

Methane mitigation achievement, including agriculture, is crucial to limiting dependence on uncertain CDR in national carbon budgeting equitably meeting Paris goals

Paul R. Price, Barry McMullin and Aideen O'Dochartaigh

Dublin City University



Funding:

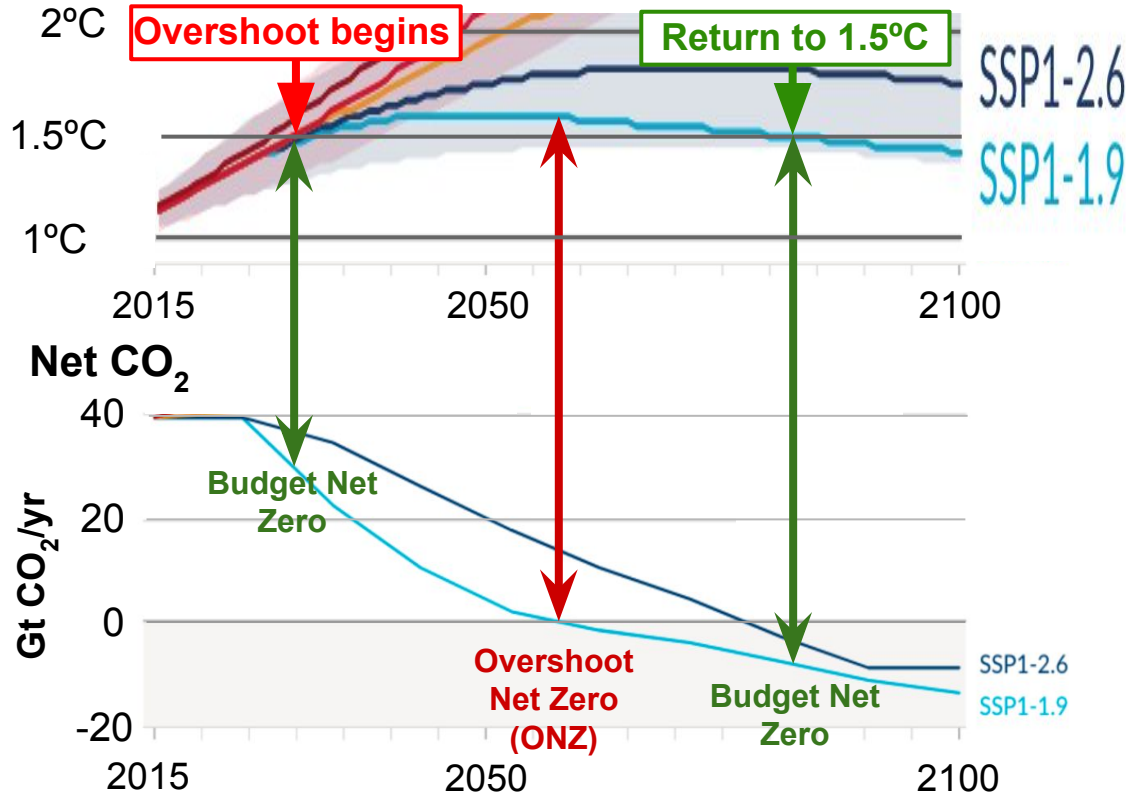


Rialtas na hÉireann
Government of Ireland

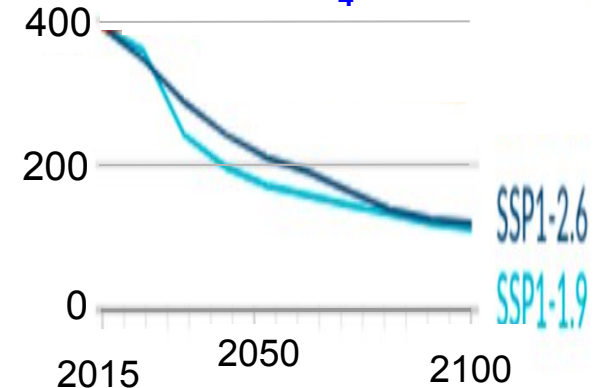
IPCC AR6 WGI Paris-consistent scenarios 2015–2100

Paris-consistent \approx **CO₂** net zero by 2055–2070 and **CH₄** cut by 50% by 2050

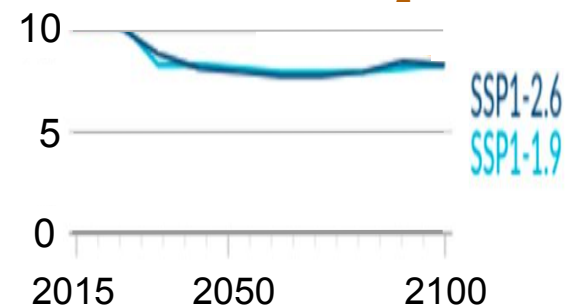
Global temperature change



Methane (Gt CH₄/yr)



Nitrous oxide (Gt N₂O/yr)



1.5°C goal: global overshoot, but wealthy nation overshoot is earlier!

