CLIMATE CHANGE

Overview of regional and local trends, policy and governance

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Contributors

Climate Change and Environment Team

Charis Kordatos | Coordinator of the Climate change & Environment team | Forester, Environmentalist, Environmental Biology (MSc)

Myrto Skouroupathi | Environmental Engineer (Meng)

Louisa Marie Shakou | Climate Change Expert | Environmentalist, Chemistry (MChem), Environmental Technology (MSc)

Marina Kyriakou | Architect (diplômée d'État), Urban Planning (MSc)

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Contents

List of Abbreviations

AR4	Fourth Assessment Report (of IPCC)
BEI	Baseline Emission Inventory
CAP	Common Agriculture Policy
CDD	consecutive dry days
CO^2	Carbon dioxide
CO^2-eq	Carbon dioxide equivalent
CoM	Covenant of Mayors
COP	Conference of Parties
EGD	European Green Deal
EFTA	European Free Trade Association
EM-DAT	Emergency Events Database
ETS	Emissions Trading System
EWE	Extreme Weather Event
FAR	First Assessment Report (of IPCC)
GHG	Greenhouse Gas
GCM	Global Climate Model
GMST	Global Mean Surface Temperature
GtCO2eq	Gigatonnes carbon dioxide equivalent
IPCC	Intergovernmental Panel on Climate Change
LAs	Local Authorities
LULUCF	Land Use, Land Use Change, and Forestry
MEI	Monitoring Emission Inventory
MHW	Marine Heatwave
$mm\ yr^{-1}$	Millimeters per year
MS	Member State
NBS	Nature Based Solutions
NECP	National Energy and Climate Plan
OFDA/CRED	Office of Foreign Disasters Assistance / Centre for Research on the Epidemiology of Disasters
OHC	Ocean Heat Content
pH	Potential of Hydrogen
ppb	Parts per billion
ppm	Parts per million
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
SAR	Second Assessment Report (of IPCC)
SEAP	Sustainable Energy Action Plan
SECAP	Sustainable Energy and Climate Action Plan
SME	Small-Medium Enterprise
SPI	Standardised Precipitation Index
SST	Sea Surface Temperature
TAR	Third Assessment Report (of IPCC)
UHI	Urban Heat Island (Effect)
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	UN Framework Convention on Climate Change
WEI+	Water Exploitation Index Plus
WHO	World Health Organisation
WMO	World Meteorological Organisation
Wm^{-2}	Watt per square meter

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Executive Summary

Climate change is one of the most pressing challenges currently facing society, affecting all of us, across all spheres of our lived experience (economy, environment, wellbeing etc.). The consequences of climate change are already being felt, and without action, are expected to become even more acute and disruptive.

This report has been prepared by the Cyprus Energy Agency with the express aim of providing the reader with an overview of the climate change challenge, what action has been taken to date and what is planned in the upcoming decades to tackle it, and how stakeholders, such as local authorities and citizens, can engage and contribute through their own actions.

Part 1 of this report describes the phenomenon of climate change and the scientific evidence that shows clearly that the climate system is changing. It summarizes the changes experienced in the climate across Europe, the Mediterranean and in Cyprus. Records show clearly that the temperature has increased since the pre-industrial period, and this has affected precipitation patterns and the incidence of extreme weather events such as heatwaves, droughts and floods. If profound action is not taken to mitigate climate change, projections by scientists indicate that more severe increases in temperature are to be expected by 2100, and that climate and weather patterns will become increasingly erratic and extreme.

Recognition of the seriousness of the climate crisis has led governments to take action, collectively at an international level, as well as regionally and at individual state level. Part 2 of this report outlines the action that has been taken at the international , European Union and national (Cyprus) level to both mitigate climate change and adapt to its consequences. It is evident that we are currently in a period of intensive activity as governments across the world, and in particular Europe, develop ambitious policies which will result in the transformation of our economies and societies making them climate resilient. The European Union aims to be the first climate neutral continent and has unveiled a suite of policy measures that have a bearing on all domains of our economy and lives, affecting our energy use, our buildings, how we travel and the food we eat.

Whilst this period has seen a heightened focus on climate change, it is nevertheless the culmination of a long process that began in the middle of the 20th century, which has resulted in the climate crisis now becoming a firm fixture on the policy agenda. This process is the outcome of the work and actions of scientists, citizens, policymakers and organised groups. Part 3 of this report highlights the importance of taking a multi-stakeholder approach.

Policymakers develop climate policies, however these will only succeed if they are implemented. Local authorities and citizens are integral partners in the implementation of ambitious policies and in achieving the goal of transforming our societies and making them climate resilient. Part 4 shows how local authorities can help achieve climate goals, and the tools and frameworks available to them. Local Authorities are the level of government closest to the citizen, and can harness this role to set and enact even more ambitious climate policies in order to increase the wellbeing of their citizens and the liveability of their cities. In partnership with citizens, the climate targets set by the European Union and Cyprus can be met.

1. Climate Change in Cyprus

1.1 What is Climate Change?

Climate describes the average weather conditions usually experienced in a particular place and over a long period of time [1]. For example, the Mediterranean climate is widely understood to be one with warm, dry summers and mild, wet winters. In scientific terms, the World Meteorological Organisation (WMO) describes climate as the measurement of the average (mean in mathematical terms) quantities and values of variables such as temperature, precipitation, wind etc. over a period of time, and how these vary. The period of time can range from months to thousands or millions of years, however the standard period used by the WMO is 30 years.

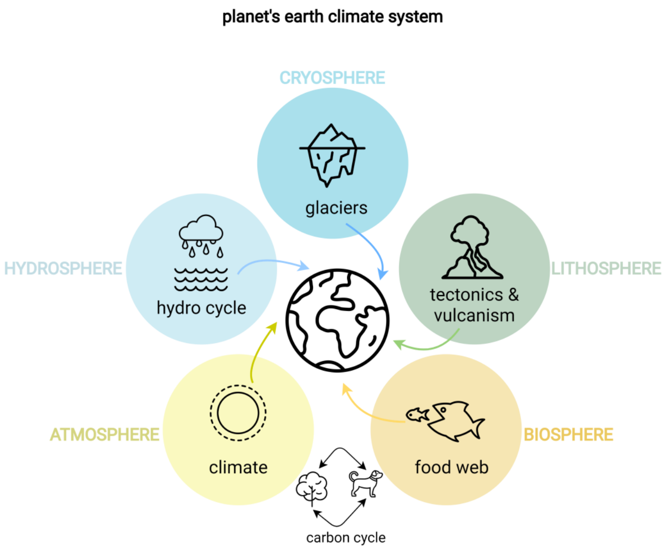


Figure 1 Planet Earth's Climate System

Icons downloaded from The Noun Project - thenounproject.com (Ozone by Fiki Ahmadi, Iceberg by The icon Z, Earth by Priyanka, Competition by Irwin Lowe, Dog by Iconic, Tree by myiconfinder, Volcano by Vectorstall, Sea by Daria Moskvina, Rain by Soremba)

The climate we experience is controlled and regulated by the five major climate components which make up the climate system[1][2]. :

- the atmosphere: the mixture of gases surrounding the earth;
- the hydrosphere: the oceans and seas;
- the cryosphere: the snow- and ice-covered regions of the planet including in the oceans (as sea-ice) and on terrestrial land (as ice and snow sheets, glaciers);
- land surface: including lakes and rivers, rocks, soil etc.;
- the biosphere: the living organisms on the planet, including plants, organisms in the soil, and animals on land and fish and plants in the ocean [2].

The interactions between these components result in a continually changing climate system, which is further altered by external factors such as volcanic eruptions or solar variations and human-induced factors such as changes to the atmosphere and changes in land use [1].

Climate Change is defined as a statistically significant variation (i.e. not random) in either the average state of the climate or in its variability, continuing for an extended period (typically decades or longer). Climate change may be a result of natural internal processes or external factors such as persistent changes to the atmosphere or changes in land use.

Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC) defines "climate change" as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus highlights the difference between climate change due to **human activities altering the composition of the atmosphere**, and climate change due to natural causes.

It is important to note that the difference between climate ***variability*** and ***change*** is in the persistence of "anomalous" conditions – when climate events that used to be rare, for example heat waves or storms, occur more frequently, or vice-versa.

1.2 How do we know that the Climate is changing?

The WMO uses eight Climate Indicators to describe and monitor the changing climate [3], which reflect changes in the three climate components of atmosphere, cryosphere and hydrosphere as well as the climate system as a whole (Figure 2). Any changes in the climate components will result in changes to the climate system and the climate we experience. These Climate Indicators therefore describe how the climate is changing at a global scale over a long period of time. Through them the scientific community is able to monitor and understand changes in the composition of the atmosphere and the amounts of greenhouse gases (GHGs), how the energy of the climate system changes due to the build-up of GHGs and other factors, and how the land, ocean and ice respond.

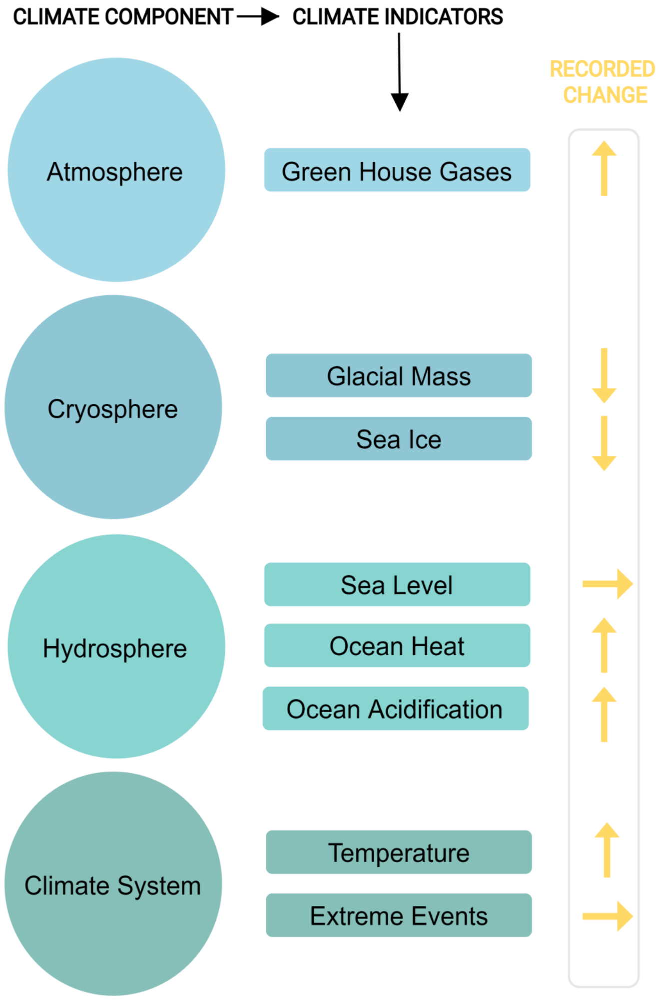


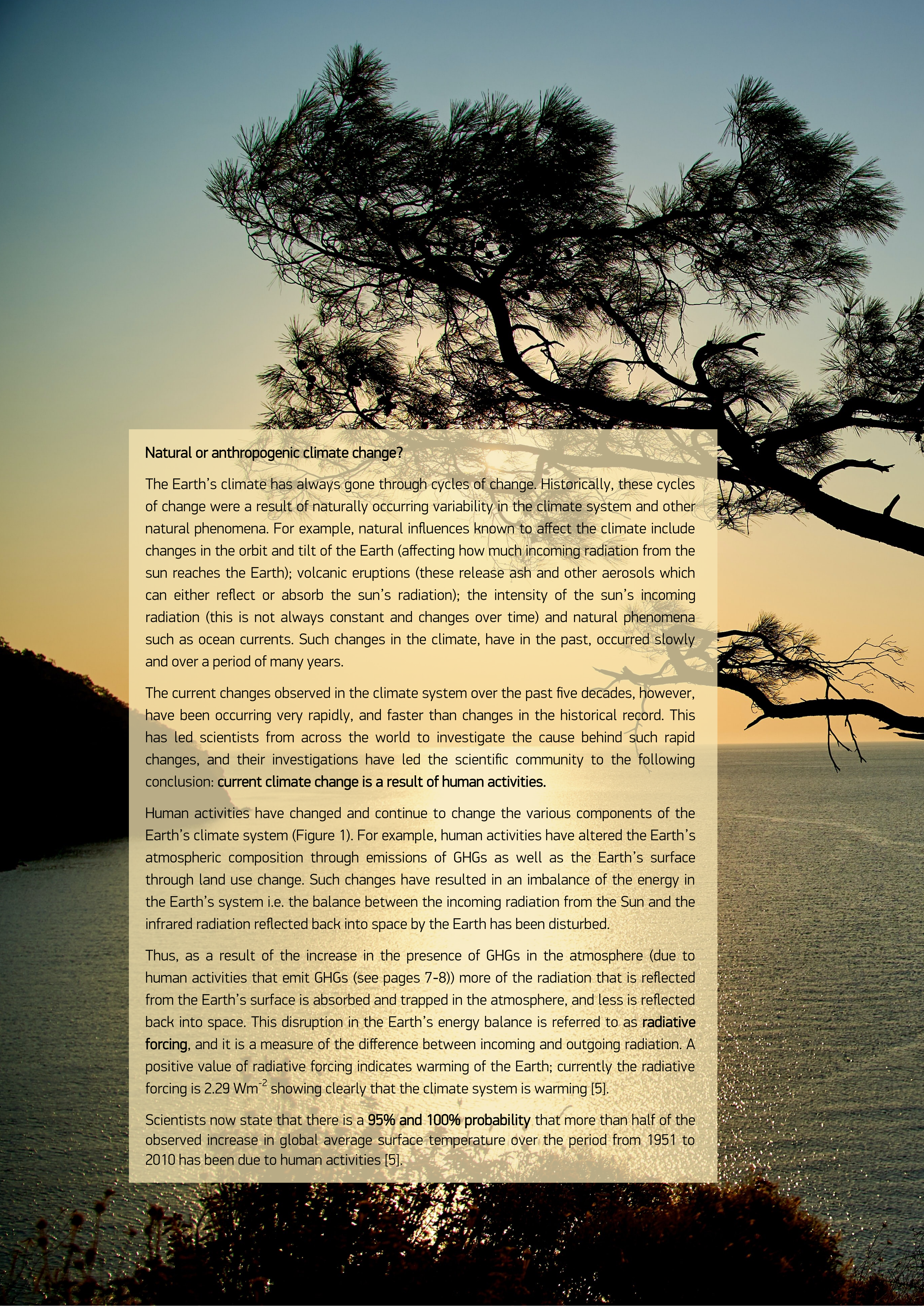
Figure 2 *Changes in the Climate system as described by climate indicators*

How long has the science of climate change been understood?

The scientific understanding that GHGs trap heat in the atmosphere has been known for over a century. The first scientist to hypothesise that there must be gasses in the Earth's atmosphere that were trapping heat, making the Earth much warmer than it was based on the amount of sunlight it received, was Joseph Fourier in 1824. In fact, Fourier further hypothesised in a paper in 1837, that natural processes and human activity could alter the amount of heat absorbed by the atmosphere and as a result alter the mean temperature in various locations. The first **experimental** evidence of the heat trapping ability of CO_2, was recorded in 1856 by Eunice Foote, whilst in 1859 John Tyndall proved and described how CO_2 and water vapour can absorb infrared radiation, and that even in small quantities, these gases absorb much more strongly than the atmosphere itself. Both Eunice Foote and John Tyndall understood that the concentrations of GHGs such as CO_2 and water vapour in the atmosphere, could impact the climate.

The next step in our understanding of the effect of CO_2 on the climate was taken by Svante Arrhenius who developed the first climate model in 1896 as he wanted to calculate how much CO_2 it would take to alter global temperatures [4]. This climate model was not computer-based like our modern climate models, Arrhenius had to make thousands of complex calculations by hand, but through this work he came to an important conclusion: **if the concentrations of CO_2 were doubled in the atmosphere it would result in an increase in the mean global surface temperature of 5 to 6 degrees Celsius**. Whilst Arrhenius' estimate is a little high, his scientific work and conclusions have been supported over decades of analysis using more sophisticated and modern instruments and computers.

Climate change is therefore not a recent discovery.



Natural or anthropogenic climate change?

The Earth's climate has always gone through cycles of change. Historically, these cycles of change were a result of naturally occurring variability in the climate system and other natural phenomena. For example, natural influences known to affect the climate include changes in the orbit and tilt of the Earth (affecting how much incoming radiation from the sun reaches the Earth); volcanic eruptions (these release ash and other aerosols which can either reflect or absorb the sun's radiation); the intensity of the sun's incoming radiation (this is not always constant and changes over time) and natural phenomena such as ocean currents. Such changes in the climate, have in the past, occurred slowly and over a period of many years.

The current changes observed in the climate system over the past five decades, however, have been occurring very rapidly, and faster than changes in the historical record. This has led scientists from across the world to investigate the cause behind such rapid changes, and their investigations have led the scientific community to the following conclusion: **current climate change is a result of human activities.**

Human activities have changed and continue to change the various components of the Earth's climate system (Figure 1). For example, human activities have altered the Earth's atmospheric composition through emissions of GHGs as well as the Earth's surface through land use change. Such changes have resulted in an imbalance of the energy in the Earth's system i.e. the balance between the incoming radiation from the Sun and the infrared radiation reflected back into space by the Earth has been disturbed.

Thus, as a result of the increase in the presence of GHGs in the atmosphere (due to human activities that emit GHGs (see pages 7-8)) more of the radiation that is reflected from the Earth's surface is absorbed and trapped in the atmosphere, and less is reflected back into space. This disruption in the Earth's energy balance is referred to as **radiative forcing**, and it is a measure of the difference between incoming and outgoing radiation. A positive value of radiative forcing indicates warming of the Earth; currently the radiative forcing is 2.29 Wm^{-2} showing clearly that the climate system is warming [5].

Scientists now state that there is a **95% and 100% probability** that more than half of the observed increase in global average surface temperature over the period from 1951 to 2010 has been due to human activities [5].

The Icons in the following pages were downloaded from The Noun Project - thenounproject.com (AC by ainul muttaquin, Agriculture by Vectors Point, Air Pollution by Eucalyp, Deforestation by Ruliani, Fertilizer by Brand Mania, Fossil Fuel by Lizzy Gregory, Increase by Gregor Cresnar, Land Use Change by Nithinan Tatah, Landfill by Drew David Park, Livestock by Laymik, Mine by Martina Krasnayova, Ocean by Bomsymbols, Oil and Gas by Firza Alamsyah

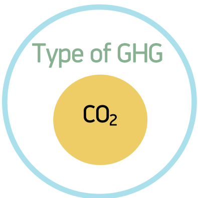
CLIMATE COMPONENT INDICATOR DIRECTION OF CHANGE

Brief definition of indicator

Greenhouse gases (GHGs) are gases found in the Earth's atmosphere which absorb infrared radiation i.e., trap heat and keep the Earth warm. These include **carbon dioxide**, **water vapour**, **nitrous oxide** and **methane.** Any change in the amounts of GHG in the atmosphere affects the amount of heat trapped within it. Since the industrial revolution , human activities such as energy production, transport, agriculture amongst others have been increasing the amounts of these gases in the atmosphere.

Trend

Annual anthropogenic GHG emissions have **increased** by 10 $GtCO_2eq$ between 2000 and 2010, with this increase directly coming from energy supply (47 %), industry (30 %), transport (11 %) and buildings (3 %) .



The most commonly monitored greenhouse gas is **carbon dioxide (CO_2)**. The amounts of CO_2 in our atmosphere have been steadily increasing, and have reached unprecedented levels, with a concentration of 410.5±0.2 ppm reported in 2019, an 148% increase from pre-industrial levels.

Observations shown in Figure 3 indicate clearly the upwards trajectory in CO_2 concentration from 1960, with about half of cumulative anthropogenic CO_2 emissions occurring in the last 40 years [6].

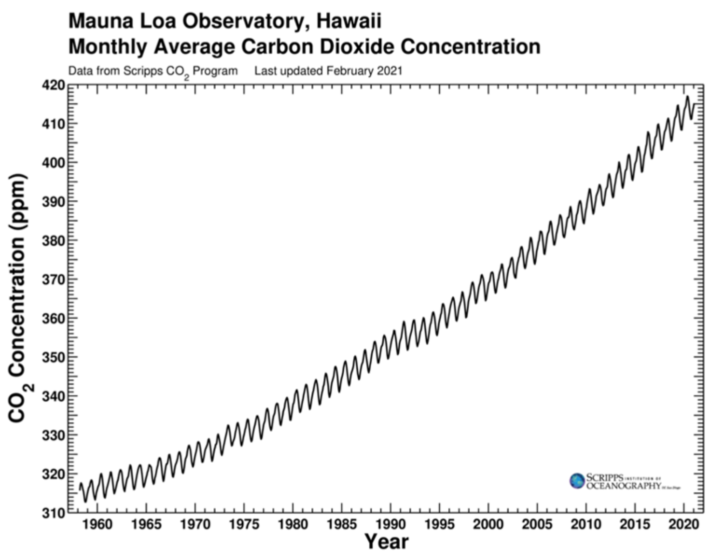


Figure 3 Increase in CO_2 concentration since the 60s [7]

Sources:

burning of fossil fuels deforestation land use change

Type of GHG

CH_4

Methane is also a very potent greenhouse gas, which is released from decomposing waste in landfills, livestock and agriculture, combustion, coal mining, natural gas and oil production. In 2019, methane concentrations in the atmosphere were recorded to be 1877±2 ppb, a 260% increase from preindustrial levels. Methane is a much stronger greenhouse gas, trapping in more heat than CO_2, however it is present in lower concentrations in the atmosphere. Nevertheless, as methane accounts for about 23 percent of global GHG emissions and is about 28 times as effective as carbon dioxide at trapping heat in the atmosphere, its increasing concentrations are of serious concern [8]. However, in contrast to CO_2, which remains in the atmosphere for hundreds of years, methane is relatively short lived and remains in the atmosphere for about 10 years. As a result, actions to reduce methane emissions will have a significant impact on the amount of heat trapped in the atmosphere.

