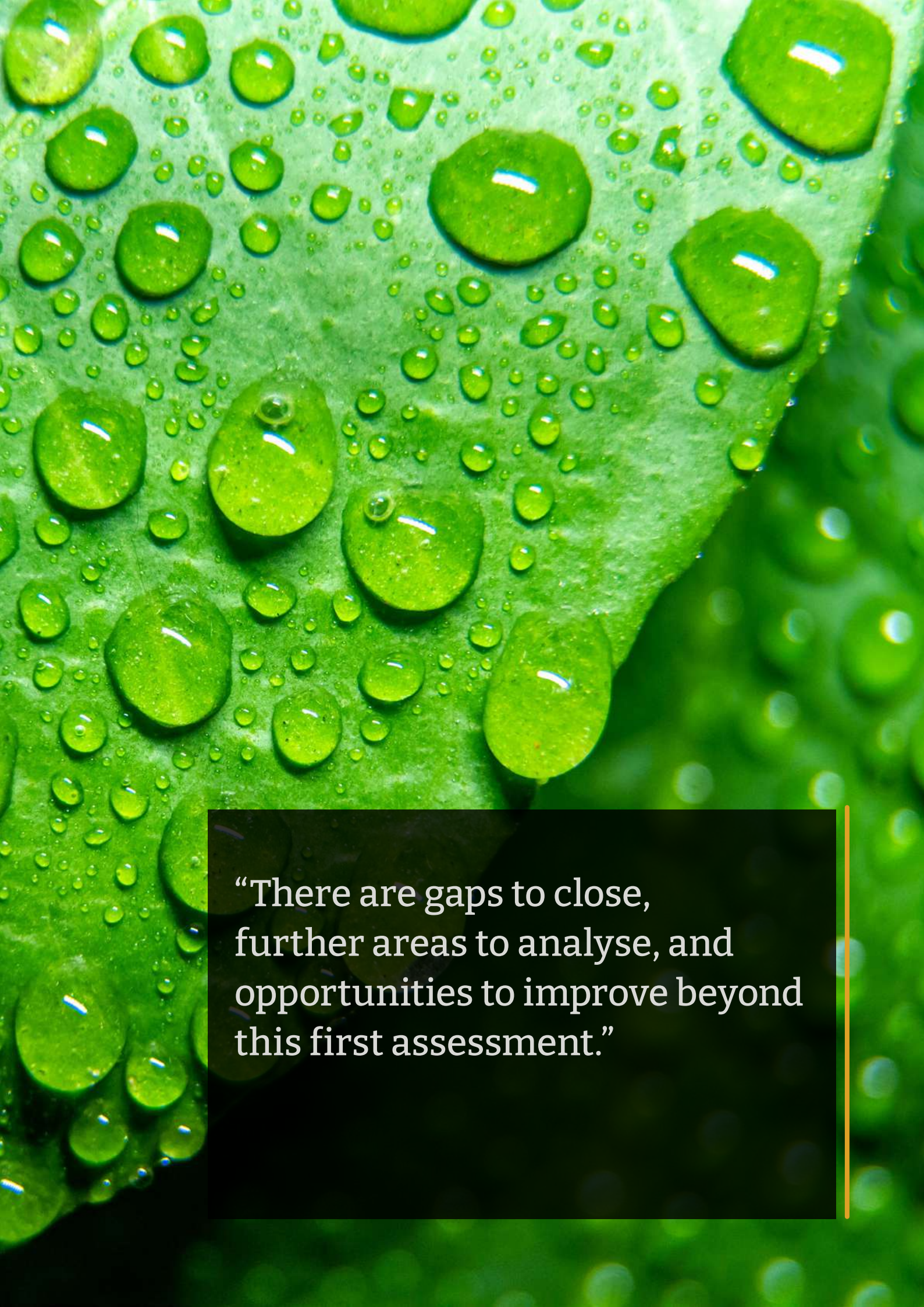

“There are gaps to close, further areas to analyse, and opportunities to improve beyond this first assessment.”

Chapter 9 | Future assessments

This report represents a first step towards a comprehensive scientific assessment of the state of Carbon Dioxide Removal (CDR). It builds on and complements a growing number of initiatives to improve the information landscape around CDR. We, the scientific convenors of this report, believe that such an assessment has an important role to play, informing and aiding the efforts of those who seek to develop CDR as part of successful climate action. There are, however, gaps to close, further areas to analyse, and opportunities to improve beyond this first step. The sections below synthesise the priority areas we have identified, on which assessments in subsequent years can build.

9.1 Expanding the community

Nearly 30 experts have contributed to this report, across three continents and a range of disciplines. And yet our author team is concentrated in Europe and North America, representing only a subset of relevant contexts and perspectives for understanding and tracking CDR developments. We are keen to grow the community to make CDR information more complete, reliable, accessible and inclusive. Specific opportunities for expanding the community include:

- Providing updated assessments of the state of individual CDR methods with regard to costs, potentials, hazards, co-benefits, technology readiness, potential and other factors.

- Incorporating scientific literature in other languages, grey literature, and local and indigenous knowledge.

- Locating and reviewing research on public perceptions from specific stakeholder groups (e.g. local communities affected by deployment, indigenous groups facing land conflicts).

