How to reverse global warming.

Restoring safe climate conditions.

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Introduction.

Climate warming poses an existential threat to human civilisation, many other species and whole ecosystems. Human activities are continuing to emit dangerous levels of greenhouse gases (GHGs) into the atmosphere, increasing global temperatures, foreshadowing devastating sea level rise, driving more extreme climate conditions, and increasing threats to geopolitical stability.

There is no silver bullet for tackling climate change. A multifaceted approach for reversing global warming and returning to safe climate conditions is fundamental in order to seek maximum protection for all people and species.

A goal of reversing hotter climate conditions is a complex and unfamiliar objective, involving many potential risks and a large number of difficult scientific, technical, social and ethical questions. Yet every moment we delay dealing with these vital questions is a step closer to new catastrophes, and a further step away from achieving a safe climate.

Reversing to a safe climate.

The amount of greenhouse gases currently in the atmosphere is in excess of safe limits and is on track to cause catastrophic consequences as global temperatures rise rapidly. For example, in past periods when greenhouse concentrations were similar to the current level, temperatures were 3–4 degrees Celsius (°C) higher and sea levels around 25 (±) metres above the present.

A safe level of atmospheric carbon dioxide (CO_2) is considered to be the pre-industrial mark of 280 parts per million (ppm) of CO_2. In 2015, as a direct result of human activities, global CO_2 concentrations exceeded 400ppm for the first time in millions of years. The last time global atmospheric CO_2 was this high, modern humans did not exist. In the meantime, CO_2 concentrations continue to increase 100 to 200 times faster than the warming transition out of the last Ice Age.

Mainstream climate mitigation strategies are deeply insufficient to deal with the risks we now face. A different approach is urgently needed in order to protect the things we care about and address the climate emergency.

A 'safe climate' identifies a band of environmental conditions known from experience to be stable for human civilisation and other forms of life. This is a very different approach to speculating about the maximum climate damage that civilisation and the Earth system can tolerate and adapt to, which has been the practice of international policy making for a quarter of a century.

To maximise the chances of successfully reversing global warming and returning to safe climate conditions, the Earth would need to be cooled by around 1°C.

This is a seemingly impossible task, so what are the challenges if we are to achieve this goal?

