

UNIVERSITY PRIORITY ACTIONS FOR MITIGATION AND ADAPTATION TO CLIMATE CHANGE

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ABSTRACT. Universities play a pivotal role in addressing climate change through both mitigation (reducing emissions) and adaptation (preparing for impacts). These institutions can undertake a range of priority actions to contribute to the fight against climate change and prepare for its consequences. Regarding mitigation, universities can adopt carbon neutrality goals, which involve reducing greenhouse gas emissions to net zero. This can be achieved through a transition to renewable energy sources, replacing traditional energy sources with clean alternatives such as solar, wind, and geothermal energy. Furthermore, it is crucial to integrate climate change and sustainability topics into academic curricula, educating students to be aware and prepared to tackle future environmental challenges. This approach not only reduces the direct environmental impact of universities but also promotes broader societal change by equipping future leaders with the necessary knowledge and skills. Universities may prepare campuses and surrounding communities to endure the effects of climate change, such as extreme weather events and rising sea levels, by participating in climate resilience planning. Biodiversity conservation is another key area, with universities managing their campuses to protect and enhance local ecosystems. Additionally, community engagement is essential; universities can work closely with local communities to develop and implement strategies for climate adaptation, fostering a collaborative approach to resilience. Universities can be powerful catalysts in addressing climate change. By driving innovation, setting an example in sustainable practices, and preparing the next generation for a sustainable future, universities can significantly contribute to the global effort to mitigate and adapt to climate change.

1. Introduction

The past few decades have seen a sharp rise in greenhouse gas emissions and in particular, in the last 3-4 decades, global surface temperatures have been rising at a rate never experienced before, reaching, in the years 2011-2020, an average of 1.1 degrees higher than the 1850-1900 mean surface temperature. This increase is strongly correlated to the rise in concentration of greenhouse gases, in particular CO₂, which is released in atmosphere as a result of fossil fuel combustion (Friedlingstein *et al.* 2020; Masson-Delmotte *et al.* 2021; Weart, Zalasiewicz, and Williams 2021). Figure 1a) shows the net global emissions of anthropogenic greenhouse gases, which include CH₄, N₂O, and fluorinated gases (sky),

as well as CO₂ from land use, land use change, and forestry (light green), and CO₂ from the combustion of fossil fuels and industrial processes (CO₂-FFI) (dark green). The atmospheric concentrations of a number of greenhouse gases, including the three main greenhouse gases shown in Figure 1b) - CO₂, CH₄, and N₂O - have increased as a result of these emissions. In comparison to the reference period of 1850–1900, Figure 1c) illustrates the nearly 1.1°C increase in global surface temperature. Ultimately, Figure 1d) shows the following human causes are responsible for the temperature change: increases in greenhouse gas concentrations, internal climate variability, solar and volcanic influences, and overall human influence (Hansen *et al.* 2000; Forster *et al.* 2020).

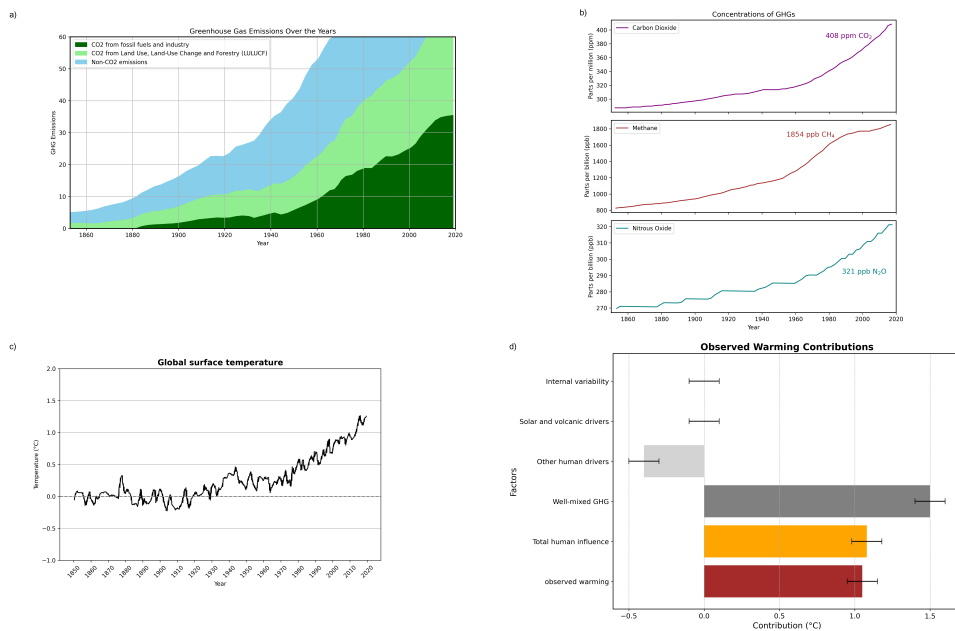


FIGURE 1. Global warming as a consequence of human activities.

