Interreg Mediterranean
URBAN TRANSPORTS

Urban mobility Adaptation to Climate Change

Executive summary

The policy brief aims to raise awareness among policymakers and provide urban planners with an overview of what will be the impact of climate change on Mediterranean cities with a particular focus on mobility issues.

So far, the focus on the transport sector had to do mostly with decarbonising it and making mobility more sustainable. Even though climate change mitigation is generally seen as the priority strategy for preventing or at least minimizing the impact of climate change, we must nevertheless be aware that its effects are already impacting our everyday life. Consequently, urban planners should be aware of this evolution and include adaptation measures in their mobility plans.

Furthermore, transport infrastructures will be exposed, in the next decades, to an increasing number of new challenges from climate impacts, which are only partly already visible. Planning today for the construction of new and the management of existing infrastructures will require the consideration of new environmental, climatic and socio-economic parameters and conditions with respect to those used in the past.

The present policy brief describes the main impacts of climate change on urban mobility and suggests possible solutions to minimise its impacts.

The work is based on a review of existing literature on the topic and on the feedback provided by experts in different fields: mobility planning, urban planning, climate change, economics and environmental health. The experts were interviewed and, in a later stage, they took part in a series of workshops organized by the Urban Transport project. They thus had the opportunity to interact, share their knowledge and explore the issue of urban mobility adapting to climate change from different perspectives.

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Setting the scene context: the Mediterranean is a climate change hot spot

Climate change is affecting nature, people's life and infrastructure everywhere around the globe. As stated by Prof Dr Hans-Otto Poertner, Co-Chair of the Intergovernmental Panel on Climate Change (IPCC) Working Group II "Climate change is a threat to human wellbeing and the health of the planet. Any further delay in concerted global action will miss a brief and rapidly closing window to secure a liveable future".

We live in a world 1.1°C warmer than pre-industrial levels, where extreme weather events such as heatwaves, droughts and floods have become more frequent and are already exceeding plants' and animals' tolerance thresholds. At the same time, such hazards, including also storms and sea level rise, are increasingly adversely affecting people's health, lives, property, infrastructures, energy and transportation systems.

Densely populated urban areas are very much exposed to climate change risks, but they are also a crucial part of the solution if adaptation strategies are well planned.

While climate change is a global issue, there are regions that are affected more than others by this phenomenon. Both the "First Mediterranean Assessment Report" (MedECC - November 2020) and the IPCC Sixth Assessment Report "Climate Change 2022: Impacts, Adaptation and Vulnerability" (IPCC – February 2022) agree that the Mediterranean area is the most threatened region in the European continent, as it is warming up 20% faster than other regions.

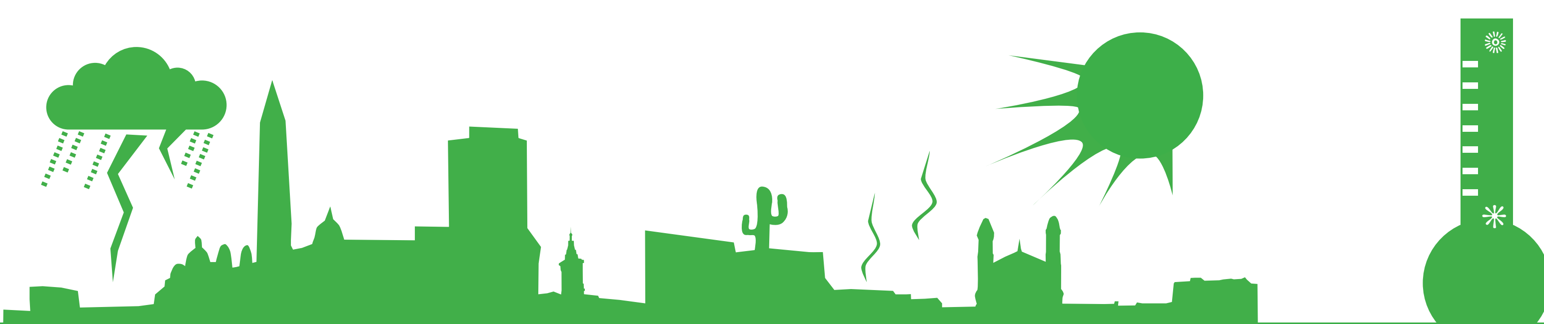
The Intergovernmental Panel on Climate Change (IPCC) back in 2013 already considered the Mediterranean Region to be "highly vulnerable to climate change" due to the influence of multiple stressors. In its latest report (2022) the IPCC defines the Mediterranean Basin as a "climate change hotspot" due to the high exposure and vulnerability of human societies and ecosystems to the risks associated with climate change, including sea level rise, heat waves and fire hazard.

Climate

The average weather for a particular region and time period, usually taken over 20-30 years.

Vulnerability

The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.



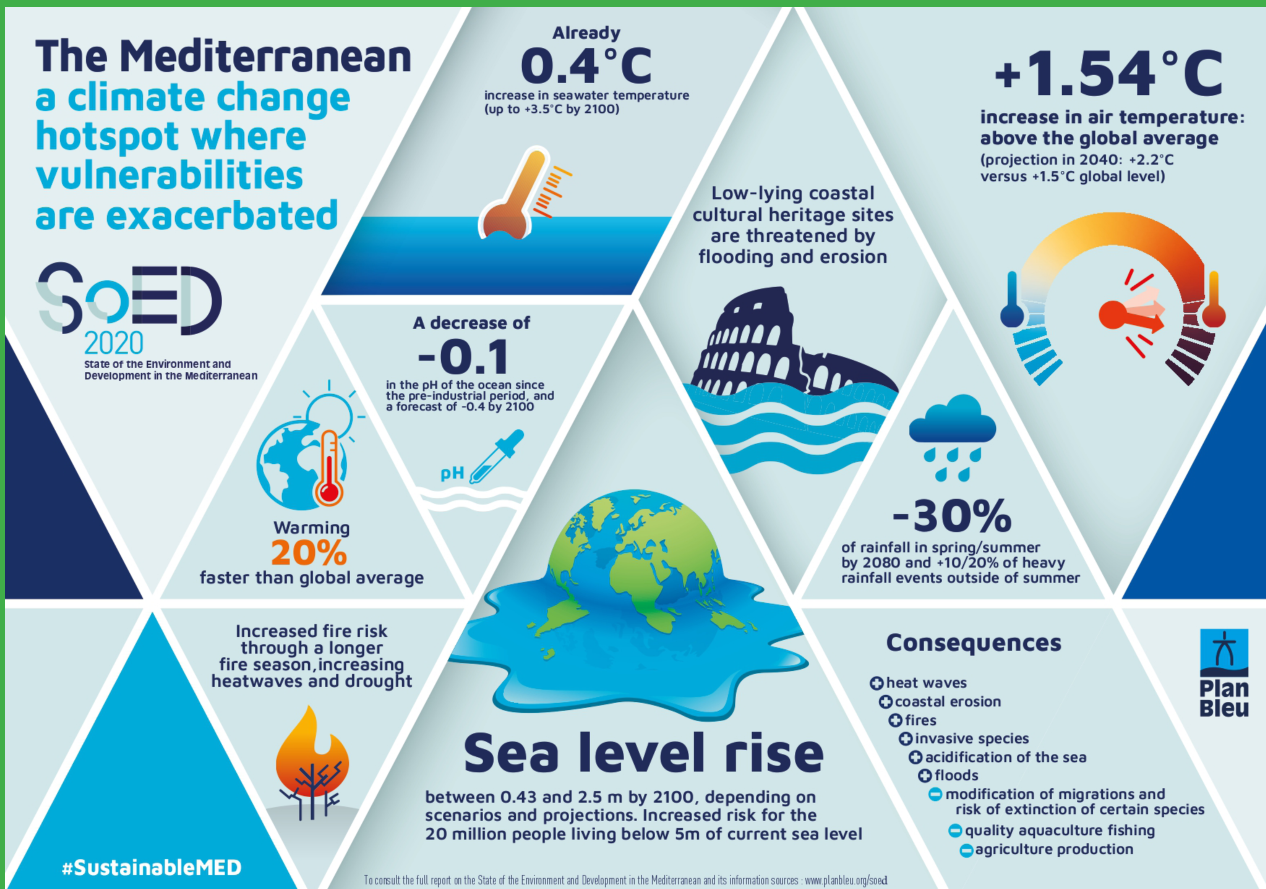


Figure 1 - The Mediterranean is a climate change hotspot
Source: UNEP/MAP and Plan Bleu, 2020

Use of climate scenarios in adaptation planning

The policy brief aims to raise awareness among policymakers and provide Socio-economic and emission scenarios are used in climate research to describe how the future may evolve according to different variables, including socio-economic change, population growth, technological change, land use patterns, and emissions of greenhouse gases and air pollutants.

The IPCC used these drivers to create the **Representative Concentration Pathways (RCPs)**, a set of four pathways developed for the climate modelling community as a basis for near- and long-term modelling experiments and projections of future GHG emissions, air pollution and land use. RCPs quantify future greenhouse gas concentrations and the radiative forcing (additional energy taken up by the Earth system) due to increases in climate change pollution. Indeed, the numeric suffix represents the radiative forcing, expressed in W/m2, estimated at 2100 compared to the pre-industrial era (1850 - 1900), for the different trajectories. The four RCPs are the following:

- The RCP 2.6 scenario aims to keep global warming below 2°C above pre-industrial temperatures. It implies the adoption of strong mitigation policies associated with a reduction of emissions.
- The RCP 4.5 represents the "intermediate scenario" where CO2 emissions will rise until 2040, and then decline thanks to initiatives aimed at controlling and reducing GHG emissions.
- The RCP 6.0 is a "stabilization scenario" in which total radiative forcing is stabilized shortly after 2100 by applying various technologies and strategies to reduce GHG emissions.
- The RCP 8.5 is the "high emissions scenario" that will deliver a temperature increase of about 3.7±1.1°C by 2100, relative to pre-industrial temperatures. Current emissions continue to grow consistently without effective climate change mitigation policies.

