

Preface

For a successful technology, reality must take precedence over public relation, for nature cannot be fooled.

—Richard Feynman, 1986

It is well known that the atmospheric carbon dioxide cycle (*carbon cycle* in short) has a vital role in maintaining the earth's dynamic system, components of that act on different time scales varying from less than a second to hundreds of years. Increasingly CO₂ is being added in the atmosphere from growing use of energy and its generation from fossil fuel combustion. This is affecting the natural carbon cycle, resulting in the global warming threat and climate change. Thus, the motivation for capturing carbon dioxide and storage comes from developing ways to remove excess carbon dioxide in the atmosphere for climate control.

The geo-engineering approach to climate change mitigation comprises 'removal of carbon dioxide' from the atmosphere as well as 'management of solar radiation' for controlling the global warming. The mechanics of reflecting part of the radiation back to space thereby preventing it to enter the earth's atmosphere is being worked out for the management of solar radiation. In this book we are focusing on carbon dioxide removal (CDR) processes. Sequestration of carbon dioxide by capture and storage or utilization into value-added products and energy fuels remains one of the most researched options for removal of excess carbon dioxide getting accumulated in the atmosphere.

The book 'Carbon Utilization—Applications for the Energy Industry' is the outcome of a capacity-building event held in India. It has appealing coverage of environment and engineering disciplines, viz. CO₂ abatement and utilization, CO₂ management in the industry towards a low carbon growth, CO₂ terrestrial sequestration and biotic options among others, for reducing carbon footprints in the atmosphere.

Scope

The book on carbon utilization incorporated invited lectures delivered at the workshop on awareness and capacity building, *Carbon Capture, Storage and Utilization: Towards low carbon growth Strategy*, held in New Delhi from July 27–31, 2015. Topics that could not be presented in the workshop, but proposed, are also included. The workshop was held by Climate Change Research Institute to highlight Indian contribution and has provided multidisciplinary perspectives for academic exchange of current research in the field of anthropogenic CO₂ sequestration and utilization as well as its application.

Although in a major policy shift, India has set a national target of achieving 175 GW installed electricity capacity from renewable energy sources by 2022 with solar energy having a major share of 100 GW, coal has been the backbone of India's electricity. India is the third largest producer and consumer of coal in the world and it is anticipated that coal continues to be dominant fuel in the coming decades for achieving the energy security. Yet we do not know how the coal use will take shape. Adoption of clean coal technologies and carbon sequestration as end-of-pipe solution provide low carbon pathways. Environment cess of INR 400 per tonne of coal use has been implemented as a policy imperative. A few questions therefore arise: whether to target use of renewable energy as the source of entire electricity (which would require huge investment), or to continue using fossil fuels and convert captured CO₂ to chemicals/fuels/plastics as it would make use of existing infrastructure to great extent? At the same time, what new conversion processes become possible in future with minimum energy consumption? Can we think of conversion of captured CO₂ directly into electricity in an electrochemical cell or its conversion to *graphene* which could eventually replace silicon chip? The solution of these would emerge with the application of science and technology to carbon capture and utilization. The possibilities are immense, a collection of state-of-the-art scientific reviews and research perspectives on carbon management strategies of relevance to the energy industry are presented in the book.

Already CO₂ sequestration and utilization are on the research agenda globally. National governments are investing heavily in carbon capture and utilization (CCU) research and there are significant ongoing research programmes worldwide. Innovations are taking place and reuse of waste CO₂ into valuable products is seen as not only environment savior, but also a step towards *circular economy*. Economics of CO₂ utilization would succeed in foreseeable future depending upon the purity and process used.

In the post-Kyoto phase, international protocols such as Paris Agreement on Climate Change have been signed by 175 countries (including European Union as one) in the 21st Conference of Parties meeting of the United Nations Framework Convention on Climate Change (UNFCCC) during December 2015. This protocol along with UN Sustainable Development Goals (SDGs) adopted in September 2015 give ample evidence of CO₂ sequestration linkages as a low carbon growth business strategy.

Structure of the Book

CO₂ sequestration and environment protection demand green energy and green technology. The book on Carbon Utilization has 19 chapters grouped into four sections namely:

- I. CO₂ Emission, Sequestration and Utilization
- II. Terrestrial Sequestration Options
- III. Low Carbon Growth Strategy from CO₂ Utilization
- IV. Current Research and Green Technology Perspectives for Industry

Part I covers a policy issues for energy and environment security in India. There is a need for all energy sources with the advancement in technology for fulfilling basic needs of people. Chapter 1 provides an overview of trends in carbon emissions, geo-engineering solutions and carbon dioxide capture and removal processes as well as the need for capacity development in this emerging technology. Experience from Indian Power industry for reducing carbon footprints is shared in Chap. 2. Chapter 3 proposes a Green Power Mission by way of clean energy technology development from renewable sources as well as coal based generation with CCS, for achieving a low carbon growth.

