Què funciona contra el canvi climàtic?

Report

What works against climate change?

Evidence to improve climate change mitigation and adaptation policies

ivàlua
Institut Català d'Avaluació de Polítiques Públiques

Generalitat de Catalunya

COAMB
Col·legi d'Ambientòlegs de Catalunya

Què funciona contra el canvi climàtic?

What works against climate change?

Evidence to improve climate change mitigation and adaptation policies

Final report:
January 2025

Thematic area
Presentation of the project

Project promoted by:
Ivàlua, Department of Economics and Finance, Department of Territory, Housing and Ecological Transition, Department of Agriculture, Livestock, Fisheries and Food and Col·legi d'Ambientòlegs de Catalunya

Authors:
Cristina Ferrer Romero and Anna Segura Lladó (Ivàlua)

Coordination
Ivàlua

Revision and support:

Steering group: Maria José del Blanco and Xavier Soto (Department of Economics and Finance); Leonardo Bejarano and Gabriel Borràs (Department of Territory, Housing and Ecological Transition); Salvador Samitier (Department of Agriculture, Livestock, Fisheries and Food); Maria Siuraneta (Col·legi d'Ambientòlegs de Catalunya); and Anna Segura and Cristina Ferrer (Ivàlua).

Expert group: Olga Alcaraz (Polytechnical University of Catalonia), Jeroen van den Bergh (Institute of Environmental Science and Technology - ICTA-UAB), Maria Crehuet (Associació de Micropobles de Catalunya), Irene González (Aliança contra la Pobresa Energètica), Albert Puigvert (Associació d'Iniciatives Rurals de Catalunya), Ana Romero (Àrea Metropolitana de Barcelona), Jordi Teixidó (University of Barcelona) and David Villar (Catalan Institute of Energy).

Què funciona contra el canvi climàtic?

Evidence synthesis and knowledge transfer project to improve climate change mitigation and adaptation policies.

A project by:

ivàlua Institut Català d'Avaluació de Polítiques Públiques

Generalitat de Catalunya

COAMB Col·legi d'Ambientòlegs de Catalunya

Què funciona?

List of contents

1. Introduction

Concern about the climate crisis has grown over the past few decades, as scientific evidence has demonstrated the adverse effects of global warming on the well-being of the planet and its inhabitants. In fact, its impact is already being felt: this year, in Catalonia, opinion surveys have shown that citizens consider drought and climate change to be the issues that preoccupy them the most. [1]

The emission of greenhouse gases (GHG) produced by human activity, primarily through the burning of fossil fuels, the forms of land use and patterns of consumption and production adopted since the Industrial Revolution, is widely accepted as the cause of the increase in planetary temperature that underlies climate change. [2] This increase in temperature affects a range of natural processes that are necessary to maintain the stability and resilience of the Earth's systems and to make the planet a safe place in which to live. [3]

The consequences of climate change are already visible all over the world, to a greater or lesser extent. They affect ecosystems, biodiversity, water availability, infrastructure, food production, and the public's health and well-being. In Catalonia, the effects of climate change include the increase in the average annual temperatures of air and sea water, changes in rainfall patterns, the increase in extreme weather events, the rise in sea level, and the retreat of glaciers and reduction in snowfall in the Pyrenees.[4, [5]

In this situation, there is an urgent need to implement effective measures to reduce GHG emissions – i.e., mitigation measures – and to minimize the adverse effects of climate change and reduce vulnerability – i.e., adaptation measures. Both tasks present significant challenges.

In fact, political scientists have described the fight against climate change as a "super wicked problem", characterized by four main aspects: [6]

1. Those who seek to solve the problem are also those who are causing it – namely, humans.

2. There is a time limit; beyond this limit, no solution will be possible.

3. This is a global problem, with no central authority responsible for finding a solution.

4. Policy responses do not pay sufficient attention to the future: they focus excessively on the immediate costs of dealing with climate change, and pay little heed to the future costs of not doing so.

Furthermore, the climate is a public good. This means that it may be affected by the problem of free riding: i.e., certain agents (countries, companies, households, etc.) can benefit from the

collective efforts of others without taking on their fair share of responsibility or costs. Fortunately, an array of multilevel projects, institutional frameworks, laws, policies and strategies have been developed to address this complex issue. In fact, according to OECD data, there are currently more than 3,900 instruments in place for combating climate change and its consequences in more than 130 countries. These include taxes, fees, tradable permits, compensation, subsidies, monetary incentives, deposit refunds and voluntary initiatives. [7]

Given the scale of the challenge and the diversity of the public policy options available, it is crucial to establish which climate change mitigation and adaptation policies are the most effective. Knowing what works and what does not will make it easier to choose viable, functional and cost-effective measures. At the same time, identifying the circumstances in which the different instruments for fighting climate change work best helps to prioritize resources and guarantee sustainable development for everyone. And this is precisely what the "What works against climate change?" project focuses on: it aims to provide public decision-makers with robust evidence regarding the effectiveness of climate change policies for bringing down GHG emissions and for reducing our vulnerability to the consequences of global warming.

2. The causes: how has the current situation arisen?

The global temperature is higher today than at any other time in human history. In 2023 it stood at 1.45°C above pre-industrial levels. [8]

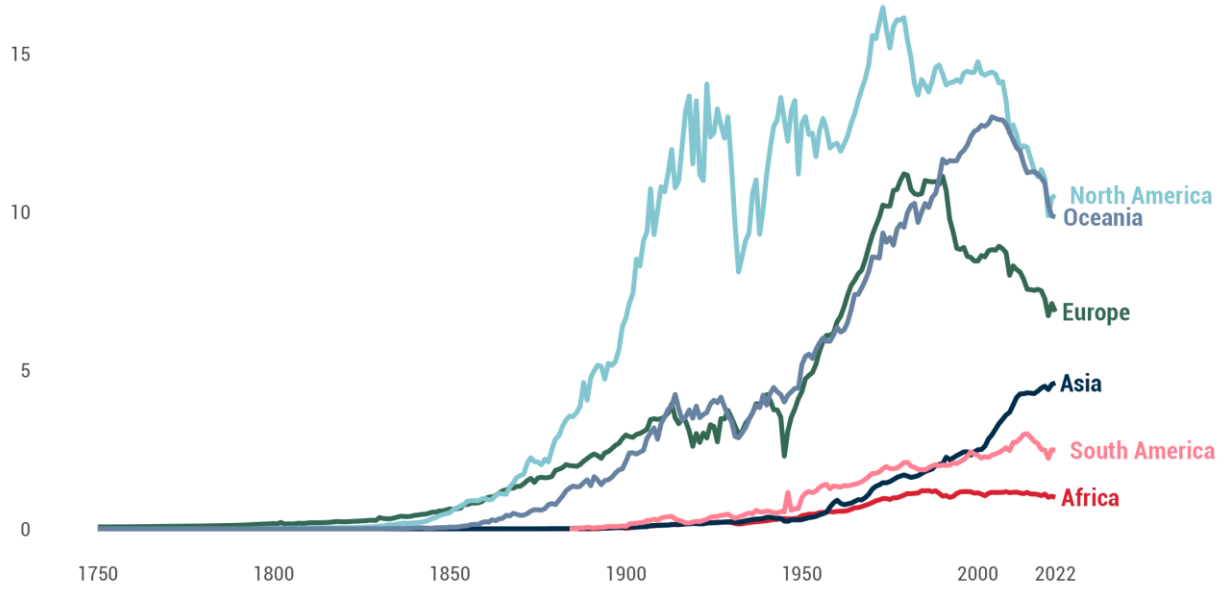
The main mechanism by which human activity has caused this global warming is the massive emission of greenhouse gases (GHGs). The greenhouse effect is a natural process of the planet, crucial for making life on Earth possible, by means of which GHGs "trap" inside the atmosphere part of the heat radiated by the planet that would otherwise escape into outer space. However, the excessive accumulation of GHGs intensifies this effect, and this causes the average temperature on the surface of the planet to increase, thus drastically altering natural cycles and weather patterns; this triggers a set of effects known as climate change. [2]

