Energy
Transitions
Commission

Mind the Gap:
How carbon dioxide removals can complement deep decarbonisation to keep 1.5°C alive

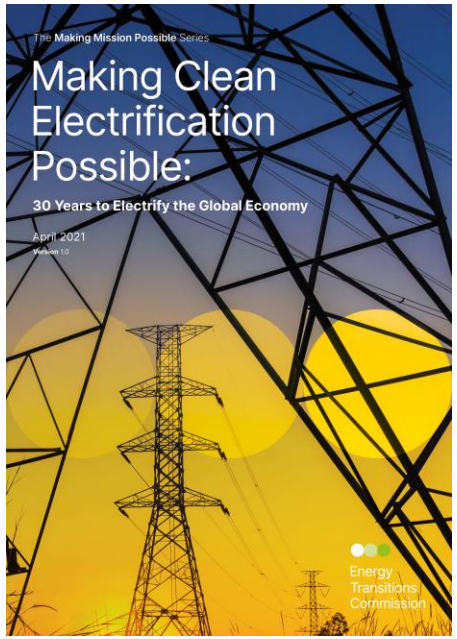
ETC Webinar – November 2023

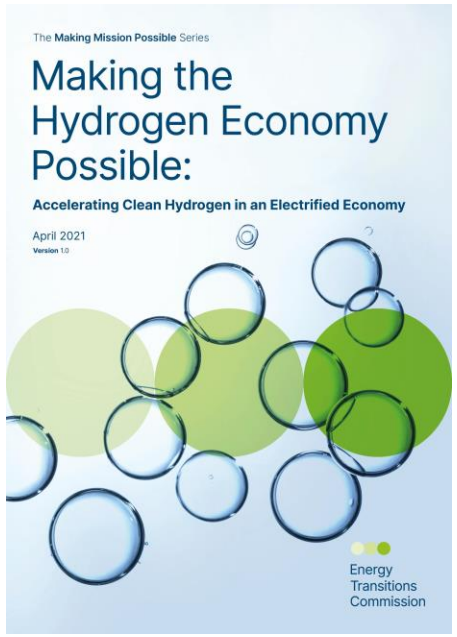
Making Mission Possible series sets out how to achieve a Net Zero economy by mid-century

