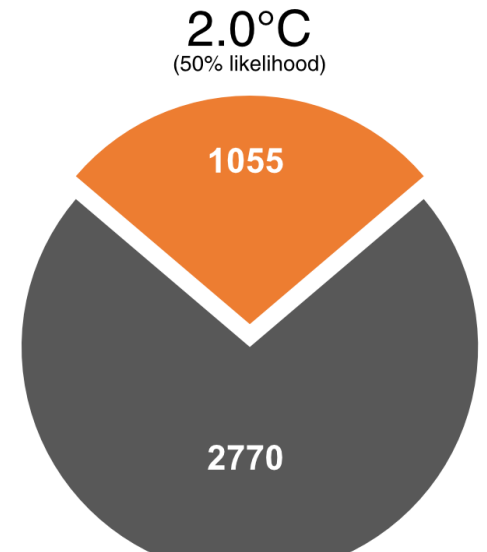
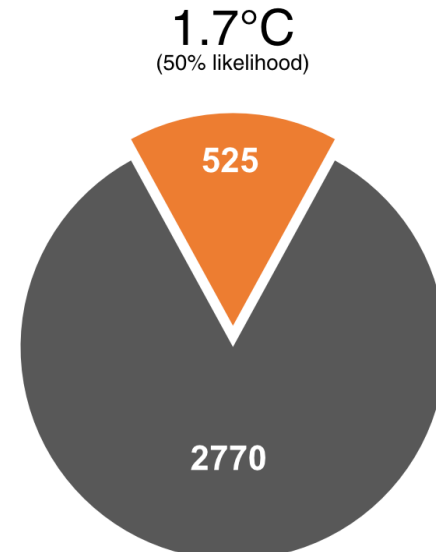
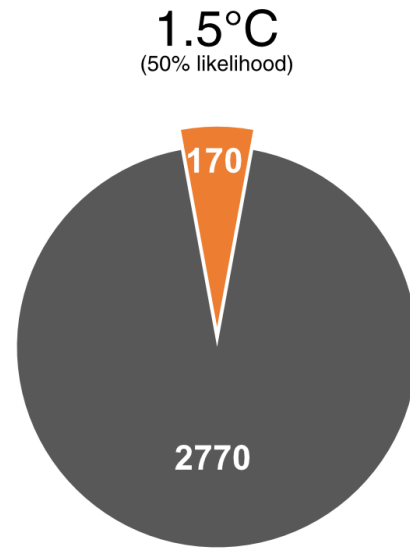
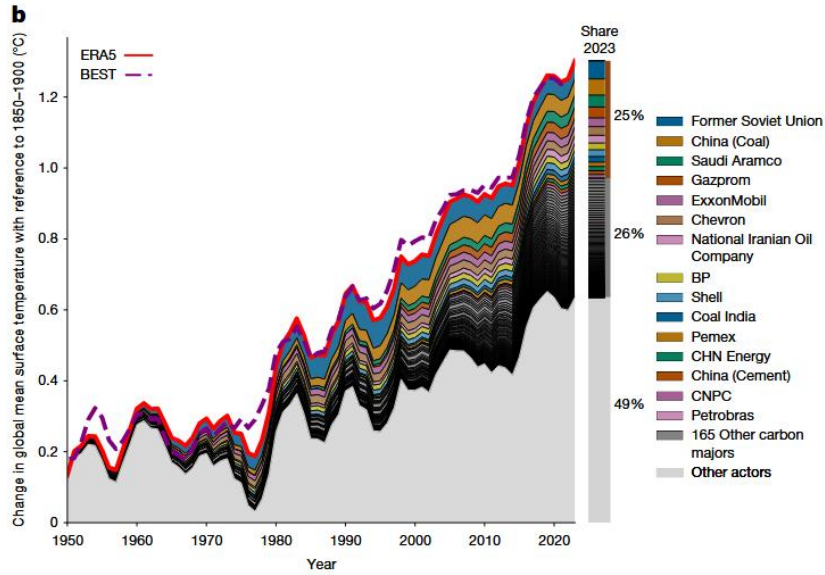


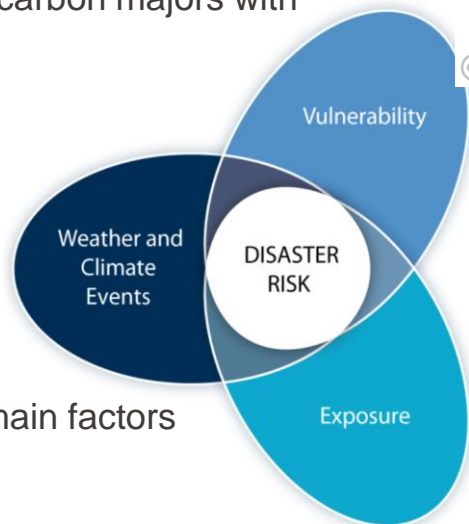
Recap from last lecture



Gt CO₂ ■ Consumed ■ Remaining

Attribution studies relating carbon majors with extreme heat waves

© Global Carbon Project



Impact depends on three main factors

We're running out of time with our carbon expenses.

| | No. | Date | Topics | Deadlines / tentative |
|--------------------------------------|-----|------------|--|---|
| Basics | 1. | 11.09.2025 | Introduction to the climate system | Questionnaire (not graded) |
| | 2. | 18.09.2025 | Climate System, Radiation | |
| | 3. | 25.09.2025 | Radiation, Earth's Energy balance, Greenhouse effect | launch of first assignment |
| | 4. | 02.10.2025 | Aerosols & clouds, Radiative Forcing | Launch of poster project |
| | 5. | 09.10.2025 | Feedback mechanisms, Climate Sensitivity | |
| | 6. | 16.10.2025 | Paleoclimate | submission of Poster proposal (graded) |
| Present and future Climate change | 7. | 30.10.2025 | Climate variability, Introduction to IPCC | |
| | 8. | 06.11.2025 | Current state of climate, IPCC – report, Paris Agreement, Climate scenarios (RCPs, SSPs) | |
| | 9. | 13.11.2025 | Emissions Gap, 1.5 vs 2.0°C vs warmer, Tipping elements, Extreme Events | submission of Poster draft (graded) |
| | 10. | 20.11.2025 | COP 30, Extreme Events Attribution Studies, Carbon budget | |
| | 11. | 27.11.2025 | Climate litigation, Metrics, Carbon offsets | submission of assignment (graded) |
| Actions | 12. | 04.12.2025 | Polar climate change | |
| | 13. | 11.12.2025 | Mitigation measures | Poster Conference (graded) |
| | 14. | 18.12.2025 | Climate engineering, questions and answers session | fill in Questionnaire in exercises (not graded) |

Carbon Dioxide Removal

Equivalent to ~5% of annual Fossil CO₂ emissions



2.2 GtCO₂ per year

Equivalent to ~1 millionth of annual Fossil CO₂ emissions



0.001 MtCO₂ per year



0.007 MtCO₂ per year

Vegetation-based CDR estimates from GCB2025
CDR not based on vegetation from the State of CDR report (2024)



More information, data sources and data files:
<https://globalcarbonbudget.org/carbonbudget>



More information, data sources and data files:
www.globalcarbonatlas.org
(co-funded in part by BNP Paribas Foundation)

Climate Litigation



German court dismisses Peruvian farmer's climate lawsuit against RWE

Court rejects argument that man's home is at risk from glacial flood but sets precedent that polluters may be held liable for costs



📷 Saúl Luciano Lliuya in Huaraz, Peru. Photograph: Angela Ponce/Reuters

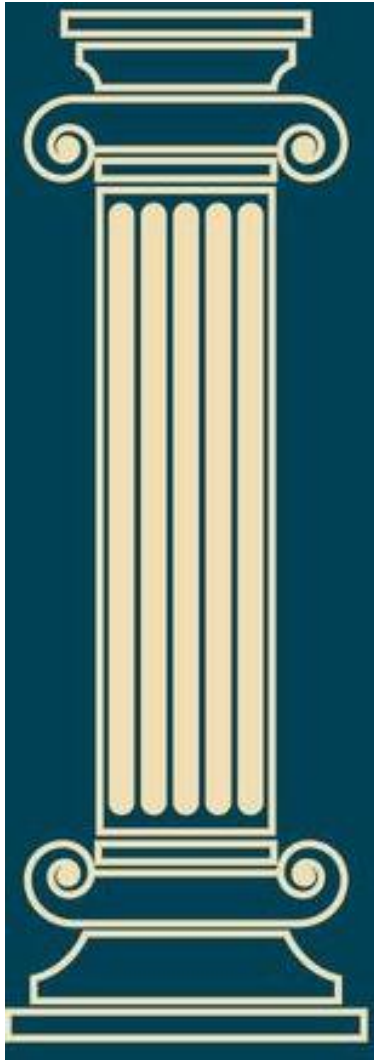
- The upper regional court in Hamm confirmed that companies could be held liable for climate damages in civil proceedings but rejected the argument by the farmer and mountain guide Saúl Luciano Lliuya that his home was at direct risk of being washed away by a glacial flood.
- However, the judge in the case ruled that companies “may be obligated to take preventive measures” to counter their emissions, according to a statement from the higher regional court in Hamm.
- “If the polluter definitively refuses to do so, it could be determined, even before actual costs are incurred, that the polluter must bear the costs in proportion to their share of the emissions,” the court concluded.
- The ruling was nonetheless a milestone for climate litigation, Lliuya’s lawyer Roda Verheyen said in a statement. “For the first time in history, a higher court in [Europe](#) has ruled that large emitters can be held responsible for the consequences of their greenhouse gas emissions,” she said.
- The outcome of the case would “give a tailwind to climate lawsuits against fossil fuel companies, and thus to the move away from fossil fuels worldwide”, she added.
- “This decision clarifies how climate science can inform judicial decision-making on corporate climate liability. It strengthens the foundation for future claims where the evidence is even more robust.”



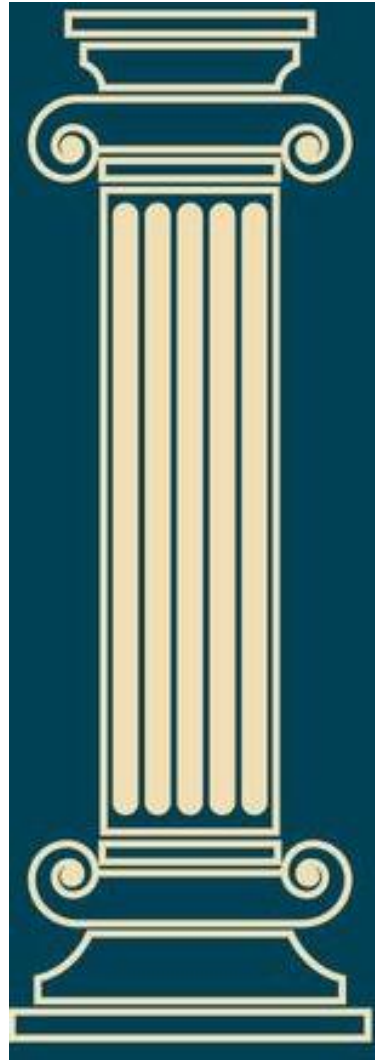
Swiss climate verdict: **carbon budgets** mattered to the judges

- On April 9, 2024, Europe's top human rights court ruled in favour of a group of elderly Swiss women, the KlimaSeniorinnen, who said the government's inadequate efforts to combat climate change put them at risk of dying during heatwaves.
- The European Court of Human Rights (ECHR) recently ruled that Switzerland had failed to meet its own climate targets and to set a national **carbon budget**.
- Ruling: Switzerland **“failed to quantify, through a carbon budget or otherwise, national greenhouse gas emissions limitations”**
- **Implication of a carbon budget:** There is a hard limit and emissions need to stay within it.

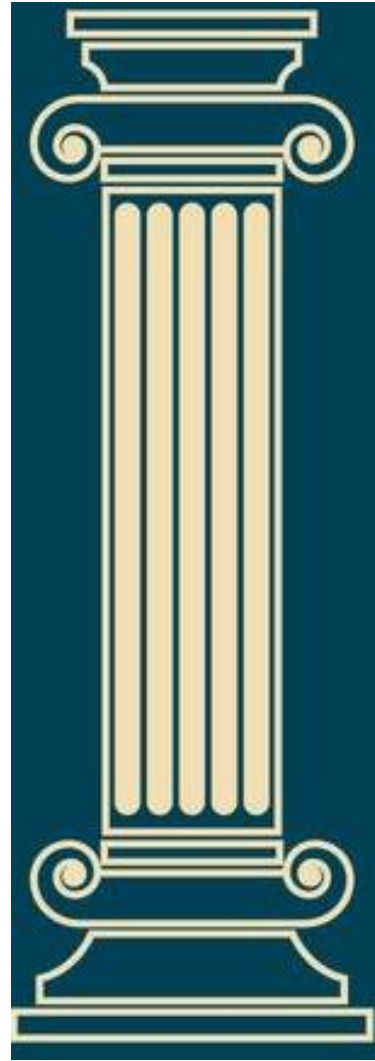
New Era of Accounting in Europe



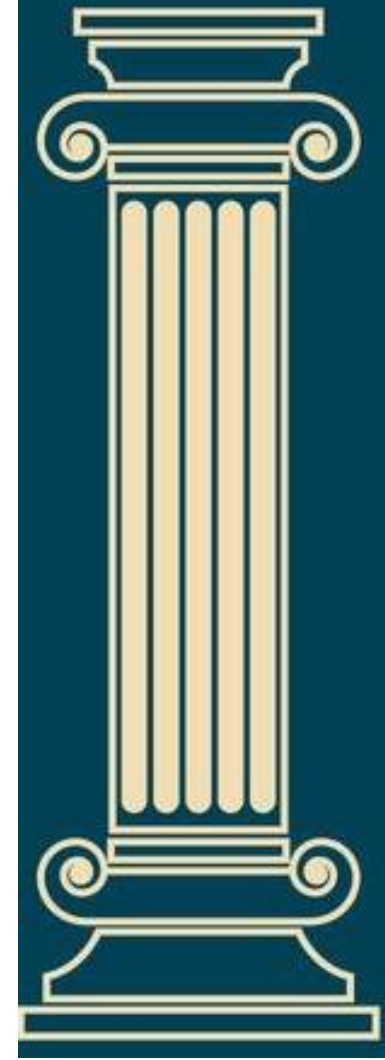
revenue



cost



capital



sustainability

Corporate Sustainability Reporting Directive (CSRD)

- In Europe, 11,700 companies, banks, and insurers will have to report their greenhouse gas emissions for the first time in 2025 because of the European Union's [Corporate Sustainability Reporting Directive \(CSRD\)](#). (formerly covered by the Non-Financial Reporting Directive (NFRD), imposed broader, less stringent rules on environmental, social, and governance disclosure.)
- Their 2025 reports will have to detail emissions from their 2024 fiscal years.