The rise of temperatures has a number of consequences which can affect the quality of life and economy in large parts of the Earth: fusion of polar ice sheets and mountain glaciers reduces the available amount of fresh water and causes increase in global sea levels; global circulation is shifted and an increase in frequency of short intense (potentially destructive) rainfall events, together with long drought periods have been observed (Hughes 2000; Seneviratne *et al.* 2014). The impacts are already dramatic and can become even catastrophic in the future if no action is taken, with damage to ecosystems, increase in forest fires, desertification, drop in agricultural production, scarcity of water for populations, submerging of coastal cities and entire island countries, intense cyclones, floods and landslides, with consequent migrations and possible conflicts (Schlenker and Roberts 2009; Diffenbaugh and Burke 2019). These catastrophic consequences could be avoided or mitigated if global CO₂ emissions are strongly reduced or cut into the maximum span of a few years (Figure 2).

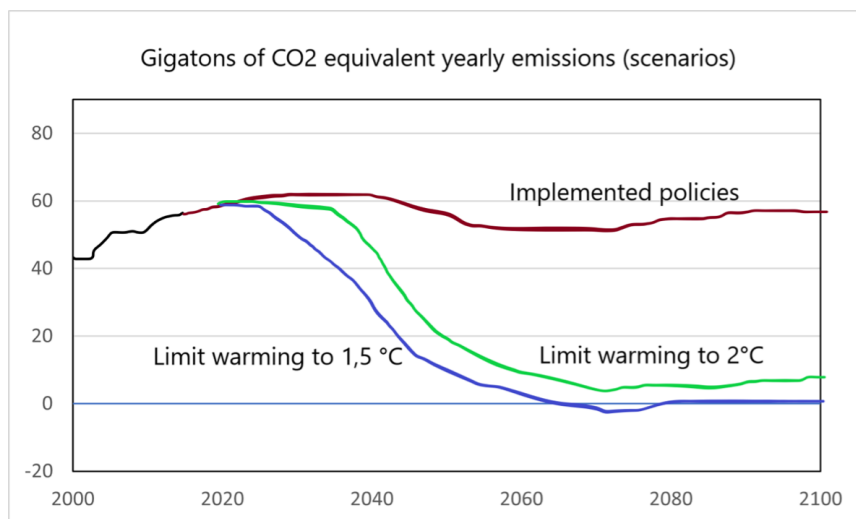


FIGURE 2. Possible scenarios if greenhouse gas emissions are reduced or cut within the next years.

In order to achieve this result, a global transition towards a fossil-free economy must be rapidly implemented. All the human communities and activities should start actions aimed to CO₂ emissions reduction or elimination («mitigation»). In addition, further actions must be implemented in order to adapt life and economy to the new climate conditions and reduce the consequences of global warming («adaptation») (Gielen *et al.* 2019; Feigin *et al.* 2023). These targets are part of the Sustainable Development Goals of the United Nations, to be achieved in 2030, the so-called Agenda 2030¹.

The actions to be taken at a global level have been decided and agreed during the UNFCCC COP21².

¹Agenda 2030

²conference held in Paris in 2015 - UNFCCC COP21

The Paris agreement



FIGURE 3. Overview of the decisions taken in UNFCCC COP21 held in Paris in 2015.

Italy is also suffering from a number of significant impacts of climate change on different aspects of the environment, economy and society. Data collected by the main researchers of the National Oceanic and Atmospheric Administration (NOOA), the “Istituto Superiore per la Protezione e la Ricerca Ambientale” (ISPRA), the Institute of Atmospheric Sciences and Climate (CNR-ISAC) and the European Severe Weather Database (ESWD) show that, in recent years, temperatures in Italy have increased faster than in the rest of the world. According to CNR-ISAC studies, average annual temperatures in Italy have risen by 1.7°C during the past 200 years. However, the previous 50 years have seen the largest increase in this rise, with an increase of roughly 1.4°C. According to the ISPRA’s analysis, the average temperature in Italy increased by around 1.0°C overall between 1961 and 2008, after declining from 1961 to 1981. The causes of global warming in Italy can be attributed to several factors. Human activities, such as the use of fossil fuels for energy production, produce large amounts of greenhouse gases such as CO₂, CH₂, and N₂O.