Today, anthropogenic GHG emissions have been accumulating in the atmosphere for more than two centuries. This process began around 1760, coinciding with the beginning of the Industrial Revolution, and since then has advanced on a scale and at a speed unprecedented in the history of the planet. In fact, global emissions have not stopped growing since then, and have gone from 4 billion tons CO_{2eq} in 1850 to 54.59 billion in 2021. [9]

The countries that industrialized first have contributed the most to the accumulation of GHGs in the atmosphere. Specifically, European countries were responsible for 33% of the global CO_2 emissions accumulated on Earth between 1751 and 2017, North America for 29%, and Asia for 29%. The contributions of other regions are far lower: South America and Africa account for only 3% each, and Oceania 1.2%.[10]

Assessing the issue in terms of the populations of each region, the differences remain notable. However, in this case North America leads the ranking of cumulative emissions per capita, followed by Europe and Oceania and, at a considerable distance, by Asia and Africa. [11]

Figure 1. Evolution of CO_2 per capita emissions by continent, 1750-2022.



Source: created using data recorded in the *Global Carbon Project*, from *Our World in Data*.

These differences can be explained to a large extent by the close relationship between CO_2 emissions and economic activity. Historically, as countries' GDP has increased, their emissions have also risen, mainly due to the greater energy consumption that social and economic development entails. In recent decades, however, several countries have broken the correlation between economic growth and emissions and have managed to increase their economic activity while reducing their emission levels. This decoupling is found even when emissions associated with the consumption of goods produced beyond the national borders are taken into account. This phenomenon is due to the offshoring of production, which mainly takes place in more developed countries and allows certain territories to reduce their emissions at the expense of increasing them elsewhere.

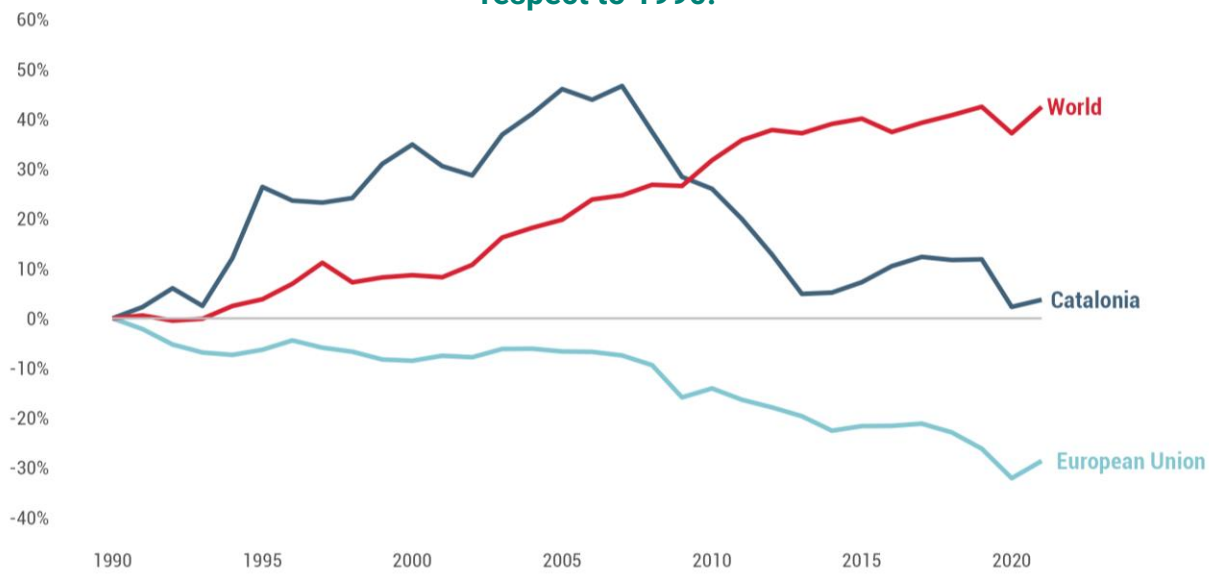
The ability to reduce energy use or make it less carbon-intensive means that some of the regions that have historically contributed most to GHG emissions are no longer the main emitters. [12] Thus, in 2021, Asia moved to the top of the list, being responsible for 53% of annual global CO_2 emissions, while the proportions corresponding to North America and, especially, Europe fell to 18% and 17% respectively. [13] In fact, over the last few decades all regions but Asia have reduced their emissions per capita.[1] In Catalonia, GHG emissions in 2022

[1] In 2022 emissions per capita were (in tons of CO_2): 10.5 in North America; 9.9 in Oceania; 6.9 in Europe; 4.6 in Asia; and 1.0 in Africa.

were 40.4 million tons of CO_{2eq}, which is equivalent to 0.075% of the world's total.[2] [14]

Regarding the recent evolution of GHG emissions in Catalonia, a marked increase was noted between 1990 and 2007, by which point they reached 57.11 million tons of CO_{2eq}. This historical peak in emissions occurred later than in the European Union as a whole (where it was recorded around 1990) but it is higher than the current worldwide average. From 2007 onwards, Catalonia recorded a drop in emission that lasted until 2013, coinciding with the economic crisis; since then, emissions have remained relatively stable, below 44 million tons of CO_{2eq} per year (a figure that fell by 9% in 2020 with the closures due to the COVID pandemic). The consequence of this stagnation is that Catalonia's emissions are still 4% above 1990 levels. (Figure 2).

