CONSEQUENCES OF GLOBAL WARMING ON THE ENERGY PERFORMANCE OF CFS WITH SEASONAL THERMAL CONTROL

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ABSTRACT

Fenestrations systems play a very important role in the energy balance of a building, impacting both on thermal and visual comfort. Especially in southern regions of Europe, windows can lead to high solar gains and glare problems. Both can strongly influence energy consumption and indoor comfort. With global warming and the increase of average temperatures, overheating may particularly be a problem in a higher range of latitudes. The changes on thermal loads induced by global warming will vary depending on locations but also on the building envelope.

This study investigates the future thermal loads for heating and cooling, in order to evaluate the total energy consumption during the year. The aim is to evaluate the performance of a novel technology for glazing envelopes such as embedded microstructures, in a climate change scenario. The overall effect of the global warming on the energy demand depends on the meteorological parameters as well as on the type of building. Focusing on a well-insulated building, a microstructured glass is considered, in order to evaluate its performance at different latitudes. Meteorological data for the probabilistic future climate projections are provided by the Meteonorm database. Simulations have been performed choosing twenty-one European locations at different latitudes.

In general the analysis shows that the predicted energy consumption is growing for southern European locations, due to a relevant increase in the cooling demand. As the latitude rises, the majority of thermal loads are increasing, up to a latitude of around 53°N; from this latitude, annual loads are getting slightly lower. All over Europe, expected energy savings provided by the studied microstructured glass, in comparison with a sun protective glass, are in a range between 3% and 18%. Such Complex Fenestration Systems (CFS), compared with conventional windows, help to decrease cooling energy demand, which is expected to increase considerably in the upcoming years.

Keywords: embedded microstructures, climate change, cooling loads, relative energy savings

INTRODUCTION

Nowadays, climate change is one of the most critical phenomena. Excessive use of fossil fuels, combined with rapid urbanization and extreme soil exploitation, are the major causes of the greenhouse effect. An increase of the mean monthly temperatures has been detected in different geographical areas since the mid-twentieth century. The last decades have been marked by a global warming of the Earth with a temperature increase between 0,6°C and 0,9°C [1]. Consequently, mitigation strategies are needed in order to reduce of the global warming effect.

In the residential and commercial building sector in particular, the energy consumption could be significantly reduced by improvements in the building envelope, through reduction of heat transfers or use of energy efficient windows [2]. The fenestration system of the building has an important influence on the HVAC requirements because it is responsible for about 40% of the heat losses in a typical building envelope [3]. Therefore, the reduction of the heating and cooling energy consumption can be realized through the installation of novel glazing technologies, such as embedded microstructures. This novel CFS is composed of a polymer film, laminated to a double glazing with low-e coating. Parabolic micro-mirrors are embedded in the polymer film and aligned with striped reflectors in such a fashion that a seasonal g-value is obtained [4]. Thermal gains are maximized in winter and reduced in summer. The proposed glazing envelope guarantees a good level of daylighting, a clear view toward outside and a significant amount of energy savings through the HVAC system [5].

This study aims at evaluating the thermal performance of the novel microstructured glass in a future scenario of global warming (in 2050), analysing the impact on the energy balance of the building at different latitudes.

METHOD AND INPUT DATA

A parametric analysis is carried out in order to estimate the influence of the microstructured glass on the required thermal loads in an office building, under future meteorological conditions induced by the climate change. Energy savings obtained by the use of embedded microstructures have been calculated and compared with a sun protective glass, both in the current climatic conditions and in the future scenario.

Chosen locations

Twenty-one locations were selected, distributed all over Europe, according to [5] in order to consider a sufficient wide range of latitudes. In Figure 1, a list of the twenty-one European locations is displayed, with the corresponding extreme latitudes (Athens and Bergen). The latitude of Lausanne is also indicated because the Swiss city is the reference location, for which the geometric configuration of the embedded micro-mirrors has been optimized, minimizing the annual thermal loads.

