The possible shift between heating and cooling demand of buildings under climate change conditions: are some of the mitigation policies wrongly understood?

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Abstract

The global warming is affecting the built environment in terms of a change in environmental conditions under which buildings operate. This change would probably mean a shift in the thermal demand, from a prevalent heating demand to higher cooling demand in many climates. For instance, in cold climates global warming seems to be a self-decreasing phenomenon, due to less energy demand in warmer environments. In warmer climates, like the Mediterranean, and in the hottest climates (both humid and arid), global warming has to be regarded as one of the main factors (others are the change in comfort standards and heat island effect) in increasing the energy demand to cool the buildings. This paper analyses the environment of different cities, with the characteristic of mild average temperatures nowadays and little thermal oscillations, and could be regarded as Mediterranean climate emplacements. These cities have today more heating than cooling demand, but would probably have in the future higher cooling requirements. Results show that by 2050 in most of considered emplacements cooling demand would be higher than heating demand, and the emissions will rise proportionally. Solutions to this problem have to be searched in a flexible operation of buildings and policies should be focused on summer problems: good natural ventilation, solar protections and internal gains reduction, instead of insulation, infiltration reduction and solar access.

Keywords: global warming, climate change mitigation, building sector energy policy, natural cooling

1. Introduction

Many cities of the world are experimenting in recent years heat waves and a general warmer environment. As a consequence, buildings are shifting from a prevalent heating energy demand to a prevalent cooling demand. Depending on the electricity matrix of the country, this cooling demand could cause an increase in the emissions of greenhouse gases. Many countries are doing an important effort to reduce emissions by improving energy efficiency of the built environment, but policies are normally generated thinking on the heating demand reduction. This means, more insulation, less infiltration, mechanical ventilation and better efficiency of heating and air conditioning systems. However, in many climates, these strategies could be in the future inefficient or have the contrary effect to avoid the heat evacuation that warmer environments will need. In Italy, for example, during the first years of operation of the buildings' energy certification (introduced to respond to the EPB Directive of the European Union of 2002), the heating demand was the only parameter considered to obtain the certification (now, things are fortunately changing). In Spain, the double system (dynamic simulation or degree-day based simplified tables) initially generated an excess of good performance certificates obtained by using the simplified methods, which are more effective in heating evaluation than in cooling calculation. In Chile and in other Latin-American countries, building sector energy policies are being introduced in these years, many times by coping the European experiences. However, climates are not always comparable, and even if they are (like in the case of Valparaiso and the central coast of Chile), the European first experiences in terms of energy performance certification have the exposed problems of not considering in a correct way the cooling performance and of not considering the climate changes as an active actor of the buildings' performance, not only the problem that have to be solved by mitigation strategies. It appears very probable that adaptation to warmer environments has to be part of the solution for the future urban life. So, certifications will have to take into account the comfort conditions and the energy performance for the entire lifecycle of buildings.

2. Methodology

In this paper IPCC data are used to simulate future energy performance of three types of buildings. Future data (2050 and 2080) are obtained by using the Climatic Change Weather Files Generator developed by Jentsch et al. [1] and typical meteorological years are obtained from US Energy Department. The selected scenario to simulate the future is the A2 IPCC scenario [2]. The A2 scenario describes a heterogeneous world, with slow population increase, differences among regions and social classes. The result is a medium-high emissions scenario. Climate description of the considered cities using the Strehler classification is:

- Rome (42ºN latitude, 12ºE longitude, 40 m height) climate is a typical mediterranean climate, with temperate winters, warm and humid summers, large autumns and springs. Temperature seasonal oscillation is reduced and the day-night fluctuation is not very high. Radiation levels are medium-high, urban density increases the humidity retention effect and breeze is sometimes present.

- Barcelona (41ºN latitude, 1ºE longitude, 0 m height) climate is similar, but something hotter in summer and a little warmer in winter. Breeze is frequently present in summer, helping to cool the urban environment.

- Valparaiso (30ºS latitude, 70ºW longitude, 0 m height) climate is also classified as Meditrranean, but it is a little different from the previous two, because of the Pacific Ocean influence: winter is milder and summer is cooler than in Rome or Barcelona.

Building typologies analysed are:

- Small family house with external walls made of cement block, insulation and mortar, with thermal transmittance of 1.77 W/m^{2}K; roof made of metal deck and insulation, transmittance 0.5 W/m^{2}K, 20% of transparency on the main façades (simple glass and aluminium, transmittance 5.1 W/m^{2}K).

