U.S. Department of Energy

Reference Designs of Carbon-free Ammonia Plants Powered by Small Modular Reactors

Project Title

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ABSTRACT:

Globally, 43% of annual hydrogen production was used for ammonia production in 2018. As the result, ammonia production accounts for 2% of global fossil energy use and 1.2% of global GHG emissions. Given 80% of ammonia produced today is used in the fertilizer such as urea and ammonium nitrate, significant production increase of ammonia is expected with the growing population. Thus, decarbonizing the existing ammonia market represents a large opportunity for carbon-free ammonia to significantly reduce global GHG emissions. While wind and solar are desirable energy source for carbon-free hydrogen through water electrolysis, their intermittency requires costly energy storage. On the other hand, installing electrolyzers at existing nuclear power plants still needs transportation of hydrogen to ammonia production sites. Leveraging its simplicity and cost advantages, small modular reactors (SMR) are in the position to help the energy-intensive ammonia production industry reduce carbon emissions. Moreover, being increasingly considered as an energy vector, ammonia has significant advantages over hydrogen in terms of the cost of storage and transportation. Thus, we expect carbon-free ammonia will play a key role in enabling carbon-free hydrogen.

The overarching goal of this project is to develop two reference designs for carbon-free ammonia plants. One design uses freshwater as the source for hydrogen, while the other design uses seawater (or brackish water) as the source. In both designs, a NuScale SMR is used as the primary energy source providing both electricity and steam for the plants. This project provides an opportunity to demonstrate examples of SMR-powered integrated energy systems (IES) for carbon-free ammonia production. Having all feedstocks such as hydrogen and nitrogen produced onsite (co-located) provides great opportunities for system integration and efficiency improvement, leading to potentially great cost reduction. Unlike wind or solar that is constraint by geographic location and season, the proposed reference design can be built essentially everywhere, opening up the opportunity to bring ammonia plants close to the point of its consumption, significantly reduce the costs and carbon emissions associated with the transportation. Also, this localized production can increase the supply stability to resist potential supply disruption in contrast to centralized production.

At the end of the project, we strive to achieve the following four objectives:

Objective 1: Develop process models of the reference designs by leveraging and expanding existing models developed by our national lab partners. *Objective 2:* Investigate potential synergies between process units and provide process integration insights for the reference designs. *Objective 3:* Conduct two IES reference designs for carbon-free ammonia production using SMR as the primary energy source. *Objective 4:* Perform design optimization and technoeconomic analysis (TEA) for the two IES reference designs through case studies.