

Evaluating Technologies for CO₂ Removal and Building a Robust Carbon Offset Strategy




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The
Deciding
Factor

The background of the slide is a photograph of an industrial facility, possibly a power plant or refinery, with several tall smokestacks emitting thick plumes of white smoke. The sky is a deep, dark red, suggesting a sunset or sunrise, or perhaps a stylized, high-contrast image. The overall scene is somewhat hazy and atmospheric. A large white circle is centered on the page, containing the main text.

Carbon dioxide removal (CDR) is **needed to limit global warming to 2 °C** or below, regardless of whether global emissions are net-zero or net-negative.

Agenda

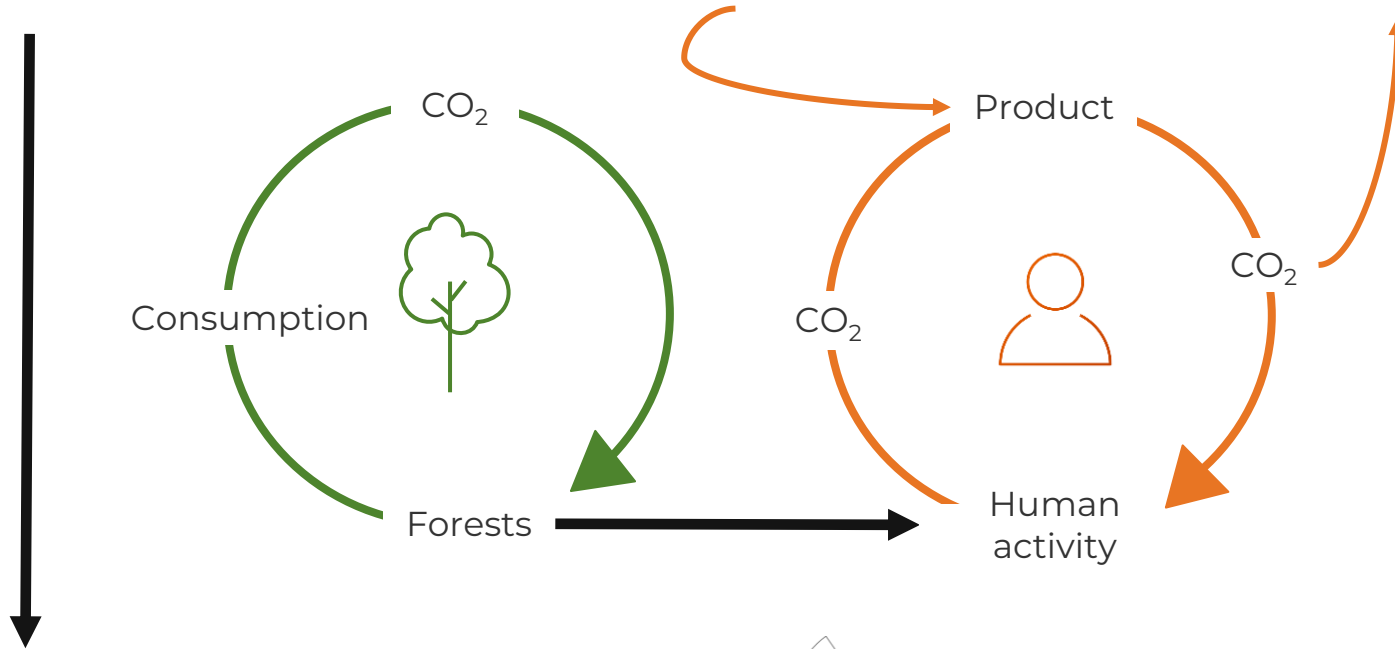
The Lux Carbon-Negative Framework

Costs and Risks: Your Offset Options and Where They're Heading

Outlook

The global carbon cycle requires three types of carbon-negative interventions

Atmospheric CO₂



Nonatmospheric CO₂



Refossilizing carbon

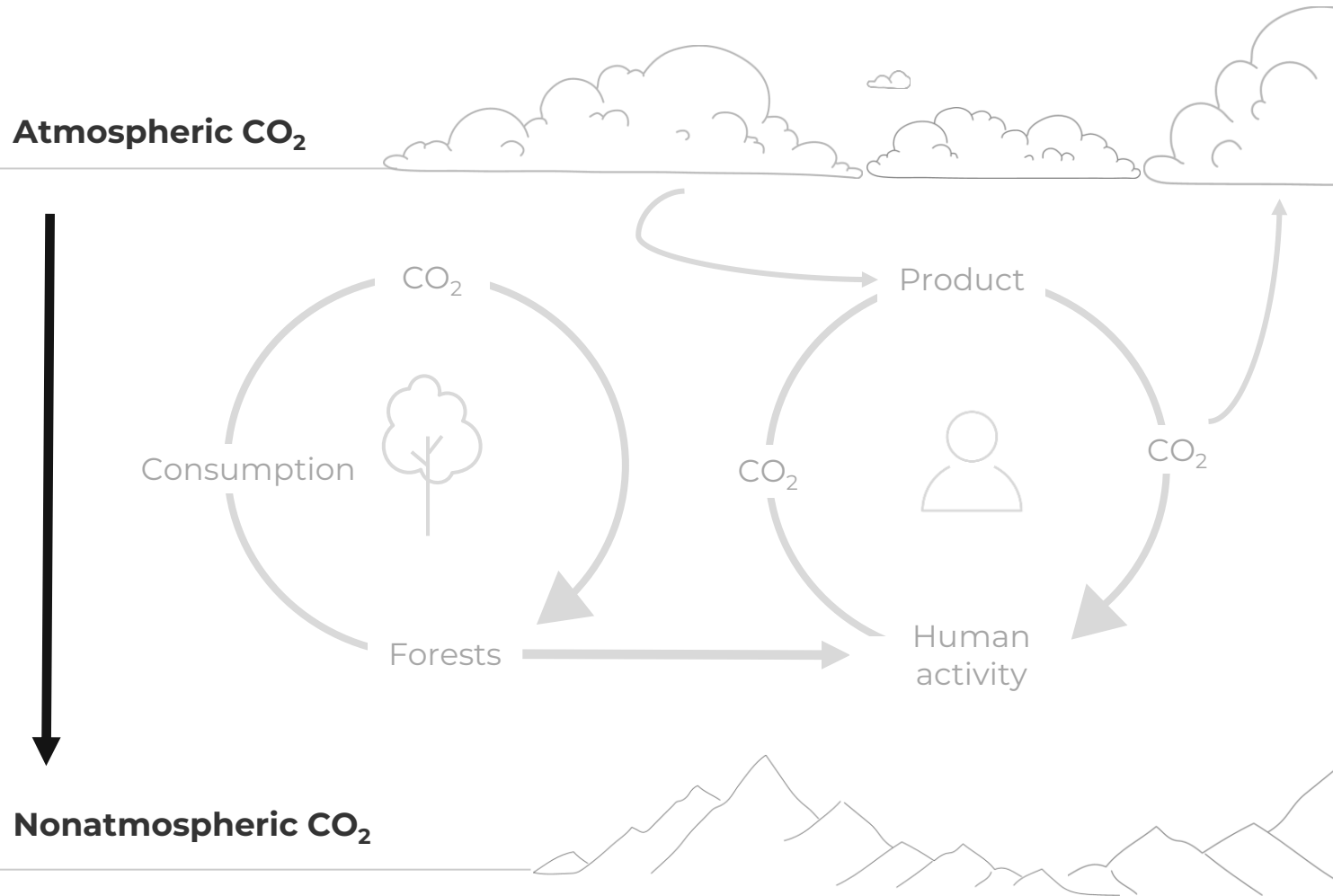


Complementing the natural carbon cycle



Augmenting the natural carbon cycle

The global carbon cycle requires three types of carbon-negative interventions (1/3)