The IPCC Sixth Assessment Report (6AR) introduced new scenarios. They combine the emission pathways (RCPs) with the **Shared Socio-economic Pathways (SSPs)**, which consider additional human elements like population and economic growth projections and technological and geopolitical trends. All these factors impact GHG emissions and society's ability to reduce them and adapt to climate change. Five scenarios have been considered in the IPCC 6AR:

- SSP1-1.9 and SSP1-2.6 are optimistic scenarios that consider the commitment of the Paris Agreements in order to contain global warming below 2°C;
- SSP2-4.5 is the scenario that is more similar to the historic pattern of socio-economic development of the world and the one we are moving towards considering the present climate actions adopted. It could lead to a global warming of about 2,7°C by the end of the century;
- SSP3-7.0 foresees a constant rise in emissions which will cause a 3,6°C increase in global temperature by 2100;
- SSP5-8.5 considers an increase in fossil fuels extraction and uses, and an energy-intensive lifestyle which will lead to a rise in temperature by 4,4°C.

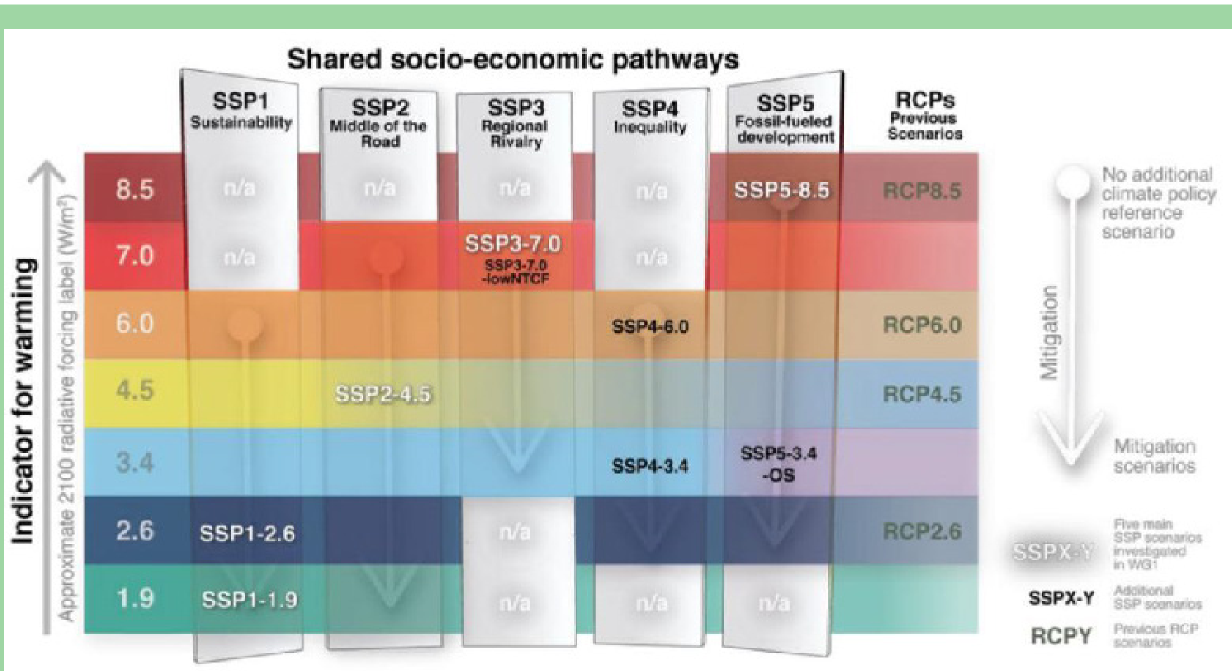


Figure 2 - The SSP scenarios used in the IPCC 6AR, their indicative temperature evolution and radiative forcing categorization, and the five Shared Socio-economic Pathways (SSP) upon which they are built.
Source: IPCC (2021) Cross-Chapter Box 1.4, Figure 1.

Climatologists conduct their studies considering time slices of about 20-30 years to reduce errors due to climate variability and different scenarios according to different possible GHG emission profiles. The IPCC 6AR consider 3 future time slices: near-term (2021 – 2040), mid-term (2041 – 2060) and long-term (2081 – 2100).

Policymakers and urban planners, on the other hand, when drafting plans like the Sustainable Energy and Climate Action Plan (SECAP) and Sustainability Urban Mobility Plan (SUMP), plan for near-term as 2030 and only seldom for mid-term as 2050. Policymakers and planners have been focused only on mitigation measures so far, concentrating in reducing emissions by a certain deadline.

However, **when planning adaptation measures, it is necessary to consider the level of global warming that will be reached at a certain date.** The year 2030 corresponds to the near-term and 2050 to the mid-term period considered by climatologists. In order to plan on the basis of climate studies, the most probable scenarios should be taken into account (apart from the deadline to 2030 and 2050), considering the present GHG emission profile and the foreseen one according to global trends and actions.

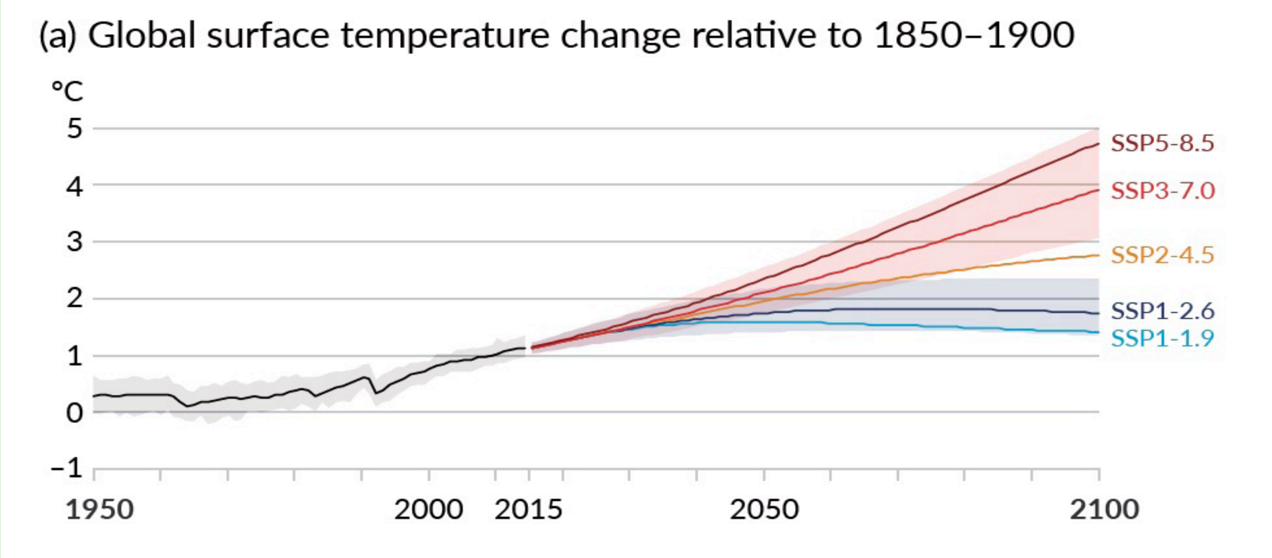


Figure 3 - Global surface temperature changes relative to 1850-1900, degrees Celsius, under the five core emissions scenarios used in AR6.
Source: IPCC (2021) Figure SPM.8a.

Scenario	Near term (2021 – 2040)		Mid-term (2041 – 2060)		Long-term (2081 – 2100)	
	Best estimate	Very likely range	Best estimate	Very likely range	Best estimate	Very likely range
SSP1-1.9	1.5°C	1.2°C to 1.7°C	1.6°C	1.2°C to 2.0°C	1.4°C	1.0°C to 1.8°C
SSP1-2.6	1.5°C	1.2°C to 1.8°C	1.7°C	1.3°C to 2.3°C	1.8°C	1.3°C to 2.4°C
SSP2-4.5	1.5°C	1.2°C to 1.8°C	2.0°C	1.6°C to 2.5°C	2.7°C	2.1°C to 3.5°C
SSP3-7.0	1.5°C	1.2°C to 1.8°C	2.1°C	1.7°C to 2.6°C	3.6°C	2.8°C to 4.6°C
SSP5-8.5	1.6°C	1.3°C to 1.9°C	2.4°C	1.9°C to 3.0°C	4.4°C	3.3°C to 5.7°C

Table 1 - AR6 assessed warming projections for each of the five core emissions scenarios in the near, mid and long term.
Source: IPCC (2021) Table SPM.1

Projections according to different scenarios do not differ much for the near term, all indicating an increase of 1.5°C compared to pre-industrial level. Policymakers and urban planners need to have this minimum temperature rise as a basis when planning for 2030.

The scenarios diverge in the mid- and long-term. Assuming that, as stated by some experts, the Paris agreement could not be met (containing global warming below +2°C by 2100), SSP1-1.9 and SSP1-2.6 scenarios should not be considered. On the other hand, **SSP2-4.5**, the so called "intermediate scenario", in line with the historic pattern of socio-economic development of the world so far, **could be the most likely to occur.** Therefore a **+2.0°C increase in temperature should be considered** when planning for the mid-term (2050) and +2.7°C as a trend for the long-term or end of the century (2100). Since 2.7°C is very close to +3.0°C, the latter value could be considered for the long-term because climate change impact scenarios are available for this global warming value[1].

When planning and designing new transport infrastructures, the long-term must be considered because, due to their service life, they will last for more than 50 years and face the climate impacts of the end of the century. If future climate change impacts are considered, the new infrastructures will remain functional and usable for a long time, avoiding the necessity of modifying them to adapt.

[1] Interactive: The impacts of climate change at 1.5C, 2C and beyond | Carbon Brief

How is climate change impacting the Mediterranean urban environments?

Cities are vulnerable to the impacts of climate change and the risks associated with it are exacerbated by a continuous and increasing urban growth and artificialization of urban environments. Flooding, heat waves, heavy precipitations, extreme hot days and droughts are the most pronounced hazards faced by Mediterranean cities and climate change is going to increase the severity and frequency of such threats due to the particular characteristics of urban environments.