Sources:

decomposing waste in landfills

Livestock

Agriculture

natural gas and oil production

Coal mining

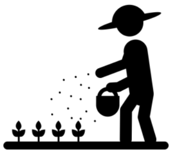
Type of GHG

N_2O

The third greenhouse gas that is monitored is **nitrous oxide**. Levels of nitrous oxide have also been steadily increasing since pre-industrial levels, with the concentrations in 2019 being 332.0±0.1 ppb an increase of 123% from pre-industrial levels. Nitrous oxide is a powerful GHG, and traps in 300 times more heat than CO_2 , and can remain in the atmosphere for 114 years, meaning action to reduce levels of these gas could make considerable contribution in mitigating climate change.

Sources:

Agriculture



Fertilizer use

decomposing waste in landfills

burning of fossil fuels

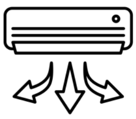
Type of GHG

HFC

There is now a fourth source of greenhouse gases, which are the **fluorinated gases**, synthetic compounds of industrial origin. These gases are long-lived, they remain in the atmosphere for about 264 years, and are powerful heat trappers, trapping 14,800 more heat in the atmosphere than CO_2. These gases further contribute to the creation of the ozone hole, and are regulated by the Montreal Protocol (see pages 37-38).

Sources:

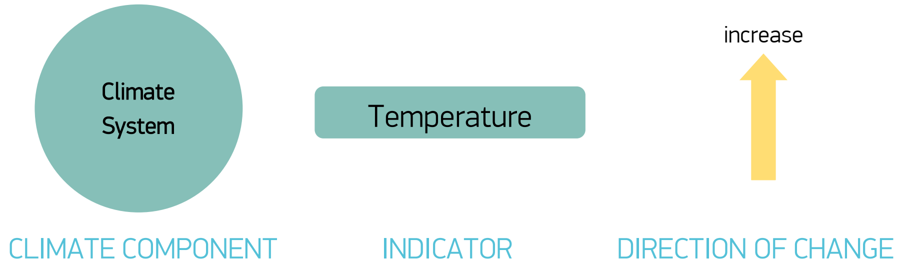
refrigeration



Air conditioning

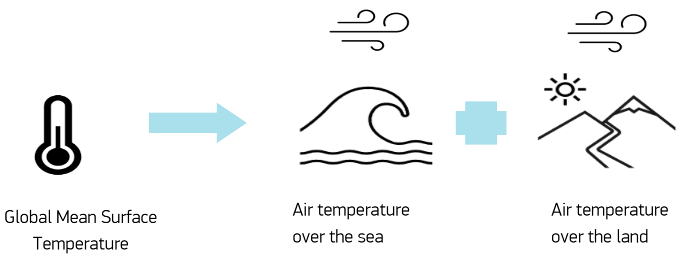
Impacts

As a result of the increase in the amounts of GHGs in the atmosphere, the atmosphere is trapping in more heat, with more heat in the form of infrared radiation remaining in the atmosphere than is radiated back out to space. This imbalance in the energy budget of the atmosphere known as radiative forcing, affects the climate system as a whole, since the atmosphere is one of the key climate components that regulate and influence the climate (Figure 1). This change in the energy budget of the atmosphere results in changes to the Global Mean Surface Temperature, which in turn results in responses from the land, oceans and sea ice.



Brief definition of indicator

The **Global Mean Surface Temperature (GMST)** is calculated by averaging the air temperature over the surface of the sea and air temperature over land, and is compared to a baseline, which has been set at pre-industrial levels. Measurements of the sea and air temperatures are taken by several different scientific groups, and the databases are averaged to produce the GMST (Figure 4).



Trend

Globally, the decade of 2011-2020 was the **warmest decade** on record. In 2020, GMST was **1.2 ± 0.1 °C** warmer than the pre-industrial baseline (1850-1900), and 2020 was one of three warmest years on record [3].

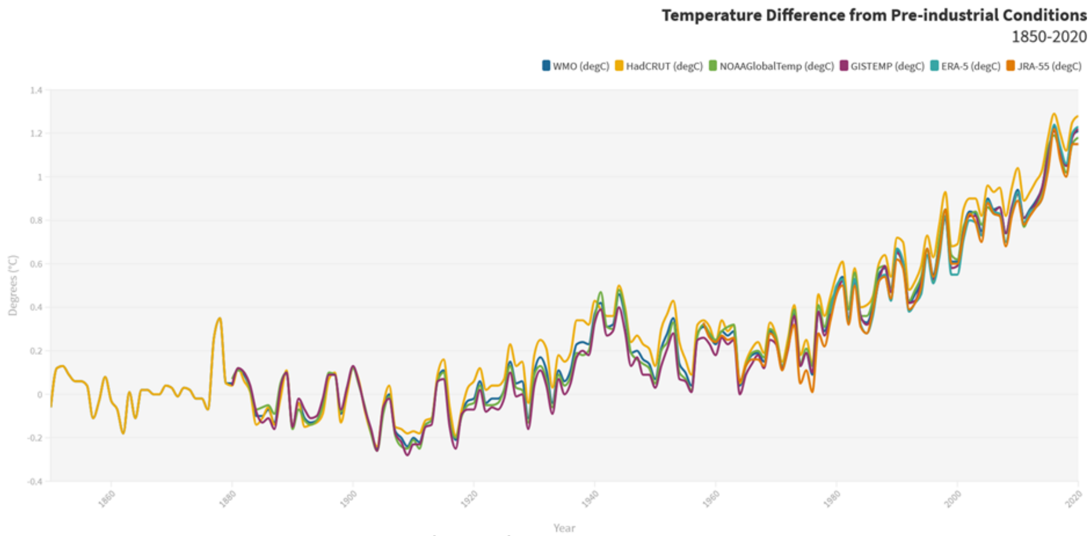


Figure 4 Temperature Difference from Pre-Industrial Conditions, Source: WMO

Impact

An increase in GMST is expected to lead to an increase in **extreme temperatures and heatwaves** across different regions of the globe, with different regions experiencing different levels of warming (see Section 1.3). At the same time, as the air warms it can hold additional amounts of water vapour, and so increasing global temperatures are expected to lead to **increased rainfall and extreme precipitation** events. Rising GMST has **already** resulted in an increase in the likelihood and severity of extreme weather events, such as heatwaves, extreme rainfall, droughts, cold waves, and severe storms. As a result, the WMO now monitors the incidence and severity of extreme weather events, as one of its climate indicators.

CLIMATE COMPONENT INDICATOR DIRECTION OF CHANGE

Brief definition of indicator

An extreme weather event (EWE) is a time and place in which weather phenomena, such as temperature, precipitation, drought, or flooding, are at the extremes of the historical trends and observations. An EWE may be a particularly severe weather phenomenon that is considered rare for a particular place or season. Some scientists define extreme events as those that occur in the highest or lowest 5% or 10% of historically observed values and measurements. Changes in the occurrence of extreme weather events, such as heat waves and floods, are the main way that most people experience climate change.

Trend

Whilst the occurrence of any individual extreme weather event is a result of a combination of different factors including, local weather conditions, the local land-atmosphere interactions, large scale ocean and climate patterns, and cannot always be attributed solely to climate change, scientists have now developed the ability to determine whether the **likelihood of occurrence and the severity of an extreme weather event has changed** due to climate change [9]. Using climate models which can simulate a world without climate change, and data records of past extreme weather events, scientists are now able to determine whether an extreme weather event is more likely or more severe because of climate change. Around three hundred and fifty attribution studies have been published over the past decade for over four hundred extreme weather events, which have shown that human-caused climate change has altered the likelihood or severity of the extreme weather event in 79% of the events studied (70% made more severe or likely and 9% made less so [10]).

Impact

EWEs can have substantial negative impacts, including loss of life, damages to buildings and other property, damages to the economy and to the environment. When damages are significant an EWE is categorised as a disaster. Data recorded by EM-DAT the International Disaster Database, show clearly that the number of climate-related extreme events leading to disasters has increased over the past two decades (Figure 5). Between 2000 and 2019, there were 510,837 deaths and 3.9 billion people affected by **6,681 climate-related disasters**. This is a near doubling of events compared with the period 1980-1999, whereby there were **3,656 climate-related events** which accounted for 995,330 deaths (47% due to drought/famine) and affected 3.2 billion people. While improvements have been made in terms of early warnings, disaster preparedness and response, which have led to a reduction in loss of life in single-hazard scenarios, increasing global temperatures is estimated to increase the frequency of potentially high impact natural hazard events across the world.

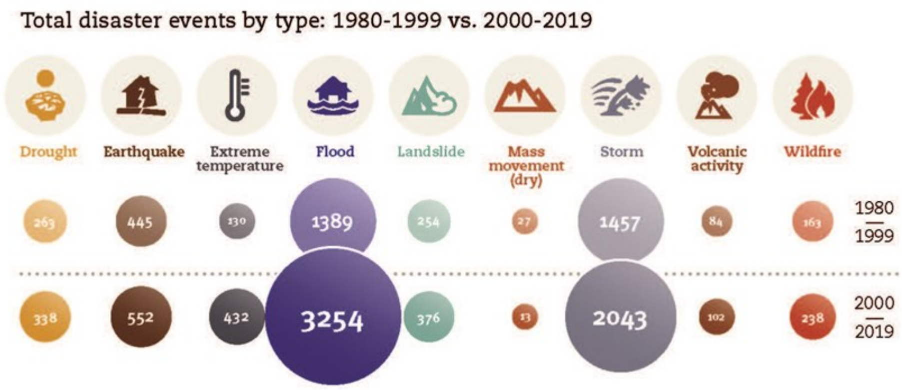


Figure 5 Increase in hydro-meteorological disasters in the period 2000-2019 vs 1980-1999

Source: EM-DAT: The OFDA/CRED International Disaster Database

Cryosphere — CLIMATE COMPONENT

Glacial Mass — INDICATOR

decrease — DIRECTION OF CHANGE

Brief definition of indicator

Glaciers are made up of fallen snow that, over many years, compresses into large, thickened ice masses. Glaciers form when snow remains in one location long enough to transform into ice. What makes glaciers unique is their ability to flow. Due to sheer mass, glaciers flow like very slow rivers [11].

Glacial mass is a measurement of the mass balance of glaciers across the world. A glacier is the result of how much mass it receives from snow and how much it loses by melting. Mass balance is the gain and loss of ice from the glacier system, where a negative mass balance indicates that a glacier is losing more ice than gaining and is therefore shrinking.

Trend

Observations indicate that in most regions' glaciers are either shrinking or disappearing. Glaciers lost 9,625 billion tons of ice between 1961 and 2016, corresponding to a sea-level equivalent of 27 millimetres. The global mass loss of glacier ice has increased significantly in the last 30 years and currently amounts to 335 billion tons of lost ice each year. This corresponds to an increase in sea levels of almost 1 millimetre per year. The melted ice of glaciers therefore accounts for 25 to 30% of the currently observed increase in global sea levels. The melt rate and cumulative loss in glacier thickness continues to be extraordinary [12].

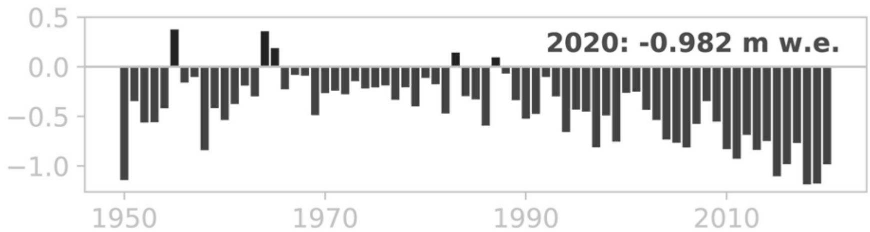


Figure 6 Global mass balance of glaciers from 1950 to 2010

Source: WMO, 2020

Impact

Glaciers cover around 10% of the world's land surface yet they store around 69% of the Earth's freshwater [11]. Beyond the contribution to rising global sea levels, loss of glacial mass can impact regional water cycles and the uses of freshwater, alter the visual landscape of glacial regions (e.g. mountain and polar regions) and influence local hazardous events [12].

For many glacial regions, glacial runoff feeds rivers and lakes, supporting ecosystems and human activities such as water supply and quality, farming, energy production (hydropower), and even tourism. As glacier mass decreases, the total runoff from glaciers will decrease in the long-term, with significant impacts on the predictability of water availability and river ecosystems. This may have knock-on effects on the human activities that are dependant on the water cycle as well as disrupt riverine ecosystems. Finally, as glaciers retreat the slopes that support them may destabilise, increasing the risk of hazardous landslides [55].

Cryosphere

Sea Ice

decrease

CLIMATE COMPONENT | INDICATOR | DIRECTION OF CHANGE

Brief definition of indicator

Sea ice is frozen ocean surface water and is primarily found in the polar regions of the Earth, the Arctic and Antarctic. Sea ice grows in the autumn and winter months and melts during the summer months, with about 15 percent of the world's oceans covered by sea ice during any part of the year.

Arctic sea ice is an important part of the climate system and helps regulate global climate. Its bright white surface means that it has a higher albedo (the fraction of light that is reflected by a surface) and reflects as much as 80% of the incoming solar radiation during the winter, keeping the polar region cooler than other regions on Earth.

Trend

To understand changes in sea ice, scientists measure sea ice extent which is a measurement of the area of ocean where there is at least some sea ice, using satellites. In the Arctic Ocean, sea ice extent reaches its maximum in March and its minimum in September. Each autumn, as air temperatures begin to drop, additional sea ice forms, and increases through the winter, reaching its maximum extent in March. Once spring arrives, bringing more sunlight and higher temperatures, the ice begins to melt back, shrinking to its minimum extent by September.

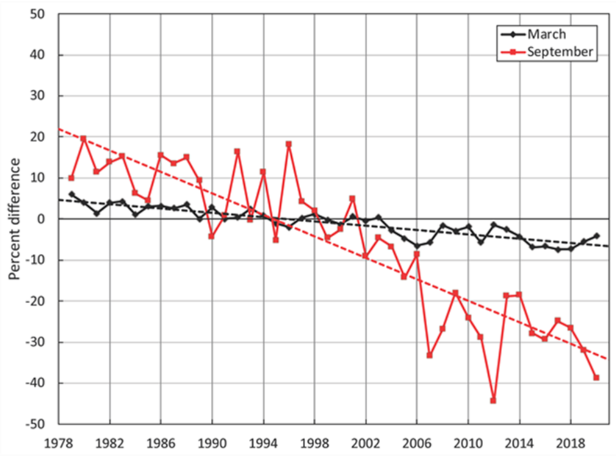


Figure 7 Monthly sea ice extent (solid lines) and linear trend lines (dashed lines) for March (black) and September (red) 1979 to 2020

Source: NOAA, Arctic Report Card 2020

Since satellite-based measurements began in the late 1970s, Arctic sea ice **extent** has declined significantly and has exhibited a decrease in all months and virtually all regions. In 2020, the annual minimum sea-ice extent in the Arctic was the second lowest on record and record low sea-ice extents were observed in the months of July and October. The 2020 Arctic sea ice minimum extent was 3.74 million km^2, whilst the maximum extent was 14.77 million km^2, which was tied for seventh-lowest in the satellite record. Furthermore, the 14 lowest minimum extents in the satellite era have all occurred in the last 14 years [13]. The rate of decline in the monthly average extent 1979 to 2020 is -82,700 km^2 per year or -13.1% per decade relative to the 1981-2010 average (Figure 7). Arctic sea ice **volume** has declined just as significantly. In the beginning of the satellite record in 1978, average sea ice thickness in August was well over 2 meters, whilst as of August 2020, average volume was just above 1 meter.

Antarctic sea ice extent remained close to the long-term average, as it is a continent surrounded by water, with the wind and ocean currents isolating Antarctica from the global weather patterns, keeping it cold. The Arctic is surrounded by land, making it more sensitive to the weather patterns around it and to changes in the climate system.

Impact

Sea ice is important in the regulation of global temperatures, its bright surface reflecting 50% to 70% of incoming sunlight back into space, keeping temperatures cooler at the poles. Melting sea ice due to climate change means there is less sea ice at the poles to reflect incoming solar radiation. Consequently, more solar radiation is absorbed at the ocean's surface, leading to a cycle of warming and melting sea ice in a reinforcing loop.

Hydrosphere

Ocean Heat

increase

CLIMATE COMPONENT INDICATOR DIRECTION OF CHANGE

Brief definition of indicator

Ocean Heat Content (OHC) refers to the energy or the total warmth stored by the oceans. Approximately 93% of the warming from the increase in GHG emissions has been absorbed by the oceans. OHC is measured at various ocean depths, from 300m up to 2000m deep.

Trend

All data sets of OHC measurements agree that the rates of ocean warming display a strong increase in the past two decades and across all depths (Figure 9). As a result, sea surface temperatures (SST) have **increased** at a rate of nearly 0.6°C per century since 1880 [6].

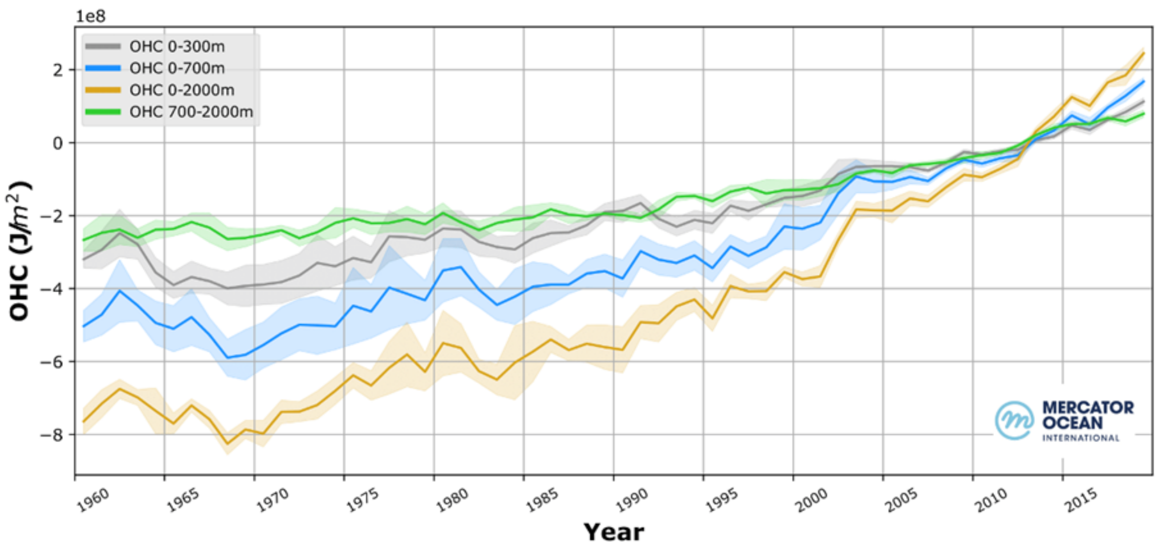


Figure 8 1960-2019 ensemble mean time series and ensemble standard deviation (2-sigma, shaded) of global ocean heat content (OHC) anomalies relative to the 2005-2017 climatology for the 0-300m (grey), 0-700m (blue), 0-2000m (yellow) and 700-2000m depth layer (green). Source: WMO State of the Climate Report, 2020

Impact

An increase in OHC is important as it has two significant impacts:

1) it results in marine heatwaves, which are unusual warm seawater events that can substantially impact marine life and marine livelihoods.

2) it contributes to sea level rise (one of the other important climate indicators) as when oceans heat up they expand .

For example, marine heatwaves can lead to coral bleaching, formation of algal blooms which release phytotoxins affecting marine life, as well as lead to a decline in the numbers and size of fish, with knock-on effects on commercial fisheries and coastal communities. Over the past century, marine heatwaves have occurred with increasing frequency and duration, with a near doubling of the global-average duration of MHWs [14]. In 2020 alone, the WMO reported that **84% of the ocean experienced at least one marine heatwave**. Crucially, as the OHC increases and the oceans heat up they expand, contributing to sea level rise [3], one of the other important climate indicators.

Hydrosphere

Sea Level

increase

CLIMATE COMPONENT INDICATOR DIRECTION OF CHANGE

Brief definition of indicator

The term sea-level rise generally designates the average long-term global rise of the ocean surface measured from the centre of the earth (or more precisely, from the earth reference ellipsoid), as derived from satellite observations. Relative sea-level rise refers to long-term average sea-level rise relative to the local land level, as derived from coastal tide gauges.

Trend

Globally, sea level has been rising an average of 3.3 (+/- 0.3) mm per year, peaking in 2020. This rise in sea levels is primarily due to melting glaciers and ice sheets as well as a result of thermal expansion of oceans due to the increase in OHC. Global sea level has recently been rising at a higher rate partly due to the increased melting of the ice sheets in Greenland and Antarctica. Sea levels have not been rising uniformly across the globe, with certain regions in the Southern Hemisphere, experiencing higher rates of sea level rise [3].

Impact

An increase in sea levels is a significant cause for concern, as it can negatively affect coastal regions and the 250 million people living within them, through coastal flooding, flooding during storm surges, and by saltwater intrusion of freshwater aquifers near the coast impacting on freshwater availability.

