

Chapter 2

Climatic Change in the Built Environment in Temperate Climates with Emphasis on the Mediterranean Area

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Abstract Climate change in the built environment is described by means of a multi-fold relationship: cities are major contributors to CO₂ emissions; climate change poses key threats to urban infrastructure and quality of life; climate change interacts with urbanization, population aging and socio-economic issues; and how cities grow and operate matters for energy demand and thus for greenhouse gas emissions. This relationship is particularly important since nearly 73 % of the European population lives in cities, and this is projected to reach 82 % in 2050. At the same time, climate change is occurring in Europe, as mean temperature has increased and precipitation patterns have changed. In terms of the Mediterranean area, increasing droughts and extreme climate phenomena (heat spells/heat waves) are key future characteristics that will put the whole region under serious pressure until 2100. They will also directly influence the built environment, including its resilience, and are expected to impact more cities with higher concentrations of vulnerable people, including the elderly, who are considered to be more sensitive to various climatic stress factors as compared to people of working age.

2.1 Introduction

Climate change is taking place and affecting cities, including their built environment as well as their residents—especially the most vulnerable ones. Impacts have already been reported and highly reliable estimates show the relationship between the increased frequency of climate extremes and the severity of the impacts. A growing number of cities in Europe have taken initiatives to modify their energy production, consumption patterns and greenhouse gas emissions and to develop adaptation policies to climate change,

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including policies for the built environment. Furthermore, the role of cities is critical in achieving the objectives of European Union for a low-carbon, resource-efficient, ecosystems-resilient society. In this chapter, climate change in the built environment is examined, with the examination concentrating on temperate climates (range of latitude between 23.5° and 66.5°), with emphasis on the Mediterranean area, and addressing changes in climatic characteristics that need to be considered in climate change adaptation and mitigation plans.

2.2 The Multi-Fold Relationship Between Cities and Climate Change

Several publications have explained the state of the environment in cities, especially in light of new challenges such as climate change (Cartalis 2014; European Environment Agency 2012, 2013; International Council for Local Environmental Initiatives 2013; Intergovernmental Panel for Climate Change—IPCC, Climate Change 2013 and European Commission 2013). In particular, the International Council for Local Environmental Initiatives (2013) speaks about the urgent need to build cities that are resilient to climate change. IPCC (2013) also refers to the impacts of climate change on cities, mostly in terms of the increase in temperatures as well as of the increased occurrence of tropical days and heat waves. The European Environment Agency (2013), in its publication on the impacts of climate change, also refers to the impact of climate change on the European continent and correlates the increase of heat waves in Europe and the spatial and temporal enhancement of thermal heat islands in several European cities to the intensified urbanization trends in Europe.

Climate change in the built environment (hereinafter referred to as “cities”) is pragmatically described by means of a multifold relationship (EEA 2010a, b; Kamal and Alexis 2009; Stone et al. 2012):

1. Cities are major contributors to CO₂ emissions. Roughly half of the world’s population lives in urban areas; this share is increasing over time and is projected to reach 60 % by 2030. Cities consume most—between 60 and 80 %—of the energy production worldwide and account for a roughly equal share of the global CO₂ emissions. GHG emissions in cities are increasingly driven less by industrial activities and more by the energy services required for lighting, heating and cooling, appliance use, electronics use, and mobility. Growing urbanization will lead to a significant increase in energy use and CO₂ emissions, particularly in countries where urban energy use is likely to shift from CO₂-neutral energy sources (biomass and waste) to CO₂-intensive energy sources.