Figure 2. Evolution of GHG emissions in Catalonia, the European Union and the world, with respect to 1990.

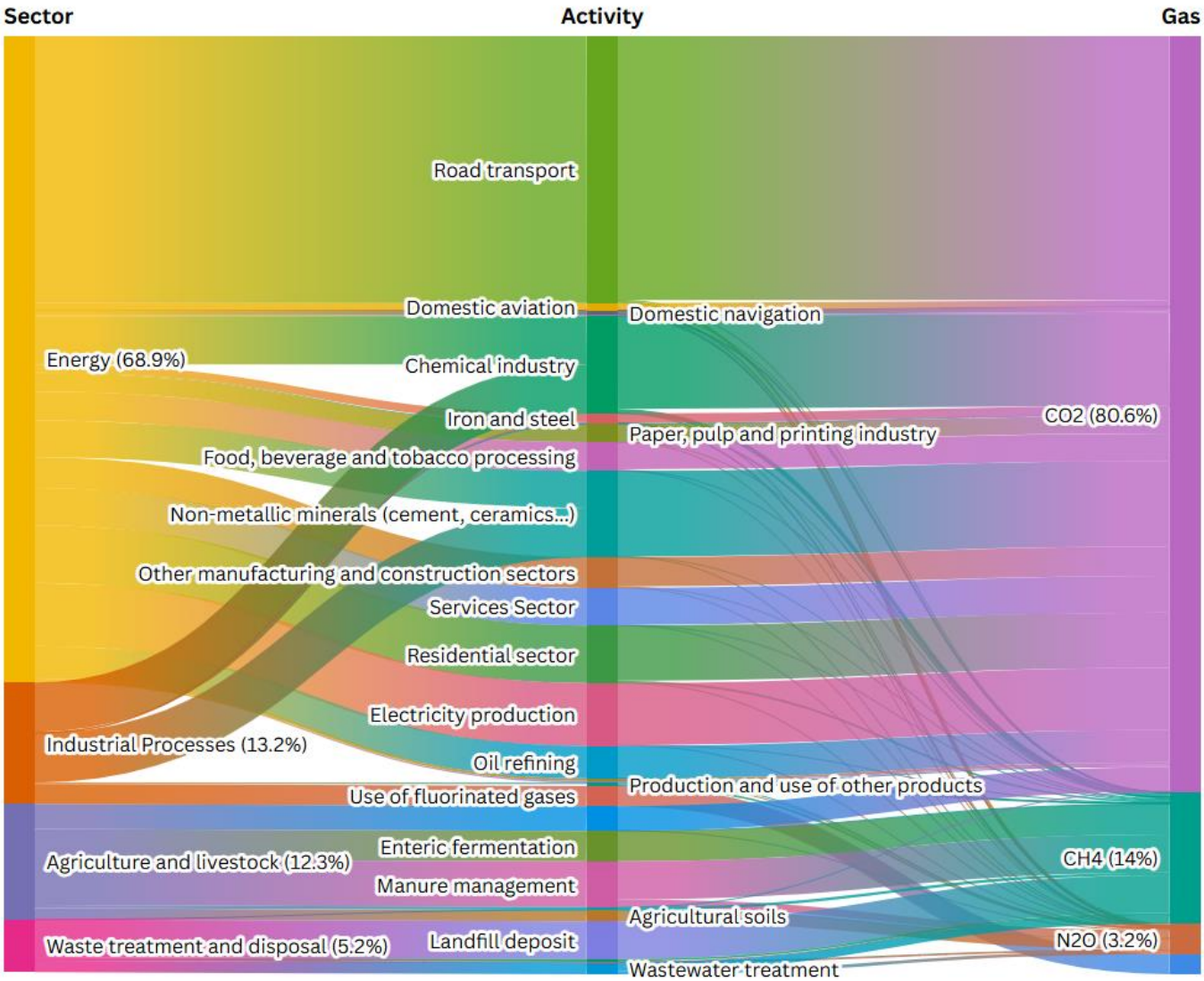


Source: created using data on GHG emissions in Catalonia, from the European Energy Agency (*EEA*) and *Our World in Data*.

Figure 3 displays data on GHG emissions from Catalonia for the year 2021, broken down according to type of greenhouse gas, the activity that produces them, and the sector in which this activity occurs.

[2] Emissions absorbed by sinks (land use, land use change and forestry, or LULUCF) are excluded.

Figure 3. GHG emissions in Catalonia, 2021. Sector, activities and type of GHG.



Source: derived from the data on GHG emissions in Catalonia.
Interactive presentation available here.

The first point to mention is the fact that CO_2 accounts for 80.6% of emissions[3] and that 68.9% are related to energy use. The reason for this is that, despite efforts to promote the use of clean energy sources and to reduce the carbon intensity of the energy mix, fossil fuels, which emit large amounts of CO_2, remain the main energy source in Catalonia.

Looking at the activities in which this energy is used, the burning of fossil fuels is predominantly associated with transport, and specifically road transport (39.8%), followed (at a considerable distance) by rail, air and maritime transport. Next comes the energy used in the manufacturing and construction industries (25.6%) and in buildings (14.2%), which includes the residential sector and services (i.e., trade, businesses and institutions). Emissions generated by the energy

[3] This is why, as in Figure 3, the convention is to express emissions of other GHGs in tonnes of CO_2 equivalent.

sector industry itself (14.6%) are distributed between thermal power plants, oil refineries and fuel transformation.

In second place, we find CO_2 emissions generated by industrial processes (13.2%), primarily the chemical and non-metallic mineral industries, beyond those linked to energy consumption: for example, those associated with cement production or the ethylene industry. In addition, the use of fluorinated gases in industry, above all the consumption of halocarbons in refrigeration and air conditioning, also generates emissions of these gases (HFC, PFC and SF6), which represent 2% of total GHG emissions.

In third place, agricultural and livestock activities (12.3%) include emissions from the use of fertilizers, methane emissions of livestock (especially cattle) and manure management (especially pigs), and the use of forestry machinery, the fishing fleet and fuels in fixed installations such as boilers and engines, among other primary sector activities. Methane accounts for the majority of emissions (70%), although the use of fertilizers in soils and the management of manure also generate emissions of nitrous oxide.

Waste treatment and disposal contribute 5.6% of total emissions, mainly tin the form of methane emitted due to the deposition of waste in landfills, wastewater treatment, and the biological treatment of solid waste or waste incineration.

Finally, we stress that the figures presented do not take into account emissions associated with imported goods consumed in Catalonia, or those associated with international air and maritime transport.

The data presented here show that GHG emissions are not restricted to particular sectors or activities, but occur across the economy as a whole.