- **Developed Parties:** overshoot likely imminent, needs early action to limit it.
- **Implications for “net zero”:** define two distinct net zero points
 - **Overshoot Net Zero (ONZ)** = “no further warming” = peak carbon debt.
 - **Quota Net Zero (QNZ)** = timing of return to fair share temperature quota.

In addition to radical reductions in gross CO₂ emissions:

- Net negative emissions to *limit* peak overshoot and to *return* to global budget level (or national fair-share) = cancelling carbon debt.
- Permanent CH₄/yr cut = one-off CO₂ removal ⇒ equivalent to CDR.

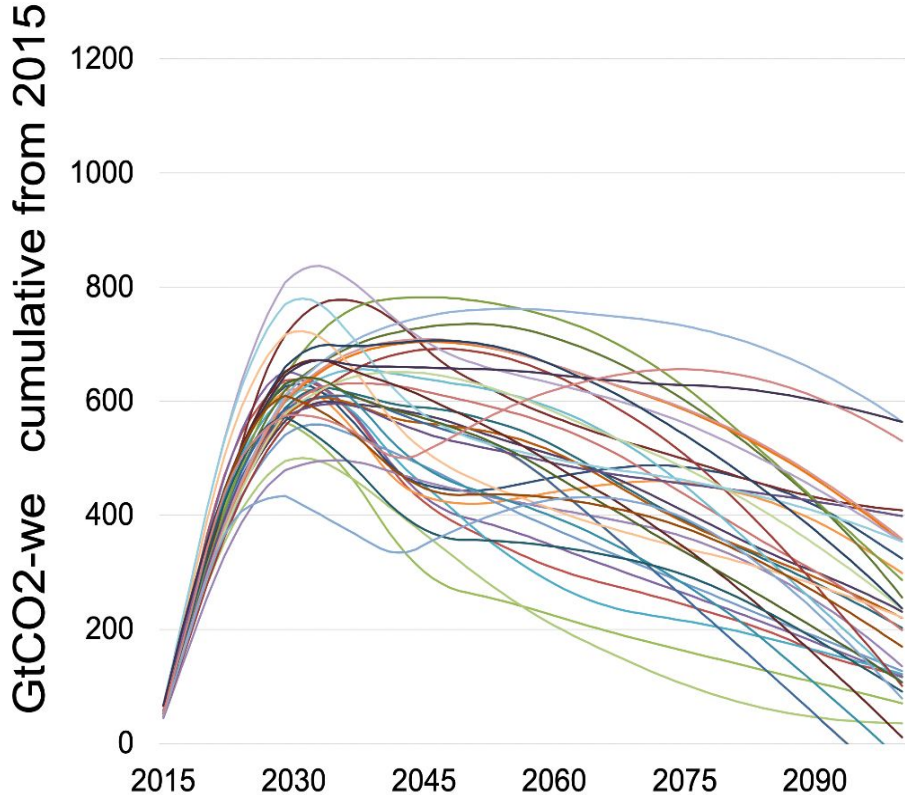
Assess UNFCCC Party climate action: carbon budgeting & warming impact – *need to include CO₂ and non-CO₂ GHGs, especially CH₄.*

⇒ **Ireland** as a case study: Compare by-gas & aggregate **warming impact**.

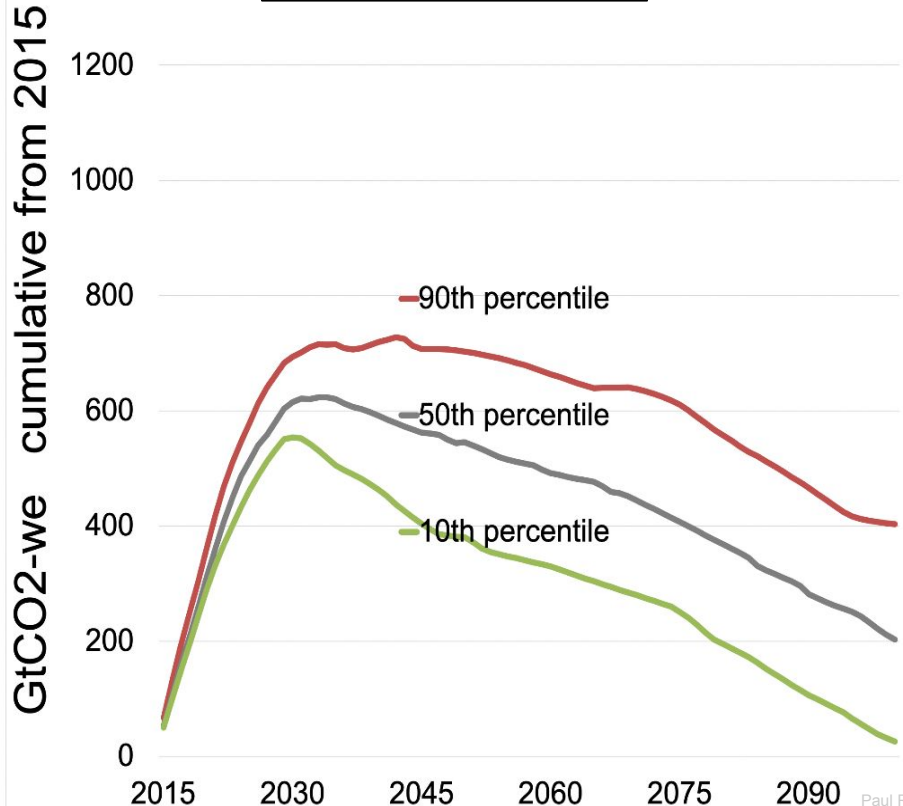
- Can use the same methodology and tool for any nation.

