Progress of the sustainable development goals and synergy with climate change action

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ABSTRACT

In 2021-2022, disasters took approximately 10,000 human lives and over $280 billion in damage in the world. It is evident that diverse forms of disasters affecting our lives cannot be separated into the nature-human relationship. At the same time, the recent statement by the UN Secretary-General, Antonio Guterres, warns the international community that progress towards achieving the Sustainable Development Goals (SDGs) has been hampered by multiple global issues and further consolidated efforts by the international community are imperative. With progress stalled and varying significantly across countries and regions, redoubled efforts are needed to accelerate transformative change. The Secretary-General identifies three priorities: (i) reducing conflict and violence, (ii) reforming the international financial system, and (iii) harnessing transitions around energy, food, and digital connectivity. To materialize this commitment, we need to further promote collaboration between policymakers, academics, international organizations and local communities. This paper, therefore, focuses on three topics: Progress of UN Agenda 2030 and summary of issues to be communicated; Recent updates of Climate COP and points to be shared with science and engineering fields experts; and interconnectedness between disaster risks, climate change and SDGs.

Key words: *Sustainable development, climate change, disaster risk, resilience, infrastructure*

1. Introduction

Sustainable development, climate change and disaster risks are fundamentally interlinked. Achieving the Sustainable Development Goals (SDGs) depends on reducing the impacts of climate change and increasing the resilience of communities. Transitioning to more sustainable pathways mitigates emissions and reduces vulnerability to disasters. Nevertheless, action taken in one of these areas has the potential to either undermine or support success on the others. It is critical to pursue integrated strategies and solutions that maximize synergies. This paper explores the interconnections between these global agendas, and identifies the vital role that civil engineers can play in delivering such synergies in both mitigation and adaptation.

2. Progress of the 2030 Agenda for Sustainable Development

2.1. Background

The 2030 Agenda for Sustainable Development was adopted by the United Nations General Assembly in 2015 (United Nations, 2015a). Comprising 17 SDGs and 169 targets to be achieved by 2030, the agenda is a global commitment to achieving sustainable development in its three dimensions: economic, social, and environmental. The 2030 Agenda built on its predecessor framework, the Millennium Development Goals (MDGs), which were to be achieved by 2015. Compared to the MDGs, the SDGs are considerably more comprehensive and ambitious, as well as universal — requiring action by all Member States, not only by developing countries.

A global indicator framework was adopted to measure progress on the SDGs and their targets (United Nations, 2017), as a voluntary and country-led instrument. Global reporting is primarily based on data and statistics produced by national statistical systems, with designated "custodian agencies" facilitating data flows (United Nations, 2017). Follow-up and review of the 2030 Agenda is informed by an annual progress report on the SDGs, which is prepared by the UN Secretary-General based on data compiled under the indicator framework.

Member States are also encouraged to conduct country-led reviews of SDG progress on a regular basis. These Voluntary National Reviews (VNRs) are presented at the annual UN High-Level Political Forum on Sustainable Development (HLPF). VNRs share insights from country progress, including successes, challenges, and lessons learned. The vast majority of Member States have presented VNRs (188 of 193, with two more due to present in July 2024). Increasingly, local and regional authorities are also conducting reviews of SDG progress at the sub-national level. These Voluntary Local Reviews (VLRs) are compiled and made available online by the UN Department of Economic and Social Affairs (2024).

2.2. Progress to date

The following summary of SDG progress to date is based on the annual reports of the UN Secretary-General (e.g., United Nations 2024) as well as independent analysis by Our World In Data (e.g., 2023) and Sustainable Development Report (e.g., Sachs et al., 2024).

In the first five years of the 2030 Agenda progress was steady but uneven, and the pace was too slow to achieve the goals by 2030. Significant improvements were evident during this period, including on SDG 3 (good health and well-being) with a reduction in the incidence of communicable diseases. On SDG 4 (quality education), the share of children and youth out of school declined. Access to safe drinking water (SDG 6 — clean water & sanitation) increased. But food insecurity was rising (SDG 2), the decline of the natural environment was accelerating (SDG 14: life below water, and SDG 15: life on land), and extreme inequality remained widespread (SDG 10).

Since 2020 progress has stalled — and even regressed — due to a confluence of global crises, including the COVID-19 pandemic, armed conflicts, trade tensions, and the accelerating impacts of climate change. SDG 1 is far off track, with an additional 23 million people living in extreme poverty in 2022 compared to 2019. The same period saw an additional 123 million more people suffering from hunger (SDG 2). Indeed, SDG 2 is the only goal that none of the 193 UN Member States are on track to achieve. On health and well-being (SDG 3) progress has slowed, particularly on maternal mortality, premature deaths from major non-communicable diseases, and access to essential healthcare. Improvements in education (SDG 4) have also slowed, including the percentage of young people completing upper secondary school (from 53% in 2015 to 59% in 2023). The pace of progress on gender equality (SDG 5) remains insufficient, with persistent inequality and high levels of violence against women and girls.

Action on the climate crisis (SDG 13) is increasingly urgent, with greenhouse gas (GHG) levels rising to record highs. The natural environment (SDG 14 and SDG 15) has continued to decline rapidly. Marine ecosystems are increasingly threatened by pollution, ocean acidification and declining fish stocks. Biodiversity on land faces a decline of forest areas and an increasing rate of species extinction.

As of 2024, only 17% of SDG targets are on track to be achieved by 2030 (United Nations, 2024). For the remaining targets, 48% have deviated moderately or severely, on 30% progress is marginal, and 18% exhibit moderate progress. Stagnation is evident for 18% of targets, and 17% have regressed below the 2015 baseline. Progress varies significantly across countries and regions, with a widening gap between the progress of the poorest and most vulnerable countries, and the average country (Sachs et al. 2024).

2.3. Priorities to accelerate progress

The latest progress report of the UN Secretary-General (United Nations 2024) identifies several priorities to accelerate progress on the SDGs. First is reducing conflict and violence, recognising that peace is a prerequisite for sustainable development. Second, reform of the international financial system is needed to unlock financing for developing countries. Third, transitions around energy, food, and digital connectivity must be harnessed for transformative progress across the goals.