2. Climate change poses key threats to urban infrastructure and quality of life due to rising sea levels, more extreme storms and flooding, and extreme heat events. Heat events in particular can compromise urban infrastructure since they are expected to be felt more strongly in urban areas due to urban heat island (UHI) effects, which are strongly related to changes in land use/land cover (LULC). In particular, due to the large amount of concrete and asphalt in cities, the difference in average annual temperatures compared to rural areas ranges from 3.5 to 4.5 °C (up to a difference of 10 °C in large cities), and is expected to increase by 1 °C per decade (Santamouris 2007; Stone et al. 2010). In addition, due to urban sprawl, hotspots are developed even at distances from the city centers.
3. Climate change interacts with urbanization, population aging and socio-economic issues; it also interacts with the economic development of cities. As cities influence to considerable extent Europe's economy, any climate-related problems may place Europe's economy and quality of life under threat. At the same time, demographic trends result in an aging population, a fact that increases the number of people vulnerable to heat waves. Urbanization also reduces the area available for natural flood management, thus exposing cities to the adverse effects of extreme weather events associated with heavy storms or rainfall. The close interaction of climate change to socio-economic changes on an urban scale may increase the vulnerability of people, property and ecosystems; for the vulnerability to be faced, adaptation measures are urgently needed.
4. How cities grow and operate matters for energy demand and thus for GHG emissions. Urban density and spatial planning and organization are key factors that influence energy consumption, especially in the transportation and building sectors. The acceleration of urbanization since 1950 has been accompanied by urban sprawl, with urban land area doubling in developed countries and increasing five-fold in the rest of the world. The expansion of built-up areas through suburbanization has been particularly prominent among OECD metropolitan areas (66 of the 78 largest OECD cities experienced a faster growth of their suburban belt than their urban core between 1995 and 2005), whereas increasing density could significantly reduce energy consumption in urban areas (Kamal and Alexis 2009). It should be mentioned that the role of land in climate change and GHG mitigation has received less attention than energy systems—despite the fact that evidence from urbanized regions, where land use activities have resulted in significant changes to land cover, suggest land use to be a significant and measurable driver of climate change as well as one that operates through a physical mechanism independent of GHG emissions. In light of this evidence, the rate of warming at regional to local scales can be slowed through a reversal of land cover change activities that serve to reduce surface albedo or produce a shift in the surface energy balance.

2.3 Urbanization in Europe

Nearly 73 % of the European population lives in cities, and this is projected to reach 82 % by 2050 (United Nations 2014). Urbanization is associated with changes in materials and energy flow in the cities (Chrysoulakis et al. 2013), can increase pressures on the environment, and may support climate change mechanisms through enhanced emissions of greenhouse gases. It may also reduce the resilience of cities to extreme events associated with climate change due to urban land take and the limited capacity to regenerate the building stock of the cities. Table 2.1 provides the urban population as a percentage of the total population (for 2011 and the projection for 2050) for selected countries in the Mediterranean area (UN 2014). It also provides the urbanization rate, which describes the average rate of change per year of the urban population, as deduced for 2010 until 2015 (UN 2014).

The interplay between the urbanization process, local environmental change, and accelerating climate change needs to be carefully assessed. According to several researchers (Stone et al. 2010; Kolokotroni et al. 2010; Grimmond 2011; Santamouris 2014), the long-term trend in surface air temperature in urban centers is also associated with the intensity of urbanization.

Urbanization is also linked to urban sprawl; emissions of greenhouse gases are higher in commuter towns not only because of car dependency but also due to the characteristics of the buildings (EEA 2012; IPCC 2014). Typically, European cities are densely populated, whereas large differences are observed in the level of sprawl, both between and within European countries (EEA 2015).

Table 2.1 Urban population as percentage of the total population (for 2011 and projection for 2050) for selected countries in the Mediterranean area (UN 2014)

Country	Urban population (% of the total population 2014)	Urban population (% of total population 2050)	Average annual rate of change 2010–2015 (%)
Albania	56	76	1.9
Croatia	59	72	0.5
Cyprus	67	72	−0.2
France	79	86	0.3
Greece	78	86	0.4
Italy	69	78	0.2
Malta	95	97	0.2
Portugal	63	77	0.9
Serbia	55	67	0.1
Spain	79	86	0.3
Slovenia	50	61	−0.2
Turkey	73	84	0.7

It also provides the urbanization rate, which describes the average rate of change per year of the urban population, as deduced for 2010–2015 (UN 2014)

Table 2.2 Urban sprawl from 2000 until 2006, using the urban sprawl index, which measures the growth in built-up areas over time, adjusted for the growth in population (OECD 2013a, b)

Country	Urban sprawl index (%)
France	−2.1
Greece	1.8
Italy	0.9
Spain	3.8
Portugal	6.2
Slovenia	−4.2

Table 2.3 Population (in million inhabitants) in major cities in the Mediterranean area (2005–2010–2015)

