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Briefing: Stocktaking Global Warming – The Outcomes of the 2023 Dubai Climate Summit (COP28)†

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ABSTRACT

This article reviews outcomes of the 28th United Nations Climate Change *Conference of the Parties* (COP28) held in Dubai, United Arab Emirates in late 2023. In particular, it considered the first *Global Stocktake* [GST] of actions taken by signatory nations to the *2015 Paris Agreement on Climate Change*. The GST examined the potential impact of *bottom-up* national pledges on 'greenhouse gas' [GHG] mitigation required to limit global warming to 1.5°C above pre-industrial levels by the end of the 21st Century. The achievements at COP28 were mixed, and disappointed many from the climate-vulnerable states at high risk from extreme weather events and rising sea levels. There is a significant GHG emissions gap between that needed to "keep 1.5°C alive" and climate actions identified in the GST. Nonetheless, the Parties agreed to "transition away from fossil fuels in energy systems" in order to reach net zero GHG emissions (i.e., carbon neutrality) by 2050, and to triple renewable energy capacity and double energy efficiency by 2030. The present assessment sets out the background to what needs to be achieved at future annual COP summits, including the next GST at COP30 to be held in the Brazilian city of Belém later in 2025.

Keywords: Climate change; Energy; Sustainability

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1. Global climate change impacts

1.1 Earth System Science and Global Warming

During the past year, the world has experienced record-breaking temperatures and extreme weather events (UNEP, 2023). These have included dramatic floods in Libya that killed more than 6000 people (Waskow *et al.*, 2023) and damaged critical infrastructure in that civil-war-ravaged country, and severe wildfires in Canada that burned an area the size of Syria. Global warming (sometimes-called 'global heating') is contributing to such events (Clarke *et al.*, 2022). This phenomenon is depicted in Figure 1 (Cohen *et al.*, 2022), where the complex thermal interactions are illustrated schematically. In simple terms (Hammond, 2000), a thin atmospheric 'blanket' surrounds the Earth and protects it from the severity of incoming short-wave solar radiation. Trace gases in the upper atmosphere, and clouds nearer the surface, then reflect a proportion of the Sun's rays back out into space. The land and oceans absorb the solar radiation that does get through the atmospheric blanket. These warmer surfaces in turn re-radiate infrared, or long-wave thermal radiation back to the atmosphere. Some of the trace gases then absorb, or trap, this heat [see again Figure 1] in an analogous manner to the action of glass in a greenhouse. Consequently, these radiation-absorbing gases are known as 'greenhouse gases' [GHGs].

Human activities since 1950, primarily those that involve burning fossil fuels, have led to

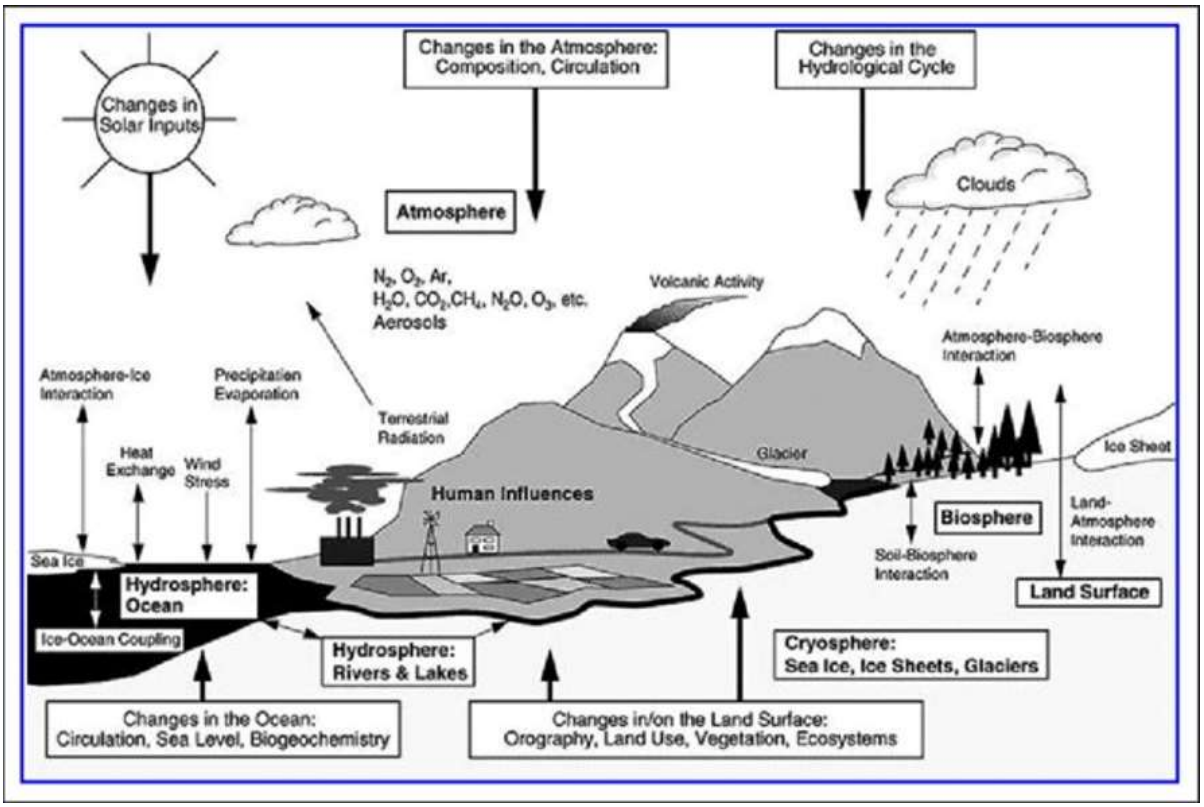


Figure 1. Schematic representation of the physical components within the global climate system [bold], their processes and interactions [thin arrows], and some aspects that might change due to global warming [bold arrows]. *Source:* Cohen *et al.* (2022); adapted from Fagmous and Kumar (2014) and IPCC (2001).

dramatic increases in atmospheric concentrations of carbon dioxide [CO_2] from 330 *parts per million* [ppm] in 1975 to about 420 ppm in 2023 (Cohen *et al.*, 2022; Hammond, 2022; Houghton, 2009; IPCC, 2023).CO_2 is the dominant GHG with an atmospheric residence time of 50-200 years (Archer and Brovkin, 2008). Such changes in atmospheric concentrations of GHGs affect the energy balance of the global climate system, giving rise to higher surface air temperatures and extreme weather events that are having significant impacts on the biosphere (CAT, 2023; Hammond 2000 and 2022; IPCC, 2023; Waskow *et al.*, 2023; WMO, 2023).

1.2 Groundwork for the COP: Scientific Assessments of Climate Change

Several reports were published by international bodies ahead of the recent 28th UNFCCC *Conference of the Parties* [COP28] held in Dubai {United Arab Emirates [UAE]} over 30 November – 12 December 2023. The *Intergovernmental Panel on Climate Change* [IPCC], in its most recent [2023] scientific assessment, asserts that human activities, principally through GHG emissions, have 'unequivocally' caused observed global warming since the mid-20th Century (IPCC, 2023), with mean global surface temperature reaching 1.1°C above 1850-1900 levels during 2011-2020. Global mean sea levels are continuing to rise, with the extent of Arctic and Antarctic sea-ice well below average.

