‘COUNTRY OF PERMAFROST’

Current and future permafrost emissions as large as major emitters

Permafrost and the global climate system

Permafrost is ground that remains frozen through the year, and covers 22% of the Northern Hemisphere land area. It is actually a frozen mixture of soil, rocks, ice and organic material, holding about twice as much carbon as currently exists in the Earth’s atmosphere.

Cold temperatures have protected this organic matter from thawing, decomposing and releasing its stored carbon for many thousands of years. Observations confirm that it is rapidly warming, and releasing part of that thawed carbon into the atmosphere as both carbon dioxide (CO_2) and methane. Permafrost thaw is projected to add as much greenhouse gas forcing as a large country, depending on just how much the planet warms. Today, at about 1.2°C, we are already committed to losing about 25% of surface permafrost.

As temperatures have risen, especially since about 1950, permafrost has not only declined in area, but thawed to deeper depth and greater volume; beginning to release its stored carbon. Most of this released carbon comes as CO_2; but if permafrost thaws under wet conditions, such as under wetlands or lakes, some of that carbon enters the atmosphere as methane. While not lasting as long in the atmosphere as CO_2, methane warms far more potently during its lifetime: about 100 times more over 20 years, leading to faster and more intense global warming.

Permafrost thaw occurs gradually over large areas, but these landscapes are also vulnerable to abrupt thaw events. These can result in large-scale erosion, ground collapse along hillsides and cliffs, and rapid formation of new lakes or wetlands. The collapsed ground rapidly exposes ever-deeper carbon pools, and further accelerates thaw rates.

The number of these rapid thaw events has increased as the Arctic warms, and might increase permafrost carbon emissions by as much as 50% as the planet warms to 1.5°C or more. Increasing wildfires in the Arctic due to warmer and drier conditions also cause deeper and more rapid thawing, which remains for decades after the fire. Like emissions from abrupt thaw events, these fire-related emissions have not been included in past estimates of greenhouse gases.

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Some permafrost is actually located beneath the coastal waters of the Arctic Ocean, on lands flooded at the end of the last Ice Age when sea levels rose. Its current and future contribution to carbon emissions remains uncertain, but could be significant. Recent estimates range from an additional 150–250 Gt CO_2 equivalent by 2100, especially with additional Arctic Ocean warming.

House collapsed in Alaska due to thawing permafrost. Ashley Cooper / Alamy Stock Photo
Adam Jones Traditional Wooden House Leans in Permafrost - Tomsk - Siberia – Russia.

Cliff collapse.

Scenario	Temperature peak	Cumulative Gt CO_2-eq (including CO_2 and CH_4) by 2100	Impacts
Low emissions	1.6-1.8°C ...and declining Peak reached between 2060-2080	150-200	Once permafrost thaw is initiated, including by extreme summer heat events, the resulting emissions continue for centuries. As a result, permafrost emissions will continue even if temperatures slowly decline. Future generations will need to deploy and continue CO_2 removal strategies equal to these long-term emissions until they cease, simply to hold temperatures steady.
Optimistic fulfillment of all current pledges	1.9°C Peak reached between 2120-40	220-300	These emissions will continue for one-two centuries after peak temperature is reached. Future generations will need to deploy and continue carbon dioxide removal strategies equal to these long-term emissions until they cease, simply to hold temperatures steady. Permafrost soils will disappear in extensive regions above the Arctic Circle, as well as below, and nearly all existing infrastructure built on permafrost soils will require replacement.
Current implemented NDCs	3.1°C Peak reached between 2150-70	350-400	These emissions will continue for one-two centuries after peak temperature is reached. Future generations will need to deploy and continue carbon dioxide removal strategies equal to these long-term emissions until they cease well past 2300, simply to hold temperatures steady. Over 70% of original pre-industrial surface permafrost globally will have disappeared by the time of this peak. Extensive erosion, due to permafrost thaw, sea ice-free conditions and more violent storms will require extensive replacement of coastal and riverside Arctic infrastructure, especially in Russia and Canada.
Current emissions growth	4-5°C ...and rising Peak reached well after 2200	400-500+	These emissions will continue for one-two centuries after peak temperature is reached. Future generations will need to deploy and continue carbon dioxide removal strategies equal to these long-term emissions until they cease well past 2400, simply to hold temperatures steady. Surface permafrost soils will largely disappear globally. Infrastructure damage, especially in Siberia and Alaska, will be extreme. Emissions from permafrost thaw are essentially permanent on human timescales, because the long-term drawdown of carbon to re-build new permafrost soils takes thousands of years.

The only means available to minimize these growing risks is to keep as much permafrost as possible in its current frozen state, holding global temperature increases to 1.5°C. This will also minimize the burden of negative emissions on future generations.

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