Changes in soil characteristics and deforestation contribute significantly to Italy's warming, along with increasing air pollution due to excessive emissions of aerosols and other pollutants that contribute to negatively affecting the local climate and temperatures. Between 1981 and 2010 the average annual temperature in Italy increased by about 1.2°C. This is quite worrying considering that the national temperature had previously taken about a century to rise by 1.7°C. According to ISPRA (2009), in 2007 and 2008 the anomalies compared to the thirty-year period 1961 - 1990 were respectively +1.24°C and +1.09°C against a global average of +0.67°C and +0.53°C in the respective years. The estimates made by numerous researchers provide average data but point to a clear trend: climate change produces real and worrying effects more in Italy than in the rest of the world. In 2021, following the easing of lockdown measures and the resumption of activities, there was a notable rise in environmental stress indicators directly tied to economic activity. This includes heightened emissions of CO₂ and other greenhouse gases, as well as an increase in the generation of municipal waste compared to the previous year. The impacts of climate change are becoming more apparent, particularly in terms of temperature and precipitation patterns (Afifa *et al.* 2024). There has been a significant uptick in extreme weather events, notably prolonged periods of warm weather and consecutive days without rainfall, when compared to historical climate data. With regard to long-term precipitation trends, Brunetti *et al.* (2006) conducted a series of studies that showed that the trends are generally negative, even if mild. The reduction in rainfall is of the order of 5% per century, Nanni and Prodi (2008) have shown that spring is the season in which the reduction in rainfall is most significant (10% per century). Several studies carried out by Toreti *et al.* (2009) highlight that the winter series of Northern Italy shows a decrease in average precipitation of 1.47 mm/year from 1961 to 2006. Another important effect of climate change in Italy is an exponential increase in extreme weather events. Extreme heat waves have become more frequent and intense in several Italian regions during the summer months. These periods of intense heat have serious consequences on public health, agriculture and the ecosystem with periods of drought. On the other hand, floods represent one of the main extreme weather events affecting Italy, especially in coastal and mountainous regions such as Liguria, Tuscany and Emilia Romagna. According to Legambiente data, intense and prolonged rainfall caused about 510 floods and 1318 extreme weather events from 2010 to September 2022. Among the human activities, universities involve thousands of people who every day travel, live, study, work, eat, sleep into their areas of pertinence (Stephens *et al.* 2008). Universities have often the dimensions of small-medium cities, in terms of people involved and occupied areas (Caccamo and Magazù 2019; Findler *et al.* 2019). Their collocation is often inside cities, with a significant interaction with the surrounding urban texture, and since universities are centers of research, development and innovation, the actions taken by a university might be inspiring examples of good practices for the entire city and the surrounding region (Cortese 2003; Caccamo and Magazù 2021). Furthermore, Elastic incoherent neutron scattering technique has emerged as a pivotal method for examining the structural behavior of materials under environmental influences, offering detailed insights into their response to various stressors (Caccamo and Magazù 2023).

2. Present situation overview

Most universities are composed by a multitude of buildings of different construction periods and architectural conceptions. Some of them are historical buildings (this is the case of the oldest universities), while the majority consists of 20th century buildings, sometimes interposed in the urban texture between other buildings, sometimes grouped into a campus or more ones, in particular for scientific faculties (Cuce and Riffat 2013; D'Agostino, Zangheri, and Castellazzi 2017; Kataray *et al.* 2023). Some interventions towards the direction of carbon neutrality have already been performed or are in progress now, but there are large differences between universities, with some of them much more active than others (Brown and Sovacool 2007; Poel, van Cruchten, and Balaras 2007; Li, Cheung, and Lam 2010). Examples of the most common actions taken:

- Thermal insulation of buildings and replacement of fixtures with more insulating ones;
- Reduction of heating operation hours and optimization of spaces with reduction of heating in the temporary unused spaces;
- Reduction of electricity consumption by replacing all lamps with LED devices and installation of twilight and motion sensors for automatic switch on and switch off;
- Replacing thermal units with more efficient ones;
- Installation of solar panels on the building roofs;

Examples of innovative actions taken by just one or a few universities:

- Installation of smart automatic curtains to reduce exposition to sunlight in the warm season;
- Automatic regulation of artificial luminosity in order to match the real needs and the number of occupants;
- Implementation of green walls;
- Installation of absorption chillers using the waste heat of power co-generator plants;
- Use of vegetal biomass as fuel for thermal units in place of natural gas;
- Installation of solar cooling and solar heating plants;
- Installation of geothermal heat pump plants;
- Creation of an energy community in order to better exploit and share the renewable energy produced by the solar plants installed;
- Subscription of energy supply contracts with companies which guarantee 100% renewable energy;
- Implementation of smart grids for an efficient distribution and management of the energy produced and absorbed;
- Introduction of the figure of the Mobility Manager;
- Studies about the mobility of people reaching the university in order to improve the public transportation and to optimize the timetable of activities in an attempt to distribute the flux in time and avoid peaks;
- Introducing electric micro-mobility inside and around the university premises;

What has been done so far is praiseworthy, yet not enough to achieve the total carbon-neutrality of universities. Here the main priorities to be pursued in the effort to reach this goal are highlighted, together with possible actions: among them, there are also the already

taken actions listed above (Mendes, Ioakimidis, and Ferrão 2011; Wang and Greenberg 2015; Reinhart and Davila 2016).

Priority 1: reduction of energy consumption

In order to reduce the carbon footprint of universities, the first action to be taken is aimed at reducing the energy consumption (Attia and Carlucci 2015; Boeck *et al.* 2015; Santamouris 2016; Torres *et al.* 2022). Many opportunities are available, among them:

- (1) Optimizing the daylight: timetable of courses and research activity can be adapted in order to exploit at best the daylight hours. For example, if dawn time is 6:50 AM and sunset time is 5:10 PM, the courses can be scheduled in the 7:00 AM - 5:00 PM time span (instead of 9:00 AM - 7:00 PM, as it is now in many universities);
- (2) Rearranging spaces: the rooms with larger windows and more natural illumination can be used as lecture and study rooms, in order to minimize the need for artificial illumination during daylight hours;
- (3) Installation of tubular skylights for illuminating with natural light the internal spaces not provided with windows;
- (4) Replacement of lamps with high efficiency LED devices and installation of twilight switches and motion sensors for automatic switch on and switch off;
- (5) Automatic regulation of artificial luminosity in order to match the real needs and the number of occupants;
- (6) Thermal insulation of all buildings in order to reduce the energy consumption for the heating (winter months) and cooling (summer months) by insulation layers on walls and double glazing on windows;
- (7) Installation of smart glass windows for reducing the amount of sunlight and internal temperature in summer months;
- (8) Installation of smart automatic curtains to reduce exposition to sunlight in the warm season;
- (9) Implementation of green walls;
- (10) Installation of smart thermostatic valves combined with motion sensors in order to avoid heating or cooling of empty spaces;
- (11) Monitoring of energy consumption, waste and dispersion in the different buildings using a network of smart sensors and artificial intelligence;
- (12) Implementation of smart grids for an efficient distribution and management of the energy produced and absorbed.

Priority 2: transition to sustainable energy

Most of the energy consumed by universities is, at the present time, obtained by burning fossil fuels (Cherubini, Bargigli, and Ulgiati 2009; Fouquet 2010). The transition to renewable energy sources is more easily reachable for electrical power generation, while it represents a challenge when heating of buildings is involved, because most of the thermal central units are fuelled with fuel oil or natural gas (Tsoutsos, Frantzeskaki, and Gekas 2005; Sovacool 2009). Here are some of the possible actions:

- (1) Installation of solar panels for electrical power generation, combined with accumulation batteries and solar collectors for hot water production on the roofs of all buildings and over the other available surfaces;
- (2) Installation of mini wind turbines in the areas of pertinence of the universities;
- (3) Installation of anaerobic digesters in campuses, in order to produce biogas and biofuel from the sewage waste, and from the organic fraction of solid waste;
- (4) Creation of energetic communities and/or insertion of the university into an existing energetic community, for a constant supply of renewable energy and optimization in management of the production and consumption peaks;
- (5) Subscription of energy supply contracts with companies which guarantee 100% renewable energy;
- (6) In areas with a large availability of biomass, installation of local power generation plants fuelled with biomass, biofuel or biogas;
- (7) Replacement of oil- or gas-powered thermal central units with ones fuelled with biomass, biofuel or biogas, or with electric heat-pump boilers;
- (8) If a local power generation unit is present, it is possible to use the waste heat for buildings heating in winter and for cooling in summer (by means of an absorption cooling unit).