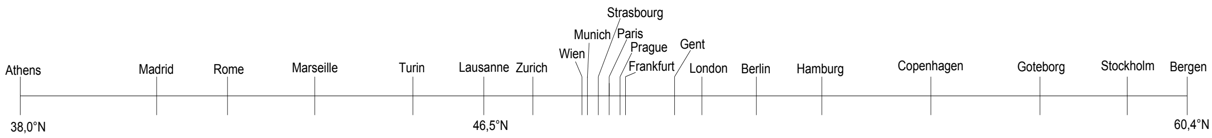

Figure 1: List of the twenty-one chosen European locations; the range of latitude is between 38°N (Athens) and 60,4°N (Bergen).

Weather data

Simulations have been performed for each location using a ray tracing program, based on the Monte Carlo method. This tool is based on the statistical evaluation of the path taken by sun rays through the glass, as explained in [4]. Meteorological variables are needed as input in the program, in order to climatically characterize the region. The sky distribution for diffuse radiation is considered according to the Perez model, taking into account hourly the direct and diffuse horizontal irradiance levels [6]. Meteorological data are provided by the Meteonorm database [7], both for the current climatic conditions and for the probabilistic future climate projections. Projections until 2050 were selected, following the A1B scenario developed by the Intergovernmental Panel on Climate Change (IPCC). The A1B scenario from the Special Report on Emissions Scenarios belongs to the A1 group, corresponding to a positive perspective. The A1 storyline describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter and the rapid introduction of new and more efficient technologies. This scenario is distinguished in three groups that describe alternative directions of technological changes in the energy system: fossil intensive (A1FI), non-fossil energy sources (A1T) and a balance across all sources (A1B) [8].

Reference office room

A south-oriented office room has been defined, in order to perform all the simulations varying the latitude and the glazing envelope. The geometric characteristics of the reference office room comprise a floor area equal to 30 m^2 and a façade wall area that amounts to 10 m^2. The window to wall ratio is about 40%. Concerning the thermal properties, the external wall is well-insulated, with a U-value of 0,15 W/m^2K. Besides the microstructured glass, a conventional glazing, such a sun protective glass, is examined. For both glazing envelopes the U-value of the window is assumed equal to 1,3 W/m^2K.

RESULTS AND DISCUSSION

Figure 2 shows the obtained thermal loads with the microstructured glass in the current situation and in the future climatic scenario. Three ranges of latitudes can be distinguished: in southern locations the annual loads are increased, in the continental region the variation is not significant and in the north of Europe the thermal loads are decreased. In the lowest range of latitudes, between 38°N and 46,5°N, the expected future thermal loads range from 22,6 kWh/m^2 (Turin) to 37,0 kWh/m^2 (Athens). In the current climatic conditions, in this range of latitudes, the cumulated loads vary from 16,7 kWh/m^2 to 29,7 kWh/m^2, corresponding to the same cities. From Zurich (47,4°N) to Berlin (52,5°N), the annual loads are slightly higher in the future scenario, except in Prague, where they decrease by 1,7 kWh/m^2. At these latitudes, the highest increment of thermal loads is in Frankfurt, equal to 3,0 kWh/m^2. The northern European locations (from Hamburg to Bergen) are characterized by a decrease of the annual loads, more accentuated in Copenhagen, Goteborg and Bergen, where the difference is around 2,5 kWh/m^2.

