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Climate

Carbon Emissions: Global Picture and Forecast

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Economic progress and social development are tied to energy use, transportation and consumption. Achieving sustainable advancement becomes nearly impossible without acknowledging and mitigating the significant environmental impact associated with the cumulative effect of carbon emissions over time. It underscores the historical reliance of most countries on fossil fuels for their growth and development and the efforts that will be needed to decouple economic growth from carbon emissions including from fossil fuel combustion, deforestation, land use changes, waste management, manufacturing processes and land degradation. A growing global population inevitably increases energy, food and economic demands, and Africa is at the front of the queue.

Emissions can be calculated variously, such as by the economic sector (construction, transportation, energy, etc.), and methodologies and numbers differ between agencies and organisations. According to the Intergovernmental Panel on Climate Change (IPCC), around 86% of global carbon dioxide emissions in 2020 were due to fossil fuels and industry processes (70-75% directly from fossil fuel combustion and 10-15% from industrial processes). In this theme, our focus is on carbon emissions from fossil fuels (coal, oil and gas), unless indicated otherwise.

Among the three sources of fossil fuels, coal has the most significant carbon emissions. Natural gas produces lower carbon emissions and air pollution than coal and oil but releases methane (a potent greenhouse gas) and other non-CO_2 pollutants. Methane is more than 80 times more potent than carbon dioxide as a greenhouse gas when considered over 20 years. As a result, even small methane emissions can have a significant climate impact. In 2021, natural gas production accounted for 40 million tons of methane emissions, roughly equivalent to the methane emissions generated by the entire oil industry.

According to the International Energy Agency (IEA), coal contributed almost 44% of global carbon emissions from fuel combustion in 2021, closely following oil at 32% and natural gas at 22%. However, whereas oil and coal can be loaded and transported in bulk over long distances, such as by ship, transporting natural gas in bulk over long distances requires a pipeline or by compressing and cooling it down to form liquefied natural gas (or LNG) prior to movement, which then has to be regasified again on the other side - an extremely energy intensive and costly process. Emissions increase if the LNG is mainly produced from shale gas that emits a substantial amount of methane, which increases during liquefaction and tanker transports, as is the case with the United States, now the world's largest exporter. According to Robert Howarth's writing in 2024

Shale gas production is quite energetically intensive, and the related carbon dioxide need to be considered in any full lifecycle assessment of the greenhouse gas emissions associated with LNG. Further, methane emissions from shale gas can be substantial. Since 2008, methane emissions from shale gas in the US may have contributed one-third of the total (and significant) increase in atmospheric methane globally.

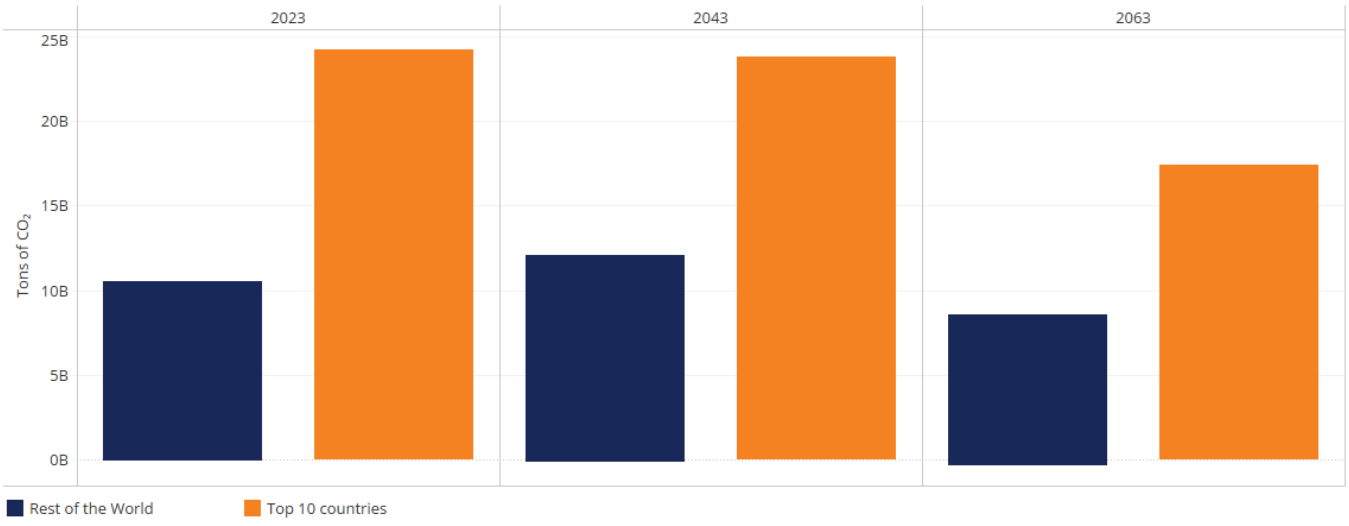
Howarth's analysis concluded that LNG is 33% worse in greenhouse gas emissions over 20 years than coal and is often not cost-competitive with other fossil fuels. Even 100 years after emission, the LNG footprint from methane equals or exceeds that of coal. The results of that study made the Biden administration reconsider increased LNG exports pending further analysis of the consequences.

