

The need and challenge to find more sustainable alternatives for the modern society

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### **Abstract**

The population of the world is expected to reach 9 billion within the next 20 years. With the limited resources on planet earth, The challenge for a more sustainable modern society is have enough food, energy, water at, among others, reduced waste, increased efficiency, reduced environmental impact and increased profit. An order of magnitude improvement is necessary in the way resources are converted into useful products while also considering efficient energy minimization and use, water management, CO<sub>2</sub> management and chemical product-process design. That is, it is necessary to not only find truly innovative and more sustainable alternatives but also to educate-train students, young engineers and researchers on the need to study these problems so that the appropriate solution methods and tools that can solve these problems can be developed. Process systems engineering can play an important role as it is able to manage the complexity related to multi-scale, multi-disciplinary nature of the problems; efficient handling of large data; systematic, robust and reliable solution of the problem; and, the ability to handle a wide range of challenges.

A three-stage solution approach, where a model-based synthesis method is first applied to systematically generate and evaluate processing routes based on currently available technologies; then a base case design is generated from the identified processing route and analyzed to define sustainable targets for improvement; in the final stage, intensified and more sustainable alternatives are generated and verified using a phenomena-based method to find the truly innovative and more sustainable designs. By combining phenomena in the same way as atoms are combined to form molecules, new unit operations are identified, leading to new and innovative process designs. In this way, the search for more sustainable alternatives is done very quickly, reliably and systematically over a wide range, while experimental resources are preserved for focused validation of only the most sustainable candidates. The concept of the phenomena-based method for process intensification leading to more sustainable process design will be presented together with illustrations of its application through case studies related to the energy, water and CO<sub>2</sub> utilization problems.



Rafiqul Gani is professor of systems design at the Department of Chemical & Biochemical Engineering, The Technical University of Denmark and the head and co-founder of the Computer Aided Process Engineering Center (CAPEC). His current research interests include development of computer aided methods and tools for modelling, property estimation, process-product synthesis & design, and process-tools integration. He has published more than 300 peer-reviewed journal and conference articles and delivered over 300 lectures, seminars and plenary/keynote lectures at international conferences, institutions and companies all over the world. Professor Gani is editor-in-chief of the Computers and Chemical Engineering journal, editor for the Elsevier CACE book series and serves in the editorial advisory board of various journals, for example, the Journal of Process Systems Engineering and Current Opinion in Chemical Engineering. Professor Gani is the president of the EFCE (European Federation of Chemical Engineering), elected for term 2014-2016; a Fellow of the AIChE and also a Fellow of IChemE.