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Sustainability and Climate Change: From Climate Migration to Education

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ABSTRACT: The manuscript explores climate change from various perspectives, including data analysis, modelling human displacement due to natural hazards, flood and global temperature modelling, and tracking the evolution of energy use and CO_2 emissions by source. Additionally, surveys of young Spaniards on Sustainable Development Goals (SDGs) reveal a gap between their awareness of climate change and actual behavioural changes. The study also examines the current SDG landscape across Europe and discusses various adaptation and resilience strategies.

KEYWORDS: Climate change, Climate migrations, Flood and climate modelling, Sustainability, Adaptation and Resilience.

1. INTRODUCTION

In an outstanding recent publication entitled “The 2024 state of the climate report: Perilous times on planet Earth”, Ripple, et al. (2024) expressed their concern about the undeniable global emergency being at the edge of an irreversible climate catastrophe. As authors refer, the very foundations of life on Earth are at risk as one enters a critical and unpredictable stage of the climate crisis despite the continuous warries of thousands of experts on rising greenhouse gas emissions and ecosystem disruption (Ripple et al. 2020) and the global warming which was predicted decades ago, not only by independent researchers but also by fossil fuel companies (Supran et al. 2023). Fossil fuel emissions have reached record highs, in July 2024 was recorded the three hottest days ever (Guterres 2024), and current policies predict of approximately 2.7°C of peak warming by 2100 (UNEP 2023). As the authors alarm, the devastating consequences of climate change are no longer hypothetical and they are bringing unprecedented disasters (Ripple, et al. 2024).

Actually, based on the daily sea surface temperature, recorded by the Climate Change Institute, University of Maine, show a clear rise of the temperature in the last decade with a pronounced maximum for 2024 (Fig.1 left-up) (ClimateAnalyzer1 2024). This phenomenon is observed as well in the case of daily surface air temperature (Fig. 1 right-up) (ClimateAnalyzer2 2024), accompanied by a decrease of the daily sea ice extent (Fig. 1 left-down) ClimateAnalyzer3 2024) and rise of the Mediterranean sea surface temperature (Fig. 1 right-down) (CEAM 2024).

Ocean temperatures have been rising due to global warming, and this trend is particularly noticeable in the Mediterranean Sea. Both the SOCIB ocean temperature data (SOCIB 2024) and the Copernicus Mediterranean Sea Surface Temperature trends (Copernicus 2024) indicate a consistent increase in sea surface temperatures in recent decades. Warmer ocean waters provide additional moisture to the atmosphere, which can fuel intense weather amplifying rainfall and storm severity.

The daily sea surface temperature time series for a specific sub-region, show data from 2024, the previous three years, and the climatological average for 1982–2015. An important gap between the mean temperature corresponding to these time series and the temperature for 2024 is clearly seen. Marine heat spikes for the current year are marked, occurring when temperatures surpass the 90th percentile of the climatological baseline (Fig. 1).