Concerns regarding the impact of carbon emissions have led to a dramatic increase in renewables, particularly solar and wind. In its 'Renewables 2024' report, the IEA states that 510 gigawatts (GW) of renewable energy capacity was installed globally in 2023, increasing the installed base to about 3 600 GW, with solar photovoltaic (PV) accounting for three-quarters of worldwide additions.

Chart 5 presents the progression of global carbon emissions from fossil fuels (i.e. excluding emissions from other sources

such as deforestation and manufacturing) since 1990, with a forecast to 2063. In 2020, due to the significant economic slowdown caused by the COVID-19 pandemic, global emissions from energy combustion and industrial processes decreased by 5.8% compared to 2019. Then, as economic activities bounced back from the pandemic, emissions rebounded sharply. By 2023, CO_2 from fossil fuels has surged to over five times the levels observed in 1960, reaching 36.1 billion tons of CO_2 equivalent annually (the most ever recorded). The most significant contributors to these emissions are China, the USA, India, Russia, Japan, Indonesia, Iran, Germany, Saudi Arabia and South Korea. These top 10 global emitters collectively account for a substantial 69% of global fossil fuel emissions, 61% of the world's GDP and house 60% of the worldwide population.

Chart 5: CO_2 emissions for top 10 emitters vs the rest of the World, 2023-2063



Source: IFs 8.34 initialising from Appalachian State University data

Despite gradual shifts in developed economies toward renewable energy sources, current mitigation efforts remain insufficient. As of 2024, atmospheric carbon dioxide (CO) concentrations have reached unprecedented levels, with a measured concentration of 427 parts per million (ppm) (Chart 2), a significant increase from pre-industrial levels of 280 ppm. Without a solid collective response and without a breakthrough in carbon sequestration technologies, atmospheric concentrations will accumulate, reaching 551 ppm by 2063 and 569 ppm by the end of the century. The Intergovernmental Panel on Climate Change Sixth Assessment Report states that atmospheric concentrations in 2050 should be around 330 to 400 ppm to keep the 1.5°C ambition alive. Such elevated atmospheric CO_2 levels pose a significant risk, intensifying global warming and placing the world on a trajectory that can see global temperatures rise by at least 3°C above pre-industrial levels by the end of the century. It will intensify the adverse impacts on ecosystems, weather patterns and vulnerable communities particularly in Africa which has the least capacity to cope. Thus, 'the world has been locked into a path that will force us to focus on adaptation for survival.'[1] Without decisive action, the escalating trajectory of CO concentrations will continue to drive severe climate-related challenges globally, potentially triggering critical tipping points.

The Current Path suggests an increase in carbon emissions from fossil fuels with a peak of 37.14 billion tons of CO_2 equivalent per annum in 2037/8 and subsequent rapid decline back to 2020 emission levels in by 2049, aligning with various Nationally Determined Contributions (NDCs) and ongoing global initiatives to decarbonise economies. The plateauing and decline is primarily driven by expected emission reductions from China, the US, India and Europe. Still, the eventual rate of decline will be principally affected by what happens with carbon emissions from Africa, given its current low levels of development, energy deficits, high rate of addiction to fossil fuels compared to other regions, and rapidly growing population.