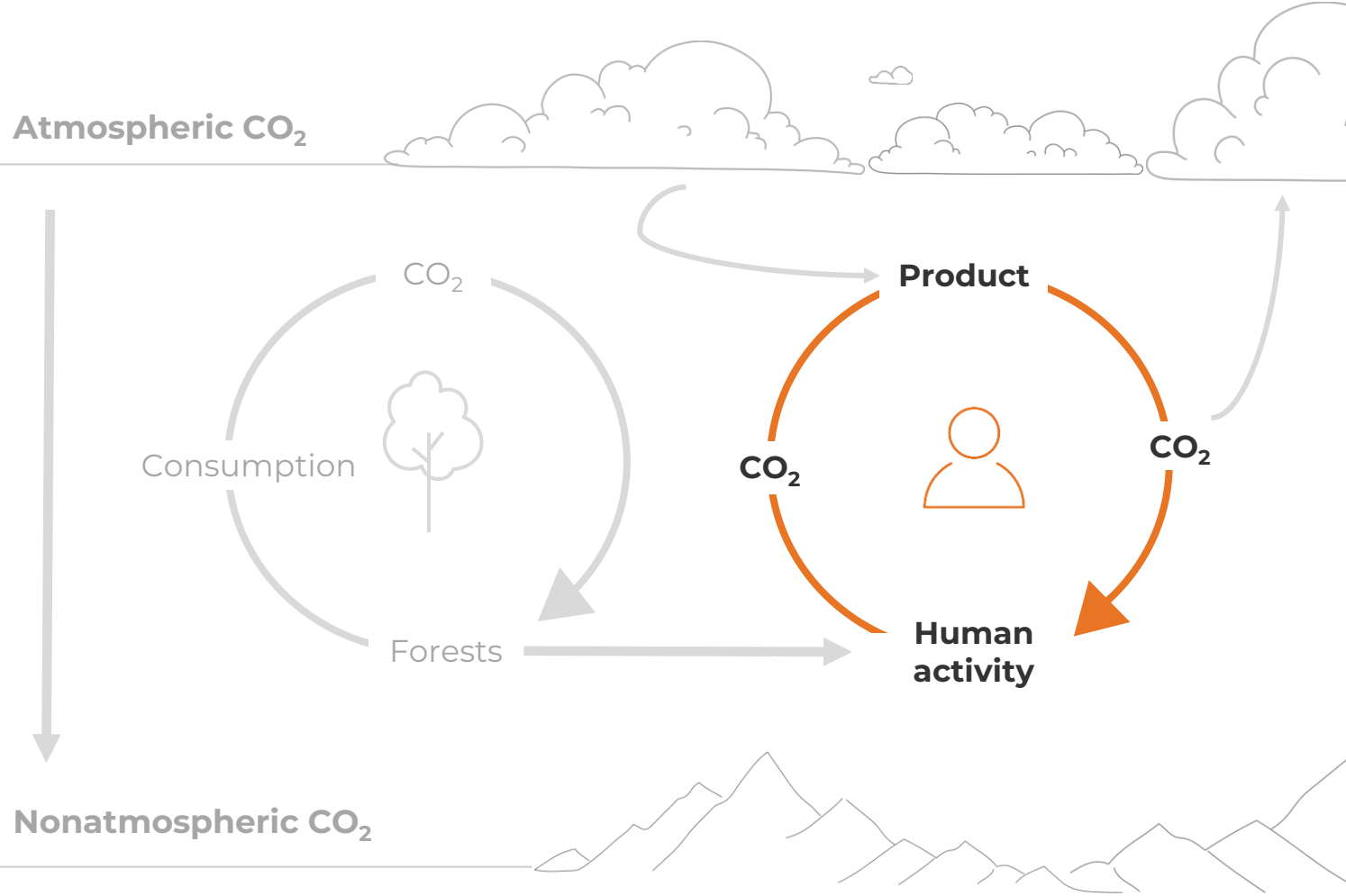
Refossilizing carbon

A corrective measure to remove excess atmospheric CO₂ that has already been emitted; the captured CO₂ needs to be refossilized so that it is permanently removed from circulation

Example technologies

- Direct air capture (DAC)
- CO₂ sequestration
- Biomass fixation
- Artificial upwelling

The global carbon cycle requires three types of carbon-negative interventions (2/3)