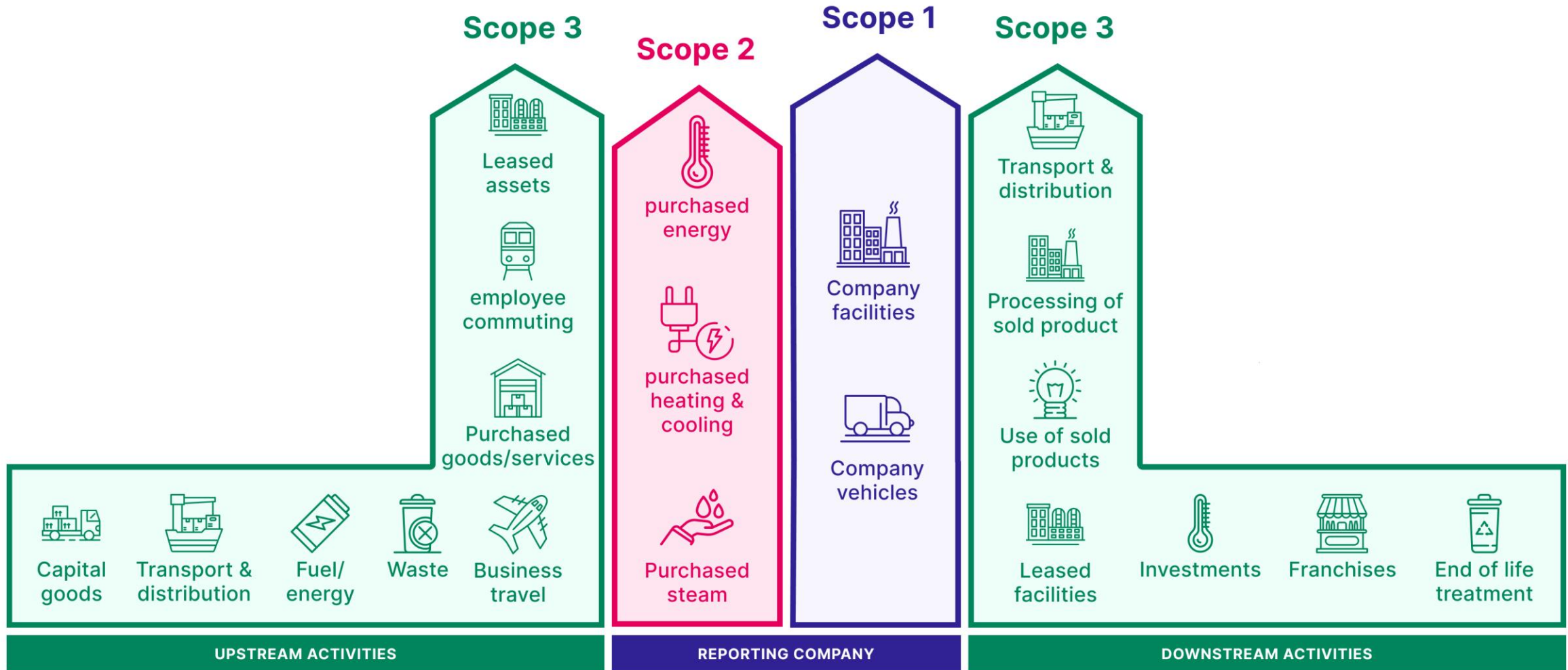
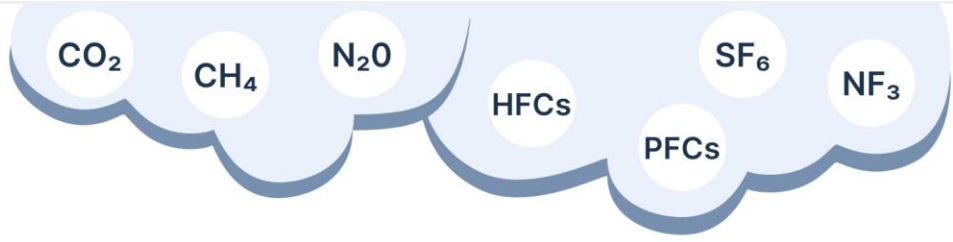
Corporate Sustainability Reporting Directive (CSRD)

- Ultimately, nearly 50,000 companies in Europe will be reporting as well as more than 10,000 non-EU companies and their European subsidiaries.
- In 2028, the CSRD takes effect for non-EU parent companies with €150 million annual revenues in the EU and at least one subsidiary or branch in the EU that conducts significant business. They must file their first report using 2028 emissions data at a consolidated group level (including non-EU activity) in 2029.

Scope 1, 2, 3 emissions

- Scope 1 encompasses direct emissions originating from sources owned or controlled by the reporting company.
- Scope 2 pertains to indirect emissions derived from the generation of purchased electricity, steam, heating, and cooling employed by the reporting company.
- Scope 3 covers indirect emissions resulting from activities involving assets beyond the reporting organization's control, but within its value chain.

The GHG Protocol



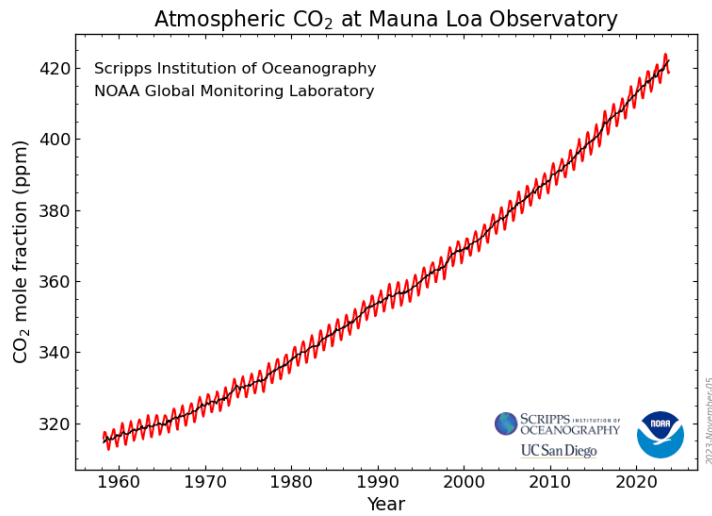
- Carbon accounting is also set to become a major factor in defining business risk as many companies begin to calculate carbon footprints using the Greenhouse Gas Protocol's Scope 1, 2, and 3 definitions for the first time.
- CSRD disclosure is also based not just on a company's carbon dioxide (CO₂) emissions but rather on its **total greenhouse gas emissions — using CO₂ equivalents.**



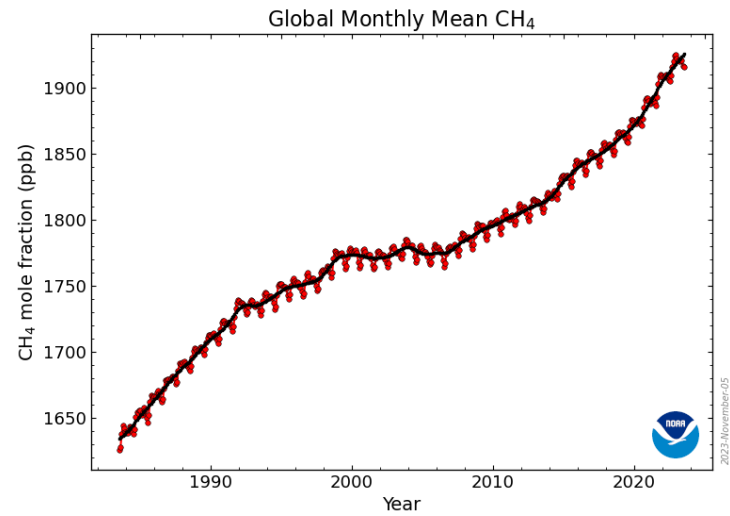
Carbon is not simply carbon
Conversion factors are needed

Trends in GHG

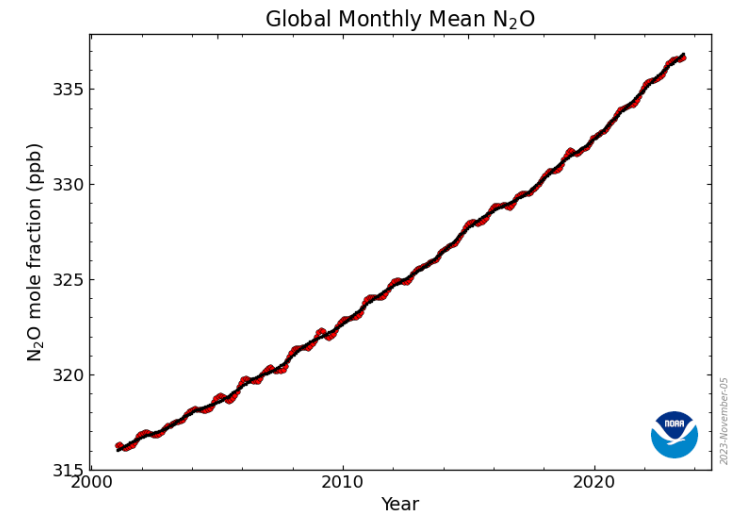
It's not only CO₂!



October 2023: 418.82 ppm
October 2022: 415.74 ppm
Last updated: Nov 05, 2023

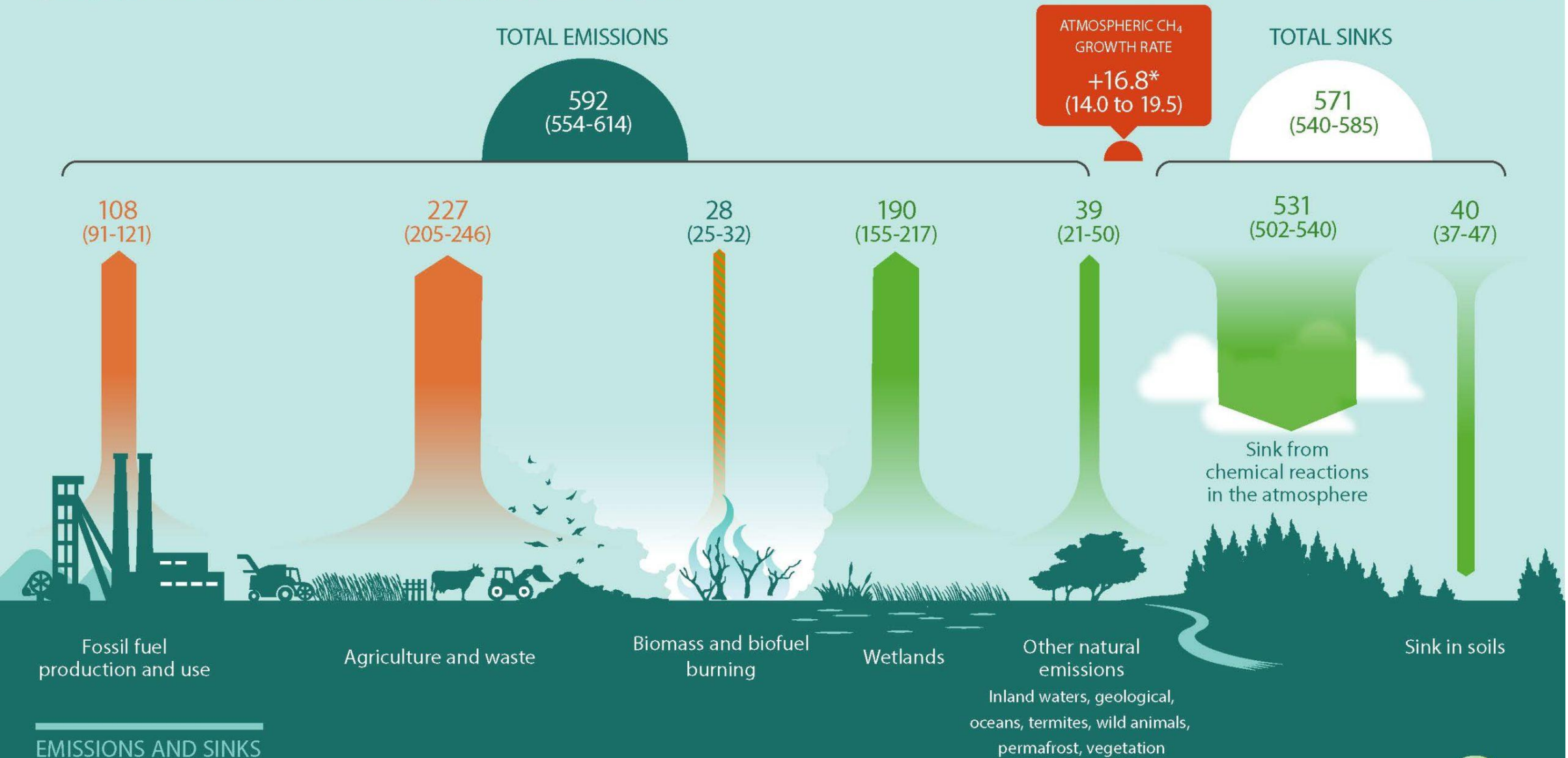


July 2023: 1915.25 ppb
July 2022: 1904.42 ppb
Last updated: Nov 05, 2023



July 2023: 336.66 ppb
July 2022: 335.56 ppb
Last updated: Nov 05, 2023

GLOBAL METHANE BUDGET 2017



N₂O Fluxes

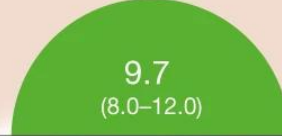
Anthropogenic sources



Change in atmospheric abundance



Natural sources



Atmospheric chemical sink
13.5
(12.4-14.6)

Climate and CO₂ effects
0.5
(-0.3-1.4)

Agriculture
3.8
(2.5-5.8)

Biomass burning
0.6
(0.5-0.8)

Fossil fuel and industry
1.0
(0.8-1.1)

Post deforestation pulse effect
0.8
(0.7-0.8)

Deforestation reduction
1.1
(1.0-1.1)

Waste and waste water
0.3
(0.2-0.5)

Surface sink
0.01
(0.0-0.3)

Atmospheric N deposition on land
0.8
(0.4-1.4)

Natural soils
5.6
(4.9-6.5)

Lightning and atmospheric production
0.4
(0.2-1.2)

Inland and coastal waters
Natural 0.3
Anthropogenic 0.5
(0.3-0.4) (0.2-0.7)

Atmospheric N deposition on ocean
0.1
(0.1-0.2)

Oceans
3.4
(2.5-4.3)

