Exploring Carbon Neutrality and the Paris Agreement Balance of Greenhouse Gas Emissions and Removals

Report on the 2018 Workshop Series by

JPI Climate and European Commission - Directorate-General for Research and Innovation

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Preface

The JPI Climate/European Commission DG Research and Innovation workshop series took place in the period from January to November 2018. It provided an important forum for consideration of climate science and policy issues at a European level. The series took place in parallel with major external developments, including publication of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C (IPCC, 2018) in October 2018 and the negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) to agree a rulebook for implementation of the Paris Agreement at the UNFCCC COP24 meeting in Katowice, Poland. The European Commission also published its updated roadmap for climate neutrality by 2050 in November 20181 and the DG Research and Innovation High-Level Panel on Decarbonisation published its report.2

These processes provided a key background for the discussions, and actors in these processes also participated in the workshop series at various times. This report is focused on the issues considered and exchanges that took place within the workshops, rather than the external processes or developments in these processes. Hence, some of the material may include incomplete information on these activities, which reflects the situation when the workshops took place. This is not considered to reduce the utility of this report or the messages it provides, and particularly the next steps identified, which can inform the future development of the European Research Area.

The range of scientific and technological expertise and excellence that exists across Europe was a key feature of the workshop series. Harnessing this is essential to elucidating the solutions that are required to address the spectrum of climate change challenges and inform the required global transitions. Realising the scientific and innovation potentials requires enhanced co-ordination of research investments across Europe and with our global partners.

Looking to the future, JPI Climate and the European Commission, through the upcoming Framework Programme, Horizon Europe, have the potential to jointly move European research and innovation to the next level of excellence. The key elements of this are:

- advancing fundamental understanding of global change;
- identifying effective response options to address the causes and consequences of climate change; and
- providing the insights and mechanisms to enable the social and economic transition that is required.

New approaches and structures are required. These would improve links and dynamics between researchers who have the scientific understanding and insights, policymakers, and practitioners who realise and enable effective actions. Putting these in place should not be a barrier.

Dr Frank McGovern
Chair, JPI Climate
July 2019

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1 https://ec.europa.eu/clima/policies/strategies/2050_en
Executive Summary

Carbon neutrality and the Paris Agreement aim to achieve a balance between anthropogenic greenhouse gas (GHG) emissions by sources and removals by sinks were explored in three JPI Climate and DG Research and Innovation workshops held during 2018. These workshops explored (1) key concepts and analysis tools, (2) official and unofficial data sets and (3) practitioner experiences of the adoption of ambitious mitigation targets and support systems for mitigation actions. Communication processes, in particular the science–policy–practitioner interface, and the sustainability of analysis capacities were cross-cutting components.

Science–Policy Interface

The centrality of the Intergovernmental Panel on Climate Change (IPCC) in providing authoritative scientific information on climate change and response options was highlighted during considerations of the science–policy interface. The IPCC Fifth Assessment Report (AR5) was a key input to the development of the Paris Agreement. The operational approach within the United Nations Framework Convention on Climate Change (UNFCCC) to facilitate science–policy engagement is a key part of this process.

Effective, timely and informed dialogue between scientists and policymakers can improve the science–policy interface process, having multiple benefits. The 2018 workshop series could provide a basis for development of a European science policy dialogue process. The objective of such a process would be to enhance science–policy communications on short-, medium- and long-term policy actions and identify opportunities for effective actions.

The importance of ongoing investment in fundamental Earth system science and systematic observations was highlighted as being essential to increasing collective understanding of the responses of these systems to anthropogenic climate change. Issues include understanding of climate sensitivity and feedbacks, which inform estimates of the global carbon budget ranges and hence inform pathways that are consistent with achievement of the Paris Agreement goals.

The concept of global carbon budgets for emissions of carbon dioxide (CO₂) and their associated level of warming provide an important framing for development of emissions pathways that are aligned with the Paris Agreement temperature goal. They can inform emissions trajectories for CO₂ and for non-CO₂ GHGs and other atmospheric species that will determine the Earth’s energy balance throughout the 21st century.

Observations underpin climate policy and will be the final arbiter of its effectiveness. The instrumental temperature records from the 19th century provide the reference data for estimation of global temperature increases that frame climate policy. A clear line of sight from these data to current global analysis is essential to framing the Paris Agreement temperature goal.

Exploring the Paris Agreement Balance of Emissions and Removals

An active debate was evident within the scientific community on the concepts contained in the Paris Agreement text, and specifically in Article 4.1, which outlines the pathway towards achievement of a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of this century. This pathway is framed by the Paris Agreement temperature goal to hold the increase in the global average temperature to well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.

Scientific consideration of the Paris Agreement balance of emissions and removals can be interpreted according to differing constructs. These include the use of an aggregate of emissions based on a common metric or the resultant aggregated atmospheric impacts on the global temperature. The implications of these choices were outlined at the workshops and warrant further elaboration, including ensuring clarity for policymakers on issues that arise from such approaches, for example the rationale for estimates of negative emissions/removals that are required to achieve a balance and which feature in most scenarios that achieve the Paris Agreement temperature goal.
Integrated assessment models (IAMs) and shared socio-economic pathways (SSPs) are key tools for the provision of such analysis. IAMs identify sectoral emissions pathways for specific atmospheric compositions or representative concentration pathways (RCPs) that can limit warming to 1.5°C or 2°C. In doing so, they provide insights into the scales and rates of emissions reductions required. They also provide information on the timings for reaching net zero emissions “balance” pathways for CO₂ and non-CO₂ GHGs and aerosols, and estimates of the scale of negative emissions/removals associated with these pathways.

Post-modelling analysis of scenarios provided by IAMs also reveals the differences that occur when GHGs are aggregated using different emissions metrics in terms of determining what constitutes an aggregate balance of GHG emissions and removals. For example, the timing of the achievement of a balance varies according to different global warming potential (GWP) values or if a metric such as global temperature change potential (GTP) is used. That choice also impacts on projected influences on the global temperature, e.g. temperature reduction or cooling, that may occur once such a balance is reached and sustained through removals. These features of metric choices in policy constructs may not be fully appreciated at policy levels. Approaches to clarify or otherwise address these issues, including through the use of a variation of current metrics, were outlined.

The need to elaborate emissions reduction pathways has led to the development of the SSPs, which provide tools for the development of self-consistent narratives about potential futures. SSPs can be used to inform and communicate cross-sectoral policy development at a range of scales. IAMs and SSPs are important tools for emissions pathway analysis. Further exploration and development of these tools is needed, including clarification of their features and the challenges they present in advancing global actions when applied at regional levels and for key sectors, e.g. for land-based removals.

**Official and Unofficial Data Sets**

Insights into the range of official data held by the UNFCCC were provided, including their key strengths, limitations and complexity. As official data they represent robust and authoritative statements by Parties on emissions and removals for which they have responsibility. At a global level there are gaps in the scope and currency of these data, which are subject to different reporting regimes. There are inherent complexities in these data, which arise from the reporting and accounting rules adopted by Parties under the UNFCCC and Kyoto Protocol, particularly in the treatment of emissions and removals associated with land use. Enhanced understanding of these aspects of the official reporting and accounting systems are essential for the use of UNFCCC data. This, along with addressing data gaps, were highlighted as areas for development. Use of the Paris Agreement Rulebook is expected to enhance the availability of official data.

Anomalies in the treatment of land-based removals, including between IPCC Assessment processes and Good Practice Guidelines, were highlighted. The need to address these issues and ensure coherency of analysis was identified as an area for development, particularly as the Paris Agreement has placed removals at the heart of international climate policy. Steps are required to ensure that a shared understanding of land-based removals and emissions of CO₂ exist, including to ensure consistency within the IPCC processes, between various data sets and in assumptions and simplifications used in models, and, specifically, in IAMs and in other approaches to analysis of pathways for achievement of the Paris Agreement balance.

Limitations and difficulties with use of official data are being managed by the research community through the use of robust unofficial data. The Emissions Database for Global Atmospheric Research (EDGAR) was the most recognised and most utilised such data set. Other data sets are held by institutions such as the International Energy Agency (IEA) and industry actors such as energy companies. The EDGAR operational and development processes aim to ensure its currency and enhance its completeness. These include its enhancement to include global removals in future iterations. The importance of EDGAR means that it needs to be well managed and resourced. The profile of this data set can also be enhanced through outreach and capacity development actions, if sufficiently resourced.

The Global Carbon Project (GCP) provided an exemplar for effective and timely communication of
CO₂ emissions and removals based on utilisation of data from a range of global data sets and analysis systems. These are combined to provide important annual updates on global emissions. The process for doing this, as well as the constraints and challenges it faces, were articulated. The need to strengthen the GCP, and options to do this, were outlined.

The development of the Global Climate Observing System (GCOS) across the terrestrial, ocean and atmospheric domains is central to observing and understanding the impacts of climate change in these domains. GCOS thereby underpins policy responses and will determine the effectiveness of these responses. The diverse components of GCOS, including its in situ and space-based remote observations, were considered to add to its potential to inform policy. Leadership by Europe is evident in the development of observation systems such as the Integrated Carbon Observation System (ICOS), as well as in the vision, range and scope of Copernicus and its products for atmosphere, climate and land monitoring services. Realising this potential is considered to be a priority.

Ambition and Leadership

The third workshop explored leadership in the adoption of ambitious mitigation goals by public and private sector actors, as well as the increased level of support systems that have emerged to enable actions. The diversity of formulations that governments, cities and communities and private sector actors have adopted to express ambitious targets was a key feature. It was noted that definitions and boundaries mainly differ in how removals/offsets are expressed or used.

The existing policy and regulatory frameworks are key factors for national and subnational actors, as well as the private sector. A key theme was that legislation helps to build continuity beyond the length of a particular government. Leading countries such as Norway have expressed longer term climate goals in a manner that provides a vision for national development and engagement with international partners. Cities and communities also deal with regulatory and administrative systems and are key actors in policy implementation. Planning and administrative systems can provide a barrier for action, which needs to be factored in to mitigation and adaptation planning. Champions and energetic communities were highlighted as agents of change.

Industry actors have different objectives and their adoption of ambitious targets will be informed by business planning and horizon scanning on issues such as options for emissions reduction, exposure to markets and opportunities for development. The importance of legislation and policy consistency for planning was clear for business investment. The importance of having good data for their areas of operation in order to assess emissions and progress to targets, as well as review mitigation options, was highlighted. Clear procedures and methods are essential for making progress in decarbonisation, and this is likely to be more important for companies than the precise definition of net zero, or exact targets, which can be reviewed in the future.

Experts and enabling bodies have an important function in supporting corporate bodies and others who plan to take actions on climate change. Although approaches and goals have similarities, differences exist that arise from policy constructs and scientific understanding. These can create communication challenges, but should not distract from urgent actions that are essential. Conceptual and structural differences can be addressed in other fora.

The need for negative emissions and how these are to be realised was a key feature of the discussion. The diversity of approaches is reflective of wider differences and developments across science and policy formulations in approaches to removals, which are typically forest/removals related. It was highlighted that such diversity is not necessarily negative and provides opportunities to initiate actions within such framing, with transparency being a key part of this. Industry leaders and winners will need to embrace solutions in a positive, proactive and open manner.

Concluding Points

The Paris Agreement signals a paradigm shift in international climate policy. It has articulated an ambitious challenge for the future: balancing GHG emissions and removals in the context of holding the global temperature increase well below 2°C and pursuing efforts to limit the temperature increase to 1.5°C. The workshops explored many aspects of this challenge, from fundamental science to tapping the social energy in deprived urban communities. They highlighted the need for a forward-looking process to enable effective and open dialogue between science, policy and practitioners. This would have multiple
benefits for actors across these areas. It would assist in enabling actions, provide clarity on issues and challenges, and support decision-making and development planning.

A number of specific issues were highlighted during each workshop, including that research investments are needed to address scientific, modelling and analysis gaps. A process is needed to enhance progress assessments in specific areas. High-quality robust data are essential and, when multiple data sets are used, it is essential to ensure alignment of these where feasible. Enhanced visibility and profiles of the contributions of various data sets and their uses are also required.

Options identified to progress these issues included continuing and developing the workshop series, addressing gaps through research calls or other investments and enabling a wider dialogue process on our shared mitigation futures. There is a need for a framing structure for these developments, such as a “Knowledge Hub”, to provide a mechanism to explore and develop these options. Such a development can be an important step in this process.
1 Background and Context

1.1 Introduction

This report provides a summary of the activities carried out during, and the outcomes from, a series of three workshops designed to explore different aspects of carbon neutrality and the Paris Agreement requirement to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases (GHGs) in the second half of this century. The workshops respectively explored:

- the context, concepts, definitions and analysis to inform interpretation of the Paris Agreement text;
- the availability and scope of global data that can inform the achievement of carbon neutrality and GHG balance, including official and unofficial data;
- practitioner experiences in adopting ambitious GHG mitigation targets such as carbon neutrality and lessons learned by countries, communities and private sector actors.

The first workshop took place on 10 January 2018 in Brussels. It set the scene for the subsequent workshops, which took place on 7 and 8 June 2018 in Oxford and 12 and 13 November 2018 in Brussels. The workshop series brought together leading scientists working in different research areas, as well as government officials and practitioners. It provided a unique forum for the exchange of information and insights on one of the key challenges of this century and how it may be addressed. A list of experts who presented material at the workshops is provided in Appendix 3. It achieved the aim of sharing knowledge on this new area of work and proved to have multiple benefits for those involved. The objective of the series was to inform JPI Climate and DG Research and Innovation on the current state of play on these issues and on possible next steps.

This report aims to capture the main issues and topics considered and points to areas for development in terms of research investments and processes to enhance communication and provide shared understanding on the achievement of carbon neutrality and a balance of GHG emissions and removals. To assist the non-specialist reader, a brief scientific and policy background is provided here as a context for the issues being considered in the workshop series. This includes the background to the United Nations Framework Convention on Climate Change (UNFCCC) adoption of the long-term temperature goal to limit the global temperature increase to 2°C; the process to review the adequacy of this limit; and approaches to quantify human influence on the Earth’s energy balance and its evolution.

1.2 Scientific and Policy Context

The role of GHGs in regulating the global energy balance and therefore the global temperature has been understood since the mid-19th century (EPA/RIA, 2011). Estimates of the global temperature increase that would result from a doubling of the atmospheric carbon dioxide (CO2) level have been provided since the 19th century. This calculation, which is referred to as “climate sensitivity”, remains a key area of uncertainty for Earth systems science. This estimate impacts on the detail of policies required to achieve the goals of the Paris Agreement, in particular, how quickly the world needs to decarbonise.