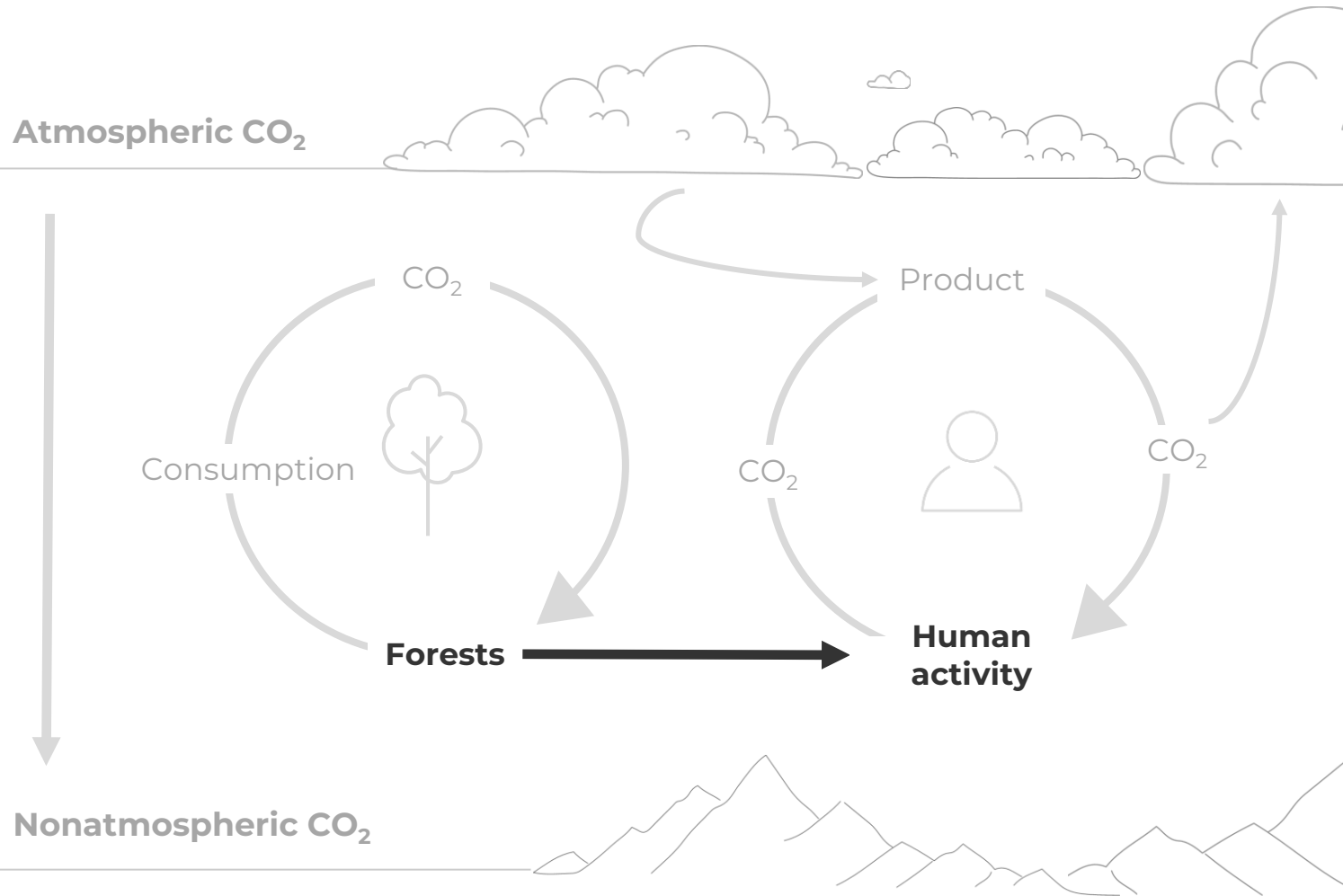
Complementing the natural carbon cycle

Acknowledging that there will be continued demand for carbon feedstock and that fossil fuels will not be easily replaced, carbon-negative technologies can address emissions from the industrial carbon cycle

Example technologies

- DAC
- CO₂ utilization
- Soil carbon management

The global carbon cycle requires three types of carbon-negative interventions (3/3)



Augmenting the natural carbon cycle

Boosting CO₂ circulation in the natural carbon cycle, and subsequently tapping into CO₂ stored in the natural carbon cycle for industrial applications

Example technologies

- Forestry
- Direct ocean capture (DOC)

A suite of carbon-negative technologies target specific use-cases and provide carbon offsets for corporate net-zero portfolios



Refossilizing carbon

Complementing the natural carbon cycle

Augmenting the natural carbon cycle

Direct air capture

Forestry

CO₂ sequestration

Soil carbon management

CO₂ utilization

Direct ocean capture




Bioenergy with CCS

Wetland restoration

Biomass fixation

Enhanced weathering

Artificial upwelling

-  *CCUS-based solution*
-  *Land-based solution*
-  *Ocean-based solution*

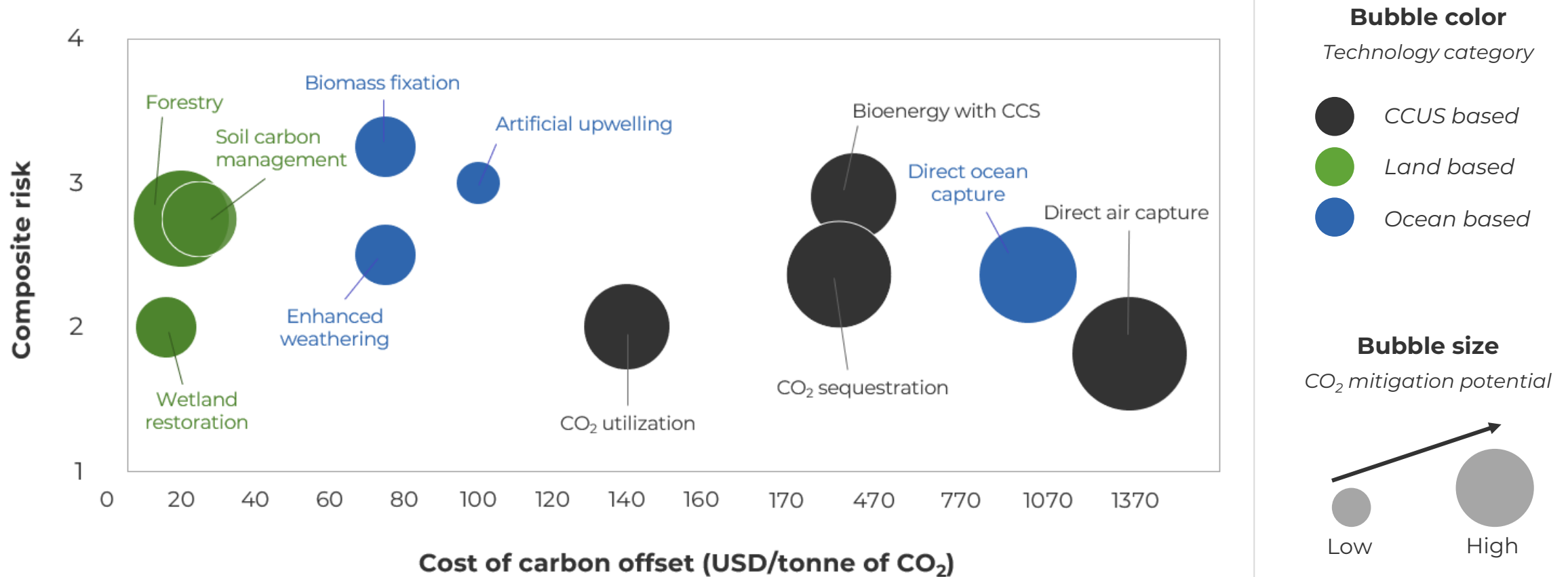
Agenda

The Lux Carbon-Negative Framework

Costs and Risks: Your Offset Options and Where They're Heading

Outlook

The Lux Carbon-Negative Framework helps clients find the optimal balance between affordability, risk, and potential of carbon credits



COMPOSITE RISK

1 CARBON RE-RELEASE



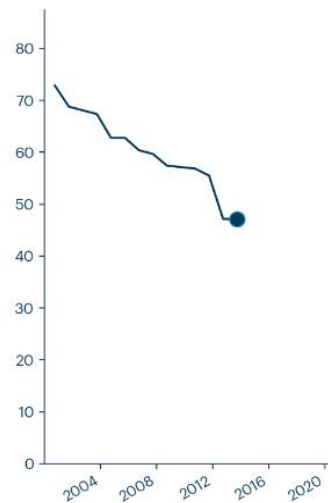
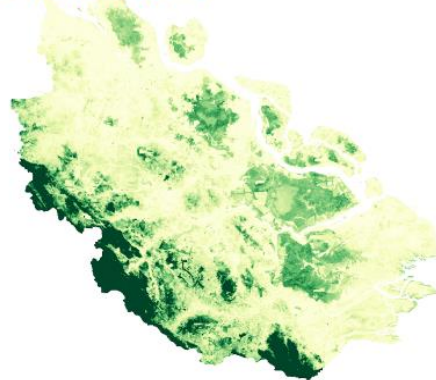
2 ADVANCING REGULATIONS