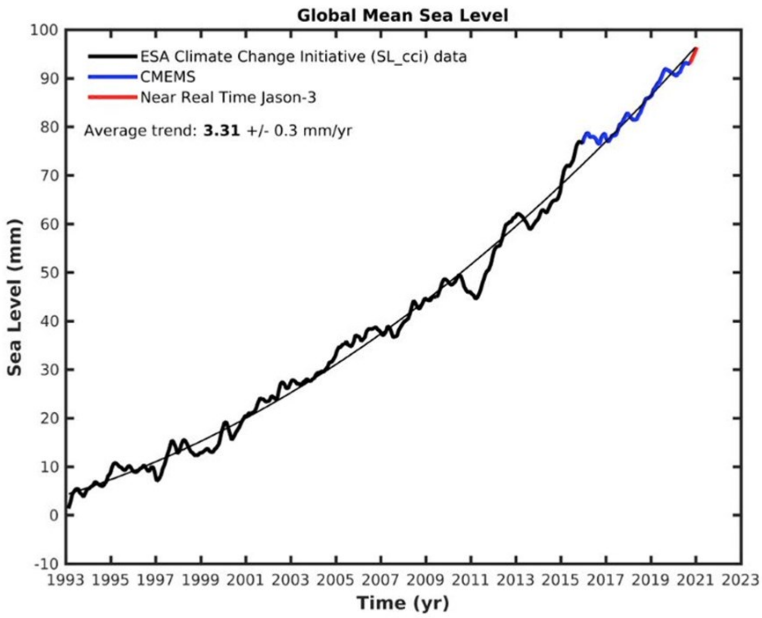


Figure 9 Satellite altimetry-based global mean sea level for January 1993 to January 2021 (last data: 21 January 2021). Data from the European Space Agency Climate Change Initiative Sea Level project (January 1993 to December 2015, thick black curve), data from CMEMS (January 2016 to November 2020, blue curve) and near-real-time altimetry data from the Jason-3 mission beyond November 2020 (red curve). Source: WMO State of the Climate Report, 2020

Hydrosphere | Ocean Acidification | increase

CLIMATE COMPONENT | INDICATOR | DIRECTION OF CHANGE

Brief definition of indicator

The ocean absorbs around 23% of the annual emissions of anthropogenic CO_2 to the atmosphere, consequently lessening the impacts of climate change. As CO_2 is acidic when dissolved in water, absorption of CO_2 emissions by the oceans results in their acidification [3].

Trend

Over the past three decades, as the concentration of CO_2 has increased in the atmosphere, the global mean ocean pH has been steadily declining as shown in Figure 10 [3].

Impact

Ocean acidification negatively impacts marine organisms, including corals, fish, marine invertebrate, and seabirds. In addition, as the acidity of the ocean increases, its ability to absorb CO_2 from the atmosphere decreases, hindering the ocean's role in regulating climate change [3].

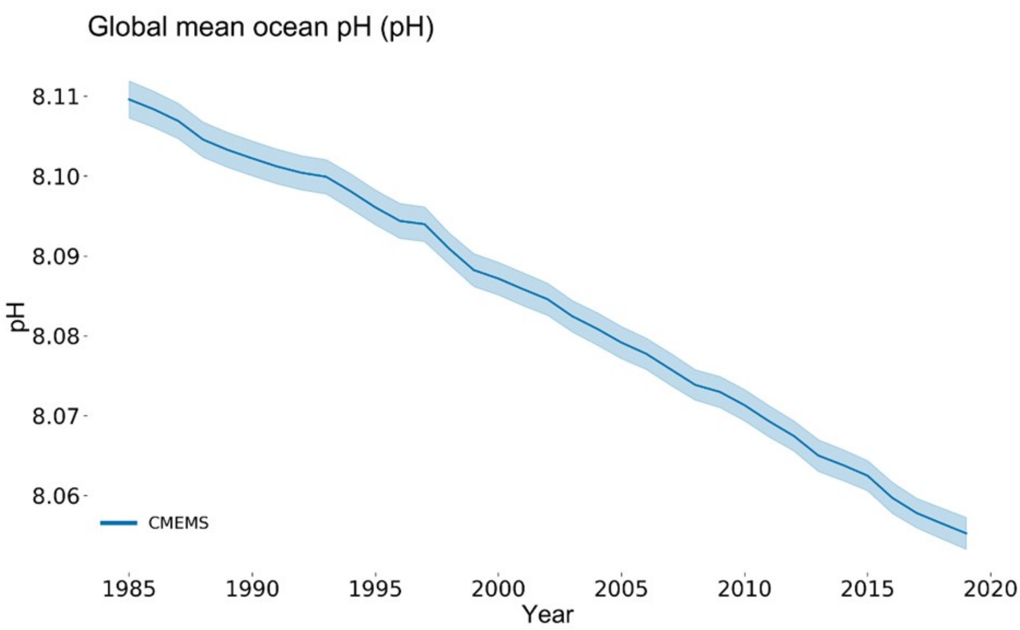


Figure 10 Global mean surface pH from 1985-2020. The shaded area indicates the estimated uncertainty in each estimate. Source: WMO, State of the Climate Report, 2020

1.3 How has climate changed in Europe and the Eastern Mediterranean?

Europe has been warming since the industrial period and has been warming at a rate faster than the global average, evidenced by the fact that annually averaged land temperatures over Europe have increased faster than global temperatures. Whilst Global Mean Surface Temperature in the decade 2010-2019 was about **0.94-1.03 °C** warmer than the pre-industrial average (1850-1899), the European land area has warmed by **1.7-1.9 °C** over the same period (however with considerable regional and seasonal differences) [15] see Figure 11.

Europe recorded its highest annual temperature in 2020 which was at least 0.4°C warmer than the next four warmest years on record, which occurred in the past decade (2014, 2015, 2018 and 2019). The winter and autumn of 2020 also set a record as the warmest, at more than 3.4°C above the 1981–2010 average [16].

In addition, as *daily maximum temperatures* have increased more rapidly than annual *averaged* temperatures, each given increase in GMST has been associated with a much larger increase in heat extremes in Europe. According to the European Environment Agency [15], heat extremes and heat waves in Europe have increased considerably since the 1950s, and in particular since 2000. Further research [17] has demonstrated that on average across Europe the number of days with extreme heat and heat stress has more than tripled (from 2 days to 6 days) and hot extremes have warmed by 2.3 C from 1950–2018. More recently, many parts of Europe experienced an exceptional heat wave in June and July 2019, during which many all-time national temperature records were broken [18]. The increase in extremely warm nights is even more noticeable, with more than a doubling from 1950–2018. As a result, cooling degree-days increased on average by almost 2 % per year during the same period, particularly in southern Europe [19]. In parallel, extremely cold nights have decreased by a factor of two to three from more than 5 around 1950 to around 2 days per year in 2018. Consequently,

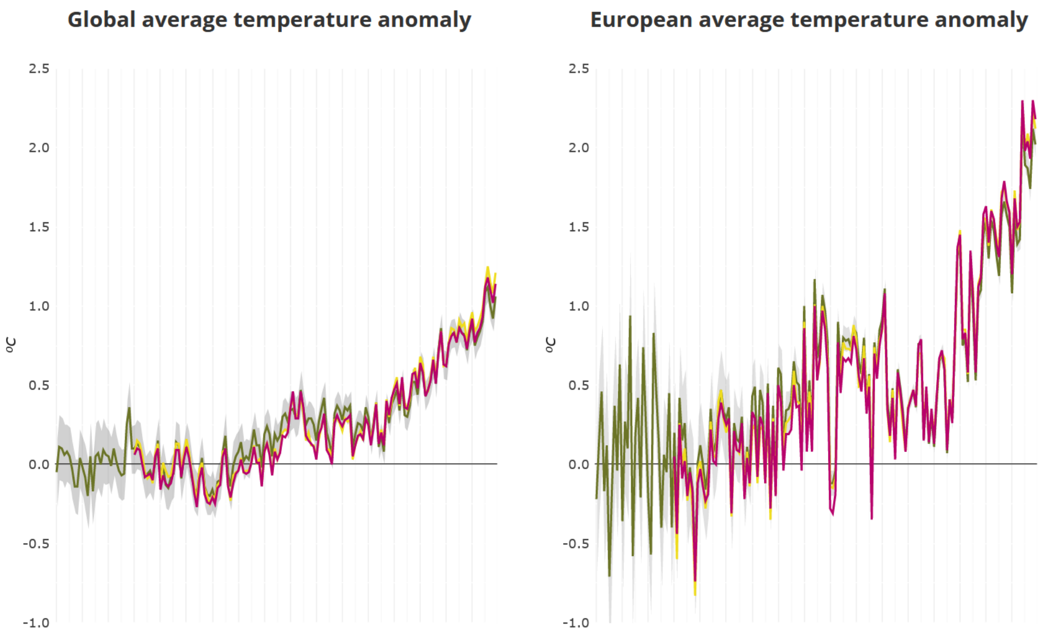


Figure 11 Global mean near-surface temperature during the last decade (2010-2019) was 0.94 to 1.03 °C warmer than the pre-industrial level, which makes it the warmest decade on record. European land temperatures have increased even faster over the same period, by 1.7 to 1.9 °C. Source: EEA, 2020

heating degree-days have decreased by about 0.5 % per year between 1981 and 2014, particularly in northern and north-western Europe. A clear signal has thus emerged over Europe with a strong trend towards more days and nights with extreme heat and heat stress and less days and nights with extreme cold.

Changes in precipitation over the same period have also been recorded, with differences in the trends between the different regions of Europe. For example, annual precipitation has decreased in parts of southern Europe, and this decrease is projected to intensify in the future with continued climate change. The combination of rising temperatures and reduction in precipitation, along with an increase in evapotranspiration, has led to an increase in drought conditions in southern Europe.

Focusing on the Mediterranean region, it has been identified as a climate change hotspot, as it warms faster than the rest of the world. Annual average temperatures in the region are approximately 1.5°C higher than during the preindustrial period (1880-1899) (Figure 12) [20] with the frequency and intensity of droughts exhibiting a significant increase in the Mediterranean since 1950. The trend in droughts is linked to the strong observed decrease in winter precipitation, particularly over the central and southern portions of the Mediterranean basin, since the second half of the 20th century and the strong evaporation increase due to local warming which in turn contributes to the observed increase in net fresh water loss (evaporation minus precipitation and river runoff) in the last decades of the 20th century [20].

Mediterranean Sea surface waters have been warming, and since the beginning of the 1980s average sea surface temperatures have increased throughout the basin, with stronger trends in the eastern basins such as the Levantine basin where Cyprus is located. As a result, marine heat waves have become longer and more intense in the region. Other changes in the Mediterranean Sea include acidification, with a decrease of sea water surface pH of -0.08 units since the beginning of the 19th century, and a rise in the mean sea level of 1.4 mm yr^{-1} during the 20th century which has accelerated to 2.8 mm yr^{-1} recently (1993–2018) [20].

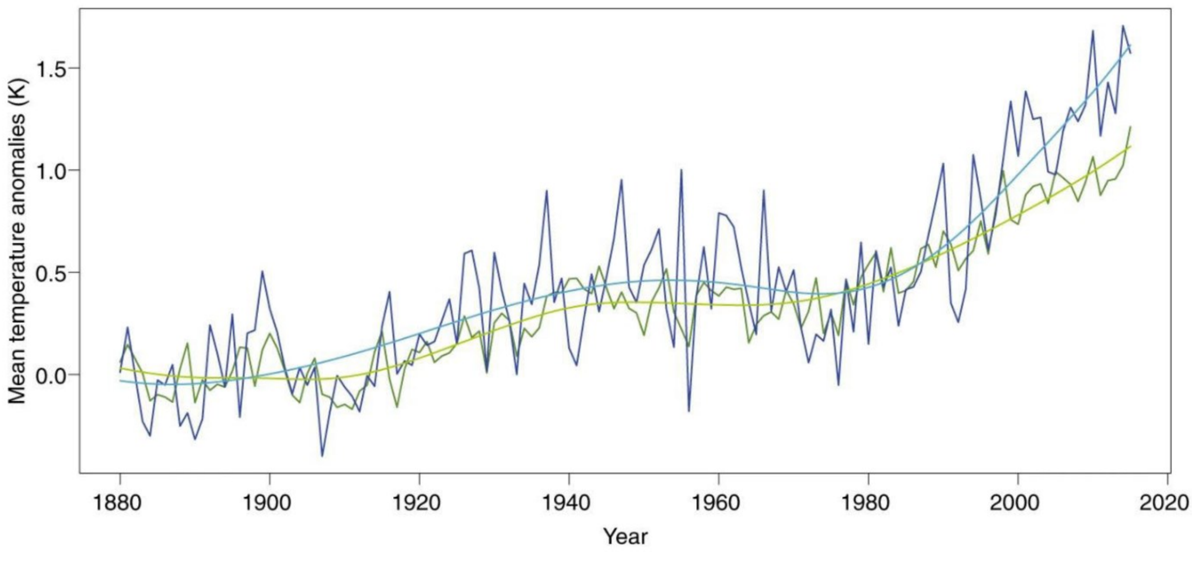


Figure 12 Warming of the atmosphere (annual mean temperature anomalies with respect to the period 1880-1899), in the Mediterranean Basin (blue lines, with and without smoothing) and for the globe (green line). Source: MedECC 2020[11]

1.4 How has the Climate changed in Cyprus?

Cyprus is a semi-arid region with a Mediterranean climate; it is characterised by hot and dry summers from mid-May to mid-October and mild, wet winters from November to mid-March, which are separated by short autumn and spring seasons of variable weather conditions [21]. An island with no borders with other neighbouring countries, its climate is strongly influenced by the surrounding Mediterranean Sea which supplies moisture and heat, and the island's orography, mainly the Troodos massif, which lead to local climate regimes such as local winds and other sea-air interactions. The interactions occurring among all these factors give rise to phenomena characteristic of the Mediterranean region, such as heatwaves and droughts and Saharan dust intrusions [22].

The average annual temperature in Cyprus displays an increasing trend, with 2010 the warmest year ever recorded in Cyprus. The annual mean temperature for Nicosia for the period 1960-1991 was 19.5 ^{0}C, whilst for the period 1992-2004 it was 20.28^{0}C, which is an **increase of 0.77 ^{0}C** [23]. The greater increase in temperature in urban centres is due to the urban heat island effect, however, the fact that an increase is also observed in rural areas, is indicative of the general increase in temperature in the Mediterranean region. The average daily **minimum** temperature, as recorded by all meteorological stations on the island, shows an even stronger increasing trend. As a result, the average number of frost days has decreased significantly.

Precipitation in Cyprus is unevenly distributed geographically, with maximum precipitation falling over the Troodos and Pendadaktyolos mountain ranges, and the minimum precipitation falling in the eastern plains and coastal areas. Average annual precipitation for the period from 2000 onwards, over the whole island is 460 mm, with the variations in rainfall across latitude and altitude shown by Figure 13.

What is the Urban Heat Island Effect?

The Urban Heat Island (UHI) effect describes the observed phenomenon of higher temperatures in urban areas (cities) compared to the temperatures of their surroundings, and in particular rural areas. The difference in temperatures is due to the large number of buildings and roads present in urban areas, which are made of materials such as concrete and asphalt, in combination with a lack of green areas. Conventional building materials such as concrete and brick absorb more sunlight and heat than trees and plants. About 80% of the solar radiation absorbed by buildings and roads is re-radiated into the air creating a warm air bubble over urban areas, which can be as 1 to 3°C higher than the temperatures in surrounding areas [24].

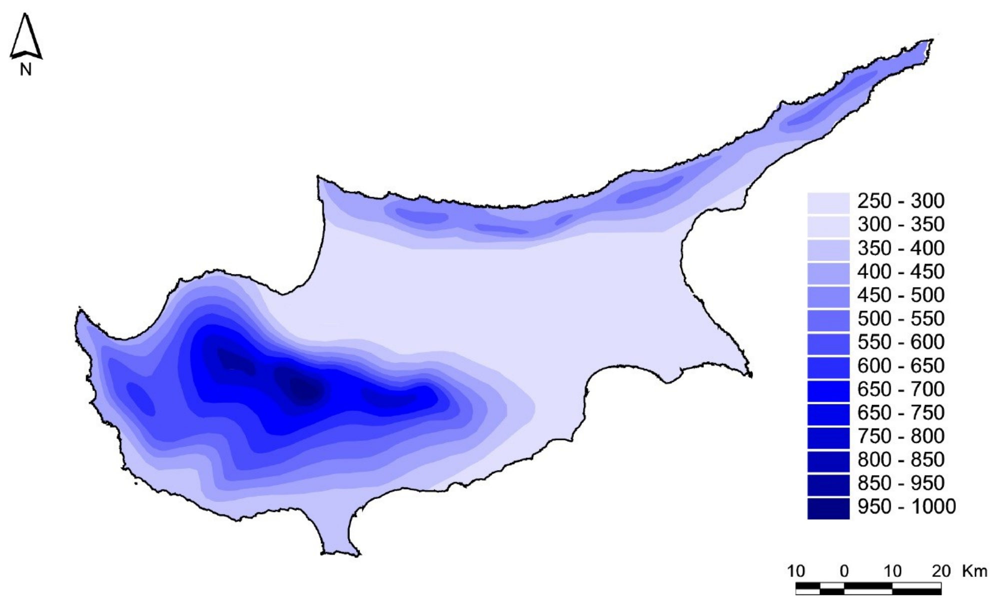


Figure 13 Distribution of precipitation over Cyprus, Source: WDD

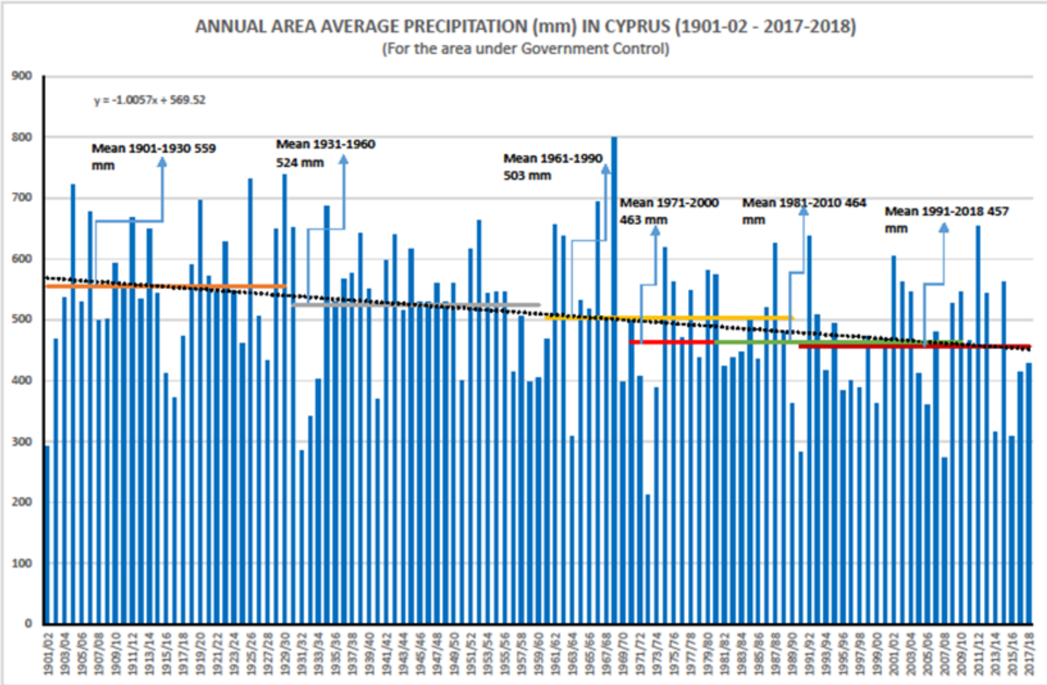


Figure 14 Annual area average precipitation in Cyprus 1901/02 – 2017/18 Source: WDD, 2020

Statistical analysis of average precipitation in Cyprus exhibits a decreasing trend of rainfall amounts in the last 116 years. Annual precipitation in Cyprus has on average **decreased by about 100mm** in the last 85 years (Figure 14). While the average annual precipitation in the first 30-year period of the 20th century was 559 mm, the average precipitation in the last 30-year period was 462 mm, which corresponds to a decrease of 17%. Specifically, the rate of decrease of the average precipitation in Cyprus during the 20th century and at the beginning of the 21st was one millimetre per year according to records by the Department of Meteorology [25].

Despite the decreasing trend in precipitation, analysis has shown that in the period 1981-2010 the number of heavy rainfall events has increased compared to the period 1961-1990, meaning that Cyprus has become more vulnerable to floods and soil erosion as a result of heavy rainfall [26]. A further analysis by the Department of Meteorology for the meteorological stations in Nicosia, show that in the period 1971-2007 there was an increase in the volumes and therefore intensity of rainfall compared to the period 1930-1970. For example, the 5 minute duration has exhibited an increase of 40,4% in the period 1971-2007 and the 6 hour duration rainfall intensity an increase 49,4% for the same period [27].

Why are we interested in the duration of rainfall intensity?

Rainfall intensity is the amount of rainfall observed in a period of time. It is also expressed as the rain that falls per unit of time i.e.:

Intensity: Amount of rainfall (mm)/time (hour)

Rainfall intensity can indicate the amount of heavy or intense rain that falls over a period of time. High rainfall intensity indicates that it is raining hard.

Rainfall duration is how long it rained at that intensity and can indicate the time for water to potentially flood a "system" or area.

Rainfall intensity duration is used by engineers to design infrastructure systems such as water and stormwater systems ensuring that the systems are able to carry the minimum amount of extreme rainfall. They are also used by government to design flood risk management plans and policies.

Maximum rainfall intensity can be derived for different durations, commonly the durations used by engineers and governments for flood management include 5-min, 10-min, 15-min, 30-min, 1-hour, 2-hour, 3-hour, 6-hour and 24-hour durations.

The increase in rainfall intensity of the 5-minute duration (increase of 40,4%) and the rainfall intensity of the 6 hour duration (an increase of 49,4%) in Cyprus in the period 1971-2007 indicate that extreme precipitation events have been increasing over the past decades.