Since the 1950s, observational data from Mauna Loa, Hawaii, have displayed the ongoing build-up of CO2 in the atmosphere. These observations are now mirrored around the world, raising scientific concerns about human impacts on the global climate system. Following two World Climate Conferences, the Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to provide a shared, authoritative understanding of global climate change, its causes and response options. The 1992 United Nations Framework Convention on Climate Change (UNFCCC) has the objective of preventing dangerous anthropogenic interference with the climate system (UNFCCC, Article 23).

The first UNFCCC Conference of the Parties (COP1) in 1994 recognised that industrialised countries should

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3 https://unfccc.int/resource/docs/convkp/conveng.pdf
lead on actions to address climate change. This was formalised in the 1997 Kyoto Protocol. Under the Kyoto Protocol, developed countries collectively agreed to reduce emissions of a “basket” of GHGs relative to emissions in 1990. This “top-down” policy construct linked economy-wide ambition to cost-effective actions to reduce emissions through the fungibility of a range of gases within the basket by way of the concept of CO₂ equivalence of emissions of other GHGs. It also enabled trading via market mechanisms, including trading with Parties without economy-wide targets. Removal of CO₂ by sinks could also be accounted for in these actions. Complex reporting and accounting rules were adopted to operationalise the Kyoto Protocol.

The Kyoto Protocol entered into force in 2005, with a first commitment period from 2008 to 2012. The second commitment period ends in 2020. Also in 2005, a dialogue process was initiated that resulted in adoption of the Copenhagen Accord at COP15 in 2009. Signatories to the Copenhagen Accord aimed “to reduce global emissions so as to hold the increase in global temperature below 2°C”. The Accord recognised that a number of Parties, particularly vulnerable nations, had called for a lower temperature limit of 1.5°C. This was formulated as a review of the adequacy of the long-term temperature goal. These provisions were more formally adopted at COP16 in Cancun and refined at subsequent COP meetings. During this period, negotiations were initiated that led to the adoption of the Paris Agreement at COP21 in 2015. The review of the long-term global goal was carried out under the 2013–2015 review process.

The Paris Agreement represents a paradigm shift in global climate policy. It moves from the top-down framing established in the Kyoto Protocol, in which actions are referenced to historical emissions of GHGs, principally in 1990, to a bottom-up system in which Parties contribute through Nationally Determined Contributions (NDCs) to collectively achieve the goals of the Paris Agreement. These include its temperature goal and associated peaking of global GHG emissions, followed by rapid reductions in order to achieve a balance of GHG emissions and removals during the second half of this century.

Collective progress is subject to regular review under the global stocktake process, which takes place every 5 years. The first review is scheduled for 2023 and will be informed by the best available science and information from Parties on actions under the UNFCCC and the Paris Agreement.

1.3 Representing Changes to the Global Energy Balance

Changes to the composition of the atmosphere are altering the global energy balance. In particular, increased atmospheric concentrations of GHGs, such as CO₂, methane and nitrous oxide, are trapping additional energy within key Earth systems. This is referred to as global warming and is causing significant impacts such as increasing the global average temperature, sea-level rise and ice-cover loss. Other atmospheric components such as particulate matter (aerosols) can reflect sunlight and have a cooling effect, which can mask some of the GHG warming. In its assessment reports, the IPCC provides estimates of how much these factors have changed the global energy balance relative to pre-industrial levels. It also assesses changes due to natural variations, e.g. variation in solar irradiance. This change in the energy balance is referred to as radiative forcing and is estimated in watts per square metre. Radiative forcing was estimated to be 2.3 W m⁻² in 2011.

In the AR5 the IPCC explored future climate conditions based on changes to the global energy balance. These are encompassed in four representative concentration pathways (RCPs). The RCPs range from ambitious climate actions to reduce GHG emissions, in which the increase in energy being trapped is kept to 2.6 W m⁻², to a “business-as-usual” scenario, in which the end-of-century energy balance is increased by 8.5 W m⁻². The specific energy balance can be achieved by different mixes of warming agents, such as GHGs, and agents that act in a cooling manner, such as reflective atmospheric aerosols. The associated global pathways and scenarios for these are described by large-scale global models. These models can explore a range of 21st-century socio-economic and technological futures that could achieve these climate futures.

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4 The EU adopted a 2°C upper limit ahead of the negotiations for the 1997 Kyoto Protocol.
5 The global oceans are estimated to be taking up more than 90% of this additional energy (IPCC AR5).
1.4 IPCC Special Report on Global Warming of 1.5°C

The IPCC Special Report on Global Warming of 1.5°C was published in October 2018 (IPCC, 2018) and presented at the third workshop. The report updates findings from the IPCC Fifth Assessment Report, including on carbon budgets, which determine the long-term global temperature stabilisation level. The report outlines that human activities are responsible for current warming of approximately 1.0°C above pre-industrial levels (defined as 1850–1900) and that, at the current rate of warming, the increase is likely to reach 1.5°C between 2030 and 2052. There are observable differences in climate impacts at an increment of 0.5°C of warming. The impacts at 2°C of warming are assessed to be more significant than previously considered.

In modelled pathways that limit warming to below 2°C, global net anthropogenic CO₂ emissions are reduced by about 25% from 2010 levels by 2030 and reach net zero around 2070 (2065–2080); in pathways that limit warming to 1.5°C, global CO₂ emissions are reduced by about 45% from 2010 levels by 2030, reaching net zero around 2050 (2045–2055). Emissions of non-CO₂ forcers are also reduced but do not reach zero; the reductions are similar for the 1.5°C and 2°C pathways, indicating that the full non-CO₂ emissions reduction potential is already considered in 2°C pathways. Carbon dioxide removal (CDR) technologies are needed to offset any overshoot in CO₂ emissions and to offset emissions of non-CO₂ GHGs that cannot be reduced to zero.

There is a trade-off in the model scenarios between early emissions reductions and later CO₂ removal. The models are at their limit with regard to how fast their emissions reductions can happen; any delays in starting to reduce emissions mean that more CO₂ will have to be removed from the atmosphere later to achieve the same result.
2 Workshop 1: Context, Definitions, Concepts and Analysis Tools

2.1 Introduction

Article 2 of the Paris Agreement states the global temperature goal, i.e. to hold the increase in the global average temperature to well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels. This goal frames the climate protection ambition of the Paris Agreement. The process for its achievement is elaborated in further statements in the Agreement and in the wider decisions taken at COP21. These include the statement on reducing GHG emissions and balancing these with removals. This is articulated in Article 4.1, which states that:

In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognising that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century [italics added for emphasis].

Scientific understanding is therefore recognised as being central to informing implementation of the Paris Agreement.

The first workshop considered the context for these statements and related concepts, definitions and analysis tools for consideration of emissions pathways and removal analysis. The science–policy interface provided a key context for these developments, particularly as exemplified by the process of considering science in the run-up to the adoption of the Paris Agreement. The UNFCCC consideration of the IPCC Fifth Assessment Report (AR5), and specifically of the adequacy of the long-term temperature goal, can provide insights on such processes and on interpretation of the Paris Agreement goals. These issues, as well the concepts, definitions and analysis tools behind the Paris Agreement “balance” statement, were explored during the workshop.

2.2 The Science Policy Context

Processes by which the scientific community, mainly through the work of the IPCC, have informed the UNFCCC were outlined. The Parties to the UNFCCC are the primary recipients of the work of the IPCC. The first UNFCCC Conference of Parties (COP1), in 1994, established a Joint Working Group (JWG) at official level with the IPCC, through its Subsidiary Body for Scientific and Technological Advice (SBSTA). The JWG provides an operational interface that enables the two bodies to manage shared issues, exchange information and identify options to address issues raised by Parties. In addition, the SBSTA has its own mechanisms and processes to provide scientific and technical analysis for the UNFCCC, e.g. through Technical Papers, in response to requests by Parties or through reports on specific activities, e.g. the UNFCCC (modelling and assessment of contributions to climate change) MATCH process.7

Interaction between the scientific community and the UNFCCC has evolved over time. Currently, the SBSTA Research and Systematic Observations (RSO) agenda item provides a regular forum for scientists to engage with the UNFCCC via the Research Dialogue.8 The Research Dialogue provides an opportunity for information sharing, in which updates on scientific developments are outlined. The RSO item also links to the development of the Global Climate Observing System (GCOS). This allows for regular updates on data and analysis of Essential Climate Variables. The establishment of Earth Day as an ongoing activity under the UNFCCC also provides an opportunity to communicate science to policy (see workshop 2).

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7 https://unfccc.int/resource/docs/2006/sbsta/eng/misc08.pdf
8 https://unfccc.int/topics/science/workstreams/research/research-dialogue
The UNFCCC has utilised a number of formats for providing information and key findings in IPCC reports to the Parties. These include special or official side events, meetings, workshops and agenda items designed to consider specific IPCC reports. The Structured Expert Dialogue (SED) provided the most elaborate process for the consideration of scientific material from the IPCC and other sources. UNFCCC side events also provide a forum for communication of science policy issues. They provide an avenue for the scientific community to bring issues to the attention of Parties.

### 2.2.1 The Structured Expert Dialogue

In the run-up to the adoption of the Paris Agreement, the Structured Expert Dialogue (SED) provided a unique format for science policy and wider implementation policy discussions. The SED was designed to inform the 2013–2015 review of the long-term global goal (LTGG) and progress in its implementation. Although its scope was wider than consideration of the IPCC AR5, it provided an important avenue for consideration of the findings contained in that report. The process had its origins in the 2009 Copenhagen Accord and decisions at COP16 in Cancun and subsequently (see section 1.2).

The review process was designed to take account of the views of Parties who considered that the goal to hold the increase in global temperature to below 2°C was not sufficient to prevent dangerous climate change and who wished to adopt a lower temperature limit of 1.5°C. The review process therefore considered the adequacy of the long-term temperature limit and the potential to adopt a lower temperature limit. It was advanced under two strands: one on the adequacy of the LTGG and the second on progress on its implementation. At the request of the COP, it was organised under the SBSTA and the Subsidiary Body for Implementation (SBI), which addressed implementation issues.

On a scientific and technical level, Parties’ engagement with the IPCC and other expert bodies took place through the SED, which was chaired by two co-facilitators. The co-facilitators were mandated to provide reports on each SED session and to provide a final factual summary report. The format was specifically established to ensure the scientific integrity and independence of the review. The final report from the SED\(^9\) provided an important distillation of the scientific material relevant to the long-term temperature goal and was a key input for the Paris Agreement negotiations.

### 2.2.2 Key points

The IPCC has a central role in providing authoritative scientific understanding of climate change response options based on assessment of published material. It provides a key focus for the science–policy interface and scientific inputs to the UNFCCC. The findings of the IPCC AR5 were a key input to the development of the Paris Agreement.

The effectiveness of the operational components of the science–policy interface under the UNFCCC was considered to be essential to science–policy communications. The SED and its final report were considered to represent an excellent process, which, although focused on informing the Parties, was informative for scientists in terms of discovering what was needed from them and in communicating IPCC findings.

It was considered that the contents and formulation of the SED report could potentially assist the development of future IPCC reports to better address policy issues. It was thought that the SED report was not widely known by scientists and that it would be better utilised if it was better known. The report itself was not published in an academic journal; however, as an official UNFCCC report it can be referenced in scientific papers and other publications.\(^{10}\)

The importance of the Research Dialogue was recognised, but it was noted that it is determined by the UNFCCC Parties and that it may not pick up on issues considered important by scientific communities. The absence of a similar forum for regular exchanges between science and policy experts at a European level was highlighted as an area for development.

**Message:** Effective, timely and informed dialogue between scientists and policymakers can improve the science–policy interface process, having benefits

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\(^{10}\) [https://unfccc.int/documents/8707#beg](https://unfccc.int/documents/8707#beg)
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for all. This workshop series could provide a basis for the development of such a dialogue process at a European level.

2.3 UNFCCC Policy Development

The Paris Agreement represents a major shift from the Kyoto Protocol approach. In the Kyoto Protocol, a top-down emissions reduction target was set by a group of developed country Parties. This was based on the Berlin mandate that industrialised countries with most responsibility for emissions should lead in taking actions to address the causes of climate change. This has been replaced by a recognition that all Parties should contribute in an appropriate manner to achievement of the Paris Agreement goals. Under the Paris Agreement, a bottom-up approach, based on Nationally Determined Contributions (NDCs), has been adopted. It includes significant flexibility to take account of differences between Parties and it is recognised that there is a need to incentivise individual and collective actions as opportunity costs can seem to outweigh future benefits, for example if the benefits are for the wider society and not only for the company or country providing the investment. The Rulebook to enable these actions is therefore essential to implementation of the Paris Agreement. 11

The state of play on actions by Parties was outlined. This indicated a high degree of variability in the currency of official emissions data. Emissions data for Parties with targets under the Kyoto Protocol, and the USA, which did not ratify the Kyoto Protocol, are provided in annual National Inventory Reports (NIRs). These provide annual GHG emissions data from 1990 to the most recent reporting year. The length of the reporting and validation process means that the official annual data are typically 2 years behind the current year.

The NIRs for Kyoto Protocol Parties include reported data, which are comprehensive in terms of sectors covered, and accounting data. The accounting data consist of a prescribed subset of the reported data and are used to determine progress to achievement of Kyoto Protocol targets. The data used for this purpose have been determined through a series of COP decisions. Accounting data also contain information on emissions reduction units obtained through the use of flexible or market mechanisms established under the Kyoto Protocol. These include reduction units from project-based market mechanisms such as the Clean Development Mechanism (CDM) in developing countries not having economy-wide emissions targets.

Emissions data for Parties are also provided under other UNFCCC processes, principally National Communications and, more recently, Biennial Reports and Biennial Update Reports. National Communications emissions data are not subject to the same review and revisions processes that are applied to data in NIRs. The reporting frequency of National Communications varies and the currency of the data from these sources is variable. Consequently, there is a reduced level of emissions data, mainly from developing countries, including from developing country Parties with major emissions. This provides significant challenges for assessment of official emissions data and options to fill gaps are required (see workshop 2).

The Paris Agreement Rulebook provides an opportunity for increasing the scope, quality and frequency of official data available within the UNFCCC process. However, the rulebook must also address the range of activities included in the Nationally Determined Contributions (NDCs). NDCs are the main mechanism by which Parties communicate how they will contribute to achievement of goals agreed under the Paris Agreement. These will be collectively considered under the global stocktake process (see section 2.3.1).

The rulebook is expected to outline how Parties will account for carbon market transfers in line with Article 6 of the Paris Agreement. Accounting is important for meeting commitments under NDCs. A key issue is how to avoid double counting of emissions reductions, i.e. inclusion of these reductions in inventory reports from two Parties to the UNFCCC. This is difficult for a number of NDCs provided by some developing countries. Developing country NDCs may not be as detailed or comprehensive as developed country NDCs. Consequently, their NDCs may not be readily turned into an emissions budget. This may give rise to

11 The Paris Agreement Rulebook was adopted at COP24 in Katowice.
analysis difficulties and also restrict access to future carbon markets. The current term used for carbon market transfers is an internationally transferred mitigation outcome (ITMO). ITMOs may be defined in a number of ways, e.g. as CO₂ emissions or in kWh. Questions have not yet been answered on whether countries should trade like with like or privately decide bilaterally, or define a metric to convert between different activities. A range of options exists but different definitions would lead to different outcomes.

