Analysis of the Hydrogen Production and Delivery Infrastructure as a Complex Adaptive System

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Project ID
ANP4

This presentation does not contain any proprietary or confidential information

Overview

Timeline

- Project start: June ‘05
- Project end: April ‘08
- 0% complete

Budget

- Total $4.073 million
  - $3.62 million (DOE)
  - $453K (contractors)
- FY04 $0
- FY05 $100K

Barriers

- Barriers addressed
  - Primary Barrier E: Lack of understanding of the transition of a hydrocarbon-based economy to a H2-based economy
  - Secondary Barriers C and D: Stove-piped analytical capabilities and lack of macro-system model that addresses the overarching hydrogen fuel infrastructure as a system

Partners

- RCF, Argonne National Lab, Air Products, BP, Ford, WRI, and University of Michigan

Objectives

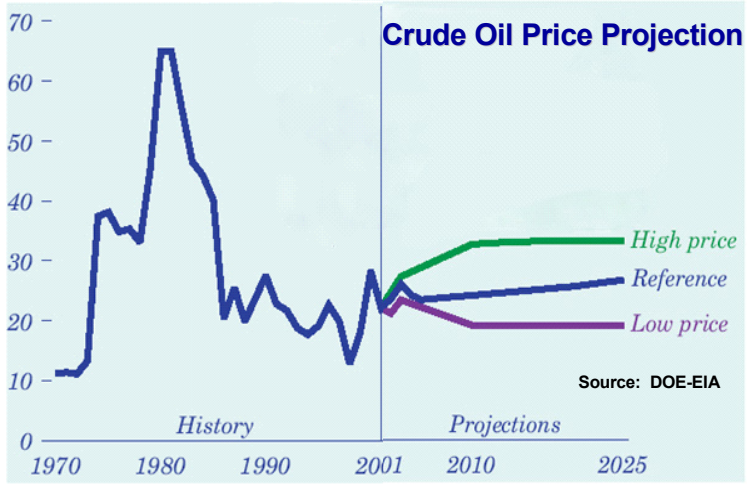
- Strengthen the understanding of transitioning to H2
- Use agent-based modeling and simulation (ABMS) techniques and complex adaptive systems (CAS) approach to study the dynamics of the transition
- Identify how the infrastructure might evolve, test solutions for robustness and determine what factors and strategies might contribute to stable/unstable market development and long-term market growth
- FY05 Objective: Initiate scoping of the model and the analysis

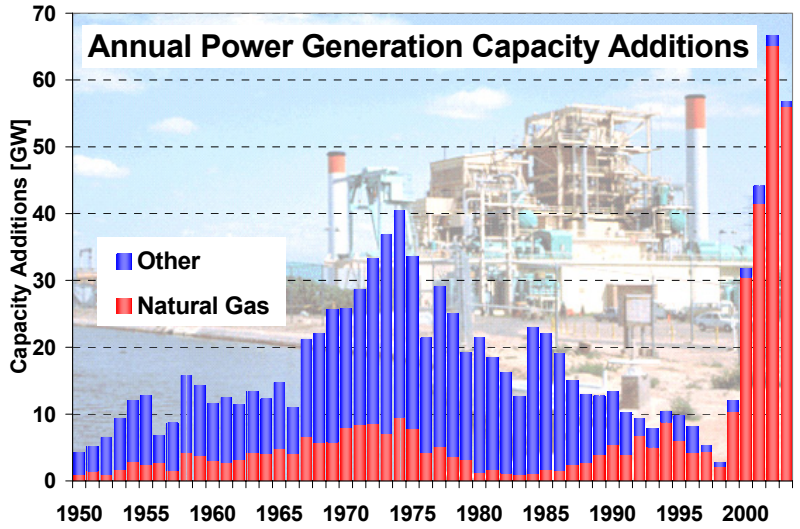
Approach

- ABMS simulates the decision rules that agents (stakeholders) follow, and their behavior as they interact with each other and with their environment
- An ABMS analysis of complex systems allows the agents to adapt their decision rules as they learn which behaviors enhance the achievement of their objectives and which result in undesirable outcomes
- This learning and adaptation process allows the agents to identify stable, periodic, and chaotic portions of the solution space as the agents explore different approaches

Current Models Do Not Adequately Capture Underlying Complexities

- Existing simulation and optimization tools are limited in accounting for volatility and uncertainty prevalent in today's energy markets
  - Single decision-maker
  - Perfect foresight
  - Rational decision-making
  - Energy markets in equilibrium
- Ignore dynamics, uncertainties, potential for sudden shocks and disruptions, market imperfections, and emerging strategies by market participants
  - California power restructuring
  - Recent crude oil/gasoline price volatility
  - Rush to natural gas for power generation and recent collapse
  - Recent blackouts