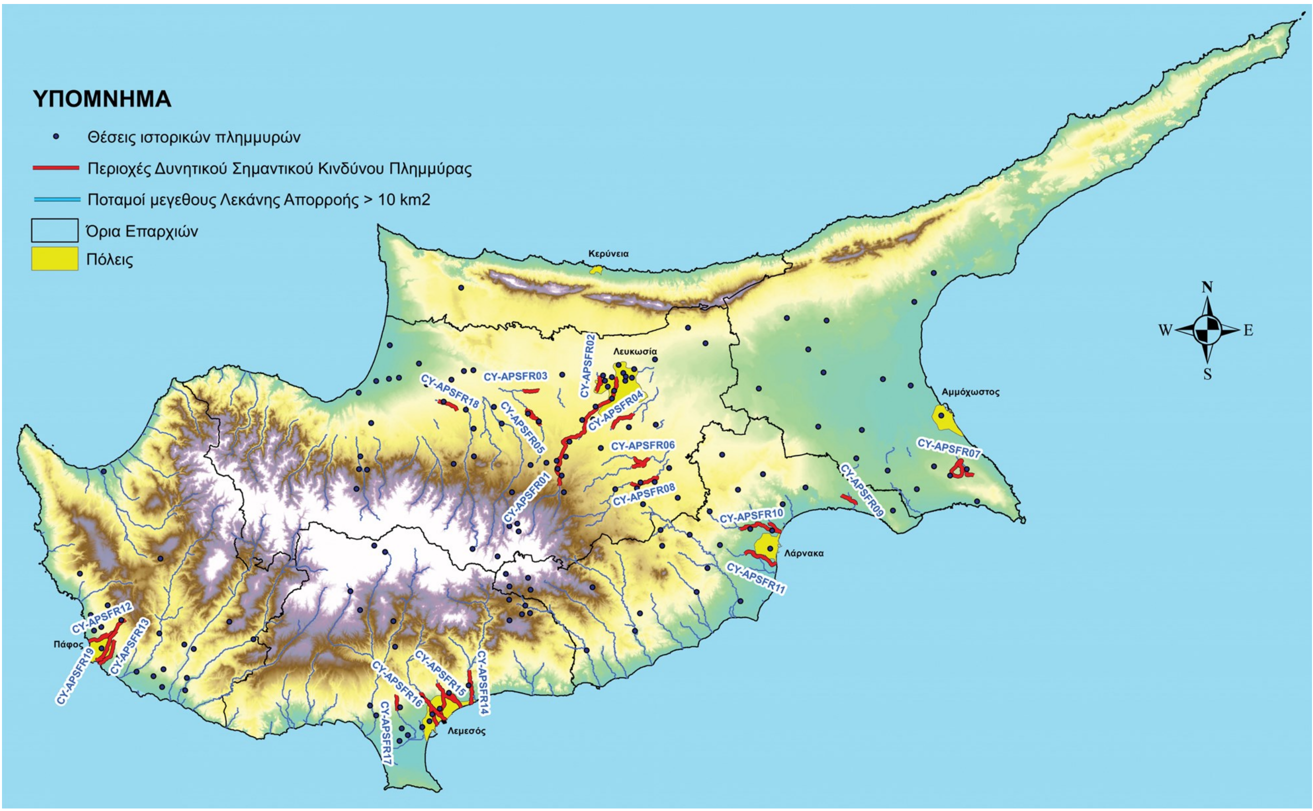


Figure 15 Map which provides an overview of the areas with significant risk of flooding

- *Location of historical floods*
- *Areas of potentially significant flood risk*
- Rivers the size of a catchment area > 10km^2
- District boundaries
- Cities

From 2011 to 2018, twelve floods in the medium to high severity categories were recorded in Cyprus. The Water Development Department has identified 38 areas with a significant risk of flooding [27] and has developed relevant interactive flood risk maps for them. Figure 15 shows the areas that have a significant risk of flooding, as well as the areas that have experienced historical flooding.

Precipitation furthermore exhibits an inter-annual variability, with frequent periods of drought [28]. Cyprus suffers from long and often severe droughts during summer, with the island classified (along with Malta) as the EU country with the most acute water shortage. This is supported by data from the European Drought Observatory which further indicate that droughts have been accompanying this decrease in rainfall. The six-month Standardised Precipitation Index (SPI-6) for Cyprus for the period 1970 to 2021, shows clearly the incidence of drought, whereby negative SPI values represent rainfall deficit[1] (Figure 16).

1. The intensity of a drought event is classified according to the magnitude of the negative SPI values such that the larger the negative SPI values are, the more serious the drought is.

What is the SPI?

The Standardised Precipitation Index is one of the most common indicators used to identify and describe a drought. It shows the deviation from the historical annual average observed precipitation of a given location over a period of time e.g. over 3 months, 6 months, 12 months or 48 months. The longer the deviation persists e.g. for 48 months the more long-lasting the drought is.

SPI values less than 0 indicate severe rainfall deficit and dry periods whilst values above zero indicate severe excess rainfall and wetter.

For more information visit the European Drought Observatory https://edo.jrc.ec.europa.eu/edov2/

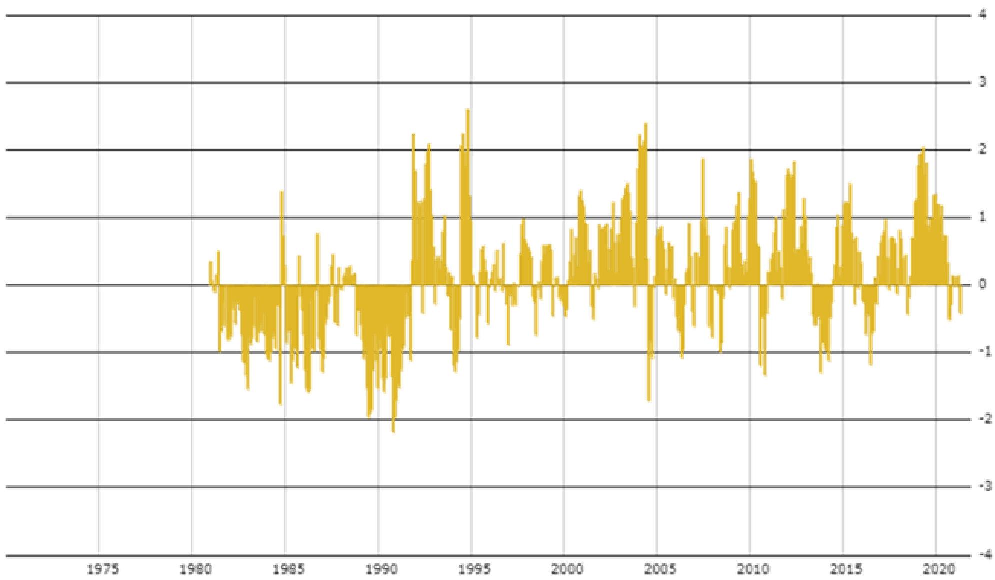


Figure 16 Six-month Standardised Precipitation Index (SPI-6) for Cyprus for the period 1970 to 2021 Source: European Drought Observatory

Did you know?

In 2008 Cyprus experienced its most intense and prolonged period of drought. In some locations in the southern and eastern parts of the island, SPI values were below -3.0 indicating extremely severe drought conditions [29].

The drought resulted in severe impacts to the environment, agriculture and the economy.

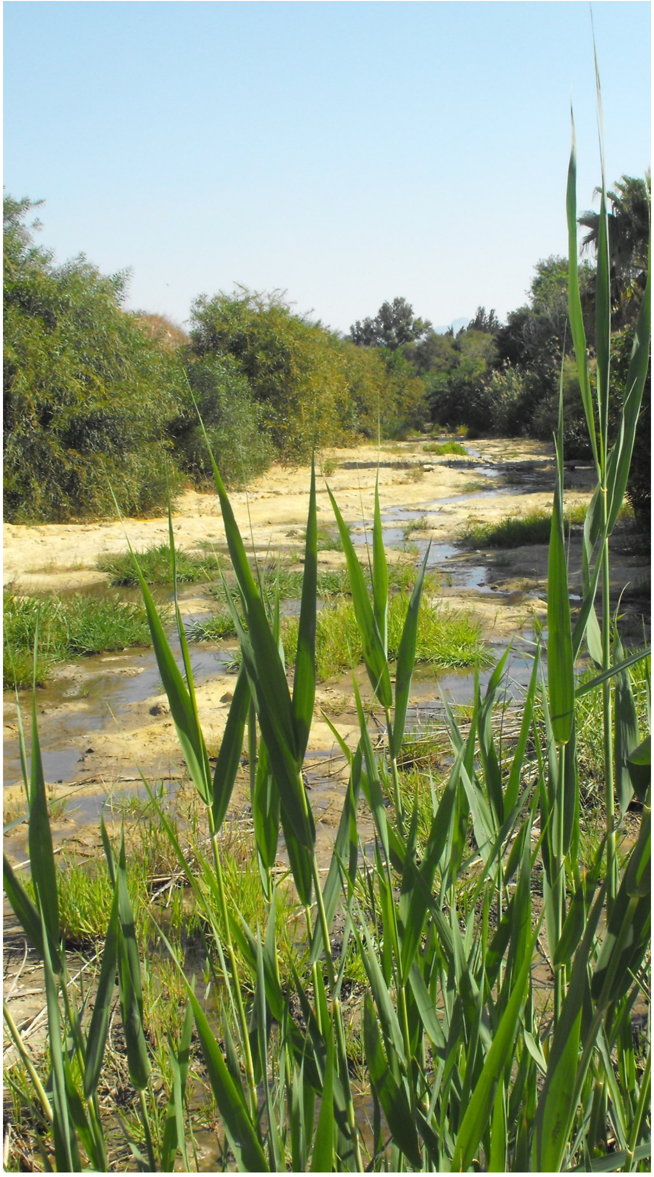
There was almost no water in the reservoirs which led to 100% water cuts to agriculture and a reduction in agriculture production. Private households were also impacted with 30% cuts to domestic water supply, meaning that households had running water for 36 hours per week. The severe impacts to water supply led to the Government importing water from Greece, at a significant cost to the economy.

Over the last 50 years, water scarcity has become one of the most pressing and growing problems facing the country, due to the declining rainfall, which has been accompanied by population growth, an improvement in living standards, growth in the tourism industry and an increase in water demand for irrigation [28].
The average Water Exploitation Index (WEI+) for Cyprus is 81.32 % for the years 2000-2017 [30], indicating freshwater sources that are highly stressed (Figure 16). Severe scarcity occurs where the WEI exceeds 40%, indicating clearly that Cyprus suffers from severe water scarcity.

The **Water Exploitation Index plus (WEI+)** is a measure of *total fresh water use* as a percentage of the total renewable fresh water resources (groundwater and surface water) available at a given time and place.

It quantifies how much water is abstracted and how much water is returned after use to the environment. The difference between water abstraction and return is considered as water use and is a measure of the pressure on renewable freshwater resources due to water demand.

Values above 20% are generally considered to indicate water scarcity, while values equal or bigger than 40% indicate situations of *severe* water scarcity, i.e. the use of freshwater resources is clearly unsustainable [30].



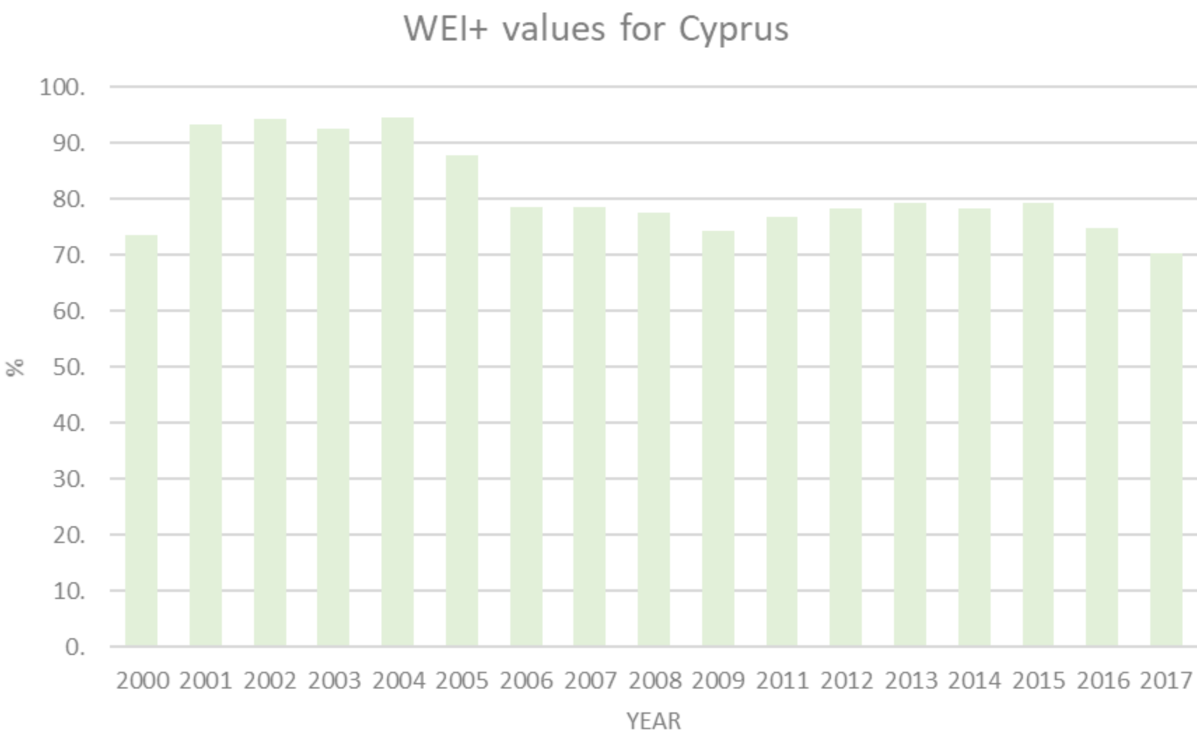


Figure 17 Water Exploitation Index plus values for Cyprus from 2000-2017 Source: EEA

1.5 Future Climate Change for the Mediterranean and Cyprus

Future climate projections for the Mediterranean show that the entire region will experience warming in the 21st century. As a **climate change hotspot**, the Mediterranean basin is projected to experience warming at a faster rate than the global average in the future, exceeding the global average value by 20% on an annual basis and by 50% in the summer period [20].

Projections based on two scenarios: 1) a business-as-usual scenario with high GHG concentrations (RCP 8.5) and 2) a scenario consistent with achieving the UNFCCC Paris Agreement targets (RCP 2.6) **show a robust warming irrespective of scenario** by 2100 (with respect to the period 1980-1999) (Figure 18). The degree of increase in temperature, varies however with the scenarios, with an increase in the temperature ranging between **0.9°C to 1.5 °C for the RCP 2.6 scenario** and **3.7°C to 5.6 °C for the RCP 8.5 scenario [31]**. It is thus clear that action to mitigate climate change will have a marked effect on the degree of warming.

Projections of indicators related to extreme temperatures and extreme events are consistent with an **increase in the frequency and intensity of heatwaves**. Under a business-as-usual scenario (RCP 8.5), projections indicate an **increase in the summer daily *maximum* temperature of up to 7°C by 2100**, in comparison with the recent past [32] [33] whilst under the RCP 2.6 scenario the increase in temperature is expected to be 3.3°C (Figure 19). At the same time, parts of the **Mediterranean will likely face an increase of more than 60% in the number of tropical nights**, and there will be almost no cold days under the business-as-usual scenario.

In parallel, climate projections indicate a drying across the Mediterranean, with a likely **decrease in precipitation** particularly for the business-as-usual scenario. Drying will be pronounced in the warm seasons (April through September, with the largest increase in drying experienced in June -July-August), whilst central and southern areas of the Mediterranean will also experience a **decrease in winter precipitation** from the second half of the 21st century. The average rate of decrease in precipitation over the land areas of the Mediterranean is dependent on the degree of global warming, with climate models indicating a **decrease in precipitation of 4% per each degree of global warming**. This results in a reduction of 4% to 22% in precipitation by 2100 depending on whether we follow the RCP 2.6 scenario or the RCP 8.5 scenario. Under such a drying regime, longer dry spells are indicated with the frequency and intensity of meteorological drought expected to increase.

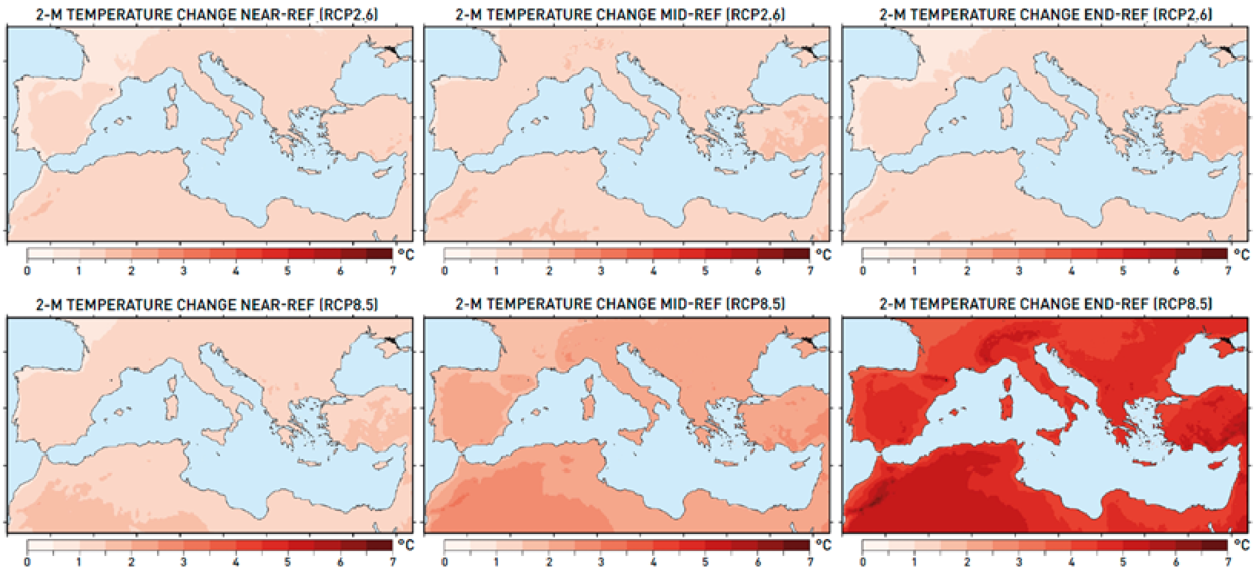


Figure 18 Projected changes in annual temperature between the recent past reference period (REF: 1980- 1999) and three future sub-periods (NEAR: 2020-2039, MID: 2040-2059, END: 2080-2099), based on the ensemble mean of EURO-CORDEX 0.11° simulations for pathways RCP2.6 (top panels) and RCP8.5 (bottom panels). Source: MedECC (2020)

The drying trend is, nevertheless, accompanied by a shift towards a precipitation regime of higher interannual variability, with climate projections showing a higher *intensity* of precipitation and greater extremes [31].

Significant warming of the Mediterranean Sea surface temperature is projected in future climate change scenarios. The annual-mean and basin-mean sea surface temperature is expected to increase by 1.1-2.1°C before the mid-21st century under the medium scenario of RCP 4.5 and by 2.7-3.8°C under the pessimistic RCP8.5. For the near-future (2020-2039), local annual-mean sea surface temperature change is positive everywhere across the entire Mediterranean basin, under all climate change scenarios, and may reach a maximum of +1.6°C in certain parts of the Mediterranean Sea. By the end of the 21st century the local annual-mean warming of the sea surface temperature is expected to range from 0.5-3.0°C for RCP4.5 and from 2 to 5°C for RCP8.5 [31].

As a result of the increase in Mediterranean Sea surface temperatures, marine heat waves will very likely increase in spatial coverage, become longer, more intense and more severe than currently experienced. By 2021–2050, it is expected that marine heat wave *frequency* will increase by a factor 1.5, *duration* by a factor of 2.4–2.7, and the average *intensity* by 1.5, with these values largely independent of the scenarios followed. By 2100, models project that under RCP8.5 **at least one long-lasting marine heat wave occurring every year** which will be up to 3 months longer, about 4 times more intense and 42 times more severe than today's events. Their occurrence is expected between June and October, and at their peak will affect the entire Mediterranean Basin [31].

Models also estimate that the basin mean sea level of the Mediterranean Sea by 2100 will likely be 37-90 cm higher (depending on the climate change scenario) with a small probability that it will be above 110 cm, than at the end of the 20th century [34] [35]. Whilst in 2100, reduction of pH might reach 0.462 and 0.457 units for the western and for the eastern basins, respectively i.e. the Mediterranean Sea is expected to acidify even further.

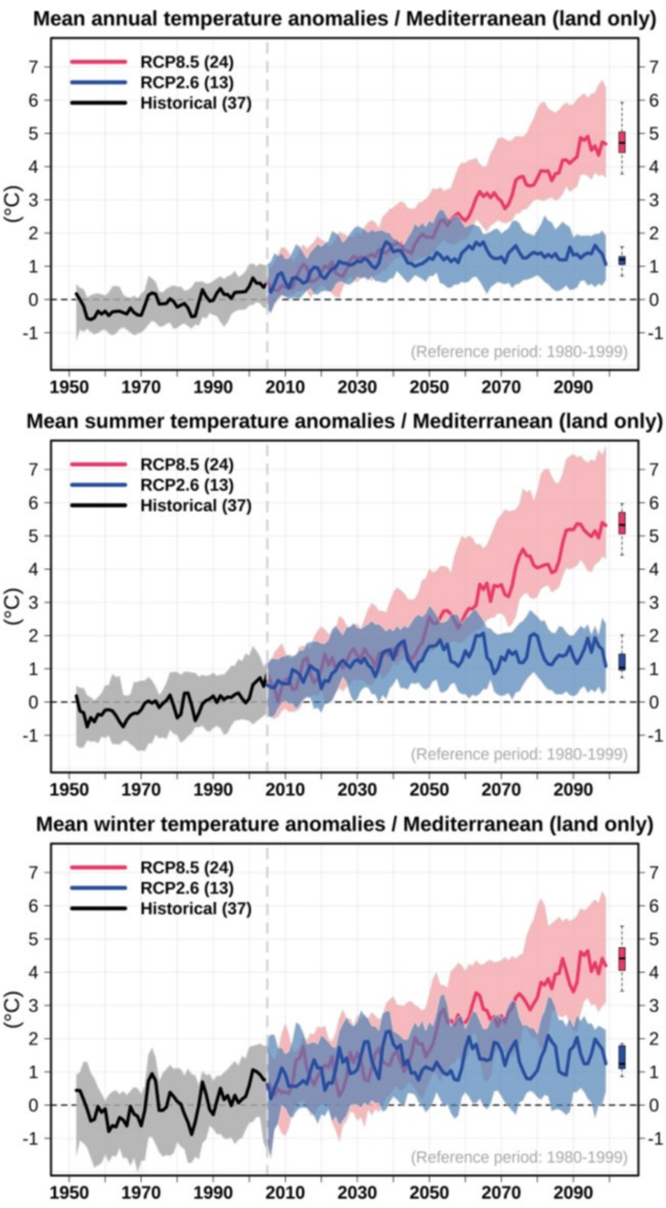


Figure 19 Time-series of simulated mean annual (top panel), summer (middle panel) and winter (bottom panel) temperature averaged over the Mediterranean based simulations for historical times (black curve) and future pathways RCP2.6 (blue curve) and RCP8.5 (red curve). Source: MedECC (2020)

Did you know?