The scientific community emphasised that accumulation of CO₂ in the atmosphere will determine the long-term warming of the Earth’s climate system. Consequently, the level of warming will depend on the level of emissions between now and when emissions are reduced to net zero. Conceptually, this differs from a statement of an annual emissions target for a specific year such as 2030, which is how some NDCs are framed or considered. The pathway to 2030 can vary, and it is better to consider the implications of the full pathway rather than just a start and end point.

From a policy perspective, it was noted that the Paris Agreement calls on Parties “to formulate and communicate long-term low greenhouse gas emission development strategies”, mindful of the goals of the Paris Agreement. The COP21 Decisions invited Parties to communicate these strategies to the UNFCCC by 2020. The intent would be to envisage the NDC process of shorter term targets as part of the overall transition process.

Creation of a mechanism to enable translation of NDCs to pathways in the context of the messages from science is a significant challenge. However, the IPCC and United Nations (UN) Emissions Gap Report have progressed such work. The global stocktake is expected to be the internal UNFCCC process to assess this.

2.3.1 Global stocktake

The global stocktake is designed to assess collective progress in achievement of the goals of the Paris Agreement. It will therefore inform the ongoing NDC update process. Key questions include how to ensure that science informs the global stocktake in a manner that its outcomes can be effectively translated into assessment of progress towards the long-term temperature goal and what the implications of short-term targets are for longer term temperature trends.

2.3.2 Key points

The global stocktake process is expected to be defined in terms of modalities and inputs in the rulebook, but some elements may warrant further development. It is expected that such discussions will be based on all available information.

It was considered that ambitious mitigation needs to be as well informed, including on how much warming has occurred to date and the current rate of warming, as is expected to be provided by the IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018). In this context there is an onus on the scientific community to continue to produce relevant evidence on this topic in a timely manner to inform Parties’ understanding of requirements to achieve the Paris Agreement temperature goal.

The Talanoa Dialogue, established at COP23, provides a means for countries, and other actors in climate action, to tell their stories and come to a shared understanding based on three questions: “Where are we?”, “Where do we want to go?” and “How do we get there?”. This is linked to the UNFCCC, but primarily has an external context that is open to a range of actors, stakeholders and institutions. Overall, it should address these questions and contribute to understanding if countries’ stories and planned actions add up to what is needed to achieve the Paris Agreement goals. This will in effect be a ratchet mechanism to bring countries into line with these goals. The best available science, as provided by the IPCC Special Report on Global Warming of 1.5°C, is a key input into the Talanoa Dialogue.

Key message: An ongoing science policy dialogue process could enable science to communicate the short-, medium- and long-term benefits of policy actions and to identify opportunities for effective actions over the transition period (see workshop 3).

12 The IPCC Special Report on global warming of 1.5°C was published in October 2018 and provided to the UNFCCC at COP24 for further consideration. Issues explored in that report, such as carbon budgets, will be more fully addressed in the Sixth Assessment Report.
2.4 Scientific Considerations and Paris Agreement Balance

The adoption of the Paris Agreement in December 2015 was a political decision. Its adoption was informed by the science in the IPCC AR5. The material contained in the AR5 had been explored in detail by the Parties in the run-up to COP21 under the 2013–2015 review. This enabled Parties to incorporate its findings into their positions ahead of COP21.

The Paris Agreement articulates the global policy to limit the temperature increase to well below 2°C, and pursue efforts to limit the increase to 1.5°C, above pre-industrial temperature levels. The formulation of Article 4.1 on balancing emissions and removals was a compromise based on a range of formulations that expressed broadly similar aspirations. A variety of such formulations was explored by policymakers ahead of COP21. These included concepts such as climate or carbon neutrality, decarbonisation and net zero. The adopted text was a way to embrace these concepts and also captures the complexity of the issue in a tangible manner.

As a consequence, there are a number of options for interpreting the actual text. As it is informed by the “best available science”, the role of scientists is considered to be inherent to its interpretation and achievement through the resolution of related scientific and technical issues. These include analysis of global temperature data, consideration of the Earth’s response to anthropogenic forcing of the climate (climate sensitivity; see section 1.2) and climate feedbacks such as methane release as a result of high latitude warming, all of which elucidate what the “balance between sources and sinks” means in the context of its framing by the Paris Agreement temperature goal and the balance of emissions and removals. For such complex topics, engagement between scientists and policymakers can increase awareness of the implications and consequences of policy choices and formulations. Such engagement is of particular value in assessing the implications of evolving understanding of fundamental Earth sciences and the climate system’s response to human-induced climate forcing. These are important for issues such as estimation of carbon budgets that are compatible with the Paris Agreement temperature goal.

**Key message:** Increasing our understanding of fundamental Earth systems and their responses to anthropogenic climate forcing is essential for informing achievement of the Paris Agreement goals.

Emissions pathways that limit warming to 1.5°C relative to a pre-industrial baseline, i.e. the average temperature over the period from 1850 to 1900, are required to inform collective and individual actions by Parties to the Paris Agreement. The warming relative to pre-industrial temperatures is defined as an average over a 30-year period, centred on that time, which is corrected for short-term natural variability. The IPCC AR5 used the global mean surface temperature (global average near-surface air temperatures over land and sea ice, and sea surface temperatures over ice-free ocean regions). Current global anthropogenic warming is estimated to be 1.0°C above pre-industrial levels. The rate of increase is approximately 0.2°C per decade, with some analysis indicating an increase of 0.3°C per decade. At the lower rate, warming of 1.5°C may be reached in about 25 years.

**Message:** The instrumental temperature records from the 19th century provide the reference data for estimation of global temperature increases that frame climate policy, and a clear line of sight from these data to current analysis is essential to framing the Paris Agreement temperature goal.

The IPCC AR5 provided a clear link between cumulative CO₂ emissions and the global temperature increase. This analysis has been expressed as a remaining global carbon budget. This was re-assessed and updated in the IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018) and will be further considered in the Sixth Assessment Report (AR6). A simple analysis of current trends presented at the workshop suggested that, in order to avoid exceeding an increase of 1.5°C, global CO₂ emissions would need to be halved in 25 years. This trend would need to continue to reach net zero emissions in about 45 years. Emissions of other positive or warming climate forcers, e.g. non-CO₂ GHGs, must also be included in emissions reduction actions and reduce the available CO₂ budget.

**Message:** The concept of a global carbon budget provides a useful framing for development of emissions pathways that are aligned with the Paris Agreement temperature goal.

Interpretation of the Paris Agreement balance text is an active issue within the scientific community (see
Figure 2.1 for an example of this). Scientifically, a number of dimensions and options are considered to be important when defining “balance”. At its simplest, the most common definition of balance of emissions, i.e. net zero emissions, could be based on the Kyoto Protocol policy construction of a basket of gases that are aggregated as CO$_2$ equivalents (CO$_2$e) on the basis of a common metric. Scientifically, this creates difficult questions around which metric to apply, to equate “apples” (short-lived forcers) with “oranges” (long-life GHGs and particularly CO$_2$). Researchers have explored options around how metrics can be developed to better align aggregate emissions data with the impacts of emissions on the global temperature. An alternative method for applying the GWP$_{100}$ (global warming potential over 100 years), called GWP$^*$, which takes account of the lifetimes of different GHGs, was shown to improve the correspondence between cumulative CO$_2$e emissions and temperature, but not necessarily for annual emission benchmarks. This metric is outlined in the IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018).

Emissions of CO$_2$ and the resultant build-up of CO$_2$ in the atmosphere is the dominant contributor to global warming; accounting for the influence of non-CO$_2$ forcing needs to be carried out in an appropriate manner so that their collective impact on warming is reflected. It was noted that use of simple methods to aggregate emissions, such as the GWP$_{100}$, can incorrectly represent their climate impacts. This warrants consideration in examination of the options for the analysis of the balance of emissions and removals. It was suggested that balance pathways for specific GHGs could provide a more scientifically accurate approach to inform mitigation policy in line with the Paris Agreement.

In an alternative formulation, the balance of emissions and removals could be defined physically, i.e. based on the characteristics of the main climate forcers. This can be expressed as net zero emissions of CO$_2$, which is supplemented with negative emissions of CO$_2$ that offset emissions of non-CO$_2$ GHGs that cannot be reduced to zero. In order to achieve a stable temperature profile, short-lived climate forcers, e.g.

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**Figure 2.1. Scientific questions arising from Article 4 of the Paris Agreement. Source: Fuglestvedt et al. (2018). Published by the Royal Society under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/).**
methane, aerosols and certain halocarbons, would not need to reach zero emissions, or be offset in the same way as long-lived emissions. Scientifically, this could be a component of a stable temperature profile. This avoids the difficult question of how to equate short-lived with long-lived climate forcers. More details on these issues are provided in Appendix 1.

**Message:** The Paris Agreement balance of emissions and removals can be interpreted according to differing policy constructs, including via the use of aggregate greenhouse gas emissions based on a common metric or through analysis of their aggregate impacts on the global temperature. The implications of these choices are significant and warrant further consideration in scientific and policy arenas.

### 2.5 Emissions Pathways and Integrated Assessment Models

The global temperature increase will be determined by the atmospheric concentrations of gases and particles that impact on, or act as “forcers” on, climate systems. The range of future atmospheric compositions explored by the IPCC has been summarised as four Representative Concentration Pathways (RCPs), (see section 1.3). These range from a no climate policy business as usual scenario (RCP 8.5), in which emissions continue to increase, to an ambitious global emissions reduction scenario (RCP2.6). The RCP2.6 scenario is the only one considered to be consistent with the Paris Agreement temperature goal. Figure 2.2 shows emissions pathways from the Special Report on Global Warming of 1.5°C that are consistent with limiting global warming to 1.5°C.

For the AR6, a set of shared socio-economic pathways (SSPs) have been developed. These are combined with climate targets to explore and quantify the range of possible emissions pathways and their socio-economic drivers; they have now been published (Riahi et al., 2017) in time for their introduction into the IPCC’s Special Report on Global Warming of 1.5°C. The SSPs provide five narratives

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**Global emissions pathway characteristics**

General characteristics of the evolution of anthropogenic net emissions of CO₂, and total emissions of methane, black carbon, and nitrous oxide in model pathways that limit global warming to 1.5°C with no or limited overshoot. Net emissions are defined as anthropogenic emissions reduced by anthropogenic removals. Reductions in net emissions can be achieved through different portfolios of mitigation measures illustrated in Figure SPM.3b.

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**Figure 2.2. Modelled pathways that limit warming to 1.5°C according to emissions. Source: IPCC (2018).**
of potential global futures. On the basis of these, the implications for population, economic growth, land use, energy demand and emissions were then explored with models, using various assumptions that could be consistent with the SSPs. By integrating the assumptions about socio-economic drivers, energy systems, land use, air pollution and GHG emissions, the resulting set of SSP emissions scenarios have been formulated to allow a more unified analysis of future climate impacts, vulnerabilities, adaptation and mitigation than in the AR5, leading to a better understanding of vulnerabilities and costs at different temperature thresholds.

All of the SSP scenarios that are classified as limiting warming to 1.5°C have zero or negative CO₂ emissions by mid- to late century (see Figure 2.2). A key feature is that the longer that CO₂ reductions are delayed, the higher the likelihood that the 1.5°C threshold will be exceeded, with the consequent need for increased levels of negative emissions to return to the 1.5°C threshold. Non-CO₂ emissions in the pathways increase after 2010 but then decline.

Integrated Assessment Models are used to produce cost-effective emissions scenarios for global pathways that are consistent with policy goals. They are a useful tool to assess interactions and trade-offs between different contributions or choices. IAMs define net zero emissions based on the Kyoto basket of GHGs. Residual CO₂ and non-CO₂ emissions are balanced with CO₂ removals. The removals are typically land based or have at least some land-use component, e.g. afforestation and use of bio-energy with carbon capture and storage (BECCS). The amount of CO₂ to be removed (negative emissions) to reach net zero emissions is determined by the metric or approach used to aggregate GHG emissions see Appendix 1. The GWP<sub>100</sub> values provided in the IPCC Second Assessment Report were used in the AR5.

In these analyses, the time at which net zero emissions is reached varies depending on which common metric or common metric value or type is used in the 1.5°C- and 2°C-consistent scenarios, i.e. GWP<sub>100</sub> values from either the Second Assessment Report or the Fourth Assessment Report or GTP<sub>100</sub><sup>13</sup> values. For all standard metrics, the model results indicate that, once net zero emissions are achieved and maintained, a steady decline in global mean surface temperature is projected to occur.

Integrated assessment models (IAMs) have also been used to explore regional scenarios and costs. Cost-effectiveness analysis suggests that some regions would need to reach net zero emissions before others. It was noted that the representation of the spread of IAM pathways for the IPCC contains significant detail and nuance. The geophysical uncertainty is not fully included in the spread, as the same climate model is always used. In addition, some scenarios are included that are very unlikely to occur in reality. Scenarios categorised as having a “66% likelihood of achieving a temperature goal” are often equated with achieving the goal. In the past, the median values were usually quoted rather than the 66% likelihood values. There has been no formal decision taken at a policy level on the issue of likelihoods to be used to determine emissions pathways. However, such a definition or decision may affect these estimates and impact on the level of mitigation ambition.

It was highlighted that a certain level of ambition is, or can be, embedded in the current policy constructs, with the level of ambition being determined by the metric used to aggregate GHG emissions. Model analysis shows that the use of different metrics to aggregate emissions leads to variation in the timing of the achievement of a balance of emissions and removals, as well as the scale of negative CO₂ emissions with associated longer term global cooling<sup>14</sup> at different rates. It is unclear whether this feature was widely known or anticipated within the climate policy community.

**Message**: Models provide important insights into prospective global emissions pathways and on how policy choices can result in variations in these, the timing of the occurrence of an aggregate balance of emissions and removals, and the projected influence on the global temperature.

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<sup>13</sup> Global temperature potential is an alternative metric to aggregate greenhouse gas emissions based on estimation of the impact on the global temperature over different time periods.