- Medium sized block of apartments with external walls of cement block, insulation and mortar, transmittance 1.77 W/m^{2}K; roof of mortar, asphalt and insulation with transmittance 0.5 W/m^{2}K, 35% of transparency, simple glass with transmittance 5.1 W/m^{2}K.

- Tall residential building, walls of cement block and insulation with transmittance 1.77, roof of asphalt, insulation and mortar with 0.5 W/m^{2}K, 70% of glazed surface (simple glass and aluminium, transmittance 5.1 W/m^{2}K).

Even if the recommended values for transmittances are different in the three emplacements, the same value is selected to help the result comparison between climatic effects. Moreover, the use of higher values of insulations and double glass for windows could only make higher the shift between heating and cooling expected as final result. All the buildings have the same occupancy of 30 m^2/person and the thermostat setting is 18-26 during the 24 hours.

Table 1 – Transmittances and glaze percentage of building typologies

Building	U wall (W/m^{2}K)	U roof (W/m^{2}K)	Glazed surface (%)
Family house	1.77	0.5	20%
Block	1.77	0.5	35%
Tower	1.77	0.5	70%

Simulations have been done using Types 56a (multizone building) in the Trnsys tool (version 16). Climatic TMY files are read in Type 109, sky cloudiness is calculated by Type 69b and psychometric variables by Type 33e. The Jentsch method to generate TMY future data uses "shift" and "stretch" modifications for temperature, "stretch" modification for wind speed and global radiation, "shift" for relative humidity and atmospheric pressure. Fore more detailed information, see the tool manual [3].

3. Results

Total heating and cooling demands are obtained by simulations for the three buildings typologies, the three climatic emplacements and considering two orientations: north-south and east-west. Figures 1 to 3 show the heating and cooling demand for the typical meteorological year and the modified climates for 2050 and 2080. In the case of the small family house the total thermal demand is decreasing in the future simulation for the cases of Rome N-S oriented 2050 and Valparaiso N-S 2050, N-S 2080, W-E 2050 and W-E 2080. However, in all cities and orientation the shift between cooling and heating energy demand is clear in 2080 simulation. In the dwelling block and tall building case of study, results are more evident, due to less exposed surface and more percentage of glazing in the façade. The results show higher dependence on orientation, always due to the same factors.

