

The hourly profile of the anthropogenic component of the surface energy balance for the urban region of the Mexico City

Gloria Victoria Salas¹, Claudia Sheinbaum²

¹Instituto Nacional de Ecología y Cambio Climático, Mexico; Instituto de Ingeniería, UNAM, Mexico



INTRODUCTION

In Mexico City the surface energy balance has been measured on several occasions, allowing only an indirect estimation of the anthropogenic component (the latter study was conducted in 1998). This study proposes the estimation of the hourly profile for this component, breaking it in its different subcomponents.

Each subcomponent was modeled using time distribution curves of emissions or daily electricity demand curves, depending on the heat source. For some subcomponents a methodological approach bottom-up was achieved, since more detailed activity data was obtained. This methodology allows to disaggregate anthropogenic heat emissions temporarily, but not at lower geographical level.

The results show variations close to 300% during the day for the component. Considering the net surface energy balance, the anthropogenic component represents up to 25%, also, this component reaches its maximum within three periods of the day where has also been observed the formation of the phenomenon of Urban Heat Island. From these results it is concluded that this component should be studied in deep to determine its relevance in the urban climatology of the Mexico City.

METHODOLOGY

The anthropogenic component was estimated from four main subcomponents, transport, industry, building and human metabolism. Among the assumptions it is that energy consumption released only sensible heat and the hourly profile of each subcomponent with a combustion processes has the same distribution followed by carbon monoxide emissions registered for that subcomponent within Mexico City. In the case of electricity it is assigned the same distribution as the demand curve for electricity. The hourly profile of heat from human metabolism is assumed by three different periods of activity during the day.

The fuel used by transport subcomponent was estimated from characteristics of the vehicle fleet like type, model, annual mileage and energy efficiency. The building and industry subcomponents considered fuels sold in the region of Mexico City for stationary combustion.

And finally, the human metabolism is modeled considering the national population recorded by the population census (2010) for each of the towns that make up the Mexico City.

Model

The anthropogenic heat component Q_F is given by:

$$Q_F = Q_{FV} + Q_{FS} + Q_{FM} \quad \text{Ec. 1}$$

Where the processes of combustion and electric power consumption by transport are represented as Q_{FV} , energy consumption by stationary sources as Q_{FS} and the heat produced by the human metabolism as Q_{FM} .

$$Q_F = [n_{ij} * L_i(t) * E_{fij} + C_e(t) + C_{lm}(t) + n * M(t)] / (A * 3600) \quad \text{Ec. 2}$$

Where:

n_{ij} : The number of cars by type (i) and by model year (j).

L_i : The distance traveled per year, by vehicle type and with the hourly profile given for CO by transport.

E_{fij} : Energy efficiency by vehicle type and model year.

C_e : The consumption of electricity for transportation.

C : Energy consumption by stationary sources. Fuel consumption in industry follows the hourly profile by CO emissions for industry, in commercial and services by the volatile organic compounds (VOC) issued from solvents, and in residential by VOC from residential leakage and inefficient combustion of LP Gas. In the case of electricity consumption for all sectors follows the hourly profile of the demand curve for the Central Area of the national electricity system.

l : The sectors industry, residential or commercial and services.

m : Consumption of fuels or electricity

n : The population of Mexico City.

M : It is human metabolic rate.

A : The area of Mexico City with urban land use.