China, the largest carbon emitter globally, is rapidly shifting from fossil fuels to renewables, evidenced by a significant increase in low-carbon electricity generation, especially from wind and solar sources. The substantial investments in low-carbon technologies, such as solar, electric vehicles and batteries, reflect the nation's stance on domestic and international climate policies. While China's substantial reliance on coal for energy may keep emissions elevated in the coming decade, the surging investments in clean energy production and its NDC commitments will see the country emerge as a critical player in the global transition towards cleaner energy sources.

The United States, currently the world's second-largest greenhouse gas emitter, is experiencing a more gradual tardy reduction in emissions - the result of fluctuating commitments to climate policies. The country is heavily dependent on fossil fuels, and the significant setbacks caused by the first Trump administration, which withdrew from the Paris Agreement and dismantled key carbon reduction policies like the Clean Power Plan. According to a study by the Rhodium Group, President Trump's actions during those years are estimated to have contributed an additional 1.8 billion tons of CO_2 into the atmosphere by 2035. The Biden administration subsequently made notable strides in recommitting to the Paris Agreement and investing in renewable energy infrastructure (most prominently with the introduction of the Inflation Reduction Act in 2022). The return of Trump to the White House in 2025 has already undone some of this progress. Already Trump signed an executive order to withdraw the US from the Paris Agreement for a second time. Looking ahead, the US appears to be placing emphasis on technological advancements within the petroleum and gas industries, such as green hydrogen production and carbon sequestration projects. However, these technologies are still in developmental stages and have not yet been proven at scale.

Compared with China, India and the US, the EU27 has the most comprehensive approach to combating climate change, including efforts to spur changes in consumer behaviour to cut emissions drastically. Other efforts include setting vehicle emission targets, defining requirements for building renovations, and adopting carbon pricing by expanding its market-driven emissions trading scheme at the heart of Europe’s decarbonisation plan. The result, the European Green Deal, embeds emission targets within the EU27 industrial policy. In the process, the EU has now legally enshrined its commitment to reduce emissions by at least 55% by 2030 compared to 1990 levels and achieve net-zero emissions by 2050.[2] Among other measures, the EU has started phasing in a carbon border adjustment mechanism (EU CBAM) since May 2023.

Emerging economies are contributing an ever-growing percentage to the global total emissions. With a rapidly growing population and expanding industrial sector, India is set to increase its carbon emissions significantly in the coming decades. The country's heavy reliance on coal for energy production and its ambitious development goals present a considerable challenge in mitigating greenhouse gas emissions. Despite efforts to diversify its energy mix and promote renewable energy sources, coal continues to dominate India's energy sector due to its affordability and accessibility.

India's industrial growth and urbanisation further contribute to rising emissions as manufacturing, construction and transportation sectors expand to meet the demands of a growing population and economy. Moreover, the country's reliance on fossil fuels for transportation and household energy needs adds to its carbon footprint. As a result, India may overtake the US to become the world's 2nd-largest carbon emitter by mid-century, with Russia in fourth position, followed by Indonesia.