The IPCC (2023) point to a large, ongoing implementation gap between projected GHG emissions under current policies – that is, the emissions aspired to – and those in the *Nationally Determined Contributions* [NDCs], or emissions reduction pledges, by individual countries, that are actually being implemented. The *UN Environment Programme* [UNEP] called on all nation-states to accelerate economy-wide, low-carbon development in order to bring down GHG emissions to levels consistent with 1.5-2°C pathways (UNEP, 2023), as recommended at the *2015 Paris Agreement* on climate change (Burnett, 2023; IPCC, 2023; UNFCCC, 2015). UNEP found that predicted 2030 GHG emissions from current policies were fall short by 28% of those estimated to be compatible with a 2°C pathway and by 42% of its 1.5°C counterpart (UNEP, 2023). They argue that industrialised countries with greater capacity and responsibility for global emissions should take more ambitious climate action and support developing, often climate-vulnerable, nations in the 'Majority South' to pursue their own low-emissions development. These findings were underpinned by a report from the *International Energy Agency* (IEA, 2023a), a Paris-based autonomous intergovernmental organisation, that estimated a comparable 30% emissions gap that they argued needs to be bridged in order to limit global warming to 1.5°C above pre-industrial levels.

The *World Meteorological Organisation* (WMO; 2023), in a provisional evaluation of the global climate, observed that GHG concentrations {specifically the 'Big Three': CO_2, methane [CH_4] and nitrous oxide [N_2O]} continued to rise in 2023, now confirmed as the hottest year on record [with global mean near-surface temperature 1.46°C above pre-industrial levels (WMO, 2023). Surface sea temperatures and sea levels both rose, whilst Antarctic sea ice was at its lowest extent since the satellite era began in1979. This was linked to extreme weather and

climate conditions (WMO, 2023) that helped to trigger wildfires in Hawaii, Canada and Europe, as well as flooding from Mediterranean Cyclone Daniel that severely impacted Bulgaria, Greece, Turkiye, and especially Libya. These conditions also induced food shortages, population migrations, and related impacts on vulnerable communities across the globe. A consortium of climate and resource non-governmental bodies produced a '*State of Climate Action 2023*' report under the umbrella of the *Systems Change Lab* [SCL], a joint effort of the *Bezos Earth Fund*, *Climate Action Tracker* [CAT], *ClimateWorks Foundation*, *The UN Climate Change High-Level Champions*, and the *World Resources Institute* [WRI] (Hammond, 2023; SCL, 2023). In their sectoral report card the SCL indicates that mitigation actions are not at the required pace and scale to reach the 1.5°C pathway; only one of 42 indicators they assessed - the share of electric vehicles in passenger car sales - was on track to reach its 2030 target. The pace is insufficient for six other indicators, well below the required speed for another twenty-four, and recent trends are in the wrong direction entirely for a further six.

1.3 Energy Systems as Contributors to Climate Change

Power generation, along with fuel use in buildings, industry and the transport sector was responsible for the bulk of global anthropogenic [i.e., human-induced] GHG emissions in 2022. Land use, land use change and forestry [LULUCF] accounted for only some 20% (IPCC, 2023; Lui *et al.*, 2023; Statista, 2023). Energy systems are therefore at the heart of the climate change agenda. However, national contributions towards global warming are obviously not equally distributed (UNEP, 2023). The six highest-emitter nations in 2022 were: the People's Republic of China [PRC] – 12.1 Gt [29.2%] of total GHG emissions; the USA – 4.7 Gt [11.2%]; India – 3.0 Gt [7.3%]; the EU-27 - 2.8 Gt [6.7%]; the Russian Federation – 2.0 Gt [4.8%]; and Brazil – 1.0 Gt [2.4%] (IEA, 2023a; Statista, 2023). These figures are mirrored in the CO_2 emissions per capita displayed in Figure 2 (Ritchie *et al.*, 2023), although this excludes those due to LULUCF. Here the UAE and some of the other oil-producing nations, or 'petrostates', are seen to be the largest emitters per head of population, followed by the USA, Australia, Canada, and the Russian Federation. China, the highest overall emitter, is ranked much lower than these countries on this basis. Per capita emissions are associated with the *Gross Domestic Product* per capita of the nations concerned, although the relationship is nonlinear – per capita emissions vary considerably between wealthy nations, indicating the scope for decoupling emissions from economic growth.

Emissions from fuel combustion in the PRC grew slightly during 2022 due to an increase in coal use, but this was more than offset by falls in emissions from industrial processes. There was a large increase in solar photovoltaic [PV] and wind turbine generation for power production; nevertheless, coal still accounted for about 60% of Chinese fuel supply into electricity generation. The overall outcome was a slight decline in CO_2 emissions of 0.2% (IEA, 2023a). In contrast, emissions in the USA grew by a little less than 1% in 2022, mainly caused by rising natural gas demand. Indigenous gas supply has been greatly aided by fracking processes (Hammond and O'Grady, 2017), and has been able to meet all US requirements. In 2022, India experienced a notable 6% increase in CO_2 emissions, primarily driven by a 5%

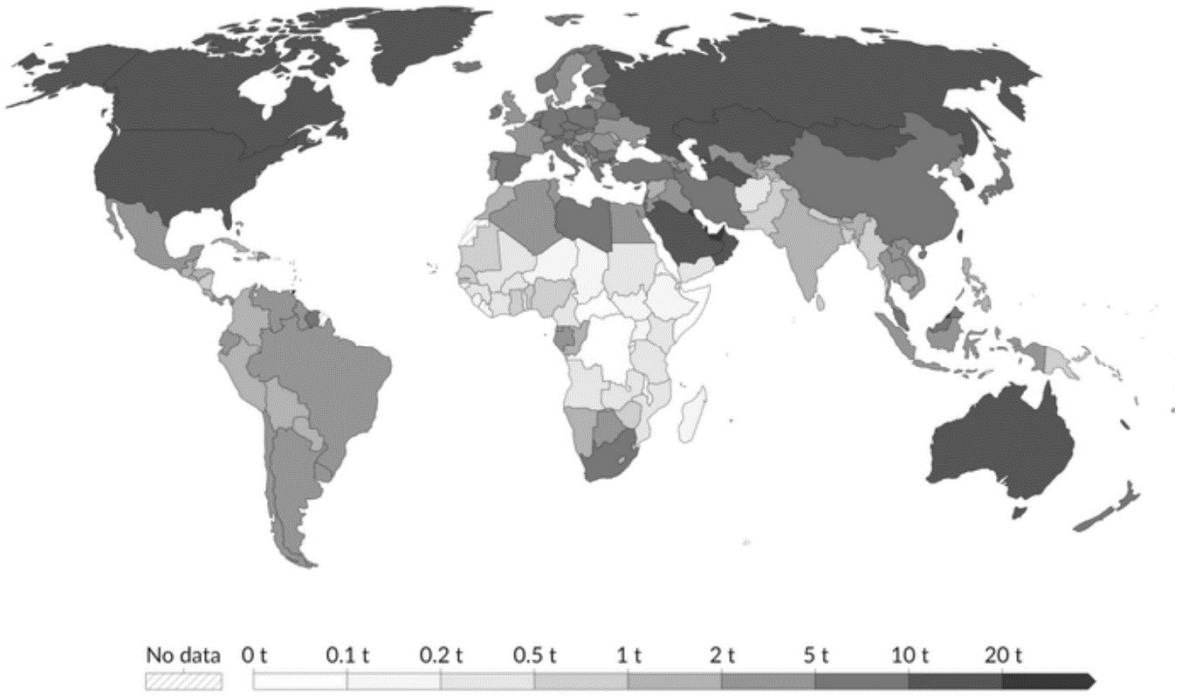


Figure 2. Per capita carbon dioxide [CO_2] emissions for countries around the world in 2022. These include emissions from fossil fuels and industry, but not those associated with land use change. *Source:* adapted from Ritchie *et al.* (2023).

increase in coal emissions and with a projected rise of around 10% in oil emissions. In contrast, emissions from natural gas were projected to decline by about 4%. These figures underscore the challenges India faces in balancing developmental needs with its commitment to addressing climate change.

