Optimal Synthesis and Planning of Sustainable Chemical Process and Energy Systems

Ignacio E. Grossmann
Center for Advanced Process Decision-making
Department of Chemical Engineering
Carnegie Mellon University
Pittsburgh, PA 15213, U.S.A.

In this lecture, we give an overview on the applications of recent models and algorithms for the discrete and continuous optimization of a variety of challenging applications in the optimal synthesis and planning of sustainable chemical processes and energy systems. We provide an overview of applications of deterministic models based on mixed-integer linear/nonlinear programming (MILP/MINLP), Generalized Disjunctive Programming (GDP) and global optimization to highlight the progress that has been made in the application of these optimization techniques to process and energy systems, many of which have been developed by chemical engineers in the area of process systems engineering. We first consider applications of MILP in energy systems that include optimization of hydrogen supply chains, and the long term expansion planning of electric power systems with high penetration of renewables. These problems give rise to optimization models with millions of variables and constraints, which can be effectively solved with special decomposition techniques such as Benders decomposition. Next, we consider applications of MINLP and GDP that include optimization of shale gas infrastructures, and synthesis of intensified distillation columns. These models have the capability of handling rigorous nonlinear models involving thousand and millions of design alternatives. Next, we consider recent algorithms for rigorous global optimization of nonconvex optimization models for which we consider applications in optimal process water networks that involve reuse and recycle, and optimal design of centralized and distributed manufacturing facilities for biomass production. The significance of these models is that they provide rigorous global optimal solutions. Finally, we briefly discuss the case when uncertainties are involved in the parameters of these models for which stochastic programming and robust optimization techniques have been developed. The variety of applications that we cover in this lecture, clearly illustrates the scope that optimization techniques have towards the optimal synthesis and planning of sustainable chemical processes and energy systems.