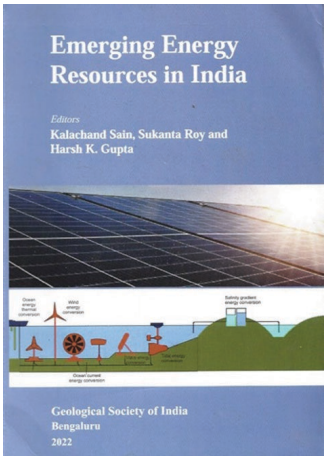
To conclude, historians of science would readily accept the idea that studies in microbiology in the decades of the mid-to-late-20th century had provided the underpinnings for not only the concepts of, but also appropriate tools for research in the discipline of modern molecular biology. Examples of such contributions from the microbiological studies have included (i) the identification of DNA as genetic material, (ii) establishment of the central dogma of molecular biology, (iii) elucidation of the mechanisms for regulation of gene expression, and (iv) development of methods for gene cloning, PCR, protein overexpression, and most recently CRISPR gene editing. It is no surprise, therefore, that these advances have, in turn, also been employed in studies of the microbiological world itself. The current emphasis is towards a better understanding of microbes not so much as solitary cells but as interacting partners within the larger biosphere, such as to exhibit social behaviours including those that are density-dependent (quorum sensing), or in biofilms, or as part of a microbiome, or in symbiotic or parasitic relationships with other host organisms. This focus is aptly reflected in the variety of articles in this volume.

1. Oren, A., *Philos. Trans. R. Soc. London B*, 2004, **359**, 623–638.
2. Alegado, R. A. and King, N., *Cold Spring Harb. Perspect. Biol*., 2014, **6**, a016162.
3. Bar-On, Y. M., Phillips, R. and Milo, R., *Proc. Natl. Acad. Sci. USA*, 2018, **115**, 6506–6511.
4. Larsen, B. B., Miller, E. C., Rhodes, M. K. and Wiens, J. J., *Q. Rev. Biol*., 2017, **92**, 229–265.

J. GOWRISHANKAR

Indian Institute of Science Education and Research,
Sector 81, SAS Nagar,
Mohali 140 306, India
e-mail: shankar@iisermohali.ac.in



Emerging Energy Resources in India. Kalachand Sain, Sukanta Roy and Harsh K. Gupta (eds). Geological Society of India, No. 30&31, B. P. Radhakrishna Bhavan, 1st Main, 3rd Cross, Byrappa Garden, Kathriguppe, BSK 3rd Stage, Bengaluru 560 085, India. 222 pages. Price: Rs 600.

At the 26th Conference of Parties of the United Nations Framework Convention on Climate Change, India updated its climate commitments. It stated that it will take its non-fossil energy capacity to 500 GW by 2030, meeting 50% of its energy requirements from renewable energy. By 2070, India plans to achieve the target of Net Zero (Ministry of External Affairs, 2021). In 2020, renewable fuel sources contributed a small but growing proportion of primary energy consumption (1%). The Geological Society of India has brought out a timely publication covering eight emerging energy resources which have the potential to meet India's expanding energy demands. Domain experts have comprehensively dealt with each of the energy resources.

Kalachand Sain has lucidly dealt with the fundamentals of gas hydrate energy resources. Methane in gas hydrates along the Indian margin had been estimated to be 1500 times more than the country's gas reserves. This large resource could bridge the supply–demand gap of gas in India and reduce carbon footprint. A brief description of the constituents of the Government of India's National Gas Hydrate Program (NGHP) is given. Success in the production of gas hydrates from Canada, the USA, China and Japan has given hope to the Asia-Pacific countries to produce this enormous energy resource. However, studies on critical parameters need to be carried out for gas hydrate resource development. Various geophysical techniques for evaluating gas hydrate reserves have been identified. The production of gas hydrates is dealt with in detail. Production methods could be logistically challenging but could be replaced, initially by reservoir simulation. Readily available reservoir simulators can solve complex coupled processes for production. Though gas hydrates have been established in the Krishna–Godavari Basin, a concerted effort must be made to develop production methods suited to Indian offshore conditions.

Geothermal energy resources have been reviewed in detail by Sukanta Roy and Prafulla B. Sarolkar. Given the background of this energy resource, they have described the different types of geothermal energy resources as a result of the geology in areas of their occurrence. High-enthalpy resources found in volcanic regions and island chains provide the most efficient utilization of geothermal energy for generating electric power. Abundantly occurring medium enthalpy resources are sufficient to produce electricity in binary cycle power plants. The low enthalpy resources, abundantly found in most continental regions, are best suited for direct heating and cooling. A detailed history of hot spring mapping in India in the Himalaya, the Son–Narmada–Tapti (SONATA), West Coast, and Naga–Lushai provinces is presented. Key issues such as reservoir characterization are yet to be addressed in tandem with optimal utilization of the resource. A realistic assessment of the geothermal energy resources of India could pave the way for further research and technology development towards optimal utilization. Concerns about capacity building have been flagged.