The energy crisis created by the Russian-Ukraine war, initiated in February 2022, pushed the European Union [EU] to mitigate anthropogenic GHG emissions via investments in clean power and energy demand reduction measures. Russian natural gas imports fell by two-thirds, somewhat offset by higher coal and oil consumption. Despite these market disruptions, along with hydro-power shortfalls caused by drought and numerous nuclear power plants going offline, EU emissions fell by 2.5% in 2022 due to a mild winter, effective energy conservation measures, fuel switching, and falls in industrial production (IEA, 2023a).

2. The United Nations COP process, COP28 and its host

The *UN Framework Convention on Climate Change* [UNFCCC] is an international environmental treaty to combat "dangerous human interference with the climate system". In large measure, this was aimed at stabilising atmospheric GHG concentrations. It borrowed its structure from the highly successful 1987 *Montreal Protocol on Substances that Deplete the Ozone Layer* (Houghton, 2009); a landmark multilateral agreement that regulates production and consumption of nearly 100 human-produced chemicals termed 'ozone depleting substances' like chlorofluorocarbons [CFCs], then used as refrigerants and aerosols. The UNFCCC was signed by 154 nation-states at the *UN Conference on Environment and*

Development [UNCED], commonly known as the 'Earth Summit', held in Rio de Janeiro in June 1992; in entered into force in March 1994. The principal decision-making body of the UNFCCC became the *Conference of the Parties* [COP], which now meets annually to assess the steps taken in tackling global warming. The 'Parties' are normally nation-states and regional bodies such as the EU.

The first instrument agreed under the UNFCCC in 1997 was the *Kyoto Protocol* (Houghton, 2009), which operated from 2005 – 2020 and sought to restrict a basket of six GHGs. It was essentially a 'top down' initiative, allocating goals for emission reduction according to judgements on a country's stage of industrial development as well as its emissions history; the absence of some high-emitter, emerging economies like China and India, was a continuing irritant in negotiations, notably to the USA. The Kyoto Protocol was superseded by the *2015 Paris Agreement* on climate change (UNFCCC, 2015) that potentially included all nation-states. It aimed to keep temperatures "well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Burnett, 2023; Cohen *et al.*, 2022; Gao *et al.*, 2017; Hammond, 2021; IPCC, 2018; IPCC, 2023). The Agreement marked a major change to a 'bottom up' approach: signatory nations were to prepare *bottom-up* national pledges on GHG mitigation efforts: *Nationally Determined Contributions* (NDCs). The recent 28th UNFCCC *Conference of the Parties* [COP28] held in Dubai [UAE] over 30 November – 12 December 2023 was the first COP to take place after a *Global Stocktake* [GST] of progress made by signatories to the *Paris Agreement*. Thus, it enabled a process whereby stakeholders can see where they are collectively in terms of meeting the *Paris Agreement* target (Townsend, 2023; Townsend and Åberg, 2023).

The UAE, the host nation for COP28, is a federation of seven emirates on the southern shore of the Arabian Gulf, and the world's seventh-largest oil-producing country. Abu Dhabi is the capital of the federation, as well as having most of its proven oil reserves. The COP28 President was Dr Sultan Al Jaber, the CEO of the state-owned *Abu Dhabi National Oil Company* [ADNOC], which caused some concern amongst environmental campaign groups and those countries that wished to see a phase- out in the use of all fossil fuels. During the course of COP28, Dr Al Jaber was quoted as saying that "there is no science out there, no scenario out there, that says that the phase-out of fossil fuel is what's going to achieve 1.5°C" and, subsequent to the summit, he indicated that ADNOC would continue to invest in oil exploration and production. However, it was the 198 'delegates' to the Dubai Climate Summit, representing the countries signed up to the *Paris Agreement*, who made consensus decisions at COP28.

3. Critical issues addressed at COP28

3.1 The Global Stocktake (GST)

As noted above, the GST examined the potential impact of submitted NDCs, or *bottom-up* national pledges on the GHG mitigation pathways required to limit global warming to only 1.5°C above pre-industrial levels by the end of the 21st Century. A technical dialogue had taken

place ahead of COP28, and the co-facilitators issued a Synthesis Report in September 2023 (UNFCCC, 2023). It stated that global anthropogenic GHG emissions were significantly out of line with these pathways. The 'implementation gap' between the emissions implied by the submitted NDCs and a warming limit of 1.5 °C through 2030 was estimated to be 20.3–23.9 Gt CO_{2e}[1] (UNFCCC, 2023). A significant task for COP28 was to deliver a response plan to this synthesis (Burnett, 2023; Waskow *et al.*, 2023). The *World Resources Institute* argued that this response needed to be 'transformational' in terms of actions to be taken on "mitigation, adaptation, loss and damage, finance and support" (Waskow *et al.*, 2023), especially in domains such as energy systems, transport, food and land use. A First Global Stocktake High-level Committee meeting just ahead of the Dubai Climate Summit (COP28UAE, 2023a) stated that there was 'urgent need for a paradigm shift' and for countries to make further "deep, rapid and sustained reductions" in GHG emissions. The COP28 Presidency emphasised that the transition should be economy-wide, just, equitable and fast-tracked (COP28UAE, 2023a).

The respected *Climate Action Tracker* [CAT] website tracked government climate action and measured it against the *Paris Agreement* target: see Figure 3 [adapted from CAT, 2023]. Historical and projected annual total global GHG emission pathways are depicted out to 2100, based on current policies and the NDCs submitted prior to COP28. A 2030 implementation GHG gap of 19–20 Gt CO_{2e} is displayed – similar to the estimate in the technical Synthesis Report - suggesting that current policies *instigated* around the world are projected to result in about 2.5°C warming above pre-industrial levels by the end of the 21st Century. In contrast, national *pledges* are anticipated to limit warming to 2.1°C (CAT, 2023). When binding long-term or net-zero 'optimistic' targets are included, this modelled figure could fall to about 1.8°C warming above pre-industrial levels [see again Figure 3]. These figures fall far short of