3. The consequences: the impact worldwide, and in Catalonia

Although the impact of climate change varies depending on geographical factors, it is already visible in all inhabited regions of the world. [2] It includes, for example, episodes of extreme heat, irregular rainfall, increases in sea level and temperature and the loss of biodiversity; it also entails a whole series of risks in the areas of food security, public health, infrastructure, ecosystems, the economy and migratory movements, which in turn generate cascade effects from one system or region to another.

Whereas the above section drew attention to the differences between different regions of the world in terms of their contribution to the problem of GHG emissions, the inequalities between (and within) regions with regard to their vulnerability to the risks generated by the impact of climate change represent another key issue. This is because it is precisely the regions that have contributed least to the generation of emissions that are most vulnerable to its consequences.

An example is the disproportionate impact of climate change on food and water insecurity in many parts of Africa, Asia, and Central and South America (the world's least developed countries), small islands, and the Arctic. Within each country, those most affected are indigenous peoples, small farmers, and low-income households. [2]

In Europe, Spain is one of the countries most exposed to the likely increases in temperature. [15] In Catalonia, the **temperature** has risen by 2.4°C since the pre-industrial era, an increase that is twice that of the planet as a whole [5] and 0.3°C higher than the average for Europe. [16] The last decade has been the warmest since at least 1950, and 2022 broke the record for temperature compiled since then. This warming of air temperature has consequences for natural systems: it increases the risk of forest fires, affects water availability, alters biodiversity, and has direct impacts on all areas of society. [17] For example, increases in temperature are associated with greater health risks due to the fact that air pollution worsens in periods of high temperatures; these episodes increase the presence of disease-transmitting mosquitoes, and at the same time heat waves may have alarming effects on mortality and morbidity.

Temperature increases are not restricted to atmospheric temperature but are also observed in **seawater**, which in Catalonia has warmed at a rate of +0.3°C per decade in the first 50 metres of depth, and +0.2°C per decade between 50 and 80 metres between 1974 and 2021. This development places the ecological balance of marine ecosystems and fishing at risk. [5] In addition, sea levels have risen by up to 3 centimetres per decade, which has put the coastal infrastructure on the alert. Additionally, the analysis of ice masses confirms that since 1980 visible glaciers have progressively disappeared (only one rocky glacier remains, in the Besiberri massif) and that the average thickness and average duration of snow on the ground at an altitude of 2,100 m are showing significant downward trends.

At the same time, a decrease in the average annual **rainfall** of almost 90 mm compared to 1950 has been recorded, falling by 1.9% per decade; in fact, throughout the country summer rainfall shows a clear downward tendency (-4.9% per decade) [5]. This decrease is a matter of particular concern, given that the summer is the time of year with the highest demand for water, as a result of the peak consumption in agricultural irrigation campaigns and pressure from tourism. In addition, the irregularity of rainfall negatively affects the availability of water, particularly in times of severe drought such as the ones experienced in 2005-2008 and 2021-2024. This lack of water affects above all the agricultural and livestock sectors, although it also impacts others such as industry, services and commerce, energy, and the insurance and financial sectors. This situation has obvious repercussions for the food and water security of the public when the restrictions reach urban areas.

Finally, along with other factors such as changes in land use, climate change also endangers **biodiversity**, as it alters the composition of ecosystems with the arrival of new species from warmer climates and modifies the life cycles of native species. According to the Living Planet Index (LPI) produced by the Observatory of Natural Heritage and Biodiversity, which regularly monitors 353 species of fauna, over the last twenty years the populations of wild animals in

Catalonia have suffered an average decline of 28%. [18] This loss of biodiversity is a matter of concern: on the one hand, in and of itself; on the other hand, because biodiversity is a factor that can enhance resilience to climate change, and degrading it means giving up its potential to mitigate risks and impacts.

In short, the impacts of climate change are multiple and diverse, affecting the entire natural environment and, consequently, human systems. In order to anticipate the risks that climate change will pose for society, we need to be aware of the complexity of the relationship between rising temperatures and their impact, as well as the existence of "points of no return" – that is, critical thresholds of climate change in which the regional or global climate passes irreversibly from one stable state to another (for example, the melting of the Arctic Ocean). At the same time, each extra degree in the average temperature makes it more likely that the point of no return will be reached, thus increasing the pressure on the adaptation limits of natural and human systems.

4. Public policies on climate change

Current climate projections estimate that, if policies to reduce GHG emissions are not implemented in the coming decades, by 2100 the planet's temperature will be between 3 and 5°C above pre-industrial levels. [19] Therefore, to avoid the spiral of impacts caused by the continuous increase in global temperature, it is necessary to adopt policies aimed at drastically reducing GHG emissions, until the goal of zero net emissions is achieved on a global scale.[4]

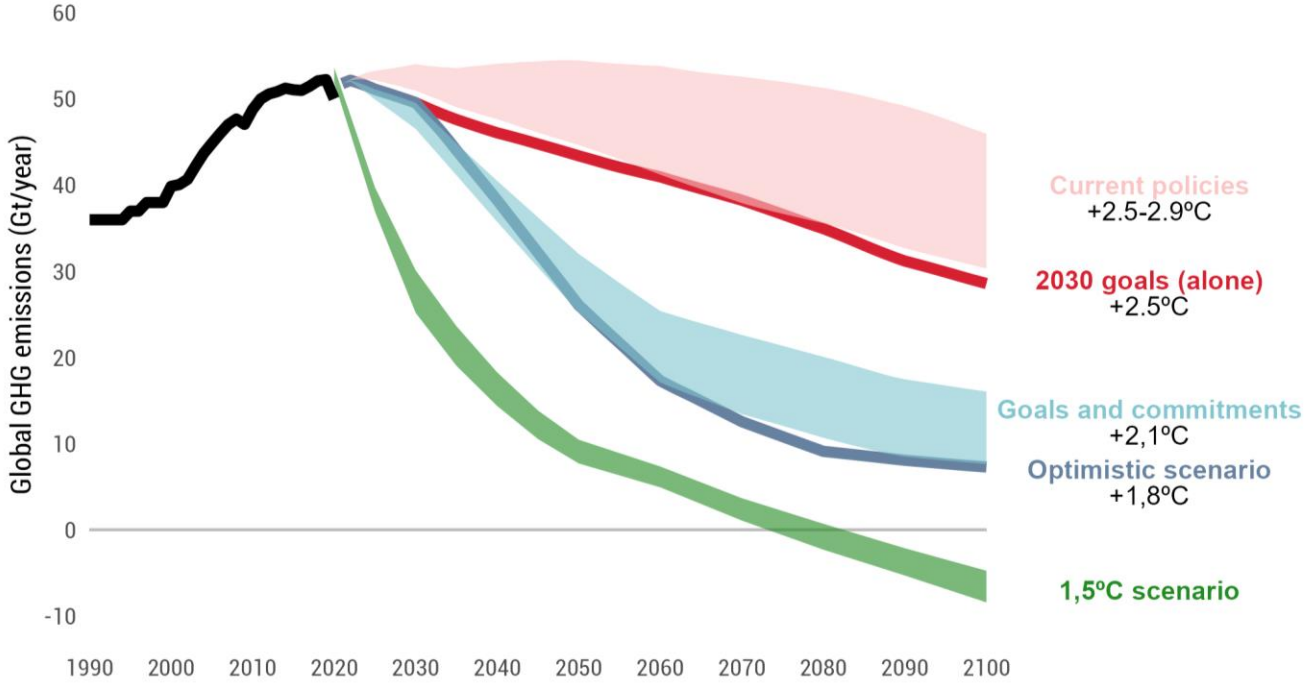
The time it takes to achieve this goal and the amount of emissions that are produced in the meantime will depend above all on the decisions that are made over the next few decades with regard to policies for combating climate change – that is to say, the climate change **mitigation policies** that are put in place, and their effectiveness (Figure 4).