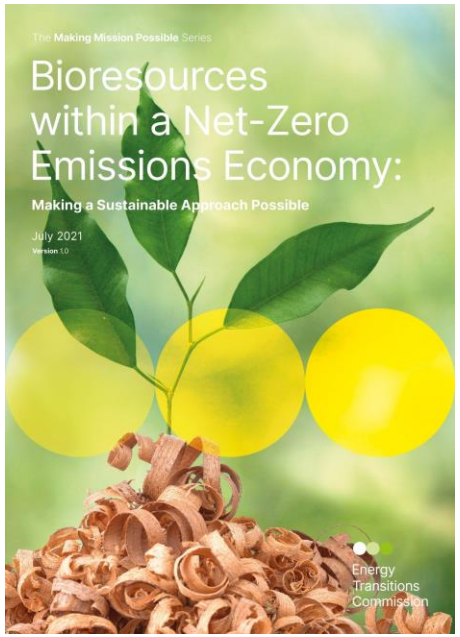
The Making Mission Possible Series

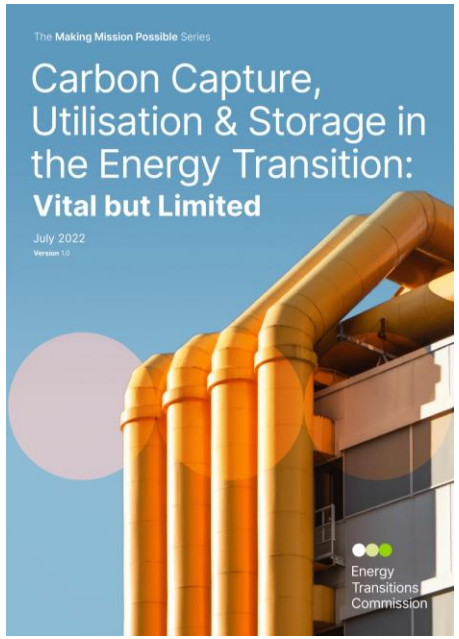
Decarbonisation

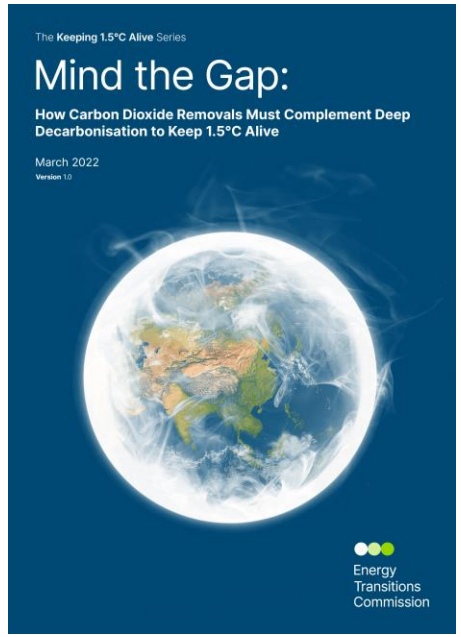
Negative Emissions

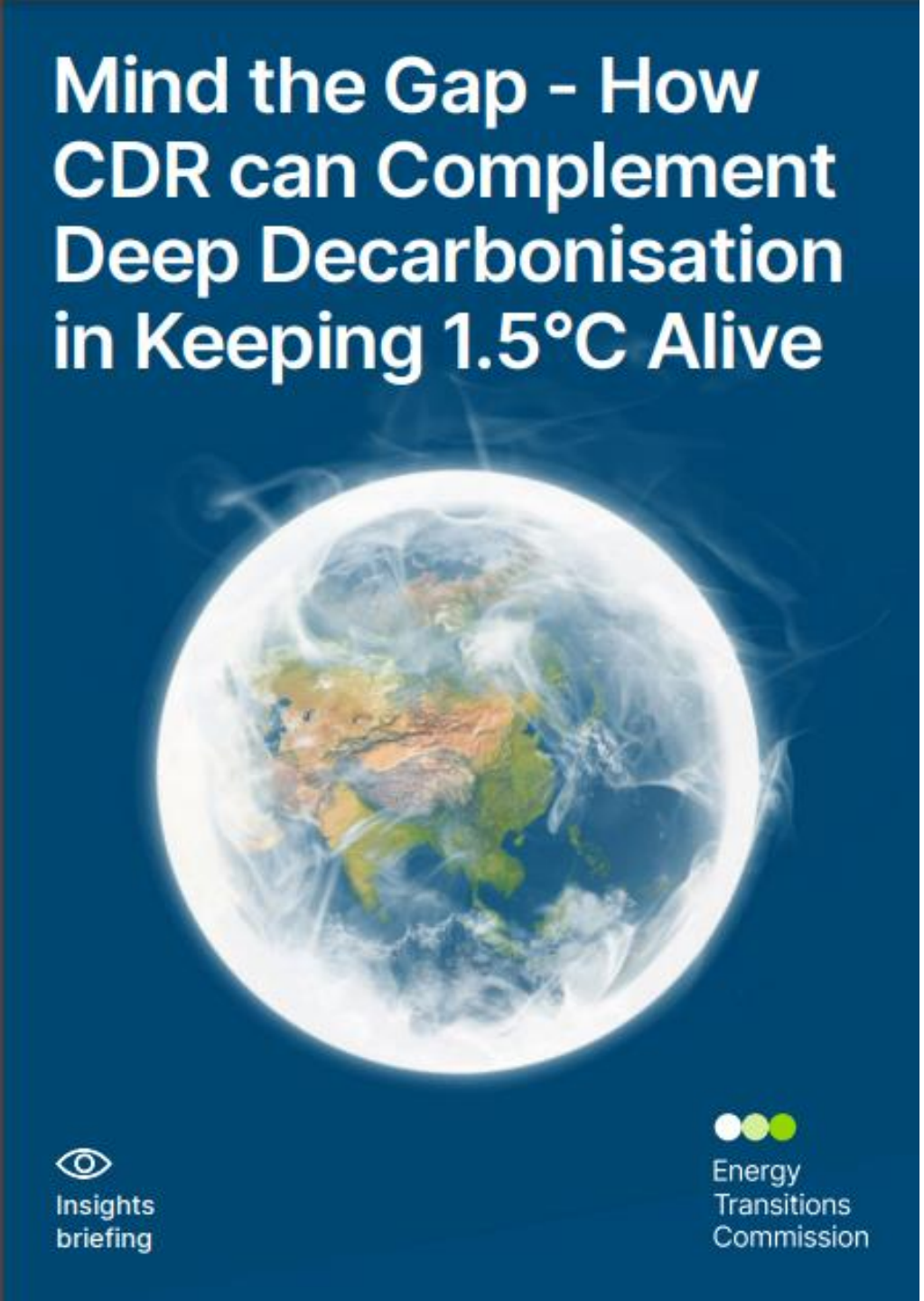








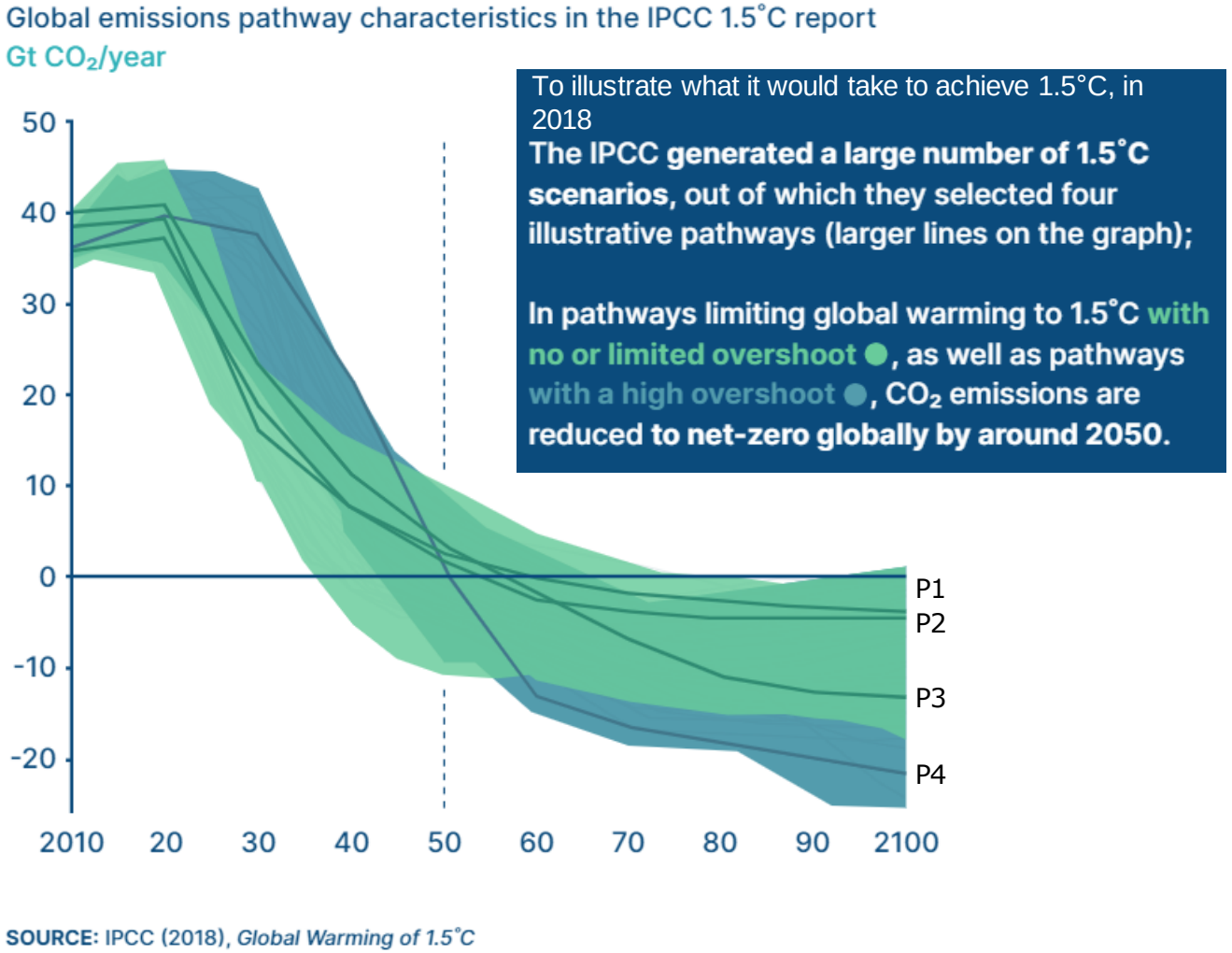




1. Despite ambitious decarbonisation strategies we will need **carbon dioxide removals** to fill a **70 ->225 Gt CO_2 carbon budget overshoot gap**
2. A portfolio of carbon dioxide removal solutions could be scaled up to cumulatively **remove 165 Gt CO_2 by 2050**, and an **ongoing rate of 3-5 Gt CO_2 p.a. thereafter**
3. Managing **risks to permanence and delivery** at scale will require robust monitoring and verification systems and secure finance
4. Removals will need to be paid for via a **combination of corporate and governmental efforts**
5. To deliver CDR at necessary scale, key policy and corporate actions must **support them in the 2020s**

Emission reduction scenarios and the overshoot gap

To have a 50% chance to remain <1.5 degree warming, IPCC estimates the remaining Carbon Budget to be around ~500 Gt CO_2 from 2020



SOURCE: IPCC (2018), *Global Warming of 1.5˚C*

Chosen carbon budget in this report

	50% chance	67% chance	~90% chance
<1.5 °C	**500** Gt CO_2 from 2020	**400** Gt CO_2 from 2020	*N/A*
<1.7 °C	**850** Gt CO_2 from 2020	**700** Gt CO_2 from 2020	*N/A*
<2 °C	**1350** Gt CO_2 from 2020	**1150** Gt CO_2 from 2020	**500** Gt CO_2 from 2020

CH_4 and N_2O reductions corresponding to chosen carbon budget

CH_4 reduction by 2050	N_2O reduction by 2050
~50-55% (42%-76% range)	~30% (-25% - 48% range)

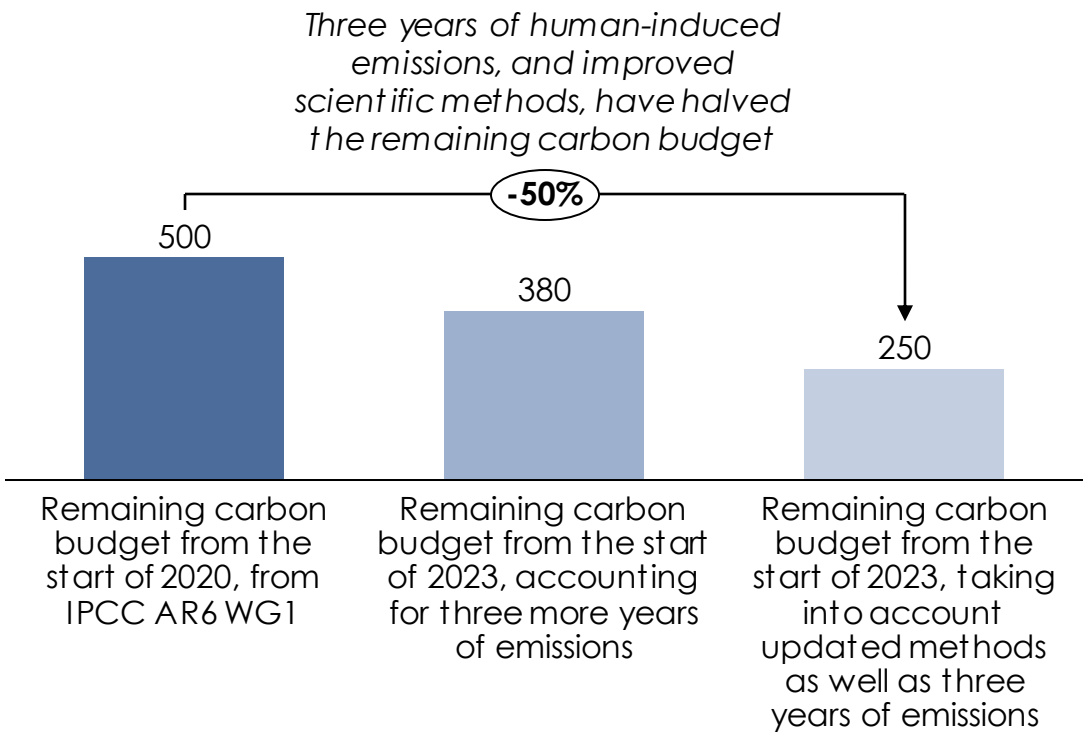
Source: IPCC (2021), *Climate Change 2021: The Physical Science Basis (AR6)*

Note: The IPCC *6th Assessment Report* (2021) only illustrated one 1.5C 'low overshoot' compatible pathway, aligned to P2 above.
Source: IPCC (2018), *Global Warming of 1.5°C;* IPCC (2021), *Climate Change 2021: The Physical Science Basis (AR6)*.

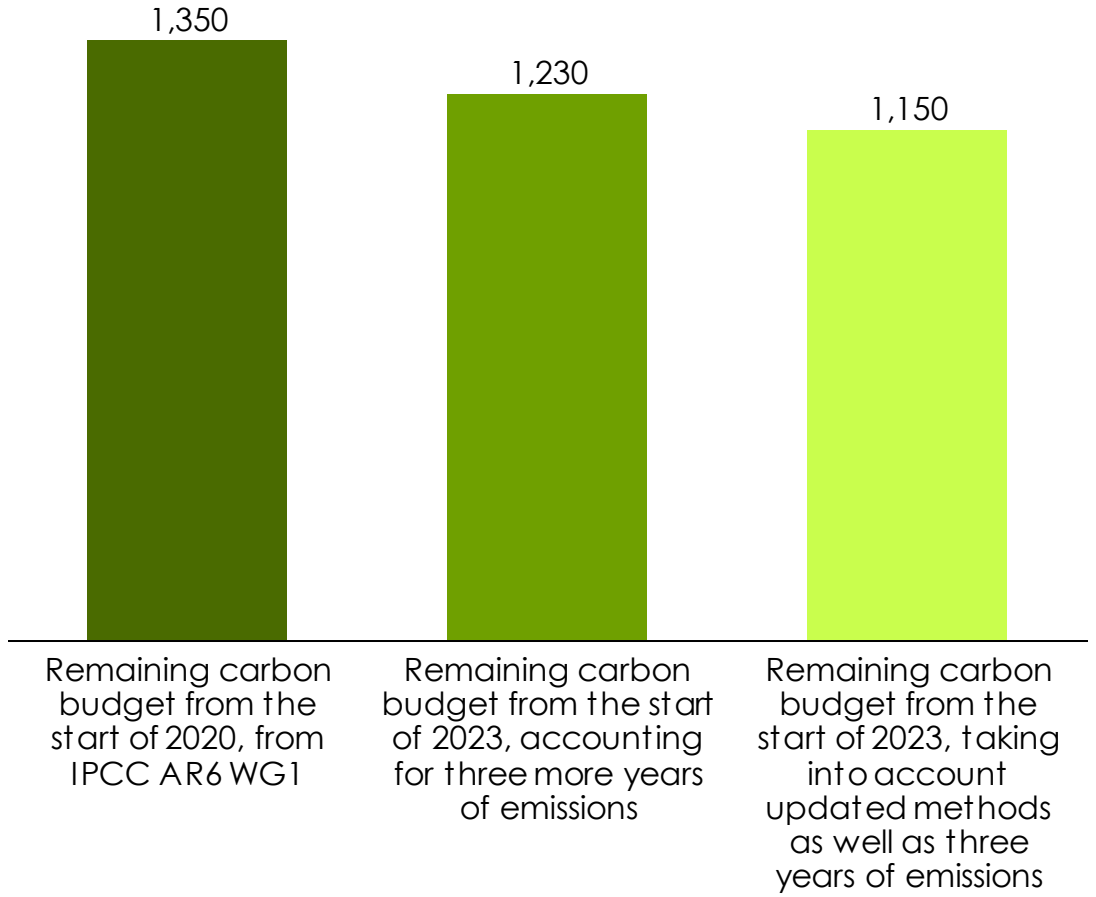
Carbon budgets to limit global average temperature increase to 1.5°C and 2°C have decreased, increasing the urgency of action in the short term

Carbon budgets for a given temperature rise, In $GtCO_2$

Budget for 50% chance of staying within 1.5°C



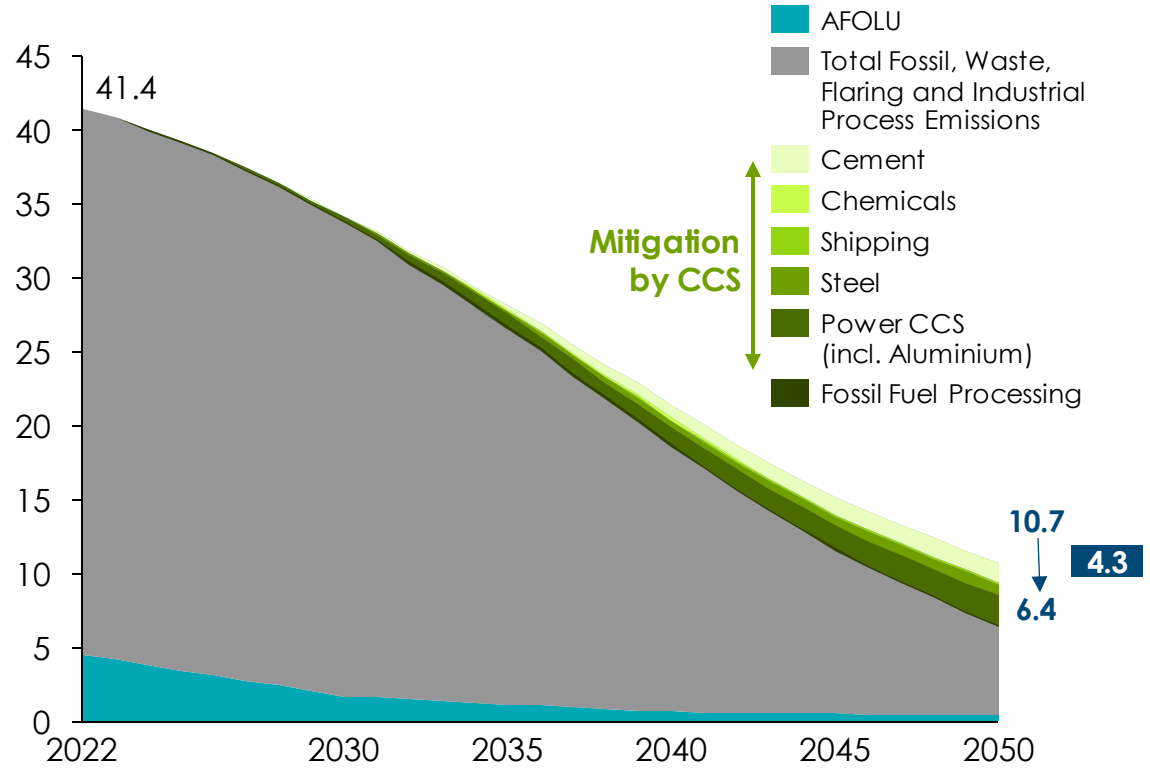
Budget for 50% chance of staying within 2°C



