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Narasinha Shurpali
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Greenhouse Gas Emissions

Challenges, Technologies and Solutions

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Preface

Energy demand has been rising remarkably due to increasing population and urbanization. Global economy and society are significantly dependent on the energy availability because it touches every facet of human life and its activities. Transportation and power generation are two major examples. Without the transportation by millions of personalized and mass transport vehicles and availability of 24×7 power, human civilization would not have reached contemporary living standards.

The International Society for Energy, Environment and Sustainability (ISEES) was founded at Indian Institute of Technology Kanpur (IIT Kanpur), India, in January 2014 with the aim of spreading knowledge/awareness and catalysing research activities in the fields of energy, environment, sustainability and combustion. The society's goal is to contribute to the development of clean, affordable and secure energy resources and a sustainable environment for the society and to spread knowledge in the above-mentioned areas and create awareness about the environmental challenges, which the world is facing today. The unique way adopted by the society was to break the conventional silos of specializations (engineering, science, environment, agriculture, biotechnology, materials, fuels, etc.) to tackle the problems related to energy, environment and sustainability in a holistic manner. This is quite evident by the participation of experts from all fields to resolve these issues. ISEES is involved in various activities such as conducting workshops, seminars and conferences in the domains of its interest. The society also recognizes the outstanding works done by the young scientists and engineers for their contributions in these fields by conferring them awards under various categories.

The second international conference on "Sustainable Energy and Environmental Challenges" (SEEC-2018) was organized under the auspices of ISEES from 31 December 2017 to 3 January 2018 at J N Tata Auditorium, Indian Institute of Science Bangalore. This conference provided a platform for discussions between eminent scientists and engineers from various countries including India, USA, South Korea, Norway, Finland, Malaysia, Austria, Saudi Arabia and Australia. In this conference, eminent speakers from all over the world presented their views

related to different aspects of energy, combustion, emissions and alternative energy resources for sustainable development and a cleaner environment. The conference presented five high-voltage plenary talks from globally renowned experts on topical themes, namely "Is It Really the End of Combustion Engines and Petroleum?" by Prof. Gautam Kalghatgi, Saudi Aramco; "Energy Sustainability in India: Challenges and Opportunities" by Prof. Baldev Raj, NIAS Bangalore; "Methanol Economy: An Option for Sustainable Energy and Environmental Challenges" by Dr. Vijay Kumar Saraswat, Hon. Member (S&T), NITI Aayog, Government of India; "Supercritical Carbon Dioxide Brayton Cycle for Power Generation" by Prof. Pradip Dutta, IISc Bangalore; and "Role of Nuclear Fusion for Environmental Sustainability of Energy in Future" by Prof. J. S. Rao, Altair Engineering.

The conference included 27 technical sessions on topics related to energy and environmental sustainability including 5 plenary talks, 40 keynote talks and 18 invited talks from prominent scientists, in addition to 142 contributed talks, and 74 poster presentations by students and researchers. The technical sessions in the conference included Advances in IC Engines: SI Engines, Solar Energy: Storage, Fundamentals of Combustion, Environmental Protection and Sustainability, Environmental Biotechnology, Coal and Biomass Combustion/Gasification, Air Pollution and Control, Biomass to Fuels/Chemicals: Clean Fuels, Advances in IC Engines: CI Engines, Solar Energy: Performance, Biomass to Fuels/Chemicals: Production, Advances in IC Engines: Fuels, Energy Sustainability, Environmental Biotechnology, Atomization and Sprays, Combustion/Gas Turbines/Fluid Flow/Sprays, Biomass to Fuels/Chemicals, Advances in IC Engines: New Concepts, Energy Sustainability, Waste to Wealth, Conventional and Alternate Fuels, Solar Energy, Wastewater Remediation and Air Pollution. One of the highlights of the conference was the rapid-fire poster sessions in (i) Energy Engineering, (ii) Environment and Sustainability and (iii) Biotechnology, where more than 75 students participated with great enthusiasm and won many prizes in a fiercely competitive environment. More than 200 participants and speakers attended this four-day conference, which also hosted Dr. Vijay Kumar Saraswat, Hon. Member (S&T), NITI Aayog, Government of India, as the chief guest for the book release ceremony, where 16 ISEES books published by Springer under a special dedicated series "Energy, Environment, and Sustainability" were released. This is the first time that such significant and high-quality outcome has been achieved by any society in India. The conference concluded with a panel discussion on "Challenges, Opportunities & Directions for Future Transportation Systems", where the panellists were Prof. Gautam Kalghatgi, Saudi Aramco; Dr. Ravi Prashanth, Caterpillar Inc.; Dr. Shankar Venugopal, Mahindra and Mahindra; Dr. Bharat Bhargava, DG, ONGC Energy Centre; and Dr. Umamaheshwar, GE Transportation, Bangalore. The panel discussion was moderated by Prof. Ashok Pandey, Chairman, ISEES. This conference laid out the road map for technology development, opportunities and challenges in energy, environment and sustainability domains. All these topics are very relevant for the country and the world in the present context. We acknowledge the support received from various funding agencies and organizations for the successful conduct of the second ISEES