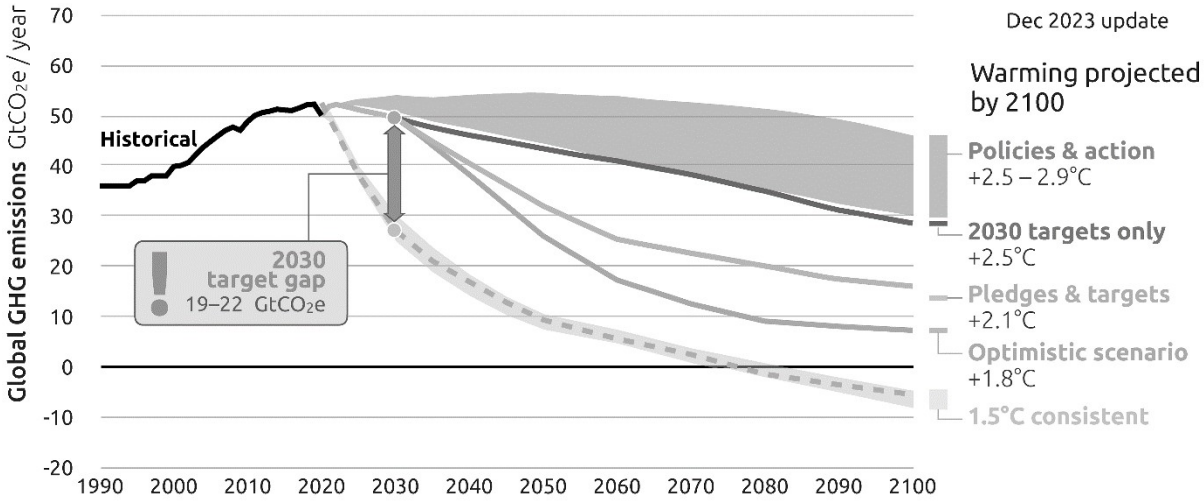


Figure 3. Historical and projected annual total global 'greenhouse gas' [GHG] emissions out to 2100 based on current policies and *Nationally Determined Contributions* [NDCs] submitted by the parties prior to COP28. Units: CO_{2e} – carbon dioxide equivalents. *Source:* adapted from CAT (2023).

[1] CO_2 equivalent for use on a comparative basis for GHGs of different *global warming potential* [GWP]

the *Paris Agreement* aspiration of limiting global warming to a 1.5°C temperature rise – a rise that was already almost reached in 2023. CAT commented that the warming projections have not significantly improved since the 2021 *Glasgow Climate Summit* [COP26] (CAT, 2021). On the basis of these and similar estimates, climate science modellers believe that humanity faces a continuing increase in frequency of extreme weather events (Cohen *et al.*, 2022; Houghton, 2009; IPCC, 2023) along with sea level rise due to melting ice sheets and glaciers, ocean acidification caused by CO_2 absorption and food shortages due to desertification (Cohen *et al.*, 2022).

In addition to tracking global warming trajectories over the 21st Century, the GST enabled the achievements of individual countries and economic sectors to be assessed. In terms of fossil fuel production/operations and the uptake of clean technologies, CAT (2023) found that China, USA, India, the EU and Saudi Arabia were all moving in "the wrong direction". However, a number of lower-emitter nations had started to introduce full decarbonisation policies (aimed at reducing carbon dioxide emissions) and were planning to end investment in new fossil fuel projects, e.g., Costa Rica, Denmark, France, Sweden, and several small island states. CAT (2023) criticised countries aiming to adopt what they regard as unrealistic technological options that come into play after fossil fuel has been burned, such as *carbon capture and storage* [CCS], a process not yet proven at scale. The IEA (2023b) observed that the story of CCS had thus far been one of "underperformance". Nevertheless, the IPCC view the technology as being potentially valuable in mitigating hard-to-abate sectors, such as cement and plastics (IPCC, 2023; Turan, 2023).

3.2 Transitioning Away From Fossil Fuels

GHG emissions from fossil fuel combustion are clearly the major contributor to global warming. Nevertheless, their mitigation has been a cause of great controversy at successive COPs. On the very last day of the 2021 COP26 in Glasgow, the G77 group of developing countries plus China [apparently led by India's environment minister Bhupender Yadav] objected to the wording "phase-out coal" in the final document and, after tense 'huddles', it was replaced by "phase-down coal" (Cohen *et al.*, 2022). The *Alliance of Small Island States* [AOSIS] and other *Least Developed Countries* [LDCs], whose nation-states are particularly vulnerable to flooding during severe weather events [but are only low GHG emitters; see, for example, the bulk of the African states depicted in Figure 2], expressed profound disappointment at this (Hammond, 2023). The issue continued to be divisive, and the final communique from COP27, held in Egypt in November 2022, reflected this. Any follow-through on phasing-out all fossil fuels, or even phasing down coal, was absent, apparently blocked by producer countries (Hammond, 2023; Masood *et al.*, 2022). The dispute rumbled on at COP28. A letter from the Secretary General of the *Organisation of Petroleum Exporting Countries* [OPEC] to OPEC member states and associates urged them to reject any wording in the final communique that targeted fossil fuels rather than GHG emissions. An early version of the 'final text' only stated that fossil fuel use "could", not "should", be reduced as part of a menu of mitigation options. A compromise text – the '*UAE Consensus*' - was eventually agreed that

referred to “transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science”, although that still disappointed many (Sanderson, 2023). It may be worth noting that transport was not mentioned by name, leaving some ambiguity around whether this is considered part of an energy system. Nevertheless, this has been the first COP declaration to explicitly mention fossil fuels, and the UN Climate Change Executive Secretary welcomed it as representing the “beginning of the end of the fossil fuel era” (Sanderson, 2023).

3.3 The Global Renewables and Energy Efficiency Pledge

Notwithstanding the weak final text on fossil fuels, more positive mitigation actions were agreed elsewhere. 130 delegates signed a pledge tripling the world’s installed renewable energy capacity to at least 11,000 GW by 2030 [proposed by the IEA (2023b)], and doubling the global average annual rate of energy efficiency improvements from about 2% to over 4% every year on the same timescale. This was partially in recognition of UN Sustainable Development Goal 7, to “ensure access to affordable, reliable, sustainable and modern energy for all”. Nearly 800 million people globally are without access to electricity; some 600 million of whom are in Africa. The Pledge formed part of the *Global Decarbonisation Accelerator* [GDA]: a series of COP28 initiatives across public and private sectors.

It was surprising to many that the PRC did not sign this Pledge, given that it has been at the forefront of renewable energy technology development and deployment. According to correspondents from the *Asia Society Policy Institute,* there are several reasons for this (Li, 2023). China can easily meets the tripling pledge on wind power and solar PV. Its innovations have brought the cost of wind power down by 80% and PV power by 90%, thereby laying the foundation for the large-scale, worldwide deployment of renewable energy. However, the scope for further hydro and geothermal power exploitation in China is very restricted. The PRC is also thought to have harnessed most of the ‘low-hanging fruit’ in energy efficiency improvement, and therefore to be unlikely to be able to meet the 4% annual goal.

