Preface

Climate change, energy and feedstock supply, and many other challenges have to be faced by society in the near future. New breakthrough solutions need to be developed that will address the balance of CO_2 in the Earth atmosphere and at the same time provide us with the needed resources. A visionary way to go would be to achieve full circle recycling of CO_2 using renewable energy sources analogous to how plants convert CO_2 to sugar and O_2, using sunlight as a source of energy through photosynthesis. Capture and conversion of CO_2 to chemical feedstock could provide a new route to a circular economy.

There is thus a new vision on CO_2 at the industrial, societal, and scientific levels. Carbon dioxide is not more considered an issue and even a waste to be reused, but a key element and driving factor for the sustainable future of chemical industry. There are different routes by which CO_2 can be converted to feedstock for the chemical industry using renewable energy sources, which also differentiate in terms of time-scale to be implemented. We will distinguish between the production of base raw materials for the chemical production chain (such as light olefins), advanced materials (such as CO_2-based polymers), and the production of fuels (also often indicated as solar fuels).

Europe with its excellent research and industrial landscape can be a key player for such a visionary approach, which can be a driver for innovation in chemical industry. As part of the general effort to identify the priorities and preferable approaches, but also to raise the interest on this topic, KT-Kinetics Technology and University of Rome "Campus Bio-Medico" have organized in April 2012 in Rome (Italy) a public workshop on "CO_2: Valuable Source of Carbon." This book originates from (but is not limited to) the contributions and discussions made during this workshop, and try to define the status and perspectives in this field. The workshop was organized in the frame of the activities of the EU project NEXT-GTL (NMP-3-LA-2009-229183), where one of the objectives is the recovery of CO_2 from the emissions of a new membrane-based process for converting methane to syngas by catalytic partial oxidation. The books and particularly the first introductory chapter reflect the discussions and recommendations held during this workshop.

The other chapters analyze specific aspects of this field. "Realizing Resource and Energy Efficiency in Chemical Industry by Using CO_2" discusses the different aspects related to the key question for the future of chemical industry: how to realize resource and energy efficiency in the chemical industry and the role of (re)use of CO_2 to achieve this objective. The necessity to improve the overall efficiency of resource consumption for industrial production and to increase the speed of innovation, particularly in Europe, caused a change in the priorities in both the social and industrial dynamics. Resource efficiency has being raised as the key topic of R&D activities. For example, a resource-efficient Europe is the flagship initiative of the Europe 2020 Strategy which objective is a radical shift toward a resource-efficient, low-carbon economy to achieve sustainable growth. New energy sources, particularly renewable, and addressing CO_2 emissions are two of the key elements to achieve this goal, and are closely interconnected as discussed in this chapter.

"Renewable Syngas Production via Dry Reforming of Methane" discusses in depth the important topic of the renewable syngas production via dry reforming of methane. Biogas produced by the anaerobic digestion of biomass can be exploited directly as a fuel for small-to-medium-scale combined heat and power production, or as a renewable carbon source for the production of synthesis gas and/or hydrogen for industrial syntheses or energetic purposes. The challenges for catalysts applied to the dry reforming of biogas (activity, sulfur poisoning, carbon formation, and sintering) are also examined.

"Reuse of CO_2 to Make Methanol Using Renewable Hydrogen" reports a technoeconomic analysis on the (re)use of CO_2 to make methanol using renewable hydrogen. The basics of the process architecture are discussed and integrated within a process scheme to analyze the effects of variables such as Capital Investment, Variable Operating and CO_2 at site costs, and electric power need for Nm^3 of produced H_2. These estimations are used to provide a comparison of the overall production cost with conventional hydrocarbon based technology.

"Ionic liquids Applied to CO_2 Fixation and Conversion" analyzes how the use of ionic liquids (ILs) offers new innovative possibilities for CO_2 fixation and conversion. An overview on the different ILs and techniques used to this purpose is reported, with the final part dedicate to analyze how the utilization of ILs can be breakthrough for passing algae-based processes from experimentation to application to produce biofuels and chemicals using CO_2 emitted from refineries or other plants.

"Sustainability in Carbon Capture and Utilization. Biodiesel from Microalgae" continues the analysis of the production of biofuels using microalgae, but focusing on the question of sustainability of the process, discussing in details the LCA (Life Cycle Assessment) studies on this subject. GHG (GreenHouse Gas) savings appear in line with the current EU standards for automotive fuel only under the most favorable conditions (biomass productivity at 25 gm^{-2} day^{-1}, lipid content at 40–45 %, water and nutrient recycle, favorable climate conditions, use of low energy wet oil extraction processes).

"Hydrogen Production by Solar Steam Reforming as a Fuel Decarbonization Route" discusses the important issue of hydrogen production by solar-powered steam reforming. This process allows some upgrading of the reformed fuel (in terms of heat value and environmental impact) and significant reduction (40–50 %) of CO_2 emission to the atmosphere, with respect to the conventional steam reforming process.

"CO_2 Conversion to CH_4" presents an overview of catalysts and processes for the conversion of CO_2 to methane, a reaction of increasing relevance for the Power-to-Gas concept of using this reaction to store renewable energy (particularly wind energy) during off-peak time. The reaction is also important for the upgrading of biogas and to produce substituted natural gas (SNG).

"Advances in Catalysts and Processes for Methanol Synthesis from CO_2" discusses recent advances on catalysts for methanol synthesis from CO_2, presenting first an analysis of the current state on the understanding of the reaction mechanism and nature of the active site and analyzing then the motivations why current catalysts for methanol from syngas (in the presence of few percentage of CO_2) should be changes in passing to the use of pure CO_2 feed.

"Methanol Production from CO_2 via Reverse-Water–Gas-Shift Reaction" is focused on reverse water gas shift reaction, the usual first step in processing CO_2. The chapter reports first a description of the process, to analyze then the critical issue of reactor simulation with a final economic assessment of the process.

Finally, "Carbon Capture and Utilization in Germany" reports a concise presentation of the activities in Germany on CO_2 utilization, because this is actually the country in Europe with the most advanced and dedicated program on this topic, involving also the participation of many major companies.

The book thus presents the topics of CO_2 (re)use from different perspectives, e.g., strategic, industrial, scientific, and societal, because this argument needs to have a holistic approach, being highly interconnected all these aspects. The editors are very grateful to all the authors for their willingness to participate in this book, and for their enthusiasm in writing the contributions, and for sharing their knowledge with the readers.

Marcello De Falco
Gaetano Iaquaniello
Gabriele Centi

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