PREFACE

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The CO_2 Capture Project (CCP) is a collaborative partnership of eight of the world's leading energy companies and three government organizations. The initiative undertakes research and develops technologies to help make CO_2 capture and geological storage (CCS) a practical reality for reducing global CO_2 emissions and tackling climate change – one of the great international challenges of our time.

Since 2000, CCP has been at the very forefront of advancing CCS; a process that involves capturing the CO_2 emitted from industrial and energy-related sources and then securely storing the CO_2 deep underground in geological formations.

Phase 1 of CCP identified next generation capture technologies that had the potential to deliver performance and efficiency improvements resulting in close to a 50% reduction in the cost of CO_2 capture. It also pioneered a risk-based approach for geological site selection, operation and abandonment; and developed new CO_2 monitoring tools and the science behind CO_2 geological storage.

In Phase 2, CCP has continued to build on achievements in capture and storage. The culmination of this five year study is found in this book.

During this second phase, CCP, leveraging its combined expertise in the oil and gas industry, has worked in collaboration with governments, industry, world-leading academic institutions and environmental interest groups' The objective for capture technology was to further the development of the promising technologies identified during CCP1 with a view to realising the expected cost reductions, reducing the range of uncertainty around cost estimates and maturing at least one technology ready for subsequent demonstration. In the matter of geological storage, CCP2 has focused on the science and steps required to deliver secure CO_2 geological storage, with a leading programme examining well integrity.

Over this period of time there has also been a sea change in scientific, political and public opinion towards recognition of the need for swift, decisive action to reduce anthropogenic CO_2 emissions. This consensus is underlined by the most recent report from the Nobel Prize-winning Intergovernmental Panel on Climate Change (IPCC), which concluded that global CO_2 emissions need to be cut from current levels by 50-80% by 2050 to avoid the most damaging effects of climate change. At the same time, scientific and economic projections clearly demonstrate the pivotal role that fossil fuels will continue to play to meet the world's growing energy needs in the short to medium-term. The projections also suggest that renewable energy capacity cannot grow quickly enough to replace them.

A major acknowledgement for CCS came in July 2005, when the Carbon Sequestration Leadership Forum (CSLF) was endorsed by the G-8 Summit in its Gleneagles Plan of Action on Climate Change, Clean Energy and Sustainable Development, and identified it as a medium of cooperation and collaboration with key developing countries in dealing with greenhouse gases. The CSLF,

currently comprising 21 countries and the European Commission, is a Ministerial-level international climate change initiative whose mission is to facilitate the development and deployment of CCS technologies via collaborative efforts that address key technical, economic, and environmental obstacles. CCP is pleased to have been selected as a CLSF Recognized Project, which was a huge vote of confidence in the contribution that CCP would make.

The scale of the challenge facing the world is immense. There is no one technology option or 'magic bullet'. A portfolio of approaches including renewables, nuclear and energy efficiency measures is likely to be required to provide secure, affordable energy that does not negatively impact our environment. It is against this backdrop that CCS has been increasingly recognized as a critical technology that can be deployed now to reduce CO_2 emissions and ensure the world continues to benefit from fossil fuels.

CCS is a bridging technology that gives society time to deliver alternative energy sources at scale. CO_2 enhanced oil recovery (EOR) is already helping the oil industry recover oil and gas that would otherwise have been uneconomical. EOR combined with CO_2 storage will offer even greater advantages. CCS also provides an opportunity for rapidly industrializing countries like India and China, and major developed areas like the US, to use their abundant sources of low-cost coal to meet demands for energy while mitigating environmental impacts.

The IEA in their Energy Technology Perspectives June 08 report, believes that CCS could account for 19% of the total CO_2 emission reductions needed this century to stabilise climate change. With considerable thanks to CCP, it is now no longer a question of whether CCS is relevant, but of how it can be applied at scale and at a cost equal to or lower than the other low carbon energy alternatives.

The CCP's work both in its Phase 1 (2000-2003) and continuing into Phase 2 (2004-2009) has been focused on providing the scientific and technical understanding and know-how necessary to reassure that CO_2 can be securely stored and the costs of CO_2 capture can be reduced. Much of the focus has been on how this can be applied to power generation and the oil and gas industry itself, to reduce its own carbon footprint and associated operating costs. This focus will become even more necessary as we find ourselves living in an increasingly carbon constrained world.

The CCP Capture Team in Phase 2 has trialled a number of different capture technologies in refinery and gas fired power stations, building deep knowledge and learning while delivering significant cost reduction potential. Additionally, some of the capture technologies have been developed to the stage where they are now ready to be tested at pilot or demonstration scale. CCP's commitment to investing in next generation technology today is critical to CCS and ensures that the results of its work can apply to a wide variety of industrial applications and power sources, as well as those of the oil and gas industry.