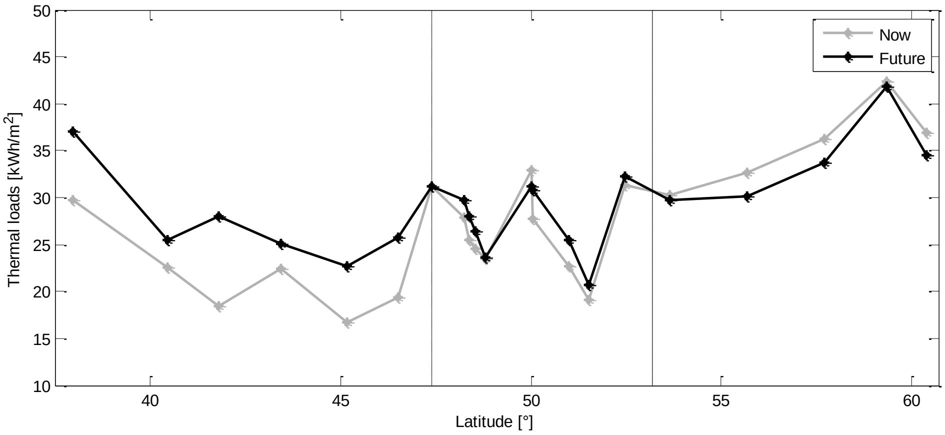

Figure 2: Annual thermal loads at different latitudes for the microstructured glass nowadays (grey line) and in the future (black line).

In general, the thermal loads are expected to significantly increase in lower latitudes (until around 46°N) and they slightly decrease in the north of Europe. This is explained by the larger increment of mean monthly temperatures for the low range of latitudes (until around 48°N). The temperature is expected to increase by between 1°C and 2,7°C in these locations. In the continental region, including locations like Frankfurt and Munich, the climate change is less significant.

In Figure 3, energy savings are shown, as compared with a sun protective glass.

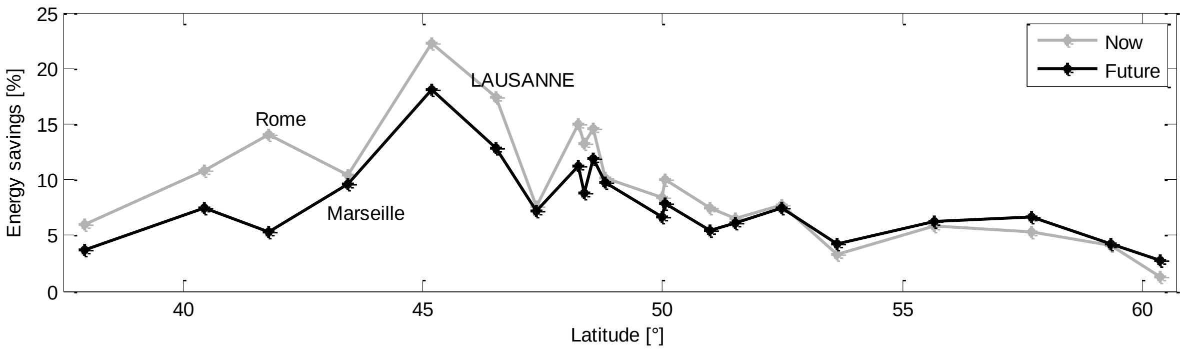

Figure 3: Relative energy savings at different latitudes for the microstructured glass, compared with the sun protective glass in the current and future scenario.

The curve representing the energy savings has the same shape in the future and present climatic scenario, with the exception of Rome, that will be described in more detail in the following paragraph. Until a latitude of 52,6°N, relative energy savings are decreasing in the future climatic conditions. Especially southern locations are characterized by a considerable reduction of the saved energy; in Athens they diminish from 6% to 3,6% (40% of reduction) and in Lausanne the decrease is about 26%. In the north of Europe, where the latitude is above 53°N, relative savings are increasing, except in Stockholm, where they remain almost the same, rising from 4,1% to 4,2%. In Hamburg the increment is of 23%, in Copenhagen around 8% and in Goteborg is 20%. In Bergen, finally, energy savings are expected to grow from 1,3% to 2,7%.

As can be noticed in Figure 4a, in Rome the direct irradiance is expected to significantly increase in the future decades.

