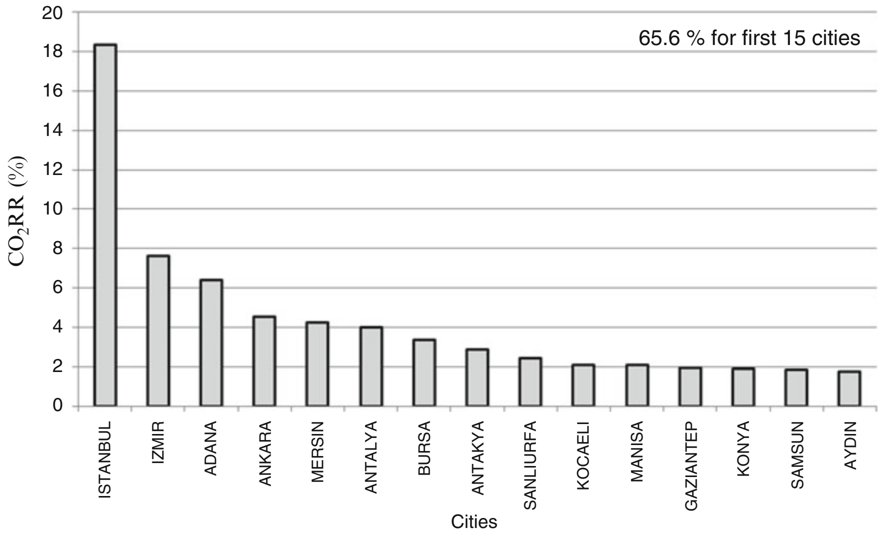

Fig. 58.1 CO_2 emission reduction rates for 15 cities in Turkey

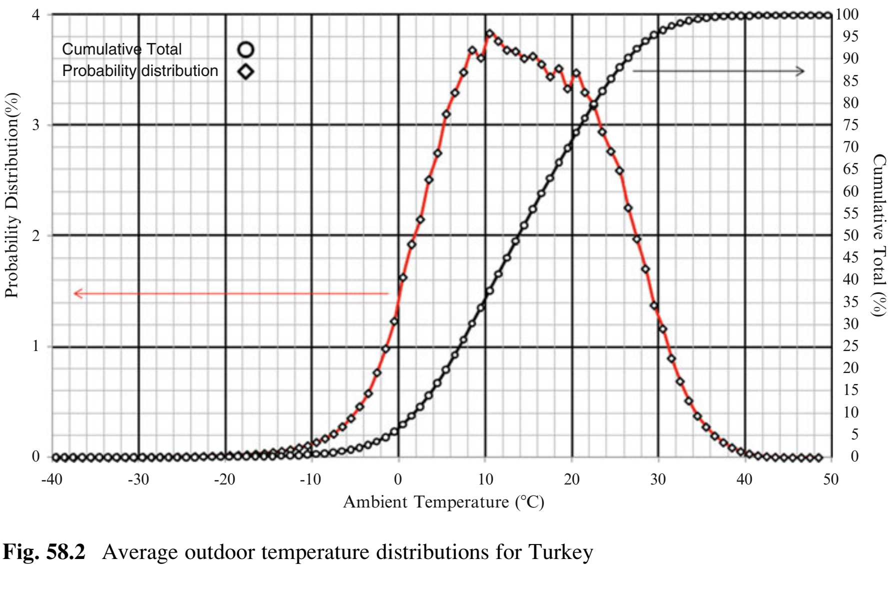

Fig. 58.2 Average outdoor temperature distributions for Turkey

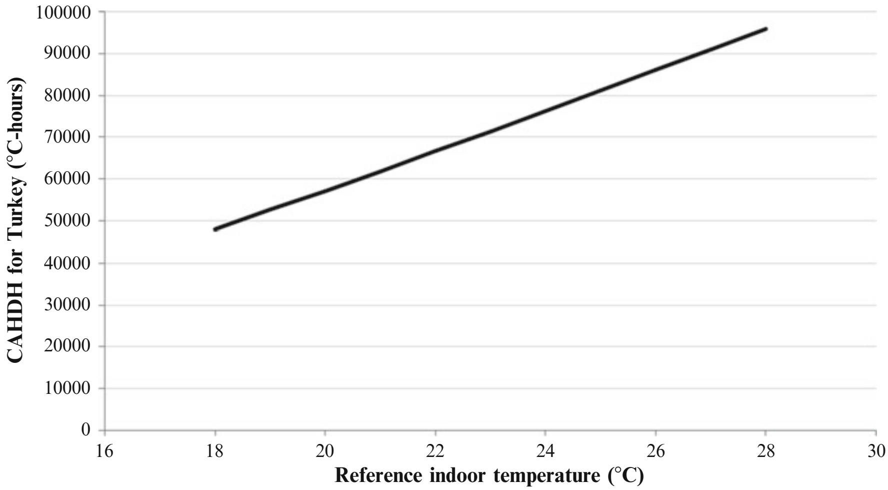

Fig. 58.3 Population density-based average heating degree hours for Turkey

58.4 Conclusions

The comfort conditions required by users have a considerable effect on residential energy use for heating and consequently for levels of heating-based CO_2 emissions. It is important to study the feasibility of decreasing indoor reference temperatures around the world if significant CO_2 emission reductions are to be achieved. Two new parameters proposed in this study, CO_2 RE and CO_2 RR, should be utilized to determine priority cities for pilot applications. For instant, heating-based CO_2 emission can be decreased 7.1 % for Turkey when indoor reference temperature decreases from 23 to 22 °C. Several significant outcomes of this study are highlighted below:

- This is the first study to investigate the effect of CO_2 reduction by changing the indoor reference temperature for Turkey.
- Two new parameters are introduced to the literature, namely, CO_2 emission reduction effect and CO_2 emission reduction rate.
- These new parameters are very useful tools in identifying key target cities for heating-based CO_2 emission reduction.

Table 58.2 Percentage effect of variation of inside comfort temperature on the heating-based CO_2 emission for Turkey

		Indoor temperature (°C)										
		18	19	20	21	22	23	24	25	26	27	28
Desired Temperature (°C)	18	0.0	−9.3	−17.1	−23.6	−29.3	−34.1	−38.4	−42.2	−45.4	−48.4	−51.0
	19	10.3	0.0	−8.6	−15.9	−22.2	−27.6	−32.3	−36.5	−40.1	−43.3	−46.2
	20	20.9	9.5	0.0	−8.1	−15.0	−20.9	−26.1	−30.6	−34.6	−38.2	−41.3
	21	31.8	19.3	8.8	0.0	−7.5	−14.0	−19.7	−24.7	−29.0	−32.9	−36.4
	22	42.8	29.2	17.8	8.2	0.0	−7.1	−13.2	−18.6	−23.3	−27.5	−31.3
	23	54.0	39.2	26.9	16.5	7.6	0.0	−6.6	−12.5	−17.6	−22.1	−26.2
	24	65.3	49.4	36.1	24.9	15.4	7.2	0.0	−6.3	−11.8	−16.6	−21.0
	25	76.9	59.8	45.5	33.5	23.2	14.4	6.8	0.0	−5.8	−11.1	−15.8
	26	88.3	70.0	54.8	41.9	31.0	21.6	13.4	6.2	0.0	−5.6	−10.6
	27	99.9	80.4	64.2	50.5	38.9	28.9	20.2	12.5	5.9	0.0	−5.3
	28	111.6	90.9	73.7	59.2	46.8	36.2	27.0	18.9	11.9	5.6	0.0

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