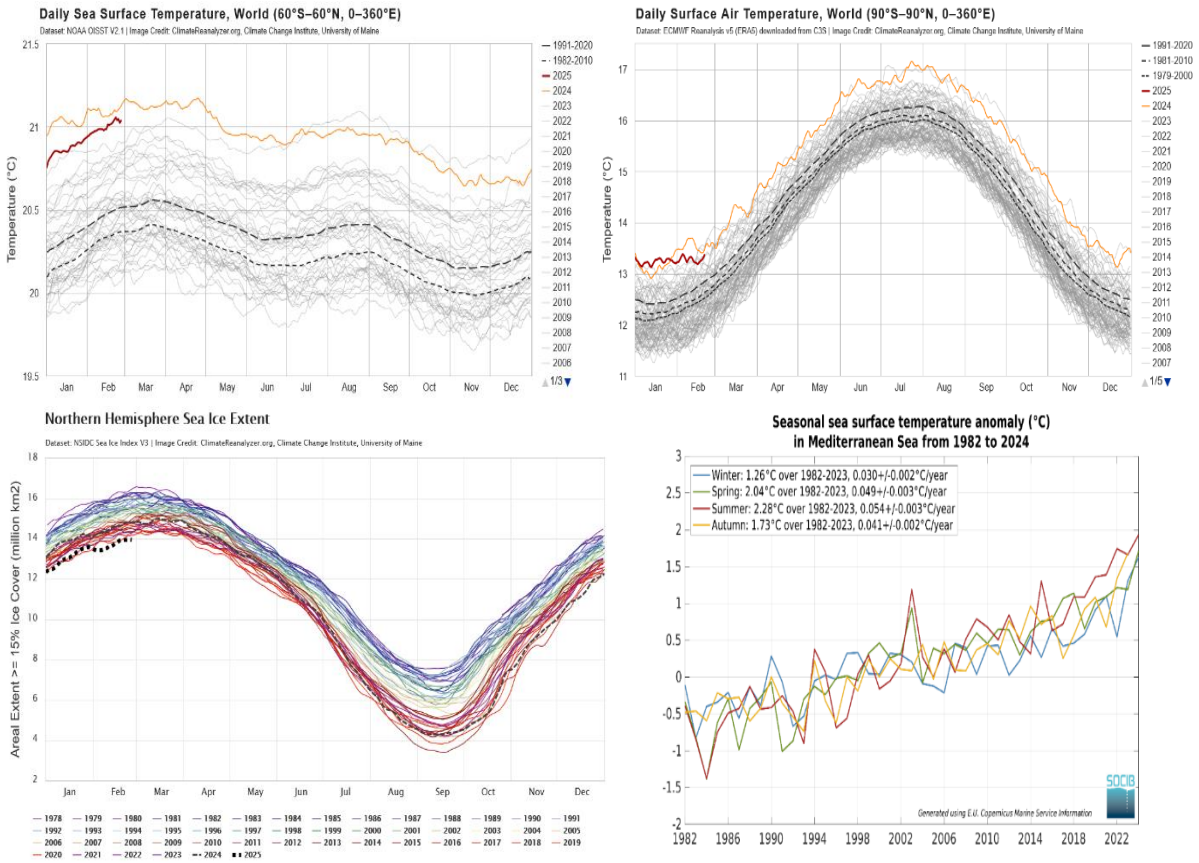

Figure. 1. Daily sea surface temperature (left-up), daily surface air temperature (right-up), daily sea ice (left-down), Mediterranean Sea surface temperature (right-down). Sources: ClimateAnalyzer 2024 and CEAM 2024.

Climate change heightens the risk of displacement and deepens the vulnerabilities of those affected. According to the latest IPCC (2023) report, climate change acts as a risk multiplier, compounding existing challenges and making populations more susceptible to displacement. It contributes to food and water insecurity, loss of livelihoods, territorial erosion, and environmental degradation. These impacts can lead to resource competition, cultural and community strain, and broader socio-economic hardships, often forcing people to leave their homes. In some cases, displacement may even trigger social unrest and destabilize governments. The risks are particularly severe in regions where climate disasters and conflicts intersect, creating compounded vulnerabilities for affected communities.

Displacement is also a significant driver of loss and damage, as it creates and sustains vulnerabilities that extend beyond those directly affected. It impacts not only displaced individuals but also host communities, those left behind, and sometimes even the broader economy. Displacement disrupts livelihoods, making it harder for internally displaced persons (IDPs) to earn income, pay rent, or contribute to taxes. Additionally, it increases demand for housing, healthcare, education, and protection services, further straining resources and social systems (WB 2023, IDMC 2024).

A warming climate is expected to affect access to essential resources like freshwater, food security, and energy. At the same time, global efforts to address climate change through adaptation and mitigation will shape development priorities. The connection between climate change and sustainable development is significant, with poorer and developing nations—especially the least developed—being the most vulnerable to its economic, social, and environmental impacts.

The 2030 Agenda for Sustainable Development reaffirms the commitment of Member States to protecting the planet and addressing climate change urgently. It describes climate change as “one of the greatest challenges of our time” and warns that its negative effects threaten global progress toward sustainable development. Rising temperatures, sea level increases, ocean acidification, and other climate-related impacts are particularly harmful to coastal areas, low-lying nations, least developed countries, and Small Island Developing States.

Sustainable Development Goal (SDG) 13 calls for urgent action to combat climate change and its effects while recognizing the UN Framework Convention on Climate Change (UNFCCC) as the main global platform for coordinating responses. Its specific targets emphasize integrating climate policies into national strategies, enhancing education and awareness, and strengthening institutions for mitigation, adaptation, impact reduction, and early warning systems. Additionally, SDG 13 includes commitments to fulfilling UNFCCC obligations and promoting mechanisms that boost climate planning and management capacity, particularly in least developed countries and Small Island Developing States (SDGS 2025).

The paper is organised as follows: In Section 2 the Methodology used in this paper is explained. Section 3 is devoted to the obtained results discussing the climate simulations and people's displacements (3.1), Flood simulation (3.2), EN-Road simulations (3.3) and results from interviews and surveys with young people on themes of climate change and sustainability (3.4). Section 4 is devoted to aspects of the European Sustainable Development and Section 5 to problems such as Adaptation and Resilience. Finally in Section 6 we present our discussions and conclusions.

2. METHODOLOGY

This paper employs a complex methodology that integrates both quantitative and qualitative approaches. It combines statistical analysis of data from various official sources and publications with proprietary simulations, modelling, and surveys conducted among young people worldwide and in Spain.

The section on the physical basis of climate change relies on meteorological and physical data on sea temperature and sea ice over recent decades. This data was obtained from the Climate Change Institute at the University of Maine (ClimateAnalyzer 2024), the Balearic Islands Coastal Observing and Forecasting System (CEAM 2024), and the Copernicus archives (Copernicus 2024).