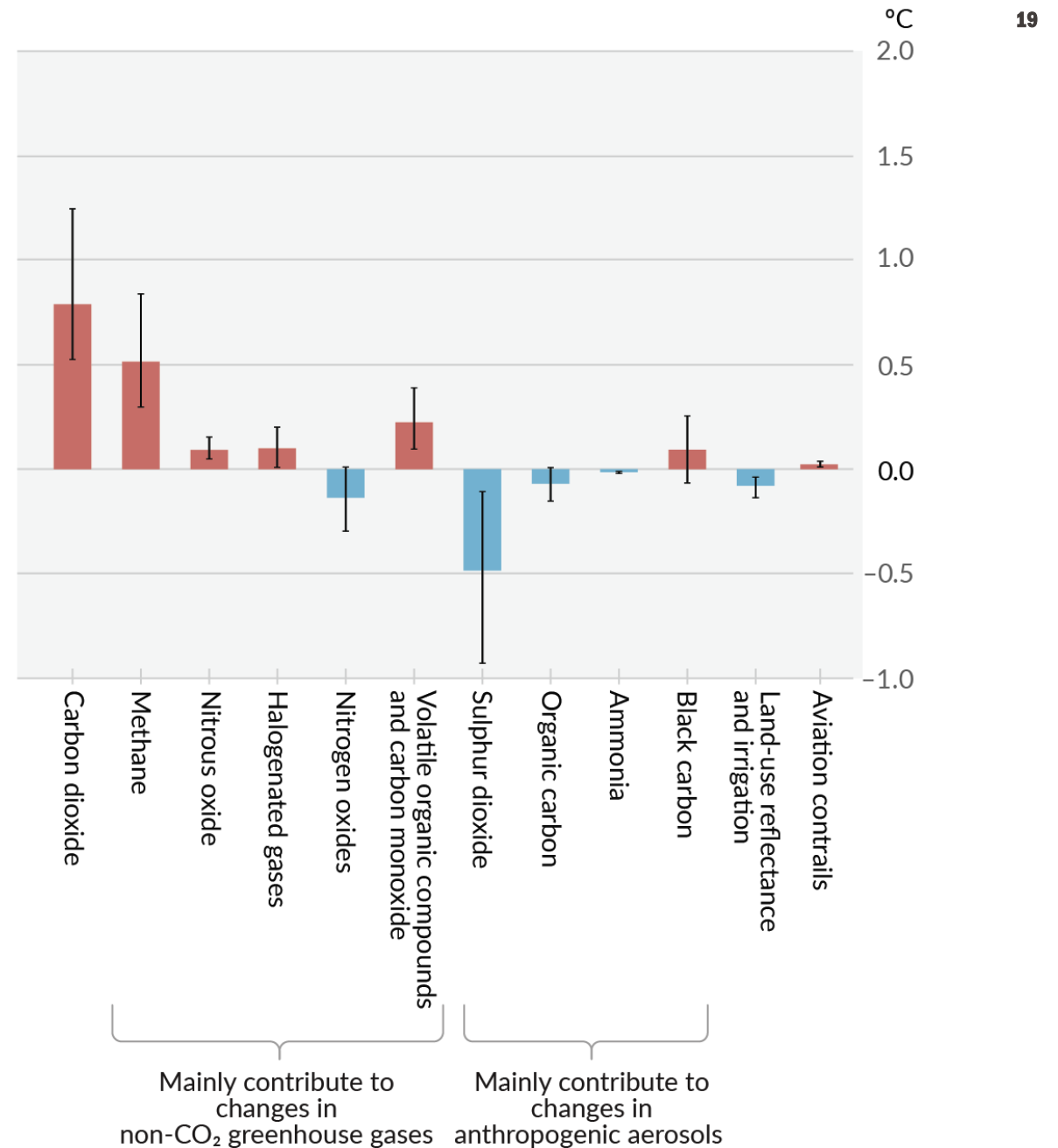
Anthropogenic emissions
Natural emissions

Many substances contribute to global warming

1. CO₂
2. CH₄
3. VOC + CO
4. Halogenated gases
5. N₂O

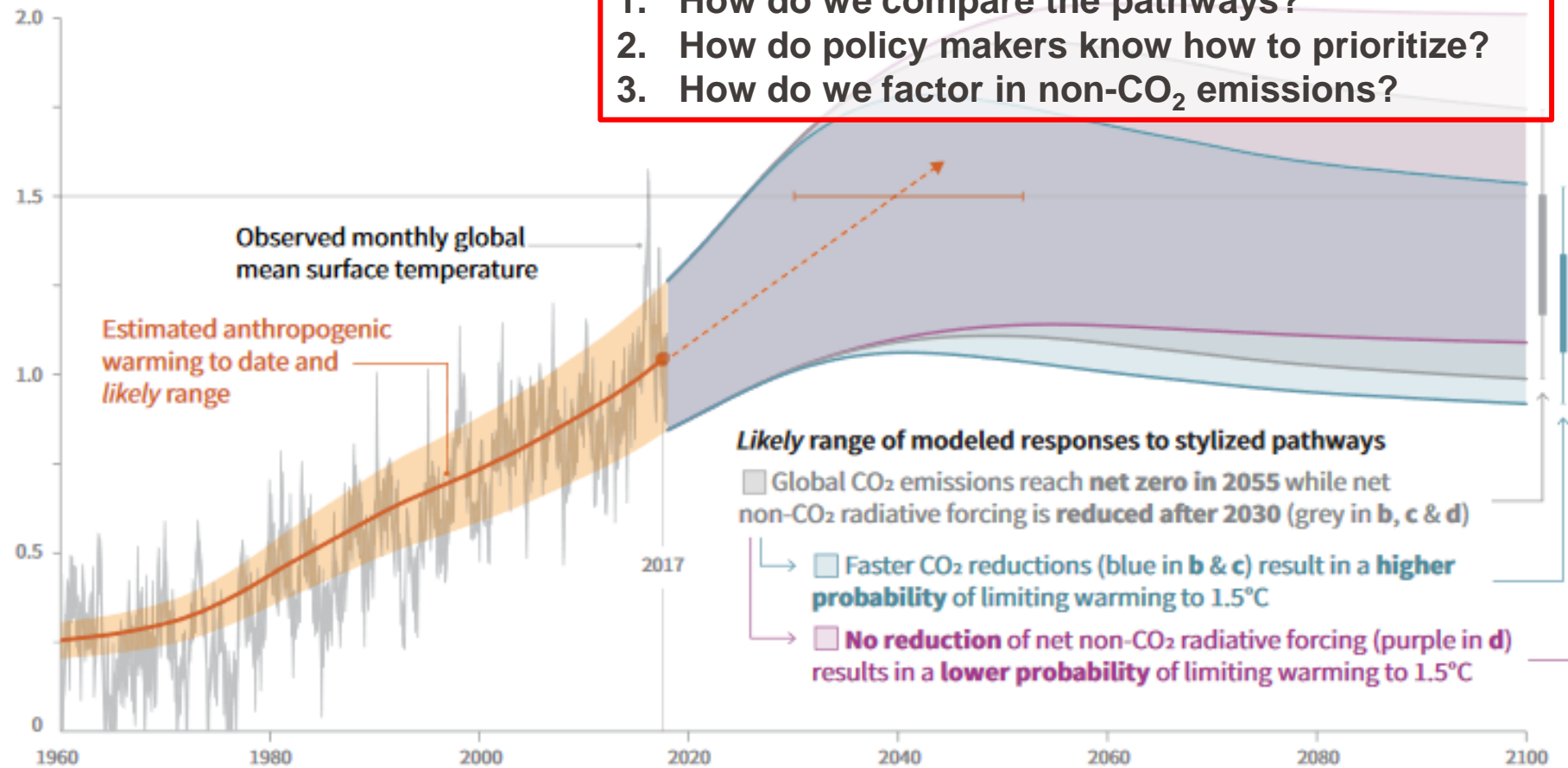
How do we make them equivalent?

→ CO₂-equivalents

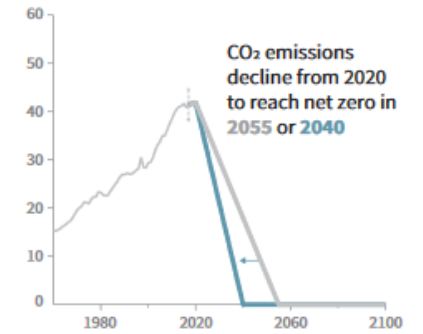


Timing and mix of reductions

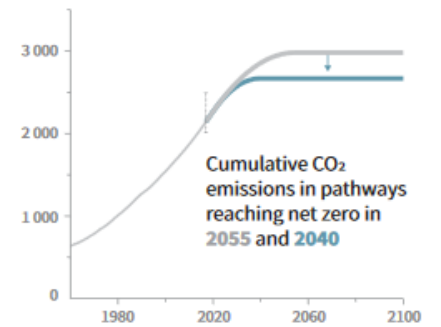
Global warming relative to 1850-1900 (°C)



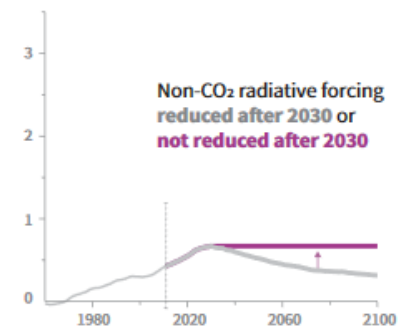
b) Stylized net global CO₂ emission pathways
Billion tonnes CO₂ per year (GtCO₂/yr)



c) Cumulative net CO₂ emissions
Billion tonnes CO₂ (GtCO₂)



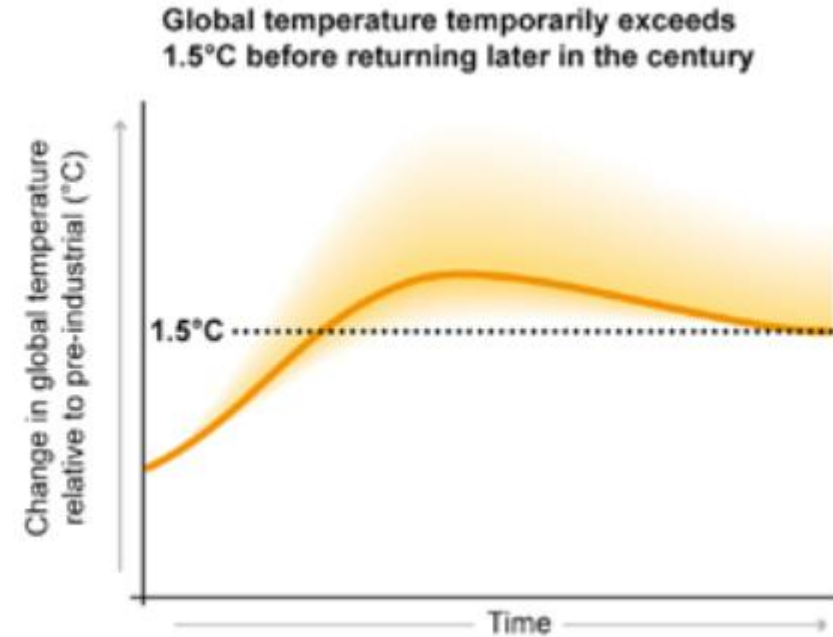
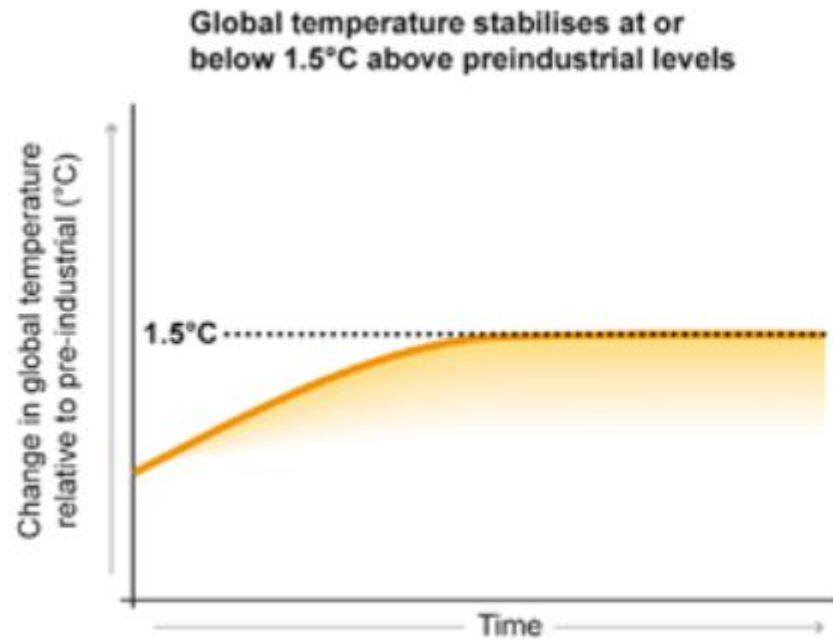
d) Non-CO₂ radiative forcing pathways
Watts per square metre (W/m²)



- The faster we reduce CO₂ emissions the more chances for success.
- Also non-CO₂ emission reductions contribute to success.



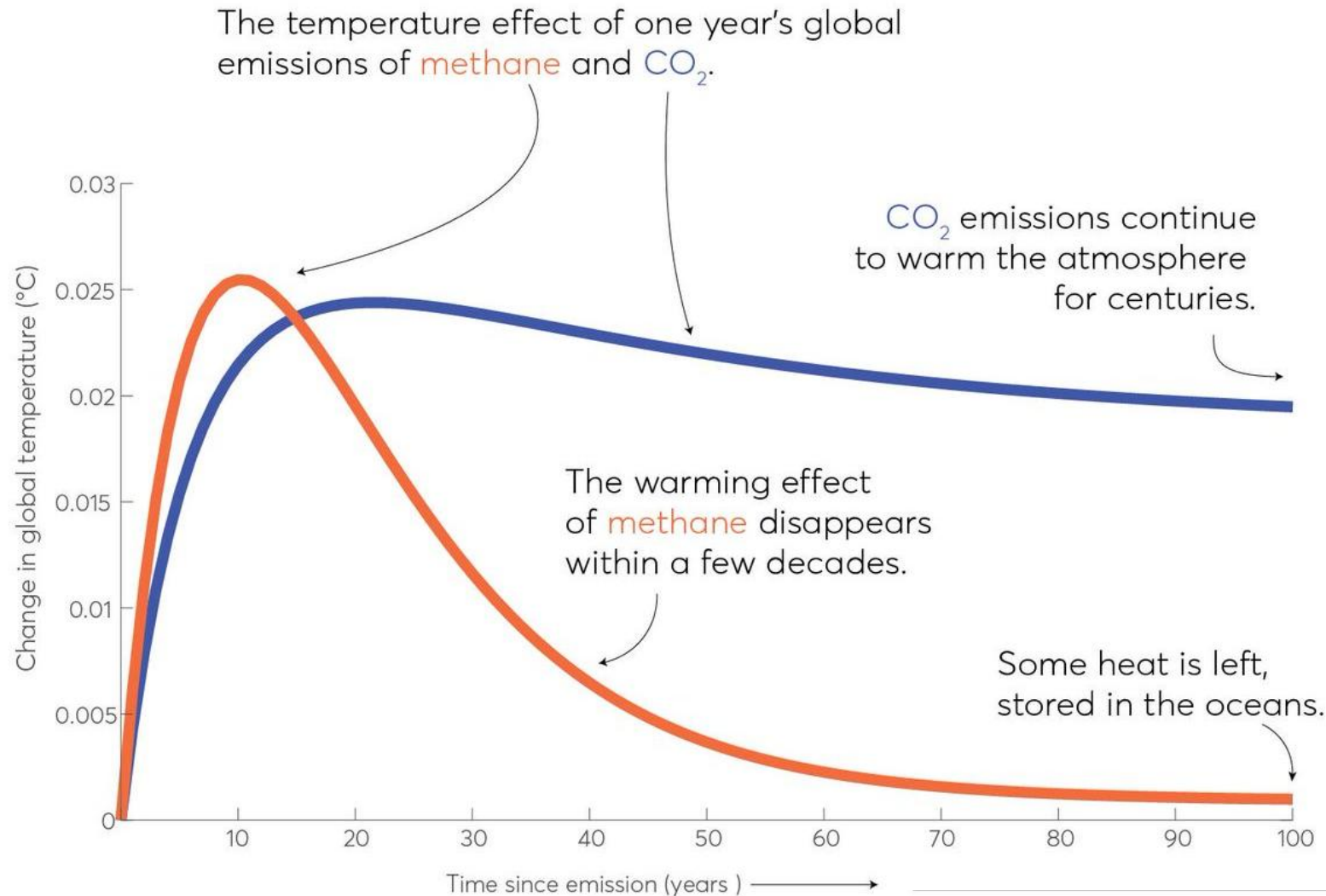
Conceptual pathways to reach the 1.5°C goal