As a point of reference, the goals established in the 2015 Paris Agreement [20] aim to achieve the objective of net zero emissions in the second half of the century and to limit global warming to values between 1.5 and 2°C above the temperature of the pre-industrial era. Fulfilling this goal will not be possible unless more ambitious policies to combat climate change are put in place soon. At the same time, it will be necessary to ensure that the transition to a sustainable model is carried out in a fair manner: that is, in such a way that the most developed countries lead the efforts, not just because they have the most capacity to do so, but (and above all) because they have contributed the most to global emissions in the past, and therefore to climate change.

[4] The goal of net zero emissions implies reducing human-caused GHG emission levels as much as possible, leaving any remaining residual emissions to be offset by an equivalent amount of anthropogenic absorption (either through nature-based solutions, such as soil restoration or forest management, or through technological solutions such as direct air capture and storage).

In fact, even if current mitigation policies are maintained in the future, experts forecast that by the year 2100 we will still be far from achieving the goal of net zero emissions, and the planet's temperature will be higher than the goal of 2°C above pre-industrial levels. While there is no consensus in the scientific community on potential long-term emission trajectories,[5] projections by Climate Action Tracker indicate that even if governments meet the Paris Agreement targets, which are set out in official documents known as nationally determined contributions (NDCs), by 2100 global temperatures will nonetheless have risen by 2.5°C. Finally, if we take into account the binding targets and commitments of countries beyond 2030, the forecasts are that by 2100 global warming will be 2.1°C above pre-industrial levels. Therefore, without more ambitious climate change policies, the goal of keeping global warming below 2°C will not be achieved.

Figure 4. Scenarios of GHG emissions and global temperature



Source: derived from data recorded in the Climate Action Tracker, 2023.

Whatever mitigation policies are implemented, and however successful they are, it is clear that climate change **adaptation policies** will be necessary to preserve the well-being of the population. As outlined in the above section, some of the consequences of the increase in global temperature are already very clear and verifiable, and reversing them will be an immensely challenging task – perhaps an impossible one.

[5] For example, the 2023 emissions gap report [21] incorporates projections up to 2035 that indicate higher emission figures in all scenarios in Figure 4.

4.1 Policies for mitigating climate change

Climate change mitigation policies aim to reduce emissions and improve the carbon sink capacity: that is, the capacity to absorb carbon dioxide from the atmosphere.

In response to the Paris Agreement, the emission reductions established by the European Union, the updates agreed upon in successive Conferences of the Parties (COP) of the United Nations Framework Convention, and the Catalan Law on Climate Change of 2017, Catalonia has committed to reduce GHG emissions during the current decade, so that by 2030 they will be 29% below 1990 levels. This implies that in 2030 Catalonia will be able to emit a maximum of 27.7 million tonnes of CO_{2eq}, 12.7 million tonnes less than the figure emitted in 2021. [22]

Broadly speaking, public policy instruments for reducing GHG emissions can be grouped into three categories:

Table 1. Examples of mitigation policies according to type of instrument

Type of instrument	Examples of mitigation policies
Economic	Carbon taxes, GHG emissions markets (regulated/voluntary), fossil fuel taxes, renewable energy subsidies, tax breaks, direct financial aid, R&D&I financial aid, loan offsets and guarantees.
Regulatory	Standards for energy efficiency, for the use of renewable sources for electricity production, for vehicle emissions, emission levels and composition of biofuels; regulation and bans on certain fluorinated gases, methane regulation and land use controls.
Others	Information programmes, voluntary agreements and commitments, infrastructure investments, public technology procurement policies and corporate emissions reporting initiatives.

Source: derived from data recorded in Shukla et al. (2022).

As shown in Figure 3, GHG emissions occur throughout the economy. Consequently, policies have been implemented to try to reduce emissions in all sectors of the economy and society. Table 2 shows some examples of sectoral policies to combat climate change.

Table 2. Examples of mitigation policies by sector

Source of emissions	Sector	Examples of mitigation policies
Energy consumption	Transport	Taxes on fuel; taxes on nitrogen oxide emissions for commercial aviation; subsidies for the purchase of electric vehicles or electric chargers; public electric charger network; investment in public transport.
	Primary sector	Subsidies for the promotion of agroecology projects; promotion of the use of renewable energies on farms and agricultural holdings.
	Industry	Energy audits; R&D&I funds for innovation in low-emission technologies; obligations on large companies to declare emissions; financial aid for investment in energy efficiency improvements.
	Services	Energy efficiency programmes; sustainability certifications for commercial buildings.
	Residential	Economic incentives for efficient boilers or aerothermal systems, campaigns to promote efficient heating and cooling systems; energy certification system for buildings.
	Electricity generation	Economic incentives for solar panel installation in buildings; support for research; development of smart grid technologies.
Industrial processes	Large industry	Support for replacing fossil fuels with biomass; promotion of low-emission technologies, such as hydrogen steelmaking.
	Use of fluorinated gases	Regulations on the use of fluorinated gases; recycling and recovery programs for refrigerant gases.
Agricultural and livestock activity	Agricultural land management	Crop rotation practices or use of plant covers to improve soil carbon content.
	Manure management	Promotion of the use of composted manure as organic fertilizer; generation of biogas from manure.
	Methane emissions	Promotion of the use of feed additives to reduce methane emissions from ruminants; promotion of diets with lower methane emissions.
Agricultural and livestock activity	Waste management	Door-to-door waste collection; regulations on packaging, waste reduction programs at source; capture and recovery of methane generated in landfills.
	Wastewater treatment	Promotion of the use of more energy-efficient advanced membranes; energy recovery from biogas produced by biosolids in water treatment plants.