Zero emission vehicles: first 'Fit for 55' deal will end the sale of new CO2 emitting cars in Europe by 2035

Press release | 28 October 2022

3 IMPRECISE QUANTIFICATION

Riau
Carbon Stock (t/ha)



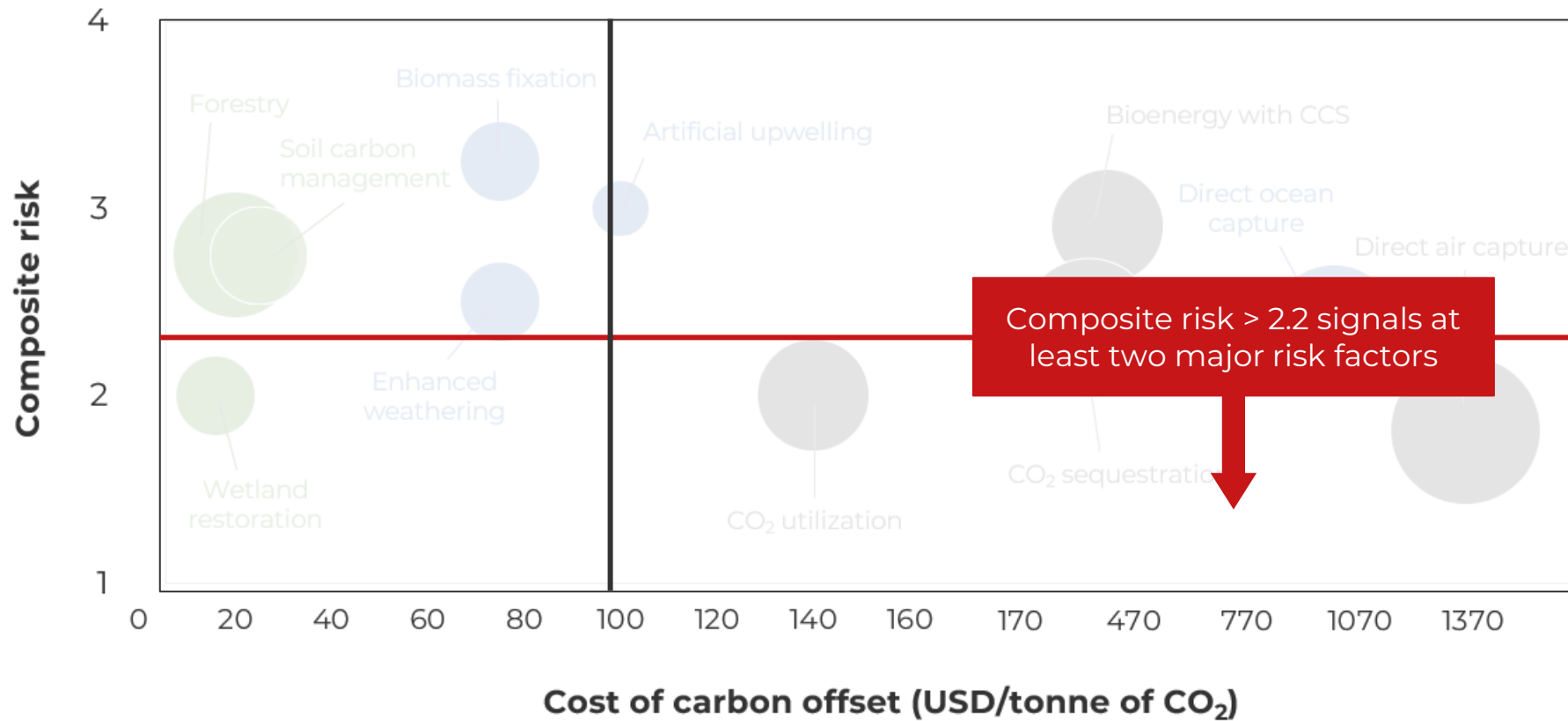
4 SOCIETAL BACKLASH



UN-convened investor group bans carbon credits pre-2030 for its members, instead urges direct emissions reduction

The Net Zero Asset Owner Alliance (NZAOA) has barred its members – about 84 organizations that cumulatively control about USD 11 trillion in assets – from counting carbon credits toward their emissions reduction targets before 2030. The decision stems from growing uncertainty around the quality of CO₂ removal through nature-based solutions like forestry and credits generated through avoided emissions.