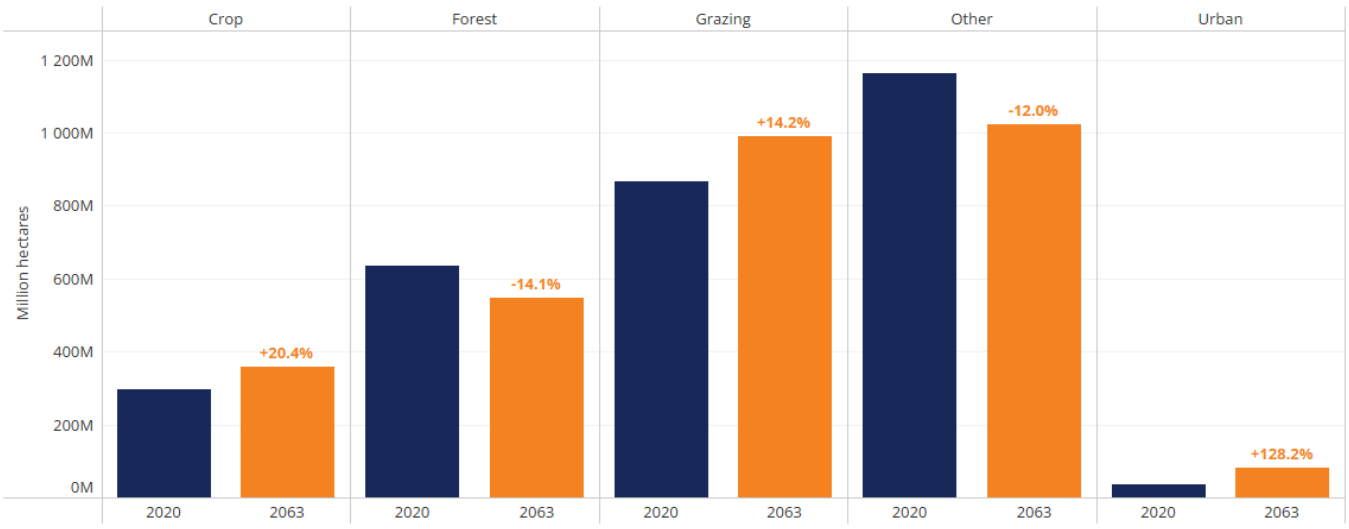
A growing population and significant land use changes, including deforestation of its rainforests, drive Indonesia’s associated increased carbon emissions.

Nigeria will likely emerge at the 9th spot globally (and largest emitter from Africa) by 2050, followed by Egypt at number twelve. Iran, Japan, Canada, Turkey and Pakistan are all likely to be part of the top tier of countries that emit large volumes of carbon from fossil fuel use.

While Chart 5 depicts carbon emissions from burning fossil fuels, the contribution from land use management practices (deforestation, agriculture, soil erosion and changes in land use) is also important. Second to energy, the agriculture sector is responsible for most carbon emissions. Land use change and management (e.g. clearing forests or grasslands for agricultural fields) is a significant source of greenhouse gas emissions. In contrast, undisturbed and flourishing land ecosystems that serve as important carbon sinks. In addition to the substantial role of forests in carbon sequestration, grassy ecosystems (such as savanna and grasslands) store a significant amount of carbon in the soil, primarily within their extensive root systems and decaying organic matter. Grasses account for over half of the soil carbon content across tropical savannas, highlighting the need to avoid cultivating and tilling them.

Globally, agricultural land is expanding, with a growing global population and increasing food needs. In Africa, crops, grazing and urban land have been expanding unabatedly at the cost of forests and grasslands. In the last three decades, 100 million hectares of forest have been cleared to make way for 66 million hectares of crop land[3]. In the Current Path (Chart 6), forests in Africa will shrink by 14% from 2023 to 546 million hectares by 2063. Much of this will come as cropland in Africa expands from 301 million hectares in 2023 to 357 million hectares, while grazing land will grow from 876 million to 990 million hectares. As Africa's population expands and urbanises, subsequent urban land will almost double from 37 million hectares in 2023 to 80 million hectares in 2063 (see the theme on Agriculture).