Major challenges identified to reverse global warming

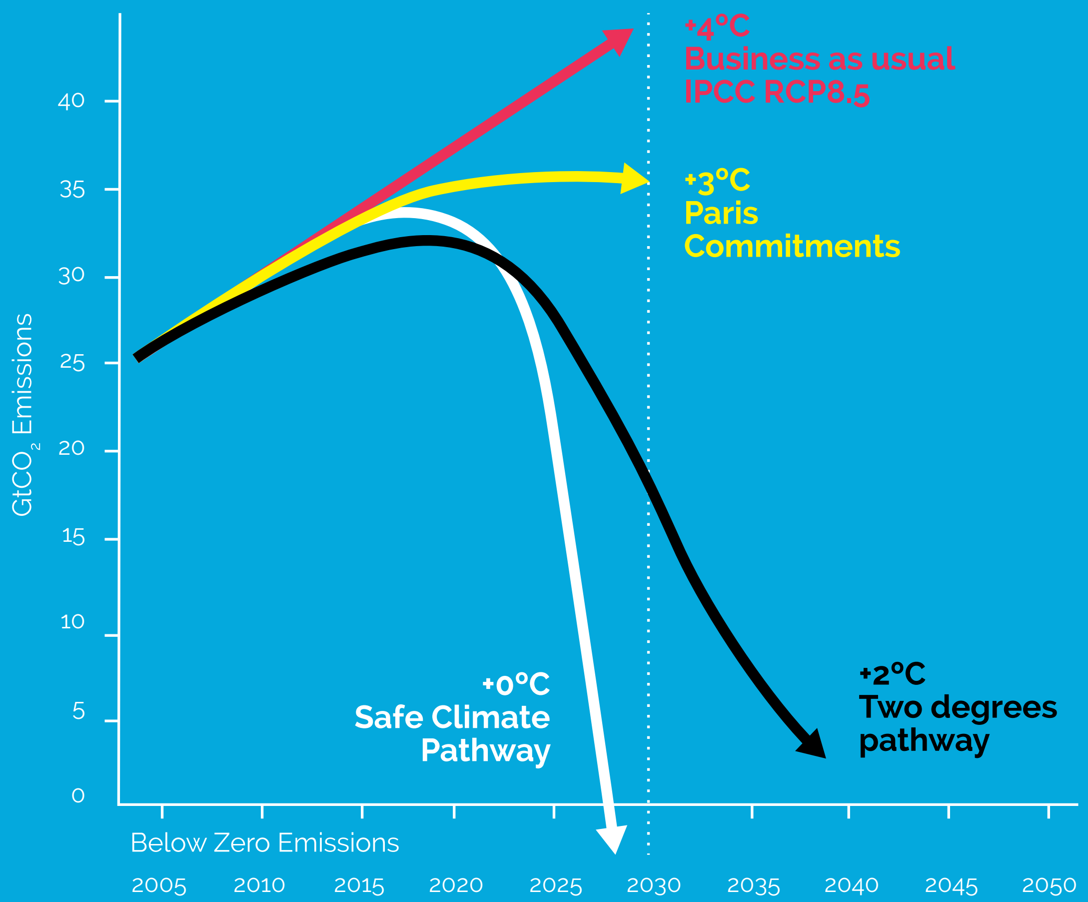
01

Stop releasing emissions

02

Remove dangerous greenhouse gases

Tracking emissions pathways



03

Prevent irreversible tipping points.

Even to stabilise the temperature at two degrees, we would need to reverse global warming.

Stop releasing emissions.

Considerations

There is no 'carbon budget' left if we want to reverse global warming and return to safe climate conditions. The longer we delay in transitioning to zero emissions, the more dangerous climate change impacts will become. Global zero emissions must be reached as fast as humanly possible.

With an emergency-scale response — one in which all the resources necessary to solve the problem are utilised — this goal may be possible within a decade. This response would require a social, economic and political mobilisation on a scale not seen since World War Two (WWII). Achieving zero emission would demand a rapid transition in energy, transport, agriculture, and other sectors.

Yet zero emissions alone would not achieve the full objective.

Risks

Eliminating emissions is a vital step in reversing global warming. However, stopping emissions is likely to have undesirable and unavoidable short-term warming consequences.

Some airborne pollutants, known as aerosols, have a short-term cooling effect on temperature, of at least 0.5°C, and up to 1°C. They are primarily the result of burning fossil fuels and significantly mask the warming impacts of greenhouse gases, including CO_2, methane and nitrous oxide. Eliminating fossil fuels emissions is a primary goal, but doing so would reduce aerosol levels and increase the global temperature.

In addition, CO_2 that has been stored in the oceans over the last century will slowly be released back into the atmosphere, as atmospheric CO_2 levels drop, adding to the drawdown challenge.

01

Explorations in zero emissions.

Greenhouse gas are emitted from all sectors of society. All sectors must be transitioned to zero-emissions energy sources and practices as soon as possible for a chance of restoring a safe climate. This will require widespread commitment from all business and industry across sectors to lead the change.

Stationary Energy

Energy accounts for a large portion of global emissions. This includes fuel combustion and fugitive emissions from fuel for the production of electricity. Transitioning to a zero-emissions energy sector would require large scale deployment of 100% renewable energy and closing all fossil fuel energy sources.

Land Use

Emissions from land include changing land use (clearing and deforestation), landfills and waste, ruminant livestock, rice cultivation, the use of agricultural chemicals, soil degradation and biomass burning.

Transport

Transport emissions are from fossil fuel combustion in road, rail, air and marine transport. Transport systems would need to be electrified, with large scale deployment of electric vehicles and rail-based systems, including a shift away from individual transport modes to renewable-powered public transport where possible. Sustainable biofuels could be used where appropriate.

Buildings

Heating and cooling, hot water, and cooking contribute to emissions in the residential and commercial sectors, as do the emissions embedded in the manufacture of fittings and furniture, clothing and food.

Waste

Waste emissions come from solid waste disposal, and treatment processes for solid waste and waste water. Solid waste disposal via landfill generates significant emissions, while also posing a number of social and environmental concerns. The need for landfill can be reduced by increasing the reusability of products and increasing recycling capacities to form a more closed economy of waste.

Industry

Industrial emissions include the minerals, chemical, electronics and metal industries. Non-energy use of fuels are also included. Transitioning industrial processes to zero emissions would require focus on the prominence of natural gas in heating and non-energy chemical processes, cement production, and the use of coal in steelmaking.