conference SEEC-2018, where these books germinated. We would therefore like to acknowledge SERB, Government of India (special thanks to Dr. Rajeev Sharma, Secretary); ONGC Energy Centre (special thanks to Dr. Bharat Bhargava); TAFE (special thanks to Sh. Anadrao Patil); Caterpillar (special thanks to Dr Ravi Prashanth); Progress Rail, TSI, India (special thanks to Dr. Deepak Sharma); Tesscorn, India (special thanks to Sh. Satyanarayana); GAIL, Volvo; and our publishing partner Springer (special thanks to Swati Meherishi).

The editors would like to express their sincere gratitude to a large number of authors from all over the world for submitting their high-quality work in a timely manner and revising it appropriately at short notice. We would like to express our special thanks to Drs. Matthew Bell, Mokhele Moelisti, Eleanora Nistor, Kofi Boateng, Beibei Yan and Rafael Eufrasio, who reviewed various chapters of this book and provided very valuable suggestions to the authors to improve their manuscript.

Climate change is a global threat. The impacts of a changing climate are evident in the form of extreme climate, increased droughts and floods, sea level rise and permafrost thawing in the Arctic with an overall impact on the global radiation balance and surface temperature. Our dependence on fossil fuels, deforestation and land use are the major anthropogenic causes that have lead to the changes in our atmospheric composition. Greenhouse gases (GHGs), essential for maintaining an average global temperature, have seen a rise in their concentrations in the atmosphere, owing to the human perturbation of the climate system. To curb the unprecedented rise in atmospheric GHGs, the global community is striving to account for the various sources and sinks of GHGs, so that high emitters can be identified, opportunities to mitigate climate change can be formulated, and adaptation majors can be sorted out. In this context, this book serves to present case studies on GHG emission scenarios from different parts of the world.

Kuopio, Finland — Narasinha Shurpali
Kanpur, India — Avinash Kumar Agarwal
Visnagar, India — V. K. Srivastava

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Avinash Kumar Agarwal is a professor in the Department of Mechanical Engineering at Indian Institute of Technology Kanpur. His areas of interest are IC engines, combustion, alternative fuels, conventional fuels, optical diagnostics, laser ignition, HCCI, emission and particulate control, and large bore engines. He has published 24 books and more than 230 international journal and conference papers. He is a fellow of SAE (2012), ASME (2013), ISEES (2015) and INAE (2015). He has received several awards such as the prestigious Shanti Swarup Bhatnagar Award in engineering sciences (2016), Rajib Goyal Prize (2015) and NASI-Reliance Industries Platinum Jubilee Award (2012).

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Chapter 1
Introduction to Greenhouse Gas Emissions

Narasinha Shurpali, A. K. Agarwal and V. K. Srivastava

Abstract Climate change is a global threat. The increasing concentrations of greenhouse gases (GHGs—carbon dioxide, methane, and nitrous oxide) in the atmosphere are blamed for the changing global climate. The greenhouse gases play a key role in causing climate change, and the biosphere can contribute positively as well as negatively to the atmospheric GHG concentrations through feedback processes. Knowledge of the feedback processes and their interactions with climate change and human activities is necessary if we are to understand to what impact feedback processes will have on climate change and to what extent manipulation of the biosphere will actually have the desired beneficial effects. In this context, a significant amount of scientific research work has been done and is continuing across different parts of the world to characterize the sources and sinks of GHGs. Thus, the book entitled, 'Greenhouse Gas Emissions,' is a compilation of select case studies on the topic authored by international scientists from different parts of the world.

