@ $ # ! We Forgot Permafrost

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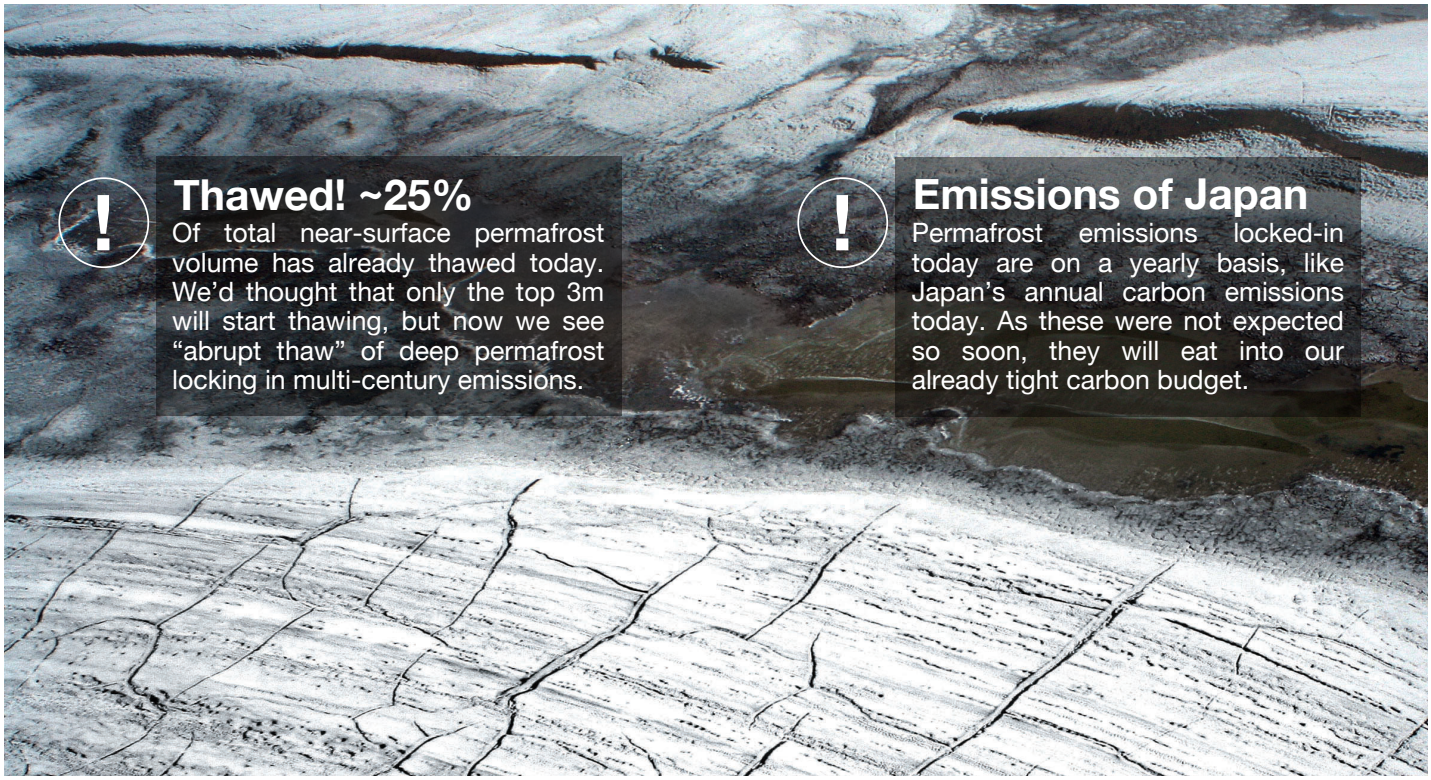
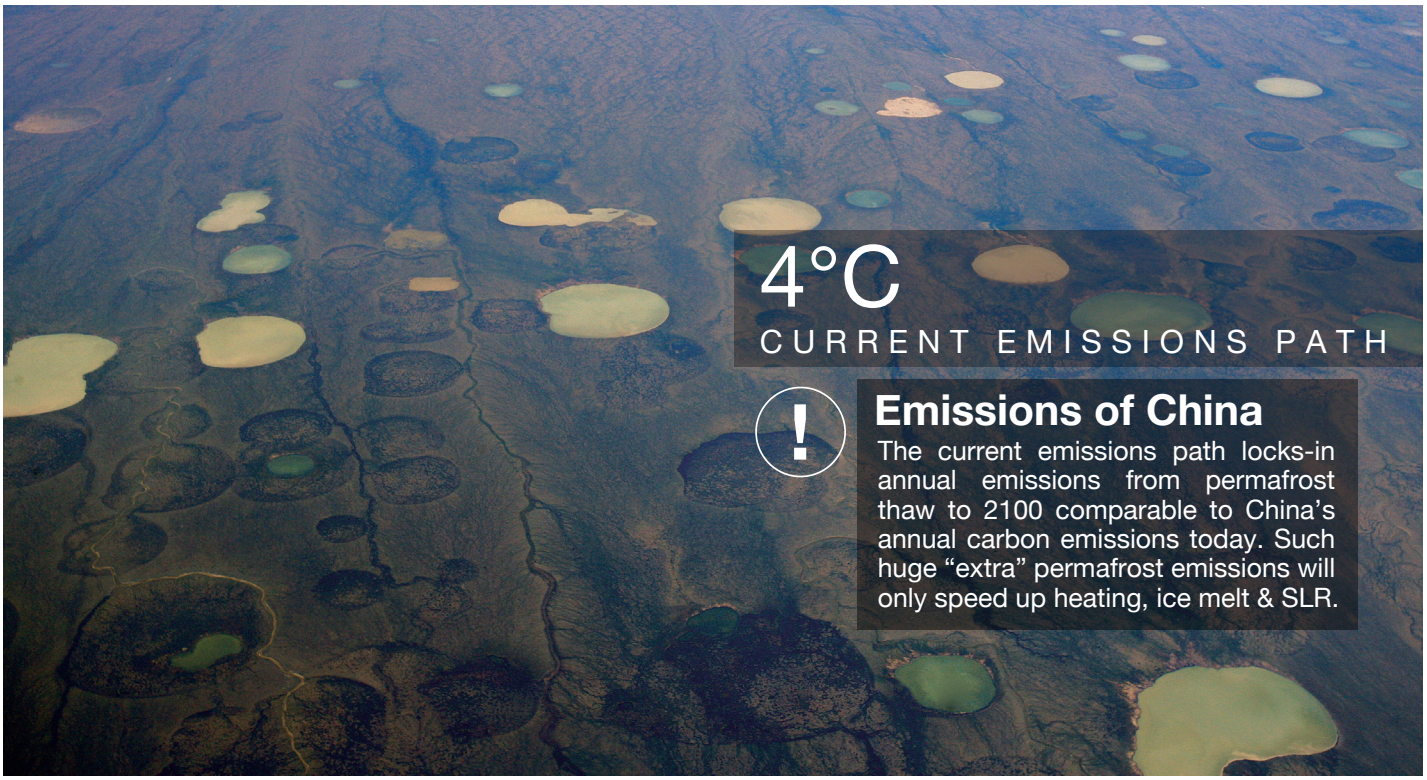