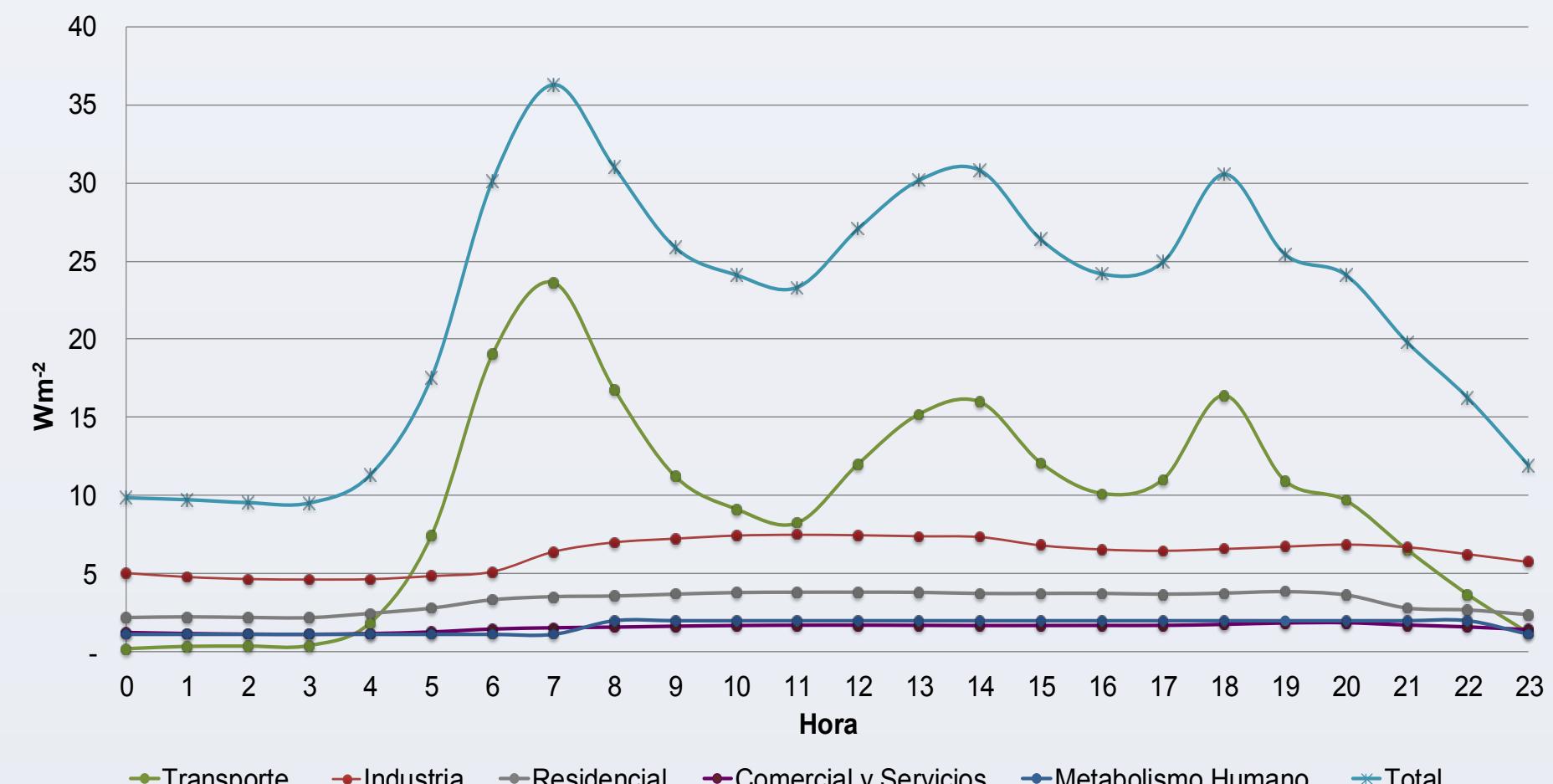
RESULTS

The average value of Q_F in 2010 is 22.63 Wm^{-2} , with daytime values within the range $[9.56 \text{ Wm}^{-2}, 37.68 \text{ Wm}^{-2}]$. The average value estimated for the Mexico City by Oke and Jauregui (1998) was about 20 Wm^{-2} .

On average during the day, fuel combustion contributes to 65.1%, the electricity consumption with 27.3% and the human metabolism with 7.6%, which was higher than the value that is generally assigned to this subcomponent (2%). The highest contribution subcomponent is transport, with an average time of 42.2% participation; followed by industry with 28.4%, residential sector with 14.7%, the human metabolism with 7.6% and commercial sectors and services with 7.1%.