<sup>14</sup> This is based on outputs from simplified climate models of long-term global actions; however, this may not be reflected in the real world.
2.6 Removals

Removals of CO₂ are embedded in the Paris Agreement and are needed to reach a “balance”. Under the UNFCCC, these removals are included in the land use, land-use change and forestry (LULUCF) sector. Complex rules have been adopted for accounting these removals under the Kyoto Protocol. The development of the agriculture, forestry and other land use (AFOLU = LULUCF + agriculture) sector was designed by the IPCC to provide a more integrated approach to managed land use. It is also used in IPCC assessment reports; however, variations occur in the definitions used. The fluxes in the LULUCF sector are not unidirectional, as CO₂ can be emitted or taken up. This leads to intrinsic complexities in scientific and reporting and accounting systems. Significant gaps exist in the scientific understanding of key areas, e.g. in relation to carbon stocks in soils and management options for these.

Methodological guidance provided by the IPCC enables countries to use the concept of managed land as a proxy for anthropogenic LULUCF in their GHG inventories. This has provided a standardised approach for development of these data, which are provided to the UNFCCC. However, as different definitions and approaches exist, including between those used by global models in the IPCC AR5 and what countries report to the UNFCCC, these result in different estimations of the net uptake/emissions. Currently, there is a large difference (>4 GtCO₂/year⁻¹) in net AFOLU CO₂ flux estimates between countries’ GHG inventories (i.e. LULUCF) and the estimates provided by the global models. This arises mostly because of differences in defining the “anthropogenic forest sink” in terms of processes included. These include inclusion of direct versus indirect effects of human activities, such as CO₂ fertilisation, and areas considered to be subject to management. This discrepancy is increasingly understood and recognised in the IPCC Special Reports on Global Warming of 1.5°C (IPCC, 2018) and on Climate Change and Land (IPCC, 2019a). These conceptual differences between models and inventories need to be reconciled to ensure consistent analysis. This is highly relevant for policy, including for credible tracking of collective progress under the Paris Agreement’s global stocktake process. Development of additional disaggregation of global model results to provide data that enable direct comparison of countries’ inventory estimates would contribute to enhancing clarity for the global stocktake.

In addition, there are ongoing efforts to improve accounting for LULUCF globally, for example through the use of satellites or through the UN-REDD (Reducing Emissions from Deforestation and Forest Degradation) programme in developing countries. A separate assessment of LULUCF estimates for the global stocktake may increase transparency.

The provision of estimates for the scale of land-based removals and negative emissions is a key outcome from IAM analysis of the 2°C and 1.5°C pathways. However, the practicality and efficacy of balancing fossil carbon emissions with biogenic sinks was also considered to be an important issue. The IPCC Special Report on Climate Change and Land (IPCC, 2019a) provides an opportunity to enhance understanding of these issues.

Message: Steps are required to ensure that a shared understanding of estimated levels of land-based removals and emissions of CO₂ exists. These include steps to ensure comparability of official data provided in national inventories and data provided by models used in IPCC assessment processes, as well as consistency in the assumptions and simplifications used in various approaches in these inventories and models and in integrated assessment models.

2.7 Conclusions

Actions to stabilise or even decrease the global temperature are far-reaching and challenging at all scales. They require coherence at a global level, as is potentially provided by the Paris Agreement. Evolving scientific understanding and analysis can inform action and help assess the implications of policy choices and constructs for enabling achievement of the Paris Agreement goals. This role of science is inherent to the Paris Agreement; however, science can only inform and enable policy decisions – it does not choose policy.

There is an onus on the scientific community to inform policy and enable decisions to be made based on best available analysis. Many climate topics are complex and technical and so precision and clarity in the requirements of policymakers can help to avoid an overabundance of information. However, scientists
are often unclear on the nuance of some policy issues. Hence, dialogue that can provide clarity on science and policy issues can enable more effective and efficient responses from science and decision-making in policy.

The workshop revealed strengths and limitations of current analysis tools. The need for greater coherence across scientific analysis and modelling communities and between models and analysis, with agreed reporting and accounting systems, was evident. Real-world situations and issues need greater attention. The Paris Agreement’s focus on removals has served to highlight issues and anomalies around understanding of land-based removals and how these are treated in reporting, accounting and analysis systems. Addressing these anomalies is fundamental to informing policy development.

It was considered that analysis of different policy options or constructs and their consequences should be clear to policymakers. This is especially important for the most ambitious mitigation scenarios, which suggest the requirement for high levels of negative CO₂ emissions. Reliance on negative emissions has significant risks and policy implications. Managing related cross-sectoral issues and expectations falls to policymakers rather than scientists. Therefore, the differences in, and implications of, policy constructs of how to achieve balance should be clear.

The effectiveness of communication systems between the IPCC and UNFCCC is essential to policy development. These have worked well in certain cases. However, the science–policy interface may be affected by various constraints, including timing issues and differences in interpretation between the science and the policy communities. A number of these issues may be addressed through an establishment of an ongoing dialogue process between the scientific community and policymakers at a European level.¹⁵

¹⁵ Initial topics of interest were identified as reporting and accounting systems, achievement of targets/goals, the global stocktake, comparing climate forcers and equivalence, land-use change, forestry and removals, global temperature change and rate of change.
3 Workshop 2: Data and Data Sources

3.1 Introduction

The first milestone for the Paris Agreement is for GHG emissions to peak and then to decline in order to limit warming to well below 2°C. The global stocktake is the primary mechanism by which this will be evaluated. Data will be required to determine whether emissions have peaked and if they are declining in line with targets. The negotiations on the Paris Agreement Rulebook, including consideration of the enhanced transparency framework discussions, were ongoing when workshop 2 took place. As recognised at the first workshop, a key aim for the rulebook is to enhance consistency on reporting and accounting across Parties’ Nationally Determined Contributions (NDCs). This bottom-up approach is fundamental to the Paris Agreement and achievement of its goals.

The objective of the second workshop was to explore the range of data sets that are available for determination of carbon neutrality and the balance of greenhouse gas (GHG) emissions and removals. These include official data held by the UNFCCC and related bodies. There are important unofficial/other data sets held by research organisations and private sector bodies. The emergence of new data sets from in situ and remote sensing systems, including space-based systems, was also explored. The issues and challenges associated with ensuring the currency of data, management of data and data harmonisation were explored in the context of the steps to determine carbon neutrality and GHG balance.

3.2 Official Data Sources and Processes

The data provided by Parties to the UNFCCC under various reporting and accounting systems are the only official data on GHG emissions and removals by carbon sinks such as forests. The scope and nature of these data and the formats by which these data are provided are informed by the IPCC Good Practice Guidelines (see Box 3.1). The Parties to the UNFCCC determine how these guidelines are used in official accounting and reporting systems through a series of COP Decisions. The Decisions address details of sectors, structures and how units obtained through flexibilities such as market mechanisms can be accounted. The area of land use, land use change and forestry (LULUCF) has proved to be complex and a number of IPCC supplementary reports have addressed this area, including issues that arose under the Kyoto Protocol. Under the Kyoto Protocol, Parties with emissions targets could also elect to account for certain land-use activities, with others being mandatory. This has resulted in a focus on forest management and afforestation.

The official Party data held under the UNFCCC are subject to a range of vetting processes. Data from Parties with targets under the Kyoto Protocol were subject to particular scrutiny and may be revised following advice from the international review process.

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Box 3.1. IPCC Good Practice Guidelines

The IPCC Good Practice Guidelines provide assistance to the analyst in the preparation of national GHG inventories. The first IPCC Good Practice Guidelines were published in 1995. UNFCCC COP3, held in 1997 in Kyoto, reaffirmed that the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories should be used as “methodologies for estimating anthropogenic emissions by sources and removals by sinks of greenhouse gases” in calculation of legally binding targets during the first commitment period. Updated guidelines were published in 2006. A number of supplements to these guidelines have subsequently been published on specific topics such as wetlands. A new methodologies report entitled 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories has been published (IPCC, 2019b).
The reporting types include:

- Reporting under the UNFCCC – Annex 1\textsuperscript{16} countries report according to a set format; guidance is provided for non-Annex 1 countries but there is not a set format. The last Annex 1 report was for the period 1990–2015; non-Annex 1 reports are typically more dated.
- Reporting under the Kyoto Protocol, in which a subset of emissions and removals are accounted for in achievement of targets adopted under the Protocol.
- Reporting under the Paris Agreement, which is related to the NDCs and is applied to all Parties, with some flexibility.

These data are available “as received” on the UNFCCC data interface, which has a searchable database. Time series for different gases are aggregated as CO$_2$e using the IPCC Second Assessment Report GWP$_{100}$ values and with and without LULUCF data. Not all GHGs are included, nor are international aviation or maritime emissions (which, are reported as separate items).

Parties to the UNFCCC have agreed a range of reporting and accounting processes, by which data on emissions of GHGs and removals of CO$_2$ by specific measures such as afforestation, are submitted to the UNFCCC. These processes vary according to the status of the Parties. In particular, developed countries are required to provide these data annually, a subset of which is used in the accounting used to determine compliance with targets adopted by these Parties under the Kyoto Protocol. Under the accounting rules adopted under the Kyoto Protocol, Parties can use removals by land sinks to offset emissions of other GHGs. Inclusion of certain forest sinks is mandatory; however, Parties can decide whether to include, or elect, other sinks such as grazing land or not. In general, the accounting rules for LULUCF are complex. Accounting rules are also designed to accommodate reductions resulting from market mechanisms.

Developed countries have reported GHG emissions and removals through their National Communications, which are reported on a 5- to 7-year basis. However, Biennial Update Reports,\textsuperscript{17} which contain data on GHG emissions and removals, are to be reported by developing countries to the UNFCCC every 2 years. Reporting and accounting systems for the Paris Agreement are to be adopted as part of the Paris Agreement Rulebook. These will be used post 2020.

### 3.3 GCOS Global Data Sets and Analysis of Emissions and Removals

The establishment of the Global Climate Observing System (GCOS) is the international response to the UNFCCC requirement to promote and co-operate in systematic observation and the development of data archives. The Paris Agreement identifies the need for an effective and progressive response to the urgent threat of climate change on the basis of the best available scientific knowledge. This requires strengthening of knowledge on climate, including systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making.

The GCOS Secretariat is hosted by the World Meteorological Organization (WMO). It has identified a series of Essential Climate Variables across the ocean, terrestrial and atmospheric domains, observations of which should be supported by Parties and which can inform and support actions to achieve the objective of the UNFCCC and the goals of the Paris Agreement. These include measurements of greenhouse gases and aerosols, as well as key elements of the terrestrial and ocean systems, through \textit{in situ} and remote sensing, including space-based measurements. Parties provide detailed technical reports on the status of their national systematic observations through their National Communications, in line with the guidelines in Decision 11/CP.13 and in consideration of the latest GCOS Implementation Plan.

**Message:** The development of the full suite of observation under the Global Climate Observation System GCOS has the potential to provide observational support for actions to reduce greenhouse gas emissions and enhance removals.

\textsuperscript{16} Annex 1 countries are listed as developed countries in the 1992 UNFCCC; non-Annex 1 countries are developing countries.

\textsuperscript{17} https://unfccc.int/BURs
3.4 Global Carbon Project

The Global Carbon Project (GCP)\textsuperscript{18} was formed to “assist the international science community to establish a common, mutually agreed knowledge base supporting policy debate and action to slow the rate of increase of GHGs in the atmosphere”.

The GCP’s carbon budget is updated annually and its publications, graphics and data can be found online at http://www.globalcarbonproject.org. The data for 1959–2016 are available to download in Microsoft Excel format, with global totals divided by source sector or by country. The GCP also produces a methane budget, with estimates from both bottom-up and top-down studies for 2000–2012, which is divided into countries and source sectors. There is more uncertainty in the methane budget, with a wide range of estimates for each source in the budget. Other activities include data on negative emissions, regional carbon balances and urban carbon emissions. The Carbon Atlas is the outreach part of the project. The GCP does not have core funding and so relies on project-based funding. It uses Carbon Dioxide Information Analysis Center (CDIAC) data; however, it was highlighted that the CDIAC is being shut down and so there is uncertainty over the availability of data in the future.

The GCP produces data-based projections of CO\textsubscript{2} emissions at the end of each year, as it takes a few years for official data to appear. This year, they have also produced the budget imbalance, which is the difference between emissions and negative emissions. As the goal of the Paris Agreement is for emissions to peak and then decline, the GCP will frame messages in this context and identify changes to sectors that could contribute to this goal. It can be confusing for readers when several different agencies (e.g. UN Environment GAP report,\textsuperscript{19} IPCC, GCP) produce slightly different reports. It can also be confusing when CO\textsubscript{2} emissions remain flat, whereas concentrations increase. A mediator can help to explain the details on how this can occur or manage consistency between messages.

\textbf{Message:} There is a need to enhance the operational sustainability of the Global Carbon Project; options to do this were outlined, which could address these issues and enable wider analysis and enhance communications.

3.5 EDGAR

The Emissions Database for Global Atmospheric Research (EDGAR) provides data on global past and present-day anthropogenic emissions of GHGs and air pollutants by country and on a spatial grid. The current development of EDGAR is a joint project of the European Commission Joint Research Centre (JRC) and the Netherlands Environmental Assessment Agency (PBL). The aim is to produce a globally consistent database for original studies. Although country-level data sets are likely to be the best for each country, EDGAR is consistent across all countries and compares well with UNFCCC data.

EDGAR uses a bottom-up approach to estimating emissions, applied consistently to all countries. International annual statistics are combined with geographical information about the location of energy and manufacturing facilities, road networks, shipping routes, human and animal population densities and agricultural land use, which vary over time. The data have been aggregated onto a 0.1° × 0.1° grid for annual and monthly means. GHG emissions for 1970–2012 are available to download in csv format from http://edgar.jrc.ec.europa.eu. EDGAR data show that population is not the only driver for increased emissions, as the rate of increase in the population is less than the rate of increase in emissions. There are differences between EDGAR and UNFCCC emissions because of the different methodologies used, although the differences between the two for the European Union (EU) are small as the methods used are very similar. For the global stocktake, gridded emissions as well as country totals will be needed.

EDGAR releases statistical trends but will not make a statement over whether emissions have peaked, as human activities are unpredictable and it has not adopted a methodology that identifies peaking of emissions in a satisfactory manner.

\textbf{Message:} The importance of the EDGAR data set means that it needs to be well managed and resourced.

\textsuperscript{18} https://www.globalcarbonproject.org/
\textsuperscript{19} https://www.unenvironment.org/interactive/emissions-gap-report/
to enable its currency and completeness. The profile of this data set can be enhanced through outreach and capacity development actions.

3.6 Copernicus

Copernicus is the EU’s Earth observation programme. It provides freely available satellite and in situ data and analysis products. At its core are the Sentinel satellites, which have been designed to meet the needs of Copernicus users. Data from the various sources are processed and provided online in a one-stop-shop for climate data. The Copernicus Atmosphere Monitoring Service, CAMS, is the theme that provides emissions data, including reanalysis and GHG flux inversions based on observational data including from elements of the GCOS systems (http://atmosphere.copernicus.eu/catalogue).