Different greenhouse gases have different effects

Difference depends on:

- Efficacy of the greenhouse gas (how powerful is the gas?)
- Lifetime of the gas in the atmosphere
 - CH₄: ~12 years
 - CO₂: ~100 years



- To limit global warming to 1.5°C or well below 2.0°C, we only have a limited number of CO_{2eq} tons left to emit.
- Generally, we need to be at net-zero by mid-century. This implies
 - Very fast reductions, and
 - Negative emissions!
- This concerns not only CO₂ but also other greenhouse gases and air pollutants.
 - **How do we compare them, given their different lifetimes and different effects?**
- It makes a difference when we reduce different kinds of emissions.
 - The longer we procrastinate CO₂ reductions the longer there is a warming effect by CO₂.
 - But methane has a faster effect due to its shorter lifetime and can limit peak warming.

→ **Timing, mix and metrics of reduction actions matter!**

- Adopted in 1997, entered into force in 2005, terminated in 2020, Paris Agreement followed in 2020
- Kyoto protocol is a multi-gas approach (or “basket approach”) including CO₂, CH₄, N₂O, HFCs, PFCs, SF₆
- No fixed overall targets, but emission reductions from major industries and industrialized countries
- The first Kyoto commitment period uses the 100-year time-horizon **global warming potential (GWP)**.
- GWP is generally accepted as an appropriate measure by the user community.
- At the time of the Kyoto Protocol, the GWP was the only metric on offer to the policy community that had been assessed by IPCC.
- There has been a sustained and vigorous debate about GWP in the academic literature (which has been referred to in IPCC assessments).
- FAR: Section 2.2.7: “It must be stressed that there is no universally accepted methodology for combining all the relevant factors into a single (metric) ... A simple approach [i.e. the GWP] has been adopted here to illustrate the difficulties inherent in the concept ...”

Global warming potential (GWP)

- Global Warming Potential (GWP) describes how much impact a gas will have on atmospheric warming over a period of time compared to carbon dioxide. Each greenhouse gas has a different atmospheric warming impact, and some gases remain in the atmosphere for longer than others.
- **Carbon dioxide (CO₂)** has the lowest warming potential, is the most abundant and lasts for hundreds of years, so it **is used as the baseline**.

- Greenhouse gas emissions are commonly presented in units of million tonnes of carbon dioxide equivalent (CO₂eq).
- Converting non-CO₂ emissions to CO₂eq: multiply the gas by its GWP₁₀₀ (global warming potential over 100 years).
 - GWP₁₀₀ of CH₄ ~ 28
 - 1Gt CH₄ ~ 28 Gt CO₂eq

| | GWP (100) |
|----------------------------------|--------------|
| 1990, CH ₄ | 21 |
| 1995, CH ₄ | 21 |
| 2001, CH ₄ | 23 |
| 2007, CH ₄ | 25 |
| 2013, CH ₄ | 28 |
| 2021, CH ₄ fossil | 29.8 ±11 |
| 2021, CH ₄ non-fossil | 27.2 ±11 |
| 2021, N ₂ O | 273 ± 130 |

The changes in the CH₄ GWP reflect new quantification of uncertainties and improved knowledge on lifetime.

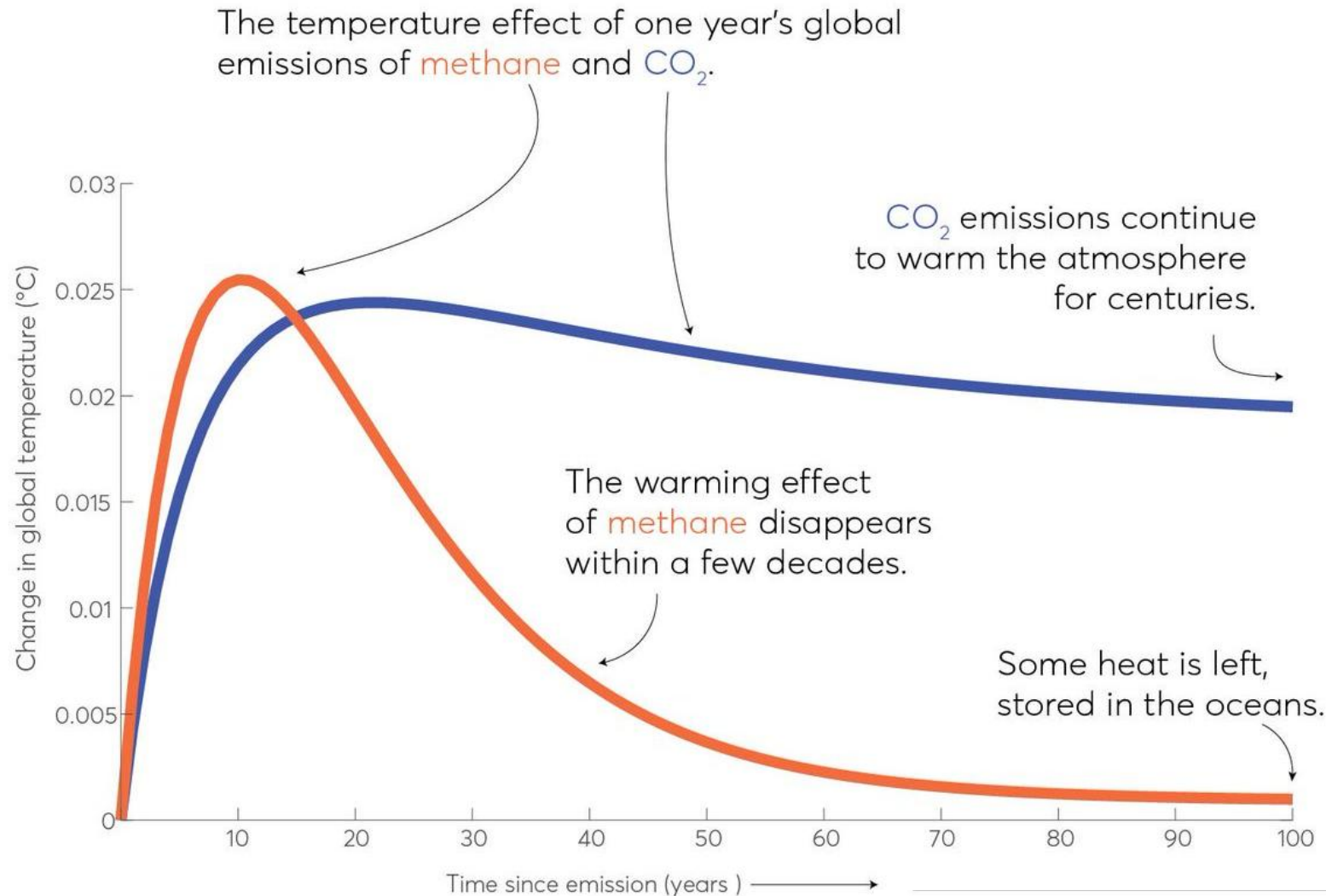
Global warming potential over 100 years (GWP₁₀₀)

- GWP₁₀₀ is the internationally accepted standard, and is used by countries for their emissions accounting, as agreed at the United Nations level.
- However, when using a blanket calculation such as GWP₁₀₀ we need to be mindful of its **limitations when making decisions around short-lived gases like methane.**

Different greenhouse gases have different effects

Difference depends on:

- Efficacy of the greenhouse gas (how powerful is the gas?)
- Lifetime of the gas in the atmosphere
 - **CH₄: ~12 years**
 - **CO₂: ~100 years**



GWP of CH₄ and N₂O

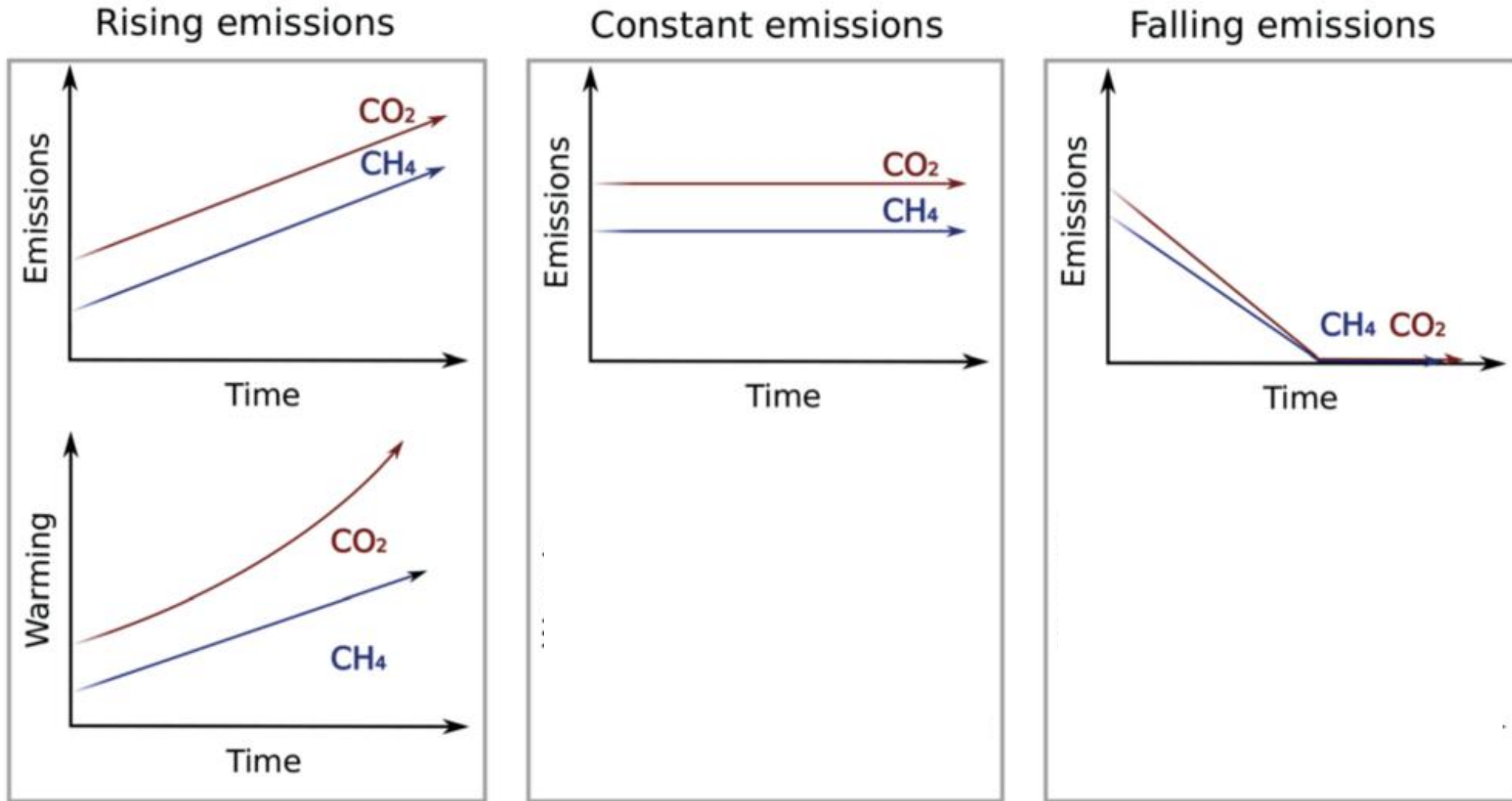
- Short-lived gases will have a higher warming potential over shorter time horizons, because their impact on a shorter time horizon is larger.
- Converting non-CO₂ emissions to CO₂eq: multiply the gas by its GWP₁₀₀ (global warming potential over 100 years).
 - GWP₁₀₀ of CH₄ ~ 28
1Gt CH₄ = 28 Gt CO₂eq
 - GWP₂₀ of CH₄ ~ 81
1Gt CH₄ = 81 Gt CO₂eq

| | GWP (100) | GWP (20) |
|-------------------------------------|--------------|----------------|
| 1990, CH ₄ | 21 | |
| 1995, CH ₄ | 21 | |
| 2001, CH ₄ | 23 | |
| 2007, CH ₄ | 25 | |
| 2013, CH ₄ | 28 | |
| 2021, CH ₄ fossil | 29.8 ±11 | 82.5 ± 25.8 |
| 2021, CH ₄ non-fossil | 27.2 ±11 | 80.8 ± 25.8 |
| 2021, N ₂ O | 273 ± 130 | 273 ± 118 |

The changes in the CH₄ GWP reflect new quantification of uncertainties and improved knowledge on lifetime.

Temperature response to changed emissions

Lifetimes:
CO₂ > 100 yrs
CH₄ ~12 yrs



- Cain blog post: <https://www.climatechange.ie/guest-post-a-new-way-to-assess-global-warming-potential-of-short-lived-pollutants/>

A more appropriate definition for short-lived GHGs: GWP*

- GWP* equates a “pulse” emission of CO₂ with an **increase in the emission rate** of methane.
- GWP is typically defined to compare pulses of emissions with each other. A pulse is when a specified mass of gas is released into the atmosphere instantaneously.
- Over the coming years, the CO₂ remains in the atmosphere, as it is a long-lived gas, and so leads to a permanent increase in the CO₂ concentration.
- A **change in the methane emission rate** also leads to higher concentrations of methane in the atmosphere.
- GWP* uses GWP, but instead of comparing two pulses it effectively spreads the methane emission out evenly over the X-year time-horizon, where X can be e.g., 20 or 100 years.