The Mediterranean Sea is able to absorb relatively more anthropogenic CO_2 per unit area than the global ocean. This is because it is more alkaline, thus giving it greater chemical capacity to take up anthropogenic CO_2, and its deep waters are ventilated on shorter timescales allowing rapid penetration of CO_2 in its interior [20].

How do scientists predict future climate change?

Scientists make predictions of how the climate will change in the future using **climate models.** These simulate what the Earth's climate will be like in future decades under different climate scenarios or **climate projections.** Consequently, scientists predict future climate change using two tools:

- Climate models
- Climate change scenarios or projections.

Climate models are **numerical computer models** which use mathematical equations to represent the processes and interactions that make up the climate system and drive the Earth's climate (i.e. atmosphere, hydrosphere, lithosphere and cryosphere see Figure 2). In other words, climate models are based on the **scientific laws and equations** that have been developed by scientists over hundreds of years to describe the mechanisms of the Earth's climate system [36] [37].

There are two types of commonly used models: models that cover the entire globe, these are known as Global Climate Models (GCMs) or models that cover a specific region, e.g., Europe, known as Regional Climate Models (RCMs) [36] [37].

Both types of models divide the Earth into a series of boxes or "grid cells", and the size of the **grid cell** is referred to as its spatial resolution. For example, a GCM often has a spatial resolution i.e. grid cell size of 100 km x 100 km whilst a RCM often has a spatial resolution i.e. grid cell size of 12 km x 12 km. The difference therefore between the two types of climate models is one of spatial resolution. For each of these grid cells the model solves the equations which represent the interactions across and between land, sea, ice, gasses, temperature, humidity, precipitation and pressure finally producing a picture of the climate in each of these cells [36] [37].

The reason for dividing the earth into grid cells is a practical one: the climate system is highly complex and the mathematical equations describing it are numerous, requiring significant computing power. The higher the resolution the more computing power is needed, for example, RCMs whilst providing much more detailed climate information for a particular area, need more computing power and longer run times. Therefore, due to current limitations in computing power a model cannot calculate all the processes for every cubic metre of the climate system. However, as computing power has increased over the past decades so has the spatial resolution of the climate models, as indicated by Figure 20 [36] [37].

As computing power continues to increase, it is likely that climate models will also increase in the level of detail and representation of the different processes within the Earth's system, in addition to the spatial resolution, giving more detailed simulations of future climate change [36] [37].

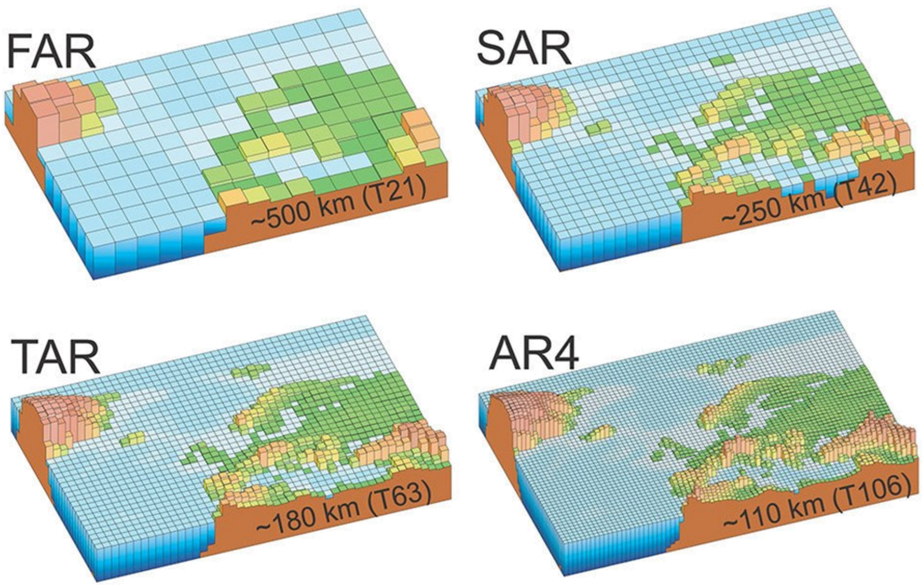


Figure 20 The figure shows how the spatial resolution of climate models has increased over the last three decades. The different climate models show the models that were used to make climate predictions through the first four IPCC assessment reports: first ("FAR") published in 1990, second ("SAR") in 1995, third ("TAR") in 2001 and fourth ("AR4") in 2007. Source: IPCC AR4, Fig 1.2

Which climate change scenarios are used by climate models?

In order to understand how greenhouse gases in the atmosphere affect the climate system, climate models simulate the future climate under individual scenarios each representing different future GHG emissions. These scenarios have been developed by scientists and represent a set of assumptions on the future world economy, population, energy use, land use and air pollutants which give rise to different levels of GHG concentrations in the atmosphere and radiative forcing. These scenarios are the inputs to the climate models, known as **Representative Concentration Pathways** (RCPs), and were developed for the IPCC's Fifth Assessment Report. The four RCPs are [38]:

RCP2.6: this is the most ambitious scenario which aims to limit the increase of global mean temperature to 2°C as per the Paris Agreement and keeps radiative forcing at 2.6 W/m^{-2} (where the name comes from) by 2100. It assumes that through enacting significant climate policy interventions, greenhouse gas emissions are reduced almost immediately (peaking at 2020), leading to a slight reduction on today's levels of CO_2 to around 400 ppm by 2100 [39].

RCP 4.5: this is the scenario which stabilises radiative forcing of the climate system to 3.8 Wm^{-2} by 2100 and is associated with relatively ambitious GHG emissions reductions whereby CO_2 emissions slightly increase before declining after 2040 and stabilising by 2100 through a transition to renewable energy, stable methane emissions and strict climate policies [40].

RCP 6.0: is a stabilization scenario in which total radiative forcing is stabilized by 2100 at 6.0 Wm^{-2}, without exceeding this value in the years before. This scenario includes the application of a range of technologies and climate mitigation strategies for reducing GHG emissions. RCP6 is considered a climate-policy intervention scenario, because in this scenario the absence of explicit policies designed to reduce emissions, will result in radiative forcing exceeding 6.0 Wm^{-2} in the year 2100. The difference with this scenario and RCP 4.5 and RCP 2.6 is the level of GHG emissions reduction required over the period 2010 to 2060 which is smaller compared to RCP4.5 and RCP2.6 [41].

RCP 8.5: this scenario is characterized by increasing greenhouse gas emissions over time, in which limited action or policies are taken for mitigating climate change. Within this scenario there is a higher population growth than in the other scenarios, with a lower rate in new technology development, which result in an economy that is highly energy intensive [42]. It is often referred to as the worst-case scenario.

The results or outputs of the climate models assist scientists to understand how we and our activities are affecting our climate. The outputs of these models provide the scientific basis on which policymakers and decision makers across the world have based their strategies, polices and laws related to climate (e.g. the Paris Agreement and European Green Deal).

What do climate change projections say for Cyprus?

The number of studies that have produced climate change projections *specifically* for Cyprus are limited. The most recent simulations conducted by the [Cyprus Institute] for the RCP 8.5 scenario project a **warming in the range 1.5–2.0 ⁰C** for the 30-year period of 2031-2061 and **a warming of up to 4 ⁰C** for the 30-year period of 2071-2100 (in comparison to the reference period 1981-2010) [43] see Figure 21.

Projections for the RCP 8.5 scenario indicate a shift to a drier climatic regime in Cyprus. **Decreases in precipitation in the range of 10% to 15%**, with respect to the reference period, are expected for the period 2031 to 2060 , whilst by 2100 the decrease in precipitation is in the range of 25% to 35% (Figure 22). The **observed** average number of maximum consecutive dry days (CDD) per year for the period 1981-2010 ranges from 50 to 60 days in the mountains to 130 to 150 days in the coastal areas. Under RCP 8.5 there will be an increase in the longest dry spells (from the observed period) of an **additional five to ten days** for the period 2031 to 2060 whilst even stronger increases in the length of dry spells are expected by 2100. Particularly for the south and east parts of the island, the longest dry spells of the year are likely to be extended by **four to six additional weeks** [43].

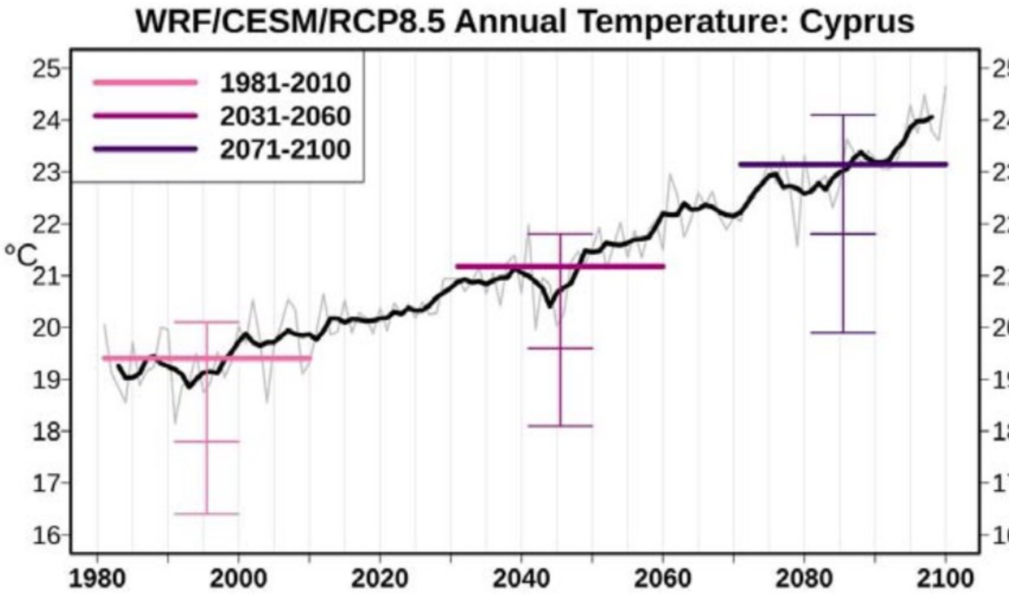


Figure 21 Simulated mean annual temperature for the RCP 8.5 scenario showing the observed annual mean temperature for the period 1981-2010, the projected annual mean temperature for the periods 2031-2060 and 2071-2100 [43]

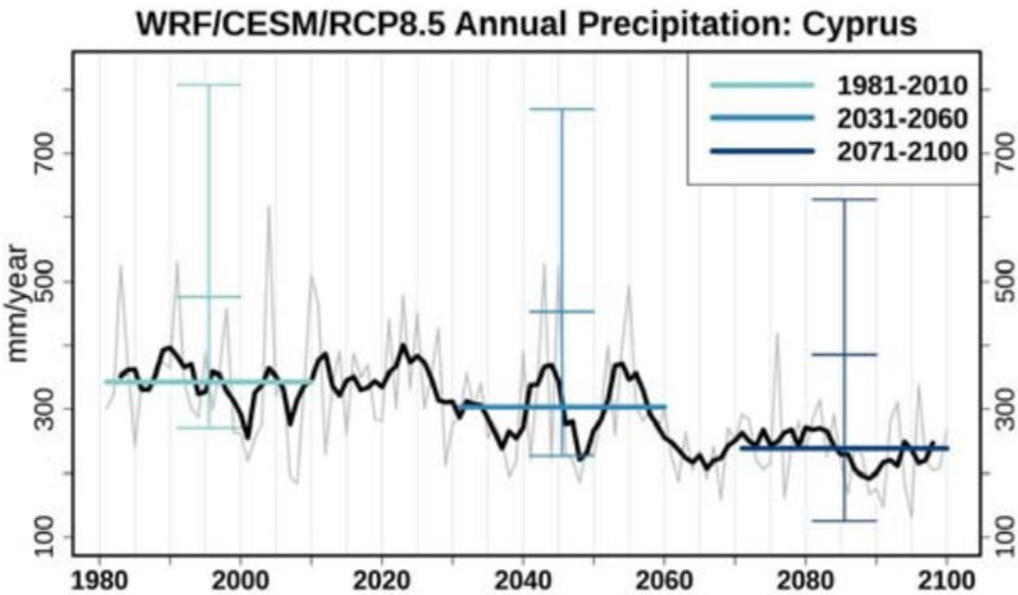


Figure 22 Simulated mean annual precipitation for the RCP 8.5 scenario showing the observed annual mean precipitation for the period 1981-2010, the projected annual mean precipitation for the periods 2031-2060 and 2071-2100 [43]

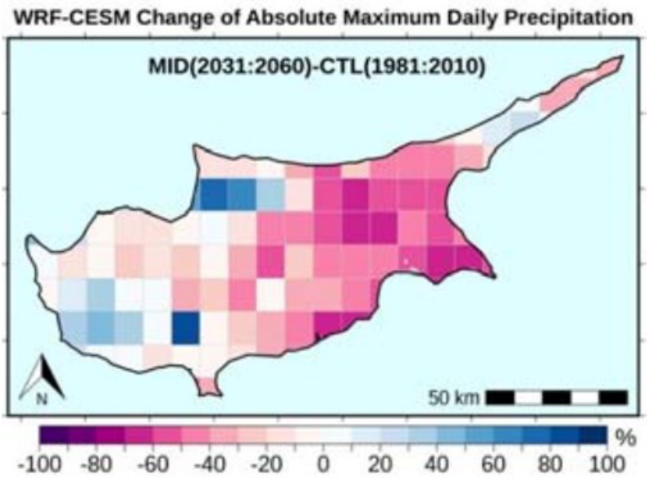


Figure 23 Projected changes (%) in absolute maximum daily precipitation for the periods 2031-2060, blue grids indicate an increase [43]

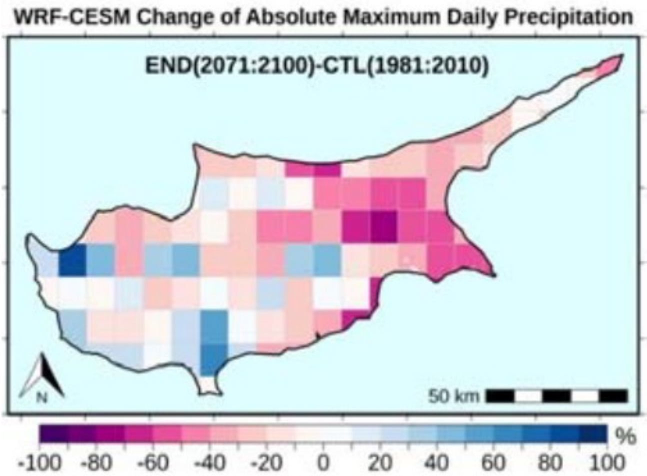


Figure 24 Projected changes (%) in absolute maximum daily precipitation for the periods 2071-2100, blue grids indicate an increase [43]

Concurrently, the models project that under an RCP 8.5 scenario there will be **reduction of up to 10 rainy days per year** for the period 2031 to 2060. By 2100, Cyprus will likely experience **15 to 20 less rainy days per year**. The results of the simulations indicate that the strongest reductions in rainy days will affect the central part of the island, which is the area that contributes most to the island's water resources, highlighting a risk to water availability in the future [43].

With respect to indicators of extreme precipitation events, the number of heavy precipitation days are projected to decrease in the range of one to two days per year for the period 2031 to 2060, particularly for the central part of the island. As we move towards 2100, the decreasing signal becomes stronger and is extended throughout the island [43].

Despite the strong drying trends outlined previously, the simulation by the Cyprus Institute shows that for some areas in Cyprus the **absolute 30-year daily precipitation maximum is expected to increase** (Figure 233 and Figure 24) i.e. higher future extremes can be expected in certain areas. The increase in the **30-year daily precipitation maximum is expected to increase** in some areas by 80% compared to the period 1981-2010 [43].

Whilst models also estimate that the basin mean sea level of the Mediterranean Sea by 2100 will likely increase by 37-90 cm (depending on the climate change scenario), for Cyprus **vertical land movement is counteracting the sea level rise** [28]. Based on archaeological records, Cyprus appears to be increasing vertically by 0 to 1 mm per year, and as such sea level rise is not expected to be as high as in other areas of the Mediterranean Basin [27]. However, as the coastline is already subject to erosion as a result of human activities, it is important that specialised studies are conducted to take appropriate management action of the coastal zone.

2. Policy

2.1 Mitigation

The international discussion around climate change and climate change policy was triggered by the first report published by the Intergovernmental Panel on Climate Change (IPCC) in 1990. Following the findings of the report, the United Nations organised the Rio De Janeiro Conference on Climate Change, where 154 countries signed the UN Framework Convention on Climate Change, the first international treaty on combating climate change. The Convention's decision body is the Conference of Parties (COP) which meets annually. The first major outcome of the COP meetings and first international agreement for reducing GHG emissions to mitigate climate change was the Kyoto Protocol. The Protocol, signed in 1997, entered into force in 2005 and set emission reduction targets for industrialised countries, including the European Union. Cyprus ratified the Protocol in 1999 as part of its accession to the EU and participated in the 2nd commitment period of 2013-2020. As a result of the Kyoto Protocol, the European Union (EU) committed to **reduce its GHG emissions by 20% by 2020** compared to 1990 (2020 climate and energy package). The overall EU target was apportioned to each Member State (MS), with **Cyprus committing to reduce its emissions by 5% by 2020** compared to 2005 levels. By 2018, Cyprus had achieved a reduction of 2% [44].

What is the Intergovernmental Panel on Climate Change?

The Intergovernmental Panel on Climate Change (IPCC) is a United Nations (UN) body, which was created by the WMO and the United Nation's Environment Programme (UNEP) in 1988, with the aim of providing policymakers with scientific information related to climate change, supporting them in the development of climate policies. The IPCC is made up of the country member states of the UN and has thousands of scientists ***volunteering*** their time to assess and synthesise the many scientific reports and papers (thousands) in order to provide an overview of what is known about the drivers of climate change, its impacts and future risks, and how adaptation and mitigation can reduce those risks. The IPCC assessment reports are released every five years, and are a key input into international climate change negotiations under the UN Framework Convention on Climate Change (UNFCCC) [45]. To date five assessment reports have been prepared by the IPCC, which show with increasing certainty the impact of human activities on the climate.

Subsequent IPCC reports, which highlighted the extent of climate change, and COP meetings, led to the establishment of the Paris Agreement during COP21 in 2015. The Paris Agreement is the successor to the Kyoto Protocol, and through it, the international community has increased its ambition related to emission reductions whilst also committing to take action on climate change adaptation. The Paris Agreement aims to keep global warming below 2°C whilst aiming for 1.5°C. Each signatory country or union has to submit their Nationally Determined Contributions (NDCs) which outline how they will contribute towards this goal. As part of its commitments through the Paris Agreement, the EU set a target of **40% reduction of GHG emissions by 2030** compared to 1990. This target was divided across all MS and through the Regulation on the governance of the energy union and climate action (EU/2018/1999) all MS were required to submit a National Energy and Climate Plan (NECP) by December 2019 describing the measures they will take to achieve the overall 40% reduction by 2030.

Meanwhile, the IPCC Special report on Global Warming of 1.5 °C issued in 2018 [46] found that to keep warming at 1.5°C, **GHG emissions must be reduced by 45% globally by 2030** compared to 2010 levels and achieve net-zero emissions by 2050 [46].

As a result of the recent developments in science and the public response to the climate crisis, the European Commission has since raised its ambition to **55% reduction in GHG emissions by 2030 and to be the first climate neutral continent by 2050**. It is expected that MS will be asked to update their NECPs to account for the increase in ambition in GHG emissions.

Cyprus's 40% reduction target is split between 43% reduction in Emissions Trading System (ETS) industries and 24% at the national level (excl. ETS). The submitted NECP of the country includes many measures to achieve this goal, however it falls short, aiming to achieve only a 20.9% reduction. With the remaining 3.1% the government plans to use the flexibility mechanism offered to buy credits from other MS. Predictions show that this will be difficult to achieve, since many MS are falling short and would need to buy emission rights. At the time of writing this report, the Environment Department of the Ministry of Agriculture, Rural Development, and Environment, is working on the draft "Long-term low GHG emission development strategy" which sets out the pathway for climate change mitigation up to 2050 [47]. The Joint Research Committee (JRC) of the European Commission, has published findings comparing the Reference Scenario of each country for 2030 (i.e. the one proposed under the NECP) and what is needed to achieve the new target of 55% reduction. Figure 25

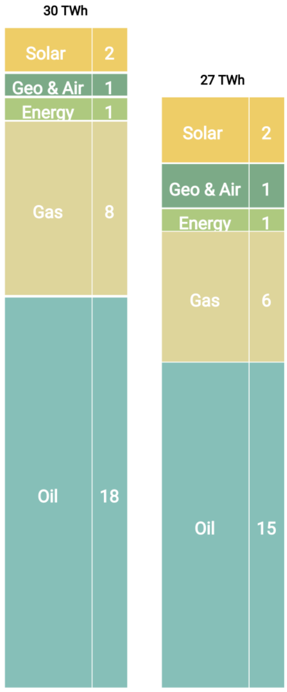


Figure 25 Comparison of 2030 Reference Scenario for Cyprus (left) and Fit for 55 Scenario (right) [48]

shows the comparison of the two scenarios for Cyprus [48]. It is clear that the scenario presented under the NECP is inadequate to meet the new EU targets. A further reduction of overall energy consumption of 3TWh will be necessary, with a complementary reduction in the share of natural gas and oil consumption in the energy mix and increase in renewable energy sources.