The main drivers of change include:

- **climate-related** drivers such as temperature, precipitation, atmospheric circulation, extreme events, sea-level rise, sea water temperature, salinity and acidification;
- **non-climate-related** drivers such as population increase, urbanisation, pollution, unsustainable uses of natural resources as land, water, terrestrial and marine ecosystems and the spread of non-indigenous species.

Due to global and regional trends of the drivers, climate change impacts will be exacerbated in the coming decades, especially if global warming exceeds 1.5 to 2°C above the pre-industrial level.

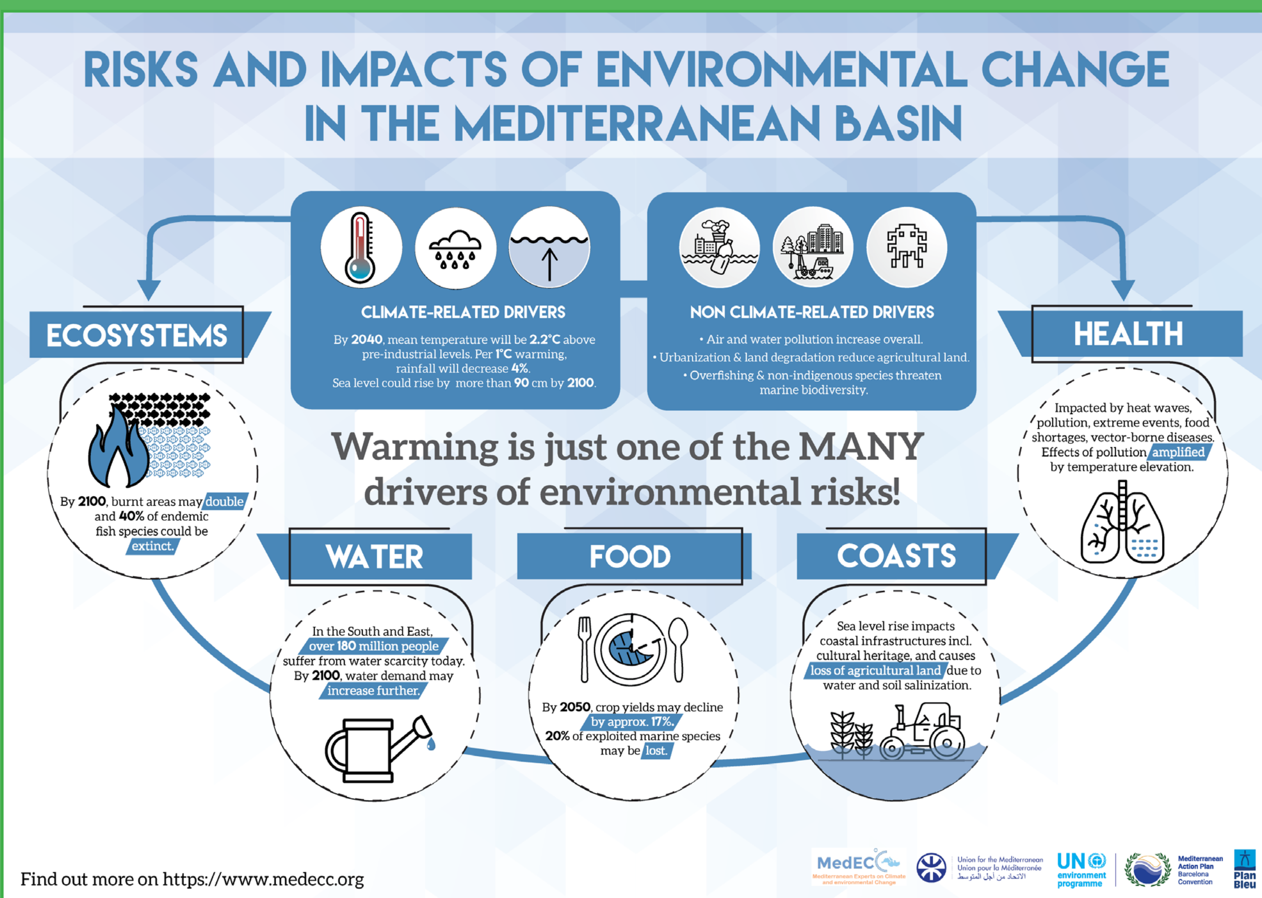


Figure 4 - General overview of drivers and impacts of climate and environmental change on the Mediterranean Region
Source: https://www.medecc.org/outputs/infographic-mar1-main-results-2020/

A warming region

Due to anthropogenic emissions of greenhouse gases, the Mediterranean Region has warmed up and will continue to do so faster than most areas of the world. Surface temperature is now **already 1.5°C higher than during pre-industrial times** (FIG 5) and it is expected to rise until 2100 by an additional 3.8 to 6.5°C in the worst-case scenario (RCP8.5) and from 0.5 to 2.0°C for the optimistic, but unlikely to happen, scenario (RCP2.6) (MedECC, 2020).

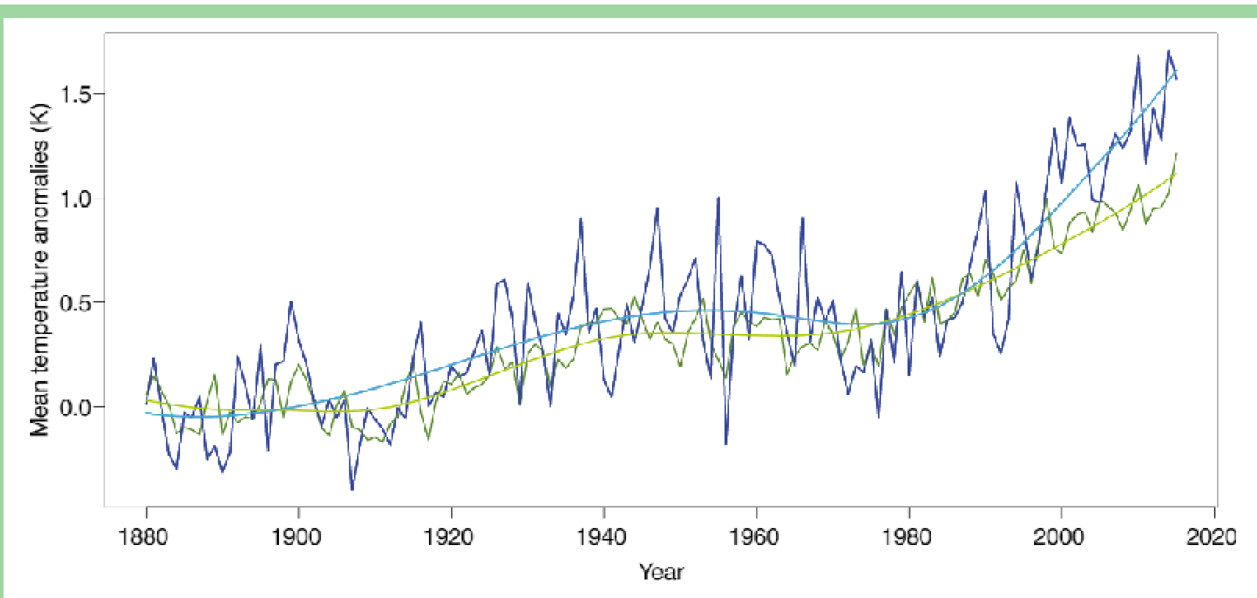


Figure 5 - Historic warming of the atmosphere globally and in the Mediterranean Basin. Annual mean air temperature anomalies are shown with respect to the period 1880–1899, with the Mediterranean Basin (blue) and the globe (green) presented with (light curves) and without (dark curves) smoothing.
Source: Data from Berkeley Earth cited in Cramer et al, 2018.

Since the beginning of the industrial era, the mean annual temperature for the Mediterranean Basin has constantly risen over the years as well as extreme temperatures, heatwaves and tropical nights that have increased in intensity, number, and length during recent decades, particularly in summer, and are projected to continue increasing (IPCC, 2022).

Tropical night
A night whose average minimum temperature is higher than 20 °C.

Heatwave
A persistent period of excessively and unusually hot weather

The **sea surface temperature** in the Mediterranean has also already warmed by around 0.4°C per decade during the period between 1985 and 2006 and is expected to reach between + 1.8°C and + 3.5°C compared to the 1961 - 1990 period by 2100. Marine heatwaves have become longer and more intense and both parameters are projected to continue increasing in the future (IPCC 2022).
The increase in heat in the atmosphere due to global warming causes more frequent and severe extreme weather events, like cyclones or Medicanes, windstorms and hailstorms.

Medicane

The term is the contraction of “Mediterranean hurricane”.

The combined effect of heat and humidity

The human body regulates its temperature by eliminating excess heat through sweating. As relative humidity increases, sweating becomes ineffective because the air is already saturated and no longer able to receive further water as vapour. In such extreme conditions of heat and humidity, the body, even at rest, cannot cool down and this causes several health problems and could even lead to death in some hours. The wet-bulb temperature is used to measure the combination of temperature and humidity in the air. When the wet-bulb temperature reaches 32°C a person is no more able to perform outdoor activities and 35°C is considered the theoretical survivability limit (equivalent to a heat index of 70 °C).

A recent study (Raymond et al. 2020) recorded occurrences of extreme heat and humidity throughout the world and found that in some areas they are increasing in frequency and intensity, although they are limited in time (some hours) for now. As figure 6 shows, such weather conditions could become a problem in some parts of the Mediterranean region too and, indeed, high daily maximum wet-bulb temperatures over 32°C have already been recorded in the Mediterranean basin.