1.5C lowOS scenarios: GWP* CO₂we for [CO₂+N₂O+CH₄]

All scenarios



Percentiles



Principles for Paris-consistent carbon budgeting

Normative choices are unavoidable but necessary.

Assessments must make equity parameters explicit.

- **Prudence:** global goal at least 50% chance of limiting to 1.5°C
- **Responsibility:** define base year (2015?) as *essential to:*
⇒ assess historic responsibility **AND** remaining carbon budget.
- **Equity:** Many “fair sharing” possible principles eg. equal per capita.



Calculating multigas global budgets and “fair share” national quotas

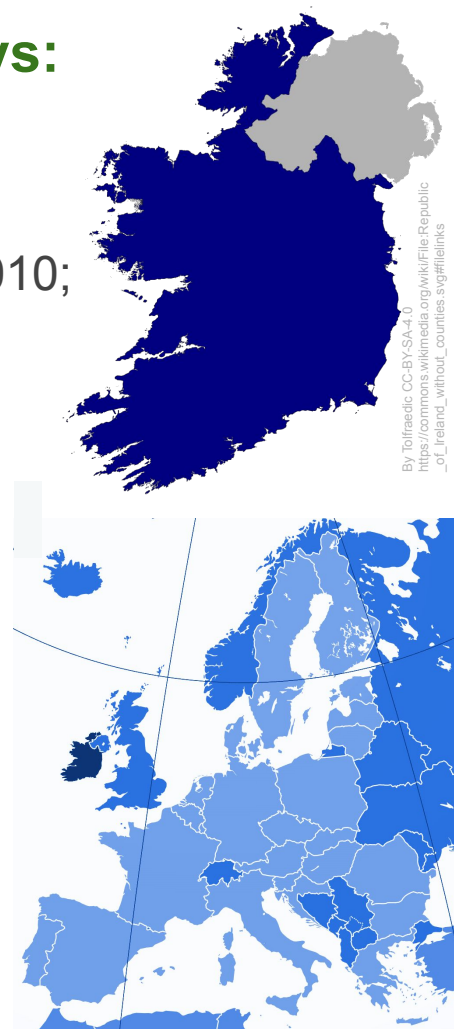
- GWP100 GHG metric does not reflect °C impact for short-lived GHGs.
- *Appropriate* use of step-pulse GHG equivalence methods such as GWP*, based on GWP100, enable rapid °C impact analysis by acting as a simple climate model.

Cumulative CO₂ warming equivalent (= CO₂we) via GWP* from defined base year

- Shows aggregate temperature impact of a scenario of defined GHG pathways.
- **GWP* enables inclusion of CH₄ & N₂O with CO₂** in carbon budgeting analysis.

Ireland: a case study of overshoot CH₄ & CDR pathways:

- Ireland has big non-CO₂ emissions from CH₄ & N₂O.
CH₄ up 19% since 2010, due to substantial ruminant agriculture including policy-directed expansion of dairy production since 2010;
- **2018:** Total 68.3 MtCO₂eq **CH₄: 17 MtCO₂eq** **N₂O: 6.6 MtCO₂**
- **Ireland's recently amended Climate Act 2021:**
 - Strongly worded Paris-consistent basis:
'The Minister and the Government shall carry out their respective functions ... in a manner that is consistent with Articles 2 and 4(1) of the Paris Agreement'
 - Sets out a programme of **5-year carbon budgets** from 2021 onwards; first two budgets accepted.
- **Note:** Ireland's practical policy limit CDR = 200 MtCO₂ as assessed by [McMullin et al. \(2020\)](#) – see *NegCO2 Conference* paper