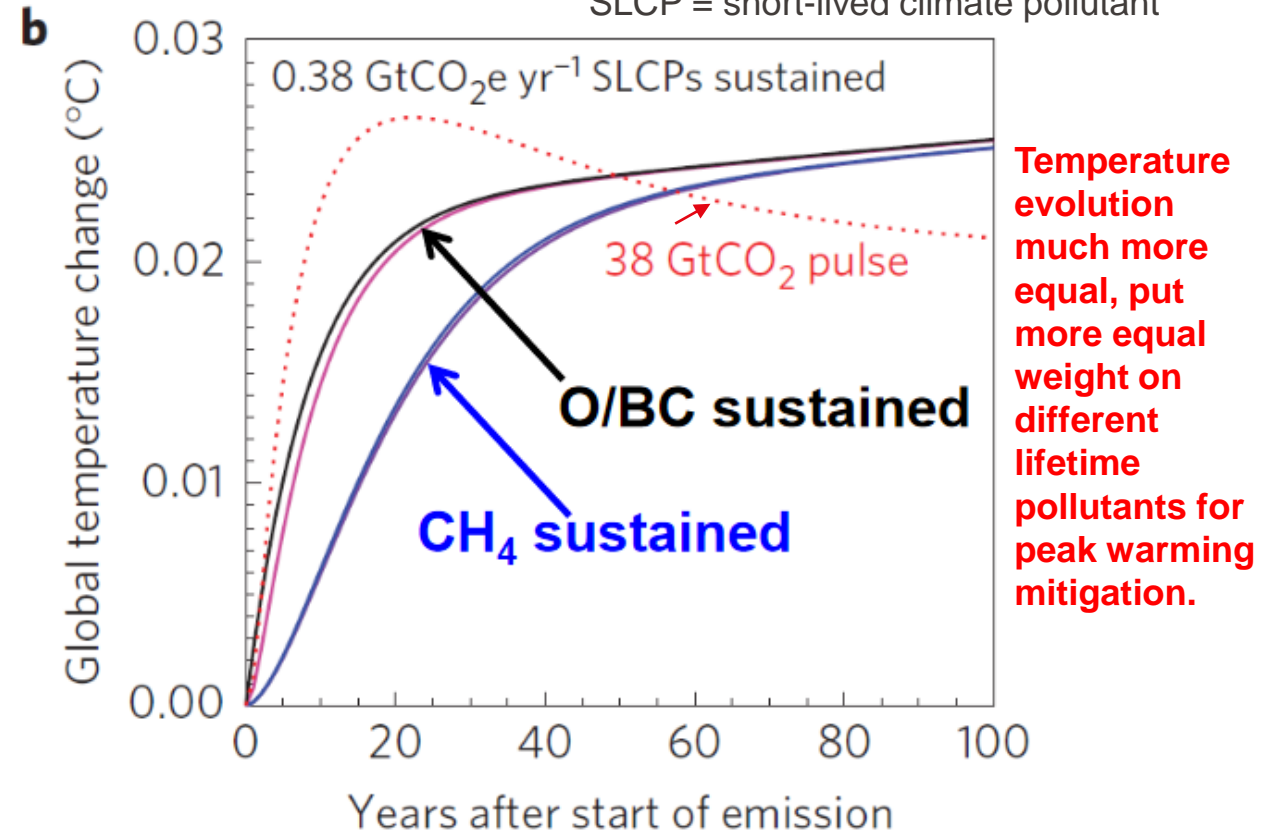
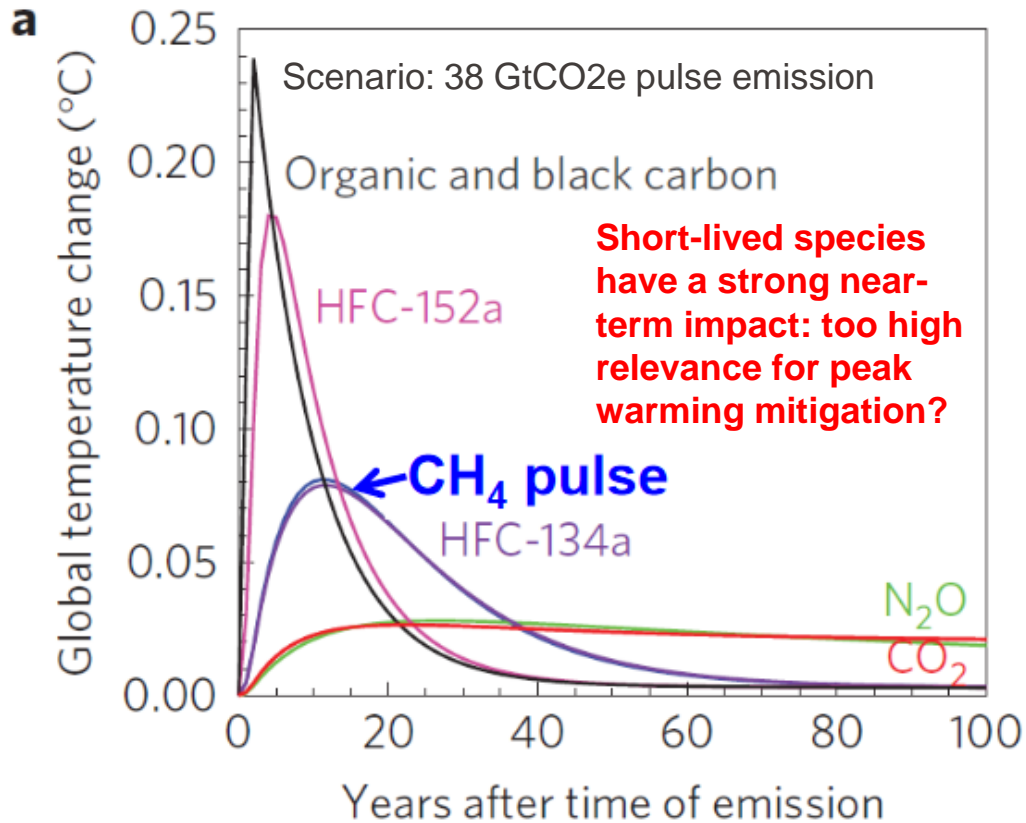
A new GWP: GWP*

Old GWP:

The “equivalence” is such that the **integrated radiative forcing over 100 years** is the same for the CH₄ pulse and the equivalent pulse of CO₂.

New GWP*:

Not comparing pulsed emissions, but continuously emitting the shorter-lived climate forcer over the 100 year time horizon such that **after 100 years the CO₂ and CH₄ have the same CO₂ equivalent**. The “equivalence” is **temperature change** rather than integrated forcing: arguably more aligned with Paris goals.



From Allen et al., 2018: the radiative forcing of cumulative pollutants like CO₂ scales with the **total stock** of emissions to date (cumulative integral). For short-lived species like methane, the radiative forcing scales with the **emission rate** multiplied by the lifetime.

Under the new GWP*, the CO₂ equivalent emission rate for short-lived species is calculated as the change in emission rates across the reference period multiplied by the warming potential over the time horizon:

$$E_{CO_2e^*} = \frac{\Delta E}{\Delta t} \times GWP_H \times H$$

CO₂ equivalents →

← Time horizon

↑ Change in emission rate

← Warming potential over time horizon

- GWP* accounts for the differences between short- and long-lived gases, and can better link emissions to warming. This means that the **true impact of an emission pathway on global temperature can be more easily assessed**.
- For countries with high methane emissions – due to, e.g., agriculture – this can make a huge difference to how their progress in emission reductions is judged.

- **Global temperature change potential (GTP)**
 - Compared to the Global Warming Potential (GWP), the Global Temperature change Potential (GTP) goes one step further down the cause–effect chain and is **defined as the change in global mean surface temperature at a chosen point in time in response to an emission pulse—relative to that of CO₂**.
 - Whereas GWP is integrated in time, **GTP is an end-point metric that is based on temperature change for a selected year, t**. Like GWP, the GTP values can be used for weighting the emissions to obtain ‘CO₂ equivalents’.
 - Needs a model to derive the temperature change from the change in forcing. The unit is dimensionless.

- **Absolute GTP (AGTP)**
 - The Absolute Global Temperature-change Potential (AGTP) represents the temperature change at a given time due to a pulse emission of a unit mass of a gas (or other climate forcing agent) at a given time. Hence the AGTP represents the GTP without comparison to a reference gas.

How different forcers act over time (AGTP)

- Lifetimes are challenges:
 - CO₂: >100 yrs
 - CH₄: ~12 yrs
- CH₄ has a strong warming influence when it is first emitted, which then diminishes rapidly over a few decades.
- CO₂ has a sustained warming effect.
- They are not equivalent!

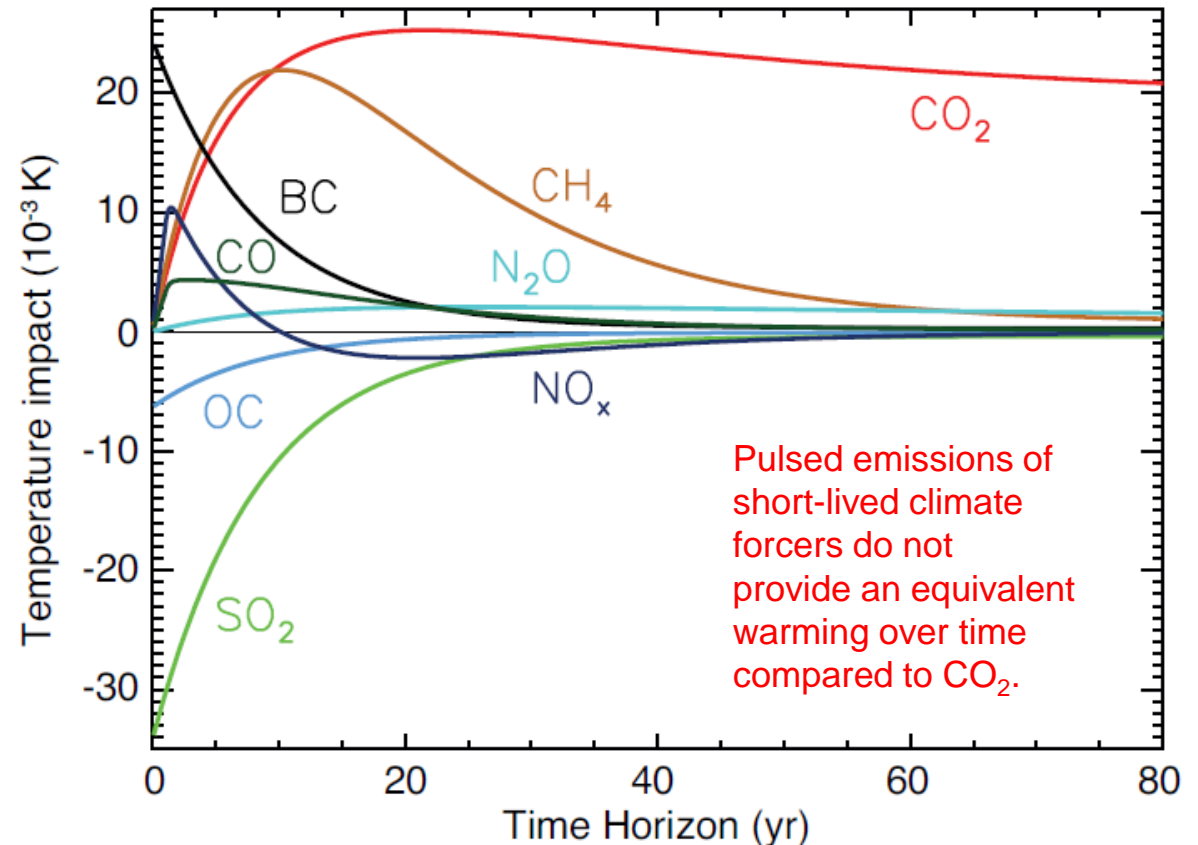


Figure 8.33 | Temperature response by component for total anthropogenic emissions for a 1-year pulse. Emission data for 2008 are taken from the EDGAR database and for BC and OC for 2005 from Shindell et al. (2012a). There are large uncertainties related to the AGTP values and consequentially also to the calculated temperature responses (see text).