3.4 The Global Cooling Pledge

Sixty-six governments, including Canada, Kenya, the UK and USA, are signatories of the COP 28 *Global Cooling Pledge,* having committed themselves to work collaboratively to bring down cooling-related GHG emissions (COP28UAE, 2023b; COP28UAE, 2023c). Cooling brings relief to human communities subject to extreme heat [nearly one-third of the world’s population], the majority of whom live in Africa and Asia (WEF, 2023b). It also provides critical services to support food security and vaccine delivery. Direct emissions from refrigerants and indirect ones via energy use in cooling account together for about 7% of global GHG emissions, and these are expected to triple by 2050 as warming intensifies (UNEP, 2023; WEF, 2023a). The *Global Cooling Pledge* targets reductions of at least 68% relative to 2022 levels by 2050 across all sectors. Potential options include increased efficiency, low–GWP refrigerants, passive cooling methods and changes in living and working practices. Co-ordinated international

action on sustainable cooling is estimated to be able to save 78 billion tonnes of CO_{2e} by 2050 – some 5-10% of what is needed to reach the Paris goal - and the UNEP (2023) believe it would improve the lives of hundreds of millions. The cooling pledge would build on the *Kigali Amendment* to the 1987 *Montreal Protocol*, to 'phase- down' the use of hydrofluorocarbons [HFCs] - a refrigerant GHG, so as to avoid an estimated 0.5°C of warming by 2100. Thus, co-ordinated actions to improve cooling efficiency alongside the phase-down of HFCs represent 'double zero' climate benefits. Parties to this pledge committed to publishing national action plans by 2026, and revised building codes that incorporate measures like passive cooling and energy efficiency strategies by 2030 (COP28UAE, 2023b). This work is intended to be undertaken in parallel with the UNEP-led *Cool Coalition*.

3.5 The Global Goal on Adaptation

The Global Goal on Adaptation [GGA] had been proposed in 2013 by the African group and established by the 2015 *Paris Agreement* (UNFCCC, 2015). It seeks to protect people, livelihoods and ecosystems, particularly in vulnerable communities. Ahead of COP28, the High-level Committee (COP28UAE, 2023a) had observed that states needed to make headway on *National Adaptation Plans* (NAPs) that provide affordable finance at scale for developing countries. Parties agreed a set of GGA targets and a framework at the Dubai COP that seeks to identify where the world needs to get to in terms of "finance, technology and capacity-building support to achieve them" (COP28UAE, 2023a). However, progress has been slow to date, and the COP28 final text only reiterates the longstanding call for developed countries to double adaptation finance without providing a clear roadmap to deliver it (COP28UAE, 2023c). It recognised "highly vulnerable countries and communities, particularly those threatened or affected by fragility or conflict, or facing severe humanitarian needs", many of which are in the LDCs and SIS category. 82 governments and some 40 organisations endorsed the COP28 *Declaration on Climate Relief, Recovery and Peace,* committing themselves to enhance finance and planning for adaptation and resilience; the underlying issues will need to be revisited at COP29 (COP28UAE, 2023c).

3.6 The Loss and Damage Fund

Since the start of the *Industrial Revolution* [in the UK *circa* 1760-1840], industrialised nations have been the principal GHG emitters (Cohen *et al.*, 2022). Both the *Alliance of Small Island States* [AOSIS] and the *Least Developed Countries* [LDC] *Group on Climate Change* believe that this responsibility should be acknowledged by the belated delivery of emissions reduction and climate promised earlier in the COP process (CHN, 2023; Cohen *et al.*, 2022). Stakeholders from the more industrialised countries have argued that *Loss and Damage* [L&D] could be financed via existing climate funds, insurance schemes, humanitarian aid, or risk management, but many developing countries call for specific financial mechanisms directed at L&D. COP28 saw the L&D Fund operationalised and the high-income countries pledging more than $792 million [US Dollars] for its implementation; nearly half of its initial funding was to be contributed by the EU and its member states. However, this falls far short of what

is required to compensate for the L&D caused to developing countries from climate change, with estimates ranging from $290-580 billion by 2030 (EP, 2022).

Other climate finance initiatives were announced throughout COP28, such as enhanced contributions to the *Green Climate Fund* and the *LDCs Fund*. A *UAE Leader's Declaration on Global Climate Finance Framework* was also signed by 11 countries: a number of European nations, India, the UAE, the USA, Barbados, Colombia, Ghana, Kenya and Senegal. It urged global leaders to unlock investment opportunities so that no nation-state has to choose between fighting poverty and tackling climate change. The ambition is huge– some $5-7tn annually by 2030. Partners aimed to report on progress immediately following the Dubai Summit, but this had not yet happened at the time of writing [March 2024].

3.7 Technology and Innovation

Technological innovation has long been seen as a key element of climate change mitigation and adaptation [and of the COP process], notwithstanding widespread recognition that most of the required technologies are already deployable, including many contributions to efficiency on the demand side, and that the main policy challenge is to deploy them effectively and equitably (IPCC 2022). Alongside the COP28 *Global Renewables and Energy Efficiency Pledge*, the COP28 Presidency and the *International Atomic Energy Agency* [IAEA] issued an *IAEA Statement on Nuclear Power*, supported by more than 50 nuclear operating and newcomer countries, arguing in favour of counting nuclear power as part of the pathway to net zero. However, Hammond (2011) – building on studies by Keepin (1990) – noted that conventional nuclear power plants are one of the least cost-competitive means of CO_2 abatement. An energy efficiency strategy would displace, for instance, "between 2.5 and 20 times more carbon dioxide than nuclear power per dollar [euro or pound] invested." Even leaving aside questions of skills availability, risk management and governance, the long lead-times for conventional nuclear power plants [let alone for so-far-unproven small modular reactors] indicate that any contribution from nuclear power to mitigating climate change will be very limited (Muellner *et al.*, 2021; Thomas and Ramana, 2022).

Just 37 countries endorsed the UAE COP28 *Declaration on Hydrogen* with a view to developing and deploying renewable and low-carbon [i.e., 'green'] hydrogen and hydrogen derivatives "as part of a people-centred energy transition to net zero that leaves no-one behind" (COP28UAE, 2023c). A major focus would be on developing international standards and certification, including the [ISO] methodology for determining emissions associated with the production and transport of hydrogen (ISO, 2023). The need to pursue mutual recognition based on "a mechanism for evidencing carbon intensity, observing the principles of tradability, transparency, trustworthiness and sustainability" (COP28UAE, 2023c) was acknowledged.

The COP28 *Global Renewables and Energy Efficiency Pledge* notes the urgent need for 'high-level political and collective action' to accelerate efficiency improvements and the deployment of renewables. From an innovation perspective, much of this work will involve connecting existing technologies effectively, improving their user-friendliness, and social innovations to

support climate mitigation and adaptation. For example, where electricity systems are concerned, Eyre *et al.* (2018) set out essential roles for infrastructure, citizens, business models and governance in bringing about rapid decarbonisation.

3.8 Other COP28 Declarations and Pledges

Several other declarations and pledges were signed during 2023 Dubai Climate Summit (COP28UAE, 2023c). Those of particular significance for climate change mitigation and adaptation are identified, and their implications summarised, in Table 1.

4. The Positions of the International Community Ahead of COP28 and their Reactions to the 'UAE Consensus'

4.1 China-US Collaboration and the Sunnylands Statement

The US Biden Administration, inaugurated in January 2021, was keen on collaboration with China over climate change by the two highest GHG emitter-nations in the world. President Biden appointed former Obama Administration Secretary of State John Kerry as the first *Special Presidential Envoy for Climate*. In turn, Kerry sought to build a relationship with PRC *Special Envoy for Climate Change* Xie Zhenhua prior to the *Glasgow Climate Summit* [COP26] in Glasgow in late 2021. President Xi Jinping of China and President Biden had also met for in-person talks on the sidelines of the G20 summit in Bali, Indonesia in November 2022. There they reaffirmed their commitment to work together, and with others, to combat climate change. In this spirit, Kerry and Xie met in Sunnylands, California in July 2023 and issued the *Sunnylands Statement on Enhancing Cooperation to Address the Climate Crisis*, setting broad boundaries for resolving issues at COP28. It addressed several critical issues for COP28: the energy transition towards renewables and the uptake of energy saving measures, a methane control plan, adoption of 'circular economy' and resource efficiency interventions, development of sustainable low-carbon communities, and deforestation.