By Tollefædic CC-BY-SA 4.0
https://commons.wikimedia.org/wiki/File:Republic_of_Ireland_without_countries.svg#filelinks

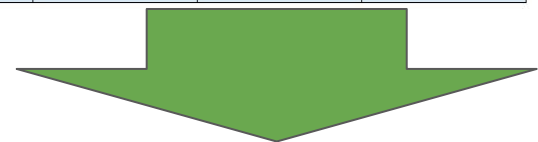
By NuclearVacuum - File:Locauropean nation states.svg, CC BY-SA 3.0,
<https://commons.wikimedia.org/w/index.php?curid=809744>

Global [CO₂+N₂O+CH₄] budgets & national quota shares from

Annual global CO₂we emissions in 2015 = 50.6 Gt CO₂we

1.5C low overshoot (37 scenarios)	Percentile		
	10th	50th	90th
	Low 2015–2100 value	Mid 2015–2100 value	High 2015–2100 value
[CO ₂ +N ₂ O+CH ₄] rGCB* in GtCO ₂ -we	562	641	768

2015 remaining tCO ₂ we per capita	76	86	103
---	-----------	-----------	------------



Ireland NCQ* = quota for 1.5°C:

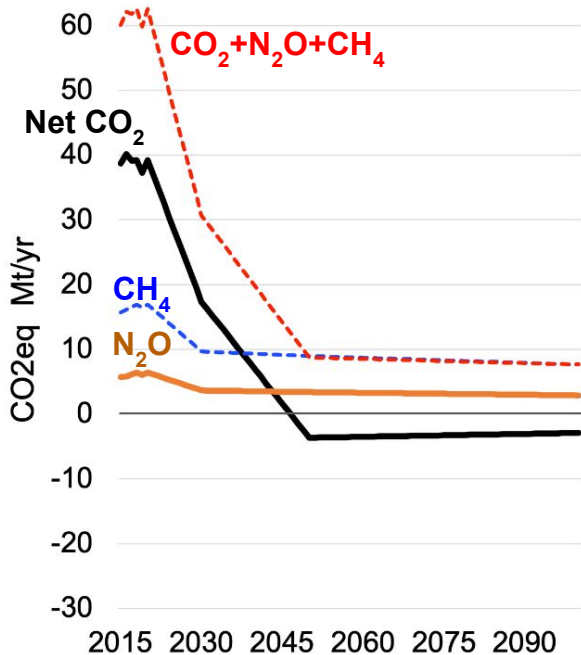
2015 population in millions	IRL	4.7	
Nation or region quota NCQ* in MtCO ₂ -we	360	410	490

NCQ*

A scenario meeting a “fair-share” 1.5°C national CO₂we quota (NCQ*) from 2015

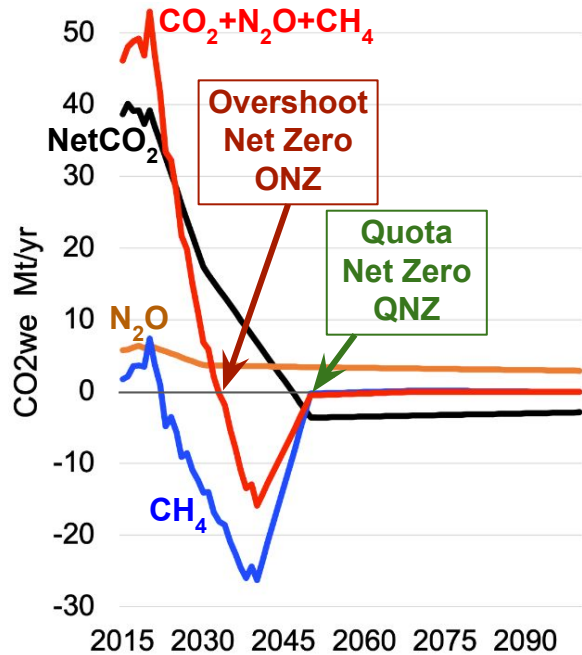
Multigas [CO₂+N₂O+CH₄] analysis for: CH₄ & N₂O cut by 43% by 2030. CO₂ to net zero by 2050.