A 20-year archive of remote sensing-based vegetation indicator products is available from Vito Belgium (https://www.vito-eodata.be/PDF/portal/Application.html#Home). Satellite data show land cover (https://land.copernicus.eu/global/), but it is not always possible to identify land use. The accuracy of land cover from satellite products is 75% based on comparison with in situ observations.

**Message:** Copernicus provides a unique opportunity to utilise an extensive data set for analysis of global change; however, there are technical, operational and communication barriers to realising its potential.

3.7 Top-down Emissions Verification

Emissions data from Copernicus/CAMS are top-down products, whereas EDGAR is a bottom-up product, as is the CO₂ budget from the GCP. Methane budgets are derived for both top-down and bottom-up methods for the GCP. Bottom-up methods use activity information and emissions factors to provide total emissions based on knowledge of what activity is taking place. Top-down methods work out what emissions are required to explain observed concentrations of gases in the atmosphere, based on a chemical transport model.

Top-down methods are important as verification for bottom-up methods, which are inevitably based on incomplete knowledge and extrapolation. Recent top-down work has, for example, identified a new source of trichlorofluoromethane (CFC-11), which has been banned under the Montreal Protocol. This kind of study allows scientists to identify whether countries’ inventories are accurate and could also be applied to GHGs that are relevant for achieving balance for the Paris Agreement. It should be noted that top-down methods also contain large uncertainties – from the measurements, which may be too sparse to form a complete understanding of the atmosphere, and from the models used to track the gases back to their source regions. Both top-down and bottom-up emissions estimates are important to provide the best understanding of global emissions. The relatively new CO₂ Human Emissions project (https://www.che-project.eu) is one example of this, as it is a synergy between top-down and bottom-up strategies, and such work will be the next step in better understanding our emissions. There will be more inversions, including using satellite data, in the AR6 and the IPCC’s Special Report on Climate Change and Land.

3.7.1 LULUCF for the Paris Agreement

Accounting is important for what counts as a mitigation action towards a target. Inventories report the net emissions only for managed land (as a proxy for anthropogenic LULUCF); however, there can be substantial differences in net emissions depending on what is included. To improve this, following the new IPCC 2019 methodological refinement, countries could provide more transparent information (IPCC, 2019b). On the other hand, global models used in the AR6 could provide their results disaggregated in a way that makes them conceptually more comparable with country GHG inventories.

3.8 Outcomes

It was evident that a range of challenges exist in the development and maintenance of key data sets. Although the associated analysis of these data sets is considered to be a vital asset for informing actions at national and global levels, there is limited support for the provision of these analyses. However, there is also a growing amount of information and number of data available from Earth observation systems and considerable resources have been invested in making data and information from these systems more widely
available; in addition, efforts have been made to enhance user uptake of these data.

Key research areas were identified as including:

- Methodologies to identify peak emissions and an emissions balance, including to address questions on, for example, peaking for specific GHGs, net emissions peak, peaking by countries or sectors, drivers of emissions have peaked, balance of CO₂ emissions and removals.
- Establishment of peaking and balance milestones, which when passed, builds confidence in actions and confirms that we have peaked.
- Development of economic analysis of trends and peaking of emissions.
- What will happen to the climate system once CO₂ emissions peak and start to decline, e.g. to the ocean sink?
- Removals are underexplored, especially quantification of sinks in developing countries. Disentangling natural and anthropogenic sinks is reliant on land management statistics at present; this needs further work and planning.
- The complexity of LULUCF means that a separate assessment for this may increase understanding and transparency for the global stocktake.
- How can developing countries be best helped to improve on their reported emissions?

There is a need to develop sustainable and timely systems to provide information and engage with stakeholders. Priorities for this were identified as follows:

- The provision of more frequent and accessible information to policymakers on key issues. The intervals between major IPCC reports are up to 7 years.
- More frequent targeted assessment updates and ongoing communication channels could provide a mechanism for enabling science–policy–practitioner communications.
- Improved communication of research to policymakers on updated fundamental issues that impact on policy, e.g. on projected occurrences of warming levels of 1.5 or 2°C.
- Enabling coherency in messaging in communications to the public and policymakers.
- Improved communication from policymakers to scientists, e.g. "What do Parties need scientists to provide?", "What questions need answering and when?".
- The sustainability of biofuels and criteria for this, which can enhance communication of the scientific understanding of this.

3.9 Conclusions

Global data that reflect the extent of GHG emissions and removals are essential to determining progress in implementation of the Paris Agreement. The workshop highlighted key developments in these areas, including the increasing availability of data from “unofficial” sources, including from remote sensing and from sophisticated analysis of observational data such as those being provided on atmospheric composition under the umbrella of GCOS. Such data do not and cannot replace official data reported by Parties to the UNFCCC as part of current and future reporting and transparency frameworks, but can contribute to development of these data and independent verification processes. These data will eventually signal that the objective of the UNFCCC and Paris Agreement goals has been achieved.

Gaps exist in all data sets and steps are required to enable understanding of their strengths and weaknesses. Ongoing efforts to enhance these data sets are welcome. It is also necessary to communicate more clearly how various data sets are related, including where consistencies and inconsistencies exist and the basis for these. Official data are limited in geographical coverage. Consequently, there is a need for the provision of robust data from other sources, as was considered in the workshop. These data provide important insights on trends and changes in global emissions and removals, e.g. the work of the GCP. Data sets such as EDGAR are indispensable for the research community. The continued and sustained development of these data sets and the programmes that support them is essential. Work to better link and, where feasible, potentially harmonise these data to official data is needed.

In this context, further development and investment in this work, as well as associated activities on outreach and engagement with data providers and stakeholders, is needed. The latter activities can act to identify and address anomalies. The nature and sources of data used should be evident in the
communications and analysis provided. An ongoing process to enhance the quality and completeness of these data is required. These efforts can be complemented by emerging observation systems at global, regional and local levels. A dialogue process between analysis groups and local actors can enable a fuller understanding of consistency issues and assist the development process. This can support capacity building efforts. This is beyond the scope of the workshop series but further steps in these areas are warranted and could usefully be explored in future workshops.
4 Workshop 3: Practitioner Experiences – Public and Private Sector Leadership

4.1 Introduction
The third workshop focused on motivation, and championing of ambitious mitigation targets. The objective was to explore the rationale and practical learning from, the adoption of, and taking actions to advance ambitious GHG emissions reduction targets such as carbon neutrality. The workshop provided an opportunity for the presentation, and consideration of adoption, of ambitious targets and sharing of learning from such experiences. The workshop heard from actors in the public and private sector and from groups who provide expert support actions. As in the previous workshops, the policy context was also key for the action in the public and private sectors. The public sector included national initiatives and subnational city and community initiatives. The private sector considered examples from energy, industry and food production. Supporting bodies provide expert services in the development of emissions accounting systems and in the use of these to determine progress to targets. The publication of the IPCC’s Special Report on Global Warming of 1.5°C shortly before the workshop (see section 1.4) provided a clear message on the levels of mitigation ambition required to achieve the Paris Agreement goals.

4.2 A Private Sector Perspective
The scale of the challenge to the private sector is unprecedented, in terms of both the ambition in emissions reduction targets and the scale of participation of companies. Over 6000 companies and investors, representing US$36 trillion in revenue, have committed to climate action. These companies, from 120 countries, make up half of the global economy. In total, 500 companies have committed to a science-based emissions reduction target and 159 of these have been approved by the Science Based Targets initiative. This action and leadership will serve to incentivise other companies to follow suit.

However, corporate leadership is also elastic and, at times, inconsistent. There are examples of companies pledging to purchase 100% renewable power, while investing in fossil fuels. Much work remains to be done to ensure a holistic approach across corporate divisions in pursuit of carbon neutrality. In addition, corporate climate ambition is stimulated by ambitious public policy. Political changes can reduce momentum. There is a danger that multinational corporations will respond to government backsliding with some backsliding of their own. It is crucial to honour the commitments and architecture in the Paris Agreement and ensure a progressive increase of ambition over time.

The most ambitious action within the private sector is consistent with holding the global mean temperature increase below 2°C. Companies are beginning to realise how climate change impacts on business continuity and success in relation to a range of risks, including fundamental strategy and business continuity, financial risk and operations risks. These, along with potential rewards, provide motivation for climate action. Financial rewards can come through investing in the clean energy of tomorrow, or by becoming market leaders because of climate action. The latter is also a factor for recruitment, especially for millennials, who are more likely to choose a company that aligns with their values.

A number of trends are enabling greater ambition and success in the private sector:

- The compelling evidence base produced by a succession of IPCC reports, the increased focus on risk and economic impact within these reports and a great improvement in how the science of climate change is communicated across diverse audiences.
- The Paris Agreement, which has sent a clear and definitive signal to the private sector that the era of high-carbon growth has ended and a new low-carbon economy is our common future direction.
- The increasing understanding of the financial opportunities created by the transition to a low-carbon economy.
- Companies do not like being left behind. Pioneers prompt action by peers. The growing volume
of action also creates an innovation laboratory. Companies can learn lessons from each other, amplify best practice and avoid mistakes.

A number of challenges and barriers need to be addressed over the coming years to retain momentum and insure a progressive increase of ambition in the private sector:

- First, translate economy-wide targets into a full enabling environment.
- Politics are becoming uncertain once more. The rise of populist leaders across the globe, most notably in the USA, in parts of the EU and, most recently, in Brazil, risk undermining the global consensus captured in the Paris Agreement.
- The Marrakech Partnership and the Technical Examination Process inside the UNFCCC has not delivered on its potential. The latter processes have become venues for "show and tell", rather than an opportunity for structured dialogue on public policy. They should be moments to address structural policy barriers to carbon neutrality. It is important to revamp these processes, to enable a genuine public–private dialogue on how to create a catalytic policy-enabling environment for carbon neutrality. The full value chain approach has to be applied to corporate climate ambition.

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4.3 State and Public Sector Actors

Action is valuable at both the country level and the city level and, as such, it can be useful to understand different actions that can be taken at each level. Each country and city will have a different situation, and we heard perspectives from Norway and the Netherlands, as well as from the city of Oslo.

4.3.1 Norway

Norway has legally binding targets to reduce emissions by 40% compared with 1990 by 2030, and by 80–95% by 2050. Cross-party agreement on climate goals and measures ensures stability for businesses operating there. The Climate Change Act was established in January 2018 and will be reviewed every 5 years in tandem with the Paris Agreement. Norway has also provided a statement on achieving climate neutrality by 2030; however, this has not been brought in by law. It may use forestry to offset emissions, which is not typically accounted for in the emissions statistics. Norway’s main emissions sectors are transport, petroleum and industry, as the country’s electricity is almost all renewable (about 97%).

A few examples of how Norway has set about advancing ambition and achieving its targets are listed below:

- **Pricing carbon.** Norway has had a CO₂ tax since 1991 and joined the European Emissions Trading Scheme (ETS) in 2005, with 80% of CO₂ emissions currently subject to pricing. Without this, it is estimated that current emissions would have been 10–15% higher. This lever has worked; however, the next challenge is how to achieve net zero emissions. It will be important to work across sectors for this.
- **Incentivising the shift to low emission transport.** This has been achieved by a mix of investing in public transport, blending in biofuels, taxation of vehicle emissions and size as well as fuel, and no road tax or value-added tax (VAT) on electric vehicles. Early on, electric vehicles were given access to bus lanes. Other benefits include no tolls, free parking and subsidised charging points. The end result is that, in 2017, 20% of new cars (4% of the total fleet) were electric.

4.3.2 Oslo

Oslo has a progressive mayor and government at the moment, who want to lead on climate. The city has targets, based on 1990 levels, of a 36% reduction by 2020, a 50% reduction as soon as possible after 2022 and a 95% reduction by 2030. It plans for use of carbon capture and storage (CCS) systems with waste incineration in order to achieve the 50% target, but is unsure when this will happen as it has to link in with the national government.

A climate budget (how much CO₂e the city can “spend”) has been integrated with the city’s regular budget and has been used to identify emissions reduction measures. The geographical and system boundaries were defined and then direct emissions (i.e. excluding imported products) were calculated for all sectors that statistics were available for. This inventory shows that roads are the dominant source of emissions. Example measures to reduce emissions
include phasing out fossil fuel use in heating, zero emission construction and road toll management.

4.3.3 The Netherlands

In the Netherlands, science has been used to help define a common storyline between the four ruling parties. The approach has been to combine top-down (government) and bottom-up (community) approaches. The Netherlands has a 49% reduction target for 2030 compared with 1990 emissions, with the ambition to be nearly carbon neutral by 2050 (95% reduction). It accepts that, in 2050, per capita CO₂ emissions need to be equal in all countries and close to zero. The Netherlands does not typically use the term “carbon neutrality”, but favours more specific terms such as “compared with 1990 emissions”. Negative emissions are under debate.

The climate agreement covers five sectors and the plan has to be cost-effective. In such a cost analysis, if a cut-off of 2030 is used, value is lost that would otherwise be gained in the future, so it is better to include the longer term. The Netherlands has had an outline agreement since summer 2018 and will aim to achieve a final agreement in early 2019. The destination is clear; however, the plan for how to get there is not. A key theme is that legislation helps to build continuity beyond the length of a particular government. Land use and agriculture are important in the Netherlands, but requirements for methane emissions have not yet been agreed.

Measures that will apply widely are as follows:

- electricity – move to renewables, including for transport;
- buildings – renewable heat, efficiency;
- industry – energy improvements, process efficiency, heat, CCS, innovation.

The elements for success include:

- having a focus on energy efficiency;
- prioritising the aim of getting emissions from power generation to near zero; 70% green by 2030 is achievable from 15% today;
- electrifying as much as possible – now at 30%;
- negative emissions will probably be required, e.g. CCS and BECCS;
- having an approach for difficult sectors such as certain industries and heavy transport;
- reducing non-CO₂ emissions from forestry and land use;
- lifestyle change.

The benefits of action in the Netherlands are as follows:

- being a leader means that you can get ahead/ export your expertise;
- national CO₂ price could be added to curb emissions;
- money has been available for renewable energy (offshore wind energy); now, money has been allocated to the manufacturing sector.

4.3.4 Summary for state actors

Progress is required at different levels, from bottom up and top down. Clean energy generation and the electrification of transport were strategies that were common to more than one region, although a range of other areas were also focused on (e.g. buildings, industry). Instruments for achieving success were typically top down, e.g. a carbon tax and legislation, which provide long-term constraints to shape action.

4.4 Communities

4.4.1 A community approach in Amersfoort

Amersfoort is a city in the central Netherlands. In one of the 14 neighbourhoods a foundation on sustainability was established in 2009 after a dispute over demolishing a railway industrial site (which is now an industrial heritage site). It is a local area with strong social cohesion, but is somewhat deprived. This has been a bottom-up approach in which local people see each other as street ambassadors. The outcome has been that now the municipalities are interested in community. It is less about concepts (e.g. carbon neutrality) and more about improving life. This type of formulation is essential to a bottom-up engagement process.

