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OPINION

Proposing a 1.0˚C climate target for a safer future

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Abstract

The Intergovernmental Panel on Climate Change concludes that climate change has already caused substantial damages at the current 1.2˚C of global warming and that warming of 1.5˚C would elevate risks of a wide-range of climate tipping points. For example, wet-bulb temperatures are already exceeding safe levels, and the melting of the Greenland and West Antartic ice sheets would lead to over ten metres of sea level rise, representing an existential threat to coastal cities, low-lying nation states, and human wellbeing worldwide. We call for a broad scientific discussion about a stricter and more ambitious climate target of 1.0˚C by the end of this century. Comprehensive electrification and highly renewable energy systems offer a pathway to sub-1.5˚C futures through rapid defossilisation and large-scale, electricity-based carbon dioxide removal. Independent scenarios show that restoring a stable and safe climate is attainable with coordinated policy and economic support.

The 1.5˚C climate target implies carbon dioxide removal at a high probability

The carbon budget for a high probability of attaining a 1.5˚C climate target was depleted in the year 2022, decades before the climate neutrality target of the Paris Agreement set for the second half of this century. According to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [1], a carbon dioxide (CO_2) budget of 300 $GtCO_2$ from 2020 until 2100 provides an 83% probability of staying at or below the 1.5˚C target. Accounting for uncertainties of 220 $GtCO_2$, the carbon budget could have been exceeded in the first few months of 2022 given total emissions of 39 $GtCO_2$/a. The latest energy system transition research identifies committed energy and industry-related CO_2 emissions of about 680 $GtCO_2$ that will be emitted from 2020–2100 even in a highly ambitious energy-industry transition scenario [2, 3]. About 580 $GtCO_2$ come from energy-industry segments with established defossilisation technologies, while 100 $GtCO_2$ are related to hard-to-abate industrial processes such as the cement industry, which may be managed with on-site carbon capture and storage (CCS). Thus, a 1.5˚C climate target very likely requires carbon dioxide removal (CDR) with negative CO_2 emission technologies [4] removing about 500 $GtCO_2$ within the 21st century [2].

Extreme weather and tipping points in a 1.5˚C world call for maximum climate safety of about 1.0˚C/350 ppm

As hard as meeting a 1.5˚C climate target seems, that level of warming would not be safe for our civilisation and environment. The present 1.2˚C climate reveals increasing vulnerability of major planetary systems, in particular ice sheets and oceans, and an increasing frequency and intensity of extreme heat, heavy precipitation, droughts, and intensification of major hurricanes [1]. With increasing temperature over land masses the humidity in the air and, thus, latent heat increases, resulting in extreme events. Changes in the jet stream can be observed, which not only cause local weather extremes but also can have global effects, thereby posing risks to global food security [5]. In addition, ice mass loss from Greenland is accelerating [6] and the West Antarctic Ice Sheet is close to, or may have already passed, a critical threshold [7]. These two ice sheets represent tipping elements that possess enough frozen water to raise global sea level by an amount that poses an existential threat to coastal settlements and entire nation states, including New York, Rio de Janeiro, London, Amsterdam, the Netherlands, Lagos, the Nile River Delta, Dubai, Mumbai, Bangladesh, Vietnam, Jakarta, Shanghai, Tokyo, and Sydney. Ice melt is already disrupting global thermohaline circulation, with potential implications for climate and marine food web stability around the world by 2040 [8]. 1.5˚C global warming may trigger additional tipping points with potentially disastrous consequences [9]. It follows that a safe climate for civilisation is below 1.0˚C above pre-industrial levels [10]. This likely requires limiting overshoot beyond the 1.5˚C climate target as strictly as possible, a return to the late 1980s CO_2 concentration of around 350 ppm by the end of this century, and may require a climate restoration in the longer term.

Low-cost renewable energy as the basis for possible pathways to reach a 1.0˚C target

Despite rising emissions, which is incompatible with a 1.0˚C climate target, a paradigm shift of historic dimensions is occurring. Solar photovoltaics (PV) and wind power have emerged as the least cost sources of electricity and these renewable energy sources constituted more than 75% of the global power capacity installed in 2022. In combination with demand-side innovations such as heat pumps, electric vehicles, and batteries, rapid electrification of the entire energy-industry system is now projected as a least cost solution [2, 3, 11–13]. All energy and feedstock demand could be provisioned by solar PV and wind power with direct and indirect electrification, while other sustainable energy sources would enhance resilience of the system [2, 3].

Low-cost renewable electricity, in particular solar PV [14], has accelerated the defossilisation of energy and industry, which could be complete around 2050. The rise of low-cost renewable electricity could also enable large-scale CDR starting in the 2030s and scaling up through the 2060s. CDR options have been increasingly discussed in recent years [4]. While natural carbon sinks such as reforestation are likely limited to a maximum of 16 $GtCO_2$/a [4], direct air carbon capture and storage (DACCS) becomes more feasible as the cost of electricity and direct air capture technology drops [15]. Renewable-powered desalination could also allow afforestation in arid regions [15], which could minimise land-use conflicts or even create