3. Insights from recent climate COPs: Challenges, outcomes and future

3.1. Issues being discussed and negotiated

The 'Conference of the Parties', more famously known as the COP, is the supreme decision-making body of the UN Framework Convention on Climate Change (UNFCCC). Countries meet every year to discuss and review the implementation of the Convention and any other legal instruments that previous COPs adopted and take decisions required to achieve the goals of the Convention, including institutional and administrative arrangements. The latest 28th edition of the COP ended on the 13th of December 2023 in Dubai, UAE, to be followed by the COP29 scheduled in November 2024 in Baku, Azerbaijan. The Paris Agreement adopted by 196 countries at COP21 in 2015 is a legally binding international treaty on climate change that targets to hold the increase in global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C (United Nations, 2015b). The COP28 last year marked a critical turning point with its first Global Stocktake of the Paris Agreement's progress of implementation. It was a year in which the world experienced record-shattering temperatures as well as the Russia–Ukraine and Israel–Palestine conflicts, with huge impacts on human lives and the environment.

Issues that were central in the discussion during the recent COPs include: (1) the imperative of limiting global temperature rise and responding to surging intensity, frequency and seasonality of extreme weather and climate events, (2) facts around rising energy prices, global food insecurity and water crisis exacerbated by climate change and non-climate factors, (3) the importance of equity questions and the best available science, (4) recognition of the fundamental linkage of climate change and action with other sectors and systems, and (5) insufficient extent of action due to finance, technological and capacity constraints (Arora, 2024; Jiang et al., 2024; Naylor & Ford, 2023; Pflieger, 2023).

With these issues driving the discussion, three major topics were negotiated at COP28:

(1) Fossil fuel transition

The imperative to transition away from fossil fuels is driven by the need to meet Paris Agreement targets. The IPCC concluded in 2020 that to have a 50% chance of limiting global warming to 1.5°C, the world would need to cut CO2 emissions to net zero by around mid-century and limit cumulative emissions between 2020 and 2050 to 500 GtCO2 (Intergovernmental Panel on Climate Change (IPCC), 2023). Fossil fuel production, processing and combustion in end-uses is responsible for 90% of global anthropogenic CO2 and 35% of methane emissions (IEA, 2023). Targeting to limit global warming to well below 2°C will then imply a combination of reductions in fossil fuel production and use, abatement of residual fossil fuel use, and scaling up carbon removals (Energy Transitions Commission, 2023). Wide efforts have been made to accelerate systemic transformations needed to reach net zero through clean energy transitions and phase-out of fossil fuels, yet commitments made in agreements like the Glasgow Pact have not curbed fossil fuel subsidies effectively as these agreements often lack monitoring mechanisms to assess their integration into national policies (Arora, 2024).

(2) Loss and damage fund

The loss and damage fund was first established at COP27, defined as funding to adapt and mitigate anthropogenic climate change-related impacts for highly vulnerable developing and small island nations. In 2022, the damage globally was estimated to be approximately USD 280 billion (Newman & Noy, 2023). The cost was expected to rise exponentially in the future as weather extremes increase, not only in frequency but also in intensity (Newman & Noy, 2023). In the African continent only, loss and damage costs required were expected to range from USD 290 billion (2°C warming scenario) to USD 440 billion (4°C warming scenario) (WMO, 2023). Many Asian countries have been the worst hit by extreme weather disasters in terms of casualties and economic damage, with flood-induced economic damages in 2022 exceeding its average damages over the past 20 years (WMO, 2024). Lack of defensive infrastructure and available shelters made the situation worse for people, especially vulnerable groups.

(3) Global goal on adaptation framework

COP28 marked the end of the two-year Glasgow–Sharm el-Sheikh work program (GlaSS) on the global goal on adaptation (GGA). At COP27, countries decided to develop a GGA framework to 'guide the achievement of the global goal on adaptation and the review of overall progress in achieving it' (UNFCCC, 2022). The GGA framework aims to guide the achievement of the GGA and the review of progress in achieving it with a view to reducing the increasing adverse impacts, risks and vulnerability associated with climate change (UNFCCC, 2024). Developing countries were particularly keen to set targets for the GGA framework around the steps of the iterative adaptation cycle and the different thematic areas that had been discussed in Sharm el-Sheikh (Fielding, 2024). While there is widespread understanding that strengthened interconnection between nature and climate change can not only foster emissions reductions but can also strengthen climate resilience and the livelihoods of people, climate adaptation often receives less attention during COPs compared to mitigation and finance (Fielding, 2024).

3.2. Key outcomes and measures

The Global Stocktake is considered the main outcome of COP28 as it contains elements to help develop stronger Nationally Determined Contributions (NDCs), which are due by February 2025. The following are the key takeaways from the Global Stocktake that marked major steps forward in the global efforts to deliver on the Paris Agreement targets:

(1) Signaling the 'beginning of the end' for the fossil fuel era

For the first time, countries agreed on the need to transition away from fossil fuels in energy systems, with actions accelerating during this decade to achieve net zero emissions by 2050 in accordance with best available science (IEA, 2023; IRENA, 2023). The call on nations to transition from fossil fuels is part of the decisions to boost climate action by laying the ground for a swift, just and equitable transition underpinned by deep emissions cuts coupled with solid finance systems. The measures include trebling renewable energy capacity and doubling the global average annual rate of energy efficiency by 2030. This is to accelerate efforts towards the phase-down of unabated coal power, phasing out inefficient fossil fuel subsidies, accelerating emission reductions from road transport and other measures to promote such transition in a just, orderly and equitable manner (UNFCCC, 2023).

(2) Operationalizing loss and damage

The decision to set up a new dedicated fund under the UNFCCC was adopted (UNFCCC, 2023). Nineteen countries have committed a total of USD 792 million to the fund to date (UNFCCC, 2023). The UN Office for Disaster Risk Reduction (UNDRR) and the UN Office for Project Service (UNOPS) plan to host the secretariat of the Santiago network for loss and damage, aiming to catalyze technical assistance for the implementation of relevant approaches for averting, minimizing and addressing loss and damage at the local, national and regional levels in developing countries vulnerable to the adverse effects of climate change. Despite this promising achievement, the contributions to the fund remain inadequate for the scale of what is needed. Studies have estimated the required loss and damage funding in developing countries is approximately USD 380 billion/year and is expected to grow (Markandya & González-Eguino, 2019).