The evaluation of the migration due to climate reasons is based on different methods combining statistical analysis of data from several official primary and secondary sources. As primary data sources one can cite the national authorities which gather information on displacement and evacuations related to disasters by collecting data at national, sub-national, and local levels such as Brazil's Integrated Disaster Information System, the Philippines' Disaster Response Operations Monitoring and Information Centre database, Uruguay's MIRA database, etc. Additionally, international and national humanitarian organizations, including NGOs and UN agencies, involved in relief efforts gather data to address the needs of affected communities, offering localized information on disaster-related displacement. One such tool is IOM's Displacement Tracking Matrix. On the other hand, the Pacific Climate Change Migration and Human Security programme, in collaboration with the Platform on Disaster Displacement offered particularly information on issues related to climate change and disaster-induced migration, displacement, and planned relocation.

Secondary data sources are given by the Internal Displacement Monitoring Centre, which has been collecting data on internal displacement caused by disasters worldwide through its online Global Internal Displacement Database. One can also cite the CLIMIG database, which includes both qualitative and quantitative studies on environmental migration as well as the Environmental Migration Portal by IOM features, which is a searchable research database (MDP 2024a, b).

A comprehensive set of future global projections has been developed, focusing on climate hazards affecting human mobility, including heatwaves, droughts, wildfires, and river floods. These projections are based on the methodology and analysis of Lange et al. (2020) and are derived from multiple climate impact models, each simulating specific weather-related physical processes.

Simulations have been presented and analysed, primarily related to climate change. These include the Flood simulator (FloodSim 2025) for assessing the impact of sea level rise as well as the En-Roads simulator (EnRoads 2025) for projecting energy use and CO_2 emissions. Additionally, extensive surveys with Spanish youth were analysed, including a dedicated study conducted by the authors in the Madrid region.

The analysis of European sustainable development was conducted and visualized using Datawrapper software and the Sustainable Development Goal Index (Lafortune and Fuller 2025). The section on adaptation and resilience processes is based on studies of wildlife and ecosystems (Adaptation 2024) and computational science methods (Gue et al. 2020; Han and Wang 2021).

3. RESULTS

3.1. Climate simulations and people's displacements

As early as 1990, the Intergovernmental Panel on Climate Change (IPCC) observed that climate change could have its most significant impact on human migration. In the mid-1990s, it was widely reported that up to 25 million people had been forced to leave their homes and land due to severe environmental pressures such as pollution, land degradation, droughts, and natural disasters **(**Brown, 2008**).**

According to the above mentioned analysis **(**Brown, 2008), by 2099, the global temperature is projected to rise by an average of 1.8ºC to 4ºC. Large regions are anticipated to become drier, with the percentage of land in constant drought expected to rise from 2 to 10% by 2050. Additionally, the area experiencing extreme drought is forecasted to increase up to 30% by the end of the 21st century. Rainfall patterns will alter as the hydrological cycle intensifies, leading to more frequent heavy rains in some areas, which will wash away topsoil and cause flooding. Altered rainfall patterns and a more intense hydrological cycle imply that extreme weather events like droughts, storms, and floods will become more frequent and severe. The South Asian monsoon is projected to intensify, with eastern India and Bangladesh receiving up to 20% more rain by 2050. Regions at low to mid-latitudes are expected to receive less rainfall. Sub-Saharan Africa, for example, is predicted to experience up to a 10% decrease in annual rainfall by 2050 (Brown 2008).

To assess the magnitude of the problem, we conducted various simulations using different models and simulators (MDP 2024a, b). The key results focus on sustainability trends under low and high warming scenarios, examining population exposure to heatwaves, droughts, wildfires, and river floods throughout the 21st century (Fig. 2). Both scenarios show an increasing trend until 2050. After

this point, population exposure continues to rise significantly under the high warming scenario, except for wildfires (Fig. 2, bottom left). In contrast, under the low warming scenario, exposure trends begin to decline after 2050 (blue bars).

Figure. 2. Representation of the people exposed in heat waves (left-up), drought (right-up), wildfire (left-down) and river flood (right-down) in the case of low (blue colour) and high (grey colour) warming scenarios. Source (MDP 2024a, b).

The estimation of environmental migration and displacement is a very complex task. The quantitative data on population, based on a recently introduced tools called Displacement Tracking Matrix (DTM) within countries and across borders due to natural hazards could be very useful for such analysis. However, for movements caused by slow-onset environmental processes, like drought or sea-level rise, most data are qualitative and based on individual case studies, with few comparative studies.

The evolution of internal displacement persons (IDPs) due to disasters during the period 2014-2023 has been recorded due to several reasons. In the following Figure 3, the IDPs due to natural weather-related and geophysical hazards during the period 2014-2023 are represented, where the rising trend due to these phenomena is observed (MDP 2024a, b).

