AIChE JOURNAL Highlight

Needed: ChEs to Solve Global Challenges

Chemical engineers and sound engineering principles have been absent from the discussions of global challenges — energy, climate change, food, and water — for too long, assert Bill Banholzer and Mark Jones of Dow Chemical in their August *AIChE Journal* Perspective article, "Chemical Engineers Must Focus on Practical Solutions." Society has thus confused what is possible with what is practical, particularly when it comes to energy, where new discoveries are greeted with over-excitement and the hope that each will provide the means to supply reliable, cheap, and almost-limitless energy, the authors say. They cite the hydrogen economy, cellulosic ethanol, and fuel cells as examples of technologies that have promised much but delivered little.

"Chemical engineers must do a better job explaining the difference between the subset of discoveries that offer practical solutions and the set that are simply possible," Banholzer and Jones say. They contend that chemical engineers are uniquely trained to understand mass and energy balances, to understand and apply scaling laws, to determine and understand rate-limiting steps, and to perform economic analyses — all of which can aid society in prioritizing resources to solve global challenges. "The world has a finite GDP [gross domestic product], and we must be exceptionally efficient so we don't waste it on ideas that require simultaneous miracles or violate thermodynamic principles," they explain.

In their Perspective article, the authors discuss energy to illustrate the use of fundamental engineering principles to differentiate between possible and practical.

Society's focus on clean energy is at odds with scientific and economic data. Consider coal, for example. While the use of renewable energy has grown substantially during the 21st century, in terms of total capacity, that growth pales in comparison to coal. Coal is inexpensive and has a high energy return on energy invested. The inexpensive power that is produced continues to drive coal's growth — illustrating the fact that the transition from one type of energy to another is slow, and this transition only occurs when a higher energy density fuel replaces a lower energy density one, and not the other way around, the authors explain.

Banholzer and Jones point out that media outlets highlight foolish efforts to grow energy crops under artificial lighting or to shroud buildings in algae, without regard for the concepts of conservation of energy and energy return on energy invested. Distributed manufacturing is heralded as an attractive aspect of biofuels, but this ignores the importance of scale in determining the efficiency and economics of production, they continue. And, they note, the conversion of CO_2 into fuel is discussed as if it is as simple as turning an arrow around to run a reaction in reverse. Sound engineering is frequently missing from these discussions.

Concerns about the grand challenges have spurred interest in clean technologies. Biofuels, solar, wind, and other alternative-energy options were the rage for most of the last decade, the authors say. However, ambitious plans for biofuels have generally failed to materialize. The costs of biomass resources have remained high, and are linked to the cost of the petroleum required to grow and harvest them. The availability of biomass remains questionable in many areas. Engineering tricks proposed to overcome the challenges of converting low energy density, nonhomogeneous feedstocks have largely failed. The renaissance of U.S. oil and gas production has stabilized prices, making the economics of biofuels less attractive. In response, many biofuels producers have pivoted toward the production of biochemicals and biomaterials, citing higher value and improved environmental footprints. Existing chemical processes, though, are tough to displace.

Banholzer and Jones issue a challenge to chemical engineers to bring their skills to bear in addressing society's grand challenges: The chemical industry continues to innovate and lessen the environmental impacts of its production processes. But while certainly valuable, that is not enough. The industry — and in particular chemical engineers — simply must do a better job of participating in the discussions about how these challenges should be addressed. Chemical engineers must drive decisions with data, and must ensure that economic considerations are part of the discussions. The innovative products manufactured by the chemical industry must be appraised in a way that not only accounts for the fossil fuels consumed, but also weighs that against the benefits they create.

The authors realize that some might disagree with their conclusions. But unlike theology or philosophy, where it might be difficult to use simple reasoning to choose between two opposing views, chemical engineering gives society the tools to quantitatively evaluate alternatives. Comprehensive energy balances, thermodynamics, mass balances, and financial analyses will produce one answer. There may be debate about assumptions around feedstock cost and availability, conversion efficiency, and so on, but there is an abundance of data to validate assumptions. Sound application of engineering does provide answers. CEP