(3) Increasing climate finance

Climate finance received a boost, including new funding of USD 12.8 billion pledged to the Green Climate Fund

(GCF), new commitments of USD 174 million announced to the Least Developed Countries Fund and Special Climate Change Fund and USD 188 million pledges made to the Adaptation Fund (UNFCCC, 2023). The Global Stocktake also underscored the importance of reforming the multilateral financial architecture, scaling up grants and concessional finance and accelerating the establishment of new and innovative sources of finance (UNFCCC, 2023).

(4) Enhancing global efforts to strengthen resilience

The agreement on targets for the GGA framework (known as the UAE Framework for Global Climate Resilience) in relation to the dimensions of the iterative adaptation cycle (i.e., assessment, planning, implementation and monitoring) strengthens long-term transformational and incremental adaptation efforts and supports. Adaptation efforts are more difficult to quantify and very specific to locations and geographies of implementation. So these agreed targets will help to strengthen the GGA through guiding adaptation planning and strategies at all levels and assisting stakeholders in aligning the finance, technology and capacity-building support needed for adaptation implementation. Most relevant to engineering fields are targets on increasing the resilience of infrastructure and human settlements, enhancing climate resilience to water-related hazards and accelerating the use of ecosystem-based adaptation and nature-based solutions (UNFCCC, 2023). Countries also established a 2-year UAE-Belém work program on the development of indicators for measuring progress achieved towards the targets.

(5) Linking climate action with nature conservation

Momentum was created through recognition for linking efforts to address the climate and biodiversity crises. Countries were called on to consider ecosystems, biodiversity and carbon stores when developing their updated NDCs (UNFCCC, 2023). The COP28 decision also emphasizes the importance of nature and ecosystem conservation, protection and restoration through protecting terrestrial and marine ecosystems and reversing deforestation and forest degradation by 2030. Nature-based solutions were also recognized as keys to mitigating climate change and protecting vulnerable communities.

3.3. Looking ahead and opportunities for progress

At COP28, a large number of countries placed emphasis on effective solutions to achieve long-term temperature goals that are nationally determined, reflecting national and regional circumstances, acknowledging a variety of technologies and mitigation options. With momentum for tackling the underlying causes of the global crises of climate change and biodiversity loss together and in the broader context of achieving the SDGs, implementation of the Global Stocktake outcome is crucial. Follow-up issues relevant to the science and engineering fields are summarized below:

(1) Synergizing climate action in energy infrastructure

Countries are strategically planning to increase the utilization of renewable energy, specifically solar and wind energy, to triple renewable power by 2030 (IRENA, 2023). However, while the energy sector is at the center of decarbonization, systematic means for planners and engineers to integrate climate mitigation and adaptation into energy infrastructure projects are limited at the point of delivery (UNOPS, 2021; Wernersson et al., 2024). Existing studies point out that integrating climate actions in the energy infrastructure lifecycle can influence the achievement of a wide range of SDG targets, and an in-depth understanding of climate action and SDG trade-offs can benefit the field of science focusing on synergies of energy projects (Wernersson et al., 2024).

(2) Promoting climate-positive infrastructure systems

Infrastructure is at the heart of climate-compatible development (Thacker et al., 2019; UNOPS, 2021). Climate-positive design principles have been used in landscape architecture, utilizing cradle-to-cradle design life assessment to ensure outdoor built environments sequester more GHGs than they emit (AILA, 2022). Extending the implementation of climate-positive design principles to deliver built-environment projects and ultimately create infrastructure systems holds considerable promise to support actions to reduce climate vulnerability and enhance societal resilience to the disruptive impacts of a changing climate (Dolan, 2024). Potential actions include prioritizing the use of nature-based solutions at the delivery stage of transport projects by managing stormwater locally through natural vegetation (UNOPS, 2021).

(3) Leveraging the full potential of climate technologies

The Global Stocktake underlines the fundamental role of technology development and transfer, endogenous technologies and innovation in facilitating urgent adaptation and mitigation actions, highlighting the uneven pace of adoption of climate technologies around the world (UNFCCC, 2023). As countries prepare their next round of NDCs, there are opportunities to broaden the scope of climate solutions considered in national and sub-national climate plans. Technology choices could support demand-side solutions, such as transport modes and building designs, for mitigating climate change that are synergistic with well-being (Creutzig et al., 2022). Balancing complex and high-tech solutions with low-tech and accessible options can leverage the full potential of climate technology in the development and implementation of NDCs (WIPO, 2023).

(4) Emphasizing the ethics of climate engineering

While science has offered a wealth of knowledge to strategize decarbonizing our energy systems through scenarios, the decision-making process needs to consider the limitations, associated risks and ethical concerns of different modelled pathways (Achakulwisut et al., 2023). There are opportunities for geoengineering on the feasibility of deliberate and massive intervention in the Earth's climate system as a potential means to mitigate ongoing climate change. Examples include carbon dioxide removal (CDR) from the atmosphere or allowing more infrared radiation to escape through solar radiation modification (SRM). However, there are still important uncertainties and risks around such technologies (Pflieger, 2023). In light of these uncertainties, ethical evaluation of climate engineering techniques is necessary and should consider the level of scientific knowledge, cultural assumption and risk distribution of such relevant technologies (UNESCO, 2023). Simultaneously, more research is needed to understand and mitigate the potential failure of climate engineering technologies to develop at scale (Achakulwisut et al., 2023).

4. Interconnectedness between disaster risks, climate change and Sustainable Development Goals

This section presents four case studies based on the UNU-EHS Interconnected Disaster Risks report, which covers the complex interplay of various global challenges. The four selected cases are diverse in nature, region and types of interconnectedness — namely, Lagos floods, groundwater depletion, unbearable heat and an uninsurable future. These cases illustrate the intricate connections between human activities, environmental changes and disaster risks.