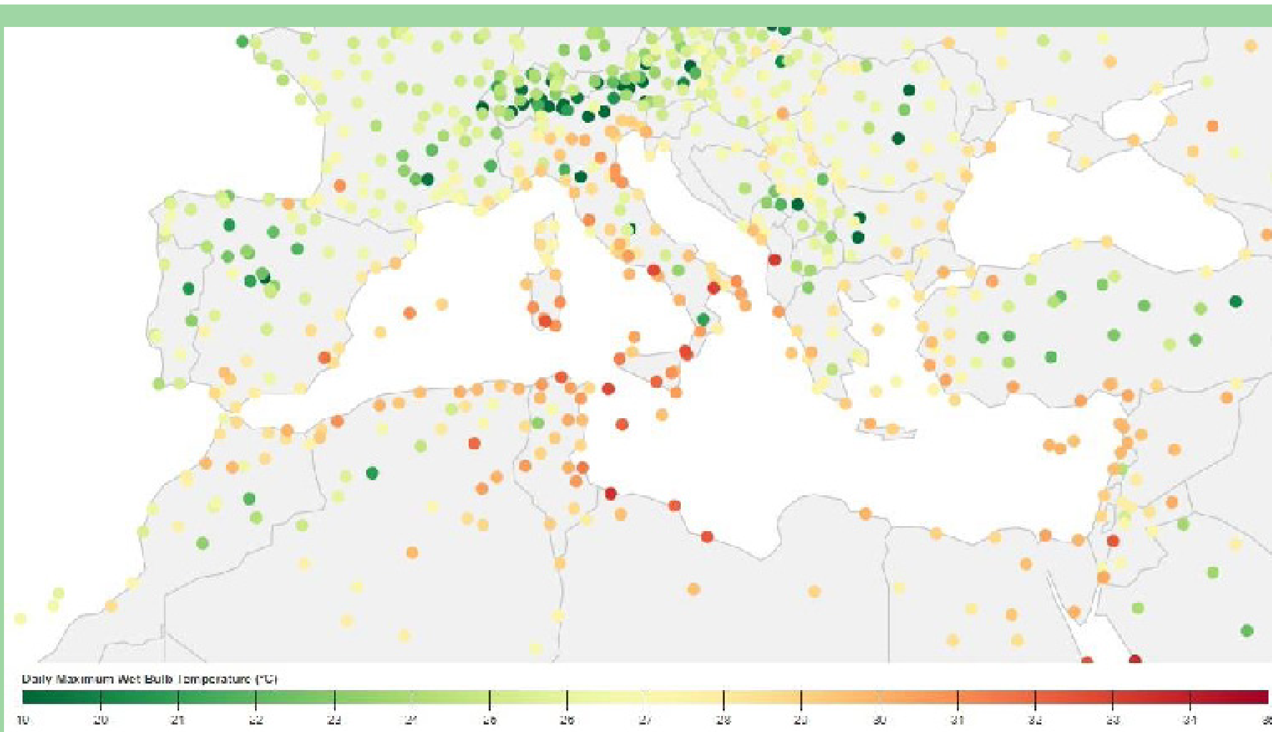


Figure 6 - Daily Maximum Wet-Bulb Temperature. Focus on the Mediterranean basin
Source: Columbia.edu

The Clausius–Clapeyron relationship of thermodynamics states that for every 1-degree increase in temperature there is a 7% increase in water content in the atmosphere. Therefore, these extreme heat and humidity conditions will be an increasingly frequent risk in the Mediterranean region.

Furthermore, the increase in sea temperature and marine heatwaves, and the consequent increase in sea water evaporation and air humidity, combined with the urban heat island effect, will **raise the number of tropical nights in coastal cities.**

Urban heat island effect (UHI)

The temperature in an urban area is usually higher than in the surrounding non-urbanized areas due to the modification of land surface and the concentration of human activities. Building materials accumulate heat during the day from solar radiation and release it at night when this phenomenon becomes more evident. The main effect is the increase in minimum temperature.

Large parking areas contribute to the increase in temperature, causing a significant microclimate modification. Besides, waste heat from cars, air conditioning systems and other human activities contribute to the UHI effect as well. The scarcity of trees in urban environments also increases the UHI due to the lack of shading of artificial surfaces and of evaporative cooling that trees can provide through evapotranspiration.

Winds can contribute to reducing this effect too, but in cities an adequate natural ventilation is often prevented by tall buildings and the disposition of building blocks. Moreover, tall buildings contribute to the UHI effect, providing many surfaces that reflect and absorb the solar radiation and thus increasing heating efficiency. These impacts caused by buildings are called **urban canyon effect.**

Despite this trend of increase in the mean temperature, extreme cold weather events like cold spells, snow, ice and blizzards are still possible with a very low frequency, but higher intensity. Cities therefore must be prepared to tackle a wider range of climatic impacts.

Main Impacts on the urban environment

Changes in temperatures, frequency and intensity of extreme weather events have effects on:

- **Electric system (both energy production and distribution)**
  During heatwaves power consumption increases due to air conditioning use (with the largest increases projected for Italy, Spain and France), causing **power outages for the excessive electricity demand**. Heat reduces solar panel efficiency too. It also increases temperature in electric substations and damages the cables, further increasing the chance of service interruptions. On the other hand, extreme weather events, like hailstorms, cyclones or windstorms, can damage energy production plants (e.g., solar panels or wind turbines) or hit electricity distribution infrastructures causing service interruptions.
- **Human health**
  Heat-related morbidity and mortality are projected to increase substantially throughout the Mediterranean countries under all climate scenarios. The main effects are related to extreme weather events, changes in the distribution of climate-sensitive diseases and changes in environmental and social conditions. Impacts are expected to be the greatest in urban areas where people are concentrated and where the urban heat islands lead to higher inner-city temperatures (Yang et al. 2016). Indeed, high temperatures have a direct impact on human health causing respiratory and cardiovascular problems, myocardial infarctions (i.e., "heart attacks"), and strokes, but they can also engender the proliferation of arthropod disease-carrying insect species (e.g., tiger mosquitoes, among others). Tropical nights cause tiredness and lower people productivity consequently. They can lead to physiologic problems for vulnerable persons as high temperatures at night are an important driver of heat stress.
- **Tourism**
  On one hand during summer tourists might prefer destinations with milder temperatures, than those experienced in Mediterranean countries, eventually contributing to a shift in tourism seasons towards months that are currently not attractive for coastal tourism.

A drying region

The Mediterranean stands out because of the magnitude and significance of its winter precipitation decline.

Global warming of 2°C will likely be accompanied by a reduction in summer precipitation of about 10-15% in Southern France, North-western Spain and the Balkans and up to 30% in Turkey. For each degree of global warming, mean rainfall will likely decrease by about 4% in much of the region (SoED, 2020). Future climate projections indicate a predominant shift towards a precipitation regime based on higher interannual variability, higher intensity and greater extremes as well as decrease in precipitation frequency and longer dry spells (MedECC, 2020).

The increase in temperatures, which triggers large evaporation of water from all wet surfaces (such as sea, rivers, land, etc.), combined with decreasing rainfall, leads to **droughts that are projected to become more severe, frequent, and longer** under moderate emission scenarios, and the more so under severe emission scenarios (IPCC, 2022).

The coupled effect of warming and drought is expected to lead to a general increase in aridity and subsequent desertification of many Mediterranean land ecosystems

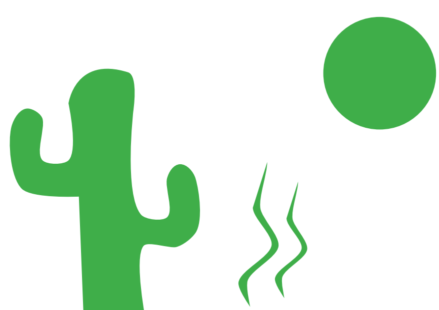
Main impacts on the urban environment

- **Water scarcity**

  The “water” resource is, and will be, the most critical one in the Mediterranean area, as unfortunately evidenced by the severe drought experienced during late 2021 and much of 2022. Due to climate change alone, freshwater availability is likely to decrease by 2 to 15% for 2°C warming (among the largest decreases in the world) and the number of days with insufficient water resources increases in all global warming scenarios (MedECC, 2020), effecting up to 54% of the Mediterranean population. The region will thus have to cope with higher water demands from all sectors (irrigation, energy production, domestic and industrial use), challenged by less available freshwater resources.
- **Energy**

  During summer hot and dry periods leading to drought could reduce electricity production, both from hydroelectric plants due to water.
- **Urban green**

  Vegetation, especially trees, **may not recover after prolonged periods of droughts**, affecting ecosystem services provided by green infrastructure, for example shading and cooling through evapotranspiration. The combination of increasing heat waves, droughts and changing land-use practices have resulted in higher fire risk, longer fire seasons and more frequent, larger and more severe fires. This phenomenon may have devastating impacts on green areas and during recent decades have caused records of burnt area in some Mediterranean countries.
- **Tourism might be affected as well.** In the mountains for example several skiing resorts might close their activities due to the lack of snow and unsustainable costs for artificial snowing.



A rising sea

In line with worldwide trends caused by warming and loss of glacial ice, sea level in the Mediterranean has risen. Primarily caused by global processes, including thermal expansion of sea water and accelerated melting of ice sheets in Greenland and Antarctica, sea level is projected to increase more strongly than previously estimated.

For the recent past, Mediterranean Sea level has increased up to 2.8 mm per year, which is consistent with global sea level trend. By the end of the 21st century (2080-2099) the projected rise in the average sea level of the Mediterranean Basin with respect to the present climate (1980-1999), is estimated to be 37 cm, 45 cm, 62 cm and 90 cm under RCP2.6, RCP4.5, RCP8.5 and high-end greenhouse gas emission scenarios, respectively (Somot et al. 2016; Jordà et al. 2020). It is clear that **sea level will rise in next centuries even if greenhouse gas concentrations stabilize.**

Sea level rise will flood some parts of low-lying coastal urban areas and increase the zones which will be exposed to coastal flooding due to high tide or storm surge and to coastal erosion.