Heading	Athens	Rome	Madrid	Lisbon	Porto	Naples	Marseille	Valencia
2005	3.251	3.345	5.619	2.747	1.303	2.255	1.413	0.804
2010	3.381	3.306	5.487	2.824	1.355	2.348	1.472	0.798
2015	3.550	3.302	5.891	2.944	1.426	2.463	1.570	0.800
Change from 2005 to 2015	9.2 %	−1.1 %	4.8 %	7.1 %	9.4 %	9.2 %	11.1 %	−0.1 %

Table 2.2 provides a view of urban sprawl between 2000 and 2006, using the urban sprawl index (OECD 2013a, b), which measures the growth in built-up areas over time, adjusted for the growth in population. When the population changes, the index measures the increase in the built-up area over time relative to a benchmark where the built-up area would have increased in line with population growth. The index equals zero when both population and the built-up area are stable over time. It is larger (smaller) than zero when the growth of the built-up area is greater (smaller) than the growth of the population, i.e., the density of the metropolitan area has decreased (increased). Urban sprawl index is higher in Portugal and Spain, at medium values in Italy and Greece, whereas it reflects negative values for France and Slovenia.

A close look at major cities in the Mediterranean area is provided in Table 2.3 for 2005, 2010, and 2015. An increasing trend is observed in most of the cities, with the most significant ones for Athens, Porto, Naples, and Istanbul.

2.4 Climate Change in Europe

Climate change is occurring in Europe as mean temperatures have increased and precipitation patterns have changed (Alcamo et al. 2007). Climate change is a stress factor for cities and ecosystems (EEA 2012), whereas climate-related extreme weather events, such as cold spells and heat waves, result in health and social impacts in Europe and may impact considerably urban infrastructure and the built environment (EEA 2010a, 2012).

High temperature extremes (hot days, tropical nights, and heat waves) have become more frequent (Vautard et al. 2013), while low temperature extremes (cold spells, frost days) have become less frequent in Europe (EEA 2012).

Climate models show significant agreement in warming, with the strongest warming in southern Europe in summer (Giorgi and Bi 2005; Hertig and Jacobbeit 2008; Goodess et al. 2009). The likely increase in the frequency and intensity of heat waves, particularly in southern Europe, is projected to increase heat-attributable deaths unless adaptation measures are undertaken (Baccini et al. 2011; WHO 2011a, b; IPCC 2014). Without adaptation, between 60,000 and 165,000 additional heat-related deaths per year in the EU are projected by the 2080s, depending on the scenario (Ciscar et al. 2011).

Finally, even under a climate warming limited to 2 °C compared to pre-industrial times, the climate of Europe is projected to change significantly from today's climate over the next few decades (Van der Linden and Mitchell 2009).

2.5 Climate in the Mediterranean Area

The climate in the Mediterranean area is affected by interactions between mid-latitude and tropical processes (Giorgi 2008; Xoplaki et al. 2003), whereas it has shown large climate shifts in the past (Luterbacher et al. 2007). Overall, the climate is mild and wet during the winter and hot and dry during the summer (Gao et al. 2006); however, a main characteristic of the Mediterranean area is the high spatial variability in seasonal mean temperature and total precipitation (Table 2.4). Such variability is enhanced by the orography of the area as well as land-sea interactions.

The winter climate is mostly dominated by the westward movement of storms originating over the Atlantic and impinging upon the western European coasts. The winter Mediterranean climate, and, most importantly, precipitation, are thus affected by the North Atlantic oscillation over its western areas (e.g., Hurrell et al. 1995), the East Atlantic, and other patterns over its northern and eastern areas (Xoplaki et al. 2004). In addition to Atlantic storms, Mediterranean storms can be produced internally to the region in correspondence to cyclogenetic areas, such as the the Gulf of Lyon and the Gulf of Genoa (Lionello et al. 2006b), or depressions originating from the southwestern Mediterranean Sea. Table 2.4 summarizes the Mediterranean climate in winter and summer (Ulbrich et al. 2006; IPCC 2013).

In addition to planetary scale processes and teleconnections, the climate of the Mediterranean is affected by local processes induced by the complex physiography of the region and the presence of a large body of water. For example, the Mediterranean Sea is an important source of moisture and energy for storms (Lionello et al. 2006a, b; Ulbrich et al. 2006) as thermodynamic instability is developed and sustained due to synoptic systems developed in the southern Mediterranean and spreading to the northeast.