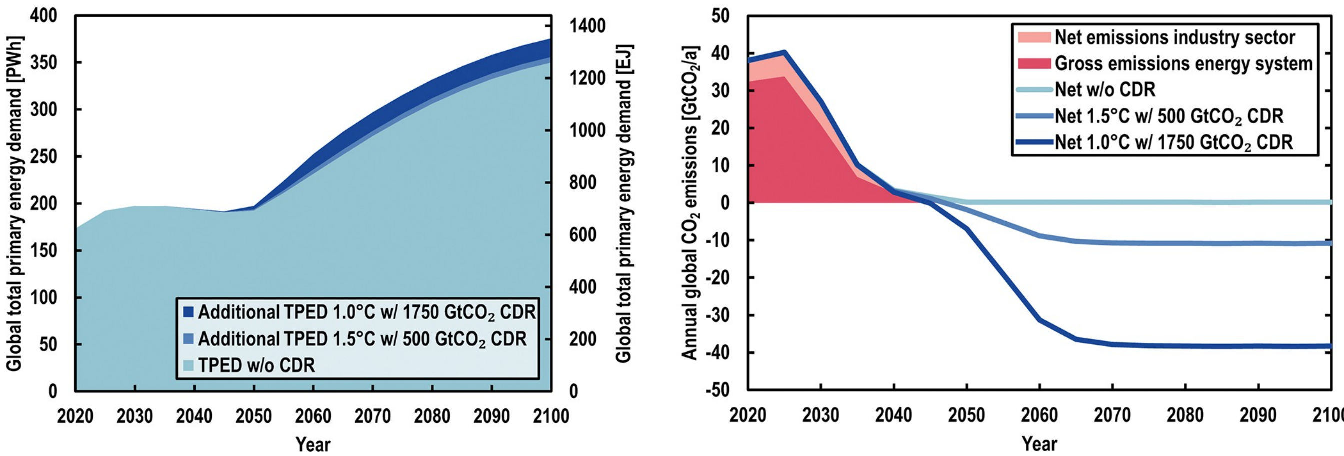

Fig 1. Global primary energy demand for a medium growth scenario with additional demand for CDR using DACCS only (left) and related CO_2 emissions in the underlying energy-industry-CDR scenario for a 1.0˚C climate target (right). For the industry sector, a full phase-in of direct CCS is assumed for process-related emissions in cement production by 2050. Data adapted from [2].

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co-benefits. The rise of low-cost renewable electricity strongly increases the attractiveness of energy-intensive though scalable novel options, such as DACCS and desalination-based afforestation, while land-use and water supply issues diminish the sustainable potential for rainfall-based afforestation and bioenergy CCS. CO_2 sequestered by DACCS may be converted to minerals for increasing the storage security and thus further enhancing the overall sustainability of the CDR endeavour.

To attain a 1.0˚C climate target within acceptable certainty, about 40 $GtCO_2$/a of CDR would be needed from the early 2060s onwards [2]. While enormous, in that it would approximate current CO_2 emissions, this amount of CDR using DACCS would require only 5–10% of global primary energy demand [2] under two conditions: continued very rapid scaling of PV [14] and strong energy efficiency gains of low-temperature DACCS by utilising heat pumps, while low-cost heat for DACCS may be also supplied by geothermal or solar thermal heat. Under these conditions, a 1.0˚C world would become plausible in industrial, financial, and societal terms (cf. Fig 1). Diverse CDR portfolios combining different natural climate solutions and sustainable technological solutions [4] can enable the massive CDR needed for achieving a 1.0˚C climate target by end-century facilitating safe climate conditions for civilisation.

Energy requirements of CDR depend most directly on energy demand growth overall. For example, if global primary energy demand grows marginally from 173 PWh in 2021 to 207 PWh by end of this century, instead of the assumed 384 PWh [2], then CDR, assuming all is DACCS, would require about 10% of primary energy supply. More pessimistic assumptions on the energy requirements of DACCS would increase this percentage further. This larger percentage may imply higher competition with other end-use and might make realising any pathway to 1.0˚C more challenging, while supply capacity for solar PV as the main source of energy in this century could grow faster than demand [14].

Call for a new discourse on climate safety

In light of the need for a revised climate target and the unprecedented opportunities arising from low-cost renewable electricity, we call for a new discourse on a 1.0˚C climate target, which involves climatic, societal, technical, and political dimensions. Recall that analysis of 1.5˚C targets following adoption of the Paris Agreeement generated new insights, e.g., about net-zero energy systems. Rather than limiting ourselves to analysis of 1.5˚C and 1.5˚C

+ scenarios which will not provide acceptable planetary security, we need to comprehensively estimate the combinations of defossilisation and CDR needed to restore Earth's climate.

Individual studies have demonstrated the technological and industrial feasibility of creating a truly sustainable global society [2, 3, 11, 12], and we now need to take the next steps to update our socio-economic scenarios with the new reality of low-cost renewable electricity [3, 13] and the potential for much more aggressive CDR. Renewable energy and demand-side solutions such as efficiency and conservation must be prioritised over the next decade, laying the groundwork for renewables-based CDR and climate restoration later this century. As the cost and rate of progress depend largely on financing, we need clarity in national and international priorities to support this two-pronged approach: First, rapid, deep defossilisation and electrification of the entire energy-industry system, and, second, large-scale deployment of CDR. Raising our ambitions to include the kind of world our descendants will want to live in is our responsibility to enable a prosperous humankind and resilient biosphere.

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