2.2 Adaptation

The European Union's first attempt to approach climate change adaptation was in 2007 with its Green Paper [49], which dealt with the impacts of climate change and the role of EU, national, and regional bodies in adaptation. In 2009, it published a White Paper, which was a European framework for action on adaptation [50]. It was accompanied by a few sectorial documents on agriculture, water, and others. The White Paper was the basis of the European Adaptation Strategy, adopted in 2013 by the European Commission. The Strategy encouraged MS to develop their own adaptation plans and strategies. Through this framework Cyprus conducted a Climate Change Risk Assessment [51]; the findings of which were used to develop its National Adaptation Strategy (NAS) and National Adaptation Plan (NAP) in 2017. In February 2021, the EC published the new EU Adaptation Strategy, focusing on a smarter adaptation (through data and risk assessment), faster adaptation (quick roll-out of solutions), systemic adaptation (looking at integration into macro-fiscal policy and local strategies), all while stepping up international action (international finance).

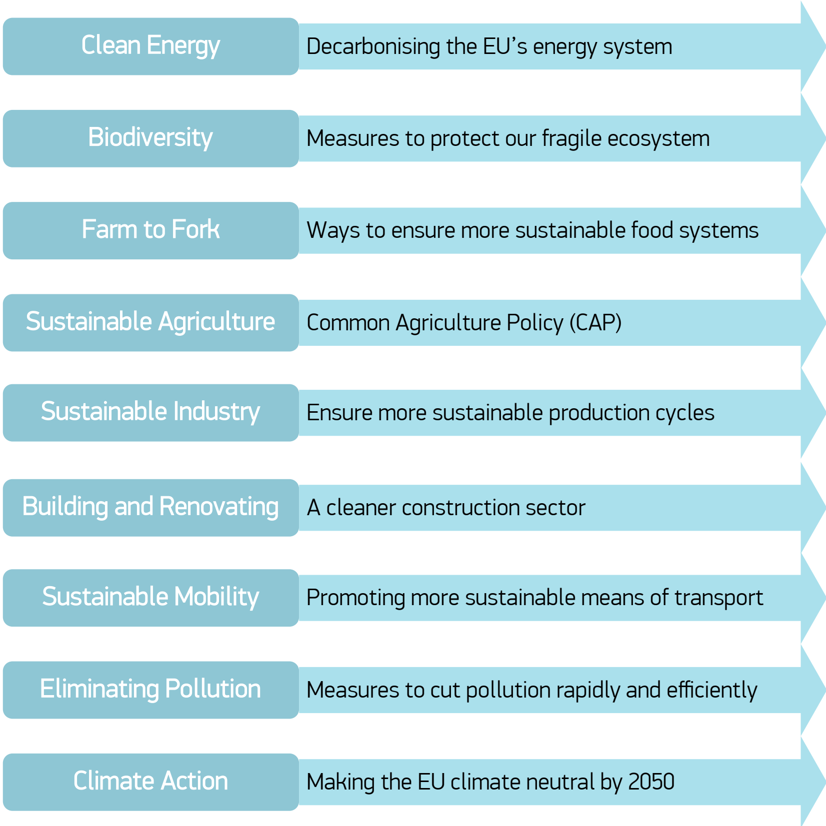


Figure 26 The nine policy areas of the European Green Deal

2.3 European Green Deal

The European Green Deal (EGD) is the EU's climate action plan for 2050, and was first unveiled by the European Commission in December 2019. The EGD has been formulated with the express aim of delivering the EU's target of reaching climate neutrality by 2050, and has been structured around nine policy areas, as shown in Figure 26. To ensure that the carbon neutrality target is binding for the EU MS, the European Commission has proposed the European Climate Law [52], which received its final approval by the leaders of the MS on June 28 2021. The European Commission is, at the same time, rolling out plans and proposals under each of the nine policy areas with concrete steps on how each area can achieve its targets. In more detail, the Policy Areas include:

Clean Energy: Energy supply in the EU is the biggest GHG emitter, accounting for 26.7% of the EU's emissions. The decarbonisation of the energy system is thus crucial for reaching the climate neutrality target. The EGD aims to achieve decarbonisation through (a) prioritising energy efficiency and developing renewable sources, (b) offering secure and affordable energy, (c) fully integrating, connecting, and digitalising the EU energy system. Key actions for achieving this include modernising infrastructure, boosting eco-design of energy products, decarbonising the gas sector, tackling energy poverty, increasing cross-border collaboration to share clean energy, promoting EU energy standards globally, and further developing offshore wind technologies. In support of all of this, the European Commission has presented the EU Strategy on Offshore Renewable Energy, the EU Strategy for energy system integration and the EU Strategy for hydrogen (together with the launch of the European Clean Hydrogen Alliance).

Biodiversity: Biodiversity has been identified as an essential sector for action, in particular due to its role in climate regulation. In addition, biodiversity is necessary for healthy ecosystems and life in general, and action is vital as the world is in the midst of what has been called the sixth mass extinction due to anthropogenic activities and climate change. The European Commission has developed the EU Biodiversity Strategy for 2030, which includes actions for protecting 30% of land and 30% of sea in Europe. It also aims to restore degraded ecosystems by increasing organic farming, restoring at least 25,000km of EU rivers, planting 3 billion trees, and reducing the use of harmful pesticides to protect pollinators.

From Farm to Fork: This policy area aims to (a) ensure access to healthy, affordable, and sustainable food, (b) tackle climate change, (c) protect the environment and biodiversity, (d) ensure fair economic return in the supply chain, and (e) increase organic farming. The specific targets of the "Farm to Fork" strategy for 2030 are 50% reduction of the use of chemical pesticides, 50% reduction of nutrient loss, 50% reduction in the use of fertilisers, 50% reduction in the sale of antimicrobials in order to halt antimicrobial resistance, and 25% of farmland to be used for organic farming. Actions such as food labelling and legally binding targets for food waste are being planned in support of the aforementioned targets.

Sustainable Agriculture: Agriculture represents 13% of the EU's GHG emissions. Actions in this policy area are mainly related to the revision of the Common Agriculture Policy (CAP). The CAP has been the main financial and policy instrument of the EU which provides support to the agricultural sector. Through the EGD, the EU aims to update the CAP and make it more sustainable (environmentally, socially, and economically) whilst boosting the modernisation of agriculture. As part of the Farm to Fork strategy and the 2021-2027 budget, 40% of the CAP will now be allocated to climate action.

Sustainable Industry: EU industry is responsible for 20% of the EU's emissions. Moreover, it is responsible for the majority of raw material extraction. To become sustainable, the EU industry must embrace circular economy principles. In March 2020, the European Industrial Strategy was adopted, focusing on (a) maintaining global competitiveness, (b) reaching climate neutrality by 2050, and (c) shaping Europe's digital future. Some of the actions of the strategy are an Intellectual Property Action Plan, a review of the EU competition rules, a White Paper for the effects of foreign subsidies and access to EU public procurement, measures to decarbonise energy-intensive industries, an Action Plan on Critical Raw Materials, and further legislation on green public procurement. An SME strategy was also published to support these businesses in the climate transition.

Building and Renovating: The building sector accounts for 40% of energy use in the EU. This policy area aims to promote actions for the reduction of both energy and material use in the sector. The Commission's flagship strategy for increasing the energy efficiency of the building stock, is the Renovation Wave, an effort to double renovation rates and reduce energy poverty across the EU. The main actions of this Strategy are stronger regulations for the energy performance of buildings, funding for energy renovations, capacity building for green jobs, expansion of the market for sustainable construction products, the Affordable Housing Initiative, and a project named "New European Bauhaus" which will act as an advisory board for the design of more sustainable and affordable products. In terms of materials, the Commission has presented the "New Circular Economy Action Plan" which tackles waste across the entire life cycle of products. As a first step, the plan focuses more on the most resource-intensive sectors, which include construction and buildings, alongside food, textiles, electronics, packaging, plastics, and batteries and vehicles (under the Sustainable Industry policy area).

Sustainable Mobility: Domestic transport is responsible for 23% of the EU's GHG emissions and is integral to achieving the EU's overall reduction targets. Thus action must be taken and EU mobility has to (a) become digitalised with smart traffic management systems and "mobility as a service" solutions, (b) shift to different modes of transport (including air transport emissions), (c) have prices that reflect the impact on the environment, (d) boost the supply of sustainable alternatives, and (e) reduce pollution through stricter standards. Sustainable mobility is especially important for Cyprus as it is the most polluting non-ETS sector for GHG emissions.

Eliminating Pollution: The European Commission has pledged to adopt a zero-pollution action plan to prevent pollution in the water, soil, and air. For water pollution, its key aims include preservation of biodiversity in water bodies, reduction of pollution from agriculture (such as nitrogen pollution), and reduction of pollution from micro-plastics and pharmaceuticals. To ensure clean air, the Commission plans to review EU air quality standards in line with the stricter World Health Organisation guidelines and provide support to local authorities in achieving them.

What are carbon sinks?

A sink is defined as "any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere" [53].

The term "carbon sinks" is used to refer to processes that absorb carbon and therefore remove CO_2 from the atmosphere. Carbon sinks can either be natural or chemical. The main natural sinks, in order of magnitude of carbon captured, are oceans, plants (e.g. rainforests, peatlands), soils, and some marine animals.

Enhancing natural carbon sinks could play an important role in achieving net-zero emissions. If the global temperature exceeds the internationally set targets, carbon sinks are necessary to reduce atmospheric CO_2 concentrations and bring the temperature back down [46].

There are many ways of enhancing natural sinks, such as reforestation, afforestation, ecosystem restoration, and soil management. Carbon sinks, as integral parts of the carbon cycle, help stabilise the climate system and, as such, need to be protected, sustainably managed, and restored. As a result, protection and enhancement of carbon sinks is a vital pillar of the EU's Biodiversity strategy.

As industry plays an important role in pollution, specific goals for reducing pollution and preventing accidents from industrial plants have been put in place. Finally, the Commission has adopted a new Chemicals Strategy which aims to protect citizens against dangerous chemicals and develop sustainable alternatives. The strategy promotes the phase-out of harmful chemicals and better access to information for consumers.

Climate Action: The policy area of Climate Action is undoubtedly at the centre of the EGD and intersects with all others. The main specific actions of the Commission under this policy area so far include (a) the **EU Climate Law**, (b) the **climate pact**, an effort to engage all EU citizens in the fight against climate change, and (c) the **2030 emissions target**. For the 2030 emissions target, the initially agreed 40% reduction compared to 1990 levels, has now been updated to 55% (page 32).

The EU Climate Law includes:

1. The new EU-wide emission reduction target of 55% by 2030 compared to 1990 levels
2. A net zero GHG emissions target by 2050 (climate neutrality)
3. Setting up an EU-wide emissions trajectory for 2030-2050 with an intermediate 2040 target
4. The creation of an independent advisory body of experts to advise on policies
5. The revision of a number of relevant policies (e.g. on energy, industry, transport, see pages 33-34) to align with the new emission reduction targets
6. An obligation to update the NECPs by 2023 and to assess and update them every 5-years thereafter to ensure consistency with the EU-wide trajectory
7. The right of the Commission to issue recommendations to MS related to actions inconsistent with the long-term target
8. An obligation for development and implementation of national adaptation strategies.

To achieve the commitments of the Climate Law, the Commission designed the **"Fit for 55"** package which includes a number of legislative proposals [54]. The

package presented includes tools such as targets, standards, support measures, and pricing mechanisms. Some of the main legislative changes proposed are:

EU Emission Trading System (ETS):

- Increase in the target for emissions reduction to 61% by 2030 compared to 2005.
- Inclusion of maritime transport under the ETS.
- Proposal for a separate ETS for road transport and buildings.
- Better tackling of "carbon leakage" through the Carbon Border Adjustment Mechanism.

Climate Social Fund:

- €72.2 billion for 2025-2032 to support citizens affected by energy poverty created through 25% of the revenues from ETS to help in the climate transition.

Land Use, Land-Use Change and Forestry (LULUCF):

- Target for net GHG removals of 310 million tonnes of CO_2eq. in 2030.
- Reach climate neutrality in LULUCF and agriculture by 2035.
- Climate-neutral production of food and biomass by 2035.

Renewable Energy Directive:

- Increase of the target for renewable energy sources in the energy mix to 40% by 2030.
- Strengthening of sustainability criteria for the use of bioenergy.

Energy Efficiency Directive:

- Increase of target for energy efficiency to 39% for primary consumption and 36% for final energy consumption by 2030.
- Requirement for renovation of 3% of public buildings every year.

Regulation for setting CO_2 emission performance standards for cars:

- All new cars and vans from 2035 to be zero-emission.
- Increase in the network of charging stations under the Alternative Fuels Infrastructure Directive.

EU Forest strategy:

- Legally binding nature restoration targets.
- Three billion trees planted by 2030.
- Sustainability principles in the bio-economy sector.

2.4 Timeline of Climate Change Policy

Whilst scientists had identified the potential for human activities to increase the global temperature from the 19th century (page 4), climate change nevertheless, only really emerged as a political issue in the 1970s. This period saw states and activists combine their efforts and take action at a global level to address the environmental crises of climate change, environmental pollution and the conservation of natural resources . In the following years, important events brought leaders together to establish bodies, programmes and treaties which advance action on mitigating the impacts humans have on the environment, including the United Nations Environment Programme, the IPCC, the UNFCCC, the Montreal Protocol etc. One of these bodies, the IPCC has played a central role in international debates and in advancing the science which has underpinned the development of climate change policies in the last decades. Its work has enabled the establishment of international treaties and targets related to mitigation

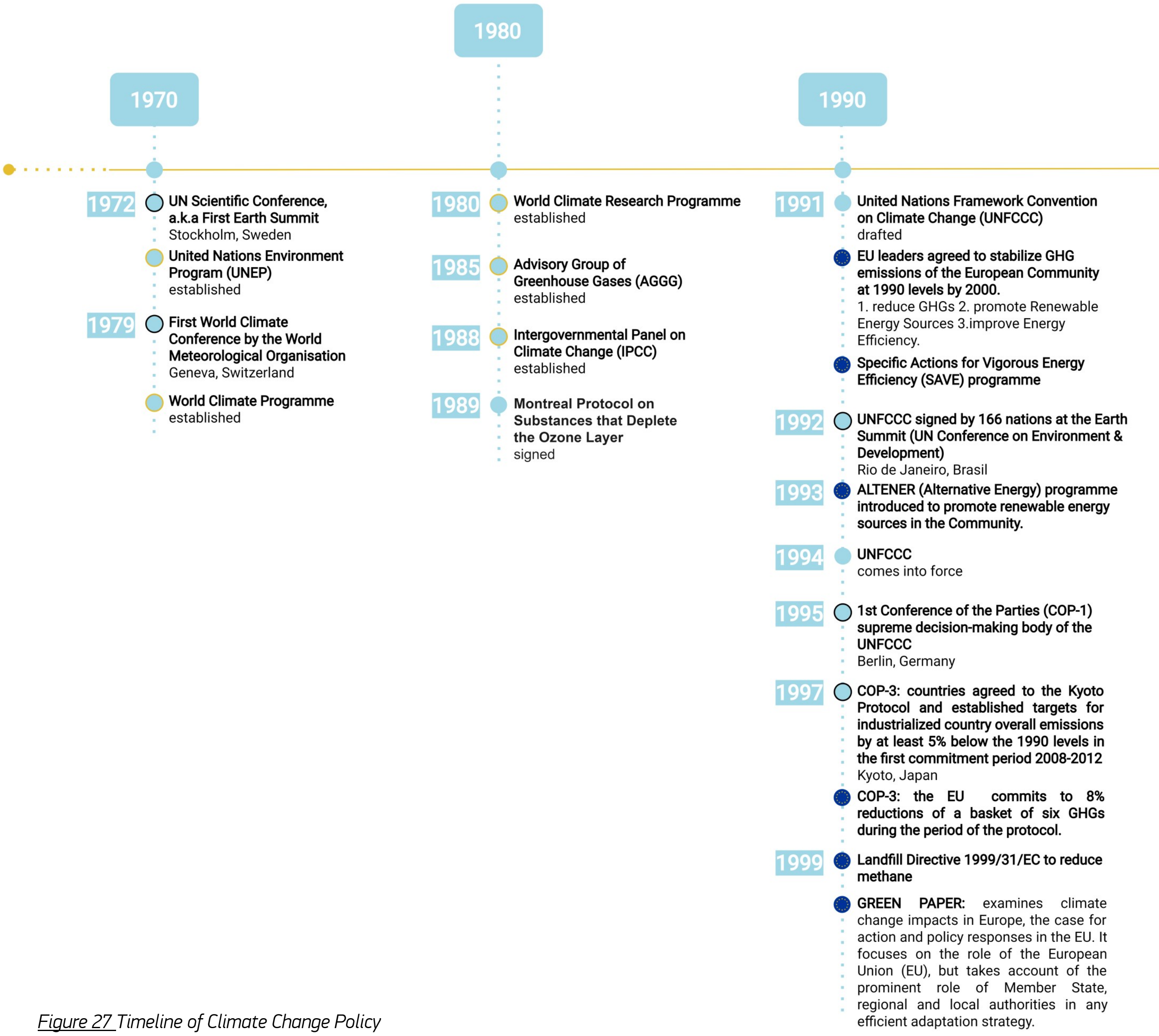


Figure 27 Timeline of Climate Change Policy

and adaptation to climate change.

Through such advancements in the scientific understanding of climate change, the 21st century has seen a wider recognition amongst the general public of the threats of climate change, and a better understanding of the phenomenon and its negative consequences driven by the experience of unprecedented weather events and patterns. As a result climate action has become a part of the political agenda and political leaders have started to take more meaningful climate action (e.g. Paris Agreement, EU Climate Law). Recognition of the need to adapt to the consequences of climate change, particularly on human wellbeing, has resulted in the elevation of adaptation to equal significance in the climate discourse, with a shift towards vulnerability-based policies that aim to support vulnerable groups and countries in the climate transition.

2000

2005

Kyoto Protocol
comes into force

European Climate Change Programme (ECCP)
extensive range of policy sectors and instruments with potential for reducing GHG emissions and developed common and coordinated strategies to fulfil the Kyoto targets.

European Emissions Trading Scheme (ETS)
national caps for emissions from power and industry sectors in each Member State, as well as proposals and communications on fields such as energy labelling, or the promotion of cogeneration and biofuels.

Renewable Electricity Directive
introduced indicative targets on the share of renewable electricity for each MS.

2007

"20-20-20"
a set of three targets by 2020 including a target on GHG emissions, Renewable Energy Sources and Energy Efficiency

2008

Climate and Energy Package

Covenant of Mayors initiative launched by the European Commission with the objective of engaging and supporting mayors to commit to reaching the EU climate and energy targets.

2009

WHITE PAPER Adapting to climate change
Towards a European framework for action

2010

2012

Cleaner Energy-Saving Mediterranean Cities (CES-MED)
extension of CoM to the European Neighborhood South Region. The CES-MED supports cities in joining the CoM and committing to ambitious sustainable development policies.

2014

Mayors Adapt
sister initiative of CoM with a focus on adaptation to climate change.

2015

SENDAI Framework on Disaster Risk Reduction 2015-2030
focuses on the adoption of measures which address the three dimensions of disaster risk (exposure to hazards, vulnerability and capacity and hazard's characteristics) in order to prevent the creation of new risk, reduce existing risk and increase resilience. Sendai, Japan

United Nations: the 17 Sustainable Development Goals
A collection of 17 interlinked global goals designed to be a "blueprint to achieve a better and more sustainable future for all". The SDG 13 invites the global community to "Take urgent action to combat climate change and its impacts"

COP-21 Paris Agreement
engages all nations to raise their ambitions and undertake local and collective actions for a common global cause to mitigate and adapt to climate change and its effects, and to support developing countries in the process.

Covenant of Mayors for Climate & Energy
CoM & Mayors Adapt initiatives are merged. Signatory cities pledge to actively support the implementation for the EU 40% GHG-reduction target by 2030 and agree to adopt an integrated approach to climate change mitigation and adaptation and to ensure access to secure, sustainable and affordable energy for all.

2016

Global Covenant of Mayors for Climate & Energy
CoM joins forces with the Compact of Mayors. This is the largest movement of local governments committed to going beyond their own national climate and energy objectives,

2019

European Green Deal
An action plan to boost the efficient use of resources by moving to a clean, circular economy, restore biodiversity and cut pollution. The plan outlines investments needed and financing tools available. It explains how to ensure a just and inclusive transition.

2020

2020

European Climate Law
To turn the political commitment into a legal obligation: The EU aims to be climate neutral in 2050.

55% emission reduction target
EU leaders endorse a new binding EU target for a net domestic reduction in greenhouse gas emissions of at least 55% by 2030 compared to 1990 levels, up from the target of cutting emissions by at least 40% by 2030 which had been agreed on in 2014.

2021

Fit for 55 Package
A set of proposals to revise and update EU legislation and to put in place new initiatives with the aim of ensuring that EU policies are in line with the climate goals agreed by the Council and the European Parliament.

2030

EVENT: Conference/Summit
ESTABLISHMENT OF A BODY
EU level
Covenant of Mayors


We the people
NEW DEAL
THERE IS NO
PLANET B


WE ARE THE
CHANGE
Solutions, Now!

3. Stakeholders in Climate Change

Quadruple Helix

In order for all the climate policies, treaties and strategies put in place (Figure 27) to succeed, cooperation and collaboration across all stakeholders in society will be key. Governments, Industry, Research & Academia, and Civil Society are thus integral in achieving our targets and goals related to climate change mitigation and adaptation.

Each stakeholder has a different role in promoting and taking climate action. Government is responsible for planning, financing, implementation and for the monitoring and evaluation of climate-related strategies. Policy -making and decision-making by Government is often based on information/data from academic research and current innovative solutions from industry.