The China-US partnership was clearly influential at the Dubai Climate Summit, where the delegations worked together to unlock stalled negotiations. Both countries agreed to update their NDCs in line with the *Paris Agreement* and the results of the first GST, and they approved the operationalisation of four joint working groups dealing with the issues highlighted in the *Sunnylands Statement*. Both envoys welcomed the compromise outcome of the Dubai Climate Summit, including the need to 'phase-down' unabated coal power. They also indicated a joint willingness to revisit and update their long-term climate strategies prior to the 2025 COP30 summit in Brazil.

4.2 The European Union

The EU has a rather complex governance structure, with responsibilities divided between its Council [representing the 27 member governments], the Brussels-based Commission [the politically-independent executive arm that proposes and enforces legislation, implements policies, and manages the EU budget], and the Parliament. Each body had representatives at COP28, negotiating through a 'European action unit', in order to promote action consistent

Table 1. Other UAE COP28 Declarations and Pledges.

COP28 Declarations and Pledges	Implications
The *Coalition for High Ambition Multilevel Partnerships* (CHAMP) *for Climate Action*	71 countries joined CHAMP with the aim of enhancing co-operation with sub-national governments on the planning, financing, implementation, and monitoring of climate strategies. The signatories embraced several major EU countries, the USA and several countries from the LDC Group. The proposed actions included work associated with the *Nationally Determined Contributions* [NDCs], the *National Adaptation Plans* [NAPs], *National Biodiversity Strategies and Action Plans* (NBSAPs) and *Long Term Low-Emission Development Strategies* [LT-LEDS].
The *Declaration on Agriculture, Food and Climate*	159 countries endorsed this declaration (COP28UAE, 2023c), which aims to support agriculture and food systems to promote activities that increase incomes and reduce GHG emissions, whilst bolstering resilience, productivity, livelihoods, nutrition, human, animal and ecosystem health, and water efficiency. Signatories agreed to integrate agriculture and food systems into NAPs, NDCs and biodiversity strategies before the next GST at COP30 in Brazil. Greater investment in and leadership from indigenous communities, who are stewards of some 80% of global biodiversity, will clearly be required.
An *Oil and Gas Decarbonization Charter* [OGDC]	This OGDC was instigated as part of the *Global Decarbonisation Accelerator* [GDA]: see Section 3.3. It commits the signatories [52 companies, representing 40% of global oil production] to reducing methane emissions to zero and ending flaring by 2030.
The *Declaration on Climate Relief, Recovery and Peace*	40 organisations endorsed this declaration with the intention of growing financial support for climate adaptation and resilience (COP28UAE, 2023c).
The *Declaration on Climate and Health*	141 national governments, alongside the EU, signed this declaration, which seeks to strengthen health systems in the face of climate change challenges.
The LDC Fund and the *Special Climate Change Fund*	These Funds were both enhanced, and currently stand at a total of $188 million.

with the EU's own *New Green Deal* (EP, 2020) and its short-term target of reducing anthropogenic GHG emissions by 43% below 2005 levels by 2030. They welcomed the compromise outcome as far as it went (EC, 2023), although they would have preferred to see greater ambition, with a peak in global GHG emissions by 2025. The EU-27 delegation supported the *Global Renewables and Energy Efficiency Pledge*, as well as the commitments on nuclear power and announced a contribution of €400 m to the UNFCCC *Loss and Damage Fund* [over half the initial funding].

4.3 The Least Developed Countries

The LDC *Group on Climate Change* represent 46 nations across Africa, the Asia-Pacific and the Caribbean [see Figure 2]. They have a combined population of over one billion people; some 14% of global inhabitants that are especially vulnerable to anthropogenic climate change, but are least responsible for its cause (Cohen et al., 2022). They have been negotiating as a Group since 2005 and are currently chaired by Ms Madeleine Diouf Sarr [Head of the Climate Change Division of Senegal's Ministry of Environment and Sustainable Development]. Ahead of COP28, the LDC Group Ministers and Heads of Delegation met in Dakar, Senegal on 28 September 2023 to prepare and agree its approach. They issued *The Dakar Declaration on Climate Change 2023* (LDC, 2023) that included the aspiration that the UNFCCC *Green Climate Fund* [GCF] should guarantee funding for the LDCs to implement their *National Adaptation Plans* [NAPs] and ensure their equitable and simplified access to the *Loss and Damage Fund*. The Group welcomed the adoption of the *Global Goal on Adaptation* framework as "a historic achievement" [10 years after it had been proposed] but would like to have seen the adoption of indicators that can measure and help track its development.

4.4 The Alliance of Small Island States

Established in 1990, the *Alliance of Small Island States* [AOSIS] carries out advocacy for 39 states in the area of international environmental policy. These small island nations are mainly located in the Caribbean, Indian Ocean and Pacific and are especially vulnerable to flooding due to sea level rise. During the second week of COP28, AOSIS issued a statement in which they asserted that their voices were not being heard and that the Dubai Climate Summit was not progressing "in the spirit of multilateralism" (AOSIS, 2023a). They were concerned that the draft final text didn't include strong enough language on phasing-out fossil fuels to keep the 1.5°C limit alive. AOSIS (2023b) objected to being asked to endorse energy technologies such as CCS that are expensive [potentially diverting resources from more promising technologies and actions] and arguably not available 'at scale' in the near or even medium term.

In the concluding COP28 plenary, the AOSIS delegation were not in the room when consensus was reached [i.e., 'the gavel came down'], because they were still trying to reach agreement amongst their own members. Ms Anne Rasmussen from Samoa [their lead negotiator] was subsequently able to address the meeting, when she acknowledged that the communique "contains many good elements" even if it was also seen by AOSIS as containing "a litany of loopholes" (AOSIS, 2023b). She welcomed the strengthening of efforts for countries to prepare and submit enhanced NDCs by the end of 2025, as well as the establishment of the technology implementation programme. However, she regretted that there was no commitment to secure a peak in global anthropogenic GHG emissions by 2025 (AOSIS, 2023b). Her statement received a longer standing ovation from COP28 delegates than that given to the COP28 President after his closing remarks.