Table 2.4 Summary of climate patterns and characteristics in the Mediterranean area in winter and summer

Period	Overall pattern	Climate characteristic
Mediterranean winter (DJF)	From very cold mountainous (Alps, Dinaric Alps, Pyrenees) to mild areas along the coastlines of to the south of the peninsulas, the eastern basin and North Africa	The total winter precipitation amounts range from 50 to 100 mm (North Africa) to over 500 mm (along western coasts of the peninsulas enhanced due to orographic forcing and land sea interactions)
Mediterranean summer (JJA)	Mean summer (JJA) temperatures show a gradient from north (cool) to south (warm) and exceed 30 °C in the southeast. High pressure and descending motions dominate the region, leading to dry conditions, particularly over the southern Mediterranean	Large areas receive no rain during summer, while in mountainous areas, precipitation totals can reach 400 mm

2.6 Climate Change in the Mediterranean Area

Increasing droughts and extreme climate phenomena (heat spells/heat waves) are key future characteristics that will put the whole region under serious pressure until 2100 (IPCC 2013). In particular, the Mediterranean area has been identified as one of the most prominent “hot-spots” (a region whose climate is especially responsive to global change) in future climate change projections (Giorgi et al. 2006).

An analysis of near-surface temperature observations over the Mediterranean land areas during the recent past shows increasing trends (EEA 2012; Ulbrich et al. 2012; IPCC 2013, 2014). In particular, the region surrounding the Mediterranean Sea has been warming during most of the twentieth century, with the warming trend being, during the period 1951–2000, about 0.1 °C/decade. The warming is found to have a remarkable spatial and seasonal modulation. During the summer in the north, the trend over western and central Europe appears to be greater than in the winter season. The largest trend (up to 0.2 °C/decade) is found in summer (JJA) over the Iberian Peninsula and western part of North Africa.

In accordance with the wide-spread increase of hot extremes, the first decade of the twenty-first century has been characterized by frequent heat waves within the Mediterranean-European region (EEA 2012).

The heat wave of summer 2003 struck Western Europe, including France, Spain and Portugal. Moreover, according to state-of-the-art regional multi-model experiments, the probability of a summer experiencing “mega-heatwaves” will increase 5–10 times within the next 40 years (Barriopedro et al. 2011). Based on the above findings, a synopsis of the changes per climatic parameter for the Mediterranean area is provided in Table 2.5.

Table 2.5 Synopsis of change per climatic parameter for the Mediterranean area

Climatic parameter	Observed change
Temperature	A general decreasing trend of cold extremes is found. Since 1970, an increase in air temperature of almost 2 °C has been recorded in southwestern Europe (Iberian Peninsula and south of France). In summer, a prominent increase is found almost everywhere and especially over the sea. Increasing trends have been particularly strong over the last 20 years (1989–2008) over the Central and Eastern Mediterranean
Precipitation	Decreasing precipitation throughout the region (mainly western Mediterranean, southeast Europe and Middle East). Southern countries are among the most water-stressed ones
Sea level	The global mean of sea-level rise was around 3 mm per year over the last two decades. The Intergovernmental Panel on Climate change predicts a sea-level rise of 0.1–0.3 m by 2050 and of 0.1–0.9 m by 2100, with significant (and possibly higher) impacts in the southern Mediterranean area
Cyclones and wind storms	General decrease in the density of cyclone tracks; general decrease in the frequency of cyclones associated with extreme winds
Overall	The Mediterranean climate would become progressively warmer, drier, and less windy in the twenty-first century

Table 2.6 Climate extremes occurring in the Mediterranean area

Extreme temperatures	General increase in the number of very hot days and nights as well as longer warm spells and heat waves, with the largest increases over the Iberian Peninsula in summer. Hot extremes in winter also increase in the western Mediterranean, whereas in the eastern Mediterranean, some decrease is observed. General decrease in the number of very cold days and nights and shorter cold spells
Extreme precipitation	Increase in heavy daily precipitation in winter over the Iberian Peninsula except for the south, southern Italy and the Aegean, and a weak general increase in the percentage of winter precipitation in association with strong daily precipitation events; decrease in the number of days with heavy precipitation over the western and central part of the Mediterranean region and an increase over the north-eastern part; general increase in the intensity of heavy precipitation events over the entire Mediterranean region in all seasons except for the southwestern part with a reduction in the warm season, mainly caused by the increased atmospheric moisture content
Cyclones and wind storms	No significant change in the intensity of the most extreme wind storms

Specific reference is made to the climate change impacts with respect to climate extremes occurring in the Mediterranean area (Table 2.6).