- Assembling a more complete picture of research and innovation across countries and methods, similar to the process followed by the International Energy Agency for energy Research, Development and Demonstration (RD&D) and by the International Renewable Energy Agency for tracking renewable projects and their pipelines.

- Broadening the analysis of CDR policies and governance. This includes quantifying CDR plans beyond those in United Nations Framework Convention on Climate Change (UNFCCC) documents. It may also include case studies of other countries, for instance high-income economies with different emissions profiles (such as Australia, Finland, Iceland, New Zealand, Sweden and Switzerland), emerging economies with growing emissions (such as China, India, and Indonesia) and low-income countries with low emissions levels but high CDR potential. More attention to policy instrument design and evaluation would be valuable, including in areas such as monitoring, reporting and verification.

- Developing local-level and up-to-date information on CDR projects. Currently, our data on novel CDR deployment has limited geographic coverage, with most recorded CDR projects in Europe and North America. The data also generally provides limited coverage of CDR methods such as biochar, which often produce CDR via a large

number of small, independently owned plants instead of large commercial plants, as is the case for Bioenergy with Carbon Capture and Storage and Direct Air Carbon Capture and Storage.

9.2 Improving the data

Throughout this report, we highlight a number of areas in which data is hard to assess, is incomplete or is missing. A better picture of the state of CDR is possible, particularly with the following additions:

- The scientific literature on CDR is vast and growing. Manual tracking and synthesising is now intensive and inefficient. Different scientific communities are adopting "living evidence" as a new paradigm for informing research, policy and practice. Using the machine-learning pipeline we have developed for tracking CDR research, we want to create a "living map" of CDR evidence – an interactive, open access and publicly available tool. Such a map can support other elements of evidence synthesis in this assessment, such as on technology readiness, cost, mitigation potential, hazards and co-benefits.

- Our assessment of innovation could include data from RD&D programmes that include CDR methods but that are not labelled as such (particularly land-based methods). Innovation investments by the private sector are typically harder to measure but are likely to be increasingly important as the industry matures.

- Governments could provide greater consistency, transparency and detail on how countries intend to balance sources and sinks of greenhouse gases. The Nationally Determined Contributions provide sparse information regarding conventional CDR on land and none on novel CDR. Long-term mitigation strategies do so in part, but only for a limited number of countries.

- As noted in Section 9.1, data for current novel CDR deployment is limited. No single repository exists to track all projects. Where available, information is not standardised and is often limited. In particular, our estimates are for gross amounts of CO_2 captured and do not account for the greenhouse gas balance over the full project lifecycles. Ideally, project data should include the CDR pathway used (i.e. the carbon pools between which carbon is moved), the location of activity, the time series of greenhouse gas sources and sinks during the full project lifecycle (including any re-release of carbon back into the atmosphere), and the time series of any subsequent transfers of carbon between non-atmospheric pools (including any fossil carbon captured during the process).

- Long-term scenarios from modelling groups should be collected and vetted more regularly and should include more detail on CDR. Specific outputs are needed for conventional CDR on land, and estimates of the gross land sink should be harmonised across different land-use models, as this is a key uncertainty in assessing and comparing the CDR levels within these scenarios. There is also scope for new scenarios that include broader portfolios of novel CDR.

9.3 Honing the analysis

There is further scope to clarify key concepts around CDR, develop consistent analytical approaches and improve analytical tools. This includes:

- Resolving definitional issues for CDR. In particular, durability is a key concept, but one that is not clearly defined for practical applications. It will be important to improve definitions and categorisation of CDR methods in ways that are widely agreed, scientifically justified and relevant for decision-making[2].

- Tracking emergent new CDR methods. The pace of innovation means that new methods are being proposed and tested rapidly, through either new processes for capture, conversion and storage or new combinations of existing processes. Such tracking will require analysis not only of scientific publications but also of patents, projects and companies.

- Adopting a more consistent approach to CDR methods across the analyses of innovation, public perception, policy, deployment and scenarios. Currently, the analyses we draw from adopt sets of varying detail and completeness. Some focus only on components of CDR methods (e.g. Direct Air Capture without considering storage) or exclude some methods (e.g. converting biomass to bio-oil injected into geological storage).

- Tracking policy developments more thoroughly in several ways, such as through case studies of states and cities developing CDR policies, analysis of interactions between government action and the private sector (including voluntary markets and advance purchase agreements), analysis of developments in the UNFCCC, evaluation of multilateral agreements and cooperation platforms (such as the Bonn Challenge, the 4p1000 Initiative and Mission Innovation on CDR), and analysis of developments to monitor, report and verify CDR activities.

- Encouraging inclusion and analysis of a broader set of CDR methods in integrated assessment models. This would enable a better understanding of how different CDR methods interact and how deployment risks can be hedged via more methods, each deployed at more moderate scales.

- Further improving methods for calculating conventional CDR on land. Generating comparable estimates for current, planned and Paris-consistent levels has required us to make assumptions about land emissions (from deforestation in particular) and indirect effects. These are a step forward but remain an approximation. Countries could improve this by separately reporting sources and sinks as well as direct and indirect fluxes from managed land. In addition, our initial methods for estimating indirect effects, both now and in the future as the climate changes, can be improved.

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THE STATE OF Carbon Dioxide Removal