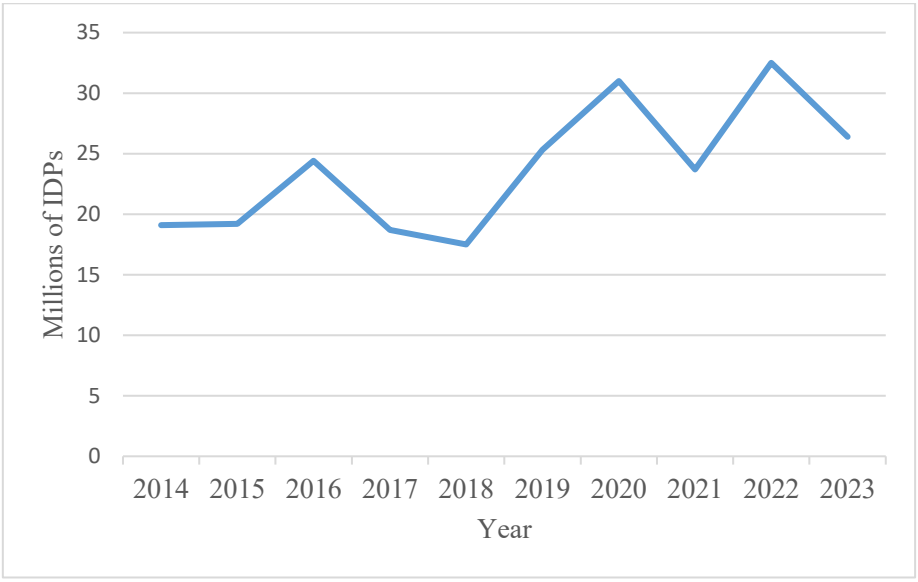

Figure 3. IDPs in millions due to weather-related and geophysical hazards, 2014-2023. Source (MDP 2024a, b).

The displacements for the same period, given by continents and represented in Figure 4, show that Asia experiences the highest number of displacements followed by Africa and the Americas (MDP 2024a, b).

The IDP's due to hazards are represented in Figure 5 (MDP 2024a). It is clearly seen an ascending trend of the flood hazards, while the highest number of IDPs due to storm hazards has been observed in 2020.

It must be noticed that the average annual weather-related displacements in millions for the period 2012-2021 indicate that East Asia and Pacific and Southern Asia lead in numbers **(**Beyer and Milan 2022, IOM 2022).

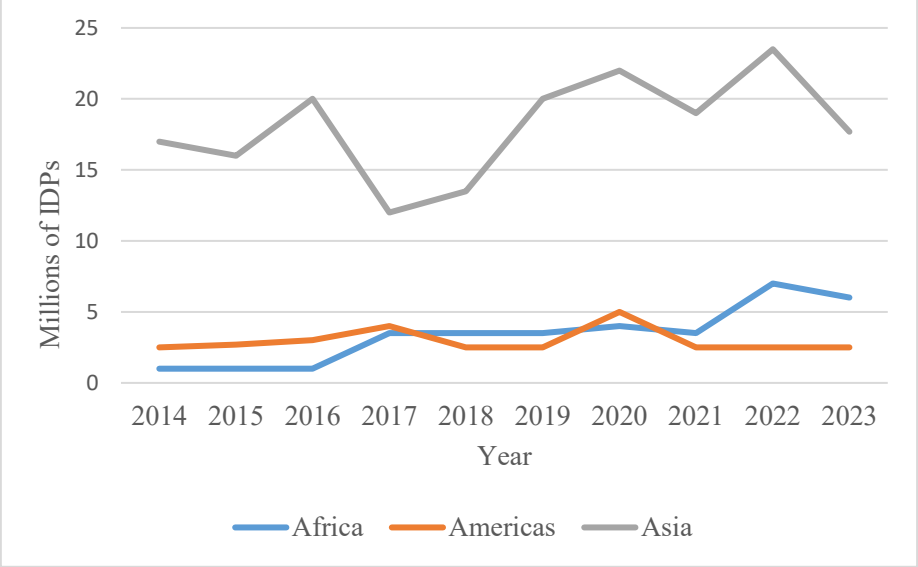

Figure 4. IDPs due to disasters by continent during the period 2014-2023. Source (MDP 2024a, b).

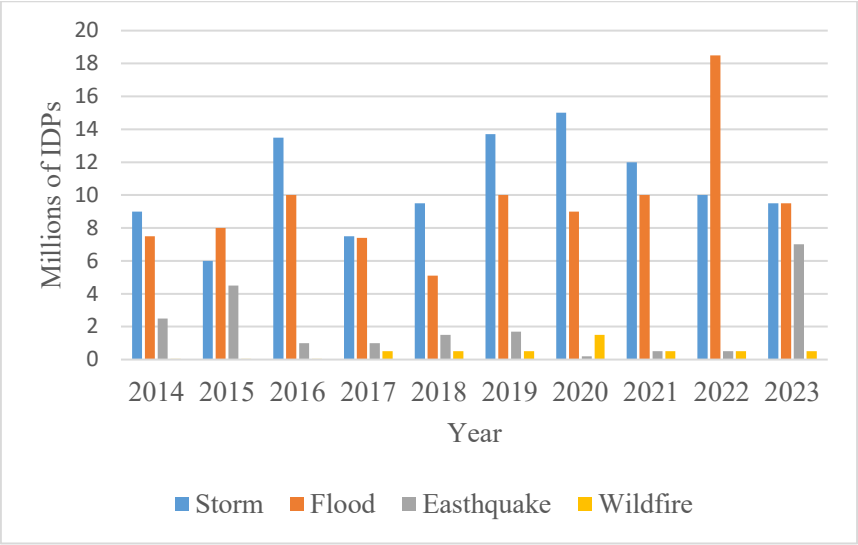

Figure 5. IDPs due to disasters by hazard during 2014-2023.Source (MDP 2024a, b).

