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Smart cooling systems for the urban environment. Using renewable technologies to face the urban climate change

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ABSTRACT

Urban heat island and global warming increase the urban ambient temperature. Increased temperatures have a tremendous effect on the energy demand for cooling, with a great impact on peak and total electricity demand.

Renewable technologies in the urban environment have been widely regarded as an increasingly important solution to deal with the climate change challenges and energy security. Significant effort is performed in the integration of photovoltaic panels (PV) and micro turbines in the urban context showing a substantial reduction in CO_2 emissions. At the same time attention is drawn to an often-overlooked aspect regarding renewable energy technologies, in that despite having low operating costs their overall benefits are often not well understood and consequently are often evaluated as being less profitable than fossil fuel alternatives, even though they are future proof about energy cost.

The aim of the present paper is to describe the role of renewable energy technologies and zero carbon technologies in covering the future increased energy demand for cooling.

The integration of photovoltaics in the urban environment through PV facades, pavements, and shading devices are discussed.

The role of Information and Computer Technology and smart grids in the efficient management of renewables in urban scale is discussed. The role of smart metering, users 'integration and demand response capabilities for future zero energy urban neighborhoods is revealed.

1. Introduction

The request for energy and energy-related services, to meet social and economic development and improve human wellbeing and health, is constantly increasing. It is well recognized that societies require energy facilities to meet human needs such as space comfort, lighting, cooking, mobility, and communication as well as to serve the various productive processes (Edenhofer et al., 2012). Moreover the significant changes in climate variables that are anticipated and already experienced in the 21st century, as well as the observed ongoing extreme weather and climate events, signifies that adaptation and mitigation to climate change will be a key issue for the urban areas in the near future (“ADAPTATION ACTION PLAN (AAP) the Executive Summary University of Catania,” 2011, Müller et al., 2014; Prutsch et al., 2010).

The extent of future climate change depends on some variables including the pace of greenhouse gas emissions, temperature increase rates, and the response of ecosystems to the changing climate. In this framework, all cities face economic, social, energy & environmental challenges each one of them being interrelated with the definite increase in urban temperatures which leads to a significant increase in the cooling demand.

On the other hand, the world's population is growing at unprecedented rates, impacting significantly on the nature of our urban and natural environments. By 2050 we will be nine billion people on the planet, of which 70% will be living in urban areas. That is the reason why Peirce et al. (2008) have rightly called the twenty-first century, the ‘Century of the City.’

Nevertheless, the technologies that can make the difference in the urban thermal environment are well documented (Akbari et al., 1997; Akbari and Touchaei, 2013; Santamouris, 2014). The use of cool materials for the urban environment, able to amortize, dissipate and reflect heat and solar radiation, are already in the market and continuously evolving. The existence of the European Cool Roofs Council, the Cool Roofs Rating Council as well as the announcement of the foundation of the Asian Cool Roofs Council proves that there is a high and global market interest. Green infrastructure, green roofs, and green facades is another growing market with a significant potential in contributing to the urban cool island effect (Oliveira et al., 2011; Skoulika et al., 2014).

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Various pilot case studies have shown that urban heat deterioration can be mitigated using the climate change mitigation techniques:

- Ng et al. (2012) studied the thermal effects of greening in improving the urban microclimate in the city of Hong Kong. As a rule of thumb, a reduction of outdoor temperature equal to 1 K is possible when tree coverage is larger than 1/3 of the total land area for areas where the building coverage ratio is almost to 44%, which is the average value in Hong Kong.
- The improvement of microclimatic conditions in Athens Greece was studied by Gaitani et al. (2011). Through a series of interventions such as increased greenery, installation of cool materials, increase shading and use of earth to air heat exchangers, the area's comfort conditions were significantly improved.
- Almost 4500 m^2 of cool pavements were used to rehabilitate a major urban park in the greater Athens area. It was found that the extensive application of reflective pavements, under the particular climatic conditions, may reduce the peak daily ambient temperature during a typical summer day up to 1.9 K while surface temperatures were reduced up to 12 °C (Santamouris et al., 2012)

But are these technologies sufficient? Can urban climate changes be adequately mitigated and simultaneously reduce the constantly increasing cooling demand? Or should we also focus on increasing the renewable energy production in the urban environment? How can we increase the potential to introduce low or zero carbon micro-renewable energy technologies in cities?

Recent studies show that future energy demands for cooling will be dramatically increased (IPCC, 2014; Santamouris, 2016, 2014) the upcoming decades. As Santamouris noted in Santamouris (2016) the growing use of air conditioning to satisfy the indoor thermal comfort will increase the cooling demand depending on the increase of the ambient temperature. At a global level, it is estimated, that a possible increase of the average ambient temperature by 1 K, may result in an energy consumption for cooling worth of 75.1 billion dollars. This trend is depicted in Fig. 1 (Petri and Caldeira, 2015) showing a significant increase of Cooling Degree Days and a considerable decrease of Heating Degree Days.