Source: Own elaboration.

At the same time, these interventions targeting specific sectors, activities and gases can be combined (in some cases, even replaced) with more cross-sectional and intersectoral policies, such as a CO_2 tax covering several sectors, green public procurement policies that require the

acquisition by all government bodies of products and services with low GHG emissions, and the promotion of a circular economy. These types of policies are important because, on the one hand, they contribute to creating and exploiting synergies between sectors with strong interdependencies and, on the other, they avoid what is known as carbon leakage – that is, a situation in which total emissions are not reduced but are transferred from one sector or activity to another.

For these same reasons, policies that are made locally and nationally must be complemented by policies of a supranational and international dimension, since synergies and carbon leakage do not only arise between activities and sectors within the same country or region. Some examples of supranational policies are: [23]

- Economic instruments: the European Union's emissions trading market, the EU's Carbon Border Adjustment Mechanism (CBAM) and the CORSIA programme to offset CO_2 emissions from international aviation.[6]
- Regulatory instruments: the ban on financing fossil fuels abroad with public resources or the obligation to calculate and report emissions following the criteria established in international guidelines.
- Other instruments: international agreements for the reduction of emissions, such as the Paris Agreement or the United Nations Framework Convention on Climate Change.

So there is a wide range of options for public policies, be it at local, national or international level. However, not all the options are equally effective, or socially desirable. Therefore, in order to ensure that the emissions trajectory followed in Catalonia over the coming years allows us to meet the commitments undertaken – and thus contribute to international GHG reduction targets – it is essential to understand the direct and indirect (as well as intended and unintended) effects of the various instruments, in order to combine the most effective ones appropriately.

4.2 Policies for adapting to climate change

Adaptation to the consequences of climate change is the other pillar of climate policies. Its focus is more local: while the negative impacts of GHG emissions are present worldwide, the direct impact of temperature changes and extreme weather events is felt at a much smaller scale. Climate risks affect specific areas and can have very different impacts on areas that are geographically close to each other.[7] Furthermore, the vulnerability to risks varies depending on

[6] CORSIA: *Carbon Offsetting and Reduction Scheme for International Aviation*.
[7] For example, due to the heat island effect, cities tend to have higher temperatures than nearby, less urbanized areas.

the degree of exposure, but also according to local socio-economic factors, such as the experience acquired or the resilience of local infrastructure.

Adaptation policies aim to reduce vulnerability and increase the resilience of regions, natural systems and socio-economic sectors to the risks caused by the impact of climate change.

A simple way to classify climate change adaptation instruments is to assess the risks faced by the various natural systems and socio-economic sectors:

Environment at risk	Examples of adaptation policies
Terrestrial and marine ecosystems	Measures for restoring natural areas, for preventing the withdrawal of occupied coastal and high-flood risk areas, for reducing the risk of forest fires; land management; reduction of stress on ecosystems and adoption of nature-based solutions.
Water security	Measures for water capture and storage, production of new water (desalination and regeneration) and, above all, efficiency and savings in all areas of consumption.
Food security	Measures for the resilience of agriculture, livestock and fisheries, land planning, improvement of food distribution and storage, reduction of food waste and promotion of changes in diet.
Human health	Measures to rehabilitate basic health infrastructure (air conditioning in homes, access to drinking water, etc.), regulations and standards in the construction and maintenance of buildings, measures to access healthcare, disaster detection and warning systems, creation of climate shelters in cities.
Standard of living and equity	Measures to strengthen social security policies, insurance and compensation mechanisms and diversification of economic activities.

Source: derived from data recorded in Shukla et al. (2022) [24].

Given that the various risks are strongly interconnected, adaptation policies can help to mitigate multiple risks at the same time – for example, the promotion and conservation of green spaces in cities contributes to improving air quality, reducing urban heat islands and increasing resilience against floods, as it allows for better management of rainwater. However, policies may also reduce risks in one area while worsening them in others – for example, the construction of dikes and walls can help protect urban areas against flooding, but at the same time may alter river ecosystems, reduce biodiversity and worsen conditions downstream, thereby increasing the risk of flooding in other unprotected areas. Therefore, a comprehensive approach to adaptation strategies is needed that takes these synergies and interdependencies into account.

Finally, as in the case of mitigation policies, cooperation between territories is also necessary in the field of adaptation, especially in areas in which the interdependence between urban and rural areas is particularly strong and in those where the impacts have cross-border repercussions, such as, for example, the health of the oceans or the migratory crises caused by climate change.

4.3 The relation between mitigation and adaptation policies

The distinction between mitigation and adaptation policies is useful in thinking about what needs to be done to avoid climate change, on the one hand, and to adapt to its effects, on the other. However, it is important to realize that the two types of policies are strongly interrelated and are framed within a common objective: namely, sustainable development, understood as the capacity of today's societies to meet their present needs without compromising the capacity of future generations to meet theirs. [25] Therefore, mitigation and adaptation policies, together, must make it possible to reduce GHG emissions in such a way that this reduction is compatible with the well-being of current and future generations.

In this context, **the better the mitigation policies that are implemented** in the short and medium term, the less the global temperature will increase in the coming decades and, therefore, the less adverse the effects of climate change will be for future generations. If this is achieved, **the need to implement adaptation policies in the future will be less urgent**.

At the same time, in addition to affecting the well-being of future generations through the containment of the increase in planetary temperature, **mitigation policies also have direct implications for the well-being of those alive today**. These implications may be either positive or negative. For instance, climate change mitigation measures also have benefits in terms of adaptation; for example, thermal rehabilitation of residential buildings helps to cut down the energy consumption of households (and, therefore, GHG emissions) and at the same time helps them to cope with extreme weather episodes caused by climate change. In contrast, mitigation measures that seek to reduce household energy consumption by increasing energy prices may make it impossible for the most vulnerable households to keep their homes at an adequate temperature during these extreme weather events, thereby reducing both their adaptive capacity and their well-being.

Finally, adaptation policies are not neutral in terms of mitigation, as different policies have different consequences on the concentration of CO_2 in the atmosphere. For example, adaptation measures such as the construction of seawalls to protect coastal areas from rising sea levels and storms contribute to aggravating climate change in the long term, as the construction of these infrastructures often involves the intensive use of cement, a material that emits a large amount of CO_2 in its manufacturing process. For their part, policies such as reforestation or the restoration of natural habitats, in addition to helping to address problems of soil erosion, loss of diversity and rising temperatures, also contribute to reducing the concentration of GHGs in the atmosphere through the capture of carbon dioxide; thus, they help to stop the planet's temperature increasing further.