Main impacts on the urban environment

- **Population**

  About 150 million people (one third of the Mediterranean population) currently live close to the sea, a number expected to grow in the next decades. This area is already facing major threats such as **coastal flooding and erosion** due to sea level rise, extreme events, seawater intrusion in coastal aquifers and habitat degradation. While coastal erosion and salinisation particularly affect agricultural production and the provision of public water supply within cities, inundation (due to accelerated sea level rise) **damages buildings**.

- **Heritage**

  Many historical sites are indeed situated on the coasts and are currently at risk of being flooded, with consequent damage both structural and from the point of view of tourist attractiveness.

- **Economy**

  Coastal industries and their supporting infrastructures, including transport (ports, roads, rail, airports), like power and water supply, storm water and sewerage, will be impacted as well by temporary or permanent.

- **Tourism**

  Many touristic destinations are endangered by the combined effect of sea erosion and sea rise. Moreover, the potential loss of cultural heritage in coastal cities could reduce the attractiveness of some Mediterranean tourist destinations.

Projected change in climatic impact-drivers in the Mediterranean region

The table n. 2 contains the list of the main climatic impact-drivers in the Mediterranean area associated with a high confidence of **increase (blue cells)** or **decrease (yellow cells)**, approximately corresponding to global warming levels between 2°C and 2.4°C.

Climatic impact-drivers	
Coastal and oceanic	Ocean acidity
	Marine heatwave
	Coastal erosion *Along sandy coasts and in the absence of additional sediment sinks/ sources or any physical barriers to shoreline retreat*
	Coastal flood
	Relative sea level
Snow and ice	Lake, river and sea ice
	Permafrost
	Snow, glacier and ice sheet
Wind	Mean wind speed
Wet and Dry	Fire weather
	Agricultural and ecological drought
	Hydrological drought
	Aridity
	Mean precipitation
Heat and Cold	Frost
	Cold spell
	Extreme heat
	Mean air temperature
Other	Atmospheric Co_2 at surface

Table 2 - Climatic impact-drivers with high confidence of increase or decrease (adapted from Table 12.7 in Chapter 12 of the WG I report, IPCC 2021)

Impacts of climate change on urban mobility and adaptation measures

Being responsible for a significant share of air pollutant emissions, **the transport sector strongly influences climate change, and at the same time it is also affected by this**. Extreme weather events, some of which are increasing in intensity and frequency, as well as slower but inexorable changes (for example, sea level rise) can indeed result in transportation infrastructure damages, which consequently have an impact on the economic and social system of the cities.

Understanding and estimating the impact of climatic hazards on the urban transport system is essential to identify and implement efficient adaptation measures.

Two broad categories of climate hazards have been taken into consideration:

1) **Long term trends** such as sea level rise;

2) **Extreme events** such as floods, heavy precipitation, extreme winds, heatwaves, and wildfires.

On the one hand, **sea level rise is a slow and inexorable phenomenon** to which coastal cities must adapt by implementing long-term measures.

Extreme weather events on the other side **cause disruptions to transport system infrastructures and services (both critical** and not critical) and generate **emergency situations and evacuation needs**. Disruptions are temporary usually, limited to the duration of the extreme weather event, and can be longer only if mobility infrastructures are damaged. The impact on mobility related behaviors is occasional and usually limited to the extreme weather event duration. People do not need to change habits or mobility patterns since these events are rare and limited in time.

For each of these climate hazards a fact sheet has been prepared based on the literature regarding impact and adaptation research and the inputs gathered within the Urban Transport series of webinars. The fact sheets include a brief introduction to the phenomenon, the expected trend for the future, the impacts on urban mobility and the possible adaptation measures that must, should or can be adopted at the EU, national and local level. The "Related climatic impact-drivers" section highlights other extreme weather events that can induce or cause the one the fact sheet refers to or whose concurrence may exacerbate its impacts.

Adaptation measures are focused on infrastructures (e.g., roads, railways, stations etc.), services (e.g., emergency plans, real time information systems, etc.) and behaviors and can be generally divided into planning, retrofitting and management. Most solutions consist of extreme weather events' impacts preventive measures and are applicable at different levels, from local to EU.

Adapt means:

- Implement actions to maintain, manage, strengthen, and protect infrastructures from climate damage by planning not considering past conditions but future trends and implementing technological innovations;
- Renovating or relocating old infrastructures that could be severely damaged in case of climatic impacts;
- Adopting Nature-based Solutions (NbS)[2] to reduce the vulnerability of urban areas and transport infrastructures;
- Improving real-time traffic information systems and early warning systems; investing in travel planning devices as tools that help the transport sector react promptly to extreme climatic events;
- Promote a flexible and multimodal urban transport structure that gives the possibility to easily find another transport option in case one becomes unusable;
- Considering and planning alongside regional and state authorities the relocation of infrastructures and restoration of places affected by climate alteration.

[2] Nature-based Solutions (NbS) are defined by the EU Commission as solutions to societal challenges that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. For more info see EEA Report No 1/2021

KEY MESSAGES FOR POLICY MAKERS

- ⚠ The first step for cities is to **conduct a thorough vulnerability assessment to understand their climate risks, both currently and in the long-term**
- ⚠ The second step is to **incorporate climate risk into urban planning**
- ⚠ Based on the risk assessment **different adaptation options should be identified, prioritized, and then implemented**
- ⚠ **Awareness raising and early warning systems** are highly effective and cost-efficient in relation to most climatic hazards
- ⚠ Decision-makers tend to invest in proposals that will generate short-term returns, while **the economic returns** from investments made to adapt the city to climate change **are visible only in the long term** or are not visible at all since they are meant to avoid the potential damage
- ⚠ Lack of financial resources and poor planning capacity are often the underlying causes of effective implementation of solutions to address the implications posed by climate change on transport infrastructure
- ⚠ **Green infrastructure** measures are effective in addressing high temperatures and flooding in cities. However, the water needs related to the implementation of these options need to be considered as well.
- ⚠ **Adaptation measures go hand in hand with mitigation measures.** In other words, encourage the use of low-carbon modes of transport to reduce emissions (e.g., electric trams, improved cycling and walking routes, electric buses, etc.), while the transport infrastructure remains resilient to a changing climate.

Sea Level Rise

/ 37% of the Mediterranean coastline is below 10 m above sea level and this area is home to 42 million people.
/ A few centimeters of elevation can lead to flooding of several square kilometers of coastal areas

Facts related to sea level rise

- The increase in sea level will affect mostly flat coastal areas with an altitude very close to the sea level
- The increase in sea level is slow and not easily perceived by the general public
- The impact on urban areas is twofold:

  a) nowadays and in the mid-term the increase in the sea level makes coastal areas more vulnerable to flooding in case of high tide or storm surges and such events will increase in frequency in the coming years;

  b) in the long term it will lead to the flooding of some areas that will be below sea level constantly or at high tide
- Many cities and economic activities in the Mediterranean have been built on the seashores. Several touristic destinations are located on sandy beaches almost at sea level and could be highly vulnerable
- Not only underground infrastructures are at risk of flooding but also several surface transport infrastructures that have been built close to the sea, like roads, railways, ports, and even airports (e.g., Venice, Nice, Cagliari, Barcelona, Brindisi and several Greek islands)

Future trends

/ Mediterranean Sea levels are projected to rise further, probably reaching 0,15 to 0,33 meter in 2050 depending on the scenario.

/ In the worst case, even not considering the possible melting of Antarctica, it will reach up to 1 meter of rising, increasing the risk of coastal flooding and erosion.

Related Climatic Impact-Drivers
- **coastal flooding**

Sea Level Rise

Impacts on Urban Mobility

	Users	Vehicles	Infrastructure	Operations
Public transport			●●●	●●
Active mobility	●		●●●	●
Private transport			●●●	●

● Low ●● Medium ●●● High

The significant impacts of sea level rise on urban mobility **affect infrastructures** (mainly existing ones), since sea level rise is a long-term change and infrastructures are long-lasting but usually hard to adapt to changes not considered during the design phase. Any harm or damage that has a big impact on the infrastructure will necessarily have a great impact on the operations of the public transport services running on that infrastructure and ultimately on the users that rely on this service.

- **Underground infrastructures flooding:** these infrastructures (e.g., underground parking, metro stations and network) are often waterproof, but in this case, water will pour in from the entrance.
- **Surface infrastructures flooding:** risk of inundation and damage to road and rail infrastructures; damage to the electrical network may disrupt tram lines, stops and storage; port facilities could become unusable.
- **Infrastructure corrosion:** existing infrastructures originally not directly in contact with saltwater environment were not designed to resist it. Therefore, the damage from corrosion will be significant, putting these constructions in danger shortening their lifetime.

Possible Adaptation Measures

At local level

MUST

⚠ **Map and assess coastal areas' vulnerability**

When the risk of sea flooding increases and coastal areas become highly vulnerable, a decision must be taken whether to abandon or protect each threatened area, including buildings and infrastructures. Such a decision must take into consideration the following elements, elaborating and comparing different scenarios:

- the economic value of the area and the cost required for its protection;

- the cultural value of the area in terms of both cultural heritage and social identity;

- its relevance for the transport network.

⚠ **Build barriers to protect coastal areas from occasional or permanent flooding**

Barriers like dikes or submerged breakwaters can protect coastal areas and mobility infrastructures from occasional flooding due to extreme weather events (e.g., high tide, storm surge, etc.), increased coastal erosion due to climate change, and permanent flooding caused by sea level rise.

⚠ **Plan with a long-term perspective**

Land use planning and the construction of new transport infrastructure (new metro lines, airports, etc.) should consider the expected rise of sea level at the end of the century according to the most likely scenario.

Sea Level Rise

Sea Level Rise

SHOULD

- **Protect infrastructures from occasional flooding**

  In areas at high risk of occasional flooding, the following measures could be implemented:

  - installation and maintenance of emergency pumping to evacuate water from underground transport systems and tunnels
  - increase the entrance level
  - promote the use of mobile barriers to block the entrance in case of flooding
  - install ventilation grates at a higher height
  - frequent maintenance of drainage infrastructure and pumping systems.

  In the case of urban transport infrastructure, the responsibility lies according to the local regulatory framework of the city, the regional authority or even the state.