GWP100 Annual



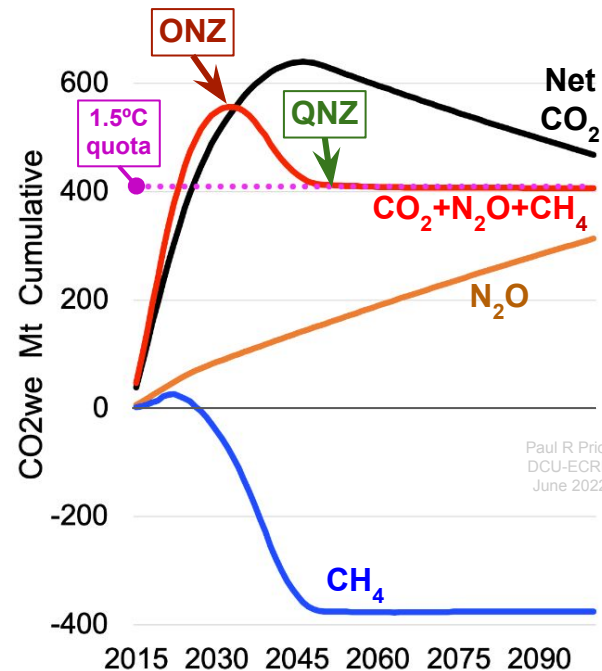
GWP100: Shows fractional mass change in each GHG but not the temperature impact?

GWP* Annual



GWP*: Solid red line shows annual aggregate and by-gas temperature contributions

GWP* Cumulative from 2015



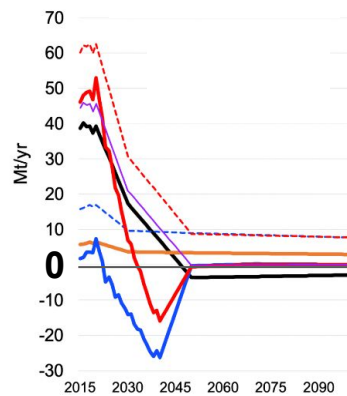
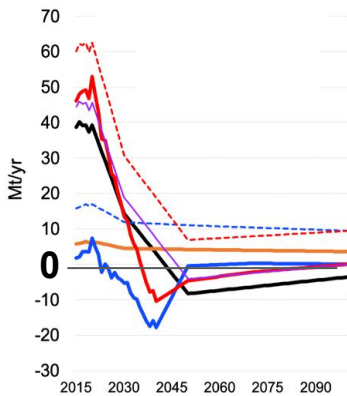
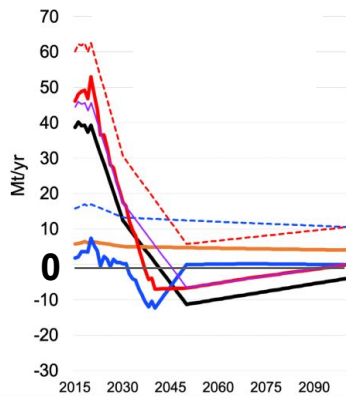
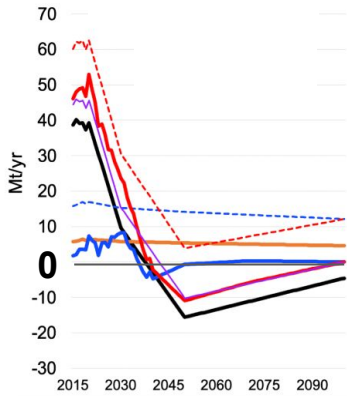
Paul R Price
DCU-ECRN
June 2022

Overshoot by 2023;
Overshoot Net Zero in 2033
Quota Net Zero in 2047

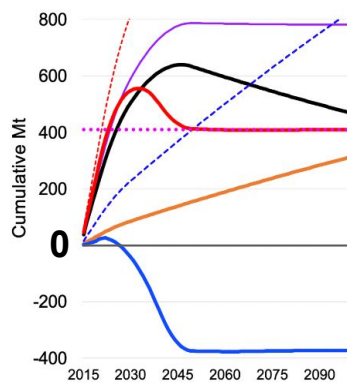
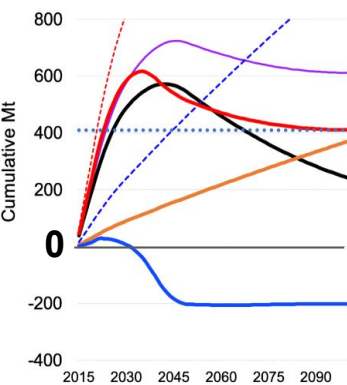
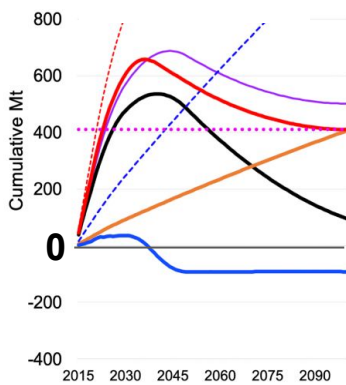
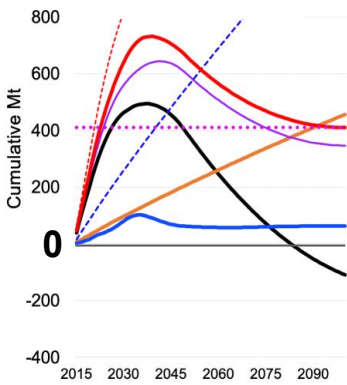
Ireland: Four illustrative mitigation scenarios 2015–2100