4.1. Lagos floods

Lagos, Nigeria is one of the largest cities in Africa. A major flood hit the city in July 2021, submerging cars and houses, bringing the metropolis to a standstill. The low-lying, flat topography coupled with many areas at or below sea level contributed to the disaster-prone characteristic of the city (Ajibade, 2017). Low elevation and land subsidence of around 87mm per year, combined with mass drainage problems, lead to trapped and built up water when heavy rainfall or storms hit (Adeloye & Rustum, 2015). Despite these challenges, the population in Lagos is projected to grow from approximately 15 million in 2022 to more than 88 million in 2100 (Hoornweg & Pope, 2017). One of the key "pull factors" is sand mining, a lucrative industry that particularly attracts young people looking for better incomes and to boost their livelihoods (Remi & Adegoke, 2011). The global trend of growing cities and urban populations is fueling fierce demand for sand. Given the high demand for sand as a raw material to produce cement, concrete, glass and asphalt for infrastructure project, its exploitation is leading to irreversible erosion of the coastline, degrading coastal ecosystems (UNEP, 2022).

There are several solutions to this issue. First, restoring ecosystem services such as mangrove forests found extensively along Nigeria's coast can provide several coastal benefits for addressing the drivers of flood risks in Lagos and other parts of the world. The root system of such mangroves is good at diffusing wave energy — wave height can be reduced up to 66% per 100m of mangrove forest. Second is to construct sustainable urban drainage systems (SUDS) with the use of innovative materials such as "porous asphalt", which has proven effective for flood management in other coastal cities including London and New York (Charlesworth et al., 2016). The third option is to adopt circular approaches. For example, storing, processing, and recovering raw material from urban waste including construction and demolition waste to use again in construction or other sectors at a similar cost to the new raw materials. As feasible as this pathway sounds, governments do need to provide regulations, incentives, and enhancement of producers' responsibility to make the solution more effective (Di Maria et al., 2013). Apart from recycling and reuse, another option is to search for alternative, sustainable materials in the construction industry. Massive timber made of glued laminated pieces of wood aims to replace concrete building materials, alleviating the need for sand while reducing GHGs associated with the production and transportation of such materials, which account for 11% of global GHG emissions (Roberts, 2020).

4.2. Groundwater depletion

Groundwater refers to freshwater resource stored in underground reservoirs called aquifers. Groundwater extracted from aquifers provides fresh drinking water to over 2 billion people, and 70% of groundwater withdrawals are used for agricultural purposes (Kundzewicz & Döll, 2009; UN-Water, 2022). On the other hand, natural events such as rainwater penetration, riverine contributions or other surface water activities can recharge some aquifers, raising the water table (Hartmann, 2022). Therefore, the balance between extraction and recharge is critical to maintain stable water levels to secure a steady supply for drinking water and agricultural use. However, 21 out of 37 top global aquifer systems are showing negative groundwater level trends as the depletion speed is faster than that of recharge (Richey et al., 2015). For example, Saudi Arabia, having no permanent lakes or rivers and with little rainfall, has one of the world's largest aquifer systems and was able to grow wheat in the desert. The relationship between groundwater extraction and agricultural production for global food supply means that local problems can quickly become global issues. Saudi Arabia was once the sixth-largest wheat exporter, but with over 80% of its aquifer depleted, the government halted wheat production and shifted to wheat imports in 2016 (Novo, 2019; Mousa, 2022; Halverson, 2015). The High Plains aquifer in the United States supplies one-third of all groundwater for irrigation used in the country. The country exports 42% of its crops grown using depleted groundwater, mostly corn, to countries such as China, Japan and Mexico. This means that these countries can no longer rely on such sources of food once the groundwater in the region is depleted (Dalin et al., 2017; Dennehy et al., 2002).

Groundwater depletion can be addressed by avoiding, adapting and transforming. First, it is important to balance groundwater withdrawals to the aquifer's recharge rates, to avoid crossing the groundwater depletion risk tipping point. This does not imply that groundwater should no longer be used, but rather that people should be aware of the interconnected processes and systems relying on groundwater resources, to ensure that it is used sustainably. Specifically, technical interventions may include practices as small as fixing water leakages in drip irrigation and improving irrigation scheduling. Second, alternative water resources to groundwater for irrigation can be adapted to relieve the pressure on aquifers. For example, treated grey, black and desalinized water can be used for crop irrigation and non-potable domestic use. Grey water normally requires little treatment and is a comparably inexpensive supplementary water source for irrigation (Oteng-Peprah et al., 2018). It is also worth noticing that the desalination process is often energy intensive, contributing to GHG emissions (Panagopoulos & Haralambous, 2020). Sustainable practices can be applied in either a weak or a strong way as it is a matter of values and choices in the local context. For any of the methods to work, it is necessary to transform how society values, utilizes and manages groundwater resources. A shared understanding of what constitutes sustainable use of finite groundwater resources to meet the needs of current and future generations is critical.

4.3. Unbearable heat

Human-induced climate change is causing temperature rise globally, resulting in more frequent and intense heatwaves. July 2023 was the hottest month recorded since data collection began in 1940 (Copernicus, 2023). In 2023 the land and ocean surface average temperature was 1.09°C higher compared to the pre-industrial average, with land surface temperatures 1.59°C higher than average (IPCC, 2023). On average, 500,000 excess deaths annually are related to extreme heat during the last two decades, and it is likely that this number will increase as global temperatures rise. The average human body maintains a core temperature of around 37°C and a skin temperature of 35°C. One of the thermoregulation processes is sweat evaporating off the skin. The evaporation of sweat is only effective when the air in the atmosphere can hold more water vapor. Therefore, it is more difficult for sweat to evaporate if the air is hot and humid (Dean, 2024). A common compound measure of temperature and humidity is called web-bulb temperature (WBT), which is measured using a thermometer covered in a water-soaked cloth (Coffel et al., 2018). As water evaporates at a given humidity level, the temperature also lowers in the thermometer, accounting for the effects of evaporative cooling. For example, 35°C WBT is comparable to 40°C at 70% humidity or 45°C at 50% humidity (Julia Żuławińska et al., 2024). When the outside temperature exceeds 35°C WBT, the body's evaporative cooling becomes less effective, resulting in heat stress and unbearable conditions for humans. GHG emissions are contributing to more frequent and hotter heatwaves in Europe, North America and China (Zachariah et al., 2023). The occurrence of extreme humid heat has doubled in frequency since 1979 (Raymond et al., 2020). Currently, around 30% of the global population is exposed to dangerous temperature and humidity conditions for at least 20 days per year, and this population could increase up to 74% by 2100 if GHG emissions continue to increase (Mora et al., 2017).