Keywords Climate change · Agriculture · Decarbonisation · Ruminants
Crop residue burning · Solar power · Mitigation

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The atmosphere forms a major part of our environment. The life on Earth dynamically responds to this environment. The atmosphere interacts with the biosphere, hydrosphere, cryosphere, and lithosphere on timescales from seconds to millennia (Jerez et al. 2018) and on spatial scales from molecules to the global level. Changes in one component are directly or indirectly communicated to the other components through complex processes and feedbacks. Human and societal actions, such as energy and land use and various natural feedback mechanisms involving the biosphere and atmosphere, have major impacts on the complex interplay between radiatively important trace gases in the atmosphere and climate (Dai 2016). The carbon dioxide content of the atmosphere has increased by 43% since 1750 (Ciais et al. 2013). The atmospheric CO_2 concentration as measured at the Mauna Loa laboratory during June 2018 was 411 ppm (as opposed to about 280 ppm during the preindustrial times). The growth rate of atmospheric CO_2 during the 1960–69 decade was 0.85 ppm year^{-1}, while it climbed to 2.28 ppm year^{-1} during the recent 10-year (2008–17) period. The reason for such a drastic change in the atmospheric composition is attributed to our overdependence on fossil fuels for energy and deforestation. Corresponding to this rise in CO_2 content, the mean global surface temperature has already increased by 0.85 °C, compared to the preindustrial era (Hansen et al. 2010). Additionally, global methane concentrations have increased from 722 parts per billion (ppb) in preindustrial times to 1834 ppb by 2013, an increase by a factor of 2.5 and the highest value in at least 800,000 years. Nitrous oxide (N_2O) is among the most important greenhouse gases (GHGs) as its one molecule has about 300 times greater warming potential than that of CO_2 over a 100-year time horizon (Myhre et al. 2013). It is produced both in natural and managed soils, agricultural soils being the largest anthropogenic source. Changes in the atmospheric composition of these GHGs are causes for a changing climate across the globe. The impacts of climate change are becoming evident across all continents in the warmer oceans, reduced snow and ice cover and rising sea levels. With this in view, we have made an attempt in this book to gather information on GHG dynamics in different parts of the world and present a few case studies on the possibilities for mitigation of climate change.

Agriculture in northern European regions, such as Finland, is limited by the short growing seasons and low cumulative degree days during the growing period. Climate change is projected to lengthen the growing seasons and increase the growing degree days. Crop yields are projected to increase in Northern Europe, although the projections allow for both positive and negative impact on crop yields. Finland is a northern country with cool and temperate climate. This has implications for the greenhouse gas balance of cultivated soils. Utilizing organic soils for food production is unavoidable in Finland owing to its high coverage of peat soils. The greenhouse gas emissions per hectare are several folds on organic soils than on mineral soils. Thus, despite their proportion being only ten percent of the total cultivated area in Finland, the organic soils are a dominant source of agricultural carbon dioxide and nitrous oxide emissions at the national level. Chapter 2 provides

an account of the emissions from organic agricultural soils in Finland as relevant to the land use and climate change policies in Finland.

In Italy, in addition to industry, transport, and energy sectors, agriculture is one of the main sources of anthropogenic greenhouse gases (GHGs) emissions. Intensive and extensive cultivation practices such as fertilization and fuel consumption for tractors are the more impactful factors in terms of global GHGs. Italy does not represent an exception to the rule, and owing to its high variability in its environmental and geomorphological conditions, a wide range of agricultural systems are adopted in the country with varying GHGs emission potentials. CO_2 emissions are primarily produced from mechanized agriculture in the country. Northern Italy is known for its paddy cultivation, which is the main source of CH_4 emissions that are produced in flooded fields from anaerobic microorganisms. Crop and animal husbandry are practiced in tandem, and thus, methane emissions from farm animals are also an important GHG source in the country. In addition, the intensive use of fertilizers contributes to N-based emissions following nitrification/denitrification and N-volatilization processes into the soil. Chapter 3 gives an account of how the Italian agriculture plays a key role in GHGs emissions.