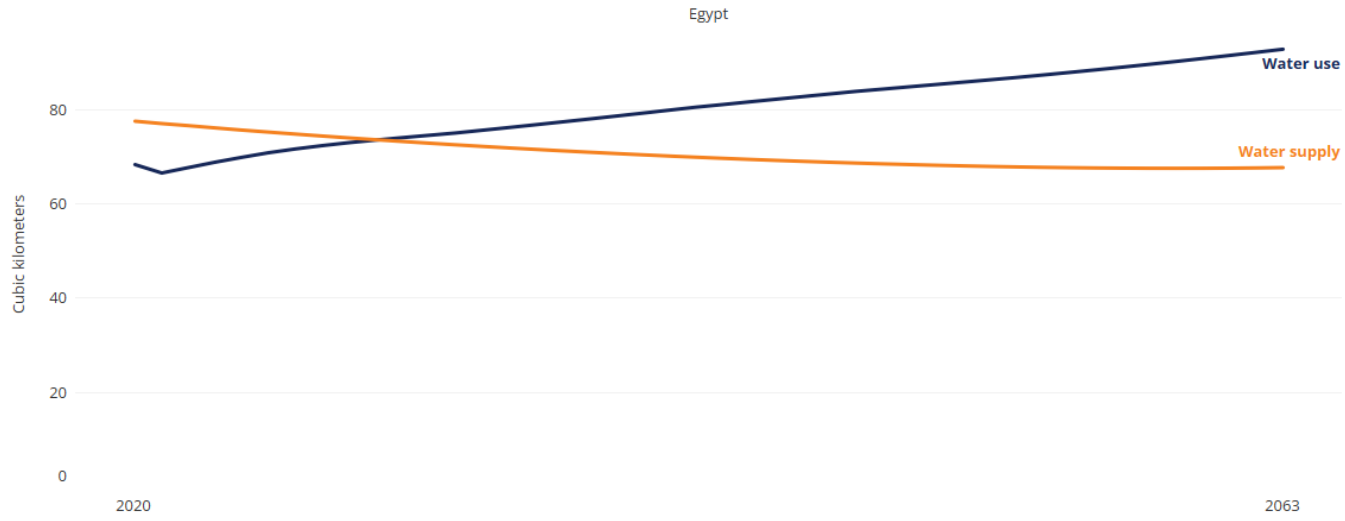
Chart 6: Land use by type, 2020-2063



Source: IFs 8.34 initialising from FAOSTAT data

Another concerning trend is the increased annual water use resulting from a rapidly growing African population and improved agricultural land and food production. Annual water use exceeded supply in 21 African countries in 2023 (Chart 7). A growing population and intensified agricultural practices will lead to overexploitation of water resources, resulting in several interconnected challenges, such as water scarcity, competition for limited water supplies, environmental degradation and potential conflicts over water access. This worrisome projection underscores the urgent need for comprehensive water governance, cooperation and management strategies to address the growing demands of population expansion and intensified agricultural activities. The IPCC's 6AR further emphasises the critical importance of sustainable water practices, highlighting the potential implications of climate change on water resources and the need for adaptive measures to ensure resilience in the face of evolving environmental conditions such as droughts.

Chart 7: Water use vs supply, 2020-2063



Source: IFs 8.34 initialising from FAO aquastat

Every African country needs proactive, climate-smart and science-based policies to mitigate the adverse effects of increased water use on ecosystems and communities. For example, water conservation measures such as rainwater harvesting and drip irrigation or investing in ecosystem restoration can significantly enhance resilience to climate change and mitigate water scarcity impacts.

Endnotes

1. Food and Agriculture Organization of the United Nations (FAO)
2. Vulnerability refers to a catch phrase that encompass socio economic vulnerability (inclusive of household composition, education, health status, basic service access, safety and security constraints and inequality)
3. internal displacement monitoring centre

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Ms Alize le Roux joined the AFI in May 2021 as a senior researcher. Before joining the ISS, she worked as a principal geo-informatics researcher at the CSIR, supporting various local and national policy- and decision-makers with long-term planning support. Alize has 14 years of experience in spatial data analysis, disaster risk reduction and urban and regional modelling. She has a master's degree in geographical sciences from the University of Utrecht, specialising in multi-hazard risk assessments and spatial decision support systems.

Dr Jakkie Cilliers is the ISS's founder and former executive director. He currently serves as chair of the ISS Board of Trustees and head of the African Futures and Innovation (AFI) programme at the Pretoria oce of the Institute. His 2017 best-seller Fate of the Nation addresses South Africa's futures from political, economic and social perspectives. His three most recent books, Africa First! Igniting a Growth Revolution (March 2020), The Future of Africa: Challenges and Opportunities (April 2021), and Africa Tomorrow: Pathways to Prosperity (June 2022) take a rigorous look at the continent as a whole.

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