Carbon Dioxide Recovery and Utilization

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Edited by

Michele Aresta
University of Bari,
Bari, Italy

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This book is dedicated to

my Family

Preface

This Book is a summary report of the EU Project BRITE-EURAM 1998 BRRT-CT98-5089 "RUCADI-Recovery and utilization of carbon dioxide". The Book presents an outline of the emissions in the EU (and a reference to the world emission) followed by a series of papers that are a roadmap to carbon dioxide utilization and cover the scientific and technical aspects of: CO_2 separation, CO_2 technological use, utilization of supercritical carbon dioxide, and actual and perspective use of carbon dioxide in chemical and biological processes. An assessment study of carbon dioxide utilization for the synthesis of methanol is also presented.

The Book has been written for consultation not only by scientists, experts and students, but also by the public. Therefore, an effort has been made by the Authors to use an open and plain language, while presenting accurate scientific and technical data and facts. The result is a collection of reports on technologies, scientific facts and data enriched with updated essential lists of references that represent the route to a deeper insight into the Science and Technology of carbon dioxide.

The work done gives a taste of the usefulness of carbon dioxide and may contribute to strengthen the paradigm shift from the concept of carbon dioxide as a waste to that of carbon dioxide as a resource.

Michele Aresta,
Editor,
Coordinator of the RUCADI Project.

Foreword

The recovery and utilization technologies can contribute to the reduction of both the emission of carbon dioxide and its immission into the atmosphere, two issues our Society has to cope with. The evaluation of the contribution that the utilization option can give to the control of the accumulation of carbon dioxide into the atmosphere is not an easy and straight task: in fact one should consider both the direct and indirect influence of the reuse of carbon dioxide. The fixation of CO_2 for the synthesis of commodities and fine chemicals is an example of the direct reduction of the emission of carbon dioxide, that is used as a source of carbon. The development of innovative technologies that use carbon dioxide and/or are simply less carbon-intensive (lower energy input, more direct syntheses, waste solvent reduction, high yield and high-selectivity syntheses with no- or low-waste production) is an indirect diminuition of the carbon dioxide emission. Both approaches are quite new and require a detailed analysis for understanding the potential of carbon dioxide utilization as a technology for reducing the CO_2 emission and immission in the atmosphere. In fact, a new synthetic methodology based on carbon dioxide does not contribute to its reduction only with the amount of carbon dioxide incorporated into a chemical, but also through the energy-mass-waste-organic solvents reduction. In some cases the latter can represent a much more important contribution than the former. Only the application of the LCA methodology for comparing the existing and the innovative technology can really consent the evaluation of the avoided carbon dioxide.

The utilization of carbon dioxide is often considered as an impossible task to achieve because of the fact that carbon dioxide lays in a potential energy well. Actually, carbon dioxide can be fixed into organic compounds through many different ways, some of which demand a very low energy input, if any.

In this Book a comprehensive analysis is made of the sources of carbon dioxide, and their purity, of the separation technologies and of the uses of carbon dioxide, as a technological fluid or a reagent, or as a reactive solvent. The fixation of carbon dioxide in biomass that can be used as source of energy or chemicals is also considered.

The Book is organized in Sections that gather Chapters dealing with homogeneous contents.

Section I presents a detailed panorama of the carbon dioxide emission by the EU Industry and a comparison with the world data. The purity of carbon dioxide is discussed as a limiting factor to its use. In fact, for some specific purposes, as in the food-industry, contaminants that are often present in carbon dioxide streams must be absent. The elimination of such species to the required level, would rise the price of carbon dioxide and make not economic its use. Therefore, the knowledge of the purity of CO_2 is a key issue for deciding its most economic use and fate. This Chapter also presents the "merchant uses" of carbon dioxide, i.e. those uses in which there is not a chemical conversion of carbon dioxide.

Section II gives a deep insight into separation technologies, presenting advantages and disadvantages of each of them and their cost. An exhaustive discussion on technical plants is also presented and most innovative tecnologies detailed.

Section III describes the use of "supercritical carbon dioxide", and the innovative technologies based on it. It is divided in six Chapters dealing each with the: Particle formation in $scCO_2$, Supercritical fluid chromatography, Homogeneous catalysis in $scCO_2$, Heterogeneous catalysis in $scCO_2$, Polymers synthesis in $scCO_2$, and Modification of polymers in $scCO_2$.

Section IV presents the chemical utilization of carbon dioxide and is organized in four Chapters that address issues such as: Carbon dioxide fixation into organic compounds, with an analysis of the synthesis of compounds that require a low energy input; Linear organic carbonates, essentially focussed on DMC production; Electrochemical conversion of carbon dioxide, that details the opportunities for electrochemical suyntheses based on CO_2; and Carbon dioxide reduction to C1 or Cn molecules, with an analysis of the high-energy options, like fuels synthesis from carbon dioxide and dry-reforming of methane.

Section V introduces the fixation of carbon dioxide into biomass. This topic is divided in two Chapters dealing with the biological utilization of carbon dioxide, as an option for generation of renewable energy. The first Chapter details the use of macro- and micro-algae as source of fuels, the

second highlights the use of terrestrial and residual biomass as source of energy, detailing the existing technologies.

The sixth and last Section of the Book presents an assessment study of the carbon dioxide utilization for the synthesis of methanol and an industrial perspective of the use of carbon dioxide..

All together the Book furnishes a comprehensive prospect of the potential of the utilization option and gives information on the state of the art of a number of uses of carbon dioxide, clarifying if they are, or will be in the short term, exploited at the industrial level. This information, coupled with the presentation of the data relevant to the emission and the detailed report on the recovery technologies, gives a perspective of the usefulness of the Recovery and Utilization options and may inspire new scientific research.

The overall picture is that if the recovery of carbon dioxide will be exploited on a large scale as a technology for limiting the immission of carbon dioxide into the atmosphere, then the utilization option may have a key role as it contributes to reduce both the emission and the immission while generating a profit, that may pay back the recovery costs.

The reader will appreciate the effort made by the Authors to use a plain language, while giving both a sound scientific and technological basis to the presentation.

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