3.2. Flood simulator

To understand the consequences of climate change on daily life, we conducted simulations using the Flood Simulator (FloodSim 2025). This new tool helps in flood risk assessment, management, and control by providing flood alerts and warnings when water levels rise at specific locations. It can map floodplains and flood lines for rivers and streams, as well as visualize the impacts of sea level rise due to global warming and climate change.

The simulation was conducted for a specific European region known for its flooding issues—The Netherlands. We simulated two scenarios: one with a water level of meters above sea level (Fig. 6, left) and another with a flood level of 2.5 meters above sea level (Fig. 6, right), which is expected to occur in year 2100 according to models projections (Sweet et al. 2917). As shown, both scenarios result in extensive flooding, requiring the relocation of millions of people and thousands of industries.

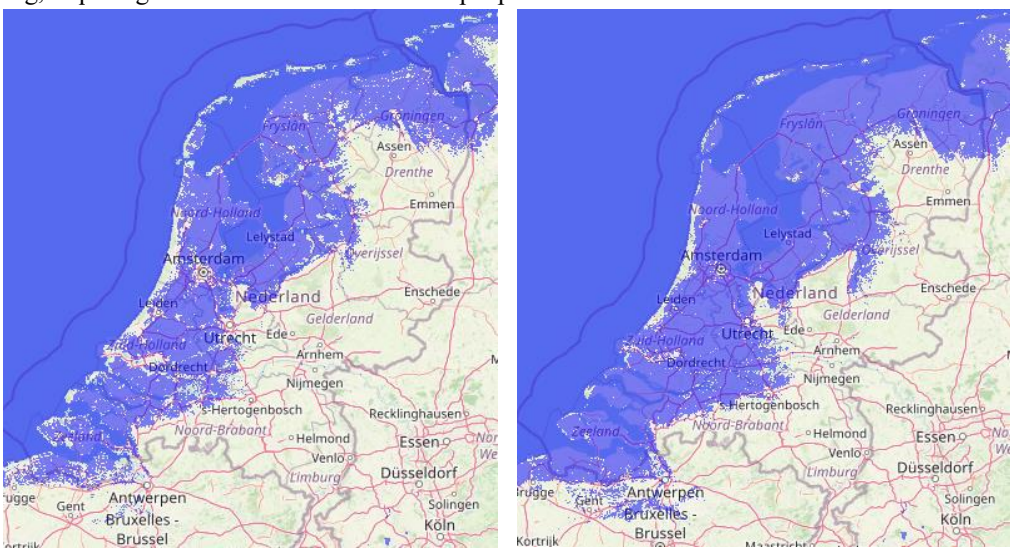

Figure 6. Results from the flood simulation in the case of Netherlands. 0 m high water (left) and 2.5 m high water (right). Results obtained with the Flood simulator (FloodSim 2025).

3.3. En-Roads simulator

Next, we used the World Climate simulator, which combines role-playing with interactive, science-based computer models to highlight the urgency of climate change issues. This approach integrates an engaging experience with interactive exploration of climate science through the En-Roads climate simulation model (Varga et al. 2021, EnRoads 2025). Our goal was to forecast the evolution of energy consumption and CO_2 emissions throughout the century. The results, shown in the following figures, illustrate the projected use of different energy sources over the decades until 2090 (Fig. 7) and the CO_2 emissions in gigatonnes per year during this period (Fig. 8). The data clearly indicates an increasing reliance on gas and renewables, alongside a decline in coal and oil use. Bioenergy and nuclear energy are expected to maintain relatively stable trends in the coming decades.

