Chapter 1
Introduction

Abstract This introductory chapter describes the broader historical context and perspective relevant to technology, engineering, and specifically application of technology and engineering to develop biofuel processes. Emphasis is given to the relationships between scientific research and global societal concerns with engineering acting as a bridge discipline between the two. Another point of emphasis that is highlighted is the need for thoughtful, integrative decision-making that accounts for aspects of research and societal concerns to arrive at processes that represent the confluence of the most desirable characteristics to meet society's needs.

Technology and engineering have long been connected to broad societal changes. The impact of technology and engineering on society easily goes back to the construction of simple tools in the Stone Age and progresses with metallurgy, the industrial revolution, the steam engine, and now advanced electronics, computers, and distributed information. Technological advances have helped to shape our society and have implications on our everyday lives.

Engineering is fundamentally a translational discipline that bridges scientific research and societal applications. While the goal is to develop technology that helps to address a problem or need in society, engineering progress is made by drawing upon advances in scientific research. Thus, in engineering there is a need to have a sound understanding of all the technical details of the relevant research and to balance that with a broad perspective of potentially competing societal interests (Fig 1.1).

As a gross overgeneralization, the majority of people on either end of the spectrum (research or society) may not have a great depth of knowledge about the other facet (e.g., a typical individual concerned about their energy usage likely is not knowledgeable about the depth and breadth of progress in alternative energy research). This concern is especially important for scientific researchers whose work drives technological innovation.

Individual researchers or research groups can be highly skilled and knowledgeable about their specific research area. As such, in terms of the research microcosm, research teams are very adept at formulating research plans and experiments

S. M. Clay and S. S. Fong, *Developing Biofuel Bioprocesses Using Systems and Synthetic Biology*, SpringerBriefs in Systems Biology,
DOI: 10.1007/978-1-4614-5580-6_1, © The Author(s) 2013

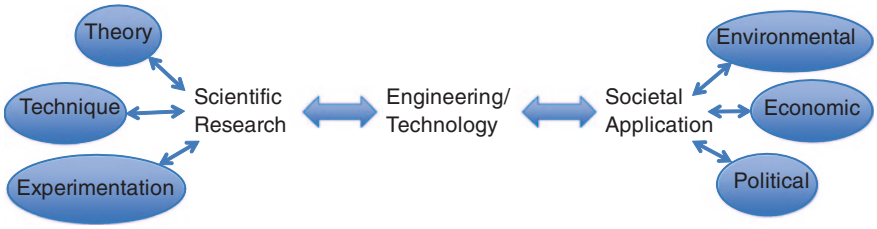

Fig. 1.1 Graphical depiction of the translational nature of engineering and technology to apply scientific research to address societal problems. *Ovals* depict illustrative examples of detailed concerns related to research or application

to advance knowledge in their area by balancing the state of knowledge in the field, techniques and methods available to researchers, and personal synthesis of ideas and hypotheses. As an academic pursuit, often the decision-making process for advancing research is largely dictated by the immediate environment of the research microcosm. Thus, not all research that advances our basic knowledge is easily translatable to an application.

One of the hallmarks of engineering and engineering education is being versed in problem solving by analysis, making appropriate assumptions, and reformulating problems (often in simplified forms). This is a decision-making process for technical problems. In the broader perspective of translating research to application and considering the variety of technical details from the research perspective and the global influences of the societal perspective, thoughtful decisions must be made, especially in terms of developing processes for biofuel production.

As a subject area, biofuels have a wide diversity of topics and details to consider. These range from social concerns that the general public is very aware of (food vs. fuel debate and economics of ethanol production) and technical research challenges in targeting the best starting materials, best fuel chemicals, and best organisms/processes for production. In addition to discussing these various topics, there is a need to consider all of these aspects to make decisions on where best to allocate resources and effort to quickly develop biofuel production processes with the best combination of beneficial characteristics. One main focus of this text will be to highlight some of this decision-making process.

In relation to biofuel production from a research perspective, biotechnology has historically utilized organisms for a variety of purposes including the early examples of alcohol fermentation and antibiotic production. A major move forward occurred with the identification and characterization of DNA as the fundamental building block of life coupled with molecular biology methods to replicate DNA in vitro (polymerase chain reaction). This led to directed modifications of organisms for various purposes including chemical production. The most recent major step forward in biological research is the improved knowledge of cell-wide components (genome, transcriptome, proteome, metabolome), their interactions (interactome), and methods to measure and manipulate whole cellular systems.

These recent knowledge and technology leaps have effectively moved biology to being an information-rich field, where early biology was characteristically information poor. With changes in available information, it may be appropriate to consider the decision-making process in biological research, especially for biofuels research where many competing constraints can be identified.

We believe that there exists sufficient knowledge from both a biological perspective and a chemical perspective to take a global view of biofuel research to suggest research avenues that would have the highest possibility of addressing all of the parameters needed for a successful fuel alternative. From a biological perspective, systems biology has helped to develop tools and a knowledge base to gain a broad, detailed perspective of cellular function and synthetic biology tools are facilitating design and controlled expression of different genes.

In relation to biofuel production from a societal perspective, there are a large number of different important and potentially competing interests to consider. These various competing interests include economic, environmental, political, and ethical considerations. In terms of developing biofuel processes, the various global societal considerations must be considered and may play a key role in identifying and developing the most promising biofuels to target and processes to produce them.

The remainder of the contents of this text is divided into Parts I, II, and III to consider the aspects of research perspectives, societal perspectives, and engineering to develop biofuel processes. Part I will provide background information on biofuels including some of the competing broader considerations for biofuel production. Part I also includes discussion of life cycle assessment (LCA) as a decision-making framework. Part II will provide information on the recent research areas of systems biology and synthetic biology that have direct relevance to bioprocessing and biofuel production. Part II will provide overviews of systems biology and synthetic biology including both experimental and computational techniques and provide example illustrations on how these apply to biofuel-producing bioprocesses. Part III will focus on describing the integration of information and approaches to engineer a biofuel-producing process and provide some perspectives on current and future areas of emphasis.