In Fig. 2.1, a combined view of “Aggregate potential impact of climate change,” “Overall capacity to adapt to climate change,” and “Potential vulnerability to climate change” is provided (EEA 2012). The Mediterranean area, including

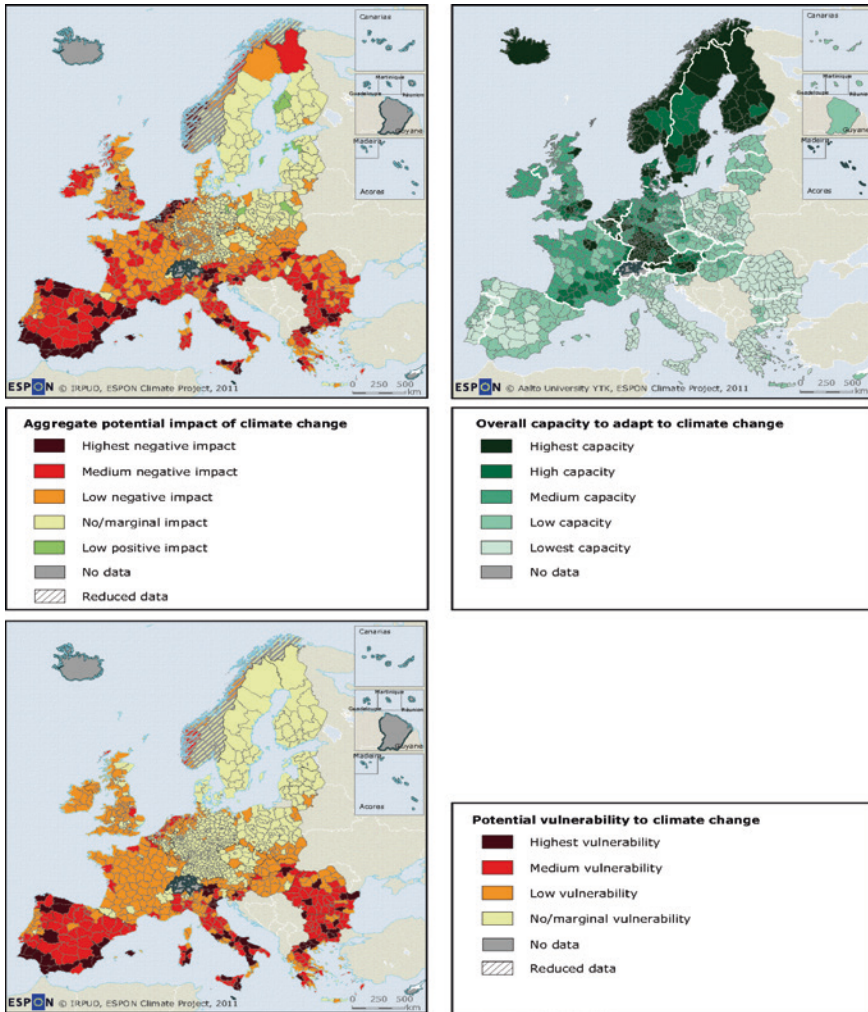


Fig. 2.1 A combined view of “Aggregate potential impact of climate change,” “Overall capacity to adapt to climate change,” and “Potential vulnerability to climate change” for the Mediterranean area (<http://www.eea.europa.eu/legal/copyright>; © European Environment Agency)

urban areas, shows, overall, medium negative potential impact; coastal areas in Spain and coastal/inland areas in Italy show the highest negative potential impact of climate change. Furthermore, the Mediterranean area shows medium to highest vulnerability to climate change (in the same overall areas as before), a fact that if linked to the limited capacity to adapt to climate change, reflects the sensitivity of the area in climate change and the urgent need to adapt measures in full temporal and spatial scales and a wide sectoral range.