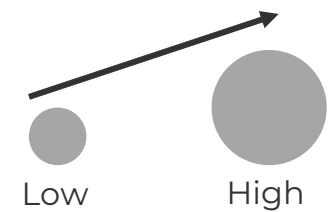
Risk reduction is paramount



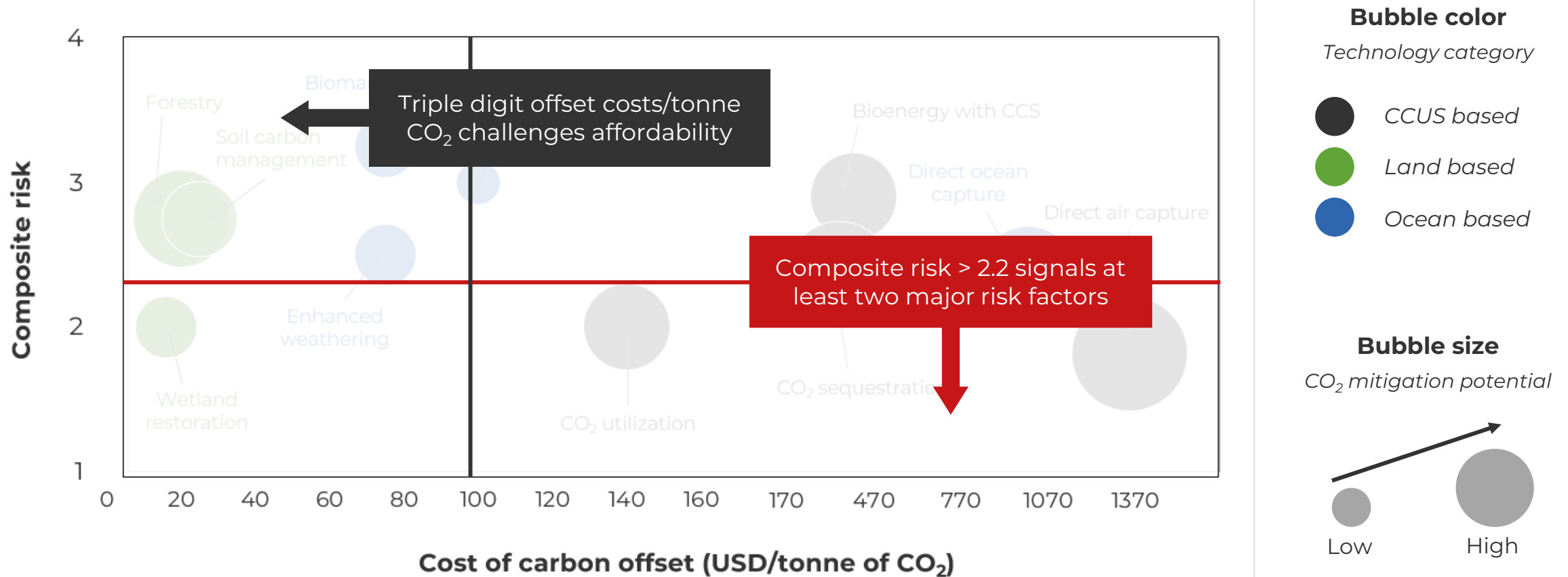
Bubble color
Technology category

- CCUS based
- Land based
- Ocean based

Bubble size
CO₂ mitigation potential



Cost reduction and risk reduction need to be parallel developments



The bubbles are not static, and budding activity is influencing their

New Pilots and Demonstrations

Impact on cost reduction



Impact on risk reduction



Technology Innovation

Impact on cost reduction



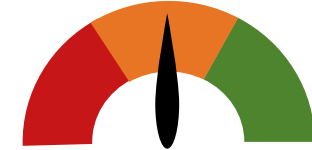
Impact on risk reduction



MRV and regulations

Impact on cost reduction

MEDIUM



Impact on risk reduction



MRV: Measurement, reporting, and verification

The bubbles are not static and budding activity is influencing their

New Pilots and Demonstrations

Impact on cost reduction

Technology Innovation

Impact on cost reduction

MRV and regulations

Impact on cost reduction

MEDIUM

Efforts in risk reduction are lacking, relative to efforts in cost reduction

Impact on risk reduction

LOW



Impact on risk reduction

MEDIUM



Impact on risk reduction

HIGH



A dark, industrial landscape with a large white circle containing text.

**CCUS-based
solutions**

A lush green forest with a large green circle containing text.

**Land-based
solutions**

A blue ocean with a large blue circle containing text.

**Ocean-based
solutions**

CCUS technologies have high momentum for CO₂ removal and show strongest potential in reducing cost and risk

New Pilots and Demonstrations	<ul style="list-style-type: none">• Booming capacity pipeline through the decade• CO₂ mineralization: 44.01 and ADNOC partnership• CO₂ sequestration of bio-oil: Charm expects 37% cost reduction by 2030
Technology Innovation	<ul style="list-style-type: none">• New market entrants• Testing of novel carbon capture technologies for BECCS
MRV and Regulations	<ul style="list-style-type: none">• DAC + storage methodology verified• CO₂ mineralization methodology verified• Growing regulatory support and financial incentives

CCUS: Case Study

New Pilots and Demonstrations

Technology Innovation

MRV and Regulations



CO₂ mineralization is approaching low-cost, low-risk territory in the CO₂ removal ecosystem

- CarbonCure sequesters CO₂ in a wet concrete mix.
- CarbonCure's methodology is validated and listed on Verra.
- CarbonCure's public registry indicates that it has delivered over 70 ktonne of carbon credits based on its approved methodology.

Lux Take

CO₂ mineralization is advancing in both scale of deployments and risk mitigation. Carbon credits, though not yet available, will be more modest than other engineered solutions. **Pursue opportunities.**

CCUS: Case Study

New Pilots and Demonstrations

Technology Innovation

MRV and Regulations



The success of bioenergy with CCS remains susceptible to regulatory incentives

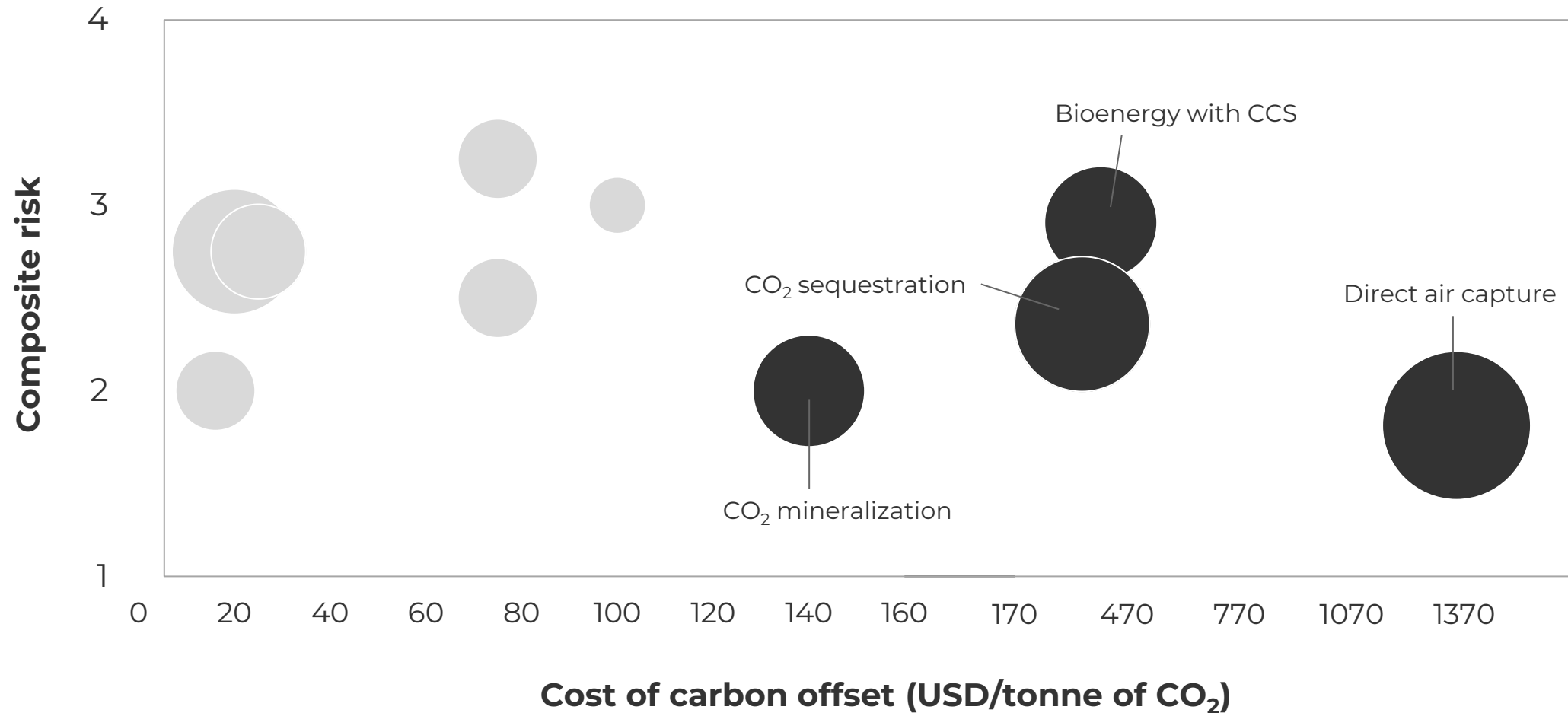
- Drax has begun setting up BECCS pilots with the goal of becoming carbon negative by 2030.
- In 2022, Drax halted developments on a USD 2 billion BECCS project, citing “lack of clarity on U.K. government support.”
- In 2023, the U.K. government confirmed support.