Non-CO₂ cut by 2030 ⇒ **-10%** **-22%** **-30%** **-43%**

Annual emissions



Cumulative from 2015



- CO₂ net
- LLCP (CO₂+N₂O)
- CH₄ in CO₂we
- - - Aggregate CO₂eq
- N₂O
- - - CH₄ in CO₂eq
- Aggregate CO₂we
- ⋯ 1.5C NCQ* for Ireland

**Overshoot Net Zero
+320 MtCO₂we**

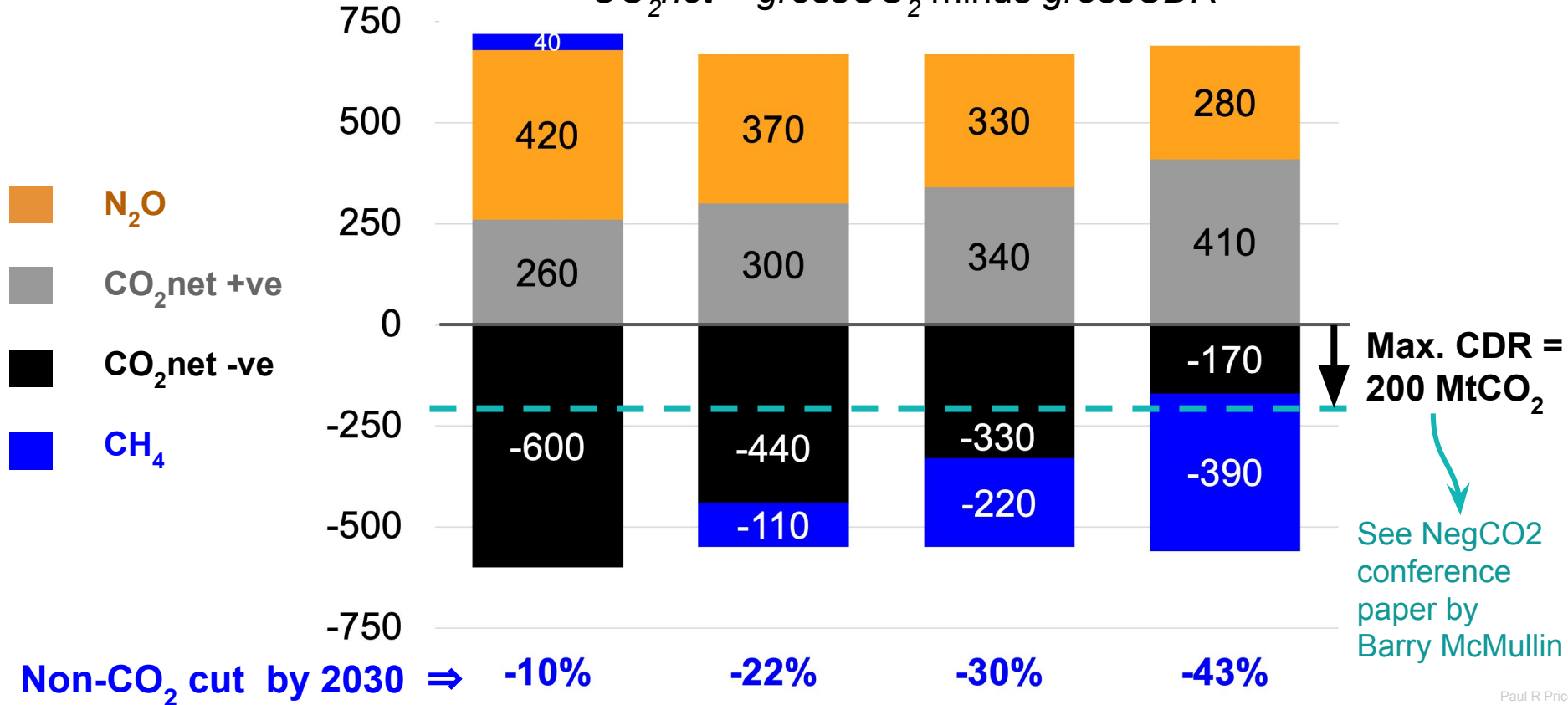
**Overshoot Net Zero
+250 MtCO₂we**

**Overshoot Net Zero
+210 MtCO₂we**

**Overshoot Net Zero
+150 MtCO₂we**

Only deepest CH₄/yr rate cut, limits CDR requirement within assessed max. CDR

Scenarios: cumulative CO₂we 2015–2100 by-gas
 $CO_2_{net} = grossCO_2 \text{ minus } grossCDR$