Emissions from fossil fuels and industry could fall rapidly over coming decades; but cumulative emissions over the period are still likely to exceed carbon budgets

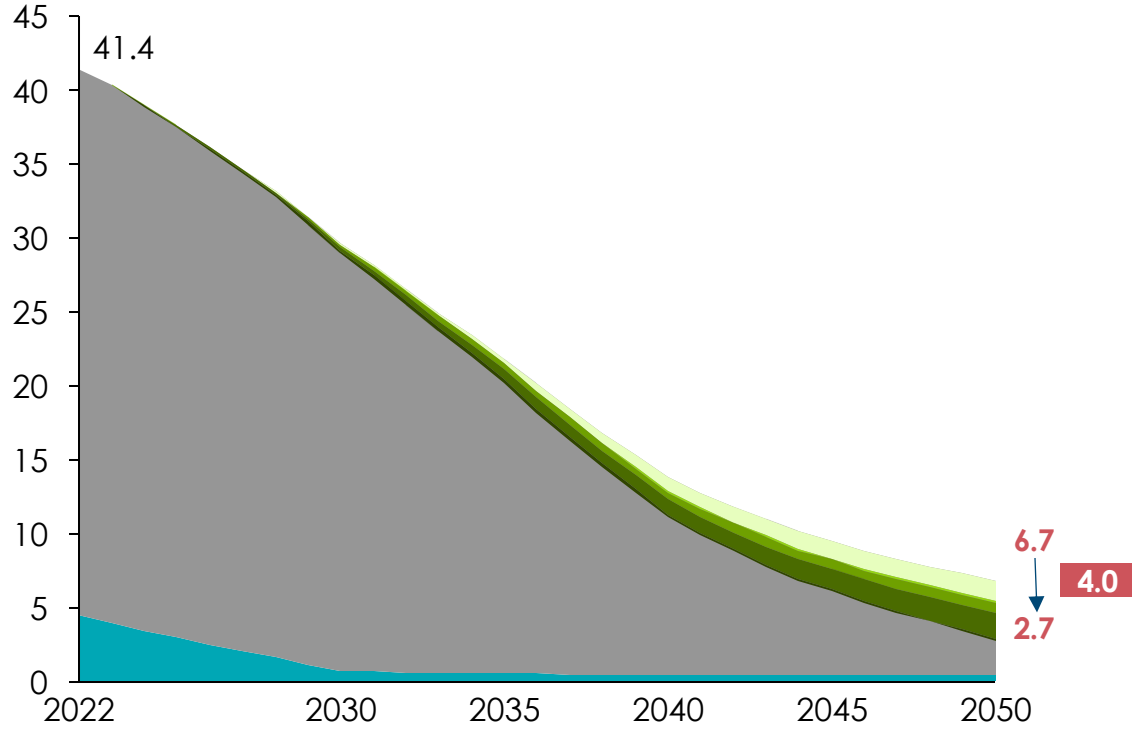
Net emissions from fossil fuels, industry and AFOLU after carbon capture and storage, $GtCO_2$

ACCELERATED BUT CLEARLY FEASIBLE



Cumulative emissions 2023-2050:
630 $GtCO_2$ from fossil fuels and industry post-CCS + 40 $GtCO_2$ from AFOLU = **670 $GtCO_2$**

POSSIBLE BUT STRETCH



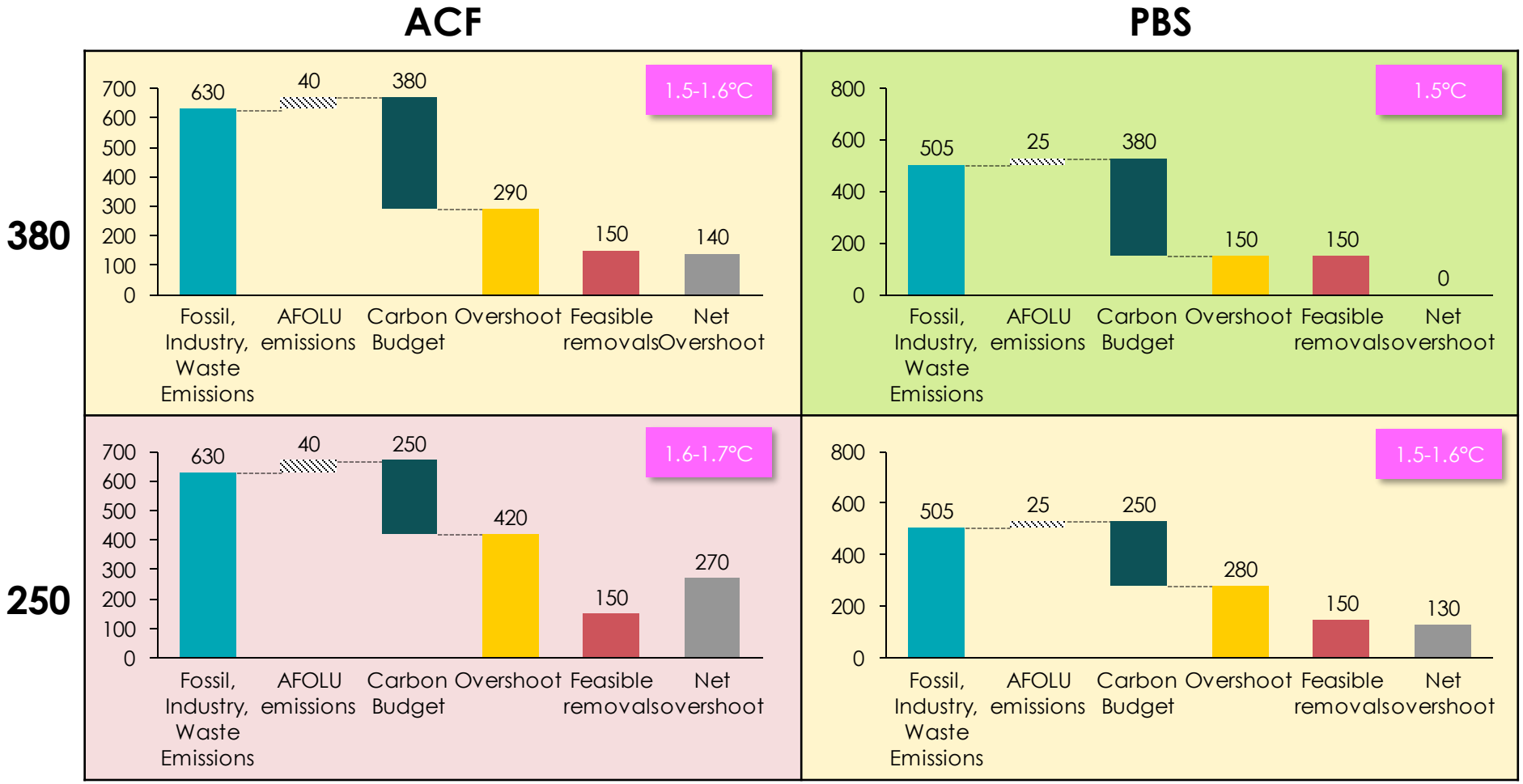
Cumulative emissions 2023-2050:
505 $GtCO_2$ from fossil fuels and industry post-CCS + 25 $GtCO_2$ from AFOLU = **530 $GtCO_2$.**

Assuming a smaller remaining carbon budget, even ambitious carbon removal projections will not be sufficient to fill the overshoot gap

Net emissions overshoot and implied temperature rise, by scenario

Remaining carbon budget 2023 – 2050 for a 50% chance of limiting global warming to 1.5°C

Gt CO_2



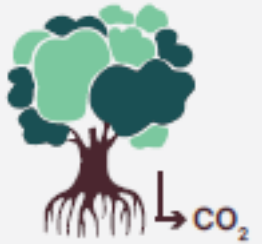
Note: [1] Estimates calculated using values for the Transient Climate Response to Cumulative Emissions of Carbon Dioxide (TCRE), using a value range of 0.27-0.63 C per 1000 GtCO_2, based on the IPCC's Sixth Assessment Report. Note that the temperature estimates calculated here will likely underestimate future warming, as these do not account for the warming impact of other greenhouse gases, notably methane and nitrous oxide.

SOURCE: Systemiq analysis for the ETC; IPCC (2021) Climate Change 2021: The Physical Science Basis; Forster et al. (2023), *Indicators of global climate change 202: annual update of large-scale indicators of the state the climate system and human influence.*

Typology of carbon dioxide removals

A portfolio of CDR solutions will be required to mitigate carbon budget overshoot

NATURAL CLIMATE SOLUTIONS



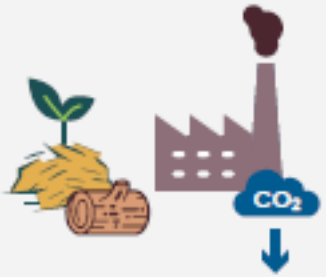
'RESTORE'

Restore natural ecosystems (e.g. forests, peatlands)

'MANAGE'