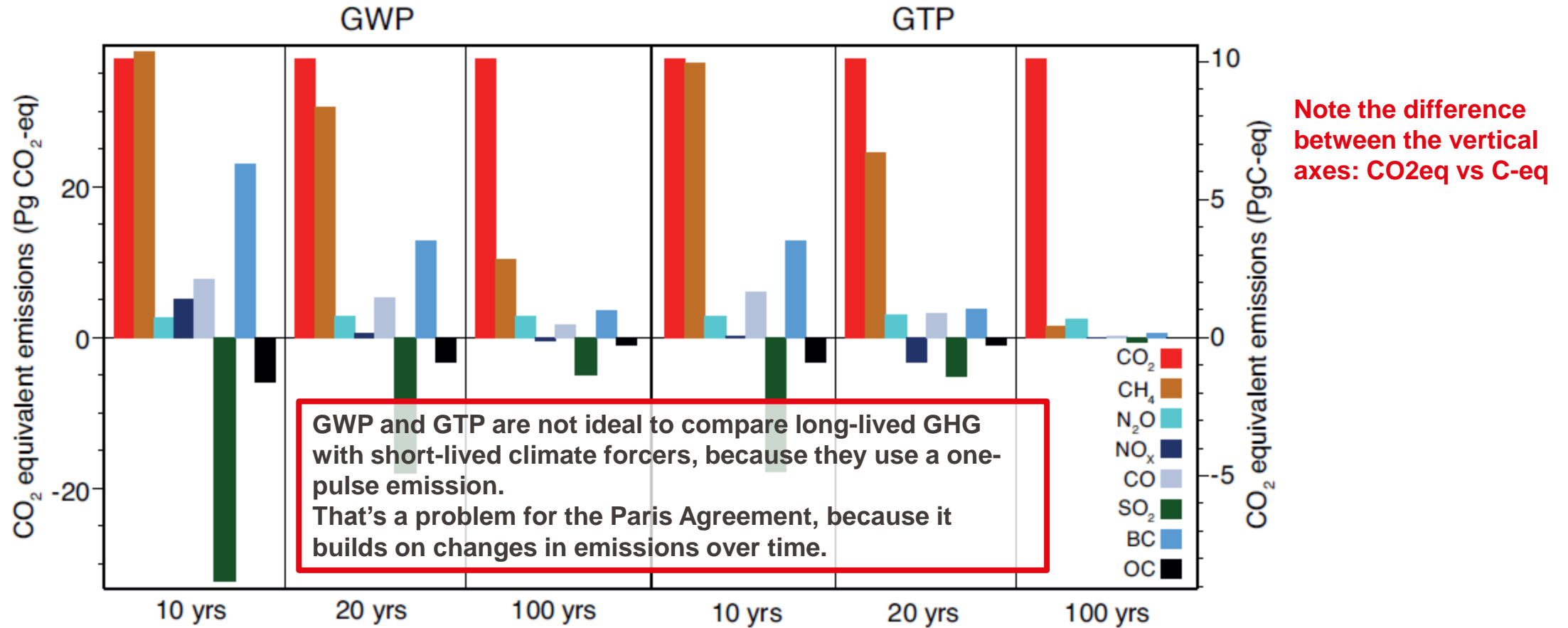
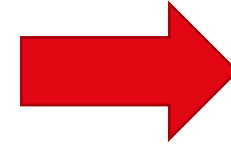
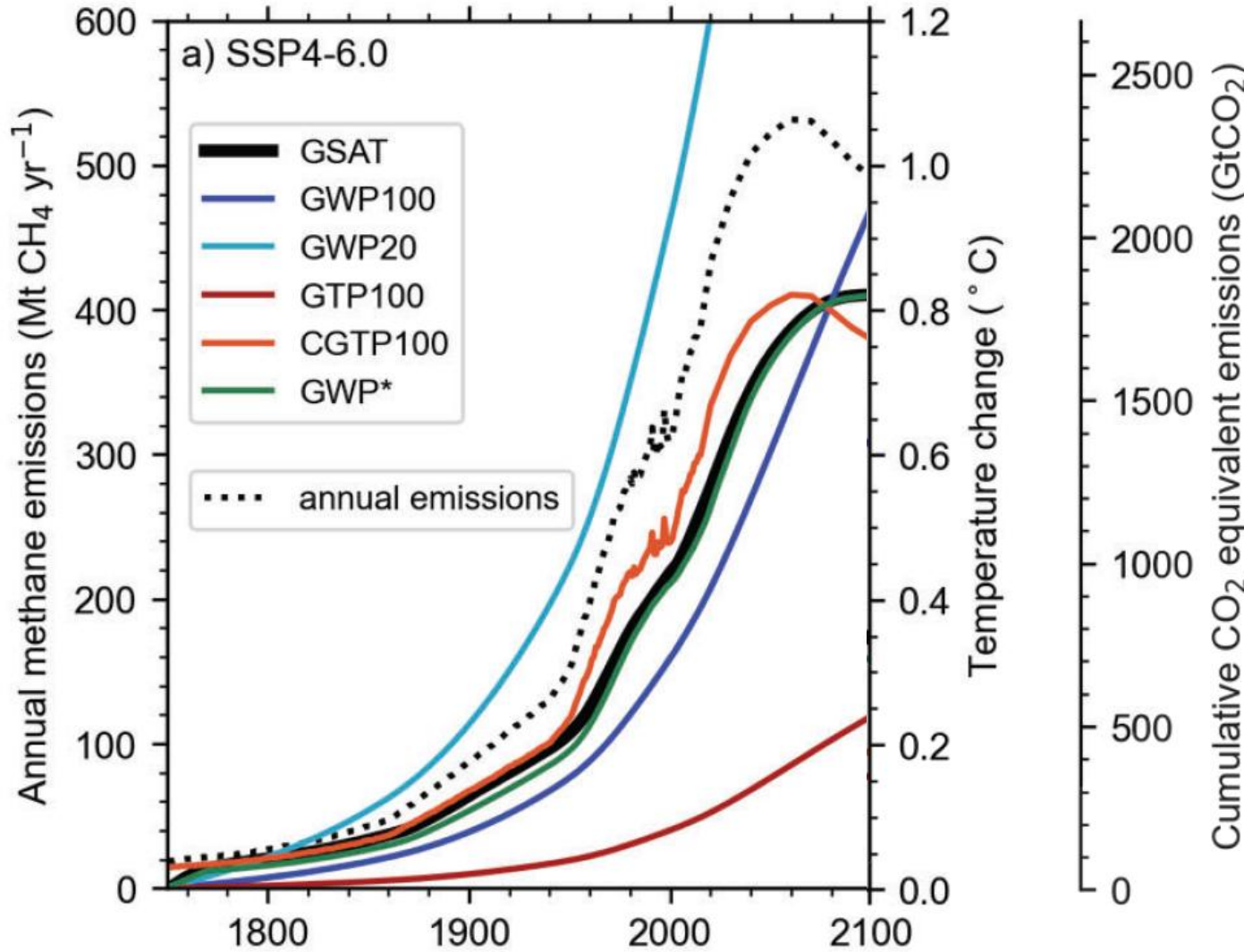


Figure 8.32 | Global anthropogenic emissions weighted by GWP and GTP for chosen time horizons (aerosol–cloud interactions are not included). Emission data for 2008 are taken from the EDGAR database. For BC and OC emissions for 2005 are from Shindell et al. (2012a). The units are 'CO₂ equivalents' which reflects equivalence only in the impact parameter of the chosen metric (integrated RF over the chosen time horizon for GWP; temperature change at the chosen point in time for GTP), given as Pg(CO₂)_{eq} (left axis) and given as PgC_{eq} (right axis). There are large uncertainties related to the metric values and consequentially also to the calculated CO₂ equivalents (see text).

Temperature projections are a function of the metric!

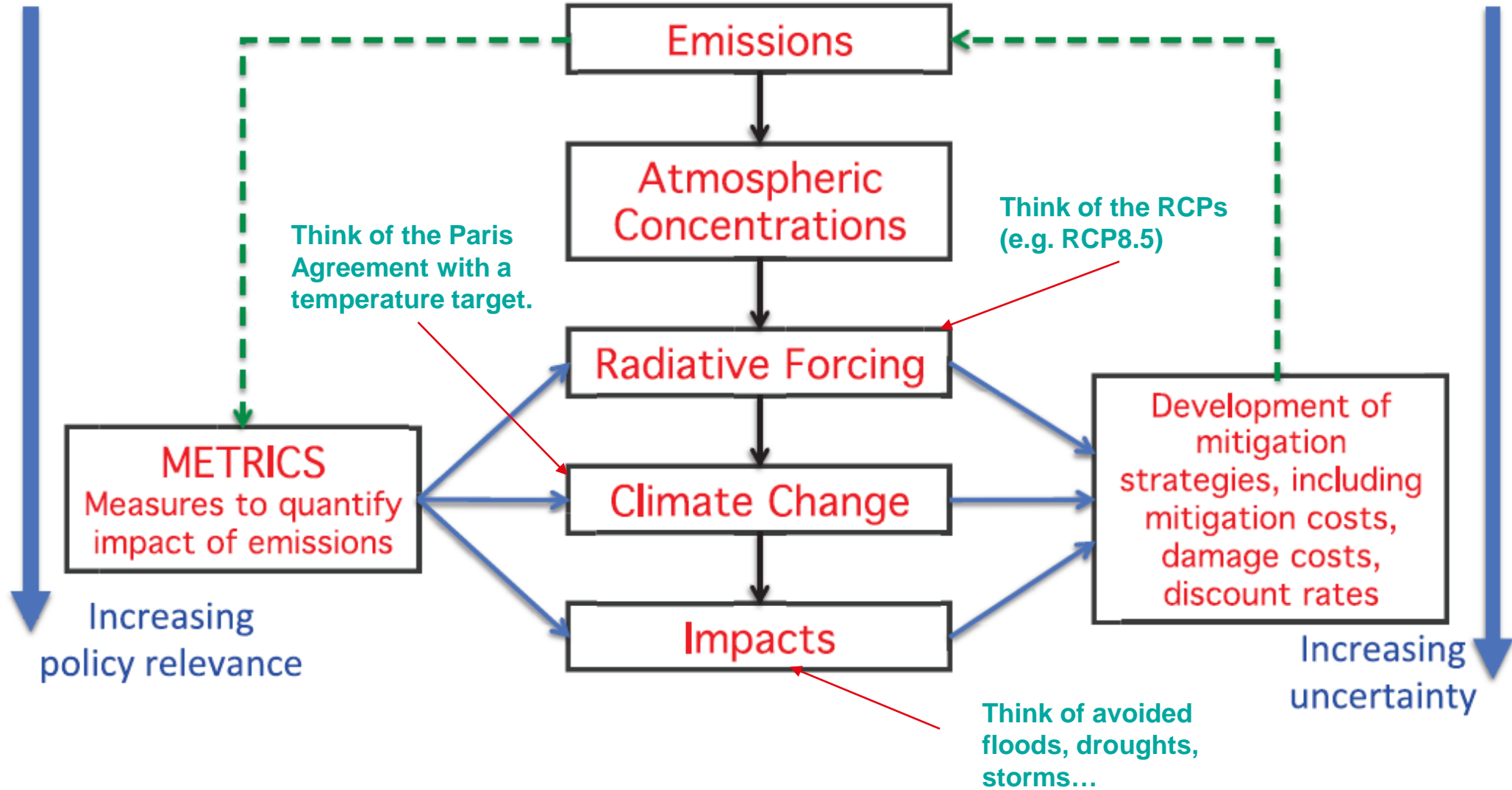


GWP* and CGTP are most realistic.

GSAT: global surface air temperature
 GWP: global warming potential
 GTP: global temperature potential
 CGTP: combined GTP

Policy needs metrics

Emission metrics are used to compare the relative effect of emissions of different gases over time in terms of radiative forcing, global surface temperature or other climate effects. (IPCC AR6) 40



Which metric to choose?

- **AR6 does not recommend an emission metric because the appropriateness of the choice depends on the purposes for which gases or forcing agents are being compared.**
- Emission metrics can facilitate the comparison of effects of emissions in support of policy goals.
- They do not define policy goals or targets but can support the evaluation and implementation of choices within multi-component policies (e.g., they can help prioritise which emissions to abate).
- **The choice of metric will depend on which aspects of climate change are most important to a particular application or stakeholder and over which time horizons.**
- Different international and national climate policy goals may lead to different conclusions about what is the most suitable emission metric [...].

- Article 2 aims to limit the risks and impacts of climate change by setting **temperature goals**.
- Article 4 foresees an **early emissions peaking target**, and the aim to “achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century”.
- **How the interpretation of the Paris Agreement and the meaning of “net zero” emissions reflects on the appropriate choice of metric is an active area of research [...].**
 - Several possible scientific interpretations of the Article 2 and 4 goals can be devised, and these along with emission metric choice have implications both for when a balance in GHG emissions, net zero CO₂ emissions or net zero GHG emissions are achieved, and for their meaning in terms of temperature outcome [...].

- In AR6 net zero greenhouse gas emissions is **defined as the condition in which metric-weighted anthropogenic GHG emissions are balanced by metric-weighted anthropogenic GHG removals over a specified period** (see 11 Chapter 1, Box 1.4, Appendix VII: Glossary).
- The quantification of net zero GHG emissions depends on the GHG emission metric chosen to compare emissions and removals of different gases, as well as the time horizon chosen for that metric. **As the choice of emission metric affects the quantification of net zero GHG emissions, it therefore affects the resulting temperature outcome after net zero emissions are achieved [...].**



📷 Cop30 president Andre Correa do Lago (C) as negotiations continue. Photograph: Pablo Porciúncula/AFP/Getty Images

- Ed Miliband. “This agreement does not have all the ambition we would have wanted but it commits to keeping 1.5C alive.”
- The nations at Cop30 agreed to triple funding for adaptationgoal of possibly \$120bn a year was pushed back five years to 2035, from the initial suggested date of 2030...“The refusal to commit to scaling up finance to the necessary \$300bn annually for adaptation leaves the unprepared defenceless against inevitable ruin. The timeline ignores the urgency of the climate disasters striking us today.”
- agreement of a just transition mechanism (JTM), a plan to ensure that the move to a green economy around the world takes place fairly and protects the rights of all people, including workers, women and Indigenous people
- Fossil fuels were not mentioned in the key final decision, despite a coalition of 90 developed and developing nations having pushed for a commitment to a roadmap to phase out fossil fuels. The final text did add a reference to the “UAE consensus”, the overall package from Cop28 in Dubai in 2023 that contained the [first pledge to move away from fossil fuels](#).
- With the roadmap for the transition away from fossil fuels was blocked from the formal Cop30 decision, the Brazilian presidency announced the plan would proceed outside the UN process. It will be merged with a plan backed by Colombia and [about 90 other countries](#), with a summit set for April. This “coalition of the willing” could push progress forward.
 - The decision also launched the Global Implementation Accelerator, meant to accelerate implementation to keep 1.5°C in reach and support countries in implementing their NDCs and NAPs. These two processes, if well designed and delivered, could still offer steps toward a roadmap for transitioning away from fossil fuels.
- Brazil’s environment minister, Marina Silva, tried to include a roadmap on ending deforestation in the core agreement at Belém. But it was killed after being tied to the fossil fuels roadmap. Brazil did launch the [Tropical Forest Forever Facility](#), again outside the UN process, but a multibillion-dollar investment fund that will pay nations to keep trees standing.

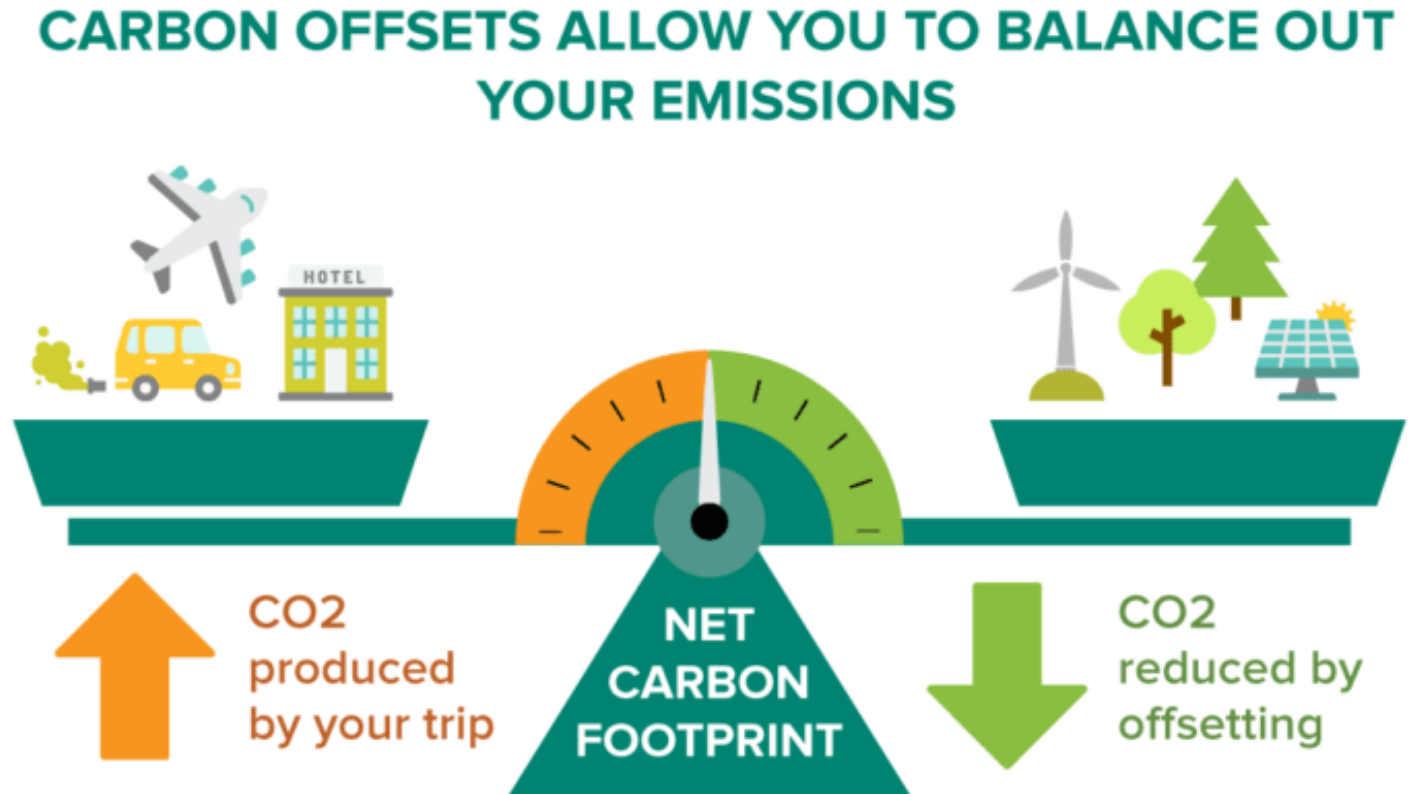
- <https://www.iisd.org/articles/insight/cop-30-outcome-what-it-means-and-whats-next>,
<https://www.theguardian.com/environment/2025/nov/22/roadmaps-adaptations-and-transitions-what-climate-measures-were-agreed-at-cop30>



Credit: L. Favre

What is a carbon offset?