The community is successful and proud, which is the result of having levels of good communication to spread the word. Mechanisms for communication include street ambassadors, a newsletter, meetings,
social media and visualising results through mapping online and in local media. Working on properties empowers people to change.

The community grew organically with no funds initially. Small amounts of funding were obtained over time as the council/government/businesses became interested. Often, however, funding with special limitations constrained the activity and so the community is stronger with no funding. However, this means that it has not been possible to expand greatly. After several years, the community did influence local government, which initiated “green deals”.

The following activities have been carried out:

- Insulating houses, many of which were draughty. Street ambassadors were used to exchange ideas over coffee. After 6 months, 18 out of 23 houses in one street wanted to make home improvements. The concept was rolled out over the whole neighbourhood when the council saw what was happening. There were 24 street ambassadors and 240 houses were insulated in 2 years.
- Built the first energy-neutral house in the Netherlands, which required builders to learn new techniques.
- Street ambassadors were used to exchange knowledge and ideas on solar panel use, with one strand focused on schools, but the market now provides enough incentives for this.
- Car sharing (borne from the economic crisis).
- An initiative called Green Track that, for example, greened empty spaces. This approach is good for engagement.
- A new eco-town area with 40 eco-homes has been initiated, with a new vision for sustainability. After 8 years of talking, the aim is to break ground in 2019.
- Central heating optimisation introduced, which provides a gas saving of 10–30% (180 households).
- Citizen science has been used to measure temperature and humidity, to measure the urban heat island.

The following issues have been encountered:

- The construction business typically does not yet understand sustainable methods.
- The municipality can be very positive towards circular economy initiatives but the existing bureaucracy can hold things up. The municipality is keen for successful implementation but is behind schedule.

4.5 Business and Industry

4.5.1 Eurelectric (represents electricity generators in Europe)

The European electric sector wants to become part of the solution. In April 2017, Eurelectric pledged no more investment in new-build coal after 2020, and it has a vision for carbon neutrality (CO₂ only) by mid-century. This will be easier for some European companies than others. New technology is an opportunity and has been rolled out faster than anticipated.

The Eurelectric plan for decarbonising Europe was published in November 2018. This plan is supported by all electricity providers in the EU. It shows that electricity will be central to decarbonisation of the energy sector and other sectors, such as heating and transport. This would result in an increased demand for electrical energy under a European decarbonisation scenario, despite efficiency improvements. A unified plan for power grids would aid in the transition. Electricity provides a solution for decarbonisation in Europe. This means more electricity demand, which is seen as an opportunity. Social sustainability, for example in coal mining regions, is an issue.

The Emissions Trading Scheme (ETS) is a key instrument for decarbonisation. The ETS is supported by Eurelectric and should be market based, technology neutral and Europe wide. However, carbon price volatility is an issue. The ETS can be an investment tool, which could drive changes by providing investments that are needed now to benefit the uptake of future technologies.

The energy sector is accepting of a goal of carbon neutrality, but has not developed a clear message on negative emissions. The technology is not yet proven. However, unless energy demand decreases globally, negative emissions will be needed. Strong regulation and changes in behaviour will be needed to achieve the Paris Agreement goals.

4.5.2 **EVONIK**

EVONIK produce speciality chemicals, many of which contribute to sustainable development goals, for example insulation and additives to improve the efficiency of machinery. The chemical industry provides value to 95% of products globally and so has to be part of the solution to climate change.

EVONIK has provided a carbon footprint estimate – including for raw materials/upstream, downstream and purchase of electricity – and an estimate of avoided emissions. The emissions from use of products have also been calculated.

A strong motivator is customer demand for low-carbon products, with high-carbon-intensity products becoming increasingly risky. The approach that EVONIK is taking is to aim for net zero emissions, through an ongoing process of consultation with stakeholders and internally. A key question relates to the role of the chemical industry in a carbon-neutral society. The targets and framework for emissions reductions will tie in with the 5-year cycle for financial planning. There is a plan to use an internal carbon price (around €50) for risk management of investments and acquisitions.

Emissions will need to be monitored to assess progress. EVONIK’s sustainability analysis has been developed in house and is not based on an external benchmark. The International Council of Chemical Associations (ICCA) does provide peer-reviewed guidelines on avoided emissions. Frontrunners in this domain, such as Evonik, have enabled progress. However, it is unclear how many companies will follow suit.

4.5.3 **Bord Bia and Origin Green**

Bord Bia developed Origin Green to help improve its sustainability and evidence base. Origin Green:

- aims to save resources for members, to build reputation and to win business on this basis.

Origin Green built on quality assurance audit schemes for food safety to develop sustainability schemes for farms, which are independently verified by the Carbon Trust to ISO standards. Data are used to drive performance, as anything that drives efficiency helps sustainability.

Origin Green worked with Teagasc to translate the carbon footprint into useful information for farmers, using a carbon navigator tool. It was found in the detailed audits by the Carbon Trust that five pieces of information were needed to determine 95% of the carbon footprint: grazing season, genetics of the herd, nitrogen fertiliser use, manure management method and energy usage.

Farmers obtain a measurement of their footprint, and where they are relative to their peers, which helps them to identify where improvements can be made – including through actions on GHG emissions, which provide cost savings. In total, 95% of Irish dairy farms have signed up and 95% of beef exporters. Visits take place every 18 months for participating farms.

To assess companies, there was no existing structure to build on. Companies will set a baseline year and then set targets for raw materials, manufacturing and social sustainability. Companies choose what targets to set and there is a verification scheme to check that these targets are good enough and then to monitor progress. In total, 95% of exports are registered and 90% of exports are verified.

Ireland’s national policy is to achieve net zero emissions by 2050, but this has not yet been fully defined in terms of its formulation. The government is funding some research on this for land and agriculture. At the same time, Ireland is trying to grow agriculture sales over the coming decade.

Trust and dialogue are important for this process, including having access to farms. The scale of buy-in to this scheme is unique – other countries have much smaller schemes (based on the percentage of total farms in the schemes).

**Key messages**: The importance of legislation for future planning was clear from the point of view of business investment. The issue of having good data for businesses’ areas of operation in order to
assess emissions and progress to targets, as well as review mitigation options, was also a key point. Clear procedures and methods are essential for making progress in decarbonisation and this is likely to be more important for companies than the precise definition of net zero, or exact targets (which can be reviewed in future), at present.

4.6 Providing Frameworks for Change

4.6.1 Carbon Disclosure Project

The Carbon Disclosure Project (CDP) runs a disclosure system for companies, cities, regions, etc. to measure and manage their environmental impacts. It is the most comprehensive scheme available for businesses, with disclosure being driven by investors. In 2018, 650+ investors, 7000+ companies, 620+ cities and 210+ states/regions reported through the CDP. This covers about a quarter of global emissions.

After AR5, CDP started developing science-based targets to inform the level of ambition for emissions reduction targets. Science-based targets:

- are consistent with limiting warming to 1.5–2°C and reaching net zero emissions in the second half of the century;
- are developed using IAM emissions pathways combined with an allocation approach (considering GHG intensity and absolute emissions) and a company profile;
- are developed with CDP, World Resources Institute (WRI), World Wide Fund for Nature, UN Global Compact and We Mean Business;
- are moving from arbitrary targets to targets that are consistent with global goals;
- cover the most relevant emissions within the boundary of a company – 95% of direct and electricity-related emissions and two-thirds of value-chain emissions;
- use a time frame to drive short-term action and enable accountability (5–15 years);
- are based on the US Greenhouse Gas Protocol to determine operational emissions;
- have set targets for value-chain emissions (supply chain downstream);
- use GHG emissions as a way for companies to see how far they are away from the net zero goal;
- aim for transparency through use of a scientific advisory group.

The CDP method is currently based on AR5, but a possible “ratchet mechanism” is being developed to incorporate the latest science and scenarios from the IPCC. At present, CDP assumes that all GHGs should reduce at the same rate as CO₂, but recognises the distinctions made in the IPCC’s Special Report on Global Warming of 1.5°C.

4.6.2 Carbone 4

“Net zero” is a very powerful concept, which can be harnessed for action. Carbone 4 launched a Net Zero Initiative in September 2018. Experts are welcome to join the scientific council to review the methodology. It highlighted some issues over the definition of carbon neutrality today:

- There is no consistency between companies in carbon neutrality, as there is no common reference.
- Companies often want to be net zero on a company scale, with no consideration of the global scale.
- Hiding carbon credits in just one net value is confusing/misleading.
- Transparency and consistency in budgets is needed.

Cardinal points for Carbone 4’s Net Zero Initiative are:

- ambition – neutrality is a path, not a snapshot/state;
- credibility – cutting GHG emissions is a priority, but it must be practical too – the initiative restores credibility for offsetting;
- universality – guided by the urge for the global, collective goal of net zero;
- transparency – restore trust in carbon offsetting and make emissions reduction visible.

The foundational idea of the Net Zero Initiative is to reduce GHG emissions and develop sinks globally. For this to happen, companies need to:

- reduce direct emissions;
- avoid indirect emissions and develop/invest in sinks;
- account for each separately.
The idea is to then foster competition between companies in these three areas. Reporting this rigorously will stimulate competition and normalisation.

Carbon neutrality can be regarded as offsetting, which can be misleading. Future options to enhance the definition of neutrality are being developed, e.g. to balance fossil CO\textsubscript{2} only with permanent CO\textsubscript{2} sequestration (i.e. re-fossilisation). However, in the coming decade, Carbone 4 are allowing a soft balance, e.g. reforestation.

4.6.3 \textit{CO\textsubscript{2} Logic: a carbon-neutral label}

\textit{CO\textsubscript{2} Logic} offers multicriteria and life cycle analysis (LCA) solutions, using the British Standards Institution PAS 2060 standard for carbon neutrality, which requires independent third-party verification every 3 years. The method involves defining the scope (scope 1, 2, 3) and then calculating emissions or carrying out LCA for a product, based on recognised standards. The next step is to reduce the emissions or footprint according to a company’s ambition. Finally, the company can also offset any remaining emissions to achieve neutrality. The standard sets out the criteria that should be met to claim carbon neutrality.

\textit{CO\textsubscript{2} Logic} have the following offsetting principles:

- CO\textsubscript{2}/GHG emissions have a global impact on one atmosphere/climate. Offsetting offers flexibility and efficiency using cost-effective mechanisms.
- Historical responsibility/climate solidarity should be considered.
- Internalise externalised costs.
- Urgency – can offset in the meantime while reduction of emissions is in progress.
- Offsets must be additional (the offset would not otherwise have happened), real and measurable, with no carbon leakage or double counting.

There are several levels of stakeholder engagement and standards (e.g. Gold Standard). A CO\textsubscript{2}-neutral label is helpful for communicating that a company is taking real action, as long as it is not simply marketing.

\textbf{Key message:} Expert supports and enabling bodies have an important function in supporting corporate bodies and others who wish to take actions on climate change. Although approaches and goals have similarities, differences exist that reflect differences that arise from policy constructs and scientific understanding. Although this can create communications challenges, it should not distract from urgent actions that are essential. Conceptual and structural differences can be addressed in other fora.

4.7 Concluding Points

The final workshop shows that understanding of scale, leadership and ambition is changing. The 2°C limit is being replaced as a benchmark for success by science-based targets that are “aligned” with a 1.5°C limit. The corporate sector will need to re-evaluate its position in this context. It is also evident that ambition must be increased to ensure carbon neutrality or net zero emissions in the second half of the century, and that steps must be taken to expedite this process over the coming decade.

The risk and reward framework used to describe the motivations and drivers in the private sector is helpful across different stakeholder groups in understanding motivation. As a consequence, there is a need to improve how climate ambition is communicated to corporations so that it is aligned with risk and reward categories.

Opportunity is a key motivator. However, the language of opportunity must resonate with different stakeholder groups. The promise and benefits of a low-carbon, climate-resilient and inclusive economy are empowering. When communities and companies understand that climate ambition leads to job creation, economic development, profitability, improved public health and better approaches to risk management they are motivated to act.

Ownership is key to internalising and motivation, but external enabling environments are critical to success. Ultimately, ambition must be self-sustaining. Communities increase climate ambition when they themselves shape the strategy, implement the projects and reap local rewards from their action. Similarly, companies can drive consistent and long-term commitment to climate ambition when the strategy is seen to be aligned with corporate interests, and owned internally by key C-suite officials.

Collaboration is necessary. No one stakeholder can achieve ambition working in isolation. Scientific understanding provides a basis for public policy. Public policy then provides a catalytic enabling environment for leadership in the private sector. Experience in
the private sector provides lessons to inform the refinement of our scientific understanding of climate change, and inputs to an evolving policy landscape. The unprecedented level of ambition in the private sector has been possible only as a consequence of the roadmap outlined in the Paris Agreement. Similarly, the ambition of the Paris Agreement will be realised only with sustained emissions reductions in the real economy, driven by the action of individual companies and their large supply chains.

Culture matters – whether national or corporate, a strategy is often a reflection of culture. This needs to be understood in order to move forward. A key strength of the Paris Agreement is that it allows countries to develop their own national climate action plans based on their national circumstances. This includes not only an understanding of their specific emissions profile, but also an understanding of their political and social realities. Similarly, different companies have different cultures. Some are innovative and risk taking, willing to make substantial commitments while determining how to meet those obligations at a later date. Others are risk averse and reluctant to make any commitments unless they are 100% sure that those commitments can be honoured. Our approach to carbon neutrality must understand and accommodate these different cultures. Specific lessons for the scientific community, the policy community, the private sector, enablers and JPI Climate are provided in Appendix 2.
5 Conclusions

The workshop series successfully mobilised key groups from science, policy and the private sector. It provided insights on specific issues and challenges that exist from fundamental science, ongoing data development and analysis, as well as considerations in terms of motivating and enabling actions. In doing this, it provided a snapshot of the state of play in an evolving panorama of research analysis and actions. The outcomes as reflected in this report provide challenges for actors at a European level and have identified options to address these.

Fundamentally, the workshops provided a forum for discussion of science policy and practitioner issues. The goals and requirements of the Paris Agreement provided the key cross-over point for the presentations and discussions that occurred. In the run-up to the operational phase of the Paris Agreement in 2020 and its first global stocktake in 2023, it is evident that there is room for ongoing sharing of information and analysis across these areas. This can enhance the dynamic between science policy and practice, which underpins the European and global response to climate change as framed by the Paris Agreement.

The workshops highlighted the strengths and weaknesses of currently available data and the challenges that exist in aligning and harmonising data, particularly data related to land and land use. This is a priority issue given that the capacity of land management to deliver removals or negative emissions is now central to climate policy. Steps are needed to address anomalies that exist within assessment systems that are essential to the transfer of scientific understanding of terrestrial carbon pools and inform effective systems for management of these. This is an urgent area for development.