Better manage current use of land

HYBRID / BIOMASS WITH CARBON REMOVAL STORAGE



BIOCHAR

Burn biomass in absence of oxygen to slow decomposition

BECCS

Produce energy from biomass then capture CO_2 produced

ENGINEERED SOLUTIONS

DACCS

Capture CO_2 direct from air and store underground

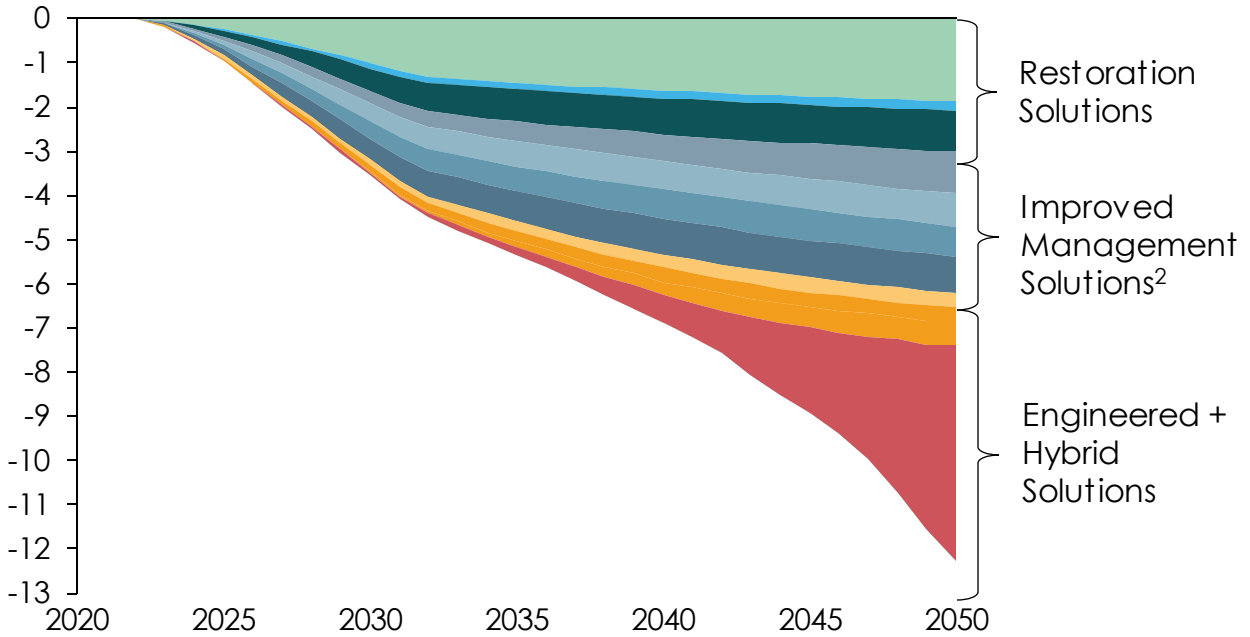
IN ADDITION

ACCELERATE CDR INNOVATION, E.G. ROCK WEATHERING, OCEAN ALKALINITY AND FERTILISATION, MICRO-ALGAE

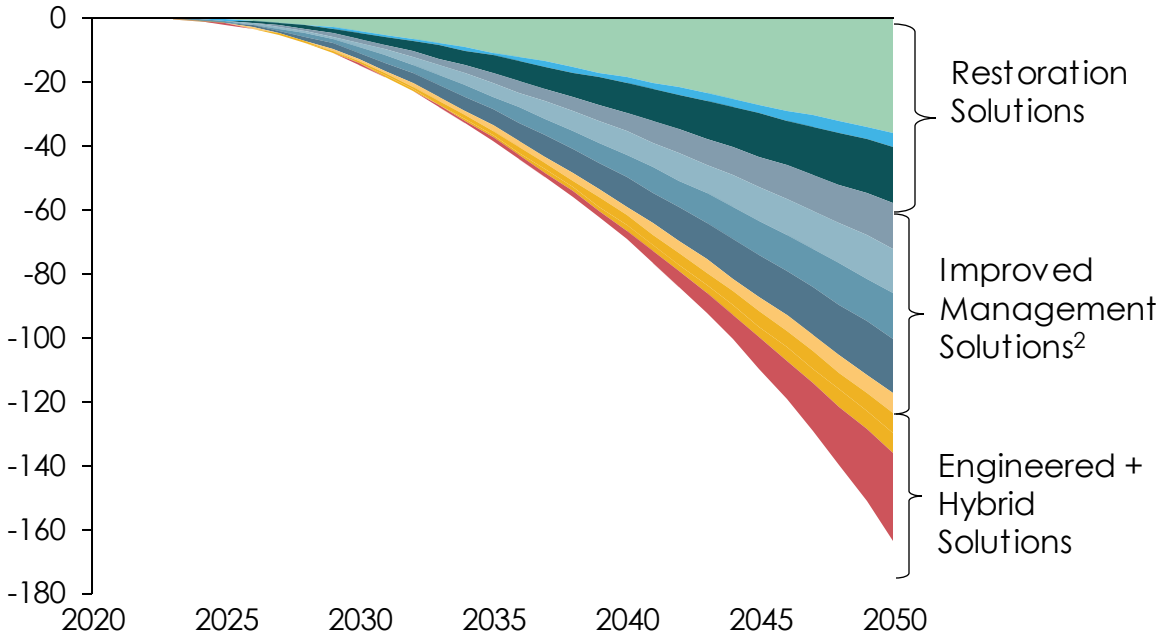
Ambitious and rapid scaling of a CDR portfolio could deliver cumulative sequestration of ~165 $GtCO_2$ by 2050

CO_2 ONLY

Potential ramp-up of CDR, $GtCO_2$/year, global



Cumulative CDR 2020-2030, $GtCO_2$, global



NCS: Restore

- Restore forests
- Restore Blue carbon[1]
- Restore drained peatlands

NCS: Manage

- Improve forest management
- Agroforestry
- Enhance soil carbon sequestration in croplands
- Enhance soil carbon sequestration in grazing lands

Hybrid and engineered approaches

- Apply biochar
- BECCS
- DACCS

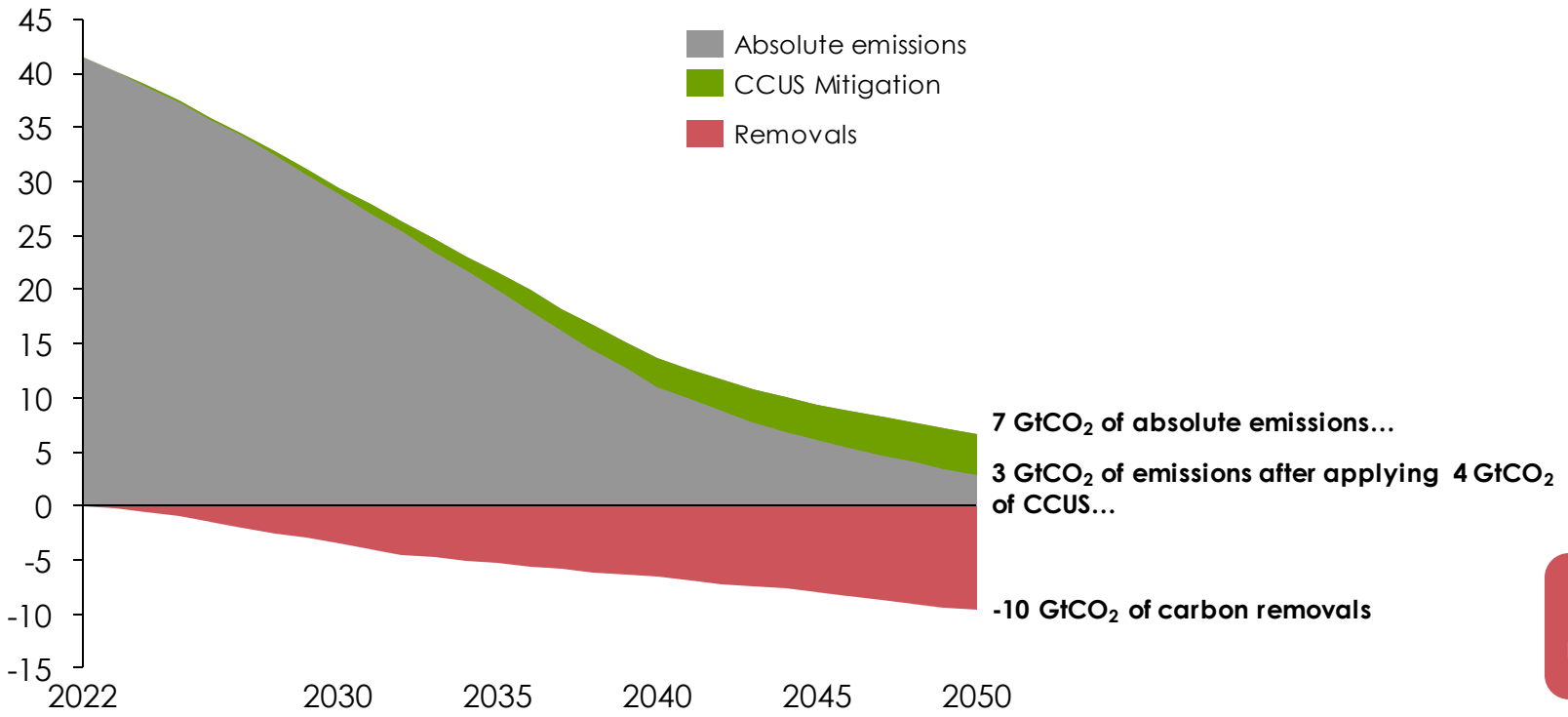
Notes: The analysis was designed to avoid potential double-counting of emissions reductions, and is adjusted from annualised average potential estimates for 2020-2050 period. The models reflect land use & management changes, yet in some instances can also reflect demand-side effects from carbon prices, so may not be defined exclusively as 'supply-side'. (1) 'Blue Carbon' is defined as ocean-based biomass sequestration including mangroves, seagrasses, and tidal marshes. (2) Improved management solutions have been adjusted for feasibility on a country-by-country basis. Overall average reduction is ~50%.

Source: SYSTEMIQ analysis for the ETC (2021), based on Roe et al. (2021), Hannah et al. (2021), Griscom (2017), ETC (2021) *Bioresources for a Sustainable Net-Zero Economy*, High Level Panel for Oceans (2020)

It is not prudent to rely on significantly higher use of CCUS or CDR – the priority must be to bring down fossil fuel demand, but CDR will be critical to reduce carbon budget overshoot