Our carbon budget doesn't account for permafrost emissions! Thawing speeds up "climate hell"



Source: CWR; ICCI; Permafrost Factsheet; IPCC AR6 WG1 (2021); ICCI State of the Cryosphere 2023; IPCC AR6 WG3 (2022); UN, Secretary-General's remarks to High-Level opening of COP27 (07 November 2022); UNEP Emissions Gap Report 2023.

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It's bad! We didn't expect permafrost thaw to be so abrupt & so deep

Permafrost is frozen earth that holds 3x the carbon that exists in the atmosphere. When this thaws, much more CO_2 and methane will be released, adding to global heating. Indeed, **the Arctic-boreal permafrost region is now a net source of GHG warming** and these emissions will rise if warming persists. Permafrost's potential to derail global decarbonisation efforts is thus too big to be ignored!

Previously, we had only expected permafrost thaw to happen to the top 3m of soil. Yet, we are now experiencing "abrupt thaw" where the ground collapses exposing cliffs of permafrost that thaw sideways. This abrupt deep thaw sets in motion irreversible emissions that will not slow for hundreds of years even if temperatures fall and permafrost re-freezes. **There's no "undo" option, no "safety margin" for acceptable thaw – preventing further warming & thaw is the only way.**

As we had not expected such deep permafrost thaw to occur so soon, these emissions **were not factored into our carbon budget nor current global climate models so we've likely under-estimated climate impacts**. Worst still, continued high emissions will trigger rapid & irreversible acceleration of subsea permafrost thaw along Arctic coastlines by 2080.

Locked-in emissions from permafrost thaw to 2100

At today's temperatures, we will need "negative emissions" equivalent to those of Japan per year just to keep our CO_2 levels stable. To keep within 1.5°C, we will need "negative emissions" equivalent to 100GtCO_2 to account for deep permafrost thaw over the course of this century. On a yearly basis, this is equivalent to the annual carbon emissions of India! As global heating continues, permafrost emissions will balloon…

Irreversible emissions from deep permafrost thaw

1.5°C
100 GtCO_2e

For stable CO_2 levels, negative emissions per year comparable to India are needed.

2°C+
220-300 GtCO_2e

For stable CO_2 levels, negative emissions per year comparable to EU are needed.