Priority 3: reduction of water consumption

The large number of people living and working in the university buildings, the need for cleaning and caring for the green areas lead to high consumption of fresh water. Climate change is progressively reducing the amount of available fresh water (Gleick 2003; Domènech and Saurí 2011). Thus, in a framework of adaptation, some actions can be performed in order to reduce this consumption, among them:

- (1) Use of the discharge water of sinks for the flushing of toilets;
- (2) Installation of local water depuration plants for the re-use of depurated water in green areas irrigation;
- (3) Installation of automatic taps activated by photocells;
- (4) Collection and potabilization of rain water.

Priority 4: sustainable mobility

Every day, thousands of people commute from their homes to the university premises. If this commuting is performed with private vehicles fuelled by fossil fuels, the impact on the carbon footprint of the university system becomes relevant (Banister 2008; Ewing and Cervero 2010; Holden and Linnerud 2011). Actions must be taken with the aim of improving public transportation and sustainable mobility for university students and workers. Here are some possibilities:

- (1) Studies about the mobility of people reaching the university in order to improve the public transportation, for example planning more bus services, a new railway, subway or tramway line reaching the university campus: this must be performed in agreement with local authorities and the ministry of infrastructure;

- (2) Optimize the timetable of activities in an attempt to distribute the flux of commuters in time and avoid peaks;
- (3) Introducing electric micro-mobility inside and around the university premises;
- (4) Promoting sustainable mobility and public transportation with benefits for the users who decide to leave the car at home.

Priority 5: sustainable food supply

Many of the students, teachers, researchers and workers spending whole days in the university premises make use of canteens, cafeterias and similar facilities (Pretty *et al.* 2005; Garnett 2011). The food supply for them can be made more sustainable with some actions like the following:

- (1) Choose locally produced food in order to minimize the carbon footprint related to food transportation;
- (2) Privilege biologic productions and the ones certified from farms and fields in which no exploitation of workers takes place;
- (3) Promote the establishment of allotments for volunteer farming inside the green areas owned by universities;
- (4) Ensure collection of the unsold food at the end of the day, for benefit distribution to people in need, in order to help people and reduce waste of food.

Priority 6: promotion of sustainability

Universities are, first of all, centres of formation and education. Their role in educating people to sustainable life styles is important, and can be enhanced (Lozano 2006; Fadeeva and Mochizuki 2010; Barth and Rieckmann 2012). Here are some proposals:

- (1) Institution of one-day events dedicated to single aspects of sustainability (for instance, one day dedicated to collective mobility, one to reduction of energy consumption, one to sustainable food...);
- (2) Distribution of informative leaflets about the possibilities of reducing one's carbon footprint by using facilities such as public transport, shared mobility, zero-emission mobility, volunteer farming, etc.;
- (3) Periodic measurements of the whole university carbon footprint, with presentation of the results in dedicated congresses and discussion about the future actions to be taken;
- (4) Network between different universities in order to share good practice and improve together;
- (5) Institution of awards for students and researchers proposing innovative technologies and new good practice for improving sustainability (in particular for the activities of the university).

3. Conclusion

This paper delineates the pivotal role that universities play in addressing climate change through both mitigation strategies (such as reducing emissions) and adaptation measures (such as preparing for impacts). Institutions of higher learning can implement critical

actions including setting carbon neutrality objectives, transitioning to renewable energy sources, integrating mitigation strategies into academic curricula, and devising plans for climate resilience, biodiversity preservation, and community engagement for adaptation. The document underscores the catastrophic consequences brought about by global warming over recent decades, including the diminution of freshwater reserves, the rise in sea levels, the occurrence of extreme weather events, and adverse impacts on agriculture and societal structures. It also emphasizes the pressing need to curtail CO₂ emissions and transform economic structures away from fossil fuel dependency, in alignment with the Sustainable Development Goals set by the United Nations and the commitments made under the Paris Agreement of 2015. Furthermore, the paper explores specific measures that universities can undertake to lessen their environmental footprint, such as enhancing the energy efficiency of buildings, shifting to renewable energy solutions, and managing water resources and mobility in a sustainable manner. The significance of sustainability education and the promotion of sustainable practices within the academic communities are highlighted as essential components in fostering an environmentally conscious ethos.

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