Net emissions from fossil fuels, and after CCUS and CDR

$GtCO_2$

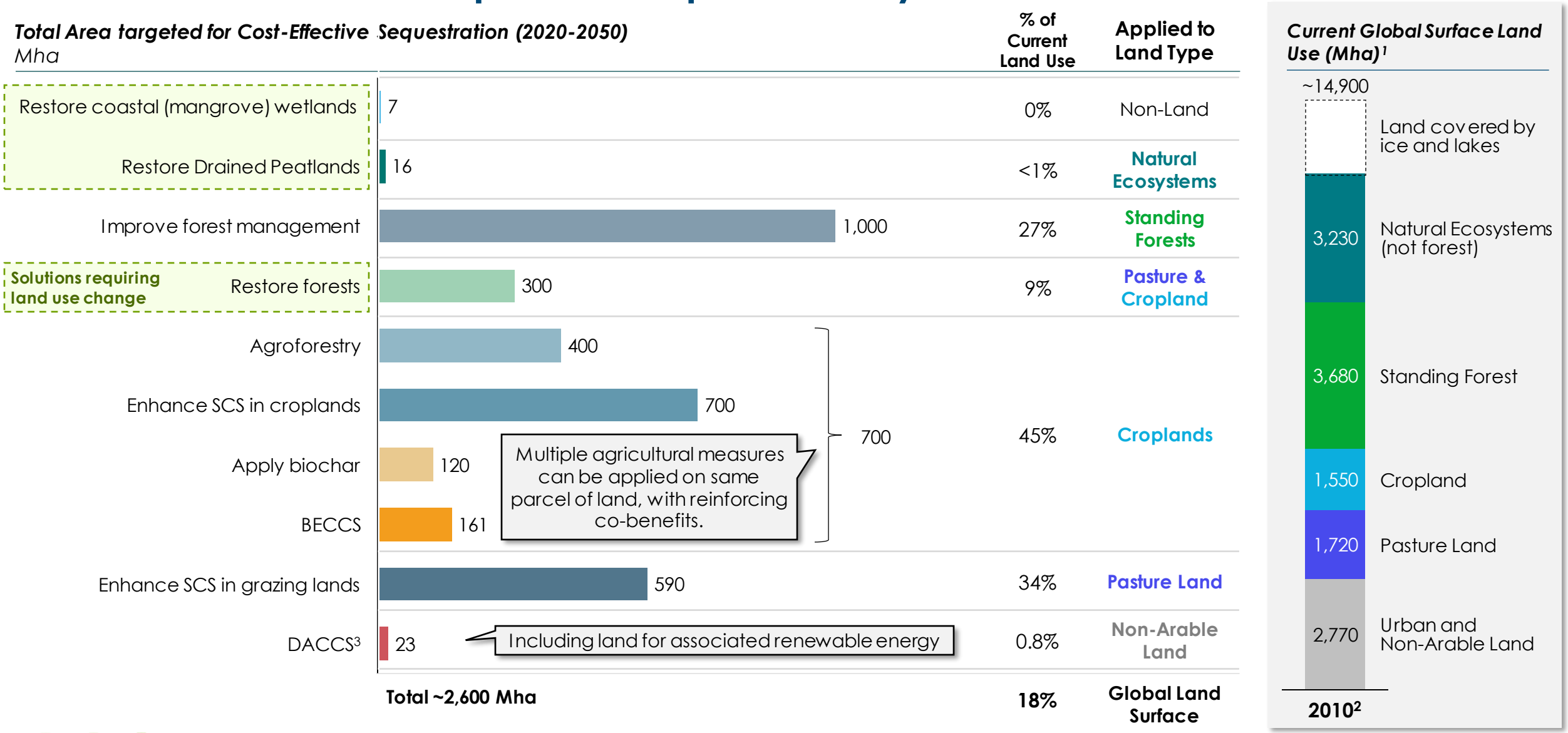


CDR needs to scale: it is crucial to reduce carbon budget overshoot and get back to 1.5°C:

- Nature-based and hybrid solutions can scale quickly in the short term, together with…
- A range of hybrid and engineered, durable solutions in the mid-to-long term

Recent developments suggest a faster scale-up in removals than shown here is very unlikely

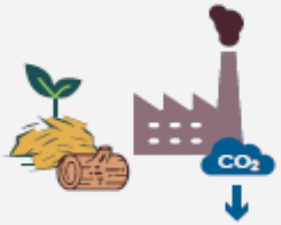
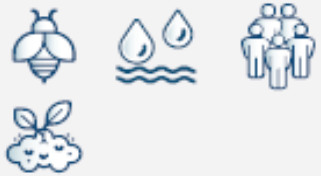
18% of global land surface would need to be engaged in CDR Solutions to achieve our feasible sequestration potential by 2050



Note: (1) Global surface area excludes oceans. Land covered by lakes and ice (e.g., Antarctica) not available. Minor difference in totals and percentages due to rounding; (2) Baseline data forecast from 2000. (3) DACCS estimate assumed for 2050.
Sources: ETC analysis interpreted from: Roe et al 2021; IIASA GLOBIOM / FOLU Growing Better 2019 Report; Ritchie et al. (2013), Land Use - OurWorldInData.org.

Risks of CDR solutions and how to manage them

Each CDR solution has risks and co-benefits to be considered

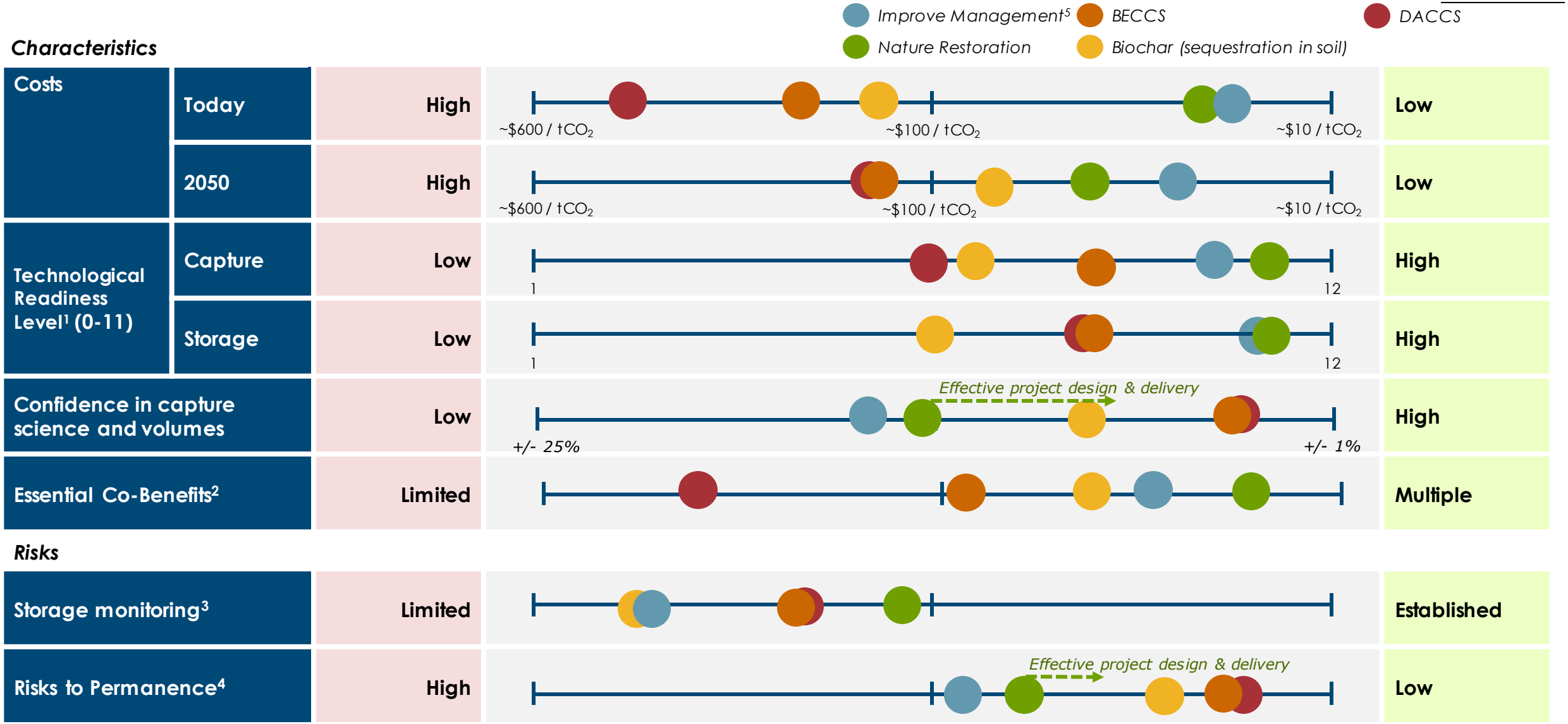
	NATURAL CLIMATE SOLUTIONS		HYBRID / BIOMASS WITH CARBON REMOVAL STORAGE		ENGINEERED SOLUTIONS
					
	'RESTORE'	'MANAGE'	BIOCHAR	BECCS	DACCS
RISKS	Permanence: carbon stored in biosphere is short-term	Permanence: improved practices are not maintained	Feedstock: biomass feedstock not sourced sustainably	Feedstock: biomass feedstock not sourced sustainably	Moral Hazard, Clean power: insufficiently available
CO-BENEFITS*					

CO-BENEFITS*

- Biodiversity
- Clean water
- Community economic return
- Soil health
- Fossil free energy generation
- Skilled jobs