The solution can be complicated. First, cutting GHG emissions is perceived as the only real approach to limit planetary warming, but the global temperature may still increase by 2.4°C compared to the 1902–1960 level even with drastic emissions reductions (Lindsey & Dahlman, 2024). Second, practical actions including urban planning can contribute to an overall risk reduction strategy (Fernandez Milan & Creutzig, 2015). For example, information on spatial distribution of the heat risk across a city can assist the planning and implementation of targeted interventions. Active and passive cooling strategies may also be considered. However, active cooling relies on electricity, which could be a contributing factor of GHG emissions. Passive cooling, on the other hand, does not require electricity. For instance, high-albedo materials such as reflective or white coatings on building or pavements can reduce air temperature in urban settings by reflecting solar energy rather than absorbing it (Santamouris et al., 2007). Low tech and low-cost solutions such as tree planting and vegetation on available surfaces have been considered useful (Moss et al., 2019). Such solutions, which are helpful in reducing heat in cities, can be scaled up to provide more habitable spaces by means of urban design. One approach to realise such benefits is "sponge cities" which have permeable pavements and green spaces to increase shade and evapotranspiration to mitigate heat impacts, absorbing rainwater for flood prevention and groundwater recharge, which provide a multi-faceted solution package for several issues (Simon, 2022).

4.4. Uninsurable future

Insurance is a risk management tool used by individuals and various organizations to safeguard themselves against damage during unexpected disasters. The damage that extreme weather events inflict is becoming more frequent and severe globally. The damage caused by weather-related disasters has increased seven-fold since the 1970s, causing insurance prices to rise and harming the viability of insurance as an option for many (Douris et al., 2021). The emission of GHGs from human activities since the advent of the industrial revolution has been accelerating the warming of the Earth's atmosphere in recent decades, leading to significant changes in climatic conditions (IPCC, 2023). Climate change continues to shift the landscape of insurance as the number of severe and frequent disasters are forecasted to double globally by 2040 (Swiss Re Institute, 2021). In places where extreme weather events increasingly cause damage, home insurance premiums have increased as much as 57% since 2015 (Debra Kamin, 2023). With the trend of increased risk of disasters and the challenge of insurance access, some areas will effectively become "uninsurable". Specifically, three criteria are identified: availability, accessibility and affordability. Once insurance is no longer available nor offered, sufficient coverage is no longer accessible, and premiums are no longer affordable, then a place can be classified as "uninsurable".

Social and economic pressures are influencing more people to flock to high-risk places along coasts, rivers, floodplains and wildland-urban interfaces (Arthur Charpentier, 2008). For example, from 1990 to 2010, the number of houses in the United States located in the wildland–urban interface grew 46% which is an area prone for wildfire risk (Mockrin et al., 1920). In the United Kingdom, over 70,000 homes built since 2009 are located in regions with the highest flood risk, including 20,000 with no physical flood protection measures (Jackson, 2020). Government decisions related to civil planning and engineering that insufficiently consider future risks impact not only individuals' exposure to disasters but also directly influence hazards. For instance, when natural soil surfaces are covered with asphalt or concrete or compacted through improper agricultural practices, rainwater absorption is hindered, leading to an increased risk of flash floods.

One obvious option to avoid catastrophic economic losses causing uninsurable areas where risk mitigation measures are unviable, is the managed relocation of people away from high-risk areas (Surminski, 2023). Investment can play a crucial role in mitigating underlying risks. Exposure to climate related hazards can be minimized by adopting innovative defenses that prioritize nature-based solutions. For instance, strategies like rewilding urban spaces and implementing hybrid infrastructure can enhance resilience to extreme weather events. An example of this approach is the restoration of shellfish reefs and adjacent coastal vegetated ecosystems in Australia (NESP Earth Systems and Climate Change Hub, 2021). Optimally, the various approaches for adaptive protection against climate change-related hazards need to be integrated as part of holistic approaches for robust infrastructure, awareness and education efforts, and collaboration with local authorities for planning to be effective (Israeli et al., 2020; Shaw, 2016). Nevertheless, even with these innovative approaches, construction in vulnerable zones must be discouraged through red-zoning, while options for strategic relocation from high-risk areas continue to be investigated.

5. What can civil engineers do in the process of climate change?

Infrastructure investment and use have a significant impact on global GHG (including carbon) emissions, and ultimately on climate change. Approximately 70% of global GHG emissions emanate from infrastructure construction and operations such as power plants, buildings and transportation systems (The World Bank, 2018). Two-thirds of these emissions are attributed to the energy sector. The current business-as-usual scenario would have considerable negative impact by 2050. Based on the current rate of emissions from key infrastructure industries, more than 720 million people would be pushed into extreme poverty, with projected deaths per year rising from 150,000 to 250,000 (WHO, 2023). The vast majority of such casualties are expected to be in emerging-market and developing economies, which are densely populated and act as global growth engines, attracting massive infrastructure investment and spending. Thus, a shift in the allocation of resources from carbon-intensive infrastructure to low-carbon infrastructure is needed. Low-carbon infrastructure helps build resilience in vulnerable countries and protects against exposure to extreme climate change events. Most importantly, low-carbon infrastructure is also crucial for preventing a reversal of development gains made so far, particularly in emerging markets and developing economies that house communities with a disproportionate exposure to climate change impacts (Pollard, 2021).