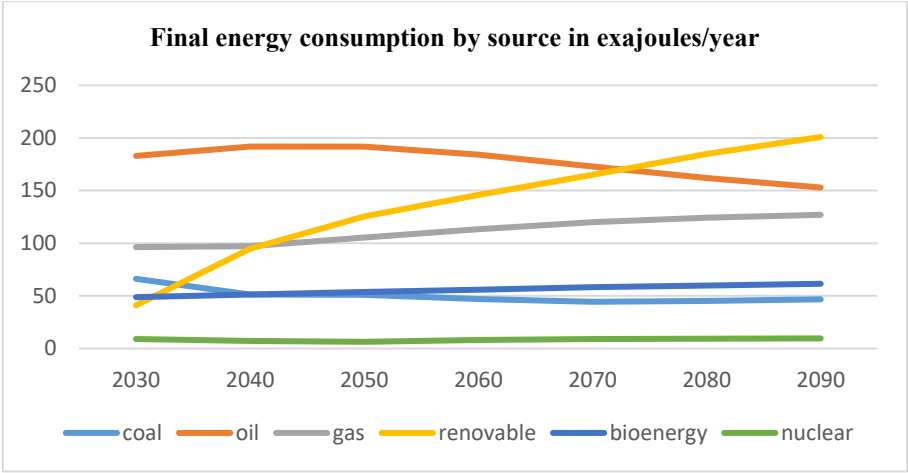

Figure 7. Final energy consumption by source from 2030 until 2090. Source EnRoads 2025.

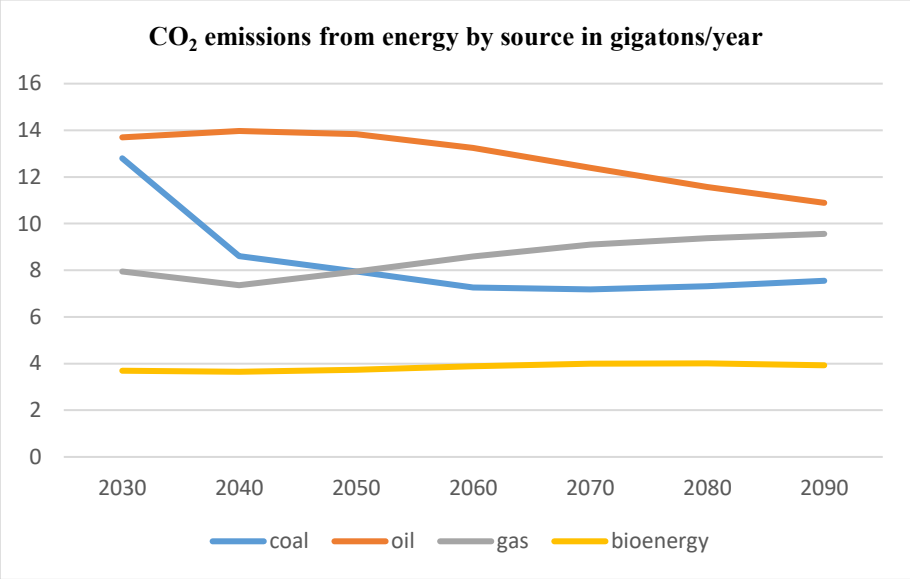

Figure 8. CO_2 emissions by source from 2030 until 2090. Source EnRoads 2025.

3.4. Interviews with young people

3.4.1. The world's largest survey on climate change

The *Peoples' Climate Vote 2024*, the world's largest independent public opinion survey on climate change, reveals that people across the globe are feeling its effects more intensely. The survey, which represents 87% of the global population, shows that climate change is a widespread concern. Worldwide, 56% of respondents think about it on a daily or weekly basis. Furthermore, 53% of people are more concerned about climate change now than they were a year ago, likely due to the growing number of climate-related events they have witnessed or heard about. In fact, 43% believe extreme weather has worsened compared to the previous year. Additionally, nearly 78% of people support stronger protections for those most vulnerable to extreme weather conditions (UNDP 2024).

The survey shows that a significant majority, 80% of people worldwide, want their countries to take stronger action on climate change. Additionally, 86% believe nations should set aside geopolitical disputes, such as trade and security issues, to collaborate on tackling the crisis. There is a strong public demand for government leadership, with 89% calling for increased climate action from their governments. However, confidence in big businesses is much lower, as only 39% feel they are effectively addressing climate change. Finally, 79% of people support climate justice, believing that wealthy nations should provide more assistance to poorer countries in addressing climate change and its effects.

3.4.2. Surveys with Spanish young people

A report by the Reina Sofía Center on Adolescence and Youth reveals that 86.8% of young people in Spain express a high level of concern for the environment, influenced by direct experiences with extreme phenomena such as heat waves and fires. (SpanishSurvey1 2024). According to the Deloitte Global Survey 2024 of Millennials and Generation Z, sustainability is one of the main concerns for 62% of Generation Z and 59% of millennials in Spain. (SpanishSurvey2 2024).

However, despite their concern, 95% of young Spaniards consider it difficult to adopt a sustainable lifestyle, due to obstacles such as lack of resources or institutional support. Furthermore, 72% of young people believe that they are incapable of abandoning their consumerist lifestyle to stop the ecological disaster (El Pais 2024).

Despite the challenges, half of teenagers (53%) say they would be willing to produce less waste, 66% of young Spaniards would be willing to pay more for food produced sustainably and locally. 83% of young Spaniards consider the sustainability strategy of potential employers to be an important factor when looking for work, which indicates an expectation of environmental commitment on the part of companies. In addition, 74% are in favor of stricter government measures to enforce changes in personal behavior in order to tackle climate change. (SpanishSost 2024).