A comparison of key characteristics and risks for selected CDR solutions

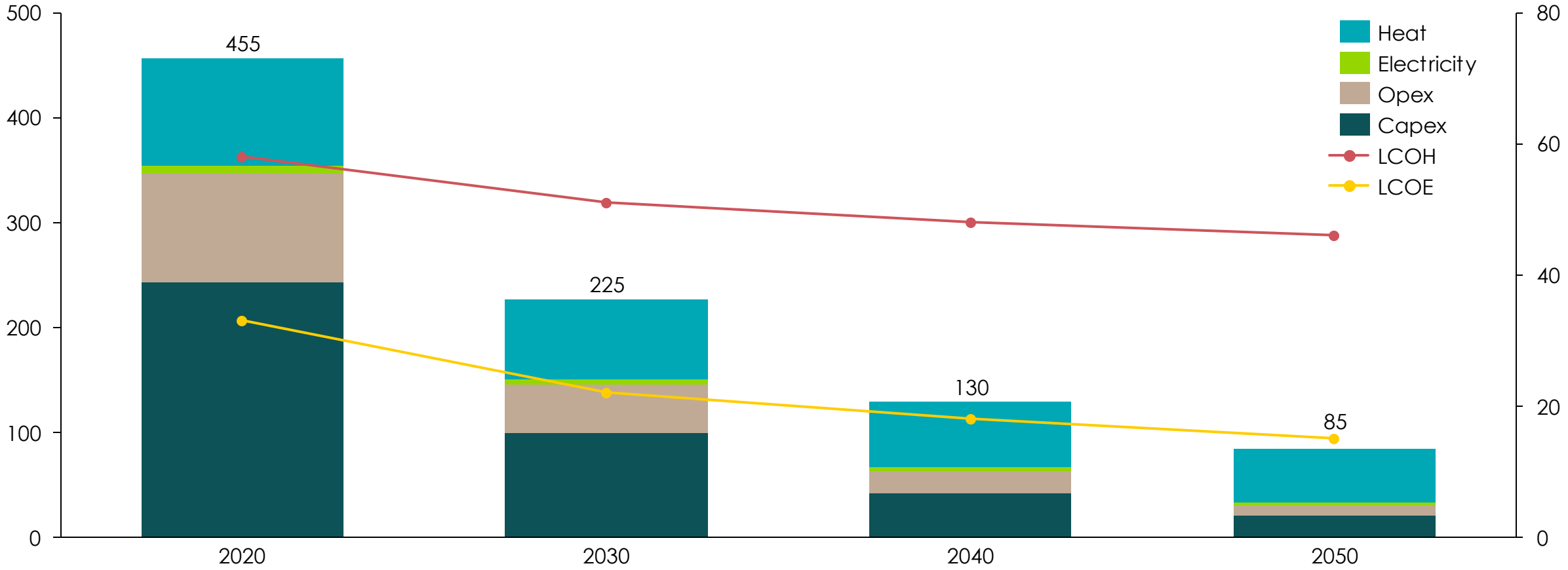
ILLUSTRATIVE



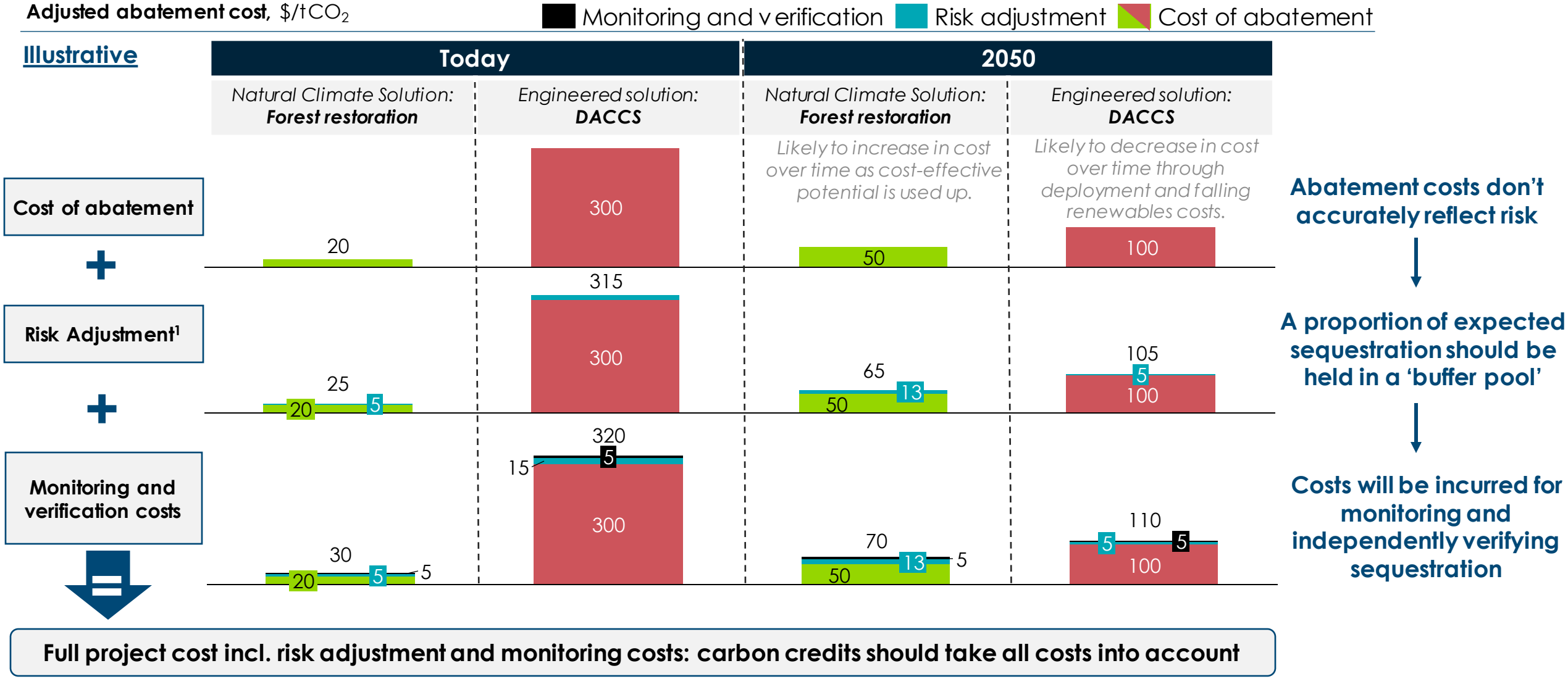
Expectations of the levelised cost of Direct Air Capture (DAC) to 2050 continues to fall; we have revised our view since the report was published

Estimated levelized cost of direct air capture (LHS); energy costs for advantaged regions (RHS)

$/tCO$_2$ (LHS); $/MWh (RHS)



Appraisal of the risks of different CDR options is likely to shift the relative costs towards engineered solutions over time

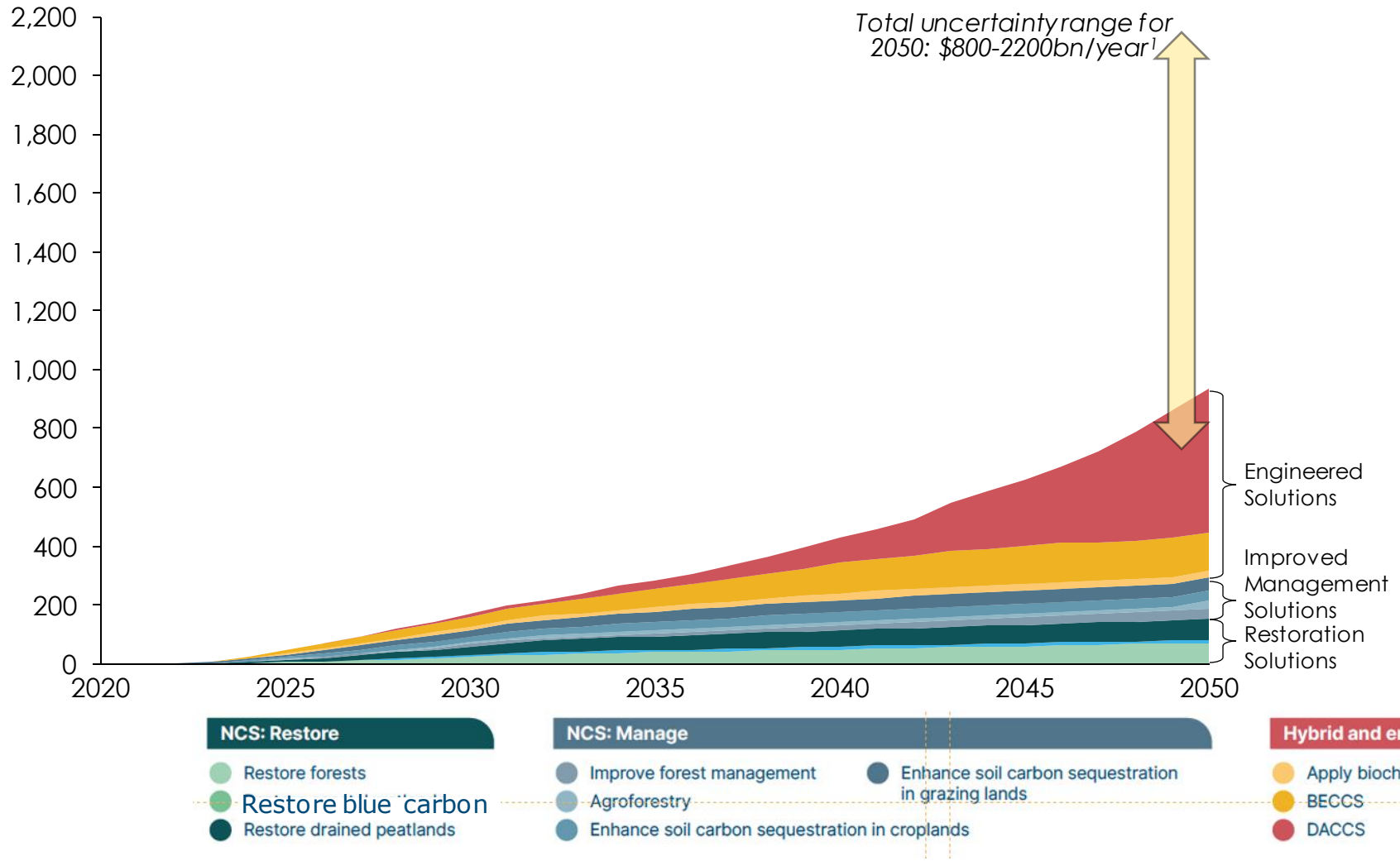


(1) Reflecting the risk of future CO2 sequestration materializing or being reversed

Funding removals

Total market for CDR could reach $200bn/year by 2030; $1000bn/year by 2050

Expected annual cost of CDR solutions
USD bn/year, global



	Cost estimate (2030)	Cost estimate (2050)	Cumulative potential (2020-2050)
Engineered and Hybrid/BiCRS solutions	$100-600/t CO_2	$100-300/t CO_2	45 Gt CO_2
NCS: Improved management solutions	$0-100/t CO_2	$0-100/t CO_2	60 Gt CO_2
NCS Restoration solutions	$5-100/t CO_2	$25-100/t CO_2	60 Gt CO_2
Total			160 Gt CO_2

To deliver the necessary CDR at scale we foresee a large funding gap by 2030

Current funding is insufficient

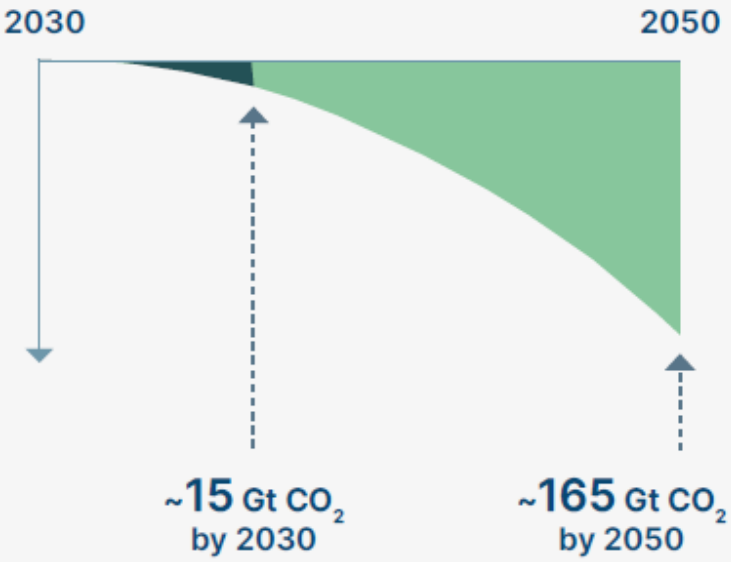
Today:

- Compliance markets cover around ~10% of global emissions, and largely exclude removals
- The Voluntary Carbon Market covers < 0.1% of emissions
- Other mechanisms (e.g., direct Govt. funding) are nascent, or not targeted towards removals

We need:

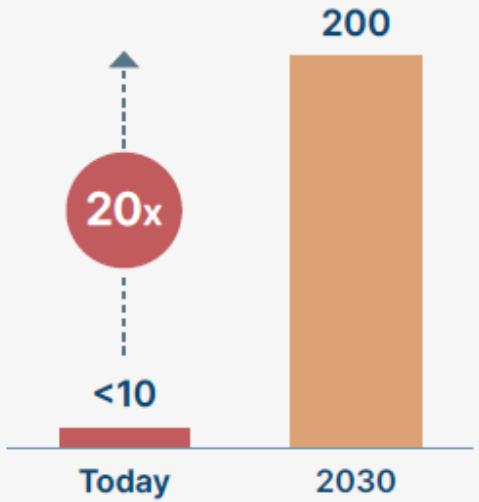
A MASSIVE SCALE UP OF CDR STARTING TODAY

Cumulative CDR



REQUIRING A 20X INCREASE IN FUNDING BY 2030

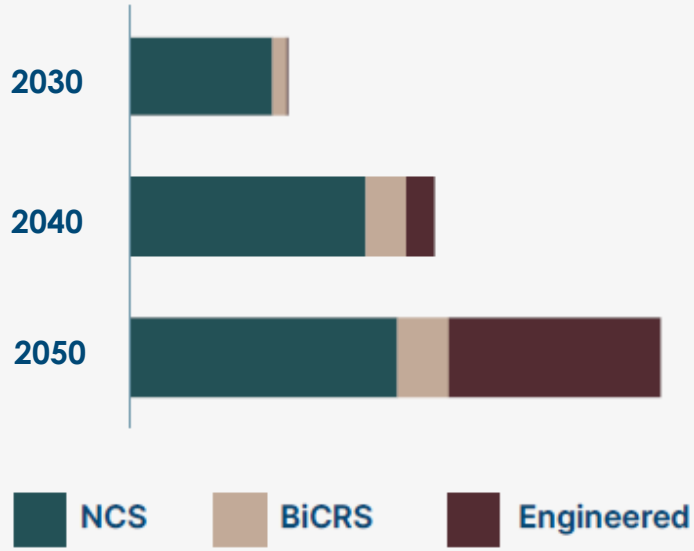
USD $bn/year



Approximately 1/3 of 2030 demand might be met by forecasted growth in Voluntary Carbon Markets