There are two main ways in which civil engineers can continue to contribute to improve social outcomes for people related to climate change. The first way is mitigation, where the aim is to reduce the amount of GHG emissions (Pollard, 2021). This can be achieved by developing renewable energy systems, using low-carbon construction materials such as timber or electrifying transport networks. Engineers can also increase the amount of carbon capture in communities that they design, through introducing more trees and green spaces (James, 2021). While focus is often placed on making changes in personal lives to reduce GHG emissions, the decisions that civil engineers make at work have greater impact. For example, concrete production is responsible for 8% of the world's CO2 emissions (Isabel Malsang, 2021). Even a small improvement to numbers of this significance makes a far bigger difference than personal lifestyle changes. Technology advancements are widening choices, such as carbon capture, utilization and storage technologies to capture up to 100% of the carbon emissions from cement manufacturing (Carbon Cure, 2020). These captured emissions can be stored safely underground, injected back into concrete to strengthen it, or used to make other products like synthetic aggregates or fuels (World Economic Forum, 2023).

The second way is adaptation, by adjusting to current or expected climate change and its effects. For civil engineers this means designing infrastructure to survive extreme weather conditions to ensure that it still provides benefits to people, even in a warming world. One example of this is the construction of flood defense schemes such as the Boston Barrier in Lincolnshire, United Kingdom, which is expected to greatly reduce the flood risk for over 14,000 homes and 800 businesses for the next 100 years (Environment Agency, 2020).

6. Concluding remarks

Synergistic approaches and integrated solutions are crucial to achieve the SDGs, overcome the climate crisis, and reduce disaster risks. The deep and complex interconnections between these agendas are starkly evident in recent disasters across the globe. Shifting to low-carbon infrastructure has massive potential to accelerate climate action and build resilience in vulnerable countries. Civil engineers can improve outcomes in both mitigation and adaptation even through incremental changes, and technological advancements are increasingly creating opportunities for greater impact.

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References

Achakulwisut, P., Erickson, P., Guivarch, C., Schaeffer, R., Brutschin, E., Pye, S., 2023. Global fossil fuel reduction pathways under different climate mitigation strategies and ambitions. Nat Commun 14, 5425.

Adeloye, A. J., & Rustum, R. 2015. Lagos (Nigeria) flooding and influence of urban planning. *Https://Doi.Org/10.1680/Udap.1000014*, *164*(3), 175–187. https://doi.org/10.1680/UDAP.1000014

Ajibade, I. 2017. Can a future city enhance urban resilience and sustainability? A political ecology analysis of Eko Atlantic city, Nigeria. *International Journal of Disaster Risk Reduction*, *26*, 85–92. https://doi.org/10.1016/J.IJDRR.2017.09.029

AILA, 2022. Climate Positive Design: Action Plan for Australian Landscape Architects. The Australian Institute of Landscape Architects.

Arora, P., 2024. COP28: ambitions, realities, and future. Environmental Sustainability 7, 107–113.

Carbon Cure. 2020. *New Low-Carbon Innovations in Cement and Concrete Production*. https://www.carboncure.com/concrete-corner/new-low-carbon-innovations-in-cement-and-concrete-production/

Charlesworth, S., Mezue, M., Maclellan, M., Warwick, F., & Bennett, J. 2016. The potential for Water Sensitivity, sustainable drainage and adaptive management in West Africa using Lagos, Nigeria, as a case study. *9th International Conference on Planning and Technologies for Sustainable Management of Water in the City*. https://hal.science/hal-03304538

Charpentier, A. 2008. Insurability of Climate Risks. *The Geneva Papers on Risk and Insurance. Issues and Practice*.

Coffel, E. D., Horton, R. M., & De Sherbinin, A. 2018. Temperature and humidity based projections of a rapid rise in global heat stress exposure during the 21st century. *Environmental Research Letters : ERL [website]*, *13*(1). https://doi.org/10.1088/1748-9326/AAA00E

Copernicus. 2023. *July 2023 sees multiple global temperature records broken | Copernicus*. https://climate.copernicus.eu/july-2023-sees-multiple-global-temperature-records-broken

Creutzig, F., Niamir, L., Bai, X., Callaghan, M., Cullen, J., Díaz-José, J., Figueroa, M., Grubler, A., Lamb, W.F., Leip, A., Masanet, E., Mata, É., Mattauch, L., Minx, J.C., Mirasgedis, S., Mulugetta, Y., Nugroho, S.B., Pathak, M., Perkins, P., Roy, J., de la Rue du Can, S., Saheb, Y., Some, S., Steg, L., Steinberger, J., Ürge-Vorsatz, D., 2022. Demand-side solutions to climate change mitigation consistent with high levels of well-being. Nat Clim Chang 12, 36–46.

Dalin, C., Y. Wada, T. Kastner, and M.J. Puma, 2017: Groundwater depletion embedded in international food trade. Nature, 543, no. 7647, 700-704, https://doi.org/10.1038/nature21403

Dean, S. 2024. *Your body's own air conditioning system*. https://spectrumlocalnews.com/nc/charlotte/weather/2022/07/23/your-body-s-own-air-conditioning-system

Dennehy, K. F., Litke, D. W., & McMahon, P. B. 2002. The High Plains Aquifer, USA: Groundwater development and sustainability. *Geological Society, London, Special Publications,* 193, 99-119. https://doi.org/10.1144/GSL.SP.2002.193.01.09

Di Maria, F., Micale, C., Sordi, A., Cirulli, G., & Marionni, M. 2013. Urban Mining: Quality and quantity of recyclable and recoverable material mechanically and physically extractable from residual waste. *Waste Management*, *33*(12), 2594–2599. https://doi.org/10.1016/J.WASMAN.2013.08.008

Dolan, T., 2024. COP28 and The First Global Stocktake: Personal Reflections on an Affirmational, Inspirational and Disappointing Experience and an Opportunity Missed. London.

