Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 134 (2017) 508–517

Procedia Engineering

www.elsevier.com/locate/procedia

9th International Conference on Sustainability in Energy and Buildings, SEB-17, 5-7 July 2017, Chania, Crete, Greece

Computational Fluid Dynamics Analysis for Evaluating the Urban Heat Island Effects

Antonio Gagliano*[a],Francesco Nocera[a], Stefano Aneli[a]

Department of Engineering Electric, Electronic and Informatics, viale Andrea Doria 6, Catania 95125, Italy

Abstract

The quality of the thermal environment within the built environment is dependent by local climate and urban design features. Therefore, the scientific knowledge on urban design and microclimate are fundamental for obtaining a tolerable thermal environment at the neighborhood scale. Such problematic interested the huge part of the world population that lives in urban area, which is currently about 50% and it is expected will increase to 66 % by 2050.
The specificity of the urban climate is frequently associated with the urban heat islands phenomenon, which refers to the elevated temperatures within the city areas compared to the rural surroundings. In this context a typical urban geometry is represented by the so called "urban canyon "that denotes an ideal infinite urban street confined by buildings on both sides
In this study an urban geometry, constituted by three urban street canyons with a canyon aspect ratio H/W of 1.0, has been examined. CFD simulations were performed to evaluate the fields of temperature and velocity of the air within the urban canyons and their surroundings. Several scenarios were examined considering alternatively the leeward or the windward walls hitted by the sunrays, while the opposite façade was shaded, as well as varying the reflective properties of the surfaces and the wind velocity. The results of simulations evidence that the adoption of materials of the building envelope with high albedo coefficient guarantees a decrease of the temperatures at least of 1.5°C. Therefore, an increase of the knowledge of urban climate may provide valuable contribution to promote energy efficiency in the built environment.

Peer-review under responsibility of KES International.

Keywords: Urban Heat Island, Street canyon, CFD simulation

* Corresponding author. Antonio Gagliano Tel.: +3932043322228.
E-mail address: antonio.gagliano@dieei.unict.it

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of KES International.
10.1016/j.egypro.2017.09.557

1. Introduction

The percentage of the world population, which lives in urban area, has crossed the threshold value of 50%, a proportion that is expected to increase to 66 % by 2050 [1].

Many of these people lives in 28 mega-cities with 10 million inhabitants or more, that host 453 million people (12 % of the world's urban dwellers); among them, sixteen are located in Asia, four in Latin America, three in Europe three in Africa and two in Northern America. Moreover, the world is projected to have 41 mega-cities by 2030. Urban areas offer most economical resources in comparison with rural area, but otherwise, for satisfying the citizen requirements, they involve high-energy consumptions, which in turn increase the emission of global warming gases and pollutants.

Nomenclature

C_p = air specific heat at 300 ($J\ kg^{-1}\ K^{-1}$)
F_r = Froude number
I_g = solar irradiation (W/m^2)
H = height of street canyon (m)
H/W = canyon aspect ratio
k = turbulent kinetic energy ($m^2\ s^{-2}$)
K = Von-Karman constant
q* = net all-wave radiation flux (Wm^{-2});
q_F = anthropogenic heat flux (Wm^{-2})
q_H = turbulent sensible heat fluxes (Wm^{-2})
q_E = turbulent latent heat fluxes (Wm^{-2})
T = air temperature (°c)
U = air velocity intensity ($m\ s^{-1}$)
u^* = friction velocity ($m\ s^{-1}$)
z =height from the ground, (m)
z_0 = inflow roughness length scale (m)
α = solar radiation absorptivity
δ = atmospheric boundary layer depth (m)
ε =turbulence dissipation rate ($m^2\ s^{-2}$)
Δq_S = net uptake or release of energy by sensible heat changes (Wm^{-2})
Δq_A = net horizontal advective heat flux (Wm^{-2}).
ΔT_{u-r} = urban/ rural temperature difference (°c)
μ =dynamic viscosity ($kg\ m^{-1}s^{-1}$)
Ψ_0 = shadow factor
ψ_s = sky view factor
Ψ_m = integrated stability function for momentum

Therefore, cities are one of the major players where sustainable policies should be directly or indirectly actuated, and therefore they have to contribute in achieving the major policy objectives in terms of sustainable and parsimonious practices. Thus, actions are needed at urban level to ensure that cities will be able to fulfil their potential in the actuation of sustainable policies, and at the same time to guarantee comfortable environmental climate.

Eurostat [2] have defined the Degree of Urbanization (DEGURBA) in order to identify real urban structures with a high concentration of population, these are cities (densely populated areas), towns and suburbs (intermediate density areas), rural areas (thinly populated areas).

In densely populated urban areas, it is observed an increase of air temperature, near the ground (canopy layer), respect to the rural surroundings, due to a difference in cooling between urban and rural areas. This phenomenon, known as urban heat island (UHI), is taking growing prominence among the scientific community [3, 4, 5].