Findings for science-policy interface and carbon budgeting:

1. **Paris-aligned, multi-gas remaining global budgets, including non-CO₂ (CH₄ & N₂O), can be estimated from a given base year using a step-pulse method such as GWP*. National fair share quotas can be derived by explicit allocation.**
2. **For developed nations Paris fair share quota-exceedance is imminent.** Therefore, policymakers urgently need to plan to limit peak carbon debt at **Overshoot Net Zero** and achieve earliest possible return to **Quota Net Zero**.
3. **Permanent reduction in CH₄/yr rate equates to substantial CDR:**
In mitigation scenarios CH₄ mitigation may be critical to staying within practical CDR limits. Early and deep CH₄ mitigation reduces CDR reliance.
4. **“Hard-to-abate” sectors do have to be abated to meet national quotas:**
⇒ In Ireland, cutting agricultural CH₄ from beef & dairy cattle is likely crucial to meeting “fair share” °C quota limiting CDR reliance within practical 200 MtCO₂ limit.

Global 1.5°C: IPCC AR6 scenario

As shown here from Rogelj et al. 2021..

- This scenario indicates <1.3 °C by 2100
= Much more CDR than for 1.5°C stabilisation?

⇒ Suggests long-term ongoing CH₄ is offset by CDR via GWP100 CO₂eq??

- This does not make sense in °C terms:
slow CH₄/year reduction results in stable °C.

But Paris ambition is 1.5°C not 1.3°C.

So the IPCC scenario may:

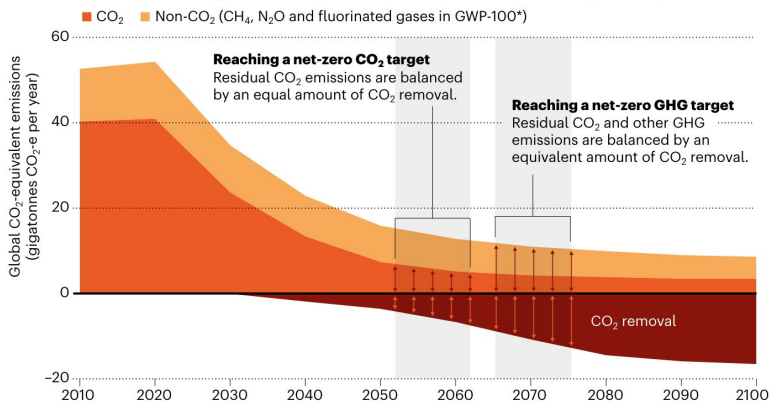
- Increase risks of CH₄ mitigation deterrence (especially if continuing CH₄ emissions are offset on a misleading CO₂e basis)
- Increase risks of North/South & generational inequity by exaggerating necessary CDR amount & cost.

IT'S ALL IN THE DETAIL

Choosing different gases, different timing for net-zero emissions and different methods of aggregating emissions can have very different outcomes.

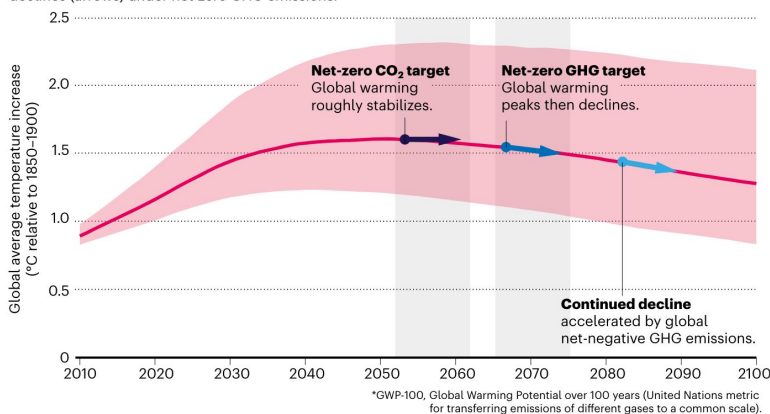
Global greenhouse-gas (GHG) emissions

Illustrative pathway for reaching net-zero carbon dioxide and net-zero GHG emissions (from ref. 3).



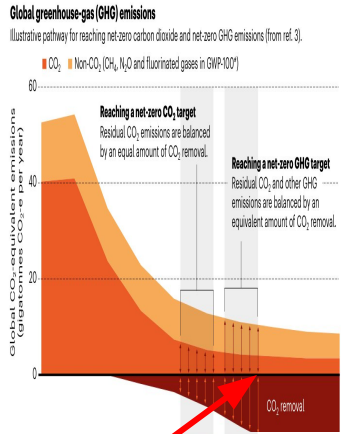
Global-warming implications

Estimated global temperature peaks (in pink) and declines (arrows) under net-zero GHG emissions.