The Project's Storage Monitoring and Verification Team have made considerable strides in scientific and operational understanding of two key facets of geological storage - well integrity and CO_2 storage site characterization. Additionally the extensive collective experience of each of the participants working in the project has been collated and published in early 2009 in a CCP Technical Publication entitled "*A Technical Basis for Carbon Dioxide Storage"*. This ground-breaking work is the definitive technical guide for potential CCS regulators, policy makers, operators and industry as to how CO_2 geological storage can be practically undertaken. The work is not just based on scientific and academic research and CCS demonstration projects but also the considerable expertise and operational data from analogous oil and gas operations held by each of the CCP's eight member companies. The report and detailed case studies further validate the fact that CO_2 can be – and is - safely stored in geological formations now. Alongside this, the Team has developed a Certification Framework to guide the evaluation of suitability of candidate sites in any given location. This consists of a platform for input of geological data, specialised tools to predict

behaviour of CO_2 in the subsurface and a tool to calculate risk. The simple and transparent results will be a useful tool to communicate with a range of stakeholders.

The Project's Policy and Incentives Team continued to work in close cooperation with the US Department of Energy and the European Commission and with environmental NGOs. The Project team has produced a number of important papers that highlight the need for early adopters of CCS to receive incentives and they have outlined positions on principles of storage certification, pipeline financing and long term storage liability. The required incentives reflect the commercial and technological costs of developing and pioneering any new mitigation technology.

This CCP2 publication presents the technical papers and findings from Phase 2 of the project in its entirety. The work is the combined effort of around 60 technology providers and academic institutions, key NGOs and each of the eight CCP member companies. A wide range of academic and commercial institutions, all subject to open and comprehensive peer review, have provided breakthrough thinking, concepts and technology. The views of external bodies, such as environmental groups and other associated NGOs, have also played a crucial role in shaping and reviewing work undertaken.

Through this international public–private collaboration, we believe CCP has made a significant impact in verifying technology for safe and secure geological storage of CO_2, influencing fit-for-purpose storage regulations and stimulating the next generation of capture technologies that can help drive down the costs of CCS.

The industrial participants in the CCP2 would like to thank all of the people who have worked so hard over the past 5 years from turning CCS from an interesting mitigation technology to something that is on the brink of commercial reality. Little would have been achieved without a huge degree of cooperation and hard work.

Our extended multi-disciplinary team and overall approach has ensured CCP is probably one of the most comprehensive scientific studies in the world on CCS. The Technology Advisory Board, which is made up of independent experts, played a key role in achieving this outcome. They provided an independent peer review of our work, ongoing assurance and advice to the CCP executive board, providing guidance on the direction of the research and verification that the project was making a unique and important contribution. I would personally like to thank the Technology Advisory board for their sage advice and commitment to help make CCP a comprehensive and highly credible technology research project.

Finally, I would like to formally thank the industrial participants – Chevron, ConocoPhilips, Eni, Petrobras, Shell, StatoilHydro, Suncor and BP – for their proactive engagement, unwavering commitment and strong leadership. Thanks are also due to our Associate participants, EPRI and Repsol YPF for their strong and valued support. Yet our partnership could not have made such outstanding progress without support from governments who worked with us and provided co-funding. Hence I formally want to recognise the US Department of Energy, Norway's Norges forskningsråd (Research Council of Norway) and the European Union (EU) for the role they planned in enabling CCP2 to accomplish its objectives and helping move forward the science and technology of CCS.

The Executive Board of CCP is confident that, with the level of expertise that the CCP has to hand, we are and will remain at the forefront of delivering the technical insight to making CCS a practical reality and thereby a major contribution to mitigating climate change.

Our efforts don't and can't stop with CCP2. We have made significant progress over the last eight years but there is still a long way to go. Every major oil, gas, chemical, power, pharmaceutical, steel and cement plant across the world has the potential to use and benefit from CCS. There are

even new ‘green’ technologies like Biofuels that could benefit from CCS. This is an industry that could still be growing in fifty years time.

As technologists and engineers we recognize the crucial role technology will continue to play. It will provide cost effective options and inform the policy debate. A CCS industry will need to continuously improve; Capture costs must diminish at pace through a mixture of “learning by doing” and application of next generations technologies, and new geological structures will need to be explored in such a way that builds confidence and reduces risk. But we also recognize that for CCS to be successful and deliver its full potential, we have to use our technical expertise and knowledge to demonstrate to consumers, NGOs and regulators that CO_2 has and can be securely stored in geological formations for millions of years.