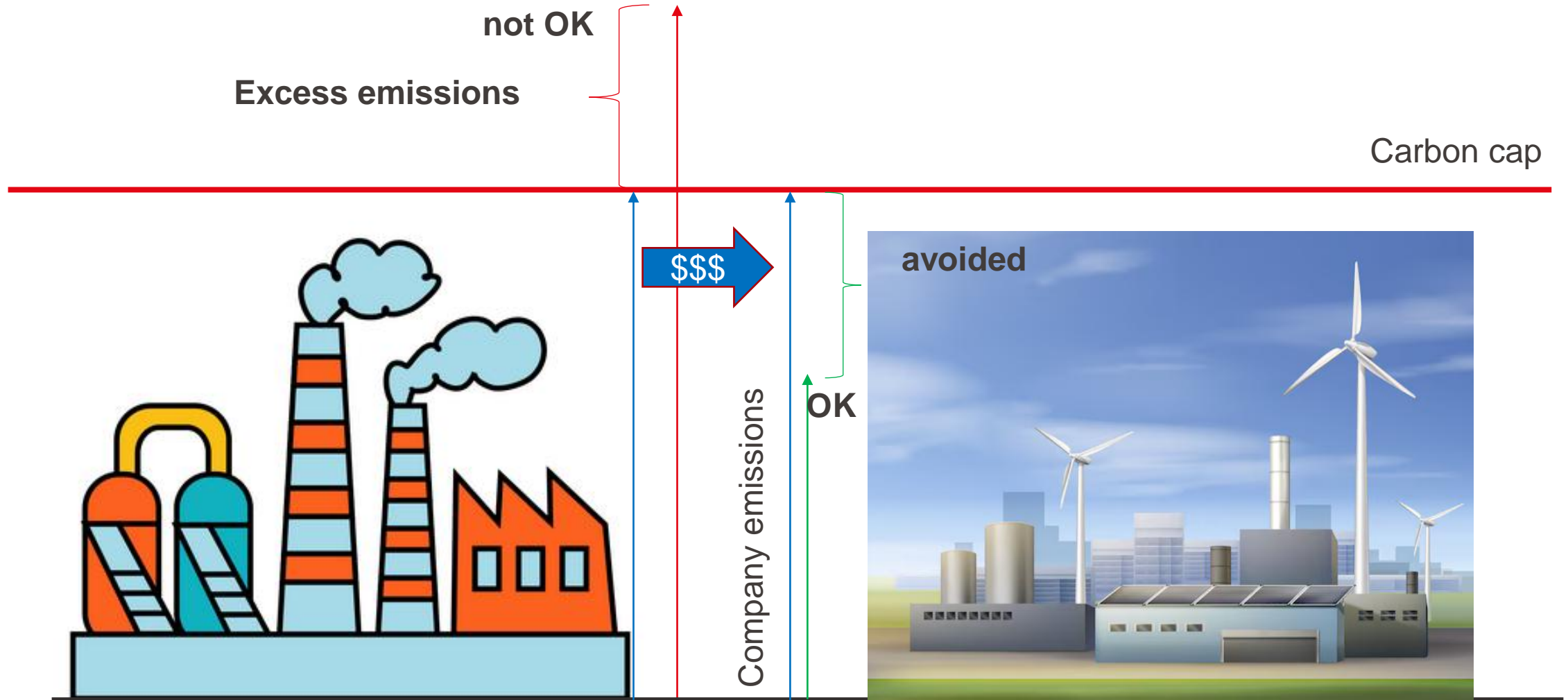
- A carbon offset is the **avoidance** or **sequestration** of carbon dioxide or other greenhouse gases emissions to compensate for (offset) emissions produced elsewhere.



Brief History of Carbon Offsets

- First ideas in the 1980s as climate change became generally evident.
- Really started under Kyoto Protocol (signed 1997, began 2005)
 - Capped greenhouse gas emissions from big industries and industrialized countries
 - The Clean Development Mechanism (CDM) allowed a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) **credits, each equivalent to one tonne of CO₂**, which can be counted towards meeting Kyoto protocol targets. → **mandatory carbon market**
- **Voluntary** carbon offset programs started to develop after 2005, as the CDM became more established and the corporate social responsibility community began to recognize that there was a demand for these instruments beyond just regulated companies and countries to the Kyoto Protocol.
 - There is now a variety of carbon offset programs primarily (or exclusively) serving the voluntary market comprised primarily of corporations wishing to make GHG emission reduction claims.

Example: Compliance System (mandatory)



Mandatory / Compliance programs

Carbon credits

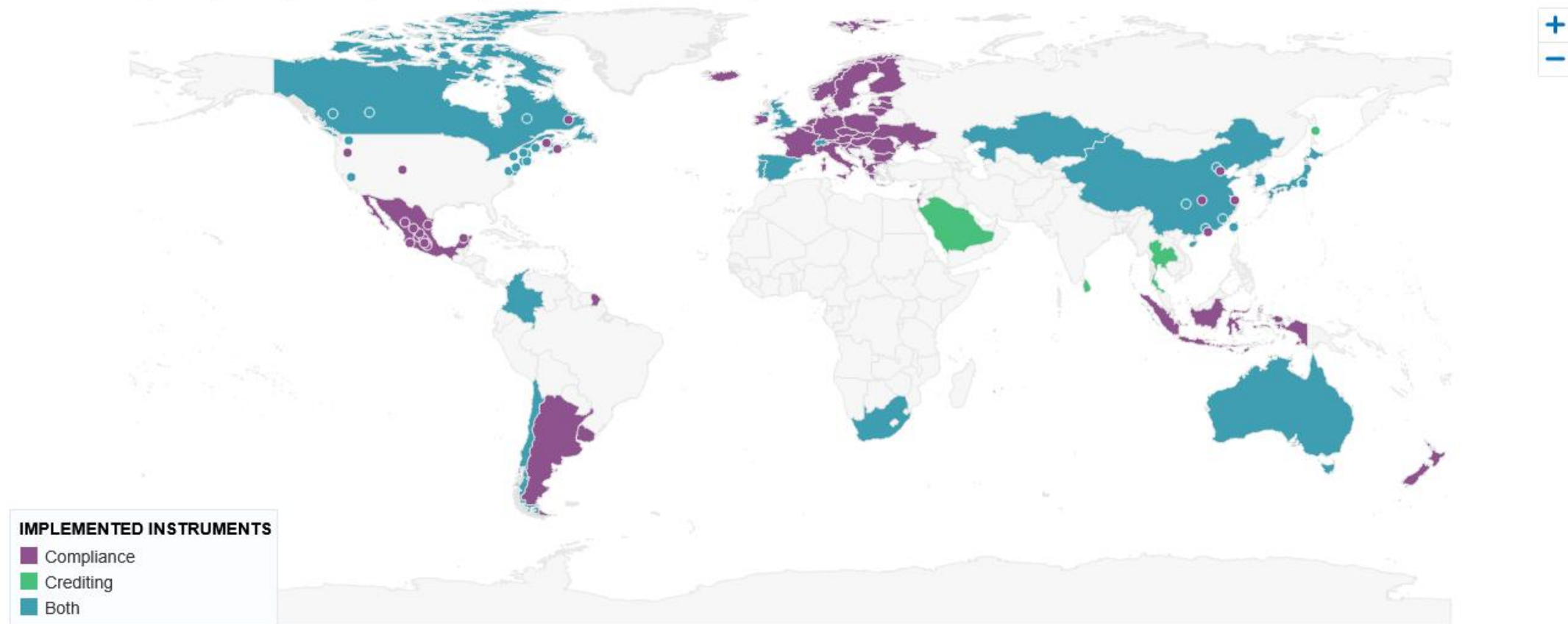
- Mandatory systems are regulated by national, regional, or provincial **law** and mandate emission sources to **achieve compliance** with GHG emission reduction requirements.
- For regulated emissions sources, offsets can serve as an alternative compliance mechanism to direct emissions reductions or allowances (tradable permits allowing a quantity of emissions) that emission sources can use to meet their emissions cap.
- Typically offset credits in a particular program are priced similarly based on the dynamics of supply-and-demand, regardless of project type and other characteristics.
- Examples
 - Regional Greenhouse Gas Initiative ([RGGI](#)) (Eastern States of the US)
 - European Union Emissions Trading Scheme ([EU ETS](#))
- The World Bank Carbon Pricing Dashboard tracks which countries have implemented compliance offset programs and other carbon pricing instruments.



Carbon pricing instruments around the world, 2025

Map shows jurisdictions that have implemented Direct Carbon Pricing Instruments - Compliance instruments (Emissions Trading Systems (ETS) and Carbon taxes) and/or domestic carbon crediting mechanisms, subject to any filters applied. The year can be adjusted using the slider below the map.

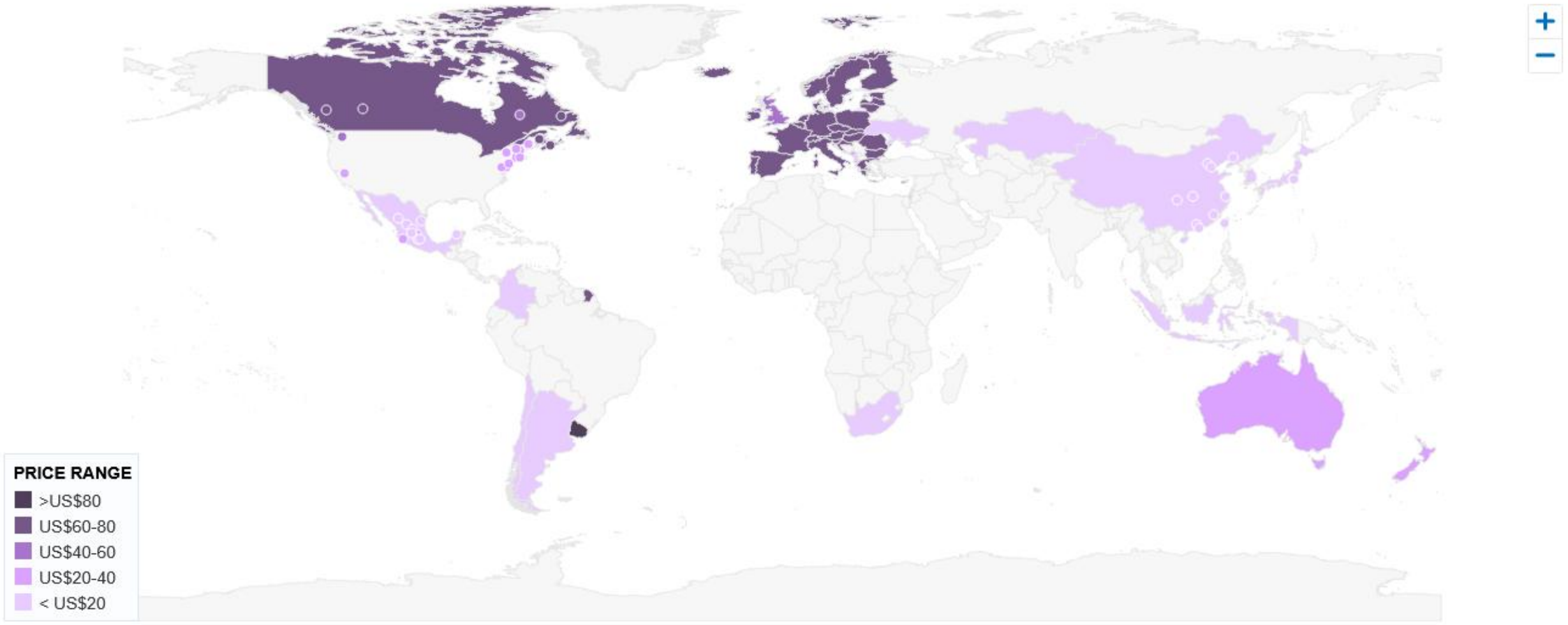
Download



Price of carbon around the world, 2025

Download

Heat map shows the level of the main price set by emissions trading systems or Carbon taxes in each jurisdiction (US\$/tCO₂e), subject to any filters applied. The year can be adjusted using the slider below the map.