The lessons from practitioners in providing leadership show how transition can take, and is taking, place. There is no single model for this and the challenges will vary across scales and sectors. However, the roles of science and policy in providing clarity and certainty are key to progress. First movers and champions are critical for articulation of positive visions of change. However, communications must recognise and address audience needs in order to build trust and the space and capacity for change. For example, science is most useful for policymakers when it answers their questions and does not simply raise new and unanswered questions.

A series of messages and possible next steps have been identified. There is a need for further fora, workshops and conferences to facilitate timely dialogue between climate scientists and policymakers, the private sector and enabling bodies. Funding for research, and research translation for specific audiences, is an ongoing process. Establishment of a knowledge hub or framing body to advance these areas was highlighted as a solution. This should also assist in enhancing the profile of the extent of scientific and technical capacity and often hidden excellence within Europe. The next step should aim to enable the fuller realisation of the expertise and technical excellence within Europe and bring this to a global level.
References


Appendix 1  Scientific and Technical Issues in Definitions of a Balance of Greenhouse Gas Emissions and Removals

A number of definitions of the balance of anthropogenic GHG emissions and removals exist (e.g. see Rogelj et al., 2015), adoption of any one of which may result in different approaches and actions to achieve the necessary balance. The balance definitions can be divided into two broad categories:

1. balancing GHG emissions and removals by sources/sinks as combined using standard emissions metrics such as GWP or GTP;
2. balancing GHG emissions and removals by sources/sinks based on their impacts on the atmosphere/climate system, e.g. single gas or multibasket approach.

They have key similarities:

- both require robust and comprehensive global GHG inventories that provide data on GHG emissions and removals by sinks;
- achievement of net zero CO₂ emissions is a necessary and pivotal component for achievement of the overall balance;
- removals/negative emissions are needed to offset residual emissions of non-CO₂ GHGs that cannot readily be reduced to the level required for the chosen definition of balance.

The key difference occurs in how emissions of non-CO₂ GHG emissions are considered and may be combined so as to determine the levels of negative emissions that are required to achieve a balance that would be compatible with a given temperature limit. Options identified for this included:

- include all GHGs together to achieve net zero emissions;
- balance all long-lived GHGs to achieve net zero emissions and have a separate stabilisation target for short-lived forcers.

The choice of definition of balance therefore has potential implications for future approaches on uses of a basket or baskets of GHGs.

A1.1  Baskets and Metrics

A category 1-type balance would be based on an official reporting/accounting system in which non-CO₂ GHGs are combined as CO₂e based on a common metric such as Global Warming Potential (GWP) or alternatives such as the Global Temperature-change Potential (GTP). Currently, under the UNFCCC, GWP₁₀₀ values provided by the IPCC, in its Second, Fourth and Fifth Assessment Reports, are used for this purpose. Such a balance would potentially have the following characteristics:

- it would differ according to the metric used and may be subject to revision, e.g. if an updated GWP value is adopted following publication of a new IPCC Assessment Report;
- the levels of negative emissions required to offset non-CO₂ GHGs would vary according to the metric value adopted;
- the emissions pathways that achieve net zero GHG emissions could stabilise the global temperature at a particular level, or could provide cooling in which the global temperature reaches a peak and then gradually declines;
- the temperature response would not be certain for many reasons, including because cumulative CO₂e emissions under these metrics do not predict the temperature response;
- the level of negative emissions required by this definition and to achieve a peak and decline in temperatures is greater than what is needed to only stabilise temperatures.

A category 2-type balance would be based on the influence of GHG emissions and removals on atmospheric radiative forcing or the global temperature increment. It would therefore:

- be dependent on the emissions and characteristics of individual non-CO₂ GHGs and not vary with changes in the emissions metrics;
- at a minimum, require achievement of net zero CO₂ emissions/removals, with additional CO₂ removals that are commensurate with those
required to address any temperature overshoot due to CO₂ and to offset radiative forcing by non-CO₂ GHGs that cannot be brought to zero;

- achieve temperature stabilisation if net zero GHG emissions are achieved and maintained, independent of whether CO₂ is removed to offset other ongoing GHG emissions.

Metrics that capture these features have been developed and published in the academic literature, e.g. GWP*; these will be available for consideration in future IPCC reports.

Under a category 1-type definition, maintaining net zero GHG emissions could result in a peak and decline in temperatures if methane is offset by CO₂ removals based on GWP_{100}.

### A1.2 Wider Considerations including Aerosols and other Atmospheric Pollutants

The above considerations are focused on GHG emissions and removals and are limited to anthropogenic emissions of GHGs and managed removals. Scientifically, this is a critical but limited subset of the systems and processes that impact on the Earth’s climate system and its stability. Critical features include assumptions around the behaviour and responses of natural systems, e.g. that these will remain relatively stable, i.e. the uptake of CO₂ by natural systems such as unmanaged terrestrial systems and the oceans will remain relatively stable, and that there will not be large unmanaged losses of CO₂ or other GHGs from stocks currently held by these systems.

These assumptions are at odds with climate projections and Earth systems models that indicate reductions in the rates of carbon uptake and loss of carbon and other GHGs from terrestrial systems (e.g. permafrost) as a result of global warming. These would need to be addressed if the temperature goals in the Paris Agreement are to be achieved.

Assumptions around the roles and impacts of aerosols (e.g. a reduction in cooling aerosols in the atmosphere) and other short-lived climate forcers are also an important consideration:

- These are included in RCP analyses but are not captured by high level climate policy, as outlined in the Paris Agreement.
- They will, however, be critical for whether temperature increases are limited to well under 2°C, as even if CO₂ warming is limited to well below 2°C, non-CO₂ warming may push warming over 2°C.

- Consideration of these impacts need to be part of the scientific analysis of the requirements to achieve the Paris Agreement balance. In addition, the high levels of uncertainty around climate forcing and wider impacts need to be addressed.

### A1.3 Research Questions/Issues

- Improvement of inventory and reporting systems are needed to better support and inform policy, including for LULUCF and other negative emissions.
- Analysis of official emissions inventory data should be developed in a manner that addresses atmospheric changes and their impacts, e.g. as well as current reporting and accounting systems, analysis tools are required.
- Improve international co-operation between countries to help to achieve balance globally.
- Improve channels for science to inform the global stocktake process and climate policy in general.
- What are the implications of short-term targets (e.g. 2030) for longer term temperatures (e.g. 2050–2100)?
- The role of metrics in integrated assessment models needs exploring. The way in which metrics are used in IAMs affects policy outcomes.
- Improved and localised Earth systems and human systems models, e.g. sectoral and economic models, are need to inform longer term actions and emissions pathways to address the risks related to carbon removal systems and protecting carbon stocks in soils and biomass.
- Global IAM analysis needs to be more refined to address the above issue at regional, national and, in some cases, subnational levels, e.g. for cities if this is realistic.
- More detailed analysis of CO₂ and non-CO₂ GHGs is needed, as well as analysis of individual and collective pathways and contributions, for achievement of a GHG balance.
- Localised analysis of these is needed to inform options to achieve the required balance at a range of scales.
- Options to reduce the risks of loss of effectiveness of carbon sinks and to protect carbon stocks are required.
Appendix 2  A Business Perspective on the Workshop Series

The workshop series was designed to explore issues around carbon neutrality and balancing GHG emissions and removals to support planning for climate actions and research investments. These can contribute to informing the implementation of the Paris Agreement to the UNFCCC. The first workshop explored scientific and technical aspects related to what a balance between sources and sinks of GHGs means in the Paris Agreement context. The second dealt with issues related to data for assessing progress towards achieving that balance. The third workshop harvested lessons from exploring learning from local communities, cities, countries and the private sector. In each case, both presentation and discussion assessed motivation for action; interrogated the approaches and indicators being used to drive climate ambition; examined the barriers that are hindering progress; and explored how best to learn from and scale the experiences of the early adopters of neutrality goals. This reflection note consists of two parts:

1. a perspective on lessons learned from engagement with the private sector;
2. challenges and next steps in “exploring carbon neutrality”.

A2.1  A Perspective on the Private Sector

This section provides a perspective from the private sector. First, we assess the scale of corporate ambition on climate change, with a focus on aggressive GHG emissions reductions. Second, we look at the motivations and drivers that generate corporate ambition. Typically, this rests on a balance between risk and reward across six strategic categories. Third, we examine the enablers and success factors that contribute to increasing corporate ambition. Fourth, we explore the barriers and challenges that need to be overcome in order to scale up ambition, consistent with holding global mean temperatures to below 2°C and achieving the Paris Agreement goal of net zero emissions well before the end of the century. Finally, we look to the future and provide a vision for what “new corporate climate leadership” could look like.

A2.1.1  Comparability and scale

When assessing the comparability and scale of private sector ambition as it relates to carbon neutrality, there are four key concepts that combine to create a comprehensive perspective on corporate climate leadership.

First, the scale of private sector leadership on emissions reductions is unprecedented in both aggregate ambition and the participation of companies. Over 6000 companies and investors, representing US$36 trillion in revenue, have committed to climate action. These companies, from 120 countries, make up half of the global economy. In total, 500 companies have committed to a science-based emissions reduction target and 159 of these have been approved by the Science Based Targets initiative. A further 157 have committed to purchasing 100% of their energy needs from renewable power. Additional initiatives contain commitments to end all commodity-driven deforestation in global supply chains; reduce short-lived climate pollutants; and establish carbon pricing mechanisms. The six largest banks in the USA, with assets in excess of US$10tn, are taking action, including assessing their exposure to stranded assets and high-carbon investments. A willingness to take action has even reached into the most carbon-intensive industries, with 41 of the 90 largest fossil fuel and cement companies, responsible for two-thirds of historical GHGs, making climate commitments. Importantly, the commitment to lead on climate change includes increased activism in politics and policymaking. In 2016, the four largest companies in the world by market capitalisation submitted briefs to the US Supreme Court to support the Clean Power Plan.

Second, corporate climate leadership is defining its impact in the market signal that it is sending to the global economy. Walmart is the largest private sector employer in the world, with more than 2 million staff on its payroll and revenues in excess of $500bn. Moreover, Walmart has more than 100,000 suppliers in the USA alone and accounts for 11% of all Chinese imports into the USA. Walmart has
adopted a science-based target and this commitment will reach deep into its complex global supply chain, with implications for how hundreds of thousands of suppliers reduce their own carbon footprint as a price for continuing to do business with Walmart. As more companies commit to climate leadership, their procurement practices, investments and supply chain management techniques will be put to the service of their climate commitments, incentivising large swathes of the global economy to begin the process of decarbonisation.

Third, corporate climate leadership is elastic, with the potential for both forward progress and backsliding. Moreover, it is inconsistent. For example, within the financial services sector, many companies have adopted climate commitments, including pledges to purchase 100% of their energy from renewable sources. However, many of the same companies continue to invest large amounts of their portfolios in fossil fuels – sometimes as much as US$15–20bn on an annual basis. Much work remains to be done to ensure a holistic approach across corporate divisions in pursuit of carbon neutrality. In addition, corporate climate ambition is stimulated by ambitious public policy. As political winds change, and some of the momentum of the Paris Agreement begins to dissipate, there is a danger that multinational corporations will respond to government backsliding with some backsliding of their own. It therefore becomes crucial to honour the commitments and architecture in the Paris Agreement and ensure a progressive increase of ambition over time.

Fourth, the ambition within the private sector should be considered as incomplete and merely the first step in a longer journey. The most ambitious action within the private sector is consistent with holding global mean temperatures below 2°C above pre-industrial levels. During 2018, this previous benchmark of success and leadership has begun to seem outdated in light of the publication of the IPCC Special Report on Global Warming of 1.5°C. Moreover, although companies have made substantial progress in acting to reduce emissions inside their own core operations, there is a pressing need for them to supplement this work by enabling ambition in others (i.e. through the provision of goods, services, innovation, technology and access to financial vehicles) and by becoming more activist-like in support of ambitious climate policies.

### A2.1.2 Motivations and drivers

Companies are realising how climate change impacts business continuity and success in relation to a range of business risk vectors, including fundamental strategy and business continuity, financial risk and operations.

Financial risks refer to the possibility of a sudden financial loss as a result of climate impacts. This could take the form of immediate losses caused by a climate-related hazard or a broad threat to profits as a company’s exposure to climate risk becomes known. It could also take the form of diminished capital availability and higher credit risk as investors and lenders refuse to make capital available to companies seen to be vulnerable to climate impacts or seen as high carbon producers and therefore stranded assets. Risks related to assets and commodity prices are particularly strong because of the impact of climate change on ecosystem services, food production and real estate. In addition, increasingly, central banks are looking closely at systemic risk – specifically the danger that the financial system globally, or the financial system of one particularly vulnerable country, could suffer severe harm because of cascading climate risks. Analysis by Mercer estimates that the cumulative global cost of climate change-related impacts on the environment, health and food security will reach between US$2tn and US$4tn by 2030. More recent assessments published in the journal *Nature* suggested that costs to the market value of global financial assets could be as high as $24.2tn under worst-case scenarios.

Financial rewards can come through investing in the clean energy of tomorrow. Between 2012 and 2015, China created 1.8 million jobs in the renewable energy sector and today the world’s largest wind energy company and five of the top six solar firms in the world are Chinese. These companies stand ready to capitalise on the estimated US$13.5tn of clean energy investments contained within the national climate action plans submitted as part of the Paris Agreement.

Strategic risks refer to the danger that a company’s strategy becomes less effective and the company therefore struggles to reach its goals. Climate change might pose strategic risks as some technologies may become obsolete, whereas rewards might result for companies providing substitutions that drive GHG emissions reductions. Alternatively, new competitors...
spurred by changing markets for low-carbon climate-resilient goods and services may respond to shifting consumer demand and address resource constraints linked to climate, thereby threatening profits and the market position of incumbents and driving profitability for the new insurgents in the market. High variability in the price of raw materials driven by exposure to climate hazards may dramatically change inputs vital to production. Reputational damage may result from a perceived failure to account for climate risk, with implications for revenue as customers and suppliers become hesitant to associate with a discredited brand and shift their business to more progressive rivals. Large accounts may be at risk if significant procurers of goods and services begin to focus their purchasing on climate-friendly suppliers.

Operational risks deal with critical damage to infrastructure, production, quality of goods and services, and disruption to logistics. Utility and telecommunication companies have been particularly exposed to infrastructure and operational quality risk as a result of climate hazards. Food, beverage and agriculture companies have suffered losses because of production shortfall risk. Corporate competitive advantage is often associated with companies with the least exposure to supply chain disruption because they have solid enterprise risk management systems that properly account for climate risk.

