What are the benefits of reducing global CO_2 emissions to net-zero by 2050?

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What do we mean when we say net-zero CO_2 emissions?

This is where total global anthropogenic carbon dioxide (CO_2) emissions are reduced to near zero, and any remaining emissions are balanced by measures to remove CO_2 from the atmosphere (Allen *et al.*, 2018). Halving all CO_2 emissions by 2030 and achieving net-zero emissions by 2050 is anticipated to meet the aspiration of the Paris Agreement by limiting the global mean surface temperature increase to 1.5 degC above pre-industrial values, as well as avoiding some of the worst impacts from climate change and reducing the probability of reaching dangerous climate tipping points. Emissions of other greenhouse gases (such as methane) and black carbon have a shorter lifespan in the atmosphere, but are nevertheless important to reduce alongside CO_2 emissions to achieve the 1.5 degC temperature target.

How do we reach net-zero by 2050?

Global surface temperatures reached 1.09 degC (0.95–1.20 degC) above preindustrial levels (1850–1900) in the most recent decade of the twenty-first century (2011–2020) due to cumulative greenhouse gas emissions from anthropogenic activities (IPCC, 2021). Achieving net-zero by 2050 and limiting warming to 1.5 degC requires large reductions in emissions through decarbonisation of the transport, agricultural, industrial and residential sectors, as well as efforts to limit demand. It is likely that gross emissions will not be reduced to zero, requiring additional removal measures such as:

- CO_2 removal measures such as direct air capture and carbon capture and storage, including bioenergy carbon capture and storage (BECCS).
- Natural mitigation measures including increased tree planting and ecosystem restoration.

Implementing these additional measures to achieve net-zero involves challenges that are technological (e.g. direct air capture), socio-economic (financial) and environmental (land area reduction for BECCS).

What are the benefits of achieving net-zero?

Weather extremes

While the Earth's climate system will still experience year-to-year variability, achieving net-zero and limiting warming to 1.5 degC, as opposed to 2 degC, above a baseline of 1850–1900, will reduce the frequency and intensity of weather events such as heatwaves, heavy rainfall and droughts (Allen *et al.*, 2018). The IPCC Special Report on the impacts of global warming of 1.5 degC (Allen *et al.*, 2018) (SR1.5) concluded with high confidence that extremely hot days are projected to be 3 degC warmer at global warming of 1.5 degC, and 4 degC warmer at 2 degC, with the largest increases in the number of hot days projected to be in the tropics. An additional 0.5 degC global warming compared to the present is associated with more intense and more frequent heavy rainfall in several regions, leading to an increase in the global land area affected by flood hazards.

Sea level

Limiting global warming to 1.5 degC is projected to reduce sea level rise by around 0.1m compared to 2 degC by 2100, although sea level will continue to rise well beyond 2100 (Allen *et al.*, 2018). Based on 2010 population estimates, this would result in up to 10 million fewer people exposed to sea-level related risks. While many climate impacts are observable in the current climate, large-scale singular events (such as Greenland ice sheet collapse, collapse of North Atlantic circulation or major global forests becoming sources of CO_2 rather than sinks) have a low probability, but potentially catastrophic, irreversible consequences. These tipping points are important because reaching them may further exacerbate projected impacts (e.g. West Antarctic ice sheet collapse would lead to 3–4m of sea level rise (Bamber *et al.*, 2009)) and would accelerate warming leading to cascading impacts (Rocha *et al.*, 2018), increasing the probability of multiple tipping points being reached (Lenton *et al.*, 2019).

Terrestrial and marine ecosystems

Achieving net-zero CO_2 emissions by 2050 and limiting global warming to 1.5 degC would reduce the probability of the most damaging effects of climate change on natural systems. However, even at 1.5 degC global warming there is a severe risk of significant local change to water resources and terrestrial ecosystems in the Arctic and some sub-tropical to temperate dry zones (Gerten *et al.*, 2013). The SR1.5 concluded that 13% of the global land area was projected to undergo ecosystem transformation at 2 degC global warming but limiting warming to 1.5 degC could reduce this area by 50%. In the oceans, limiting global warming to 1.5 degC reduces risks of severe impacts on ocean carbon uptake, coral reefs, bivalve fisheries and coastal protection amongst other impacts (IPCC, 2018). However, it does not avoid the very high risk of significant irreversible impacts to warm water corals due to the combined effect of warmer oceans and acidification from higher levels of dissolved inorganic carbon.