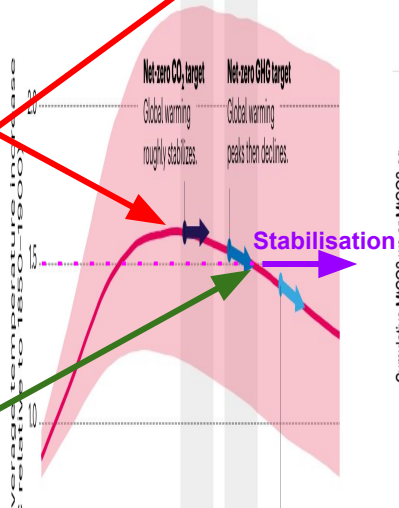
Rogelj, J., Geden, O., Cowie, A., Reisinger, A., 2021. Net-zero emissions targets are vague: three ways to fix. Nature 591, 365–368. <https://doi.org/10.1038/d41586-021-00662-3>

Global scenarios: AR6 1.3°C by 2100 versus 1.5°C Stabilisation



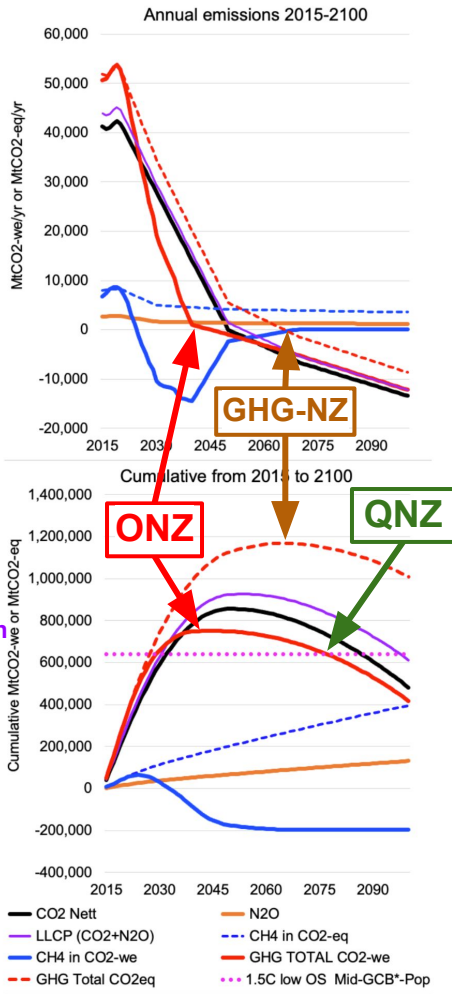
**Overshoot
Net Zero**

**Quota
Net Zero**

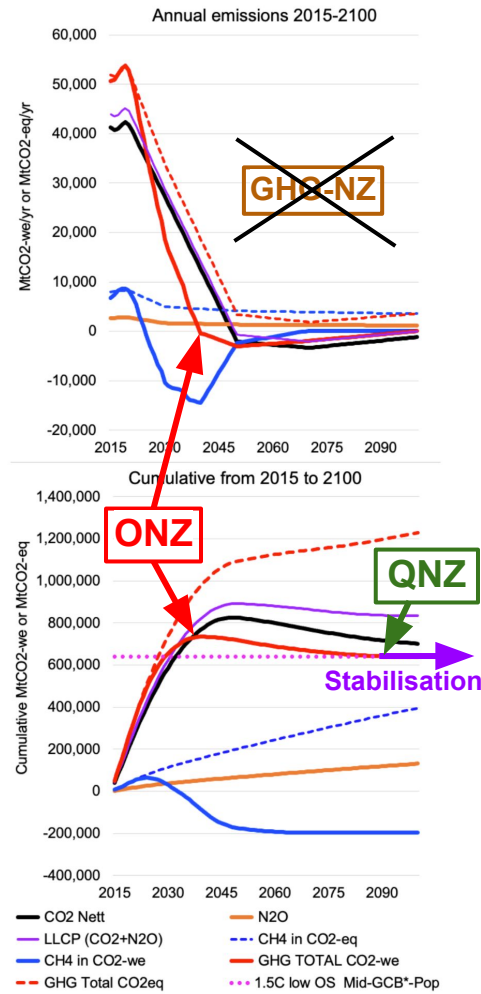


AR6 1.5°C

AR6-approx scenario



Stabilisation scenario



Thank-you...

Questions?

Full paper title:

Methane mitigation achievement, including agriculture, is crucial to limiting dependence on uncertain carbon dioxide removal in national carbon budgeting equitably meeting Paris goals

Email: paul.price@dcu.ie



Funding:



Rialtas na hÉireann
Government of Ireland