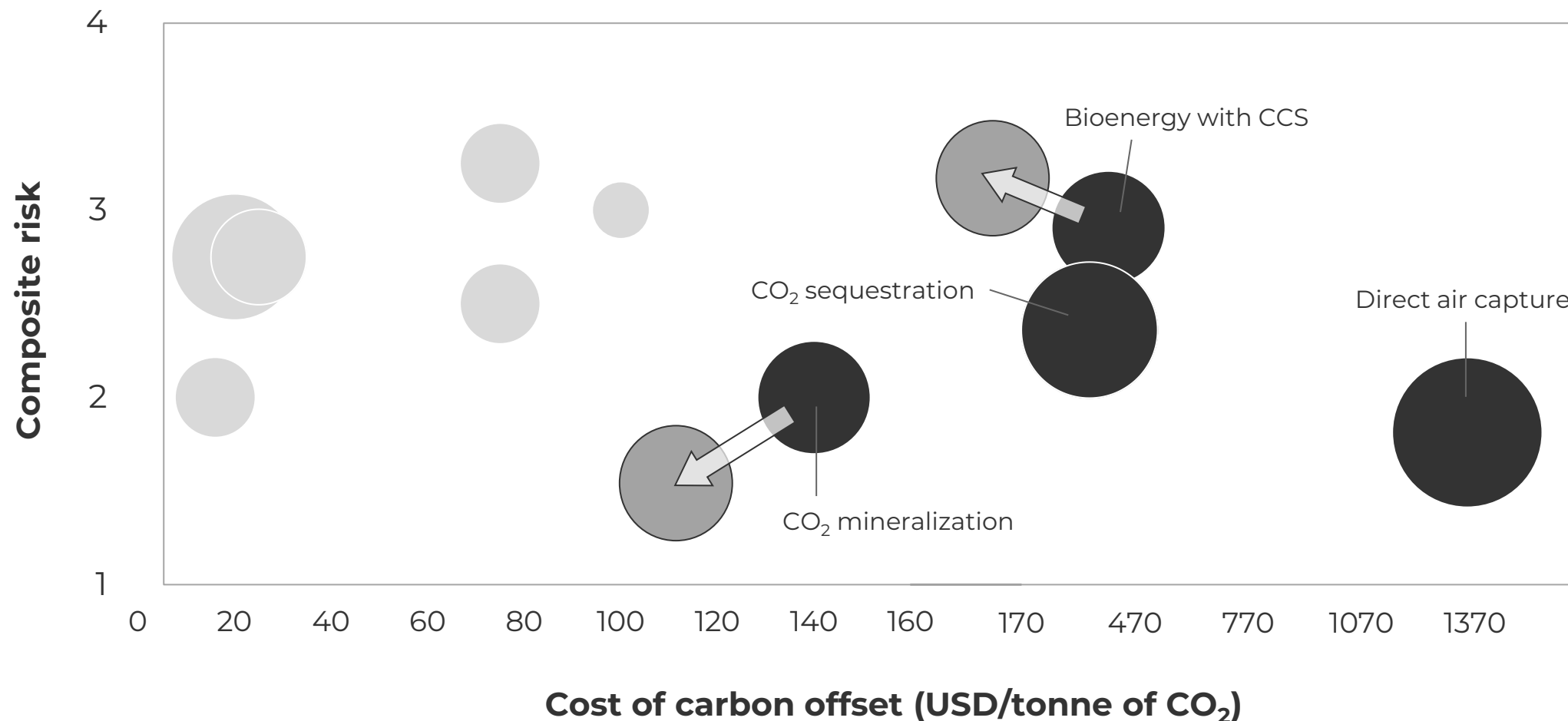
Lux Take

Oscillating support and skepticism of BECCS keeps it at a higher risk than other CCUS options for CO₂ removal. In the long run, **BECCS will rely heavily on regulatory incentives and reduced cost of carbon capture.**

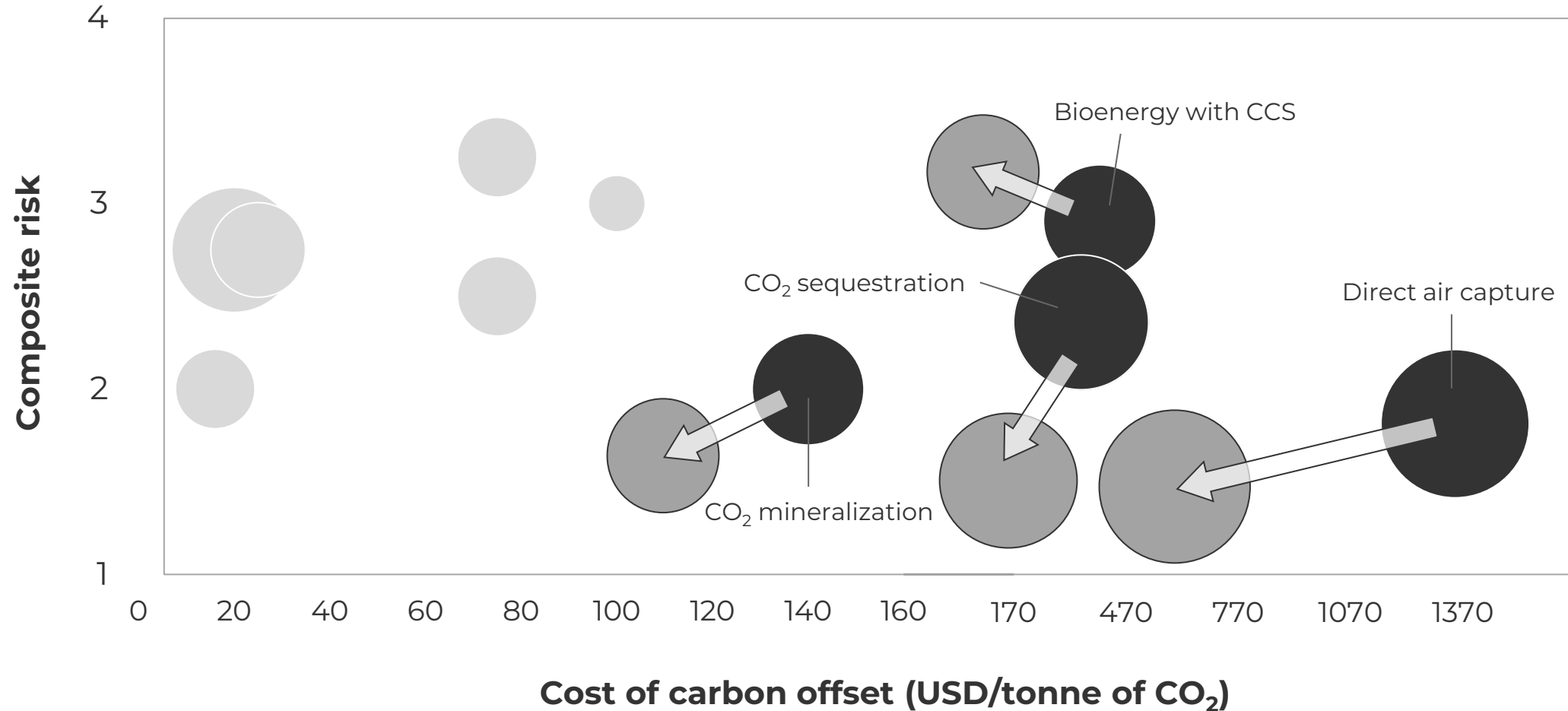
What shift can you expect from the CCUS technologies given recent developments?