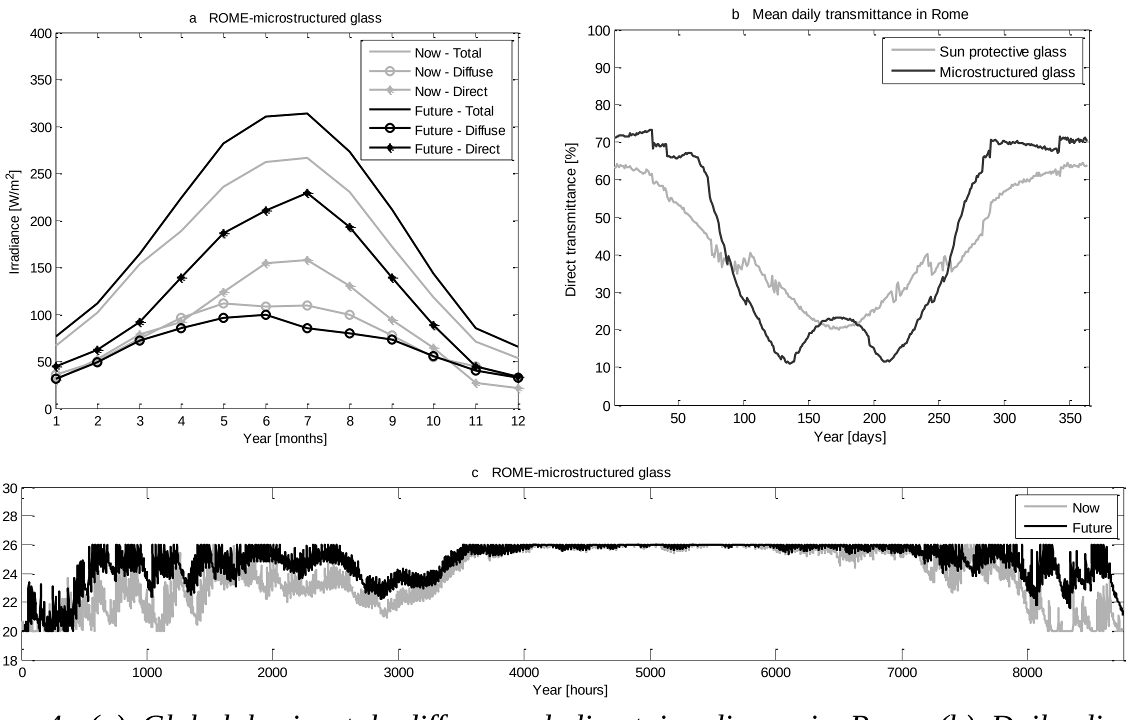

Figure 4: (a) Global horizontal, diffuse and direct irradiance in Rome (b) Daily direct transmittance in Rome with the sun protective glass and the microstructured glass and (c) Mean hourly temperatures in Rome for the microstructured glass in current and in future scenario.

During summertime, the increase is about 30%, causing considerable solar gains. In winter the direct horizontal radiation increases by between 14% and 40%, depending on the month. The diffuse irradiance is slightly decreasing during the hot season; consequently, the global irradiance is increased all over the year. The increased temperatures combined with the rise of the direct portion of the irradiance induce overheating. In Figure 4c, it can be noticed that, according to the IPCC projections, there is a first need of cooling from the end of January until April. In these months, the transmitted energy through the microstructured glass is around 70% (Figure 4b). When the direct transmittance is between 30% and 11% in spring, there is no need for cooling. Then the cooling is required again in the end of May until December. In Rome, heating requirements are drastically reduced in a future scenario (by about 81%), while the cooling loads are increasing by 43,6%. In a future scenario of global warming, the annual thermal loads in Rome are increased by 34%, going from 18,4 kWh/m^2 to 27,9 kWh/m^2.

Another particular case among southern locations is Marseille, where the saved energy is almost the same, passing from 10,4% to 9,6%. The reason is that future and present meteorological conditions in this location are comparable. Both in the current and in future years, high solar gains will be registered in the building early during the year, before the sun elevation angle reaches the blocking range of the embedded microstructures.

The variation of the energy savings all over Europe can be explained by the change in distribution of thermal loads between cooling and heating. The expected cooling and heating loads are shown in Figure 5a and 5b, respectively.