2.7 Impacts of Climate Change on Cities

Potential changes in the climate characteristics in the Mediterranean area are expected to impact cities, buildings and infrastructure, and the ecosystem. Cities, in particular, may be considered climate change hot spots in the sense that potential climate change impacts on the urban environment or different activity sectors can be particularly pronounced. Some of the impacts are determined by complex relationships between various aspects of the climate changes, i.e., changes in temperature and in precipitation, urban characteristics, such as urban density, type and age of buildings, and various socio-economic aspects, i.e., the possibilities for adaptation to these changes, share of vulnerable population, and energy poverty (Wilby 2007).

1. Detection of climate-driven changes and trends at the scale of individual cities is problematic due to the complexity of a number of coupled processes and the high inter-annual variability of local weather and factors, such as land-use change or urbanization effects. Furthermore, climate change can influence the dynamics of a city, and a city may modify the climate at the local level. Table 2.7 provides a number of coupled processes that may be influenced by the interaction of urbanization and climate change.
2. The physical constituents of built areas within cities also interact with climate drivers. For example, runoff from impervious surfaces can increase risks of flooding and erosion, and will reduce evapotranspiration with impact on the energy budget of the respective area, whereas it may also result in poor water quality due to uncontrolled discharging of storm water.
3. Atmospheric circulation patterns are a major factor affecting ambient air quality and pollution episodes, and hence the health of urban populations as witnessed during the 2003 heat wave (EEA 2003; Gryparis et al. 2004). Several studies have indicated that weather patterns favoring air stagnation, heat waves, lower rainfall and ventilation could become more frequent in the future, leading to deteriorating air quality (Leung and Gustafson 2005).
4. Built areas have UHIs that may be up to 5–6 °C warmer than in the surrounding countryside (Oke 1982; Santamouris 2007; Mihalakakou et al. 2004; Santamouris et al. 2015). Building materials retain more solar energy during the day and have lower rates of radiant cooling during the night. Urban areas

Table 2.7 Coupled processes that may be influenced by the interaction of urbanization and climate change

Coupled process	Example
Altering small-scale local processes	Land–sea breeze
Modifying synoptic meteorology	Changes in the position of high pressure systems in relation to UHI events
Enhancing radiative forcing	Changes in the energy budget due to increase of GHGs
Enhancing urban heat islands (UHI)	Changes in land use/land cover

also have lower wind speeds, less convective heat losses and evapotranspiration (due to the limited share of such land cover as bare soil or green areas), yielding more energy for surface warming. Artificial heating and cooling of buildings, transportation and industrial processes introduce additional sources of heat into the urban environment causing distinct weekly cycles in UHI intensity (Wilby 2003) and its overall increase with years. Using statistical methods, it has been found (Santamouris 2012) that the nocturnal UHI in Athens could further intensify during the summer by the 2050s. This translates into a significant increase (more than 30 %) in the number of nights with intense UHI episodes.

5. With increasing surface and near-surface air temperatures, heat waves are expected to increase in frequency and severity in a warmer world (Meehl and Tebaldi 2004; Santamouris et al. 2015). UHIs will enhance the effects of regional warming by increasing summer temperatures relative to peri-urban and rural areas.

In Fig. 2.2, the modeled number of heat wave days [termed as combined tropical nights (days in which the lowest temperature is higher than 20 °C) and hot days (>35 °C)] are provided in the background. Higher values (in purple) are seen in the Mediterranean area, mostly in Greece, Italy, and southern Spain and Portugal. In the same figure, urban areas are depicted graphically in terms of their population density and the share of green and blue areas; it can be seen that the share of green and blue areas in southern cities is less than 30 % and in many cases even less than 20 %. The higher the population density and the lower the share in green and blue areas, the higher the intensity of the UHI. To this end, a large number of cities in Europe, and in the Mediterranean area in particular, are considered to have strong UHI potential and are thus expected to experience relatively strong increases in heat load in the future.