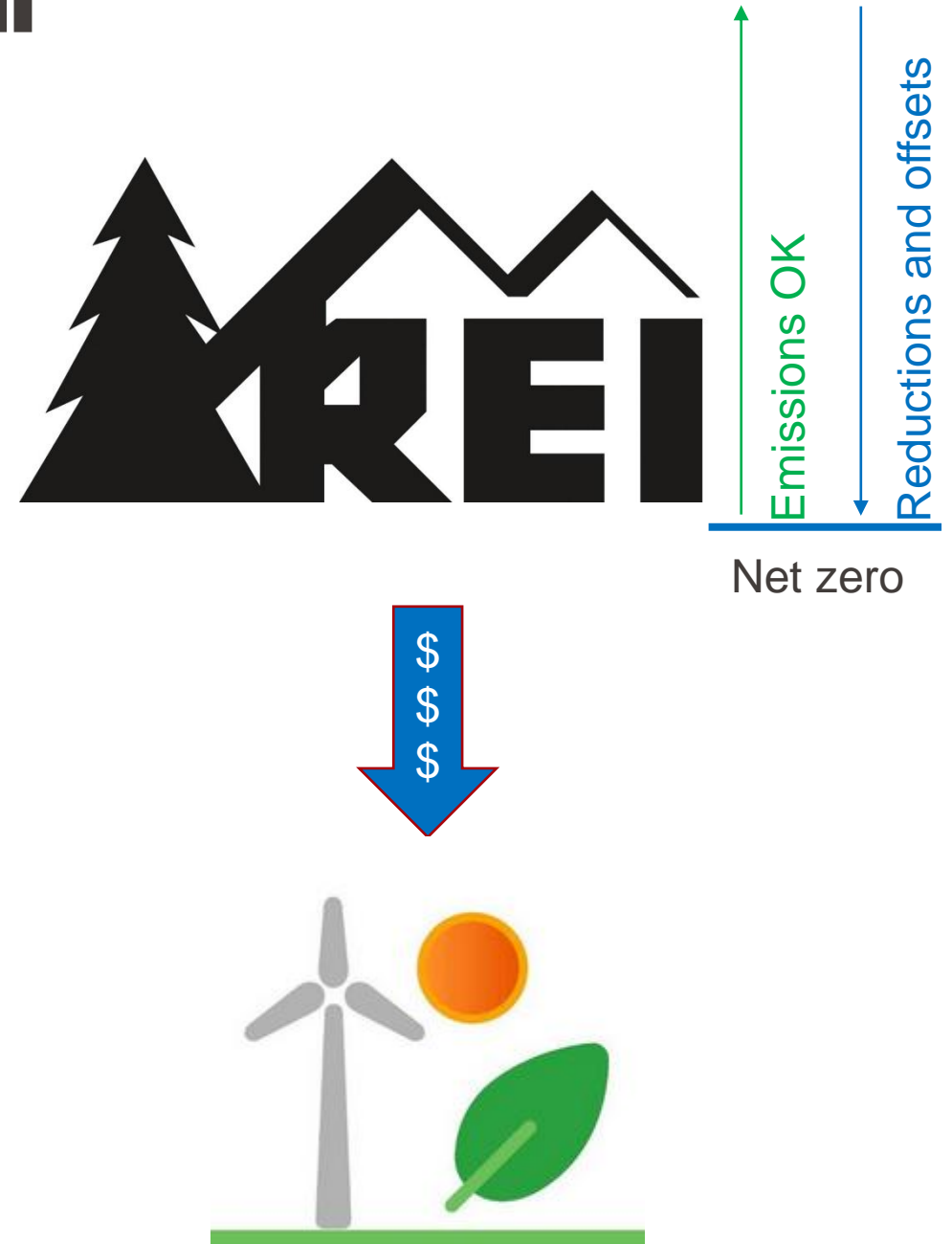


- Voluntary carbon markets enable businesses, governments, nonprofit organizations, universities, municipalities, and individuals to offset their emissions **outside a regulatory regime**.
- These entities can purchase offsets that were created **either through the voluntary or compliance markets**.
- Trading and demand in the voluntary market are created only by voluntary buyers whereas, in a compliance market, demand is created by a regulatory mandate.
- Because voluntary offset credits cannot be used in compliance markets, they tend to be **cheaper**.

Example: Voluntary Program

- The **Science Based Target initiative**, a global body focused on enabling businesses to set ambitious emissions reductions goals in line with the latest climate science, has approved these targets:
 - In the near-term, REI has committed to reducing the absolute scope 1, 2 and 3 greenhouse gas (GHG) emissions 47% by 2030 from a 2019 base year, while further committing 41% of suppliers by emissions will have science-based targets by 2025.
 - In the long-term, REI has committed to reduce absolute scopes 1, 2, and 3 GHG emissions 90% by 2050 from a 2019 base year.
 - Overall, REI has committed to **reach net-zero GHG emissions across its value chain by 2050**.

- <https://www.rei.com/>



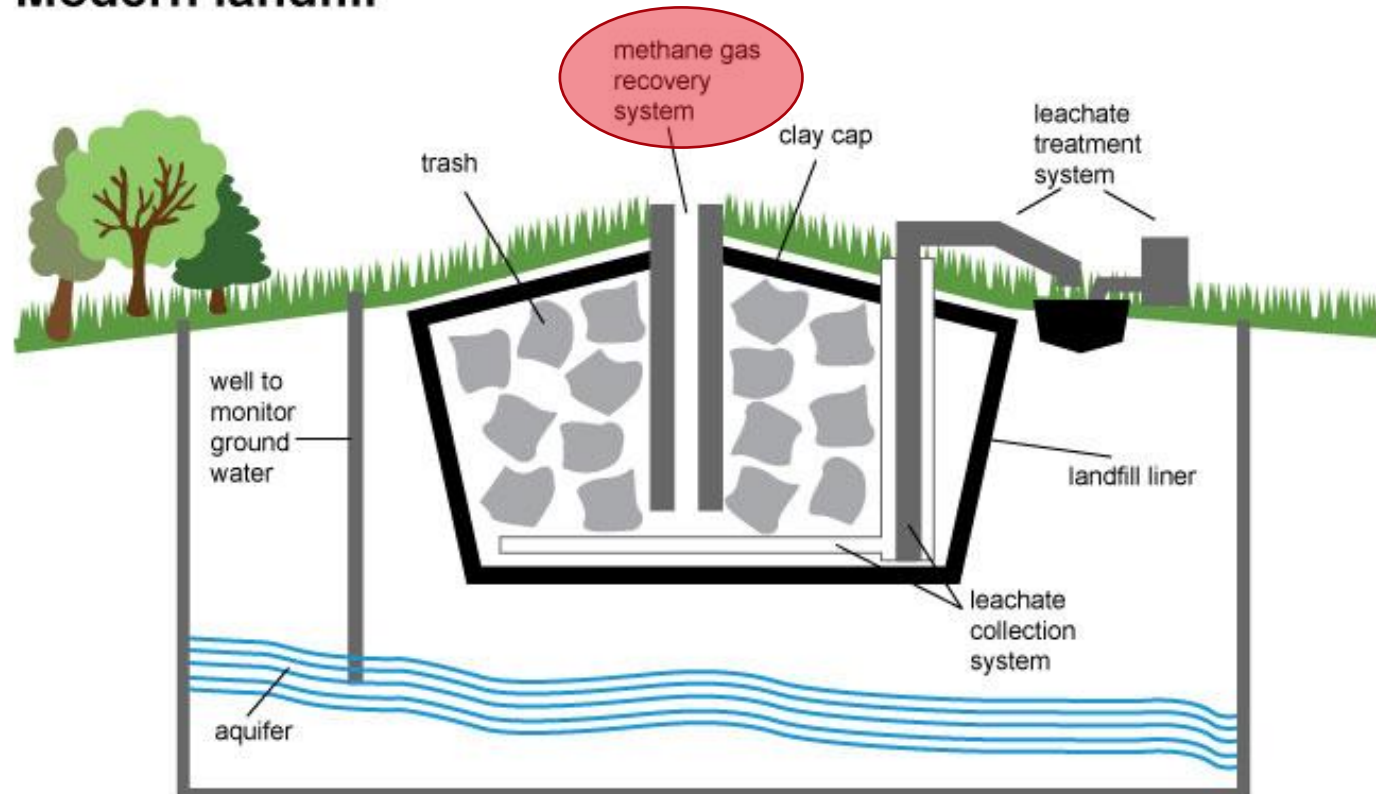
Key quality assurance concerns

- All offset programs include some form of **administrative body** to oversee the **project approval process** to ensure that the offset projects developed meet established **program requirements**. Although there are common components of the project approval process, programs have developed varied approaches **to key quality assurance concerns**.
 - **Validation requirements** provide ex-ante assessment and confirmation of offset project eligibility as defined by the rules of the program.
 - **Verification requirements** provide ex-post assessments and confirmation of quantification of the volume of emission reductions or removals that have been produced from an offset project across a certain period of time.
 - **Registries** are used to reduce concerns regarding double counting by tracking information regarding ownership of the offset projects and the credits generated.
 - **Third-party auditors** are required by most programs to help limit any potential conflict of interest between offset project developers and buyers, which both have financial incentives for inflating the volume of offset credits generated.
-

Basic criteria for an offset project

- **Additionality:** Would the project have happened anyways?

Modern landfill



Example landfill:
If the site had anyway planned / or was obliged to implement methane recovery, this cannot count as an additional measure.

- **Additionality:** Would the project have happened anyways?
- **Permanence:** How will the project be maintained?



Example reforestation:
How is it ensured that
trees grow long
enough to actually
sequester carbon?

- **Additionality:** Would the project have happened anyways?
- **Permanence:** How will the project be maintained?
- **Baseline:** How will success of the project be measured?



Example clean cookstove implementation:
What were emissions without the new cookstove versus the new emissions?

- **Additionality:** Would the project have happened anyways?
- **Permanence:** How will the project be maintained?
- **Baseline:** How will success of the project be measured?
- **Social/environmental impacts:** Does the project help the host community?

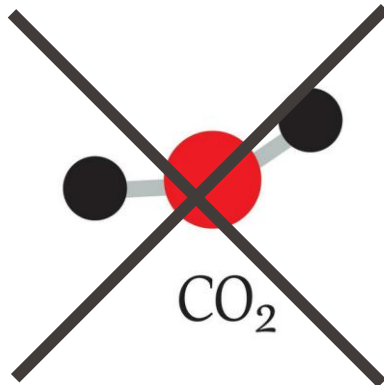


Example solar panels:
Does the
implementation benefit
everyone?

Offset strategies and sectors

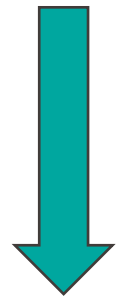
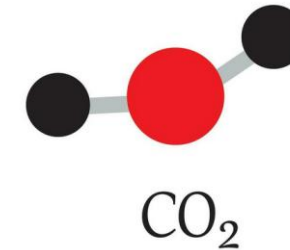
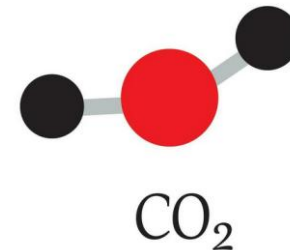
- There are two strategies that work with different sectors.

Avoidance



CO₂ is not released.

Removal



CO₂ is released AND removed.

Because CO₂ is globally distributed, emission and avoidance or removal can happen anywhere across the world.

- These projects **prevent carbon emissions** that would have been released into the atmosphere. It can be divided into 4 categories:
 - 1. Renewable Energy**
e.g., renewable power infrastructures that contribute to the decarbonization of the local energy grid.
 - 2. Energy Efficiency and Fuel Switching**
e.g., energy-saving measures that reduce carbon emissions and replace fossil fuels with sustainable energy sources.
 - 3. Household Devices**
e.g., efficient cookstoves that significantly reduce wood consumption. Or individual biogas digesters that provide sustainable fuel to local communities, prevent deforestation, and avoid GHG emissions.
 - 4. Water Management**
e.g., projects that supply clean water to households in rural communities, remove the need to boil water, and reduce GHG emissions.
-

- These projects **reduce carbon emissions** by absorbing them from the atmosphere. It can be divided into 3 categories:
 - 1. Agriculture**
e.g., agricultural practices that store carbon in soils while restoring biodiversity and developing new sources of income for smallholders.
 - 2. Forestry and Land Use**
e.g., projects that protect and restore existing forest areas threatened by deforestation.
 - 3. Waste Management**
e.g., landfill projects designed to capture the methane released by waste disposal, which can turn it into clean fuel.

Isn't it wonderful?



- Strong emitters are regulated in mandatory carbon credit systems.
- The rest of the world can get ahead of time and engage in voluntary carbon reduction.
- We'll be at net-zero in no time!

Too good to be true

- Voluntary carbon offsets have grown into a multi-billion-dollar industry.
- Many companies take advantage of voluntary carbon offsets, and more than a few claim this makes them climate neutral.
- The skyrocketing demand for cheap offsets incentivizes project developers to scale up projects with increasing speed.

1. Additionality

- The most prominent reason why carbon projects fail is that they are not additional, meaning that the project does not contribute to achieving additional climate benefits - compared to if the project had not existed.

2. There are significant risks to forests

- There are significant risks to forests after a project ends, as any carbon sequestered is likely to be released back into the atmosphere. This risk can manifest in several different ways, from natural disasters to illegal logging - especially in countries with unstable political situations.

3. Unreliable baseline inflate emissions premises

- A common issue seen in many projects is artificially inflating baseline emissions in order to generate more carbon credits for the project, thus taking credit for what the project did not do.

4. Carbon credits cause community conflicts

- In some cases, in order to establish projects that generate carbon credits, landowners (such as governments) may forcefully evict people living on the project area territory.

5. Emission reductions rely on vague predictions

- Credits promising that emission reductions will materialise in future are often referred to as 'ex-ante credits'.

~84% of voluntary projects fail





- The **Verified Carbon Standard** is a full-fledged carbon offset program developed and run by the non-profit Verra. It focuses on GHG reduction attributes only and does not require projects to have additional environmental or social benefits. The VCS is broadly supported by the carbon offset industry (project developers, large offset buyers, verifiers, and projects consultants) and is active globally.
- The **Gold Standard (GS)** is a voluntary carbon offset program focused on progressing the United Nation's Sustainable Development Goals (SDGs) and ensuring that project's benefit their neighboring communities. The GS can be applied to voluntary offset projects and to Clean Development Mechanism (CDM) projects. It was developed under the leadership of the World Wildlife Fund (WWF), HELIO International, and SouthSouthNorth, with a focus on offset projects that provide lasting social, economic, and environmental benefits.



- **Plan Vivo** is an Offset Project Standard for forestry, agricultural, and other land-use projects with a focus on promoting sustainable development and improving rural livelihoods and ecosystem services. Plan Vivo projects work closely with rural smallholders and communities and the standard emphasizes participatory design, ongoing stakeholder consultation, the use of native species, and biodiversity enhancement within a variety of payment for ecosystem service schemes – including carbon sequestration and emissions reductions.
- The **Climate Action Reserve** was launched in 2008. It is a USA based voluntary offsets program whose projects are implemented within North America. The Climate Action Reserve (CAR) establishes standards for quantifying and verifying GHG emissions reduction projects, provides oversight to independent third-party verification bodies, and issues and tracks carbon credits, called Climate Reserve Tonnes (CRTs).
- The **American Carbon Registry** (ACR) was founded in 1996 as the GHG Registry, the first private voluntary GHG registry in the USA, by the environmental non-profit organization Environmental Resources Trust (ERT).



Your key questions to assess the trustworthiness of a carbon offset project

- Is the project certified?
- Is it proven that the project has taken place?
- Is the emission removal/avoidance measurable against a credible baseline?
- Does additionality apply?
- Has the emission removal/avoidance been assured by an independent third party?
- Has the carbon credit only been attributed once?
- Are the carbon credits permanent?
- Does the offset project have co-benefits?
- Is the carbon credit pricing transparent?