Industry, following national and international targets and guidelines redesigns its processes, services and products in order to minimise its impacts on natural resources and reduce its CO_2 emissions.

Academic and Scientific Research provides input and support to government, local authorities and industry in directing their actions towards climate change mitigation and adaptation. (R&D, education, incubators, spin offs).

Civil Society advocates for new measures and actions for mitigation and adaptation to climate change. It acts as a mediator to support and accelerate changes in industry and government whilst advocating for vulnerable groups ensuring they are not disadvantaged by the climate transition.

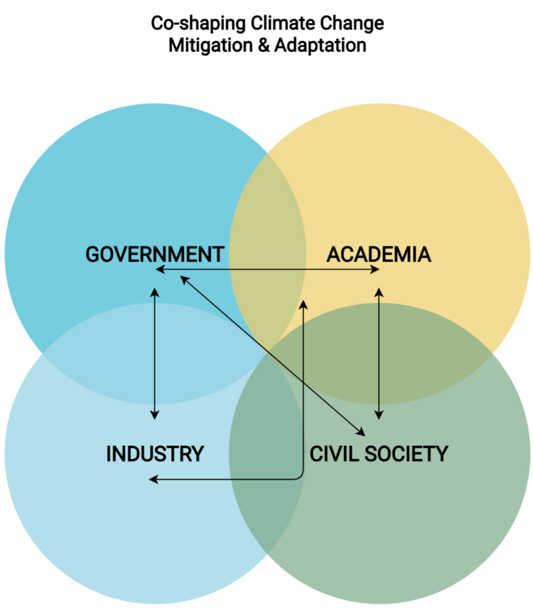


Figure 28 Quadruple Helix model [56]

Interaction between these four actors results in the co -development of diverse knowledge and innovation modes, i.e. of interdisciplinary and transdisciplinary knowledge ensuring that no sector or person is excluded in the action against climate change. Crucially, when they collaborate and provide feedback to each other, the resulting policies and practices are more likely to be socially accountable and acceptable [56].

Stakeholders in Cyprus

Figure 29 provides an overview of the type of local stakeholders in Cyprus across Government, Research and Academia, Civil Society.

As the effects of climate change will impact all sectors of our economy and society, Figure 29 provides an outline of stakeholders that represent the most vulnerable sectors in Cyprus such as water, coastal zones, fisheries and aquaculture, agriculture and soils, biodiversity and forests, energy, infrastructure, tourism and public health.

Figure 30 shows the diversity of stakeholders that can finance climate change related projects in Cyprus.

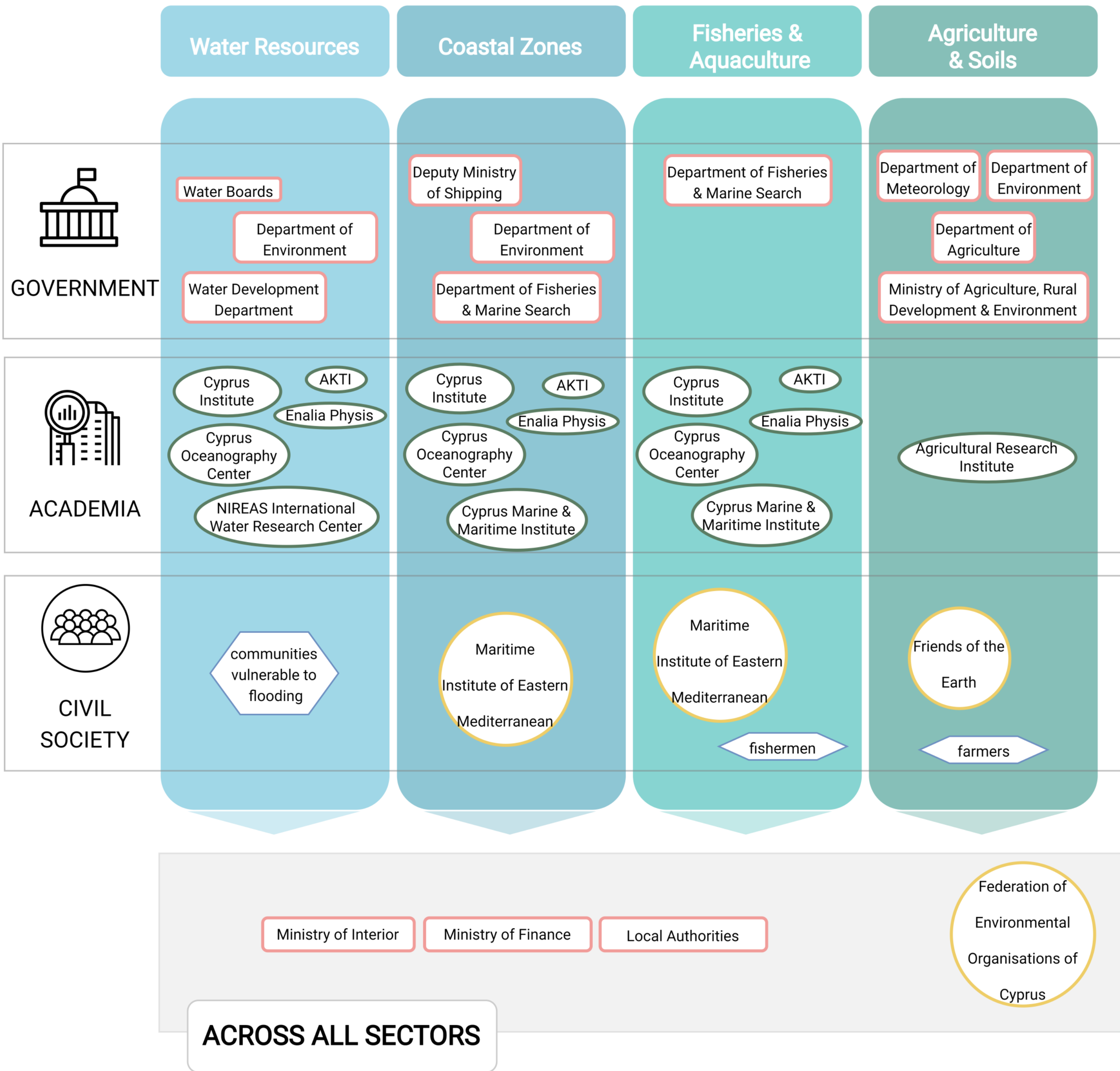


Figure 29 Stakeholders Mapping per sector

This list of stakeholders is not exhaustive

Figure legend

- Government Stakeholder
- Stakeholder from the academic and research community
- Stakeholder from CSOs and NGOs
- Impacted citizen groups and individuals

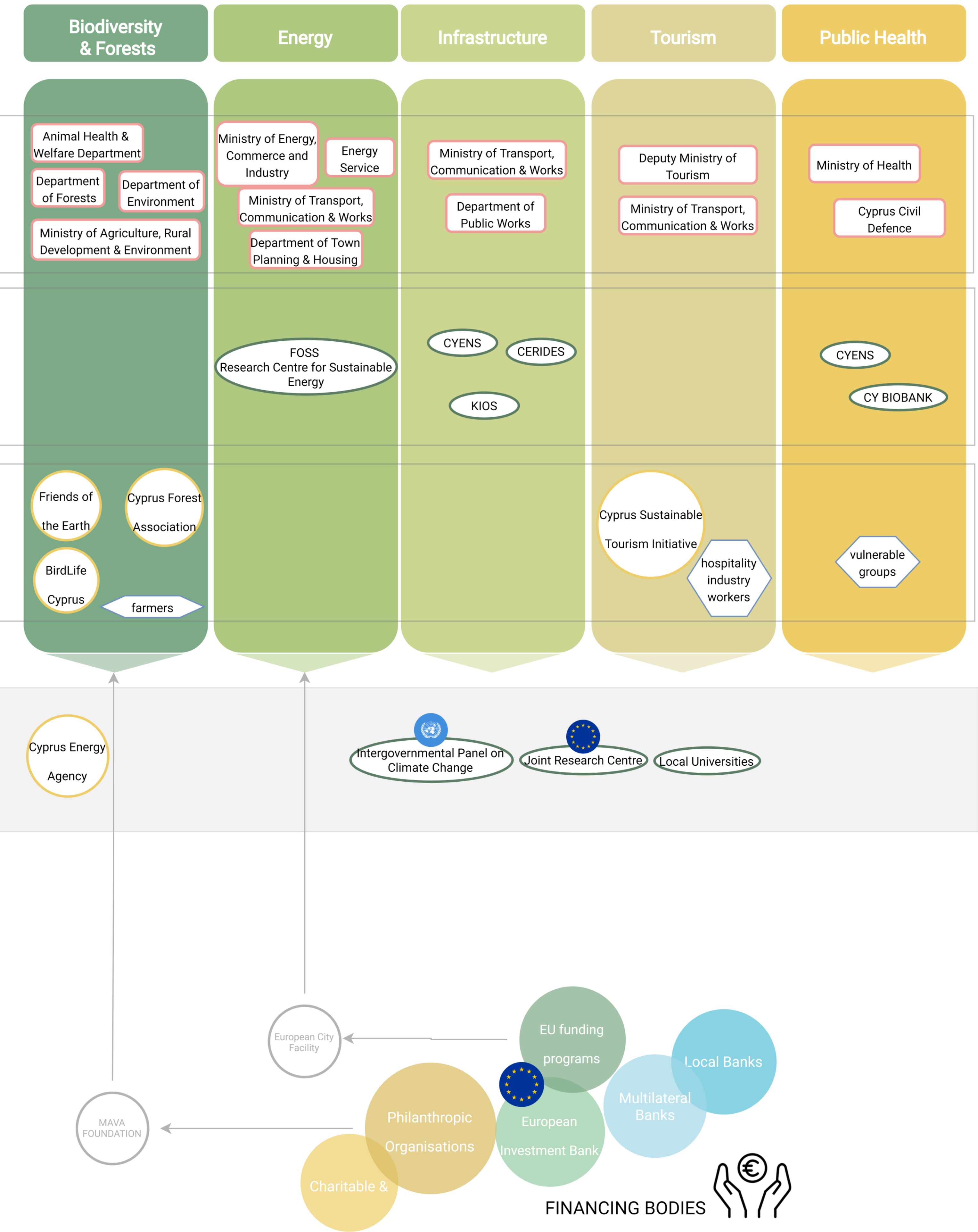


Figure 30 Stakeholders that provide funding for climate change related projects

4. The role of Local Authorities

One of the key stakeholders within Government are Local Authorities (LAs), which represent government at the local scale. LAs play a central role in achieving the commitments set out across different international and EU policies like the 2030 Agenda for Sustainable Development, the Paris Agreement, the Sendai Framework and the latest EU Green Deal.

As the level of government closest to the citizens, LAs have been identified as a central stakeholder best placed to promote the goals and targets related to climate change. Particularly with regards to the 2030 Agenda, it is worth noting that 65% of the 169 targets underlying the 17 Sustainable Development Goals (SDGs) cannot be achieved without meaningful engagement and coordination with Local Authorities [57]. The same applies with the EGD, which without the direct involvement of the LAs in the development, implementation and assessment of the numerous initiatives, the EU's strategy to reach climate-neutrality by 2050 will be hard to achieve. For this reason the European Committee of the Regions has launched a new working group to ensure that cities and regions can bring the European Green Deal to fruition with concrete projects and direct funding to local and regional authorities [58].

The successful implementation of the different agendas therefore requires LAs to be politically and financially empowered, autonomous and accountable with sufficient technical capacity to carry out their mandate.

This section provides an overview of the ways in which LAs can be climate champions and how through local action they can help achieve the energy and climate goals defined at EU and national level.

Setting a Vision, Commitment and Goals

The first step in achieving climate neutrality in LAs is setting a long-term, clear vision, which is underpinned by climate targets and supported by strong political commitment and will. The vision can act as the unifying component that all stakeholders can refer to, including, leading politicians, industry, citizens and interest groups. It can also motivate radical climate action and be used for promoting the local authority to the rest of the world. The vision should be compatible with EU climate action, the European Green Deal and with the Covenant of Mayors' commitments, i.e. it **should commit to the 55% GHG emission reduction by 2030 target** (at a minimum) and commit the city to gradually become resilient and adapted to the impacts of climate change. Moreover, the vision could commit the LA to even more ambitious targets such as the EU's 2050 climate neutrality objective (European Climate Law).

Important initiatives that can support LAs in successfully fulfilling their climate commitments and goals are the Sustainable Development Goals (SDGs), Sendai Framework and Covenant of Mayors (CoM). These initiatives provide a long-term framework on climate and energy actions including guidance and steps for adapting to climate change and disaster risk reduction.

Finding the right path through long term strategies

Sustainable Development Goals (SDGs)

The 2030 Agenda for Sustainable Development , adopted by all UN Member States in 2015 [59], includes 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership that aims to end poverty, enhance wellbeing and protect the planet [60].

The 17 SDGs cut across several interlinked challenges. Tackling climate change and achieving sustainable production and consumption patterns, for instance, are central to the implementation of the

2030 Agenda and can unlock vast potential and opportunities in all regions and for all people. Creating peaceful and just societies are cornerstones of the 2030 Agenda, with the interrelation between security, humanitarian action and development being the very basis for the achievement of all SDGs.

The success of this collective journey to 2030 will greatly depend on how effectively the major groups and other stakeholders will work together [61]. Among these stakeholders are the LAs that provide the link between the private sector and civil society and can unlock new environmental, social and just opportunities for all.

The inclusion of Goal 11 to "Make cities and human settlements inclusive, safe, resilient and sustainable" is, in large part, the fruit of the hard-fought campaign by local governments, their associations and the urban community. SDG11 marks a major step forward in the recognition of the transformative power of urbanization for development, and of the role of city leaders in driving global change from the bottom up. However, the role of LAs in the achievement of the Agenda goes far beyond Goal 11. All of the SDGs have targets that are directly or indirectly related to the daily work of local and regional governments. Thus local governments can be policy makers, catalysts of change and best-placed to link the global goals with local communities.

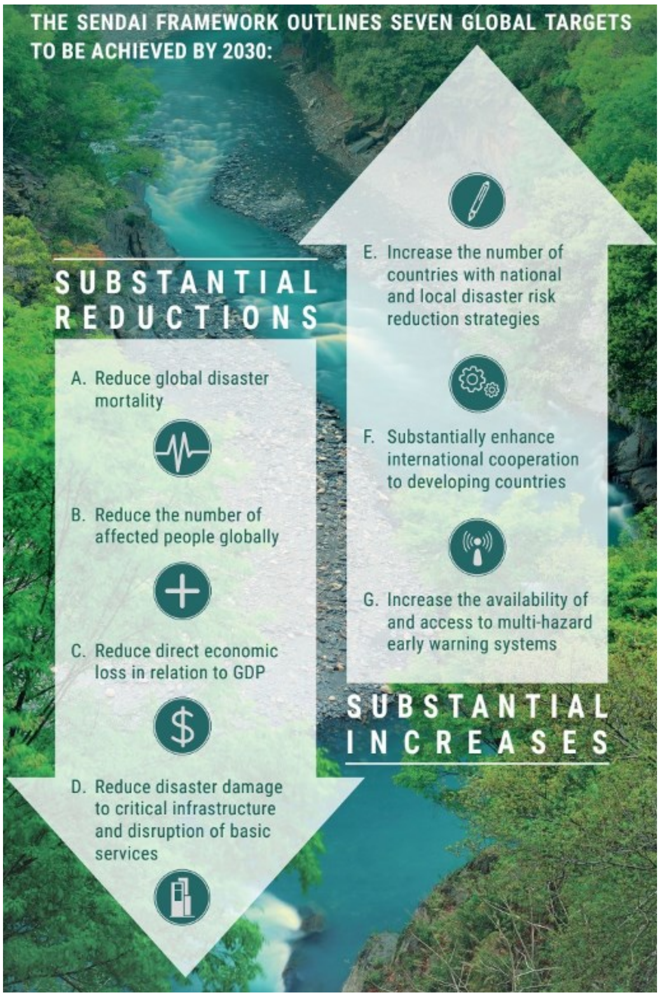


Figure 31 The seven targets of the SENDAI framework, to be achieved by 2030. Source: UNDRR [62]

Sendai Framework

The Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) provides Member States with concrete actions to protect development gains and human wellbeing from the risk of disaster. The Sendai Framework works hand in hand with the other 2030 Agenda agreements, including The Paris Agreement and the Sustainable Development Goals.

It was endorsed by the UN General Assembly following the 2015 Third UN World Conference on Disaster Risk Reduction (WCDRR), and advocates for "the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries".

It recognizes that the State has the primary role to reduce disaster risk but that responsibility should be shared with other stakeholders including **local government**, the private sector and other stakeholders.

The significance for disaster risk reduction (DRR) and resilience building is nowhere more recognized than by local government, which are often at the forefront of disaster response and recovery.

The "Making Cities Resilient: My City is Getting Ready Campaign" [63] was launched in May 2010 "to support sustainable urban development by promoting resilience activities and increasing local-level understanding of risk". By 2016, over 3000 cities have joined the Campaign and committed to lead their risk reduction activities based on the Ten Essentials for Making Cities Resilient.

Both the Sendai Framework and the SDGs are key frameworks that can support LAs in implementing sustainable strategies and achieving a just climate transition.

Covenant of Mayors

The EU Covenant of Mayors for Climate & Energy brings together thousands of local governments that have voluntarily committed to implementing EU climate and energy objectives.

The Covenant of Mayors was launched in 2008 in Europe with the ambition of bringing together local governments that have committed to taking action and exceed the EU climate and energy targets. The initiative now gathers 10,000+ local and regional authorities across 57 countries drawing on the strengths of a worldwide multi-stakeholder movement and the technical and methodological support offered by dedicated offices.

Covenant signatories commit to adopting an integrated approach to climate change mitigation and adaptation. They are required to develop, within the first two years of adhesion, a Sustainable Energy and Climate Action Plan (SECAP) with the aims of cutting CO_2 emissions by at least 55% by 2030 and increasing resilience to climate change [64].

The process of developing a SECAP for a local authority includes the creation of a baseline emissions inventory, **stakeholder engagement**, **vision-setting with specific targets**, and creating actions to achieve these targets. The mitigation actions address all sectors within a LA, namely municipal buildings and fleet, street lighting, tertiary buildings, residential buildings, transport, production of renewable energy, agriculture, and other sectors such as waste and wastewater management, carbon sinks, and urban planning (in line with the EU's action see Section 2.3). With respect to adaptation, actions address biodiversity, water, public health, buildings, transport urban planning, and risk reduction. As can be seen clearly, the structure of a SECAP has been formulated to assist in action-taking across all sectors of the economy, corresponding with EU actions (Section 2.3). SECAPs thus provide a framework for LA authority action which **compliments and reinforces** the actions taken at an EU level, supporting the achievement of EU climate goals and targets.

Multi-level Governance

The IPCC has clearly identified multilevel governance as a lever to achieve the Paris Agreement's objectives: "Strengthening the capacities for climate action of national and sub-national authorities, civil society, the private sector, indigenous peoples and local communities can support the implementation of ambitious actions implied by limiting global warming to 1.5°C" and "Cooperation on strengthened accountable multilevel governance that includes non-state actors such as research and academia, industry, civil society/NGOs [65].

The greater attention given to the specific role of local authorities in the issue of climate change has been motivated by various arguments along the past decades: LAs are better suited and more agile than central governments to address the sustainability challenges (air quality, local development, etc.) that they are confronted with; their capacity to innovate and experiment with policies and tailored strategies; the failure of intergovernmental cooperation and the COP process, etc [66] [67]. Other benefits of LA action include short decision-making pathways, good knowledge of the local situation, and proximity to citizens and visibility of results [67] [68].

In Cyprus, the question of power and responsibilities, financial means, the technical expertise held by local authorities, greatly determines the possibilities for proper engagement and consultation with a variety of stakeholders in tackling climate change issues.

10 reasons to join the CoM

1. Gain high international recognition and visibility for your local authority's climate and energy action
2. Contribute to shaping the EU's climate and energy policy
3. Strengthen the credibility of your commitments
4. Secure long-term support for your climate and energy actions
5. Boost access to financing for your local climate and energy projects
6. Participate in networking events, capacity building sessions and discussions
7. Receive tailored guidance
8. Enjoy easy access to 'excellence know-how'
9. Benefit from facilitated self-assessment and benchmarking
10. Get connected to national and subnational authorities

Participatory Process

Before completing the long-term climate strategy for 2030 or 2050, each Cypriot LA must initiate a strong participatory process with different stakeholders (presented in Figure 3), according to the local context of the area. Through ensuring stakeholder engagement, the LAs secure among others:

- concrete actions for addressing climate change challenges in each sector,
- technical support and greater efficiency in local implementation,
- prevention of conflicting and opposing measures thus supporting coherence between policy and municipal action,
- sharing of information and experience between different stakeholders and levels of governance leading to possible synergies and funding opportunities.

Local actions for adapting to climate change

The level of ambition of European cities is higher than that of the EU MS. On average EU-28 cities have committed to a 31 % emissions reduction by 2020 from 2005 levels, ten points higher than the minimum target required, and 47% by 2030.

Even in times of Covid-19, LAs remain places of innovation and experimentation for climate policies and actions. At the city level, the densification of services is now seen as the remedy to the health and climate crises [67] [69].

Progress of the CoM in Covenant Regions and Cyprus

The Covenant of Mayors for Climate and Energy is the first initiative of its kind addressing local authorities and endorsing their efforts in the implementation of sustainable energy and climate policies whilst providing them with a harmonised data compilation, methodological and reporting framework, and supporting them in translating mitigation and adaptation goals into reality. One of the distinctiveness of the CoM, compared to other similar initiatives, is the participation of small and medium-sized towns with less than 50 000 inhabitants (90% of the total signatories).

The initiative is built around three pillars:

- Mitigation (at least 55 % emission reduction target by 2030 for EU cities, corresponding to EU target)
- Adaptation to Climate Change
- Secure, sustainable and affordable energy.