5. Concluding Remarks

The achievements at COP28 were clearly mixed, and disappointed many delegations [including those from the climate-vulnerable countries at high risk from extreme weather events]. The results of the *Global Stocktake* [GST] had identified a significant GHG emissions gap between actions needed to "keep 1.5° C alive" and those identified in the GST that were being carried out (CAT, 2023; UNEP, 2023). The NDCs submitted prior to the summit would result in a 2.4°C global warming by the end of the century; a long way short of the 1.5°C aspiration. However, if further pledges, for example, by India [of achieving net-zero emissions by 2070) were fully achieved, then estimated global warming would peak at around 1.9°C before falling to 1.8°C by 2100 (CAT, 2023)]: see again Figure 3. Even that would be a disappointing return on the 2015 *Paris Agreement* target, given the impacts of global warming already experienced around the world. The Parties did agree to "transition away from fossil fuels" in order to reach 'net zero' anthropogenic GHG emissions [carbon neutrality] by 2050, and to triple renewable energy capacity and double energy efficiency by 2030. But many regretted the absence of references to the phase-out or phase-down of fossil fuels. The fact that it has taken 28 years of negotiation before fossil fuel is even named in a COP agreement is remarkable. It illustrates the scale of the transition challenge facing governments who are increasingly threatened by the consequences of fossil fuel combustion, but still rely on it to some extent for energy services and, in several powerful countries, for export revenues. The reference in the COP28 final text to "transition fuels" (COP28UAE, 2023c) was seen by many as a 'back door' way to retain the burning of natural gas [with lower carbon intensity than oil and coal, but far from zero at approximately 200-230 $kgCO_2/MWh$]. Some have criticised the UN rules that decisions should be made unanimously at COP summits, thereby often delaying progress. The former US Vice President and joint Nobel Peace Prize winner, Al Gore proposed that member states should consider making decisions based on agreements by 75% of nations (Sanderson, 2023). Clearly, the interests of fossil fuel- producing nations will tend to stand in the way of resolutions to phase out such fuels; on the other hand, progress is not possible without the cooperation of these countries.

This assessment has set out the background to what was achieved during the *Dubai Climate Summit*. Clearly, there are issues that will require more urgent attention from 2024 onwards. Although the climate science was referenced in the final text (COP28UAE, 2023c), there was insufficient action proposed to meet the 1.5-2°C pathways as recommended at the *2015 Paris Agreement* (Burnett, 2023; IPCC, 2023; UNFCCC, 2015). The emissions, adaptation, and finance gaps all need to be closed (AOSIS, 2023b; CAT, 2023; IEA, 2023b; IPCC, 2023; Waskow *et al.*, 2023), largely with technologies and processes that are already known and tested.

The next full GST will take place at COP30, to be held within the lower Amazon basin at the Brazilian city of Belém in late 2025. President Luiz Ignacio Lula da Silva of Brazil lit up the preceding 2022 COP27 summit in Sharm El-Sheikh, Egypt with a promise of a zero-deforestation policy, including the Amazon Basin, by 2030 (Hammond, 2023), a prompt to more concerted climate action that is badly needed. In the meantime, COP29 will be held in Baku, Azerbaijan [another petrostate], where the focus will be on securing a transnational

climate finance fund in line with the scale and urgency of the challenge, estimated to be trillions of US dollars (EP, 2022). For the intervening period, the work of co-ordination and monitoring of the outcomes from COP28 will be down to the no doubt over-stretched UNFCCC secretariat [now designated as *UN Climate Change*] and their Executive Secretary Simon Stiell from Grenada. The world will keep warming and hundreds of millions of people, as well as co-located wildlife, will suffer the effects of severe weather events, particularly in geographically vulnerable communities.

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References

Alliance of Small Island States [AOSIS] (2023a) *Initial feedback on fossil fuel phaseout in draft GST text –This cannot be the COP that kills 1.5*. AOSIS [<https://www.aosis.org/aosis-on-draft-cop-presidency-gst-text-this-cop-cannot-kill-1-5/ >] (accessed 12/12/2023).

Alliance of Small Island States [AOSIS] (2023b) *Statement on the Global Stocktake*. AOSIS [<https://www.aosis.org/cop28-closing-plenary-aosis-statement-on-gst-decision/>] (accessed 14/12/2023).

Archer D and Brovkin V (2008) the millennial atmospheric lifetime of anthropogenic CO_2. *Climatic Change* **90** (3): 283-297.

Burnett N (2023) *COP28 – The United Nations Climate Change Conference*. Research Briefing, House of Commons Library, London, UK.

Clarke B, Otto F, Stuart-Smith R and Harrington L (2022) Extreme weather impacts of climate change: an attribution perspective. *Environmental Research: Climate* **1** (1): 012001.

Climate Action Tracker [CAT] (2021) *Glasgow's 2030 Credibility Gap: Net Zero's Lip Service to Climate Action – Warming Projections Global Update*. CAT [<https://climateactiontracker.org/publications/glasgows-2030-credibility-gap-net-zeros-lip-service-to-climate-action/>] (accessed 21/12/2021).

Climate Action Tracker [CAT] (2023) *No Change to Warming as Fossil Fuel Endgame Brings Focus Onto False Solutions – Warming Projections Global Update*. CAT [<https://climateactiontracker.org/publications/no-change-to-warming-as-fossil-fuel-endgame-brings-focus-onto-false-solutions/>] (accessed 06/12/2023).

Climate Home News [CHN] (2023) *Green Climate Fund may have to curb ambition as funding stagnates*. CHN, Broadstairs, Kent, UK. [https://www.climatechangenews.com/2023/09/21/green-climate-fund-may-have-to-curb-ambition/] (accessed 12/01/2024).

Cohen R, Eames PC, Hammond GP, Newborough M and Norton B (2022) Briefing: The 2021 *Glasgow Climate Pact* – steps on the transition pathway towards a low carbon world. *Proc. Instn Civil. Engrs: Energy* **175** (3): 97-102.

COP28UAE (2023a) *First Global Stocktake High-level Committee – Summary of High-level events*. COP28 Presidency, Dubai, United Arab Emirates [<https://www.cop28.com/en/>] (accessed 14/12/2023).

COP28UAE (2023b) *Global Cooling Pledge for COP28*. COP28 Presidency, Dubai, United Arab Emirates [<https://www.cop28.com/en/>] (accessed 11/12/2023).

COP28UAE (2023c) *Summary of Global Climate Actions at COP28*. COP28 Presidency, Dubai, United Arab Emirates [<https://www.cop28.com/en/>] (accessed 14/12/2023).

European Commission [EC] (2023) *EU at COP28 Climate Change Conference*. EC, Brussels, Belgium [<https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/climate-action-and-green-deal/eu-un-climate-change-conference/eu-cop28-climate-change-conference_en>] (accessed 12/01/2024).

European Parliament [EP] (2020) *The European Green Deal*, EP Document P9_TA (2020)0005, EP, Brussels, Belgium.

European Parliament [EP] (2022) *Briefing: Understanding Loss and Damage – Addressing the unavoidable impacts of climate change*, EP Document PE 733.598, EP, Brussels, Belgium.

Eyre N, Darby SJ, Grunewald P, McKenna E and Ford R (2018) Reaching a 1.5°C target: socio-technical challenges for a rapid transition to low-carbon electricity systems. *Phil. Trans. R. Soc. A* **376**: 20160462.

Faghmous JH and Kumar V (2014) A big data guide to understanding climate change: The case for theory-guided data science. *Big Data* **2** (3): 155-163.

Gao Y, Gao X and Zhang X (2017) The 2°C global temperature target and the evolution of the long-term goal of addressing climate change—From the United Nations Framework Convention on Climate Change to the Paris Agreement. *Engineering* **3** (2) 272–278.

Gore A (2006) *An Inconvenient Truth – The Planetary Emergency of Global Warming and What We Can Do About It*. Bloomsbury Publishing, London, UK.