Zero emissions is just the beginning.

Remove dangerous greenhouse gases.

Considerations

Human activity has already emitted more greenhouse gases than is safe for the planet, and those elevated levels would remain in the atmosphere even if zero emissions was reached tomorrow.

Climate change impacts will continue for many decades to centuries (in the case of sea levels) after zero emissions is reached, because once tipping points —such as for permafrost melt and polar ice loss — are passed, these systems may continue to change due to internal dynamics.

Atmospheric greenhouse gas concentrations above safe levels must be reduced to prevent extremely dangerous and potentially catastrophic climate change.

CO2 is gradually removed by the atmosphere through natural processes, but this alone is far too slow. The amount required to be removed in order to return to safe climate conditions would take tens to hundreds of thousands of years or more.

While there are some viable drawdown methods available today, the scale of greenhouse gas removal required to reach safe levels is immense. Urgent research and development is required to develop large-scale CO_2 drawdown capacity.

Risks

There are a number of concerns with current drawdown methods and technologies.

To date, Bioenergy with Carbon Capture and Storage (BECCS) remains an unproven technology at scale, still firmly in the research and development phase. It is unknown to what extent BECCS technology could contribute to the total drawdown task, yet some emission-reduction models assume deployment at a very large scale.

Technologies for storing CO_2 underground are in the demonstration phase, and whether underground geological sites would be environmentally safe, secure and stable in the long term is questionable. These include storage risks of CO_2 leaking back into the air, and risks in destabilising geological structures, increasing levels of tremors and earthquakes. Research is needed to develop safer methods.

Land-use intensity is a prominent issue for BECCS, and for reforestation. These activities could compete with land use for food production. Arable land is forecast to become increasingly scarce as food production demands increase with predicted global population growth. Competing land uses also pose challenges to indigenous land rights.

Due to the vast scale of CO_2 drawdown that is necessary, the full scaling up of drawdown technologies and storage capacity will create risks of environmental damage through the accumulation of side effects. The whole system for CO_2 drawdown will need to be designed to produced a clear net environmental benefit.

Further research is needed to develop drawdown methods for other greenhouse gases, despite their lower concentration relative to CO_2.

02

Explorations in greenhouse gas removal.

A number of potential photosynthesis- and non-photosynthesis-based processes are currently being researched or implemented for removing greenhouse gases from the atmosphere. Major components include carbon capture from the atmosphere and long-term secure and safe storage. A conversion process to ensure CO_2 stability for storage purposes may also be necessary.

Reforestation & Afforestation

Changes in land use are contributing to greenhouse gas emissions, undermining the traditional role of the terrestrial biosphere as a carbon store.

There is recent evidence that tropical forests are now becoming a source rather a store of carbon: that is, they are emitting more CO_2 than they are drawing down. Current levels of deforestation hugely outweigh reforestation efforts, with more than seven million hectares of forests lost each year. Large scale reforestation and afforestation can play an important role in drawing down carbon from the atmosphere, while sustainable timber storage can lock carbon away for decades.

Soil Carbon

Industrial agriculture and global population together have degraded healthy and rich soils. Erosion and intensive agriculture expose soil to oxidation, during which soil carbon is lost. It is estimated that the world's cultivated soils have lost 50-70% of their carbon stocks, in addition to important nutrients and microbes. These impacts can be managed with regenerative agricultural practices that utilise soil as a carbon sink, by drawing down carbon from the atmosphere back into the soils, while also boosting soil productivity and resilience to droughts and floods.

Biochar

Biochar is produced from plant matter by heating biomass in a low-oxygen environment to fix carbon as charcoal, thus preventing it from being released back into the air. Biochar production, and storage in soils, has been suggested as a means of sequestering carbon, while simultaneously helping increase crop yields and nutrient retention, water retention and soil microbe biodiversity. Uncertainties exist regarding the level of impact, capacity and sustainability of biochar at the global level.

BECCS

BECCS involves using biomass as an energy source (such as liquid fuels) while capturing the CO_2 produced during fuel production for storage. While many other carbon drawdown methods use biomass to naturally store CO_2, BECCS uses biomass as a fuel source while injecting the liquified CO_2 into deep geological rock formations.