DELIVERING AN EVOLVING PORTFOLIO OF CDR SOLUTIONS

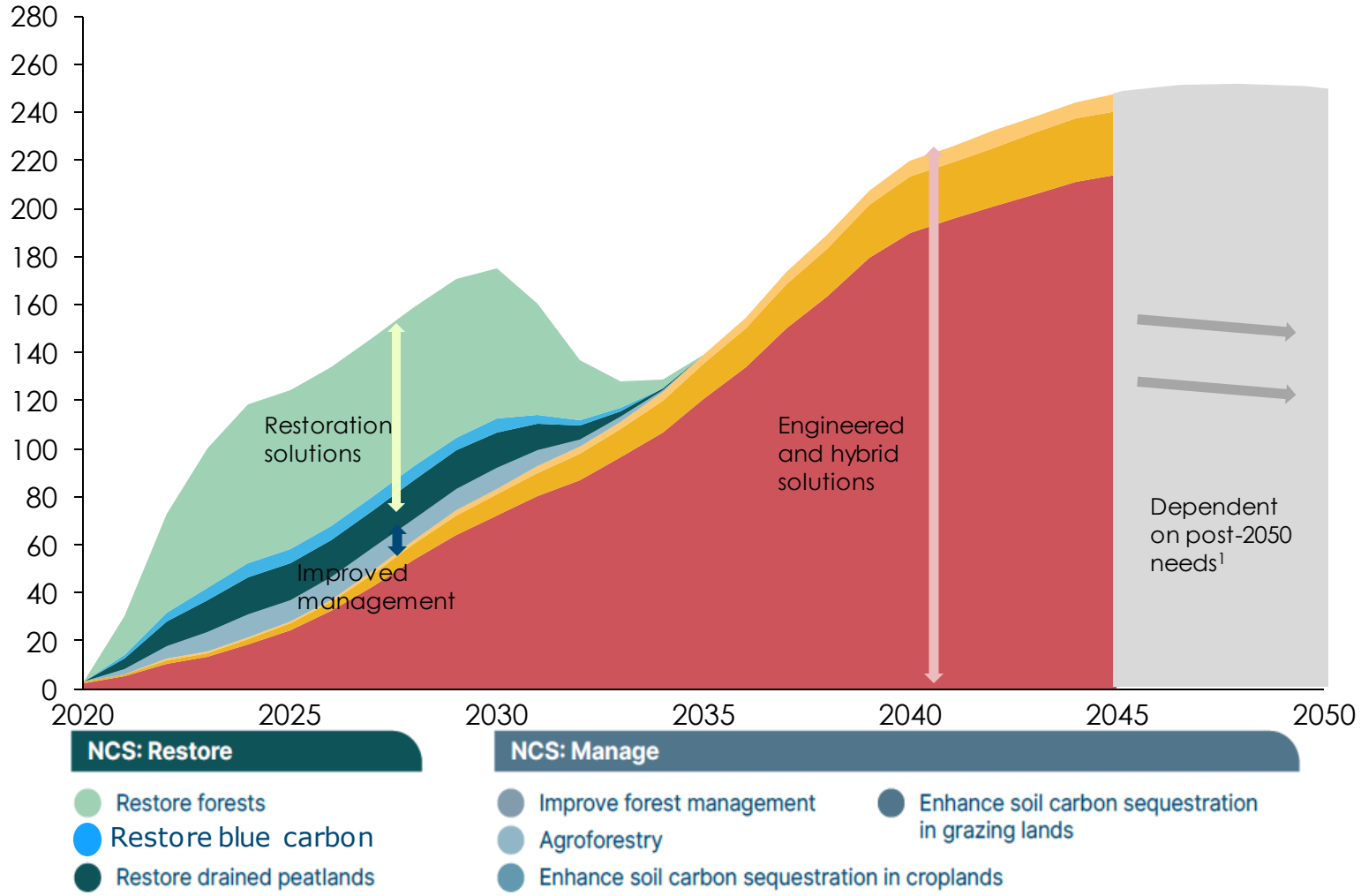
Gt CO_2/yr removed



Capital investment for CDR averages c. $100bn/year over next 3 decades; significant investment in nature restoration required in 2020s, alongside scaling DACCS

Expected annual capital investment for CDR solutions

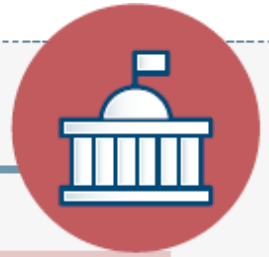
USD bn/year, global



	Annual average investment	Cumulative investment (2020-2050)
Engineered and Hybrid/BiCRS solutions	$100 bn	$3,000 bn
NCS: Improved management solutions	$7 bn	$200 bn
NCS: Restoration solutions	$25 bn	$700 bn
Total	~$130 bn	~$4,000 bn

Who should pay for removals?

GOVERNMENTS, VIA:



- Direct finance & purchase of removals
- Enhancing and creating compliance markets with a limited quantity of removals
- Reforming existing policy and subsidy regimes

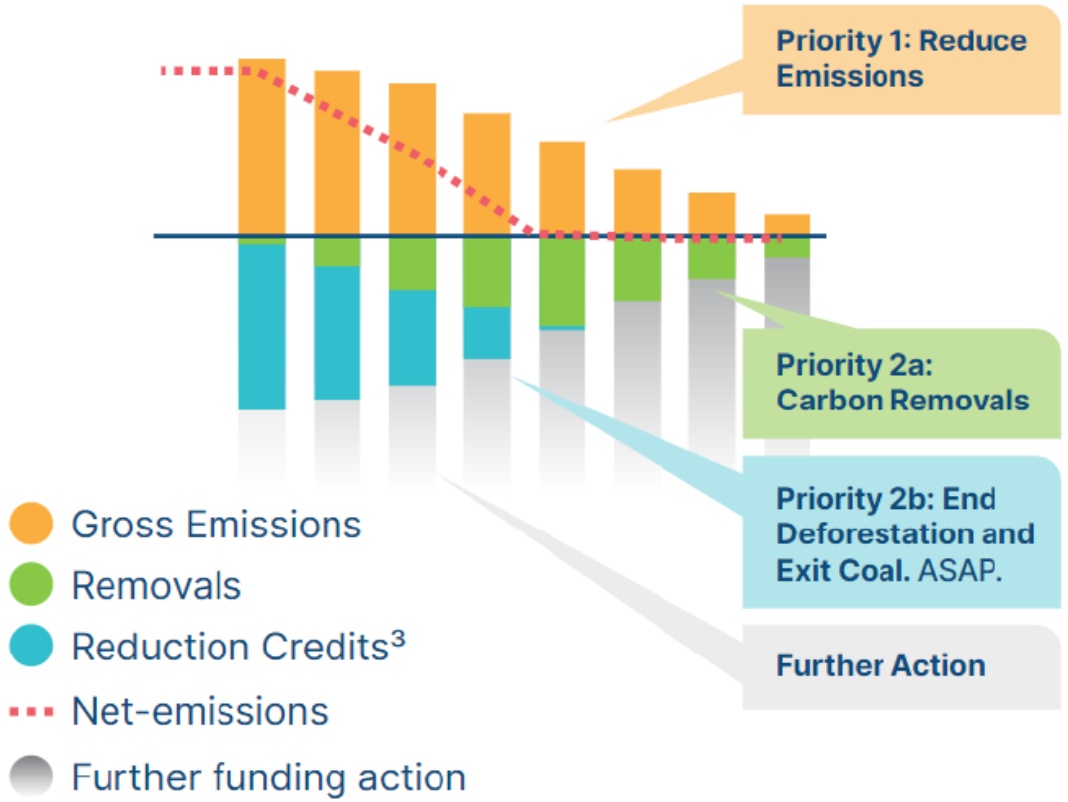
+

CORPORATES, VIA:

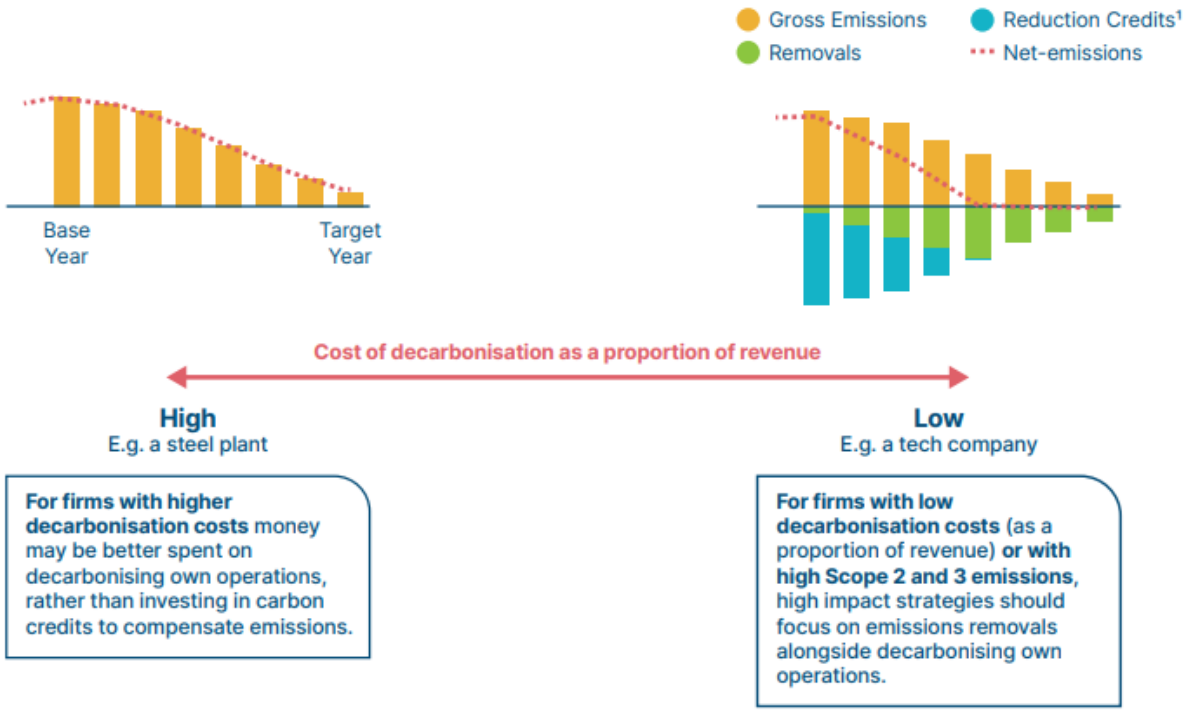
- Meeting obligations in compliance markets (e.g., EU ETS)
- Committing to net-zero decarbonisation pathways...
- ...neutralising any remaining emissions with carbon removal credits in the voluntary market.

Our report therefore offers a definition of 'high ambition' corporate action, recognizing strategies will need to differ by type of company

Illustration of a high ambition strategy towards Net Zero



Ambition should follow a continuum of action, based on cost as a proportion of revenue



Notes: (1) Overshoot of the carbon budget as defined by the IPCC (2021) and SYSTEMIQ Analysis for the ETC (2021). (2) Assuming time needed to scale up removals market in the 2020s, especially for BECCS and DACCS. Offsetting strategies should transition towards removals over time. (3) Likely to be restricted to time-limited credits for avoided deforestation and possible 'exit credits'. For the purposes of this illustration reduction credits don't contribute to net emissions.

