Hydrogen supply chain resilience: Inventory positioning and backup capacity under supply disruptions

Hydrogen is a key input for decarbonizing energy-intensive industries. Many industrial regions in Europe cannot produce renewable hydrogen at competitive cost and will source a large share of their demand from renewable-rich regions. These imports are planned to flow through a small number of long-distance pipeline routes. A cost-minimizing network concentrates supply on these routes. As a result, importing regions are exposed to supply disruptions, both at the production site and along the transport route. Firms and regions can mitigate this risk in two ways. The first is inventory. Hydrogen storage acts as safety stock, but its cost depends strongly on location: large-scale cavern storage is cheap but only available at certain sites, while storage close to demand is costly and limited in capacity. In addition, storage only buffers demand against disruptions that occur upstream of it. The second is backup capacity, for example a second import route or local electrolysis, which allows dual sourcing. The two levers interact. This raises the question of how much storage and backup capacity an importing region should hold, where storage should be positioned in the network, and how costly it is to move from an efficient to a resilient supply chain.

Building on the literature on hydrogen network design and supply chain resilience, the thesis develops an optimization model for an import-dependent hydrogen supply chain. Based on the student's initial analysis and proposed research design, the most suitable modeling framework (e.g., deterministic models with scenario-based disruption analysis or two-stage stochastic optimization) will be selected collaboratively. The model should be multi-period, so that it captures the replenishment of storage after a disruption and the dual role of storage in balancing variable renewable supply and buffering against disruptions. It should also capture the efficiency–resilience trade-off under disruptions that differ in location and duration, for example by using time-to-survive and time-to-recover as resilience measures. The thesis should show when storage and backup capacity act as substitutes and when as complements, and how the optimal inventory position depends on the disruption profile.

Prerequisites:

- Programming skills (e.g., Python)
- Knowledge of optimization (e.g., linear and mixed-integer programming)