In conclusion, there is a clear need for a comprehensive approach that addresses the two objectives – reducing emissions and preserving the well-being of the population – in a parallel and simultaneous way, taking into account both the impact that mitigation efforts have on the

well-being of the population and the costs in terms of GHG emissions of policies aimed at preserving this well-being.

5. The project “What works against climate change”?

The project “What works against climate change?” is promoted by *Ivàlua*, the Department of Economy and Finance, the Department of Territory, Housing and Ecological Transition of the *Generalitat* (the Catalan government)and the College of Environmental Scientists of Catalonia. The project aims to contribute to the design and implementation in our country of the best policies for fighting climate change, or for adapting to its consequences. It does so by using the most rigorous scientific evidence available regarding the effectiveness (and cost-effectiveness) of interventions, in order to steer Catalonia towards the adoption of evidence-informed climate policies.

This approach promotes the design of public strategies based on rigorous scientific knowledge. This does not imply that political decisions are based exclusively on evidence, but that evidence is made available to decision-making bodies for use in the design and implementation of solutions for the different social problems and challenges they face.

Scientific evidence demonstrating the scale of climate change and its consequences has pushed this issue to the top of government agendas. However, it is rare to find governments (among them, the Catalan government) applying the existing evidence on the effectiveness of current policies and interventions to the design of mitigation and adaptation strategies for reducing emissions. It is precisely this situation that the project “What works against climate change?” seeks to address in Catalonia.

In search of solid scientific evidence able to guide the design of successful policies for climate change mitigation and adaptation, this project will review the existing academic literature on the effectiveness of different public policy instruments aimed at dealing with the environmental challenges facing Catalonia today. For example, the types of questions this project aims to answer could include: What measures are effective in reducing household energy consumption, and in reducing the carbon intensity of this consumption? How can we promote more sustainable mobility? What are the most effective ways of making the primary sector more resilient to drought, or of preventing the adverse health effects caused by heat waves? In practice, the selection of topics to be explored in our reviews will depend on the knowledge areas that the agents involved in the project need to reinforce and on the availability of rigorous evidence.

The literature reviews will be carried out applying the “What Works?” methodology, a movement which began in England in the 1990s in the field of health and which, over the past few decades, has gained prominence and has spread to other countries and areas of study. Basically, the

"What Works?" perspective seeks to draw conclusions about the effectiveness of different interventions (i.e., policies, programmes, regulations, services, etc.) through the systematic review of academic studies that provide causal and rigorous evidence on the capacity of these interventions to achieve the objectives set for them. This implies that the "What works?" approach only includes studies and impact evaluations that use solid methodologies and are capable of establishing causal relationships between the interventions studied and changes in the variables of interest: that is to say, studies that use robust experimental or quasi-experimental methods.[8] In this regard, it is important to recognize that the current body of evidence on the effectiveness of climate policies is far from exhaustive; it is limited to the subset of instruments that have been implemented so far and have been evaluated using rigorous techniques, and so it does not include policies that have not yet been put into practice. It is also biased towards the interventions that are easiest to evaluate.

In the case of "What works against climate change?", the extra criteria listed below will also be applied to the selection of the studies to be included in the evidence reviews:

1. Systematic reviews will be prioritized, because these are the studies that provide the best balance between robustness and bias. However, in their absence, or if only a few are available, evaluations or primary studies will also be included.

2. When the existing evidence comes from other countries, studies carried out in contexts similar to ours in Catalonia will be prioritized.

3. Regarding the type of policies, programmes, and interventions for climate change mitigation and adaptation, priority will be given to the ones that aim to promote pro-environmental behaviour among the various economic agents, above all households, companies and government institutions.

4. Since the objective is to improve climate change mitigation and adaptation policies in Catalonia, priority will be given to those interventions that are best suited to specific regional or local needs in the areas where the Catalan government has jurisdiction.[9]

Turning now to the ways in which the effectiveness of climate policies will be measured, three types of indicators will be applied in the case of **mitigation policies**: [26]

- **Attitudinal and behavioural** indicators, i.e., those that measure changes in levels of awareness, attitudes towards climate change and the adoption of pro-environmental behaviours, such as the installation of energy-efficient technologies, modifications in diet or mode of transport, etc.

[8] For more information on the "Què funciona?/What works?" philosophy, see https://ivalua.cat/ca/que-funciona
[9] For example, this means that climate policies such as emissions trading schemes, which are currently being implemented at European level and which require a significant level of international coordination to be effective, fall outside the scope of this project.

- **Environmental** indicators, i.e., those that measure changes in GHG emissions either directly or indirectly through changes in the activities that generate emissions: energy consumption, use of fossil fuels, waste generation, etc.

- **Socio-economic** indicators (when available): i.e., those related to the well-being of the population; for example, monetary savings, prices of goods, health status or subjective well-being.

In the case of **adaptation policies**, the indicators vary significantly depending on the sector and type of intervention. However, they can be generically classified into four types: [27]

- **Vulnerability to climate impacts and risks**: for example, indicators that measure the extent of the impacts of climate change on the population, such as the volume of the population affected by extreme climate episodes, the effects on population health, and the levels of food insecurity.

- **Adaptive capacity**, i.e., indicators that measure changes in the capacity of the different social agents to make proactive and informed decisions in order to adapt to changing conditions, such as the possession of the knowledge and skills needed for adaptation or for access to credit.

- **Adoption**, i.e., indicators that measure the adoption of adaptation solutions, such as changes in the type of crops, the installation of less intensive technologies in terms of water consumption, the construction of protection infrastructures, and so on.

- **Resilience of natural, socio-economic and institutional systems**, i.e., indicators that measure systemic changes in the physical, socio-economic and institutional environment which enable better and more lasting adaptation, such as public policies or regulations promoted by governments, or the extension of protected natural areas or social capital.

In practice, however, each review will include information on the impact of policies in the areas explored in the studies analysed.

In terms of content, the reviews will not be limited to summarizing what is known about the policies or interventions that work best, but will also highlight what we know about the sections of society in which they are most effective, in what circumstances, and how their costs and benefits are distributed across dimensions such as gender, income level, or geographical area. The synthesis will also address issues more closely related to the design and implementation of policies, including aspects such as the ability of these policies to reach the segments of society they are intended to target. All the reviews will contain a final section in which the conclusions drawn from the international evidence will be extrapolated to the Catalan context, with the help of a group of experts in environmental policies linked to government bodies, the third sector, and the university environment in Catalonia.

In short, the aim of the project “What works against climate change?” is to distil the existing scientific evidence on the most effective policies and interventions in order to make recommendations regarding the climate policies that are likely to be best suited to the Catalan context, and what characteristics they should have in order to be effective. The project also aims to bring this evidence into the debate on the design of climate policies in Catalonia, using a format that combines scientific rigour, accessibility, and relevance to the climate challenges the region faces today.