M. Ravindran and G. A. Ramadass have contributed a well-illustrated chapter on Ocean energy resources – tidal or ocean thermal energy conversion (OTEC). As 70% of the earth's surface is covered by oceans, this renewable resource has enormous potential in various forms. India began its research on this energy resource in the 1980s and initiated installing shore-based plants on the islands and floating power plants along the main shoreline. Substantial progress has been made, and has crossed 20% share in renewable energy. The development of this energy resource is facing great challenges because of the high cost of the production plants and the cost of setting up offshore infrastructure. Reducing the cost of installation per MW production of electricity and increasing revenue from the plant could contribute to a brighter future for it.

Juzer Vasi has exhaustively dealt with the topic of solar energy – a renewable energy resource. India launched the National Solar Mission in January 2010 with a target of 22 GW of solar power by 2022, of which 20 GW is grid power and 2 GW is off-grid power. This required 20 million square metres of solar collector area by 2022. The 20 GW could be solar PV or concentrating solar power (CSP). Since then, the landscape of solar energy production has dramatically changed globally, with costs plummeting with new technologies and applications emerging. The basic operations of a solar cell which can provide power suitable for stand-alone and grid-connected usage have been described in this chapter. The author describes CSP, citing international examples. Despite this, PV has come to dominate the world, including India, due to several reasons. The author has further given the current status of solar photovoltaics globally and in India and given examples of two of the world's three largest solar parks established in India. Policymakers and implementation agencies are responsible for India reaching the 5th position among countries for cumulative capacity of solar power by 2020. The Government of India had announced measures to encourage Indian manufacturers to produce and supply state-of-the-art components. Prognosticating the future, the author has emphasized solar PV R&D, the International Solar Alliance, and the recycling of solar modules.

Coalbed methane (CBM) and Underground Coal Gasification (UCG) in the evolving energy landscape of India are dealt with by Amalendu Sinha and Debadutta Mohanty. In the backdrop of India's quest for a gas-based economy, the authors have critically evaluated both CBM and UCG technologies. The production of CBM is lucidly explained. The critical parameters for any successful CBM venture are gas content and permeability. Describing the production of CBM, they have enumerated critical factors to trigger desorption – Newtonian diffusion and Darcy's flow of gas. The authors have given the fundamental concepts and processes of *in situ* conversion of coal to gas. The key factors of a UCG project depend on proper site selection, choice of UCG reactor design, and operations in accordance with strict guidelines, and monitoring and mitigation of associated geo-environmental risks. Limitations of UCG development, such as subsidence and contamination of groundwater, have been described in fair detail. In the Indian context, the authors believe that since the country has vast resources of coal/lignite, which are not mineable, UCG could generate syngas of the order of 25 TCF.

Shale gas resources: an Indian perspective is presented by V. K. Rao. The author has described the current status of shale gas exploration in India in this chapter. Fifty well locations in four prospective basins were identified to be drilled. To date, only 31 wells have been drilled. The author has dwelt on the potential of shale gas in the Cambay Basin, in which the Cambay shale has the appropriate amount of TOC, thickness and thermal maturity. The shale gas potential of Gondwana sediments, Assam–Arakan, Krishna–Godavari, and the Cauvery basins are reported. A total of 540 TCF of shale gas potential has been reported in the country.

Shika Wadhwa and Devesh Kumar Avasthi present the global status of hydrogen production technologies. They give details of hydrogen production from different sources and argue that production of hydrogen from hydrocarbons is the most cost-effective. Biomass is a significant energy resource, and a range of biomasses can be employed to convert to hydrogen energy. Solar energy mediation in hydrogen production is dealt with in some detail. According to the authors, about 120 million tonnes of hydrogen are generated each year, two-thirds of which is pure hydrogen, while one-third is mixed with other gasses. About 95% of hydrogen is generated from natural gas, while 5% is produced as a by-product of chlorine production via electrolysis. Worldwide usage of hydrogen has also been described by the authors.

Anjan Ray, Ojasvi, Sudhakar Reddy Yenumala and Sunil Kumar present a lucid description of 'waste carbon' resources abundantly available in agrarian countries like India, which could be considered as an alternate renewable energy source and is presently a traditional means of energy in low-income societies. Waste carbon can contribute five times more energy than wind and solar energy combined. Biomass can be used as a substitute for fossil fuels to produce electricity, thermal energy and transportation fuels through various routes. Sources of bio-industrial wastes have been described in detail. The authors opine that energy from biomass can substantially replace fossil fuel utilization replacement.

Overall, this volume is handy to the budding as well as practising professionals in the field of unconventional and non-conventional energy sources.

JAMES PETERS[1]
SUBODH K. SHARMA[2,*]

[1]*124/5, Lane 9, Street 4,*
Rajinder Nagar,
Dehradun 248 001, India
[2]*352, 6th Street, Rajendra Nagar,*
Lucknow 226 004, India
**e-mail: subodh3329@gmail.com*