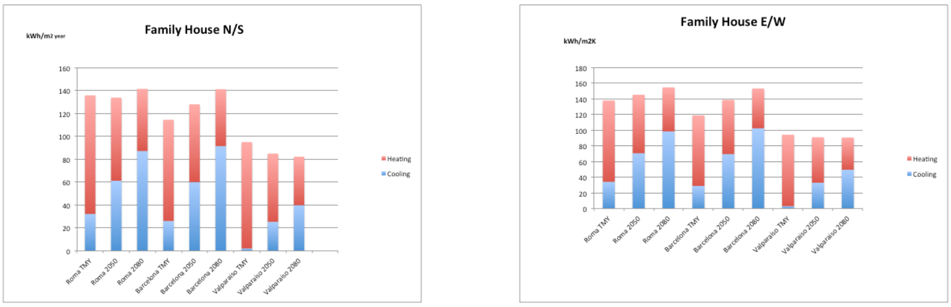

Figure 1 – heating and cooling demand for the family house, N-S and E-W oriented

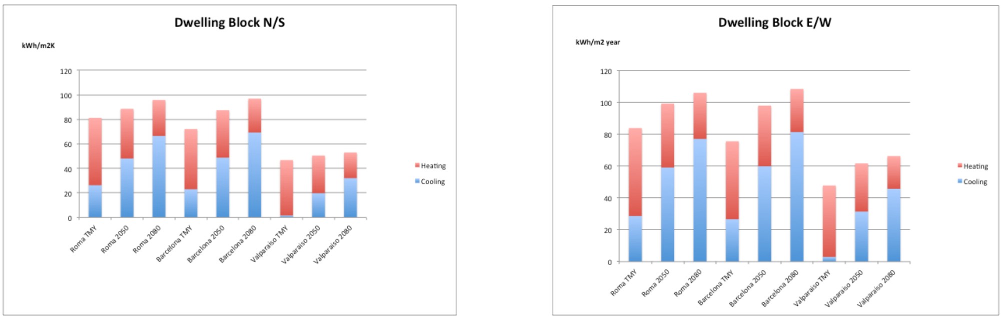

Figure 2 – heating and cooling demand for the medium block, N-S and E-W oriented

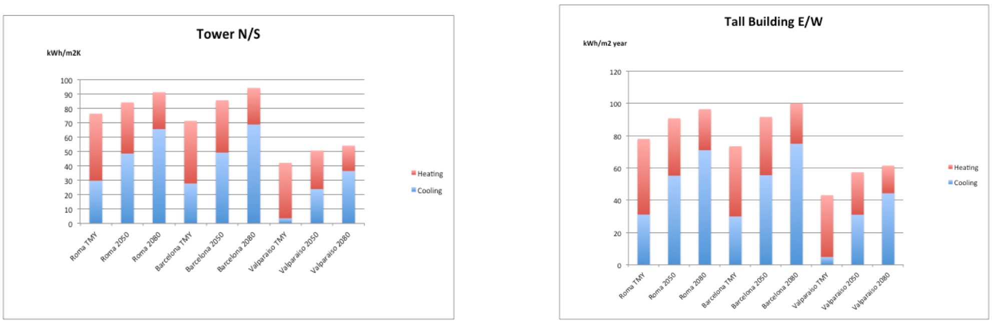

Figure 3 – heating and cooling demand for the tall building, N-S and E-W oriented

To estimate the relative greenhouse gases emissions, a boiler system is considered for heating and a heat pump is selected for cooling, with respective efficiencies of 0.95 and 3.0. Emissions are obtained by using the transformation coefficients that depend on the energy matrix and especially on the renewable energy share for electricity production of the countries and regions. In Chile, for example, the renewable contribution to electricity is different in the north and central south because of the presence of two different systems: the SING and the SIC. Valparaiso belongs to the SIC region, which has a 40% of hydroelectric contribution and a 60% of carbon thermoelectric contribution [4]. In the case of Italy and Spain, energy matrix is more complex, with a total renewable contribution share comparable with the SIC in Chile [5] [6]. Resulting coefficients for all the countries are resumed in table 2.

Table 2 – Coefficients to calculate emissions (kg CO_2/kWh final energy)

City	Heating coefficient (natural gas)	Cooling coefficient (electricity)
Rome	0,20	0,33
Barcelona	0,20	0,39
Valparaiso	0,20	0,37

Table 3 resumes the energy demand and the emissions caused by thermal conditioning for average building form and orientation between the considered in this study.

Table 3 – yearly final energy consumption and emissions of greenhouse gases

City	TMY energy (kWh/m^2)	2050 energy (kWh/m^2)	2080 energy (kWh/m^2)	TMY emissions (kg CO_2 /m^2)	2050 emissions (kg CO_2 /m^2)	2080 emissions (kg CO_2 /m^2)
Rome	98,9	107,0	114,3	17,8	16,8	16,3
Barcelona	87,7	104,9	115,7	16,3	17,5	17,8
Valparaiso	61,6	66,1	68,0	12,7	11,5	10,7

4. Conclusions

The present work showed the heating and cooling trend for future climatic scenarios in different regions of the world and discuss the appropriate building sector energy policies that should be undertaken to respond to the predicted situation. Warmer environments will cause the shift between heating and cooling in all the considered countries. Total energy demand will increase in all scenarios, except in Valparaiso family house case. As a consequence, final energy demand for HVAC will increase in about 10% in average in all considered countries. Emissions will not increase due to the 40% share of renewable electricity generation present in Italy, Spain and in the SIC of Chile. These results reflect the selection of the boiler system for heating. If heating would be provided by the same heat pump of the cooling, then the change in the thermal demand will generate more emissions in the future for all considered scenarios.

5. References

[1] M.F. Jentsch, A.S. Bahaj and P.A.B. James (2008) Climate change future proofing of buildings – Generation and assessment of building simulation weather files, *Energy and Buildings* **40** (12), pp. 2148-2168.
[2] IPCC Special Report (2000) Emissions Scenario, download link: IPCC official site www.ipcc.ch
[3] Climatic change weather file generator manual (2009), download link: UKCIP official site www.ukcip.org.uk or Southampton School of Civil Engineering and the Environment official site www.serg.soton.ac.uk
[4] Chilean Government (2015) Energy Ministry. http://huelladecarbono.minenergia.cl/sistemas-electricos
[5] Spanish Government (2014) Ministry of Industry, Energy and Tourism.. Available online: http://www.minetur.gob.es/energia/desarrollo/EficienciaEnergetica/RITE/propuestas/Documents/2014_03_03_Factores_de_emision_CO2_y_Factores_de_paso_Efinal_Eprimaria_V.pdf
[6] Italian Government (2013) National Information System for Environmental Protection. Available online: http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni/fattori-di-emissione-per-la-produzione-ed-il-consumo-di-energia-elettrica-in-italia/view

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