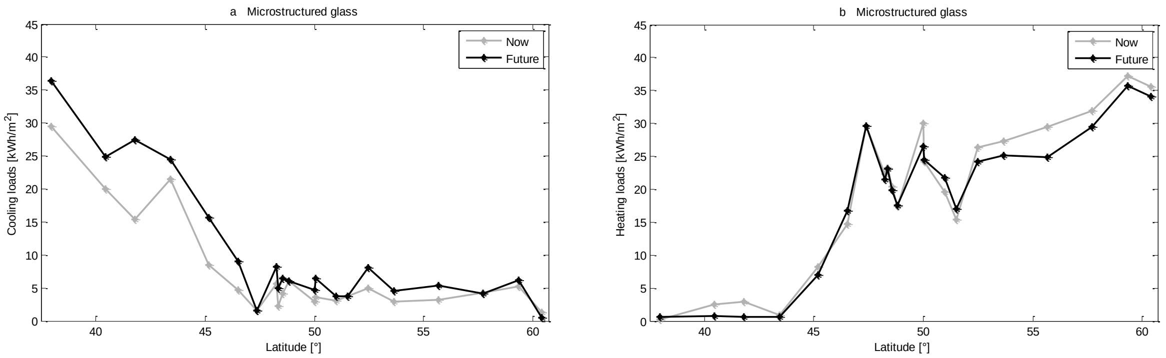

Figure 5: Current and future (a) cooling loads and (b) heating loads for the microstructured glass at different European latitudes.

In general, as can be seen in Figure 5a, the requirement for cooling is increasing for all the locations except Zurich, Paris, London and Goteborg, where it is roughly maintained. The highest increment of cooling loads is seen in southern European locations. In Athens, cooling loads currently amount to 29,7 kWh/m^2, while in the future they are reaching 36,4 kWh/m^2. The increase of cooling consumption is less accentuated at higher latitudes; there is a peak in Berlin, where the cooling is expected to vary from 5 kWh/m^2 to 8 kWh/m^2. Concerning the annual heating loads, Figure 5b shows the trend at different latitudes. In Madrid and Rome the heating loads undergo a significant decrease. In Madrid it is expected to diminish from 2,5 kWh/m^2 to 0,7 kWh/m^2 (of about 72%), while in Rome from 3 kWh/m^2 to 0,55 kWh/m^2 (down to 81%). For the locations situated in a middle range (between 43°N and 52°N), the heating consumption is not importantly changed according to the future climatic projections. At higher latitudes (above 52°N), where energy savings are expected to slightly increase, heating loads decrease by around 4%-16%. The reduction of heating energy consumption depends on the location and is negligible in continental Europe.

CONCLUSION

Several studies on climate change indicate that in 2050 the mean global temperature and the irradiance are expected to rise, more or less significantly, depending on the location. In the south of Europe this increment is larger, amounting to more than 2°C. In the north the increase of mean temperatures is less accentuated but still foreseen. The attention to energy consumption in buildings is becoming important as well as the promotion of a smarter energy management. In this paper, the impact of global warming on the thermal loads in a well-insulated building has been investigated. In particular, the thermal performance of a microstructured glass is evaluated in a climate change scenario, in comparison with a sun protective glazing. Focusing on the microstructured glass performance, it can be affirmed that climate change significantly alters the heating and cooling requirements. Despite the variation of climatic conditions, relevant energy savings are still achieved by the novel CFS technology. With the global warming effect, the energy consumption for heating tends to decrease; on the other hand, the need for cooling rises. The effect of climate change is more acute in southern European regions, where the need for cooling is more important. For this range of latitudes, also a proper design of the sun protective glass can potentially be a solution for the reduction of the cooling loads in a future scenario. Additionally, a further optimization of the geometric configuration of the micro-mirrors is possible in southern locations, in order to obtain a more significant reduction of the annual loads. In locations situated at latitudes higher than 53°N, the increment of temperature is larger in winter than in summer. Consequently, the cooling consumption is not importantly increasing in the north of Europe, while heating loads slightly diminish. The analysis shows that, all over Europe, energy savings expected with a microstructured glass compared to a sun protective glass are between 3% and 18%. The microstructured glass could be a potential solution in a future climate scenario, for the reduction of overheating in buildings, helping to decrease the cooling energy consumption, which is likely expected to grow more and more in the coming up years.

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