Industrial Carbon Capture

Industrial carbon capture systems are currently being developed to remove CO_2 from the atmosphere to be recycled for repeated use. These systems generally yield concentrated gaseous CO_2, but are not yet widely used.

Prevent irreversible tipping points.

Considerations

While zero emissions and drawdown strategies are being developed and applied, elevated global temperatures will continue to trigger major tipping points and potentially accelerate warming.

This dilemma presents the third major challenge in the goal to reverse global warming and return to safe climate conditions. Can and should we investigate strategies to manage incoming solar heat, in order to help reduce global temperatures while we draw down dangerous greenhouse gas emissions?

Solar reflectivity is one mechanism that aims to directly cool the planet by blocking or reflecting more of the sun's radiation back into the atmosphere. These methods would not reduce greenhouse gas concentrations in the atmosphere, but they could temporarily reduce global warming impacts, in order to prevent dangerous tipping points being reached.

Solar radiation management (SRM) suggest the potential to effect more rapid cooling than drawdown methods, and may offer an interim measure to limit some of the short- to medium-term consequences of climate change, while zero emission and carbon drawdown strategies are scaled up and take full effect.

Risks

Solar reflectivity is still in the early research and development phase and understanding of the potential climate, social and environmental impacts is limited. This is particularly important for space-based SRM, which could have far greater consequences than surface reflectivity options.

Adding aerosol to the atmosphere will likely impact global and local precipitation levels. Some early studies have identified the potential for sulphate aerosol solar reflection to disrupt monsoons and seasonal rains in Asia and Africa, threatening the food supply of millions of people.

Prominent researchers also identify that the impacts of aerosol SRM technologies may be long term, and that even after 10 years of SRM deployment we may still know very little about their effectiveness.

This points to a need for extensive research, to understand the potential risks, consequences and possibilities of reflecting solar radiation.

03

Explorations in reflecting solar radiation.

Technologies for managing incoming solar radiation vary widely. Land-based methods for albedo modification have had some mainstream traction to date, while atmospheric, stratospheric and space-based methods have received very little mainstream attention. The technological possibility and associated risks also varies widely between such methods.

Land-based

Land-based SRM methods concern changing the reflectivity (albedo) of Earth's surface. Surfaces with higher albedo levels reflect more light, and absorb less heat. Managing surface albedo could enable the reflection of some solar radiation back into space, having a net cooling effect.

Cool roofs

Solar reflective 'cool roofs' absorb less solar radiation than traditional roofs, as well as reducing the urban heat island effect.

High-albedo crop varieties

The albedo levels of crops differ with leaf wax properties, leaf morphology and hairiness. High-albedo crop varieties could be used to increase the reflectivity of croplands and grasslands. But the use of such crops with higher albedo levels than woodlands or native shrublands raise concerns over competing land uses and the potential for increased native vegetation clearing.

Atmospheric/ Stratospheric

Atmospheric and Stratospheric SRM methods seek to have a cooling effect by blocking incoming solar radiation at atmospheric and stratospheric levels.

Stratospheric aerosols

Stratospheric aerosol injection seeks to mimic the effects of volcanic eruptions, where millions of tonnes of reflective sulphur particles are released into the stratosphere. Studies of volcanic eruptions have shown that these sulfate particles have a cooling effect for one or two years following an eruption.

Marine cloud brightening

Brighter surfaces reflect more sunlight back into space due to higher albedo levels. Marine stratus clouds, which cover large areas of ocean, could potentially be brightened by spraying small droplets of sea water into them.

Ocean sulfur-cycle enhancement

Limited iron fertilisation of the Southern Ocean could stimulate the natural sulphur cycle, which could increase cloud reflectivity.

Space-Based

A number of space-based SRM technologies using reflective materials have been proposed. However, to compensate for the current increase in greenhouse gas emissions, more than 10,000 square kilometres of reflective material would have to be deployed, and this category of solutions is extremely costly in comparison with other proposed technologies.

Space mirrors

It is proposed that space mirrors be used as a 'sunshade' to reduce the level of incoming

How to reverse global warming

Speed, Scale & Safety

Climate change poses an existential threat to human civilisation, all species and our planet.

The next ten years rae critical for out planet. We stand on the edge of major ecological tipping points.

Appropriate risk management demands that we take immediate action.

We must act as fast as possile to lower the earth's temperature to restore a safe climate.

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