As a general goal of process development and design, process intensification aims at substantially improving process performance with a wide spectrum of chemical engineering skills. One important area, where process intensification can play a crucial role, is to handle uncertainty. An intensified process system design that considers varying input parameters can result in a more reliable set of operation decisions in order to tackle uncertainty. Shale gas processing systems remove valuable natural gas liquids (NGL) and undesired constituents from raw shale gas and serve as important components in the shale gas value chain. An important issue complicating the design of novel shale gas processing systems, however, involves handling uncertainty in feedstock compositions. Shale gas from various shale plays is subject to significantly different compositions and processing needs. Since a shale gas processing plant is usually designed to process raw shale gas collected from multiple shale wells, the composition of the received feedstock usually keeps fluctuating. If a processing plant is designed to process shale gas with fixed compositions, a large amount of off-spec gas will be produced when the real composition deviates from the designed composition. In order to maintain stable supply of qualified gas products, uncertain feedstock compositions must be considered in the intensified shale gas processing system designs.

In this work, we develop a systematic simulation-based process intensification algorithm for shale gas processing and NGLs recovery process systems under uncertain feedstock compositions. A deterministic design upgrades raw shale gas with a fixed feedstock composition, while a corresponding intensified design in this work applies the same process layout, but employs equipment units with strengthened capacities to hedge against uncertain feedstock compositions. In order to develop an intensified design, we first perform detailed process modeling and rigorous process simulation for a set of
deterministic designs. Next, the capacity of each unit in the intensified design is selected as the highest operating level of the same unit in deterministic designs. As an integral part of the intensified design, the operating conditions when feedstock uncertainty is realized are estimated as the set of deterministic operating conditions resulting in the highest operating cost. For the purpose of comparison, a thorough techno-economic analysis is later conducted for the deterministic designs and the intensified design. Lastly, we test all the designs with a wide range of representative compositions and the entire procedure is iterated until there is no more feasibility issues in the intensified design. We consider two shale gas processing and NGLs recovery process systems for illustration of the proposed method. A novel process system consists of a monoethanolamine absorption process in an acid gas removal section, a condensation process in a gas dehydration section, a turboexpander process in an NGLs recovery section, and a triethylene glycol absorption process in an NGLs dehydration section. The condensation process and the turboexpander process are further integrated to improve the overall energy utilization efficiency. The systems are used to process raw shale gas from 8 wellsites and generate pipeline gas for a downstream power plant. The results are compared between the deterministic designs and the intensified designs, as well as between the two process systems. We find that the intensified designs are effectively hedged against uncertain feedstocks.