The predominant contribution of activities that implies fossil fuel combustion was vehicular transport. This contribution has three periods during the day with local maximum values they are: from 4 to 10 hours, from 11 am to 16 pm; and 17 to 21 hours. Then contributions of industry, residential, human metabolism and commerce and services show a steady behavior. The anthropogenic component of heat reaches the minimum value at 0 hours and the maximum at 7 hours (Figure 1).

Figure 1 Anthropogenic contribution to surface energy balance of Mexico City by source (Wm^{-2}), 2010



CONCLUSIONS

The estimation of the anthropogenic component (Q_F) of the surface energy balance for Mexico City in 2010, through methodologies bottom-up and top-down provided a value close to experimentally estimated in 1998 by Oke and Jauregui of 20 Wm^{-2} , it is within the range of uncertainty for this study, $22.08 \pm 4.94 \text{ Wm}^{-2}$.

The hourly profile of Q_F as a result of the transport, industry, residential, commercial and services, and human metabolism, allows understanding the contribution of each subcomponent, being more significant the participation of transport sector.

According to the Q_F hourly profile obtained, there is a considerable increase in the early hours of the day (4 to 10 hours), which coincides with the period of highest incidence of solar radiation in Mexico City.

It also notes that the dominant subcomponent in most of the day is transportation, specifically for fuel consumption, reaching at certain times of day the average value calculated for Q_F .

Furthermore, the local maxima of Q_F determined at 7, 14 and 18 hours, are within each of the three periods set by Jauregui for the ICU formation. The local maximum of 7 hours, which is also the maximum total is within the period in which the urban heat island is more frequent and intense in Mexico City, 21-10 hours in these hours is observed during the ICU the dry season, also, in this period 50% of the anthropogenic heat is emitted on average. The following maximum, set at 14 hours, is within the period where daytime ICU is observed from 11 to 15 hours, but having a lower intensity of 3 to 5 °C and with relatively shorter duration. Likewise, in this period it is released on average 26% of the anthropogenic heat.

The last local maximum recorded at 18 hours, is in the evening period ranging from 16 to 20 hours where the ICU has an intensity of between 4 and 5 °C, and is observed both in the dry season as rain. Also, within this period it is issued on average 24% of the anthropogenic heat.

BIOGRAPHY

- Oke, T. & Jauregui, E. (1999). The energy balance of central Mexico City during the dry season. *Atmospheric environment*, 33, 3919-3930.
- Taha, H. (1997). Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat. *Energy and Buildings*, 25, 99-103.
- SMA, (2012). Emissions Inventory of Mexico City Metropolitan Area 2010. Mexico: Ministry of Environment of the Federal District.
- CFE, (2011). Electricity curves demand. Direct consultation.
- Grimmond, S. (1992). The suburban energy balance: Methodological considerations and results for a mid-latitude west coast city under winter and spring conditions. *International Journal of Climatology*, 481-497.
- INEGI. (2012). Geostatistical framework updated National Census of Population and Housing 2010. Mexico, D.F.: INEGI.
- Smith, C., Lindley, S., & Levermore, G. (2009). Estimating spatial and temporal patterns of urban anthropogenic heat fluxes for UK cities: the case of manchester. *Theoretical and Applied Climatology*, 98(1-2), 19-35.
- Chavez, B., & Sheinbaum, P. (2014). Sustainable passenger road transport scenarios to reduce fuel consumption, air pollutants and GHG (greenhouse gas) emissions in the Mexico City Metropolitan Area. *Energy*.
- SEDESOL, (2012). Delineation of Metropolitan Areas of Mexico 2010 Mexico: Ministry of Social Development, National Population Council, National Institute of Statistics and Geography.
- Gartland, L. (2011). Causes of the heat islands. En *Heat Islands Understanding and Mitigating Heat in Urban Areas*. Londres: Earthscan.
- Jauregui, E. (1997). Heat island development in Mexico City. *Atmospheric Environment*, 31(22), 3821-3831.