- **Set up a proper weather forecasting service, an integrated early warning system and emergency plans**

  Protective solutions to occasional flooding should be coupled with a proper weather forecasting service, an early warning system and the adoption of emergency plans.

CAN

- **Seize the opportunity to make protection barriers multifunctional**

  When the construction of barriers, dikes or submerged breakwaters is required, these barriers could also be used for energy production from tide or wind or as walking and cycling routes.

- **Seize the opportunity to exploit Nature-based Solutions (NbS)** Sand dunes are a Nature-based Solution that can prevent coastal inundation from rising sea levels. Nonetheless, they require much space and time for growing to levels which would actually provide an efficient protection. Other measures, like coastal wetlands and wave attenuating measures as under-water reefs and - to a certain extent - Posidonia fields along the coastline, can reduce waves and storm surges, reducing erosion but not coastal inundation from rising sea levels.

At the National and local level

MUST

⚠ **Adopt adequate design features and review technical construction standards**

If an area is considered at risk of sea flooding new planned mobility infrastructures should be designed with a higher entrance level, sea water resistant material, and equipped with pumps and adequate drainage systems.

⚠ **Raise risk awareness among the public at large, policy makers and urban planners**

There is also a need to increase the general public's awareness about the specific risks related to sea level rise. This will increase the acceptance of the regulation and of the infrastructures needed to protect from sea level rise and floods. However, a more tailored awareness raising campaign should also address urban planners and policy makers.

SHOULD

- **Policy framework for the implementation of NbS**

  Create a regulatory framework to oblige or recommend the implementation of NbS for the planning and construction of infrastructures

At European and national level

SHOULD

- **Make sea level rise assessment mandatory in planning**

  Since the awareness of policy makers and urban planners is not always appropriate, it is recommended that the assessment of sea level rise risks is made mandatory, for all regional and local plans that define the use of coastal areas, by means of an ad hoc EU Directive. National legislation should comply with such EU requirements, and national governments should apply these principles when planning new transport infrastructure.

Floods

Aside from droughts, floods are and will likely remain the most dangerous meteorological hazards affecting Mediterranean countries.

Facts related to floods

Floods are weather-related hazards classified under the category "extreme weather events" whose pattern is likely to be significantly affected by climate change. There are different types of floods according to the cause that generates them.

- **PLUVIAL FLOOD:** it occurs when an extreme rainfall event creates a flood regardless of the nearby presence of a river, lake, etc. It can happen in any location, urban or rural.
- **RIVER FLOOD:** triggered by heavy rainfall, melting snow in upstream areas or tidal-related influences. It occurs when the river run-off volume exceeds local flow capacities due to intensive rainfalls.
- **COASTAL FLOOD:** Extreme sea levels can occur during storms in combination with high tides leading to coastal flooding in the absence of sufficient coastal protection. Disastrous **flash floods** are much more frequent especially in the western part of the Mediterranean, an area that is much more exposed to high impact and high magnitude events, due to the local climate, which is prone to short and intense local heavy rainfall. Flooding may happen because urban drainage systems, banks or dikes are no longer adequately designed for sudden and forceful "water bombs", whose magnitude has been amplified by climate change.

Future trends

/ Current projections, probably due to the limitations of the available datasets and some complex overlapping signals, do not point to a change in extreme flood patterns in the Mediterranean region linked to climate change. However, flood vulnerability will likely increase due to population growth and urban development in flood-prone areas in the coming years.

/ Drought exacerbates the impacts of floodings, since it reduces the soil's ability to absorb water, making it impermeable, increasing runoff and, therefore, the likelihood of floodings. Furthermore, the total amount of rainfall will be approximately the same. However, it will be concentrated over a few days, increasing the possible flooding of public spaces, buildings, and transportation infrastructure.

Related Climatic Impact-Drivers

- **heavy precipitation**
- **sea level rise**

Floods

Impacts on Urban Mobility

	Users	Vehicles	Infrastructure	Operations
Public transport	●●●	●●●	●●●	●●●
Active mobility	●●●	●●	●●	●●●
Private transport	●●	●●●	●●●	●●●

● Low ●● Medium ●●● High

Floods seriously impact all aspects of urban mobility and modes.

- **Circulation and safety:**

  Minor floods can cause traffic disruptions and congestion and increase weather-related accidents. Significant floods, on the contrary, with high water levels and/or strong flow can drag away vehicles and threaten people life severely.

- **Unusable underground infrastructures:**

  During and after a flood, underground infrastructures, like metro networks, road underpasses and parking facilities, are unusable since they are submerged with consequences on public transport services as well.

- **Reduced or impeded usability of mobility infrastructures:**

  The flooding of an area causes transport network interruptions, resulting in public transport service disruptions too. During flash floods or river floods, transport infrastructures washout is possible, resulting in long-term disruptions and high costs for reconstruction. As far as river transport is concerned, floods could result in service interruptions for safety reasons, in damaged wharfs and reduced navigability of waterways due to the increased debris deposition. More frequent dredging could be necessary, with an increase in maintenance costs[3].

- **Reduced accessibility to mobility infrastructures**

  During and immediately after a flood, access to mobility infrastructures - and public transport services as a consequence - could be reduced due to the flooding of an area (e.g., a public transport line stop or station or underground metro lines).

- **Increased infrastructure deterioration**

  Floods can increase infrastructure deterioration (e.g., road surface erosion or road base erosion which can reduce road stability), requiring more frequent maintenance and consequently higher costs. River floods also increase erosion, which can accelerate bridge scouring, threatening the stability of such infrastructures. The risk of bridge collapse must also be considered due to the material transported during the flood which can get stuck and form a dam when the water flows, increasing the action of the water on the bridge structure.

Floods

[3] Ibidem

Solutions/Possible Adaptation Measures

At local level

MUST

⚠ **Map and assess flood vulnerability of urban mobility infrastructures**

Flood risk of areas must be assessed, considering the possible type of flooding (pluvial, river or coastal) and topography. Then urban mobility vulnerability must be mapped according to the presence of flood-prone mobility infrastructures in areas at high flooding risk.

⚠ **Adopt protective measures for existing flood-prone urban mobility infrastructures**

Active or passive protection measures must be adopted locally to protect the flood-vulnerable mobility infrastructures.

-Active protective measures: river floodplain areas maintenance to keep them clean from vegetation; effective alert system; pumping system.

-Passive protective measures: physical barriers; raised entrance to underground facilities; drainage systems.

Relocate and or eliminate infrastructures that are worsening the effects derived from climate alteration or severely affected by it.

⚠ **Plan and design new urban mobility infrastructures considering flood risk**

When planning new urban mobility infrastructure avoid high flood hazard areas in the long term and adopt specific design features to protect infrastructures.

CAN

▶ **Inform and educate**

Improve weather forecasting, develop and implement emergency management plans and early warning systems. Organize community training events to increase knowledge and awareness on how to behave and respond during a flood.

At the national level

SHOULD

▶ **Adopt protective measures for existing flood-prone urban mobility infrastructures**

At the national level flood vulnerability assessment of urban mobility infrastructures should become compulsory and be the starting point for developing a local plan to gradually implement protective measures for highly flood-vulnerable mobility infrastructures. Relocate and or eliminate infrastructures that are worsening the effects derived from climate alteration or severely affected by it.

▶ **Plan and design new urban mobility infrastructures considering flood risk**

At the national level guidelines, technical building standards or laws should be issued to make this approach compulsory.

At European and national level

CAN

▶ **Inform and educate**

Educational guidelines can be published and campaigns on emergency evacuation can be promoted.

Floods

Heavy precipitation

Extreme precipitation events are one of the most frequent natural hazards and of the highest negative impact, eventually leading to landslides, and floods (pluvial, fluvial, flash).

Facts related to heavy precipitations

- Heavy precipitation events have increasingly grown in the last years in southern Europe, especially in the Mediterranean region and are highly correlated with the Mediterranean Sea surface temperature.
- These occasional episodes occur mainly during the fall season and can result in more than 200 mm of rainfall in less than 24 h, producing devastating flash floods with very high social and economic losses. Hailstorms are included in the heavy precipitation category.

Future trends

Heavy precipitations are projected to decrease in frequency but become more intense in all seasons except the summer. Future projections show an increase in the probability of damaging events especially in the eastern part of the Spanish Mediterranean region (see also the section on floods).

Related climatic impact-drivers

- **flood (pluvial flood)**

Heavy Precipitation

Impacts on Urban Mobility

	Users	Vehicles	Infrastructure	Operations
Public transport	●●●	●●●	●●●	●●
Active mobility	●●●	●●	●●	●●●
Private transport	●●	●●●	●●●	●●

● Low ●● Medium ●●● High

Impacts on infrastructures

- **Damages to mobility infrastructures**

  Heavy precipitation can cause hydrogeological instability of slopes, especially after a dry period, increasing the landslide hazard with potential damages to transport infrastructures (e.g., roads, railways).

- **Road surface deterioration**

  Heavy precipitation increases road erosion, resulting in lower road safety and higher maintenance costs.

Impacts on vehicles

- **Unusability of vehicles due to damages**

  In case of extreme hailstorms vehicles can be seriously damaged (e.g., broken windows), making them unusable long after the extreme weather event.

Impacts on users

- **Private motor vehicle traffic congestion**

  Heavy precipitation events discourage active mobility and public transport use, resulting in a higher number of cars and traffic congestion on the road network.

- **Discomfort and safety**

  Heavy precipitation impacts people's comfort during travel and increases the accident hazard due to higher motor vehicle traffic congestion, reduced visibility, and slippery roads. Moreover, people's ability to walk and use non-motorized means of transport is reduced and they can be directly injured as well in case of severe hailstorms.

Impacts on service

- **Public transport service delays**

  Heavy precipitation could cause public transport service delays, because both of higher traffic congestion on the road network and lower speed for safety reasons.of transport is reduced and they can be directly injured as well in case of severe hailstorms.