Douris, J., Kim, G., Abrahams, J., Lapitan Moreno, J., Shumake-Guillemot, J., Green, H., & Murray, V. 2021. WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019) (WMO-No. 1267). *WMO Statement on the State of the Global Climate*, *1267*(1), 1–90. https://library.wmo.int/index.php?lvl=notice_display&id=21930

Energy Transitions Commission, 2023. Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels.

Environment Agency, U. 2020. *Boston Barrier flood gate fully operational*. https://www.gov.uk/government/news/boston-barrier-flood-gate-fully-operational

Fernandez Milan, B., & Creutzig, F. 2015. Reducing urban heat wave risk in the 21st century. *Current Opinion in Environmental Sustainability*, *14*, 221–231. https://doi.org/10.1016/J.COSUST.2015.08.002

Fielding, O., 2024. Decoding the Global Goal on Adaptation at COP28. New York.

Halverson, N. 2015. *What California can learn from Saudi Arabia's water mystery - Reveal*. Reveal. https://revealnews.org/article/what-california-can-learn-from-saudi-arabias-water-mystery/

Hartmann, A. 2022. The Hydrology of Groundwater Systems - From Recharge to Discharge. *Encyclopedia of Inland Waters, Second Edition*, *3*, 324–330. https://doi.org/10.1016/B978-0-12-819166-8.00097-9

Hoornweg, D., & Pope, K. 2017. Population predictions for the world's largest cities in the 21st century. *Environment and Urbanization*, *29*(1), 195–216. https://doi.org/10.1177/0956247816663557/ASSET/IMAGES/LARGE/10.1177_0956247816663557-FIG4.JPEG

IEA, 2023. World Energy Outlook 2023. Paris.

Intergovernmental Panel on Climate Change (IPCC), 2023. Climate Change 2021 – The Physical Science Basis. Cambridge University Press.

IPCC. 2023. *AR6 Synthesis Report: Climate Change 2023 — IPCC*. https://www.ipcc.ch/report/sixth-assessment-report-cycle/

IRENA, 2023. NDCs and renewable energy targets in 2023: Tripling renewable power by 2030. Abu Dhabi.

Israeli, F., Caggiano, C., Mittman, T., & DelVecchio, D. (2020). *PLANNING FOR FUTURE CONDITIONS Is Your Community Ready?*

Jackson, H. 2020. *High and dry?: Preventing tomorrow's "flood ghettos"* . Bright Blue. https://www.brightblue.org.uk/high-and-dry-preventing-flood-ghettos/

James, S., 2021. *Why should successful urban tree planting matter to engineers?* Civil Engineer blog, ICE.

Jiang, T., He, X., Su, B., Havea, P.H., Wei, K., Kundzewicz, Z.W., Liu, D., 2024. COP 28: Challenge of coping with climate crisis. The Innovation 5, 100559.

Kamin, D. 2023. *Home Insurance Premiums Rise as Americans Flock to Weather-Worn States - The*

New York Times. https://www.nytimes.com/2023/05/05/realestate/home-insurance-climate-change.html

Kundzewicz, Z. W., & Döll, P. 2009. Will groundwater ease freshwater stress under climate change? *Hydrological Sciences Journal*, *54*(4), 665–675. https://doi.org/10.1623/HYSJ.54.4.665

Lindsey, R., & Dahlman. L. 2024. *Climate Change: Global Temperature*. Climate.Gov.

Malsang, I. 2021. *Concrete: the world's 3rd largest CO2 emitter*. Phys.Org. https://phys.org/news/2021-10-concrete-world-3rd-largest-co2.html

Markandya, A., González-Eguino, M., 2019. Integrated Assessment for Identifying Climate Finance Needs for Loss and Damage: A Critical Review. pp. 343–362.

Mockrin, M. H., Fishler, H. K., Kramer, H. A., Radeloff, V. C., & Stewart, S. I. 1920. A Tale of Two Fires: Retreat and Rebound a Decade After Wildfires in California and South Carolina. *Society & Natural Resources*, *35*, 875–895. https://doi.org/10.1080/08941920.2022.2081895

Mora, C., Dousset, B., Caldwell, I. R., Powell, F. E., Geronimo, R. C., Bielecki, C. R., Counsell, C. W. W., Dietrich, B. S., Johnston, E. T., Louis, L. V., Lucas, M. P., Mckenzie, M. M., Shea, A. G., Tseng, H., Giambelluca, T. W., Leon, L. R., Hawkins, E., & Trauernicht, C. 2017. Global risk of deadly heat. *Nature Climate Change 2017 7:7*, *7*(7), 501–506. https://doi.org/10.1038/nclimate3322

Moss, J. L., Doick, K. J., Smith, S., & Shahrestani, M. 2019. Influence of evaporative cooling by urban forests on cooling demand in cities. *Urban Forestry & Urban Greening*, *37*, 65–73. https://doi.org/10.1016/J.UFUG.2018.07.023

Mousa, H. 2022. *Food and Agricultural Import Regulations and Standards Country Report*.

Naylor, A.W., Ford, J., 2023. Vulnerability and loss and damage following the COP27 of the UN Framework Convention on Climate Change. Reg Environ Change 23, 38.

NESP Earth Systems and Climate Change Hub, A. 2021. *The Australian guide to nature-based methods for reducing risk from coastal hazards*.

Newman, R., Noy, I., 2023. The global costs of extreme weather that are attributable to climate change. Nat Commun 14, 6103.

Novo, C. 2019. *Saudi Arabia's groundwater to run dry*. https://smartwatermagazine.com/blogs/cristina-novo/saudi-arabias-groundwater-run-dry

Oteng-Peprah, M., Acheampong, M. A., & deVries, N. K. 2018. Greywater Characteristics, Treatment Systems, Reuse Strategies and User Perception—a Review. *Water, Air, and Soil Pollution*, *229*(8), 1–16. https://doi.org/10.1007/S11270-018-3909-8/TABLES/6

Panagopoulos, A., & Haralambous, K. J. 2020. Environmental impacts of desalination and brine treatment - Challenges and mitigation measures. *Marine Pollution Bulletin*, *161*, 111773. https://doi.org/10.1016/J.MARPOLBUL.2020.111773

Pflieger, G., 2023. COP27: One step on loss and damage for the most vulnerable countries, no step for the fight against climate change. PLOS Climate 2, e0000136.