CO₂ mineralization is fast approaching the favorable — low-cost and low-risk — region of the graph



CCUS solutions offer low-risk carbon credits, but will largely remain expensive because of their engineered attribute





**CCUS-based
solutions**

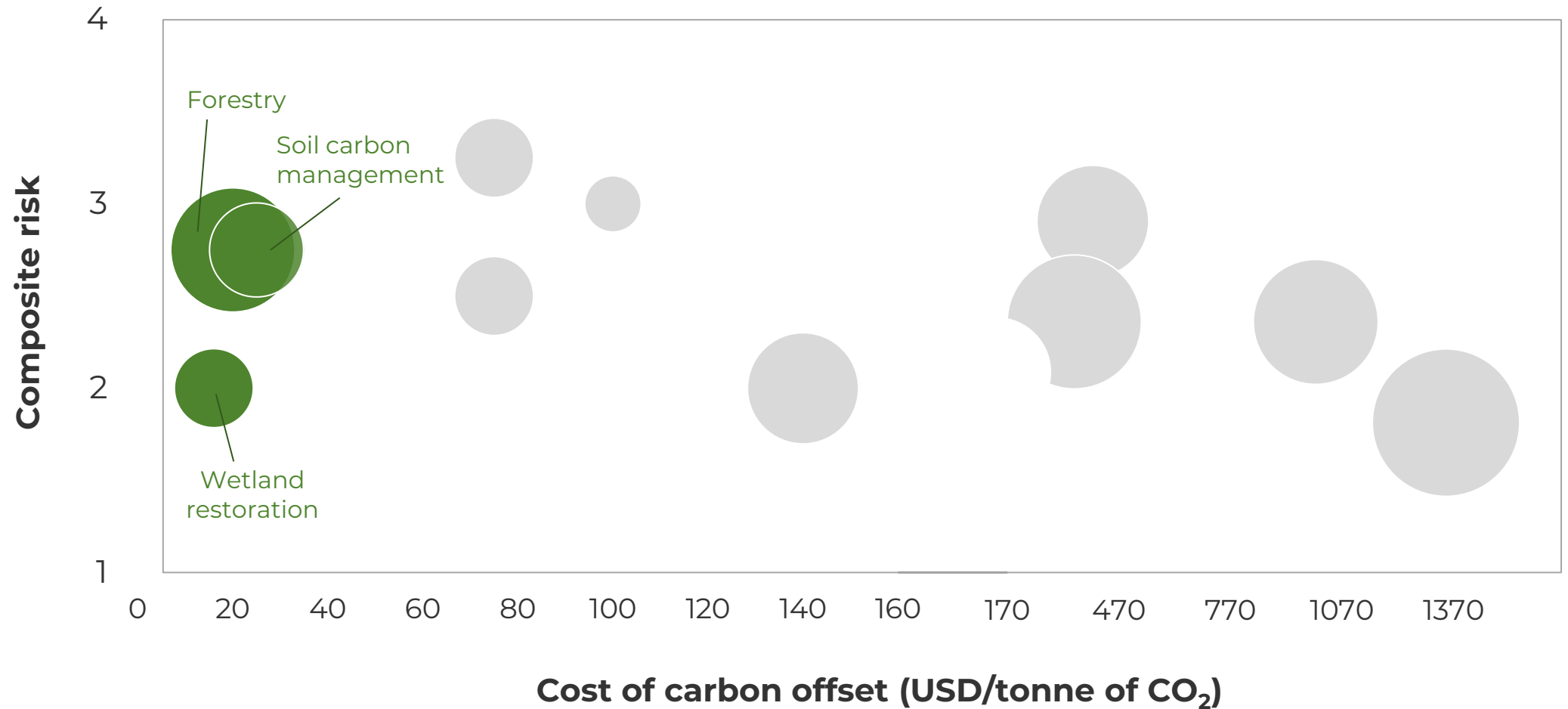


**Land-based
solutions**



**Ocean-based
solutions**

Forestry does not require cost reductions, but carries high risk with little scope for reduction



Forestry: Case Study

New Pilots and Demonstrations

Technology Innovation

MRV and Regulations



High-risk forestry credits, with low-risk mitigation, can delay CO₂ removal targets

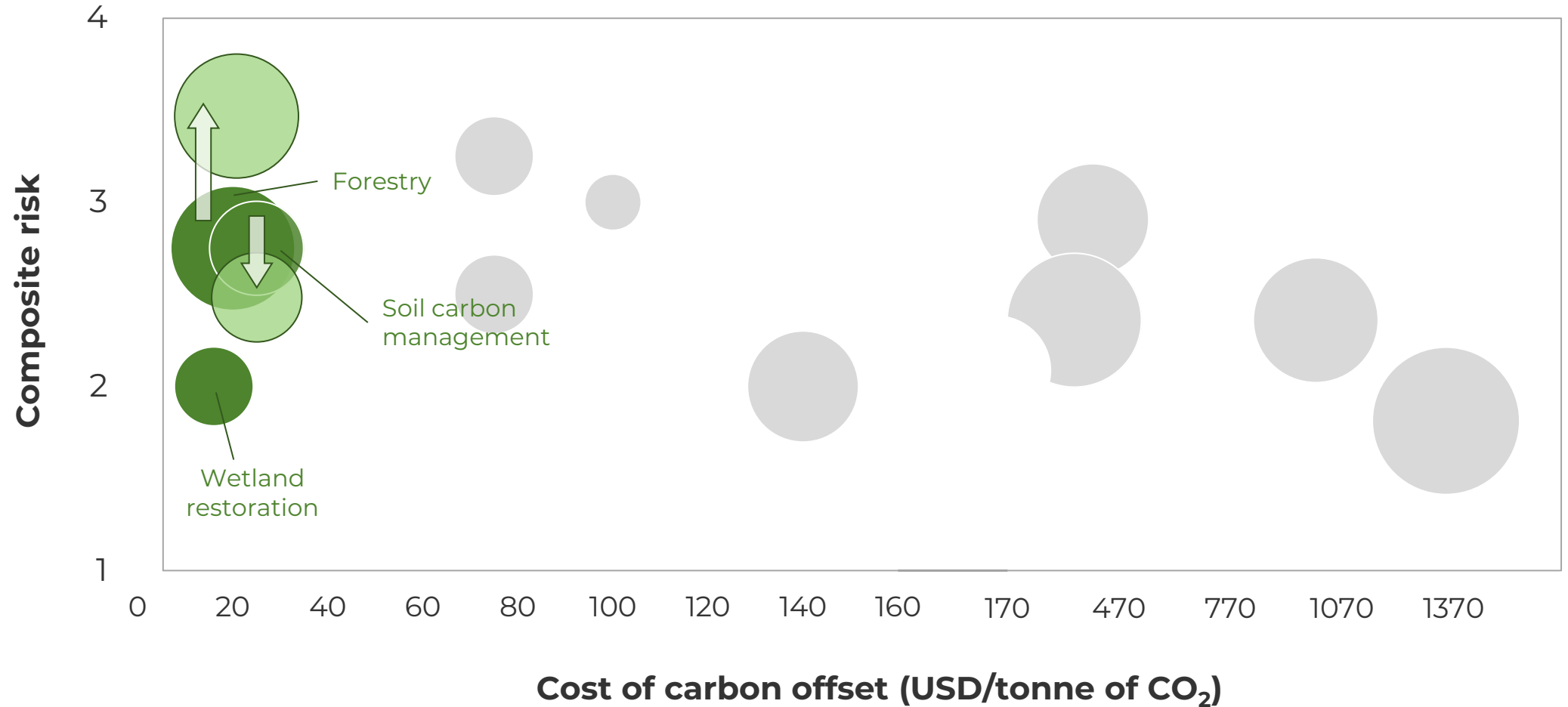
- Verra's forestry projects account for 95 million carbon credits. In 2023, an independent study concluded that only 6% of the credits were real reductions in emissions.
- Verra suspended a Kenyan project as it continues investigations — accusations against the project include overcounting, unaccounted deforestation, and disruption of indigenous herders.
- Verra has published drafts of an updated methodology, slated to come into force in 2025.