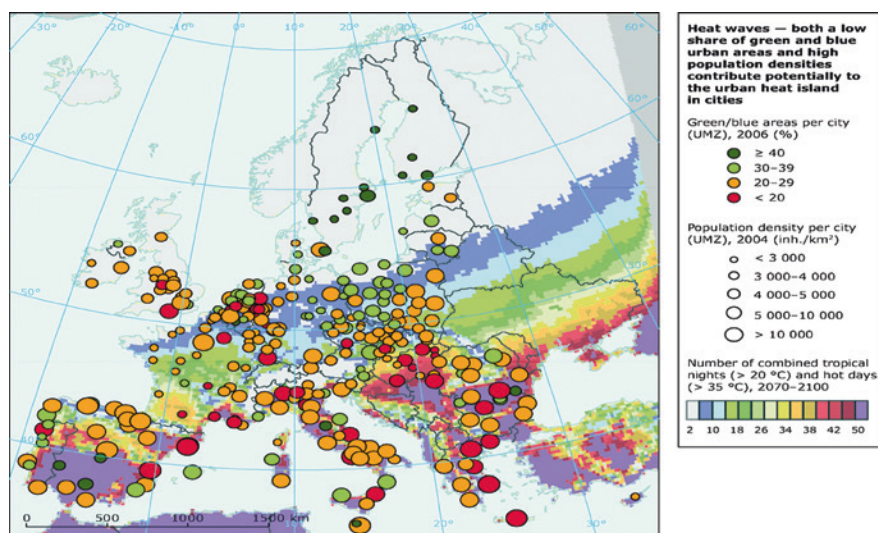


Fig. 2.2 Projection of heat wave days for Europe for the period 2070–2100 (<http://www.eea.europa.eu/legal/copyright>; © European Environment Agency)

6. Mortality increases in hot weather, especially among the most vulnerable, including the elderly. During the great European heat wave of 2003, urban centers, such as Paris, were particularly affected due to extreme day temperatures (Tobias et al. 2010). Under existing air pollution abatement policies, 311,000 premature deaths are projected for 2030 due to ground-level ozone and fine particles (EEA 2006). Full implementation of measures to achieve the long-term climate objective of the EU in terms of limiting global mean temperature increases to 2 °C, would reduce premature deaths by over 20,000 by 2030.
7. Urban air pollution concentrations may also increase during heat waves, with significant consequences for mortality as in the summer of 2003. This is because high temperatures and solar radiation stimulate the production of photochemical smog as well as ozone precursor volatile organic compounds (VOCs).
8. The impacts of climate change, including increasingly hot weather and heat waves, are expected to rise in areas with higher concentrations of vulnerable people, including the elderly, who are considered to be a group more sensitive to various climatic stress factors than younger people. As seen in Fig. 2.3, a significant number of cities in the Mediterranean area have proportions of vulnerable people (aging 65 and over), in medium and high percentages: in the range of 15–17 % for Athens, Naples, Porto, Valencia, etc., of 17–20 % for

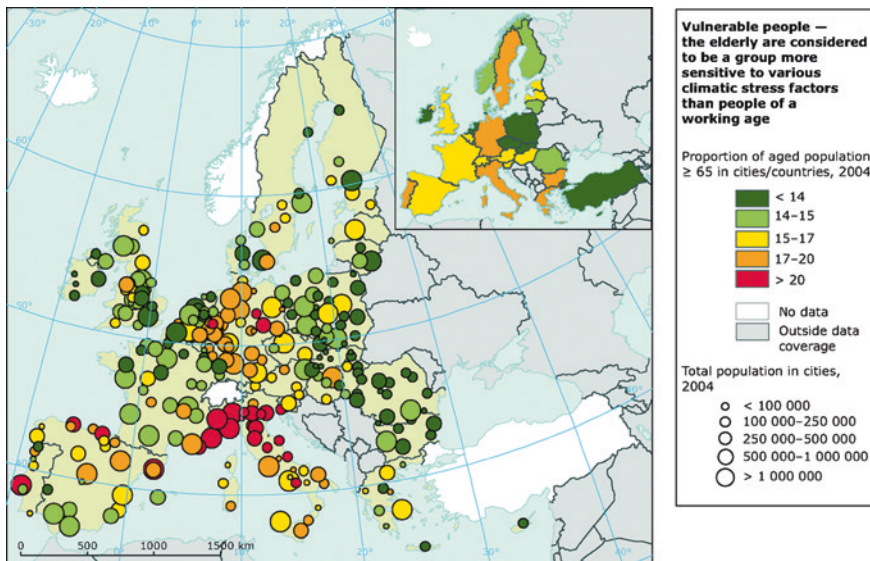


Fig. 2.3 Proportion of population over 65 years old in cities and countries. Elderly people are considered to be more vulnerable to various climatic stress factors (<http://www.eea.europa.eu/legal/copyright>; © European Environment Agency) the urban

Barcelona, Madrid, Marseille, Naples, etc., and more than 20 % for Lisbon, Nice, and Milan.