6. References

[1] Centre d'Estudis d'Opinió. (2024). *Baròmetre d'Opinio Política (BOP). 1a onada 2024.*

[2] Calvin, Katherine; Dasgupta, Dipak; Krinner, Gerhard; Mukherji, Aditi; Thorne, Peter W.; Trisos, Christopher; Romero, José; Aldunce, Paulina; Barrett, Ko; Blanco, Gabriel; Cheung, William W.L.; Connors, Sarah; Denton, Fatima; Diongue-Niang, Aïda; Dodman, David; Garschagen, Matthias; Geden, Oliver; Hayward, Bronwyn; Jones, Christopher; … Péan, Clotilde. (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change (IPCC).

[3] Richardson, Katherine; Steffen, Will; Lucht, Wolfgang; Bendtsen, Jørgen; Cornell, Sarah E.; Donges, Jonathan F.; Drüke, Markus; Fetzer, Ingo; Bala, Govindasamy; von Bloh, Werner; Feulner, Georg; Fiedler, Stephanie; Gerten, Dieter; Gleeson, Tom; Hofmann, Matthias; Huiskamp, Willem; Kummu, Matti; Mohan, Chinchu; Nogués-Bravo, David; … Rockström, Johan. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, *9*(37).

[4] Generalitat de Catalunya i Institut d'Estudis Catalans. (2016). *Tercer informe sobre el canvi climàtic a Catalunya*.

[5] Servei Meteorològic de Catalunya. (2022). *Butlletí anual d'indicadors climàtics*. https://www.meteo.cat/wpweb/climatologia/butlletins-i-episodis-meteorologics/butlleti-anual-dindicadors-climatics/

[6] Levin, Kelly; Cashore, Benjamin; Bernstein, Steven i Auld, Graeme. (2012). Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences*, *45*(2), 123-152.

[7] *Policy Instruments for the Environment Database—OECD*. (s.d.). Downloaded 20 September 2023, from https://www.oecd.org/environment/indicators-modelling-outlooks/policy-instruments-for-environment-database/

[8] Climate Action Tracker. (2023). *The CAT Thermometer*. https://climateactiontracker.org/global/cat-thermometer/

[9] Jones et al. (2023) [original data] – Obtained from *Our World in Data*. "Annual greenhouse gas emissions in CO_2 equivalents" [data set]: https://ourworldindata.org/greenhouse-gas-emissions.

[10] Friedlingstein et al. (2023) – Global Carbon Project, "Global Carbon Budget" [original data] – Obtained from *Our World in Data*. "Cumulative CO_2 emissions – GCB" [conjunt de dades].

[11] Global Carbon Project, "Per capita CO_2 emissions" [original data]. – Obtained from *Our World in Data* [data set].

[12] Ritchie, Hannah. (2021). Many countries have decoupled economic growth from CO2 emissions, even if we take offshored production into account. *Our World in Data*. https://ourworldindata.org/co2-gdp-decoupling

[13] Ritchie, Hannah. (2019). Who emits the most CO2 today? *Our World in Data*. https://ourworldindata.org/annual-co2-emissions

[14] *Emissions de GEH a Catalunya | Dades obertes de Catalunya*. (s.d.). Downloaded 23 May 2024, from https://analisi.transparenciacatalunya.cat/Medi-Ambient/Emissions-de-GEH-a-Catalunya/7xn6-46kz/about_data

[15] European Environment Agency. (2024). *European Climate Risk Assessment. EEA Report 01/2024* [Publication]. https://www.eea.europa.eu/publications/european-climate-risk-assessment

[16] European Environment Agency. (2023, 29 June). *Global and European temperatures*. https://www.eea.europa.eu/en/analysis/indicators/global-and-european-temperatures

[17] Departament d'Acció Climàtica, Alimentació i Agenda Rural. (2023). *Marc Estratègic de Referència d'Adaptació al Canvi Climàtic per a l'horitzó 2030 (ESCACC30). Resum executiu*.

[18] Indicador del Planeta Viu a Catalunya 2024. Observatori del Patrimoni Natural i la Biodiversitat. Consultat el 17/02/2025 de: https://observatorinatura.cat/trends/home/lpi_cat/

[19] *SSP Database*. (s.d.). Consulted16 May 2024: https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=40

[20] United Nations Frameworkd Convention on Climate Change. (2015). *Paris Agreement*. https://unfccc.int/es/acerca-de-las-ndc/el-acuerdo-de-paris

[21] UNEP. (2023). *Emissions Gap Report 2023*. https://www.unep.org/resources/emissions-gap-report-2023

[22] Oficina Catalana del Canvi Climàtic. (2023). *Estimació de la contribució mínima de Catalunya a l'objectiu de reducció d'emissions de gasos amb efecte d'hivernacle a la UE per a 2030*. https://canviclimatic.gencat.cat/web/.content/03_AMBITS/mitigacio/INDC/Estimacio-objectiu-GEH-2030-Catalunya_Nov23_f.pdf

[23] Nachtigall, Daniel; Lutz, Luisa; Cárdenas Rodríguez, Miguel; D'Arcangelo, Filippo Maria; Haščič, Ivan; Kruse, Tobias i Pizarro, Rodrigo. (2024). The Climate Actions and Policies Measurement Framework: A Database to Monitor and Assess Countries' Mitigation Action. *Environmental and Resource Economics*, *87*(1), 191-217.

[24] Shukla, P. R., Skea, J., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., & Malley, J. (Ed.). (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.*

[25] United Nations. (1987). *Report of the World Commission on Environment and Development*. https://digitallibrary.un.org/record/139811

[26] International Initiative for Impact Evaluation. (2020). *Evidence Gap Map on Energy Efficiency*. https://gapmaps.3ieimpact.org/evidence-maps/energy-efficiency-egm

[27] Doswald, Nathalie; Sánchez Torrente, Luis; Reumann, Andreas; Leppert, Gerald; Moull, Kevin; Rocío Pérez, Jerónimo José; Köngeter, Alexandra; Fernández de Velasco, Guido; Harten, Sven i Puri, Jyotsna. (2020). *Evidence Gap and Intervention Heat Maps of Climate Change Adaptation in Low- and Middle-Income Countries* (Vol. 02/2020). Deutsches Evaluierungsinstitut der Entwicklungszusammenarbeit (DEval).

Què funciona contra el canvi climàtic?

Què funciona contra el canvi climàtic?

Evidence synthesis and knowledge transfer project to improve climate change mitigation and adaptation policies.

A project by:

ivàlua
Institut Català d'Avaluació de Polítiques Públiques

Generalitat de Catalunya

COAMB
Col·legi d'Ambientòlegs de Catalunya

Què funciona?