Lux Take

The risks around forestry and nature-based solutions are growing. Expect escalating policing and scrutiny and **proceed with caution.**

Forestry and other land-based solutions will not provide high-quality carbon credits in bulk





**CCUS-based
solutions**



**Land-based
solutions**



**Ocean-based
solutions**

Ocean-based solutions are far from commercial, but have picked up high momentum in a short timeline

New Pilots and Demonstrations	<ul style="list-style-type: none">• First pilots and open-ocean trials announced• Regional expansion: Beyond the U.S., recent activity shows traction in Singapore, Portugal, and the Middle East• Support from industrial investors
Technology Innovation	<ul style="list-style-type: none">• Unique biproducts: High-purity carbonates, hydrogen, hydrochloric acid• Integration with agricultural practices
MRV and Regulations	<ul style="list-style-type: none">• Public MRVs: For stakeholder input and to catch the eye of regulators• Research partnerships: Studying ecosystem impact• Verra sets up an MRV body for enhanced weathering

DOC: Case Study

New Pilots and Demonstrations

Technology Innovation

MRV and Regulations

Equatic

CAPTURE6

 **CAPTURA**

Three major DOC startups announced planned pilots in 2023

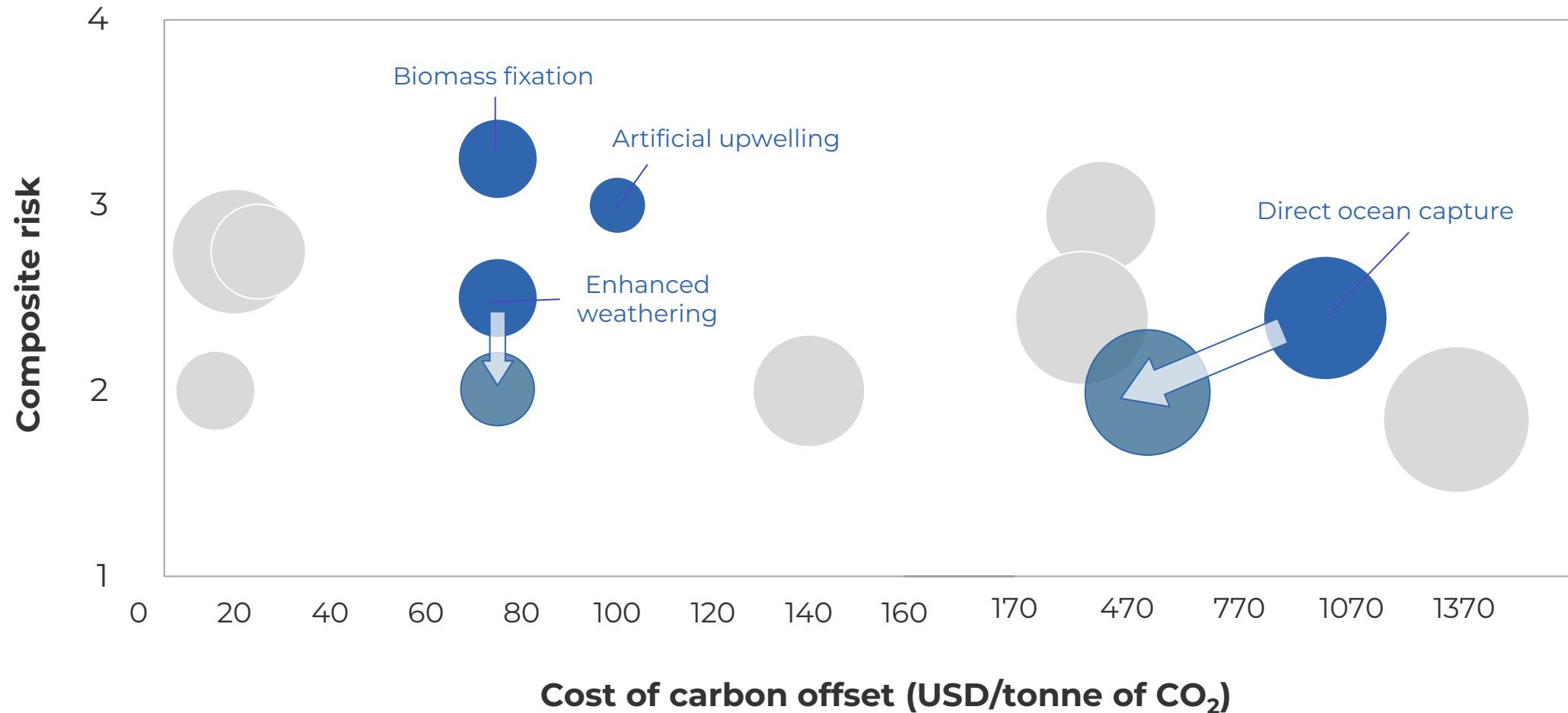
- **Captura:** Caltech spinout to set up a 100-tonne/y pilot
- **Capture6:** Integrated with Palmdale Water District's seawater treatment
- **Equatic:** UCLA spinout to deliver 62 ktonne of credits to Boeing



Lux Take

DOC developers will increasingly retrofit projects with existing seawater processing infrastructure to reduce costs. With a sparse commercial landscape, clients should monitor progress of **open ocean trials**.

Direct ocean capture, as an engineered solution, shows maximum potential for risk reduction among ocean-based solutions



Outlook

1 Carbon credits can help buy time to reduce direct emissions

2 Focus on minimizing risks in your carbon credit strategy — cost reduction alone will not suffice

3 The price of offsetting will be hefty; engage early to book supply

Thank you

A link of the webinar recording will be emailed within 24–48 hours.

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