Compliance and legal risks refer to the growing body of climate and non-climate laws that is being used to drive transparency and accountability in both emissions reductions and climate risk. There is a growing danger that companies will face additional and unexpected regulations or may even fall short of interpretations of current laws if they fail to act decisively on climate change. This may include companies facing a heightened liability risk for failing to properly care for socio-ecological systems within their zone of operations. Meanwhile, companies who are active in shaping policy incentives can use a changing regulatory environment to drive innovation across their supply chains.

Human resource risks focus on two distinct aspects. Workplace safety risk involves threats to employee health as a result of climate-related events. Talent management risk is the growing concern that recruitment and retention of staff – and millennials in particular – will become difficult for companies that have a reputation for being poor on climate resilience. A growing number of skilled millennial workers are looking to join companies with an overt sense of mission, purpose and values, particularly relating to environmental stewardship.

A2.1.3 Enablers and success factors

A number of trends are enabling greater ambition and success in the private sector.

The first is the compelling evidence base produced by a succession of IPCC reports, the increased focus on risk and economic impact within these reports and a great improvement in how the science of climate change is communicated across diverse audiences, including the private sector. Natural science has always been, and continues to be, core to our understanding of the climate system. However, as social sciences and economics have contributed increasing volumes of analysis, the changing climate system, its implications for socio-ecological systems and its threat to the real economy have enabled the translation of climate science into the language of enterprise risk management.

Second, the Paris Agreement was and continues to be a vital enabler of success. The key provision of the Paris Agreement is that the combination of 196 signatories, coupled with 189 national climate action plans, sends a clear and definitive signal to the private sector that the era of high-carbon growth has ended and a new low-carbon economy is our common future direction. In addition, the goals of the Paris Agreement, focusing on temperature/emissions reductions, resilience and finance, provide a blueprint for how companies should understand their own climate strategies. The architecture of the Paris Agreement helps companies to understand the importance of establishing a stretch target, including periodic milestones towards meeting the target, and to recognise the value of sequenced approaches to raising ambition, and provides them with the freedom and flexibility to include their own measures of conditionality as they set their climate targets. In total, the Paris Agreement provides companies with political continuity, which enables business continuity planning and provides a level playing field across complex global supply chains. It further provides companies with a methodology that they can follow in setting their own targets and finally allows them access to
decision-making so that they can help shape the enabling environment for success.

Third, there is increasing understanding of the financial opportunities created by the transition to a low-carbon economy. All major economies are committing to restructuring their energy systems, changing transport patterns and transforming infrastructure, buildings and land use. Collectively, the national climate plans under the Paris Agreement represent at least a US$13.5tn market for the energy sector alone, with similarly large amounts committed in other sectors. This shifts the conversation from burden sharing to economic opportunity.

Finally, companies do not like being left behind. Pioneers prompt action by peers. As more companies commit to aggressive GHG reductions, this creates momentum and a gravitational pull for other companies. The growing volume of action also creates an innovation laboratory. Companies can learn lessons from each other, amplify best practice and avoid mistakes.

A2.1.4 Challenges and barriers

A number of challenges and barriers need to be addressed over the coming years to retain momentum and ensure a progressive increase of ambition in the private sector.

First, we need to translate economy-wide targets into a full enabling environment. For example, those companies committing to 100% renewable energy procurement are now faced with additional challenges and barriers. Many of them are faced with procuring energy from monopoly energy providers that will provide only fossil fuel alternatives. The same companies are located in jurisdictions where zoning and permitting regulations prevent on-site renewable energy generation. In addition, finally, many of these companies are struggling with access to capital that would enable them to invest in energy efficiency and the procurement of renewable energy through on-site energy production. A huge array of non-climate-related public policies, ranging from protection of intellectual property to addressing endemic corruption, building access to appropriate financial vehicles and mainstreaming low-carbon principles into public procurement, now stand as barriers to further progress and must be addressed.

Second, our politics are becoming uncertain once more. The rise of populist leaders across the globe, most notably in the USA, in parts of the EU and, most recently, in Brazil, risk undermining the global consensus captured in the Paris Agreement. For many years, the political consensus emerging from the G7, the G20 and the UNFCCC pointed to deep decarbonisation before the end of the century, with consistent global policy to support this endeavour. This provided business continuity and certainty, enabling the private sector to commit to climate ambition and make substantial investments. As that political consensus begins to unravel, it becomes more difficult for businesses to trust that deep decarbonisation is our collective journey.

Third, we have failed to fully utilise the Marrakech Partnership and the Technical Examination Process inside the UNFCCC. These processes have become venues for “show and tell” rather than an opportunity for structured dialogue on public policy. They have become opportunities to showcase best practice and to earn reputational reward, when instead they should be moments to address structural policy barriers to carbon neutrality. It is important to revamp these processes, to enable a genuine public–private dialogue on how to create a catalytic policy-enabling environment for carbon neutrality. We have not deployed a full value-chain approach to our corporate climate ambition.

A2.2 Next Step in Exploring Carbon Neutrality and GHG Balance

A2.2.1 General conclusions

The first general conclusion is that our understanding of scale, leadership and ambition is changing. This is a result of the observed climate impacts during 2017 and 2018 and is driven in part by deeper understanding of the implications of global mean temperature rises as a consequence of the Special Report on Global Warming of 1.5°C (IPCC, 2018). Article 2.1 of the Paris Agreement commits the international community to holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels. As 2018 ended, it became clear that 2°C should no longer be considered as the benchmark for success and that therefore
science-based targets in the corporate sector would need to be re-evaluated and aligned with a 1.5°C goal. Similarly, Article 4.1 of the Paris Agreement outlines a sequence to reduce GHG emissions, starting with the global peaking of emissions as soon as possible, “rapid reductions thereafter” and leading to “a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century”. It is now equally clear that ambition must be increased to ensure carbon neutrality or net zero emissions in the second half of the century, and that steps must be taken to expedite this process over the coming decade.

The second general conclusion is that the risks and rewards framework, used to describe the motivations and drivers in the private sector, is helpful across different stakeholder groups in understanding motivation. As a consequence, there is a need to improve how we pitch climate ambition so that we can better align it with these categories of risk and reward.

The third conclusion is that opportunity is a key motivator. For the past two decades, our ability to communicate climate risk has improved dramatically as the science has solidified and our ability for audience segmentation has increased. Today, we are far better able to downscale climate risk for specific geographies and to translate climate risk for individual economic sectors and for unique communities and populations. However, one of the clear messages from this workshop series is that the language of opportunity resonates with different stakeholder groups. The promise and benefits of a low-carbon, climate-resilient and inclusive economy are empowering. When communities and companies understand that climate ambition leads to job creation, economic development, profitability, improved public health and better approaches to risk management they are motivated to act.

The fourth lesson is that ownership is key. Internalising the motivation creates a positive loop. External enabling environments are critical to success, but ultimately ambition must be self-sustaining. Communities increase climate ambition when they themselves shape the strategy, implement the projects and reap local rewards from their actions. Similarly, companies can drive consistent and long-term commitment to climate ambition when strategies are seen to be aligned with corporate interests and owned internally by key C-suite officials.

The fifth lesson is that collaboration is necessary. No one stakeholder can achieve ambition working in isolation. Scientific understanding provides a basis for public policy. Public policy then provides a catalytic enabling environment for leadership in the private sector. Experience in the private sector provides lessons to inform the refinement of our scientific understanding of climate change, and inputs to an evolving policy landscape. The unprecedented level of ambition in the private sector has been possible only as a consequence of the global decarbonisation roadmap outlined in the Paris Agreement. Similarly, the ambition of the Paris Agreement will be realised only with sustained emissions reductions in the real economy, driven by the action of individual companies and their large supply chains.

Finally, it is clear that culture matters – whether national or corporate, a strategy is often a reflection of culture. This needs to be understood in order to move forward. One of the great strengths of the Paris Agreement is that it allows countries to develop their own national climate action plans based on their national circumstances. This includes not only an understanding of their specific emissions profile, but also an understanding of their political and social realities. Similarly, different companies have different cultures. Some are innovative and risk taking, willing to make substantial commitments while determining how to meet those obligations at a later date. Others are risk averse and reluctant to make any commitments unless they are 100% sure that those commitments can be honoured. Our approach to carbon neutrality must understand and accommodate these different cultures.

A2.2.2 Lessons for the scientific community

There were two major lessons for the scientific community. First, it is important for research to be accessible: the right language, the right vehicles, appealing to effective motivations and incentives, and translated/tailored for target audiences. In the past, scientific reports have been written using language that was accessible only to other scientists and have been presented in vehicles that are inappropriate for many audiences (including the private sector), seemingly unaware of the motivations and drivers of significant portions of the target audience.
Second, it is important for research to be actionable: raising awareness on climate risks elevates the issue on the decision agenda. Providing tailored menus of climate interventions empowers action and drives ambition. The recently published Special Report on Global Warming of 1.5°C from the IPCC is an important step in the right direction in this regard, as it includes guidance on “development pathways”, which can be translated into tangible action.

A2.2.3 Lessons for the policy community

During the past 18 months, the policy community has focused on finalising a rulebook for the implementation of the Paris Agreement. This is undoubtedly an important exercise, ensuring environmental integrity, transparency and accountability in accounting for GHG emissions reductions, validating climate action and ensuring a level playing field. As the policy community continues to build the rulebook, it is important that it also supplements this with two important elements.

First, communicating continuity in the global commitment to decarbonisation is vital. This includes ensuring that the ratchet mechanism, central to the Paris Agreement, is fully used. Article 3.2 of the Paris Agreement states that “the efforts of all Parties will represent a progression over time”. Meanwhile, Article 4.3 states that “each Party’s successive nationally determined contribution will represent a progression beyond the Party’s then current nationally determined contribution and reflect its highest possible ambition”. Together, these elements of the Paris Agreement provide regulatory certainty, enabling businesses to make long-term investments, secure in the knowledge that governments across the globe will remain committed to deep decarbonisation irrespective of changing political or economic circumstances. Retaining this continuity, particularly in the face of rising populism in key industrialised and emerging economies, is vital to driving continued ambition in the private sector.

Second, there is a need for innovation in government. Setting economy-wide emissions reduction targets is an important first step, but there is a need to move forward with policy mechanisms that send clear and unequivocal messages to the market. This could include increasing the number and effectiveness of carbon pricing mechanisms (there are 71 mechanisms at the national and subnational levels at the time of writing); phasing out and prohibitions of fossil fuels and fossil fuel subsidies; the use of fiduciary laws to hold companies accountable for misleading investors about stranded assets; greening public procurement; and so on. In addition, it is important for governments to be joined up, ensuring that the policies made in environmental departments are reinforced by the incentives emerging from finance ministries.

A2.2.4 Lessons for the private sector

The private sector is committing to unprecedented levels of climate ambition. However, it is time to progress ambition beyond the Paris 2015 vintage and create a “new corporate climate leadership”, consisting of three components.

1. **Act.** Companies should commit to climate ambition within their core business, with leadership across all corporate divisions. Moreover, they should re-evaluate their commitment in line with the findings of the Special Report on Global Warming of 1.5°C (IPCC, 2018) and supplement their efforts to reduce emissions at source, with increased investments in sinks and strategies to enhance socio-ecological resilience.

2. **Enable.** Companies should encourage, incentivise and resource leadership across complex global supply chains through their procurement, investments and ability to drive action across six capital assets vital to climate resilience, namely human, physical, social, financial, natural and political capital.

3. **Influence.** Companies should work to shape public policy at the global, regional, national and local levels with strong, consistent and comprehensive advocacy, including within coalitions and industry peer groups. They should also work with their “captive audience” to promote behaviour change in consumers, including their purchasing habits and their engagement with climate issues.

A2.2.5 Lessons for the enablers

Enablers should draw a number of lessons in order to catalyse further progress towards carbon neutrality. First, disclosure has been a very effective tool for elevating understanding of climate risk and prompting companies to design and communicate
Climate strategies. There is now a pressing need for "disclosure+", meaning moving to streamline disclosure methods to make them less burdensome for companies and to enhance their effectiveness as tools for internal strategy development. At present, disclosure is looked at as a necessary burden, a requirement for communicating with investors and civil society, rather than as a tool to drive ambition inside companies. Reforming disclosure platforms could reinvigorate this approach as an aid to ambition.

Second, enablers should be comfortable changing their theories of change. Most philanthropies and civil society actors work within a comfort zone of funding/supporting grassroots activists. They have historically been uncomfortable working with companies. And yet it is clear that the search for greater impact requires deeper engagement with the private sector. Are these enablers going to be flexible and capable enough to evolve their theories of change and work more directly with the private sector?

Third, companies are constantly approached to sign up to one initiative or another, one petition or another, to contribute to one financial mechanism or another, and to speak at one event or another. This causes great fatigue and confusion and prevents true scale. It is therefore important that stakeholders seeking to catalyse private sector leadership avoid going to the well too often, and that when they do make an approach to a company they are coherent, sophisticated in their understanding of the private sector and capable of offering partnership as well as making an ask.

A2.2.6 Lessons for JPI Climate

JPI Climate was launched in 2011 and involves 17 European countries that are committed to co-ordinating their activities in the field of climate research with the view to support climate action to implement the Paris Agreement. JPI Climate provides a platform for climate knowledge and decision support services for societal innovation, connecting scientific disciplines, enabling cross-border research and increasing the science–practice interaction.

Three potential roles for JPI Climate in improving the science–practice interface were discussed during the workshop series. First, could JPI Climate develop a knowledge hub? There is value in being a repository of knowledge as long as this does not become a euphemism for an information dump. There are already many platforms providing climate information and most fall into the trap of providing generic rather than tailored knowledge and of generating research that is inaccessible and difficult to action, carried out by issue experts alone rather than being co-created with those who understand the private sector. If JPI Climate decides to develop a “knowledge hub”, it needs to be carefully curated, avoid duplication and learn from some of the lessons presented above.

Second, could JPI Climate become a convener? Convening can be valuable as long as we deviate from the show-and-tell model and focus on structured dialogue. Too many meetings and fora – the Technical Examination Process under the Paris Agreement being a case in point – provide an opportunity for governments and companies to engage in storytelling and broadcast communications rather than facilitating a genuine public–private dialogue on policy and practice. For example, the companies committing to 100% renewable energy procurement are now being hampered in reaching those goals as a result of policy barriers relating to monopoly energy providers, zoning/permitting laws and cost of capital issues. A meeting to discuss renewable energy should therefore concentrate on ways to overcome these policy barriers rather than providing an opportunity to merely showcase corporate commitments.

Third, could JPI Climate commission new research? Currently, it would be wiser to focus on better rather than new research. There is often a temptation to restate what we know. It might be wiser to translate what we know and to tailor the knowledge that we possess to specific sectors and audiences.
Appendix 3  Workshop Participants

Table A3.1. Workshop participants

<table>
<thead>
<tr>
<th>Participant</th>
<th>Affiliation</th>
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