As of the end of August 2019, there were a total of 9.693 CoM signatories covering a total CoM population of 312.5 million inhabitants [69].

Covenant Regions

The distribution of GHG emissions across the different CoM sub-sectors reported in the CoM Baseline Emission Inventory (BEI) 2019, is presented in Figure 32. The analysis covers 64% of the total signatories (e.g. 6200 action plans) and 67% of the signatories population.

The three most-emitting building sub-sectors are responsible for 28.3 % (residential buildings), 15.4 % (tertiary buildings) and 15.4 % (non-ETS industries) of the total CO_2-eq emissions, respectively.

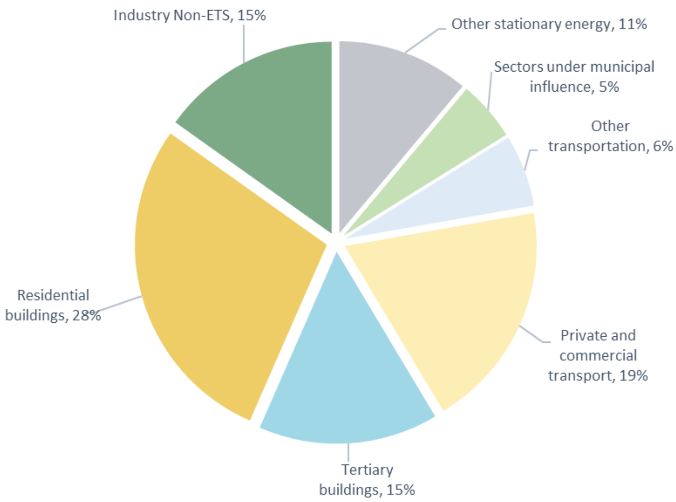


Figure 32 GHG emissions in CoM sub-sectors reported in BEIs in the CoM dataset 2019 [69]

Area	Number of action plans	Population of signatories (million)	GHG emissions in BEIs [Mt CO_2-eq/year]
European Union	5959	169.7	967.8
Eastern Partnership	167	17.6	48.8
Europe -non-EU	51	19.3	54.8
Southern Mediterranean	23	4.2	8.9
Total	**6200**	**210.9**	**1080**

Table 1 GHG emission per Covenant Regions - CoM BEI dataset 2019 [69]

The emissions in the transport macro-sector are largely dominated by the private and commercial transport sub-sector, which contributes to 73 % of the GHG emissions from transportation and to 19 % of total GHG emissions. All the emissions in the transport sector which are not classified in a specific sub-sector are grouped under 'Other Transportation, representing 5.7% of the total CO_2 eq emissions. The "municipal influence" represents only the 5% of the total emissions, which includes municipal buildings and facilities (2.5 %), municipal fleet (0.2 %), public transport (1 %), waste management and water management (1.3 %).

Mitigation Part

In the EU Covenant signatories, a reduction of 25 % (145 Mt CO2-eq) has been achieved, from the baseline year inventory (BEI-2005) to the year of the last submitted monitoring report (MEI-2017), as reported by 1802 signatories, representing 88.8 million inhabitants; The drop in emissions is more obvious in the buildings sector with a decrease of 22 % from BEI to MEI but less pronounced in the transport sector with an 16 % reduction from BEI to MEI; (Figure 33) EU Signatories which submitted monitoring emission inventories have an overall target of 30 % for 2020, compared to 2005 and are on track to reach it [69].

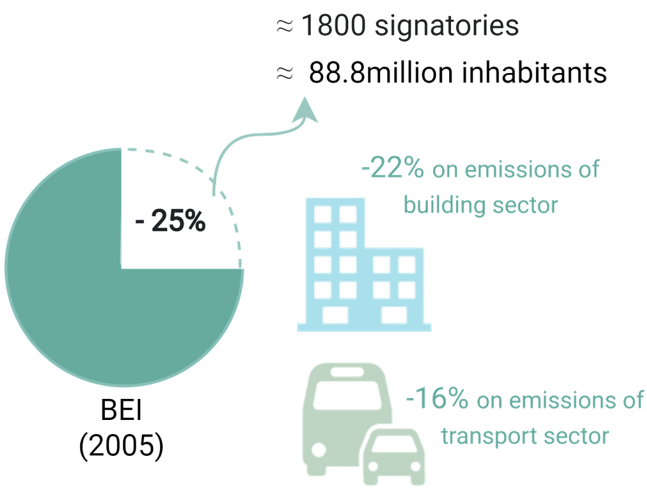


Figure 33 Emissions reductions of EU Covenant signatories between 2005 (BEI) and 2017 (MEI).

Adaptation Part

For the period 2021-2030 a new major part has been added in the Action plans of the CoM: climate change adaptation. However, only 429 signatories (370 from EU28+EFTA and 59 non-EU28+EFTA) have already provided information regarding their adaptation goals, risk and vulnerability assessments or action plans.

The main climate related hazards threatening CoM municipalities are extreme heat, droughts, extreme precipitation, forest fires, floods and storms. For future projections, it seems that sea level rise will have the highest increase in terms of hazardousness, followed by extreme heat. Floods and forest fires are not expected to increase much more than current levels [64].

Cyprus

In Cyprus a total of 24 local authorities have committed to reduce their CO_2 emissions by at least 20% by 2020 compared to 2009 which is considered as the baseline year. A typical municipal distribution of CO_2 emissions across the different CoM sectors is presented in Figure 34 (2009 BEI, Final energy consumption).

The most emitting sectors responsible for 96% of the CO_2 emissions are: transport (51%), residential (23%) and tertiary (22%) sector. It's thus obvious where LAs must give priority when developing mitigation goals, policies and actions.

Figure 35 presents the progress of the 24 Cypriot signatories according to the MEI (2017), representing ≈570.000 inhabitants. A total 619.169 tCO_2 were reduced by 2017 in the territory of the LAs, reflecting a 16,3% reduction. While it appears that LAs in Cyprus are on track to reach the 2020 target, an increase of their energy consumption is expected in the coming years as the economy recovers following the financial crisis.

Currently, only five (5) LAs in Cyprus have committed to increasing the CO_2 reduction target by 2030 and introducing climate adaptation actions and initiatives.

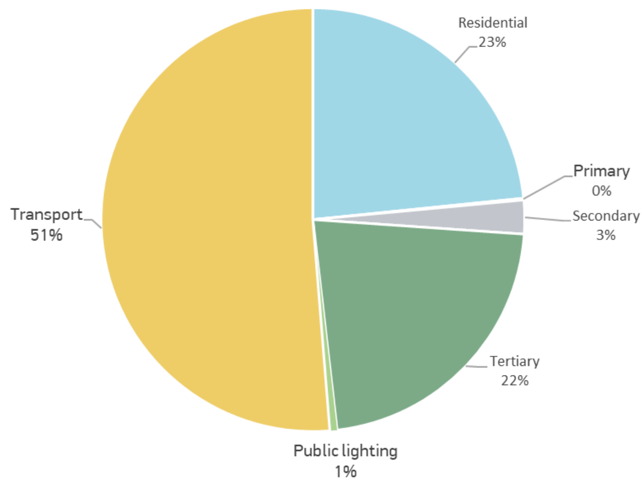


Figure 34 Municipal CO_2 emissions distribution in CoM sub-sectors, 2009 BEI Source :CEA & EAC

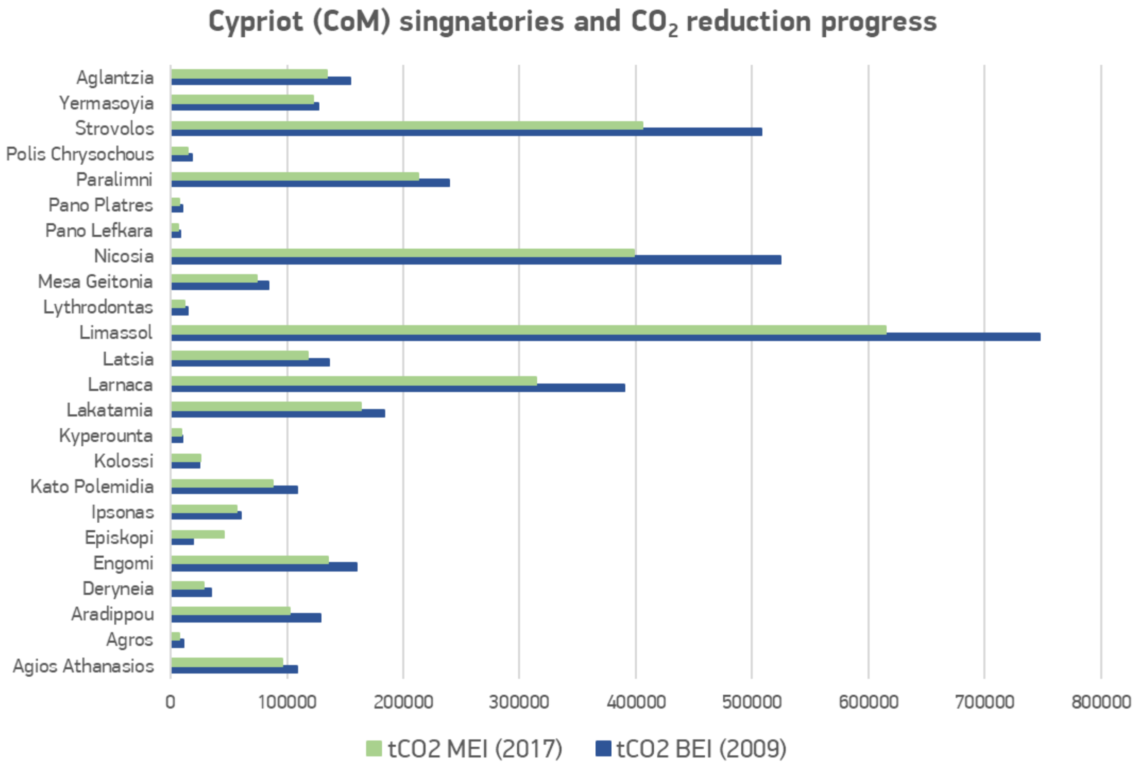


Figure 35 Progress of Cypriot signatories in CO_2 reduction Source : CEA

There is a variety of adaptation actions that can be adopted and implemented by the Cypriot local authorities. Table 2 provides an indicative set of actions adapted from the Sustainable Energy and Climate Action Plans (SECAPs) of Strovolos and Lakatamia cities.

Water

- Management and restoration measures of important habitats (e.g. Pedieos river)
- Improvement, expansion of the rainwater drainage network
- Implementation of nature-based solutions (NbS) for flood mitigation
- Actions to save and use water efficiently
- Reduction of losses from the water supply network
- Incentives for house-rainwater harvesting

Buildings

- Promoting green roofs
- Promoting bioclimatic design in buildings
- Implementing Green Public Procurement

Transport

- Upgrading of bus stops, public and parking spaces with shading structures
- Upgrading the network of cycle paths
- Infrastructure design considering climate change effects

Environment & Biodiversity

- Awareness raising actions on the importance of biodiversity
- Actions for urban green growth and biodiversity enhancement (especially in important habitats)
- Creation of biodiversity/pollinator theme parks
- Developing an inventory, monitoring, and assessment mechanism for biodiversity

Land Use Planning

- Using cool/permeable pavements to reduce heat island effect
- Prohibition of complete soil sealing in areas sensitive to floods
- Protecting green areas from urban development

Table 2 Indicative set of actions proposed in Sustainable Energy and Climate Action Plans

CoM supporters in Cyprus

LAs are supported in the development and implementation of SECAPs by CoM supporters. With expert knowledge of the regulatory, legislative and financial framework under which they operate, CoM Supporters are ideally placed to provide tailored advice to signatories and identify synergies with existing initiatives.

The Cyprus Energy Agency together with the Union of Cyprus Communities and the Union of Cyprus Municipalities, comprise the official CoM supporters in Cyprus.

The Cyprus Energy Agency, as an independent non-governmental organisation, has been set up to support local authorities and citizens in Cyprus in the transition to a carbon neutral and climate resilient future. As the main technical expert, the Cyprus Energy Agency has carried out and monitored the implementation of SEAPs/SECAPs, supporting the role of LAs in confronting the new climate and energy challenges at local and national level.

Specifically, 26 SEAPs/SECAPs have been prepared and monitored by the Cyprus Energy Agency. This has resulted in a reduction of carbon dioxide (CO_2) emissions by 759.716 tones and a decrease in energy consumption of 2.333.104 MWh by 2020 from the period of implementation.

In order to capitalize on the success of the past decade, and to widen participation to more LAs, the Union of Cyprus Communities and the Cyprus Energy Agency have secured funds through the Recovery and Resilience Facility. This support scheme will provide technical support in the development of 32 joint SECAPs, for a total of 348 rural LAs. Furthermore, investments related to sustainable mobility, nature-based solutions and green infrastructure will be provided, increasing the LAs resilience to climate change and enhancing citizens' quality of life.

For more information about the Cyprus Energy Agency please **scan the QR code**.

What can citizens do?

Scholars and policymakers highlight the importance of **engaging citizens** in climate action to secure the legitimacy of mitigation and adaptation actions as well as to ensure the inclusion of locally relevant knowledge [70]. The necessity of citizen engagement is further addressed in the 5th IPCC report which notes that citizen participation has so far been limited in practice [71]. The Paris Agreement, the Green Deal and many national adaptation policy documents stress the role of **active citizenship** in reversing the impacts of climate change and improving the quality of life, especially in urban areas.

The Cyprus Energy Agency, as part of its role in promoting climate action, has had an active role in engaging with citizens and providing tools and guidance which helps the ordinary person take action to mitigate and adapt to climate change. Examples of the tools and guidance available include:

⇒ ***Nature-Based Solutions for adaptation to climate change***

Detailed guidebook for citizens describing small actions at home-scale that can promote biodiversity and tackle climate related hazards like extreme heat and floods. More details can be found in the link:

NBS for Citizens (GR) https://www.cea.org.cy/wp-content/uploads/2021/06/odigos-efarmogis-lyseon-vasismenon-sti-fysi-nbs-idiotikes-perioysies.pdf

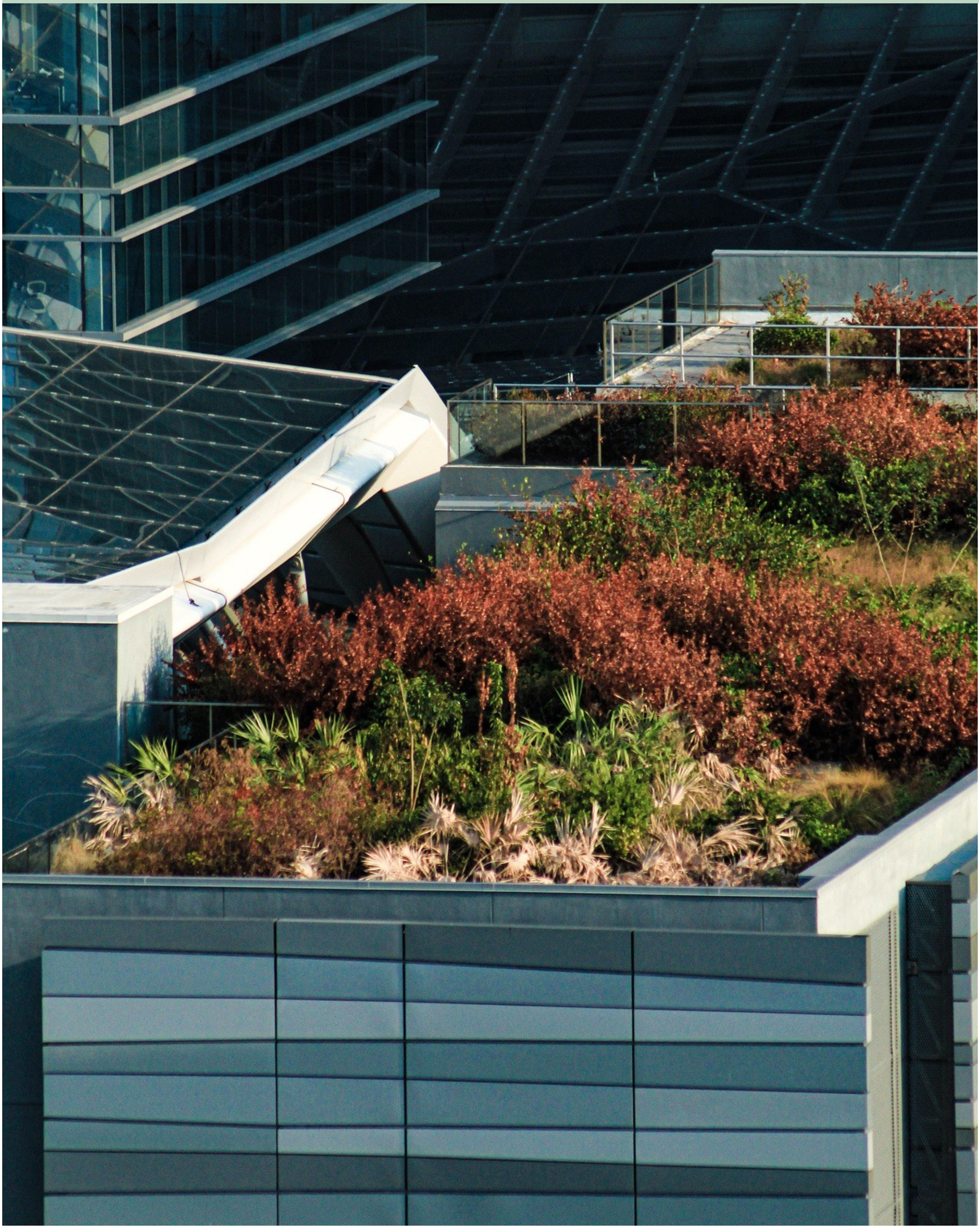
Nature Based Solutions for Citizens

- Pollinator Gardens including insect hotels and bird feeders
- Rain Gardens
- Using permeable instead of impermeable surfaces
- Green roofs instead of grey / conventional roofs
- Indigenous plants with less water demands
- Vegetated canopy shading

⇒ *Energy Saving in Households*

An easy-to-use online tool prepared by the Cyprus Energy Agency in collaboration with the Energy Service of the Ministry of Energy, Commerce and Industry to guide citizens in saving energy in households. The tool performs a simplified energy check for households and prepares suggestions for energy efficiency improvements. In addition, users can compare electrical appliances using the energy label to make informed decisions as well as calculate the benefits of installing solar thermal or solar PV on their rooftop.

The tool can be accessed at: http://energysavingstool.cea.org.cy/EN/index.php



5. Conclusion

Our world is warming, with a global average temperature 1.2°C higher than pre-industrial levels. This relatively modest increase has *already* resulted in a reduction in glacial mass and sea ice extent, an increase in ocean heat content and acidification, with rising sea-levels and more frequent extreme weather events.

The Mediterranean Sea Basin specifically, is warming faster than the rest of the world, and is a known climate change hotspot. Annual average temperatures are approximately 1.5°C higher than preindustrial levels, higher than global average temperatures. Projections for the area show that under all scenarios of climate change, temperatures will increase further, particularly in the summer period, leading to more heatwaves, whilst precipitation will decrease leading to more periods of drought. For Cyprus, climate projections are equally clear, showing a further warming in the range 1.5–2.0 ^{0}C by 2061 and a warming of up to 4 ^{0}C by 2100 under the RCP 8.5 scenario. Under such a warming regime, the climate of Cyprus will be hotter and drier, with an increase in heatwaves, droughts, and other extreme events.

The extent of these changes and the degree of warming, however, will be strongly influenced by which path humanity takes. A pathway with strong climate action, leading to the transformation of our economies and way of living, will limit warming and thus minimise the adverse consequences of climate change to human well-being. Climate action is thus key. The most important instrument currently at our disposal is the UNFCCC Paris Agreement, the leading international agreement on climate, which will shape all future climate action. At the EU level the Commission has unveiled its European Green Deal, the most ambitious EU plan to date for tackling climate change, shaped by the Paris Agreement. The European Green Deal will affect all sectors of our economy, from our energy use, transport, to how we grow our food, how we use our land and treat nature, and how we plan our economies. The next few years will see considerable changes, including plans, policies, and strategies which will reconfigure our way of life in line with the latest climate science.

In Cyprus, national climate policies have been set following the directions and targets of the EU and are designed to ensure that Cyprus contributes to the overall targets of the European Union. The challenge facing Cyprus on its decarbonisation journey is significant, and the targets and policies that have been set in its National Energy and Climate Plan currently fall short. If Cyprus and the EU are to have any success in achieving their climate goals and targets, multi-level stakeholder engagement and governance will be critical. Strong participatory processes with various stakeholders will support the efficient realisation of both climate change mitigation and adaptation targets.

One type of stakeholder with an integral role is local government. Further promotion and expansion of the role of Local Authorities in climate action is an important pathway towards our climate goals. Local Authorities have already taken action through the Covenant of Mayors initiative and have set targets that are often more ambitious than National and EU targets. Local Authorities in Cyprus are currently on track to reach their 2020 targets however the economic recovery may prevent them from reaching the 20% CO_2 emissions reduction, highlighting the importance of designing economic recovery packages with climate resilience in mind.

In the near future, as the consequences of climate change are increasingly felt, adaptation to the impacts of climate change will gain in importance. This has been reflected in the Covenant of Mayors, which has now included adaptation to climate change in its framework. However, whilst EU Local Authorities are making good progress in the mitigation pillar, the adaptation pillar needs further capacity building and tailored technical support so that more Local Authorities take up adaptation action.

The Cyprus Energy Agency works to support local authorities and citizens in the transition to a carbon neutral and climate resilient Cyprus. It achieves this through offering technical support to local authorities in the development and implementation of Sustainable Energy and Climate Action Plans, whilst developing tools for citizens which empower them to take climate action and minimise their carbon emissions and adapt to climate change.

Further information can be found on our website.

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Cyprus Energy Agency

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2-12 Lefkonos Str., 1011 Lefkosia Cyprus

Tel: +357 22-67716, Fax: +357 22-667736

email: info@cea.org.cy , web: www.cea.org.cy