

Preface

As the largest agricultural country in the world, almost 810 million tons of crop residues and more than 1600 million tons of animal manure could be collected for biomass resources every year in China, which has provided solid energy foundation for the daily life of rural residents (i.e., cooking and heating). However, with the economic reform since 1979, the energy structure of China's rural areas has experienced tremendous changes. The commercial energy began to replace the conventional biomass energy to be the dominant energy consumption categories. According to the National Bureau of Statistics of China, only 5% of agricultural residues was fully utilized, which leads to the disorder stacking and severe waste of agriculture slurry. In addition, the consumption amount of commercial energy was 1.5 times large as that in the 1990s, resulting in the risk of energy crisis and environmental degradation. Thus, it is urgent to provide adequate, clean and affordable energy (renewable energy) for rural residents to meet basic energy demand and raise living standards as well as the mitigation of carbon emissions.

Biogas as a renewable energy is well thought to be an important option to satisfy the growing energy demand of rural areas in developing countries. It can be generated by anaerobic digestion process using categories of locally available biomass residual, i.e., animal waste, domestic sewage, agricultural residue. The comprehensive utilization of biogas in the agricultural system is an important application for the development of recycling economy. This means the multiple reuse and recycling of biogas products and by-products produced substitute for chemical fertilizer, feed, additives as well as commercial energy of agricultural activities and household issues, through which a closed ecological chain with efficient materials flows and energy flows could be achieved, bringing about the multilevel benefits covering both economic characteristics and environmental performance.

With regard to the environmental performance, ecological service and support (nonmarketable energy, materials, ecosystem service for diluting the emissions and subsidizing wastes) from the larger biosphere system are provided to guarantee upstream process demand of biogas system. Environmental cost for the resource generation and service support from a donor-side should be accounted to have a better understanding of the natural contribution to the biogas system. From the

downstream perspective, although biogas and biogas by-products generated could be substitute for commercial energy and bring about the GHG mitigation, there exist nonrenewable energy, consumption and environmental emissions in the upstream of the biogas system, e.g., biogas digester construction, and emissions during the process of biogas fermentation and generation. It is therefore necessary to introduce quantitative measures to improve the understanding of the ecological and environmental performance covering both upstream and downstream processes of the biogas system. Apart from energy resource utilization and environmental impacts, the economic feasibility and efficiency should be investigated to find the hot spots of cost accounting. Currency outflows for initial construction and installation cost, maintenance cost as well as utilization cost should be considered. Moreover, both actual and potential monetary inflows for the substitute benefits of biogas products should be listed. It would be crucial to construct economic framework to have an integrated view of the monetary flows and find the key to improve economic feasibility.

The goal of this book is to evaluate the economic feasibility and efficiency, environmental impacts, renewability, and sustainability of the biogas system from different perspectives and diagnose the key sections in minimizing environmental impact and maximizing economic output. First, the conceptual biophysical economic framework with the nexus of economy–ecology–environment was constructed to evaluate eco-economic property of the biogas system considering both direct and indirect support and feedback between system and the external. Based on the accounting framework established, the economic cost–benefit analysis combined with data envelopment analysis (DEA) was conducted to assess the economic feasibility, and then, efficiency, optimization ways to improve the economic performance are proposed based on the DEA. A hybrid life-cycle assessment model was established to evaluate both direct and indirect GHG emission and reduction of the biogas project from a supply-side perspective, and possible pathways to achieve sustainable and low-emission discharge of biogas system were also analyzed based on scenario analysis. Finally, emergy thesis combined with financial accounting was used to recognize and quantify ecological service and ecosystem contribution in the upstream process from a donor-side perspective. Moreover, emergy-based statements and reports were provided to reflect environmental pressure, renewability, and sustainability, based on which managerial interventions can be made to achieve sustainable biogas system.

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