3.4.3. Survey with Spanish university students

In May 2022, the Sustainability Group of the Faculty of Physical Sciences at the University Complutense of Madrid (UCM) conducted a survey on climate change and the environment. The survey aimed to assess public perceptions and attitudes towards critical issues. According to the results, A significant majority of respondents expressed high awareness and concern about climate change (92%). 79% responded that they the protection of the environment degradation is very important. Many participants reported adopting more sustainable practices in their daily lives, such as reducing waste (86,7%), conserving energy (80.5%), and supporting eco-friendly products (55%). Finally, respondents indicated a strong desire for increased action from governments and educational institutions (84%) to address environmental challenges (SurveyUCM 2022).

3.4.4. Survey with secondary students of a Madrid's municipality

A similar survey was conducted by the authors with 50 Spanish students from two secondary schools in a municipality in the Madrid region. The participants' ages ranged from 12 to 16 years. Regarding their awareness and concern about climate change, the majority (85%) expressed concern about the issue. About 70% stated that protecting the environment from degradation is very important to them. However, when it comes to behavioural changes, 65% of the students reported difficulties in adopting a sustainable lifestyle. Among 16-year-olds, only about 20% reuse materials, though the majority recycle, and none use local products. For 14-year-olds, some recycle enough, others are aware of environmental issues, a few know about composting, and almost none are familiar with the use of local products.

Javier (13 years old): I am very concerned about the environment and the climate change. We are listening a lot of stories and reading documents at school. I am very informed and try to reduce energy and recycle all that I could do.

Ana (16 years old): I believe we can consume in a more eco-friendly way and be more respectfully towards the nature.

Juan (14 years old) I am aware about the climate change and I am recycling, but I cannot limit myself to use only local product.

4. EUROPEAN SUSTAINABLE DEVELOPMENT FOR 2025

According to the European Sustainable Development report for 2025 (Lafortune and Fuller 2025), there are ten priority actions addressing internal SDG priorities, among which are: Reduction of the risk of poverty and social exclusion of European citizens, Achieve Net-zero Emissions in the EU by 2050, Support the Transformation Towards a Sustainable Trade System, Move towards Mutually Transformative Cooperation, Research and Innovation, Engagement with the Civil Society, including Youth, and within the European Parliament on SDG Pathways and Policies.

The analysis of this report says that in 2024, the EU's average SDG index score stands at 72.8%. Between 2020 and 2023, the EU's progress on the SDGs slowed significantly, advancing by only 0.8 points per year, less than half the pace seen between 2016 and 2019 (+1.9 points per year). In some of the most developed regions, such as Western and Northern Europe, SDG performance has slightly declined since 2020, mainly due to setbacks in socio-economic goals (Lafortune and Fuller 2025).

Using the data provided in the report, we visualized the performance of the EU and European countries on the SDGs in 2025 (Fig. 9). As shown, the Nordic countries and Iceland are leading in SDG achievement, followed by the western European countries. In contrast, Eastern European countries, including Greece and a Baltic country (Lithuania), are at the opposite end of the spectrum.

Similar results are observed when analysing inequalities within countries, using a subset of indicators that reflect progress in poverty reduction, income, and equality. Once again, the Nordic countries and Iceland are the leaders, followed by western countries such as the Netherlands, Belgium, Ireland, and Germany. On the opposite end are Eastern and Southern European countries, including Hungary, Serbia, Bulgaria, Romania, Greece, and North Macedonia. In this context, Southern Europe, Central and Eastern Europe, and the Baltic States fall below the European Union's average value (Lafortune and Fuller 2025).