Heavy Precipitation

Possible Adaptation Measures

At local level

MUST

- **Keep the drainage system efficient**

  Check the efficiency of the drains regularly. It is necessary to clean the manholes and road drains from foliage and waste accumulated at the edges of the roadway to avoid flooding and minimize inconvenience. Increase pumping capacity to evacuate water from tunnels, also considering the deployment of mobile pumps during heavy rains.

- **Upgrade the drainage system with stormwater storages ("grey solutions")**

  Implement the "Keep the rain where it falls" principle by equipping the existing drainage system with stormwater storages, both grey and natural (e.g., low lying parts of urban parks, wetlands, etc.), to retain the excess water and to drain it gradually after the extreme rain event. According to the local precipitation levels, consider strengthening the existing drainage system with the construction of a separate one for stormwater.

- **Build Sustainable Urban Drainage System (SUDS)**

  Since the increase in magnitude of heavy precipitation events, exploit the water retention capacity of urban green infrastructures (e.g., rain gardens) coupled with efficient traditional grey infrastructures (i.e., drainage systems).

- **Map and assess pluvial flood vulnerability of urban mobility infrastructures**

  Pluvial flood vulnerability of urban mobility infrastructure must be assessed and mapped in order to plan and prioritize adaptation actions.

- **Set up a proper weather forecasting service, an early warning system, and an emergency plan.**

  A proper weather forecasting capacity coupled with an early warning system allows the activation of emergency plans to reduce inconvenience and potential damages.

SHOULD

- **Inform and training**

  At the regional level emergency management training centres should be strengthened or established, if not already present, providing training on how to behave in case of storms to both citizens (commuters) and workers of the mobility sector.

CAN

- **Provide shelters and covered active mobility paths**

  As heavy precipitation events can happen unexpectedly and can be very intense. Shelters could be provided in the public space for active mobile users and bike economy operators as well (e.g., riders). Moreover, covered paths, like porticoes or tree-lined streets, could promote active mobility encouraging more people to walk even on bad weather days.

At the national level

MUST

- **Update the drainage systems' technical design regulations**

  At the national level, the drainage systems' technical design regulations must be updated – especially the return periods series - in order to be able to cope with the increased magnitude and frequency of rainfall events.

Extreme Winds

A phenomenon that regularly causes large economic damage to Europe

Facts related to extreme winds

- Extreme wind affects cities through damage to transport systems, energy infrastructure, vegetation, private property, and human health.
- Coastal regions are particularly affected by windstorms and given the concentration of urban environments in these areas. This generally increases the exposure of European cities to wind hazards.
- The built structures in cities, such as tall buildings, alter how the wind flows and may create wind tunnels where the wind speed is very high, increasing the risk of damage.
- Windstorms and most intense cyclones often produce high-impact weather events such as storm surges, landslides, and flooding, and they can also contribute to the rapid spread of wildfires.

Future trends

Two factors need to be considered in the context of global change: a) the frequency of strong winds, and b) their intensity measured in terms of wind speed. The frequency of winter Bora events is projected to increase, while the frequency of Sirocco events is expected to decrease. Conversely, the mean wind speed, during Bora and Sirocco events, is expected to decrease, except for Bora in northern Adriatic.

Related climatic impact-drivers ■ heavy precipitation ■ coastal floods ■ wildfires

Extreme Winds

Extreme Winds

Impacts on Urban Mobility

	Users	Vehicles	Infrastructure	Operations
Public transport	●●●	●●●	●●●	●●●
Active mobility	●●●	●●	●	●●●
Private transport	—	●●●	●●	●●

● Low ●● Medium ●●● High

- **Interruption of public transport services and inconvenience to traffic**: windstorms may damage road and railway infrastructure, causing service disruption and inconvenience to circulation if winds leave trees or other storm debris on railway tracks. Strong gusts of wind can also cause trucks to overturn, affecting city traffic. This may result in greater fuel consumption in the event of a diversion of the route, with an increase in pollution-related negative externalities.
- **Damages to city electrification systems**: damage to electrical equipment and power outages may disrupt service, tram stops, trams themselves and their depot facilities.
- Infrastructures such as **bridges and viaducts can be damaged** due to wind pressure and falling debris. High windspeed may result in the closure of bridges and viaducts to traffic for certain types of vehicles, such as heavy-duty trucks.
- Windy events can cause **navigation difficulties and service interruptions**: difficulty berthing ships and the inability to operate cranes may cause congestion in ports and nearby areas and shipping delays; strong winds can also limit navigation for ferries, cruise ships or other tourist vessels, creating inconvenience to both citizens (e.g., commuters) and tourists.
- Preventing active mobility: walking and riding a bike becomes more strenuous and dangerous due to the risk of direct falling or being hit by flying debris.

Possible Adaptation Measures

At local level

SHOULD

- **Improve soft measures**

  The accuracy of weather forecasting and early warning systems should be improved, strengthening the emergency response. This will lead to better preparation and potentially fewer damages.

- **Take care of urban green and adapt it to atmospheric events**

  Urban trees should be checked regularly, and dangerous ill or dead parts should be removed.

  Vulnerable vegetation, such as tall conifers near buildings and other assets should be replaced with more wind-resistant species (e.g., broad-leaved trees). This could prevent harm to people or damage to buildings and infrastructures caused by branches or entire tree falling.

- **Construct strategic wind breaks and shelter**

  Mobility infrastructures negatively affected by strong winds should be protected with wind breaks that allow their use even during windstorms. Wind breaks can be artificial structures or made with vegetation. Shelters should be built to offer protection in case of extreme winds to active mobility users during their travel and public transport users while waiting

At regional and national levels

MUST

Adapt infrastructure technical design standards

It must be assessed if current design standards can withstand more frequent and intense windstorms. If not, the technical design regulation of new mobility infrastructures such as bridges, flyovers, stations, buildings, etc., should be adapted to the expected increase in wind speed

CAN

Protect power infrasctructure

Moving power infrastructure underground can avoid prolonged power outages which can cause disruptions and service interruptions if urban mobility is mainly electric powered (e.g., trams, metro lines, vehicle charging infrastructures).Plan and design new urban mobility infrastructures considering flood risk

Extreme Winds

Wildfires

Facts related to wildfires

- Their predominant cause is to be found in human activity and data also suggest that around 60% of the human-caused fires in Europe are deliberate.
- While the spark may originate in human activity, climate and weather strongly influence the establishment and spread of a wildfire. Droughts and heatwaves can induce plant activity decline and severe spread of wildfires, and high wind speed can change the fire regime and characteristics, favouring fire propagation.
- Spain, Portugal, and Turkey are the countries with the highest current and projected danger associated with fire. Greece, parts of central and southern Italy (including the islands of Sicily and Sardinia), Mediterranean France and the coastal region of the Balkans also show increasing vulnerability to this hazard.
- Wildfires are hazards causing a significant source of greenhouse gas emissions.

Future trends

Climate change is expected to increase wildfire risk in the region, owing to increased incidence of droughts and reduced soil moisture. Despite increasing wildfire hazards, forest fires generally decrease in the European part of the basin, due to efforts to improve fire suppression, fire risk management and prevention.

Related Climatic Impact-Drivers

- extreme winds

Impacts on Urban Mobility

	Users	Vehicles	Infrastructure	Operations
Public transport	●●●	●●●	●●●	●●●
Active mobility	●●●	●●●	●	●●●
Private transport	●●	●●●	●●	●●●

● Low ●● Medium ●●● High

- Possible both temporary or long-term interruptions of transport systems due to safety reasons, reduced visibility, or damages.
- Reduction of walkability and other active mobility modes due to smoke. The increased air pollutants (e.g., PM, dioxin, etc.) negatively impact cardiovascular and pulmonary health, increasing cancer risk.

Possible Adaptation Measures

At local, regional, and national levels

MUST

Plan urban and mobility developments considering fire risk

Avoid new developments in urban areas and mobility infrastructure in the high fire risk area. Create a firebreak area between the natural and the urban areas or mobility infrastructures and implement soil and vegetation changes to increase fire resilience.

Fire management and emergency plan

Manage natural areas surrounding the built environment and mobility infrastructures, controlling the amount of "fuel" (i.e., grass, leaf litter, twigs, bark, and other live vegetation which can burn) in the bush to prevent the outbreak of wildfires. As far as emergency management is concerned, develop evacuation plans to avoid life losses.

SHOULD

Provide redundancy in the mobility system

At the regional level emergency management training centres should be strengthened or established, if not already present, providing training on how to behave in case of storms to both citizens (commuters) and workers of the mobility sector.

At national and European level

SHOULD

Invest in communication

Since most wildfires start because of human activity, awareness raising is a crucial measure to promote responsible behaviours in fire prevention (thus reducing the risk of wildfires) and proper response during emergencies.

Heat waves

"This could be the coolest summer of the rest of your life. Get used to it"
June 2022

Facts related to heat waves

- Heatwaves are a prolonged periods (more than three days) of abnormally hot weather.
- A heatwave has no absolute reference temperature values; it occurs when daily maximum temperatures in a specific area are above the standard climate pattern of the past, with increasing mean summer temperatures, also threshold values defining heatwaves show an upwards trend.
- Heatwaves exacerbate the urban heat island (UHI) effect, amplifying temperatures in the built environment and resulting in poorer air quality due to the creation of ozone that negatively impacts human health.

Future trends

Heatwaves are expected to increase in intensity and length by the end of the century. Temperatures reached during exceptionally intense heat waves observed early in the century could become the normal summer temperatures by the end of this period.

Related Climatic Impact-Drivers

- wildfires

Heat waves

Impacts on Urban Mobility

	Users	Vehicles	Infrastructure	Operations
Public transport	●●●	●●	●●●	●●●
Active mobility	●●●	●●●	●●	
Private transport	●	●●	●●	

● **Low** ●● **Medium** ●●● **High**

The impacts of heatwaves affect almost all aspects of urban mobility, often interrelated, with direct negative consequences on costs for the infrastructure and vehicles and on mobility behavior of PT's users and working staff.