Hammond GP (2000) Energy and the environment, In *Towards a Collaborative Environment Research Agenda: Challenges for Business and Society* (Warhurst A (ed)), Macmillan, London, Ch. 7, pp. 139-178.

Hammond GP (2011) Nuclear power in the twenty-first century, In the *Handbook of Sustainable Energy* (Galarraga I, González-Eguino M and Markandya A (eds)), Edward Elgar, Cheltenham, Ch. 16, pp. 331-356.

Hammond GP (2021) Editorial. *Proceedings of the Institution of Civil Engineers - Energy* **174** (3): 95-97.

Hammond GP (2022) The UK *Industrial Decarbonisation Strategy* revisited. *Proc. Instn Civil. Engrs: Energy* **175** (1): 30-44.

Hammond GP (2023) Editorial. *Proc. Instn Civil. Engrs: Energy* **176** (1): 1-3.

Hammond GP and O'Grady A (2017) Indicative energy technology assessment of UK shale gas extraction. *Applied Energy* **185** (2): 1907–1918.

Houghton J (2009) *Global Warming: The Complete Briefing*. 4th ed. Cambridge University Press, Cambridge, UK.

Intergovernmental Panel on Climate Change [IPCC] (2001) *Climate Change 2001: The Scientific Basis*. Cambridge University Press, Cambridge, UK.

Intergovernmental Panel on Climate Change IPCC] (2018) *Global Warming of 1.5°C – Summary for Policymakers*. World Meteorological Organization, Geneva, Switzerland.

Intergovernmental Panel on Climate Change IPCC] (2022) *Climate Change 2022: Mitigation of Climate Change Summary for Policymaker - Working Group III contribution to the Sixth Assessment Report of the IPCC*. IPCC, Geneva, Switzerland.

Intergovernmental Panel on Climate Change [IPCC] (2023) *Climate Change 2023: Synthesis Report – Summary for Policymakers*. IPCC, Geneva, Switzerland.

International Energy Agency [IEA] (2023a) *CO_2 Emissions in 2022*. IEA, Paris, France.

International Energy Agency [IEA] (2023b) *Net Zero Roadmap – A global pathway to keep the 1.5°C goal in reach*. IEA, Paris, France.

International Standards Organisation [ISO] (2023) *Hydrogen Technologies — Methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption gate*. **n** ISO/TS 19870. ISO, *Geneva,* Switzerland.

Keepin B (1990) Nuclear power and global warming, In *Global Warming: The Greenpeace Report*, Leggett J (ed), Oxford University Press, Oxford, UK, pp. 295-316.

Less Developed Countries [LDC] Group (2023) *The Dakar Declaration on Climate Change 2023*. LDC Group Ministerial Declaration, LDC Group [<https://www.ldc-climate.org/wp-content/uploads/2023/10/2023-Ministerial-Declaration_Final-.pdf>] (accessed 10/12/2023).

Li S (2023) Three observations on China at COP28. *Asia Society Policy Institute*, New York, USA, Press Release [<https://asiasociety.org/policy-institute/three-observations-china-cop28>] (accessed 14/12/2023).

Liu Z, Deng Z, Davis S and Ciais P (2023) Monitoring global carbon emissions in 2022. *Nature Reviews* **4**: 205–206.

Masood E, Tollefson J and Irwin A (2022) COP27 climate talks: what succeeded, what failed and what's next. *Nature* 21 November.

Muellner N, Arnold N, Gulfler K, Kromp W, Renneberg W and Liebert W (2021). Nuclear energy – the solution to climate change? *Energy Policy* **155**: 112363.

Ritchie H, Rosado P and Roser M (2023) Per capita, national, historical: how do countries compare on CO_2 metrics? *Our World In Data*, Oxford Martin School, University of Oxford, Oxford, UK [<https://ourworldindata.org/co2-emissions-metrics>] (accessed 10/12/2023).

Sanderson K (2023) COP28 climate summit signals the end of fossil fuels – but is it enough? *Nature* 13 December.

Statista (2023) *Distribution of greenhouse gas emissions worldwide in 2022, by major emitter*. Statista Inc., New York, USA [<https://www.statista.com/statistics/500524/worldwide-annual-carbon-dioxide-emissions-by-select-country/>] (accessed 10/12/2023).

Systems Change Lab [SCL] (2023) *State of Climate Action 2023.* SCL, Washington DC, USA.

Thomas S. and Ramana MV (2022) A hopeless pursuit? National efforts to promote small modular reactors and revive nuclear power. *WIREs Energy and Environment* **11** (4): e429.

Townend R and Åberg A (2023) *What is COP28 and Why is it Important?* The Royal Institute of International Affairs, Chatham House, London, UK [<https://www.chathamhouse.org/2023/09/what-cop28-and-why-it-important>] (accessed 02/12/2023).

Townend R (2023) *COP28 Must Tackle Climate Impacts That Cascade Over Borders.* The Royal Institute of International Affairs, Chatham House, London, UK [<https://www.chathamhouse.org/publications/the-world-today/2023-10/cop28-must-tackle-climate-impacts-cascade-over-borders>] (accessed 08/12/2023).

Turan G (2023) Brief: CCS in the IPCC Sixth Assessment (AR6) Synthesis Report. *Global CCS Institute*, Melbourne, Australia.

UN Environment Programme [UNEP] (2023) *Broken Record: Temperatures hit new highs, yet world fails to cut emissions (again)*. UNEP, Nairobi, Kenya.

UN Framework Convention on Climate Change [UNFCCC] (2015) *Adoption of the Paris Agreement*. UNFCCC/CP/2015/L.9/Rev.1. UN Campus, Bonn, Germany [<https://unfccc.int/>] (accessed 23/12/2023)

UN Framework Convention on Climate Change [UNFCCC] (2023) *Technical dialogue of the first Global Stocktake - Synthesis report by the co-facilitators on the technical dialogue*. UNFCCC/SB/2023/9/. UN Campus, Bonn, Germany [<https://unfccc.int/>] (accessed 02/12/2023).

Waskow D, Carter R, Bhandari P, Thangata C, Alayza N, Laston V, Davey EL, Cogswell N, Srouji J and Waraszawski N (2023) *Benchmarks for Success for COP28*. World Resources Institute [WRI], Washington DC, USA [<https://www.wri.org/insights/cop28-benchmarks-success?/>] (accessed 02/12/2023).

World Economic Forum [WEF] (2023a) *Global cooling pledge – Can the world slash emissions from industrial cooling systems by 68%?* WRI, Geneva, Switzerland. Press Release [<https://www.weforum.org/agenda/2023/10/global-cooling-pledge-slash-cooling-emissions-2050/ >] (accessed 14/12/2023).

World Economic Forum [WEF] (2023b) *Global cooling pledge: Over 60 countries commit to slash cooling emissions*. WRI, Geneva, Switzerland. Press Release [<https://www.weforum.org/agenda/2023/12/cooling-emissions-air-conditioning-refrigeration-un-cop28/>] (accessed 14/12/2023).

World Meteorological Organisation [WMO] (2023) *WMO confirms that 2023 smashes global temperature record*. [<https://wmo.int/news/media-centre/wmo-confirms-2023-smashes-global-temperature-record/>] (accessed 08/02/2024).