A risk analysis framework for evaluating the safety, reliability, and economic implications of electrolysis for hydrogen production at NPPs (RAFELHyP)

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ABSTRACT:
Nuclear Power Plants (NPPs) present an attractive opportunity to enable cost-efficient high temperature steam electrolysis hydrogen production facilities (HTEFs) in the U.S., enabling a new mechanism for clean energy storage and more flexible operating paradigms for NPPs. The ability to deploy HTEFs at nuclear plants in the U.S. will rely, in part, on the use of quantitative risk assessment (QRA) to conduct safety analysis that demonstrates conformance with Nuclear Regulatory Commission (NRC) regulations. Furthermore, QRA can be used to provide insight into design and safety requirements, such as recommendations for plant layouts and features that balance the interplay between risk, reliability, safety, and costs.

This work will examine how postulated failure events at a generic HTEF impact the safe operation of an NPP by utilizing quantitative risk assessment (QRA) as the organizing principle.
The objectives of this project are to:

- Develop a modular risk analysis framework that enables evaluating the safety, reliability and economic implications of upcoming deployments of electrolyzers for hydrogen production at NPPs.
- Implement the framework in conducting an integrated safety, reliability, and economic analysis of multiple plant configurations to provide detailed recommendations for plant protective features and layouts.

These objectives will be achieved through five closely integrated tasks: 1) Development of QRA scenarios, probabilities, and consequences 2) Development of the causal algorithmic capabilities to model complex causal interactions and emerging behaviors 3) Techno-economic analysis 4) Integrated safety, reliability, and economic analysis to produce design and safety recommendations 5) Broader industry and stakeholder engagement.

The insights generated will be used to propose design and safety recommendations for the layout of integrated HTEF-NPP systems and to establish cost-benefit tradeoffs for implementing these recommendations. This work will have two-fold immediate and long-term impact for the DOE, nuclear power, and the hydrogen generation community by providing new, foundational knowledge surrounding QRA and safety analysis capabilities for hydrogen electrolysis at NPPs, and by providing specific design and safety recommendations that can inform early-stage deployments and accelerate safe, reliable clean energy.