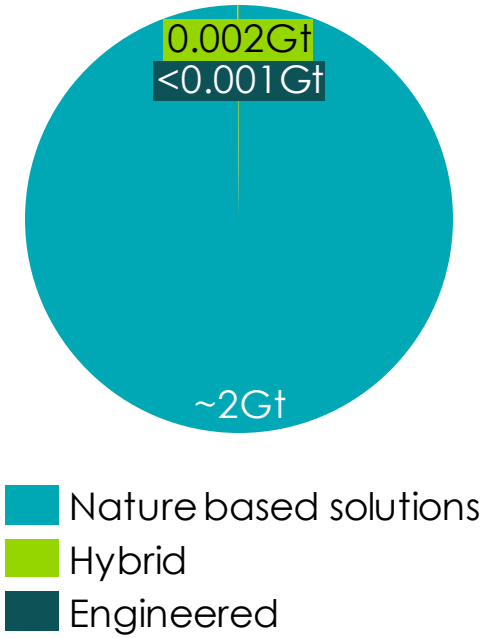
Recent developments

Removals currently account for a tiny share of voluntary carbon market credits; within this, nature-based removals entirely dominate

1

Only a tiny fraction of CDR today is hybrid / engineered methods

Current levels of CDR by type
GtCO2 / yr

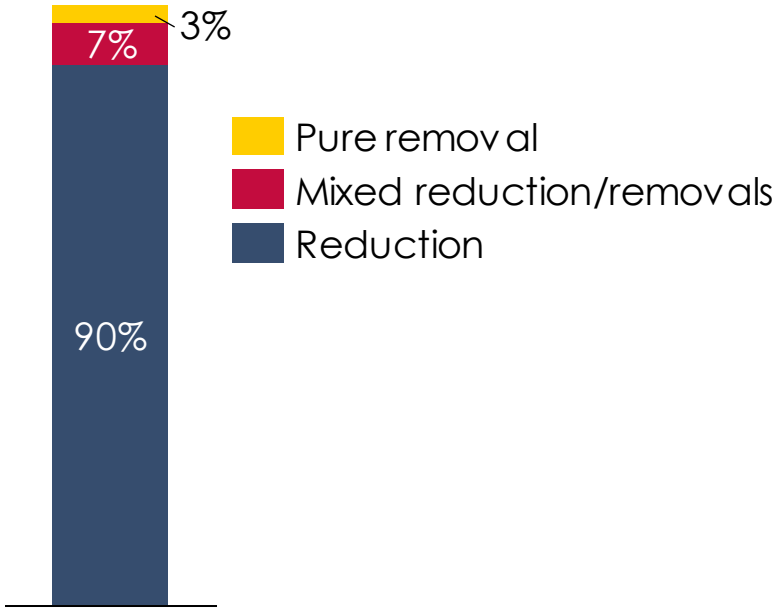


Source: University of Oxford's Smith School of Enterprise and the Environment (2023), *The State of Carbon Dioxide Removal*

2

Removals account for just 3% of voluntary carbon market credits

Voluntary carbon market credits by type
% of VCM credits (2022-H1 2023)

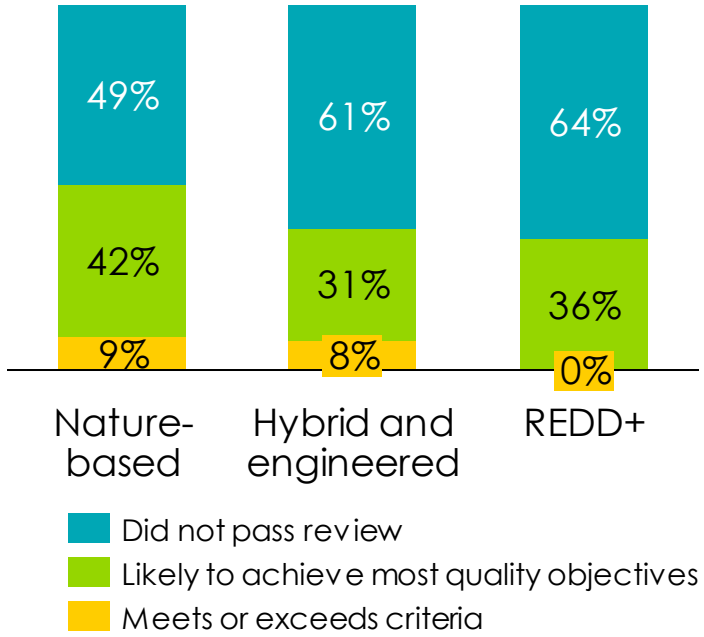


Source: Carbon Direct (2023), *State of the Voluntary Carbon Market*

3

Concerns over the quality of carbon credits is leading to greater scrutiny

Assessment of VCM credit quality
% of VCM credits



Source: Carbon Direct (2023), *State of the Voluntary Carbon Market*

The VCM consists of a stagnating emissions reduction and avoidance market, and an emerging quality-orientated removals market

4

Scrutiny over quality is leading to stagnation for reduction credits

- Quality concerns, reputational backlash and uncertainty have led to both a fall in demand and supply of credits – resulting in a fall in prices
- Key issues are concerns over permanence and a lack of price transparency
- REDD+ credits saw the biggest fall in demand, 40% between 2021-22

Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows

5

Positive outlook for growth in removals credits

- 2021 through Q3 2023, removals credits have increased fivefold – but much of this is forward purchasing
- Reflects growth in global commitments
- Market is growing quickly, but driven by a small set of motivated buyers – Microsoft and Airbus represent over 80% of high-durability removal credits 2022-23

6

But long-term outlook for the VCM remains strong

- BNEF expect value of VCM to increase from $2bn today to:
  - $15-50bn by 2030
  - $200-500 by 2050
- Need for improved standards
- Energy Transition Accelerator, proposed by John Kerry at COP27, to use funding by corporates via VCM for critical climate funding (e.g., to accelerate coal phase out)

Sources: BNEF (2023), *Long-Term Carbon Offsets Outlook;* Carbon Direct (2023), *State of the Voluntary Carbon Market.*

Actions for the 2020s

2030 Targets for Carbon Dioxide Removal

By 2030 we aim for:

CDR per year

Funded by :

$200 bn/yr for CDR

NATURAL CLIMATE SOLUTIONS

'RESTORE'

1.6 Gt CO_2 per year

300 Mha
marginal degraded land (tropics) planted

7 Mha
of mangroves restored

13 Mha
of peatland recovered

MANAGE

1.6 Gt CO_2 per year

500 Mha
(~12-15 %) of forest under improved management

400 Mha
(12 %) of cultivated land under improved management

HYBRID / BIOMASS WITH CARBON REMOVAL STORAGE

BIOCHAR

0.1 Gt CO_2 per year

2-5 EJ
of sustainable crop residue biomass

40 Mha
of biochar applied to farmland

BECCS

0.2 Gt CO_2 per year

~4 EJ
of sustainable biomass from residues and dedicated energy crops

~170
BECCS 1 $MtCO_2$ /yr scale facilities

ENGINEERED SOLUTIONS

DACCS

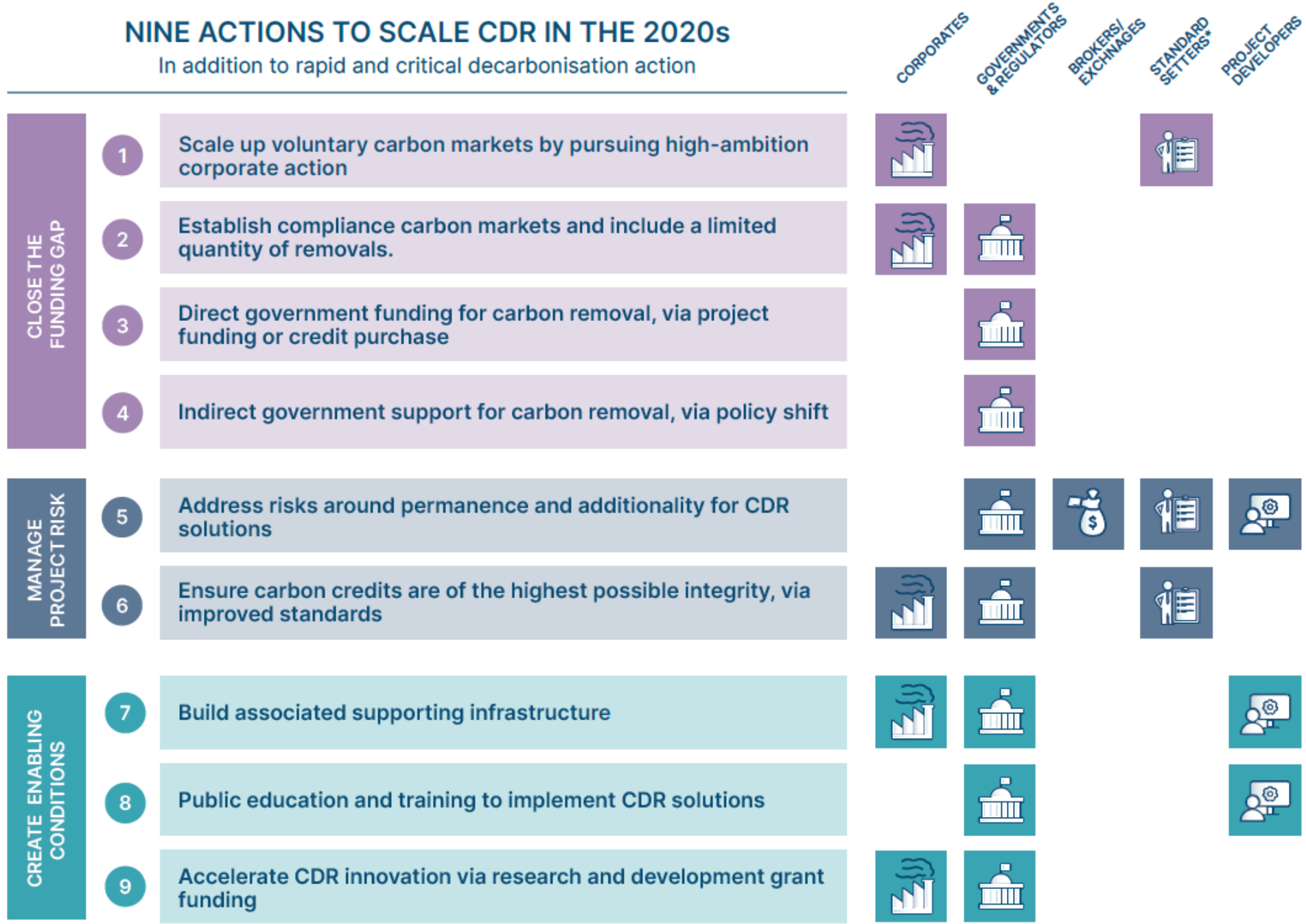
0.1 Gt CO_2 per year

235 TWh
Of clean power, <10% of 2050 supply

~80
DACCS facilities

NINE ACTIONS TO SCALE CDR IN THE 2020s

In addition to rapid and critical decarbonisation action



** 'Standard Setters' include voluntary bodies setting standards for corporate action and credits, credit standard setters are often closely associated with brokers and exchanges*