Pollard, K., 2021. *Everything we thought we knew about civil engineering improving the world is wrong.* ICE Community blog.

Raymond, C., Matthews, T., & Horton, R. M. 2020. The emergence of heat and humidity too severe for human tolerance. *Science Advances*, *6*(19). https://doi.org/10.1126/SCIADV.AAW1838

Remi, J., & Adegoke, I. 2011. An Appraisal of the Factors Influencing Rural-Urban Migration in Some Selected Local Government Areas of Lagos State Nigeria. *Journal of Sustainable Development*, *4*(3). https://doi.org/10.5539/jsd.v4n3p136

Richey, A. S., Thomas, B. F., Lo, M. H., Reager, J. T., Famiglietti, J. S., Voss, K., Swenson, S., & Rodell, M. 2015. Quantifying renewable groundwater stress with GRACE. *Water Resources Research*, *51*(7), 5217–5238. https://doi.org/10.1002/2015WR017349

Roberts, D. 2020. *Sustainable building: The hottest new material is, uh, wood - Vox*. https://www.vox.com/energy-and-environment/202

0/1/15/21058051/climate-change-building-materials-mass-timber-cross-laminated-clt

Sachs, J.D., Lafortune, G., Fuller, G. 2024. The SDGs and the UN Summit of the Future. Sustainable Development Report 2024. Paris: SDSN, Dublin: Dublin University Press. https://doi.org/10.25546/108572

Santamouris, M., Pavlou, K., Synnefa, A., Niachou, K., & Kolokotsa, D. 2007. Recent progress on passive cooling techniques: Advanced technological developments to improve survivability levels in low-income households. *Energy and Buildings*, *39*(7), 859–866. https://doi.org/10.1016/J.ENBUILD.2007.02.008

Shaw, R. , C. M. , and C. R. 2016. *Climate change adaptation by design - a guide for sustainable communities*. Climate-ADAPT . https://climate-adapt.eea.europa.eu/en/metadata/guidances/climate-change-adaptation-by-design-a-guide-for-sustainable-communities

Simon, M. 2022. *If You Don't Already Live in a Sponge City, You Will Soon | WIRED*. https://www.wired.com/story/if-you-dont-already-live-in-a-sponge-city-you-will-soon/

Surminski, S. 2023. *Staying above water: a systemic response to rising flood risk*. https://www.marshmclennan.com/insights/publications/2023/february/staying-above-water-a-systemic-response-to-rising-flood-risk.html

Swiss Re Institute. 2021. *Global property & casualty insurance premiums expected to more than double to USD 4.3 trillion by 2040, Swiss Re Institute forecasts*.

Thacker, S., Adshead, D., Fay, M., Hallegatte, S., Harvey, M., Meller, H., O'Regan, N., Rozenberg, J., Watkins, G., Hall, J.W., 2019. Infrastructure for sustainable development. Nat Sustain 2, 324–331.

The World Bank. 2018. *Low-Carbon Infrastructure Private Participation in Infrastructure (PPI)*.

United Nations. 2015a. Transforming our World: the 2030 Agenda for Sustainable Development. A/RES/70/1. https://undocs.org/en/A/RES/70/1

United Nations. 2015b. Paris Agreement. C.N.92.2016. TREATIES-XXVII.7.d of 17 March 2016 (Certified true copies). https://treaties.un.org/doc/Treaties/2016/02/20160215%2006-03%20PM/Ch_XXVII-7-d.pdf

United Nations. 2017. Resolution adopted by the General Assembly on Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development (A/RES/71/313). https://undocs.org/A/RES/71/313

United Nations. 2024. Progress towards the Sustainable Development Goals. Report of the Secretary-General. https://unstats.un.org/sdgs/files/report/2024/secretary-general-sdg-report-2024--EN.pdf

United Nations Department of Economic and Social Affairs. 2024. SDG Localization and the Voluntary Local Reviews. Accessed 27 June 2024. https://sdgs.un.org/topics/voluntary-local-reviews

UNEP. 2022. *Sand and Sustainability: 10 strategic recommendations to avert a crisis*. www.un.org/Depts/Cartographic/

UNESCO. 2023. Report of the World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) on The Ethics of Climate Engineering. Paris.

UNFCCC. 2022. Sharm el-Sheikh Implementation Plan. Decision -/CP.27.

UNFCCC, 2023. Outcome of the first global stocktake . Draft decision -/CMA.5.

UNFCCC. 2024. Glasgow-Sharm el-Sheikh work programme on the global goal on adaptation referred to in decision 7/CMA.3. Decision -/CMA.5

UNOPS. 2021. Infrastructure for climate action. Copenhagen.

UN-Water. 2022. *UN World Water Development Report 2022*. https://www.unwater.org/publications/un-world-water-development-report-2022

Wernersson, L., Román, S., Fuso Nerini, F., Mutyaba, R., Stratton-Short, S., Adshead, D., 2024. Mainstreaming systematic climate action in energy infrastructure to support the sustainable development goals. npj Climate Action 3, 28.

WHO. 2023. *Climate change*. https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

WIPO, 2023. Green Technology Book: Solutions for climate change mitigation. Geneva.

WMO, 2023. State of the Climate in Africa 2022. Geneva.

WMO, 2024. State of the Climate in Asia 2023.

World Economic Forum. 2023. *Low-carbon concrete: Is the future now?* https://www.weforum.org/agenda/2023/01/low-carbon-concrete-is-the-future-now-emissions/

Zachariah, M., Philip, S., Pinto, I., Vahlberg, M., Singh, R., Otto, F., Barnes, C., & Kimutai, J. (2023). *Extreme heat in North America, Europe and China in July 2023 made much more likely by climate change*. https://www.worldweatherattribution.org/extreme-heat-in-north-america-europe-and-china-in-july-2023-made-much-more-likely-by-climate-change/

Żuławińska, J., Szyk, B., & Bowater, J.. 2024. *Wet Bulb Calculator*. https://www.omnicalculator.com/physics/wet-bulb