4°C
400-500 GtCO_2e

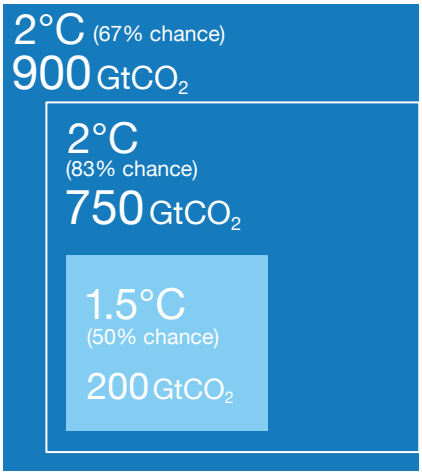
For stable CO_2 levels, negative emissions per year comparable to the China are needed.

Blowing our carbon budget

The IPCC AR6 said our carbon budget for a 50% chance of staying below 1.5°C was 500GtCO_2 at the start of 2020. Sadly, as we are still emitting, the UN says this has shrunk to 200GtCO_2 as of January 2024. At the 2023 rate of CO_2 emissions of 41GtCO_2, the UN says that our 1.5°C carbon budget will be depleted in around 5 years time, by 2028. But this doesn't factor in deep permafrost thaw.

Scientists estimate that 100GtCO_2 will have to be subtracted from the global carbon budget to stay within 1.5°C. This leaves us with 100GtCO_2 which at the current rate we will gobble up in less than 3 years – by 2026. Transitioning to net zero just got a lot harder with deep permafrost thaw!

Remaining CO_2 budget from January 2024 (does not factor in deep permafrost thaw)



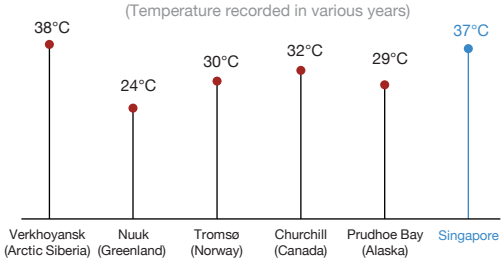
! 2-4X ARCTIC WARMING ACCELERATES PERMAFROST THAW

Arctic warming & fires

Nearly all permafrost is located in the Arctic, with smaller amounts in Antarctica & high mountain regions like the Tibetan Plateau. Sadly, all these regions are heating up faster than the global average which means permafrost thaw will likely only worsen. As can be seen from the chart, summer temperatures in these regions have soared. In addition, extensive fires across Siberia and Canada will only speed up the thaw.

An idea of how hot Arctic summers can get …

(Temperature recorded in various years)



Water cycle changes & infrastructure collapse …

Permafrost thaw also changes the Arctic water cycle. Under high emissions, it'll see up to 25% more above-ground runoff and 30% more below-ground runoff by 2100, with the southern Arctic becoming progressively drier. This could affect sea ice, biodiversity, ocean freshening/currents & global climate. Erosion also destabilises riverbanks putting buildings, power lines, roads & energy pipelines at risk.

Methane & viruses set free!

Methane, ~30x more potent than CO_2 over a 100yr period at trapping heat is also released when permafrost thaws under wet conditions. If current emissions persist, methane from just sub-Arctic North American wetlands will triple! Now, "talik" layers in dryland permafrost are also found to release methane nearly 3x higher than northern wetland emissions! In addition, thawing can also release viruses trapped deep below the frozen surface.

It's happened before! Vanishing permafrost …

Around 3 million years ago, during a warm period, 90% of the permafrost at the time disappeared under climate conditions like those projected under the high emissions scenario.

If we breach 2°C, over 75% of permafrost peatlands in Northern Europe & Siberia will become too warm to maintain permafrost by 2060. It's time to wake up !

We have to do so much more. Every year we don't do something is one more year of feedback loops that deliver a vicious cycle of more emissions and permafrost thaw.

Not including permafrost in our global carbon budget is just lying to ourselves that this thaw is not happening when it plainly is. There is no "undo-ing" the thaw, deep carbon cuts today are the only way.

Deep Cuts

Current Path

Source: CWR; Ramage et al. (2024), Glob. Biogeochem. Cycles (38); See et al. (2024), Nature Climate Change (14); IPCC AR6 WG1 (2021); ICCI State of the Cryosphere 2023 & 2024; Nitzbon et al. (2024), Nature Climate Change (14); IPCC AR6 WG3 (2022); Creel et al. (2024), Nat. Commun. (15); IPCC SR15 (2018); UN (2024) Surging Seas in a warming world; Climate Change Tracker "Current Remaining Carbon Budget & Trajectory"; WMO; various news sources; Extreme Weather Watch; Rawlins & Karmalkar (2024), The Cryosphere (18); Douglas et al. (2023), JGR Earth Surface (128); Walter Anthony et al. (2024), Nat. Commun. (15); Fewster et al. (2022), Nature Climate Change (12).

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