- **Road and railway infrastructure damages**

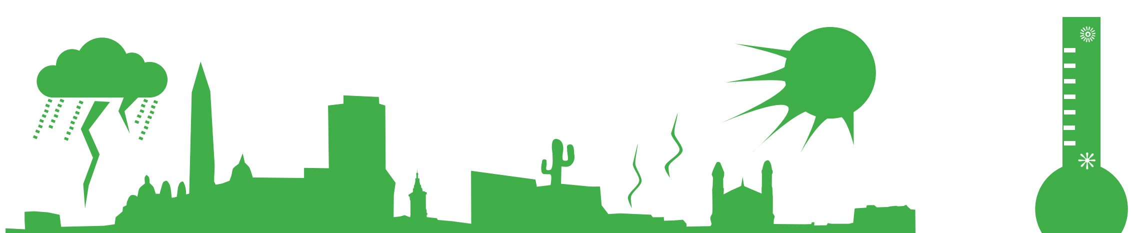
  As a result of heatwaves, high temperatures damage infrastructure material, such as roads asphalt, railway steel, also affecting bridges' expansion joints, altering the physical properties of materials used in the construction of transport infrastructure. Potential risks for roads include road deformation, asphalt melting or rutting, resulting in unsafe road conditions and slowing down the transport system. Exceptional thermal expansion due to heatwaves also occurs on railroad tracks, producing bending and rail bucking (so called "sun kinks") contributing to instability and derailments. High temperatures can also threaten the underground metro network and trains, when not adequately ventilated.

- **Private and public transport vehicles increased deterioration**

  Damaged asphalt and high temperature road surfaces can accelerate the process of deterioration and consumption, accentuating unsafe traveling conditions, while resulting in higher costs both to repair the infrastructure and for public and private vehicle maintenance. Moreover, heat can be hard on engines, especially diesel ones, triggering overheating and deterioration of other equipment.

- **People (PT passengers and service operators, infrastructure workers and active mobility users)**

  High temperatures reached during heatwaves furthermore reduce thermal comfort and indoor air quality which are often a challenge for passengers and drivers already under normal conditions, because of the tightly enclosed space, poor indoor air quality, the heat generated by train motors, unshielded windows, and density of human bodies. On the top of all this, the heat stress experienced by passengers while waiting at un-sheltered transit stations, especially during peak hours, may be severe. Also, maintenance and building staff of the infrastructure can experience intense fatigue when working long hours in hot weather conditions, especially when a heatwave hits. People who walk or bike may feel intense heat stress and experience health problems too. They may decide to shift to public transit or, in the worst scenario, avoid travel if they cannot afford a private vehicle.



Possible Adaptation Measures

At local level

Heat waves

MUST

Adopt climate-sensitive design for PT stops

Plant trees or provide other shelters as well as resting seats for vulnerable people at public transport stops. If relative humidity is not high, set up misting systems in waiting areas to be activated when heat waves hit. Keep stations and underground transit tunnels ventilated and cool.

Protect people

Create shade on main walking and cycling routes as well as resting areas with seats, shading, and water fountain for vulnerable people. Manage work time shifts of maintenance workers to avoid exposure to extreme heat.

SHOULD

Develop and apply climate-sensitive design for PT vehicles

Use low-energy ventilation systems on buses and metro trains, paint buses white, and apply tinted windows to shade off the sun. Also Install thermometers inside buses and trains for drivers to monitor temperature. Reroute buses to reduce passengers' exposure to the heat (making operational adjustments often cost less than intervening on infrastructure) provide Demand-Responsive Transport (DRT) services for vulnerable people (especially outside the city centre where public transport service frequency is lower).

Adapt urban areas

Avoid overheating by increasing the number of green areas and changing the albedo by choosing light colours for pavements and buildings.

_ Reduce urban emissions of particulate matter by shifting to less impactful heating systems.

_ Apply alert systems on the tracks to detect rail deformation.

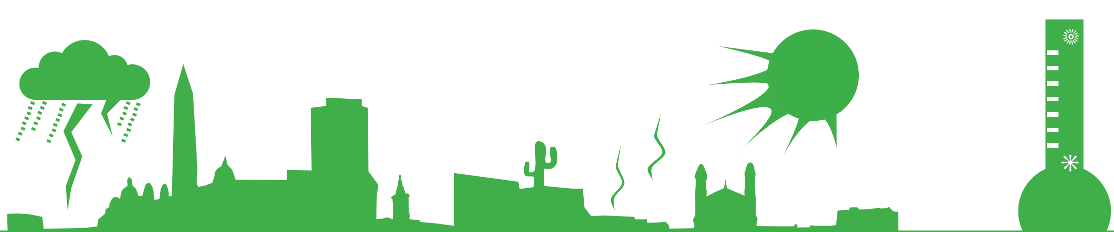
_ Enhance road construction with more durable pavement materials (heat resistant asphalt binders and more rut-resistant asphalt) and improve the design of bridges' expansion joints to withstand high temperatures.

_ Establish speed and vehicle weight limits on road infrastructure sections at risk during heat waves.

CAN

Educate people

Launch a campaign to raise awareness of the dangers of extreme temperatures and provide valuable recommendations for active mobility and PT users (i.e., stay hydrated, use caps, choose light and airy clothes, travel when it is cooler, avoid needless trips, avoid or reduce sugar and salt consumption that can aggravate thirst, etc.)



Project co-financed by the European Regional Development Fund

At regional and national level

MUST

⚠ **Support local authorities**

Support local authorities in the co-planning of green and built areas implementing urban design strategies in favour of natural ventilation in the streets.

SHOULD

- **New standards for PT stations**

  Codesign new standards for PT stations to avoid extreme heat at their interior, by applying energy efficient solutions.

- **Protect people**

  Extra-urban cycling routes should be shaded and resting areas with water fountains should be made available.

At European level

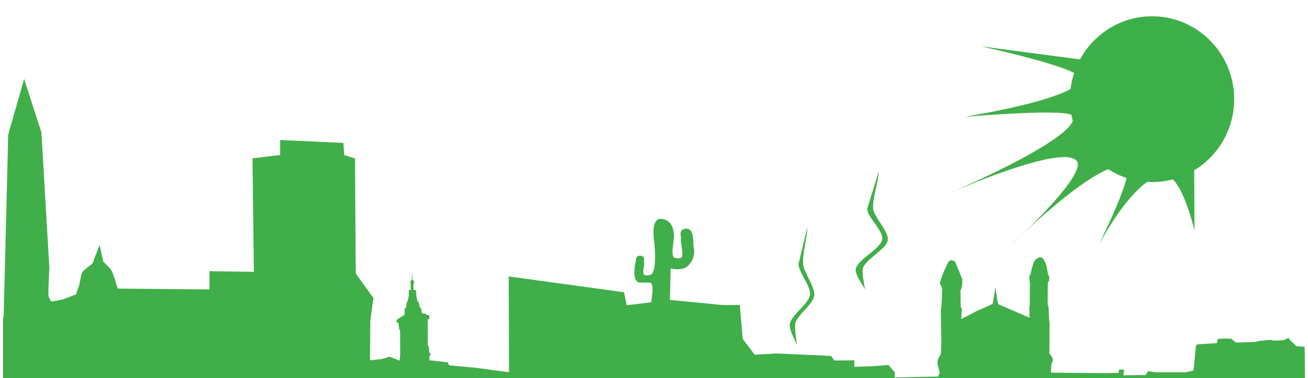
SHOULD

- **New standards for vehicles**

  _New standards should be set for vehicles to reduce waste heat that contributing to overheating of urban areas and enhance the effects of urban heat islands.

  _ New standards should also be set for PT vehicles to provide proper comfort for passengers even in case of extreme heat, by means of light colours, shaded windows, ventilation, and cooling systems.

Heat waves



Project co-financed by the European Regional Development Fund

BIBLIOGRAPHY

- IPCC, Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the IPCC, 2021.
- MedECC, Climate and Environmental Change in the Mediterranean Basin. Current Situation and Risks for the Future. First Mediterranean Assessment Report, 2020.
- UNEP/MAP and Plan Bleu, State of the Environment and Development in the Mediterranean, 2020.
- P. Bertoldi, Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP). Part 2 - Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA), 2018.
- D. Black, N. Pyatt, Adapting Urban Transport to Climate Change. Module 5f. Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities. 2nd Edition, 2021.
- MIMS, Cambiamenti climatici, infrastrutture e mobilità. Soluzioni e strategie per gli investimenti infrastrutturali in un contesto di adattamento ai cambiamenti climatici e di mitigazione delle emissioni di gas-serra. Rapporto della "Commissione cambiamenti climatici, infrastrutture e mobilità sostenibili", 2022.
- POLIS, and Rupprecht Consult - Forschung & Beratung GmbH, Topic Guide: Planning for more resilient and robust urban mobility, 2021.
- UNEP, Beating the Heat: A Sustainable Cooling Handbook for Cities, 2021.
- Raymond C., Matthews T., Horton R.M. The emergence of heat and humidity too severe for human tolerance. Science Advances, 2020.
- W. Cramer, J. Guiot, M. Fader, J. Garrabou, J-P. Gattuso, A. Iglesias, M.A. Lange, P. Lionello, M.C. Llasat, S. Paz, J. Peñuelas, M. Snoussi, A. Toreti, M.N. Tsimplis, & E. Xoplaki, Climate change and interconnected risks to sustainable development in the Mediterranean, 2018.
- S. Somot, L. Houpert, F. Sevault et al., Characterizing, modelling and understanding the climate variability of the deep water formation in the North-Western Mediterranean Sea, 2018.
- G. Jordà, D. Gomis, F. Adloff, Vulnerability of marginal seas to sea-level rise: The case of the Mediterranean Sea, 2020.
- P. Bertoldi, Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP)'. Part 3 - Policies, key actions, good practices for mitigation and adaptation to climate change and Financing SECAP(s), 2018.
- EEA, Nature-based solutions in Europe: policy, knowledge and practice for climate change adaptation and disaster risk reduction. Report No 01/2021.

EXTERNAL REFERENCES

- IPCC WGI Interactive Atlas
- The impacts of climate change at 1.5C, 2C and beyond

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