9. Thermal comfort is important for the built environment for two reasons: (1) the temperatures that people set in their homes are an important factor for energy consumption, and (2) whether a person feels comfort or discomfort depends on the state of the thermal environment, the quality of the building stock they occupy, and their ability to afford to mechanically heat or cool the building. Since thermal comfort depends directly on air temperature, it is expected to deteriorate in warming cities (Polydoros and Cartalis 2014).
10. Housing infrastructure is vulnerable to extreme weather events that may be caused due to climate change. In practical terms, buildings that were originally designed for certain thermal conditions will need to operate in drier and hotter climates in the future (WHO 2008).
11. Climate change is expected to result in the increased use of cooling energy and reduced use of heating energy (Cartalis et al. 2001; Santamouris 2001, 2012). Asimakopoulos et al. (2012), in his projections for Greece, indicates reductions of energy use for heating of up to 25 %, and highly increasing needs for additional energy for cooling. Future estimates show that 15 more days of heavy cooling will be required over parts of southern Spain and Italy, eastern Greece, and western Turkey and Cyprus (Giannakopoulos et al. 2009a). Elsewhere, increases of fewer than 15 days are evident for the near future (2021–2050). In another study, Giannakopoulos et al. (2009b) states that an additional two to three weeks along the Mediterranean coast will require cooling, whereas up to five more weeks of cooling will be needed inland by the end of the twenty-first century, i.e., by 2071–2100.
12. Regarding both heating and cooling, the total annual energy demand for the Mediterranean area as a whole is estimated to increase in future decades due to climate change (Giannakopoulos et al. 2009a; Santamouris et al. 2015); as a result, increases in the net annual electricity generation costs in most of the Mediterranean countries is estimated (Mirasgedis et al. 2007).
13. The cooling potential of natural ventilation falls with rising outdoor temperatures; as a result the demand for summer cooling could grow as internal temperatures rise during heat waves. For example, a study of energy demand in Athens showed a 30 % increase by the 2080s during July and August (Giannakopoulos and Psiloglou 2006).
14. Climate change will affect the built environment that is culturally valued through extreme events and chronic damage to materials (Brimblecombe 2010). In particular, marble monuments in the Mediterranean area will continue to experience high levels of thermal stress (Bonazza et al. 2009).
15. Green space is regarded by many as a crucial component of urban landscapes: for countering the UHI, reducing flood risk, improving air quality, and promoting habitat availability/connectivity (Julia et al. 2009). Green spaces are also susceptible to climate change, which implies that consideration needs to be given so that vegetation will not lead to local drying of soils.

16. Coastal cities are particularly vulnerable to climate change as this increases their vulnerability to rising sea levels and storm surge, presenting severe risks to the building stock and urban infrastructure (Nicholls 2004). Assessments of future flood risk for coastal cities reflect the added complexity of interactions between sea level rise, tidal surges, and storminess (Nicholls 2010).

2.8 Conclusion

Increasing droughts and extreme climate phenomena (heat spells/heat waves) are key future characteristics that will put the entire region, and especially cities and their built environments, under serious pressure until 2100 (IPCC 2013). In light of this, the Mediterranean area has been identified as one of the most prominent “hot spots” in future climate change projections (Giorgi 2006).

The high density and the poor (from an energy efficiency point of view) building stock of several Mediterranean cities, and the limited share of green areas within the boundaries of the cities, in conjunction with the higher percentage shares of vulnerable people (including elderly and urban poor), are key factors raising their vulnerability to climate change, including climate extremes (Grimmond 2011; IPCC 2014).

Building cities that are resilient and sustainable should be the basis of any local, regional, or national adaptation plan to climate change. This is highly important as if urbanization trends in the Mediterranean area are sustained, nearly 85 % of the population in the northern countries of the area will live in cities. Plans need to reflect multidisciplinary cooperation and sector policy reforms, such as urban transport policies, low carbon, and energy efficiency measures with emphasis on the building stock, and sustainable and resilient city planning. Decisions taken today define the future of many Mediterranean cities, in which the building and urban infrastructure for 2050 is being built today, yet 2050 will be very different from today—at least from a climatic point of view.

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