Human health, livelihoods, water and food security

As net-zero would be achieved by reducing the burning of fossil fuels, we can expect to see direct and immediate benefits to human health due to reduced air pollution, particularly in urban areas. Additionally, the measures we take to achieve net-zero may also benefit human health. For example, by encouraging active travel such as cycling, we would expect to have a healthier population with reductions in respiratory illnesses, fewer traffic deaths, and reduced noise pollution. Similarly, where diets have more red

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meat than is recommended by healthy eating guidelines, replacing red meat with pulses and other vegetables would both reduce associated greenhouse gas emissions and improve health outcomes.

Achieving net-zero may also reduce the severity of regional hydrometeorological events such as drought and flooding due to heavy rainfall. Drought events can affect water quality and availability, food production and increase risks of wildfires as well as decreasing land carbon sequestration. Limiting warming to 1.5 degC may reduce the global land area under aridification (a long-term increase in dry and hot conditions) by up to two thirds (Park *et al*., 2018). Achieving this target may also help to limit risks of flooding in major catchments around the world (Alfieri *et al*., 2017).

Summary

Achieving net-zero CO_2 by 2050 and consequently stabilising global mean temperatures at approximately 1.5 degC above preindustrial levels would avoid some of the worst impacts of climate change predicted at 2 degC and above. These benefits are likely to be experienced in most natural and human systems. Furthermore, the co-benefits of achieving net-zero in terms of a healthier population are also an important consideration.

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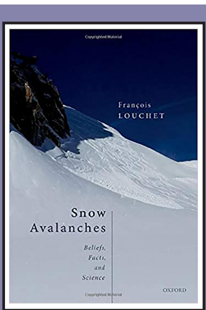
Book review



Snow Avalanches – Beliefs, Facts and Science

François Louchet

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Snow avalanches are among the most serious of natural hazards to life and property. Globally an average of over 150 people die each year from avalanches, but the deadliest have killed over a thousand people. Although avalanches can occur on any slope, some can be more dangerous than others, given the right conditions, location and time of year. Several factors may affect the likelihood of an avalanche other than the obvious ones such as temperature and wind direction. The steepness and orientation of the slope, the terrain, the vegetation and general snowpack conditions all play important roles.

François Louchet is Professor of Condensed Matter Physics at Grenoble University and over the past 15 years has been a technical consultant to the international snow and avalanche community. An avalanche may be defined as the destabilization and flow of part of the snow cover. This book essentially deals with the former, focussing on the mechanisms that trigger and release avalanches, and providing, in Louchet's own words, *'a critical update of the most recent and innovative developments of avalanche science'*.

The book begins gently, introducing the reader to many of the terminologies that appear throughout the text. These include the three main types of snow avalanche: 'slab', which is responsible for most human fatalities, 'loose snow' and 'full-depth'. Other types, such as 'dense' and 'airborne powder' avalanches, are briefly discussed. More detail is given to the role played by the 'weak layer' in a snow pack. Chapter 2 provides the minimum basic concepts useful for understanding avalanche science, detailing the complex structure of snow and the changing mixtures of ice, air and water. Chapter 3 is dedicated to some mechanical and physical concepts surrounding deformation, fracture and friction processes. The following three chapters provide a thorough scientific explanation of avalanche release mechanisms. Observation and field experiments are analysed before the author moves on to modelling and analytical approaches.

Throughout the book Louchet adopts a multidisciplinary approach, using tools and concepts from a variety of scientific fields such as those used in the study of rock and mud slides, and large-scale movements of ice, for instance in glaciers. Louchet provides a balanced and practical scientific study with detailed formulae and calculations for specialists. Included are links to on-line field experiments and lectures on triggering mechanisms, risk management and decision-making. The reader learns, in practical terms: how an avalanche can be triggered by a person from far away (even up to a kilometre from the slope); why avalanches are not triggered by the first person on an unstable slope; and why an unstable slope of snow is not triggered most of the time (even though it should have generated an avalanche). In