Part II covers research on terrestrial sequestration options in Chaps. 4–8. Chapter 4 is about the need for information on the spatial distribution of soil type for advancement of appropriate management techniques for carbon sequestration at the national level. In Chap. 5 authors further examine the soil carbon stock and soil CO₂ flux in the different terrestrial ecosystems, i.e. forest, bamboo and grasslands and relates it to land use patterns in north-east region of India. Chapters 6 and 7 provide assessment of the biomass potential plant species at different altitudes and in the coastal zone for regulating the carbon pool in these regions, respectively. A detail review of enzymatic CO₂ capture potential and current research in advancements made in the production of recombinant carbonic anhydrase is provided in Chap. 8.

In Part III Chaps. 9–14 describe CO₂ utilization as a low carbon growth strategy for India. The CO₂ chemical and biological conversion routes, innovative chlathrate hydrates to cage CO₂ and CO₂ injection in earth reservoirs for enhanced recovery of fuels are the research topics explained by the leading scientists and technocrats from an Indian perspective. Challenges of enhanced oil recovery in oil fields in India, strides made in enhanced coal belt methane recovery, recent success of CarbFix demonstration project in Iceland in June 2016 for utilization of CO₂ through accelerated mineralization in basaltic rocks and need for introduction of oxy fuel combustion of coal as a low carbon strategy for India are some of the important highlights.

Part IV of the book is on current research and green technology perspectives in energy industry covered in five chapters. Chapters 15–19 present technology advancement taking place in aluminum, steel and cement industry for mitigation of greenhouse gases. Exciting results from national companies in India are presented and the experiences are shared. Carbon footprint of Aluminum industry and

perspectives for carbon neutrality through R&D measures is the theme of Chap. 15. Chapter 16 explains result of a pilot plant at a National Aluminum industry in India for micro-algae based CO₂ capture to create accelerated carbon sink. Critical scientific inputs and strategies are required for achieving CO₂ reduction in iron and steel industry by technology management. In Chap. 17 emerging technology solutions for carbon reduction in steel production are dealt. Chapter 18 covers approach to mitigation of carbon emissions in cement production through application of new technology. More efficient CO₂ capture using ammonia process in the Indian context is explained in Chap. 19.

The views expressed are those of authors. It is hoped that whether you are a student of science, researcher, postdoctoral fellow, professor, or policy planner or in industry you would surely find the book Carbon Utilization as an Indian contribution inspiring, educating and motivating.

Acknowledgements

We would like to convey our profound gratitude and appreciation to all renowned authors and contributors for their strong engagement and commitment. We also take this opportunity to thank members of review team especially Prof. Satyanarayana, Delhi University and Dr. V.A. Mendhe, CIMFR for their time and valuable help.

The book on carbon utilization could not have happened without the workshop on awareness and capacity building. We thankfully acknowledge and express our sincere thanks to Ministry of Earth Science, Government of India and ONGC Energy Centre for providing financial support for the workshop organized by Climate Change Research Institute (CCRI). We also convey our thanks to Dr. J. S. Sharma, Head of Environment Division, ONGC, Dr. Anupam Agnihotri, Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur, Dr. V.A. Mendhe, CSIR-Central Mining and Fuel Research Institute, Dhanbad and Prof. Tapas Bhattacharyya, International Crops Research Institute for the Semi-arid Tropics, ICRISAT Development Centre, Patancheru for extending support.

We are indebted to Dr. M.O. Garg, Director General, CSIR who graced the workshop and delivered the inaugural address; Shri. M.P. Narayanan, former CMD Coal India and Dr. Jyoti Parikh, ED, IRADE who delivered special addresses. We express our gratitude to Dr. Anupam Agnihotri, Director, Jawaharlal Nehru Research, Design and Development Centre, Nagpur for the Keynote address on *CO₂ Management—Indian Aluminium Industry Perspective* and Dr. B. Bhargava, Director General, ONGC Research Centre who also spoke in the inaugural session. Our thanks are to Shri R.K. Sachdev, Former Adviser, Ministry of Coal for steering the workshop concluding session.

We benefitted from the wisdom and insights of Prof. D.P. Agrawal, Chairman, Governing Council, Climate Change Research Institute, and its members especially Prof. V.S. Verma and Shri Gautam Sen for their heartening support. We extend our sincere thanks to Shri L.K. Bansal, Dr. Neha and Shri Anish Tripathi as well as

other members of executive committee of CCRI. We thank all participating institutions in India as per annexure I as well as Jupiter Oxygen Limited, USA.

Last but not least Swati Meherishi, Executive Editor, Applied Science & Engineering, Springer and her team deserves to be praised for their constant support.

New Delhi, India
Kochi, India
September 2016

Malti Goel
M. Sudhakar

Carbon Utilization

Applications for the Energy Industry

Goel, M.; Sudhakar, M. (Eds.)

2017, XXV, 297 p. 58 illus., Hardcover

ISBN: 978-981-10-3351-3