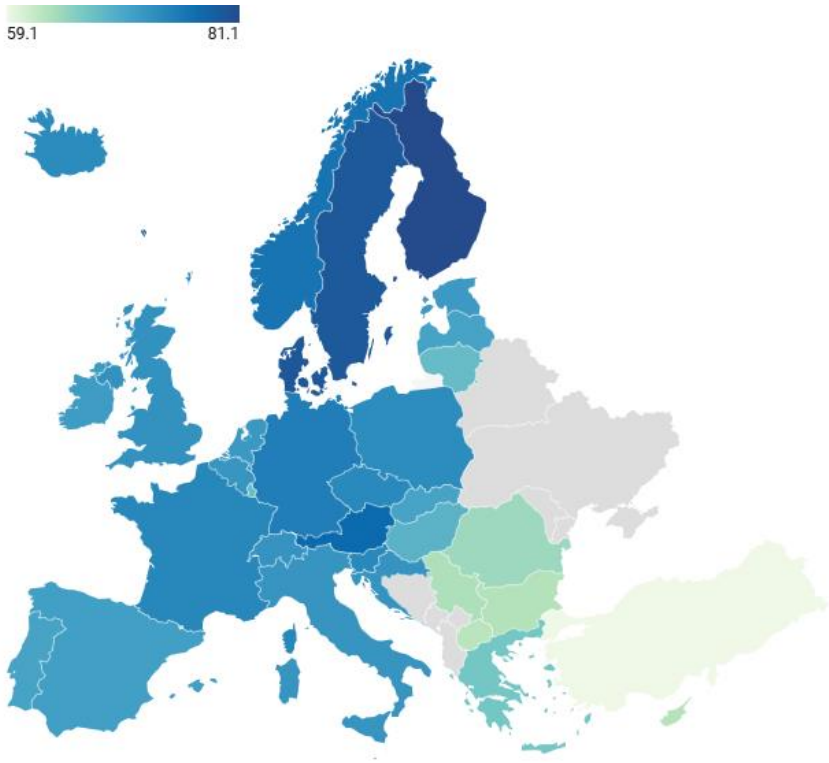

Figure 9. European performance of the SDG for 2024 - own visualization by using Datawrapper: https://datawrapper.dwcdn.net/oxF8a/1/

To understand the differences in SDG performance between various countries, we created a detailed StoryMap (ArcGIS StoryMaps 2024) for educational purposes. This focused on the sustainable balance between economic growth, social justice, and environmental protection, particularly in rural, tourist, business, and historically/culturally significant areas in some Eastern European and Caucasus countries. Results and discussions can be found in Koroutchev (2024).

5. ADAPTATION AND RESILIENCE

From increasingly severe extreme weather events to rising sea levels and growing food and water shortages, climate change presents serious threats to lives, livelihoods, and economies worldwide. The financial and human toll of these impacts continues to rise. Over the past 50 years, extreme weather events have resulted in an estimated two million deaths and $4 trillion in economic losses. Looking ahead, projections indicate that climate-related hazards could cause an additional $12.5 trillion in economic losses and over two billion healthy life years lost by 2050.

The Climate Promise initiative assists countries in their efforts to adapt to and build resilience against the climate crisis by focusing on policies and plans for adaptation, enhancing resilience in food security, protecting livelihoods, improving water management and coastal adaptation, strengthening climate information and early warning systems, providing integrated climate security solutions, boosting urban climate resilience among others (A&R 2025).

Many adaptation efforts must take place locally, with rural areas and cities playing a crucial role. These actions could include planting drought-tolerant crops, employing regenerative agricultural practices, improving water storage and management, managing land to reduce wildfire risks, and strengthening infrastructure to withstand extreme weather events like floods and heatwaves. However, effective adaptation also requires action at national and international levels. Governments must create policies to guide adaptation and implement large-scale solutions, such as reinforcing or relocating infrastructure in coastal areas vulnerable to rising sea levels, constructing buildings that can endure extreme weather, enhancing early warning systems and disaster information, developing climate-focused insurance programs, and providing stronger protections for wildlife and ecosystems (Adaptation 2024). These policies are closely connected to the scientific community, which plays a vital role in achieving these ambitious tasks. The use of modelling in computational science and AI techniques will be crucial to accelerate adaptation and resilience processes. Examples of these efforts span a wide range of issues, such as clean water and sanitation, affordable and clean energy, sustainable cities and communities, responsible consumption and production, and more (Gue et al. 2020, Han and Wang 2021).

6. CONCLUSION

Climate change is one of the most complex challenges and touching on various aspects such as science, economics, society, politics, and ethics. It is a global issue with local impacts and will continue to affect us for thousands of years. Carbon dioxide, the primary

greenhouse gas driving recent global warming, remains in the atmosphere for millennia, and the planet, especially the oceans, requires time to adjust to the warming. Even if greenhouse gas emissions were halted immediately, global warming and its consequences would still impact future generations. The severity of climate change will depend on how current emissions evolve and how the climate responds to them (NASA 2024).

Throughout the manuscript, several simulations have been discussed that examine the impact of climate change on exposed populations and their displacement due to sea and river floods, droughts, heatwaves, or wildfire hazards. Additionally, the evolution of energy consumption and CO_2 emissions by source, along with the effect of CO_2 on climate warming, have also been analysed.

Extensive surveys with young people have been discussed to understand their awareness of climate change and their readiness to confront the challenges through appropriate adaptation strategies. It would be valuable to explore the integration of socio-emotional learning with geomedia in secondary education, aiming to enhance sustainability education with a focus on climate change. An important aspect could involve addressing climate change mitigation challenges by creating digital storytelling maps that illustrate human actions for climate change mitigation. In fact, the European Sustainable Development Goals for 2025 emphasize the importance of these efforts at all levels and highlight the varying levels of progress between the Nordic countries and the Eastern and Southern European countries.

Finally, the relationship between climate change and human mobility is complex, and regions or countries unprepared for climate-related migration may face significant costs. Addressing climate mobility, preparing cities and host communities for climate-induced migration, or relocating entire households and communities will require substantial and carefully planned investments. Development funding for climate mobility is growing, with increasing contributions from various sources, particularly from bilateral government funders, who are among the most active donors (Huang, L. and Davidoff-Gore 2025).

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