Romania is a major European wine country with rich historic and cultural traditions, many of them directly related to wine. The national policies are geared towards making this country a producer of high-quality wine and thus a valued member of the world wine community. The total area under viticulture in Romania represents about 2% of the total arable land area. Viticulture accounts for about 7% of the total agricultural production and wine ranks third among the exported agri-food products. While there are not many studies reporting GHG emissions from grape cultivation in Romania, Chap. 4 provides the perspective on Romanian viticulture.

Agriculture in the sub-Saharan African sub-continent, although still rudimentary in terms of management practices and production efficiency, provides the mainstay for majority of its people. Chapter 5 takes a look at the sub-Saharan African agriculture, its contribution to the emission of Greenhouse gases, and their pathways. It aims to address the effects of a changing climate on SSA agricultural productivity. The contribution of SSA agriculture to the socioeconomic well-being of its people is also discussed. Adaptation and resilience building among the dominating smallholder farmers in the region are captured as well as the factors that hinder the effective scaling up of strategies aimed at ameliorating the effects of climate variability on local agriculture. Finally, policy interventions geared toward the significant reduction of climate change effects on SSA are discussed.

South Africa is a major emitter of greenhouse gases (GHG) and accounts for 65% and 7% of Africa's total emissions and agricultural emissions, respectively. South Africa has a dual agricultural economy, comprising a well-developed commercial sector and subsistence-oriented farming in the rural areas. The country has an intensive management system of agricultural lands. Agriculture, Forestry and Land Use are the second largest emitter in the country. Chapter 6 presents characteristics of GHG emissions from crop management in South Africa with a national perspective sustainable mitigation options.

In 2017, the UK powered itself for a full day without coal for the first time since the Industrial Revolution. In addition, in the beginning of this year, it laid out a strategy to phase out all coal-fired power plants by 2025. This has been made possible by an upsurge in the use of renewable energy in the country. Such efforts to combat climate change show a significant decrease in CO_2 emissions during the last 5 years. Adoption of positive national climate change strategies has lead UK on a steady transition toward a low-carbon economy. Chapter 7 reviews the current state of the greenhouse gas emissions in the UK and describes what measures UK has adopted to take the nation on the path of a low-carbon economy.

While the above chapters provide country-specific GHG emission scenarios, this book also provides insights into other issues that are relevant to national GHG accounting. Some such case studies include methane emissions from cattle and emissions from crop residue burning. Humans depend on livestock as they are an important source of meat, milk, fiber, and labor. Energy is lost in the form of methane gas when the ruminants digest plant material through rumen fermentation. Ruminant livestock is a significant source of atmospheric methane, with an estimated 17% of global enteric methane emissions from livestock. Methane is a potent GHG with about 25 times higher warming potential than CO_2. The chapter on measuring methane emissions from ruminants (Chap. 8) provides a review on the measurement techniques and discusses their advantages and limitations with a perspective on accurate accounting of these emissions from this important source.

India is one of the key global producers of food grain, oilseed, sugarcane, and other agricultural products. Agriculture generates huge amounts of crop residues. With an expected increase in food production in the future, crop residue generation will also increase. These leftover residues exhibit not only resource loss but also a missed opportunity to improve a farmer's income. Currently, the farmers in India resort to residue burning, a practice that is perceived to enhance soil carbon sequestration. While such a practice is being followed since a long time, its impact on the environment is not well understood (Chap. 9). There is a need for extensive research with large-scale GHG measurements from crop residue burning in India.

At the Paris COP21 climate summit held at the end of 2015, a Breakthrough Energy Coalition and Mission Innovation plans were formulated by the participating countries. These are strategies aimed at reducing global GHGs, the use of clean energy and limiting the global surface temperature increase to 2 °C or less by 2050. With abundant solar energy available in India, attempts are in full swing to harness this renewable source of energy in the country. The chapter on rooftop solar power generation (Chap. 10) exemplifies these attempts with a case study from a metropolitan city in western India, while the chapter on renewable energy sources in India (Chap. 11) focusses on policies of the central and state governments in India to promote renewable energy, especially solar energy, to reduce national GHG emissions.

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