Based on the above, the integration of renewables in cities to cover future increased cooling demands should be a top priority.

Existing literature in renewable energy shows that renewable energy technologies continue to grow as improved performance, efficiency, and reliability, at lower costs, is pursued by researchers ("Cities, Towns & Renewable Energy Yes In My Front Yard," 2009). The potential offered by distributed energy systems, which usually involve a significant share of renewables, is becoming apparent as smart meters and intelligent grids (Tsoukalas and Gao, 2008) are deployed.

The starting point of the present work is the fact that urban overheating is here and that adaptation to climate change in cities is an absolute necessity. Therefore, the aim of the present paper is to analyze the role and potential of renewable energy integration in the urban environment. Advanced and cutting edge renewable energy technologies are presented in Section 2 showing the research potential of renewables 'integration in cities.

Section 3 is devoted to the role of Information and Computer Technology in efficiently deploy renewables to cover urban cooling demand in local urban scale. Finally, conclusions and prospects are included in Section 4.

2. Advanced renewable technologies in urban environment

The integration of renewables in the urban environment represents a significant challenge for the research community. Some cities have already shown a substantial interest in integrating renewable energy.

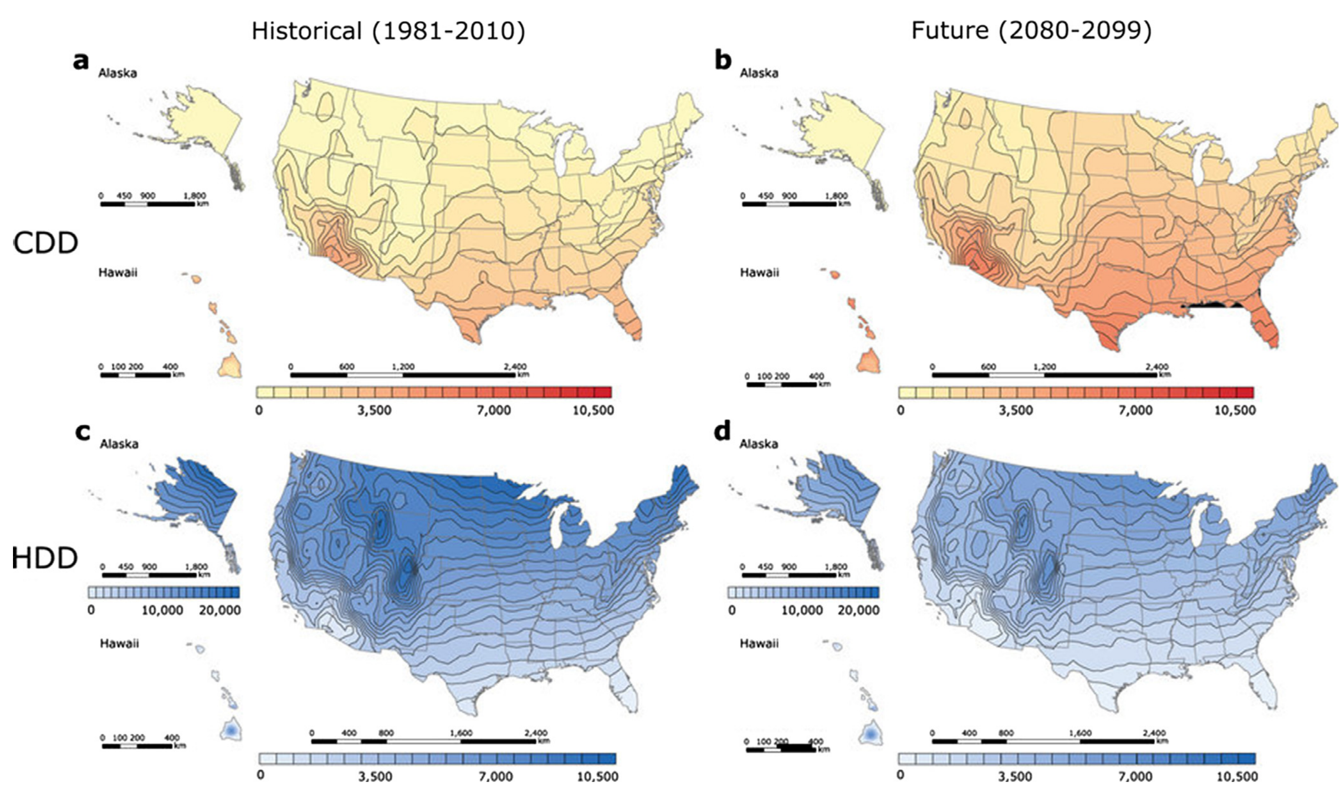

Fig. 1. The evolution of cooling and heating degree days in the USA (Petri and Caldeira, 2015).