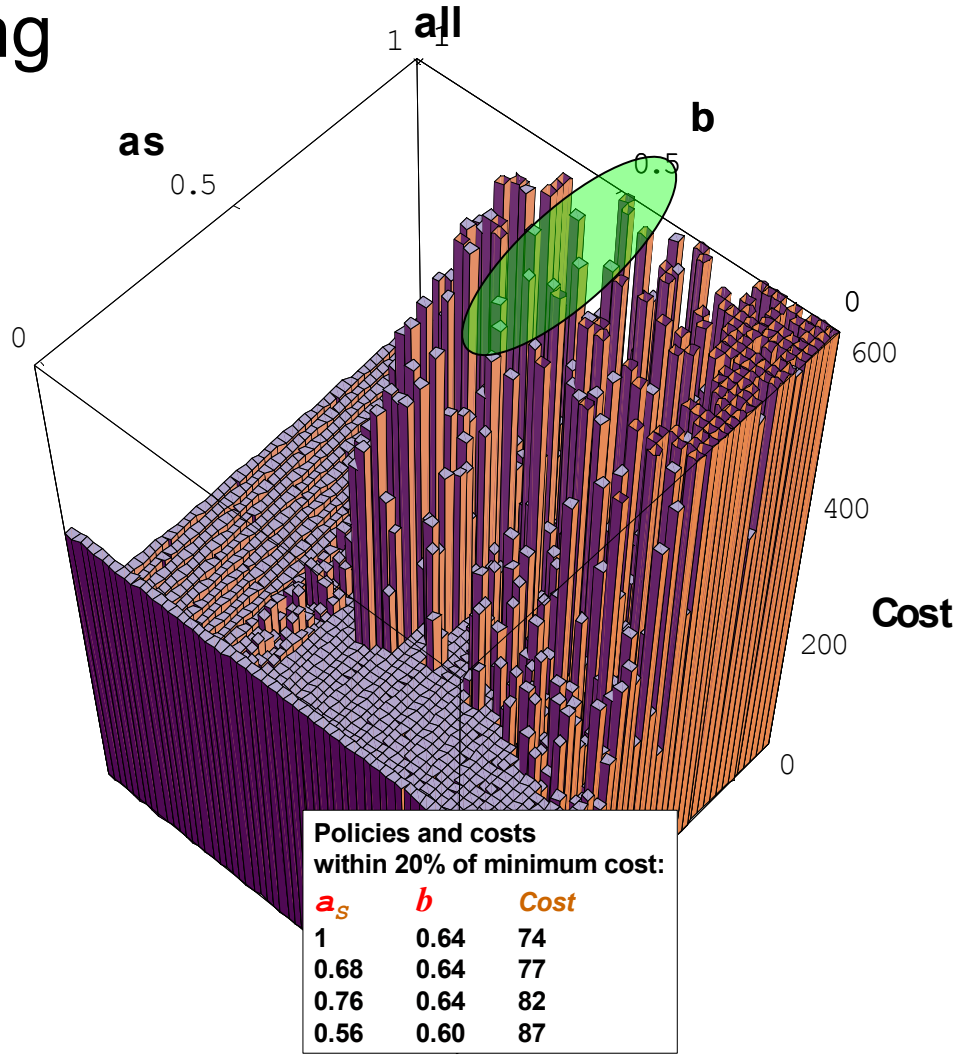


Transition Will Evolve as a Result of Complex Interactions Between Multiple Stakeholders

- Interest groups/stakeholders have different objectives, strategies, business profiles, and risk preferences: *not one single objective*
- Each interest group/stakeholder maximizes own objectives: *not social welfare*
- Objectives are often conflicting
- Decisions are based on imperfect knowledge and a mix of private (local) and public information
- Stakeholders learn and adapt to real or perceived changes in behavior of others or operating environment
- Transitory behavior may be of equal importance than equilibrium stage

New Models Are Needed to Explore Solution Space and Test Robustness of Solutions

- Better insights and understanding of complex behavior of large systems
- Explicit representation of uncertainty, system dynamics, decentralized decision-making, emergent behavior
- "Optimum" or "least-cost" solution a useful benchmark, but only one data point in the solution space
  - –Sudden, sometimes small, shifts in key parameters may expose downside risks
  - –May offer little flexibility to adapt decision mid-course to unexpected market developments



Agent-Based Complex Adaptive Systems Offers an Appealing Approach to Analyze Large Energy Systems

- Complex adaptive systems (CAS) consist of *numerous heterogeneous* individuals/entities that *interact* with each other and their environment, and *adapt* to change and evolve their behavior

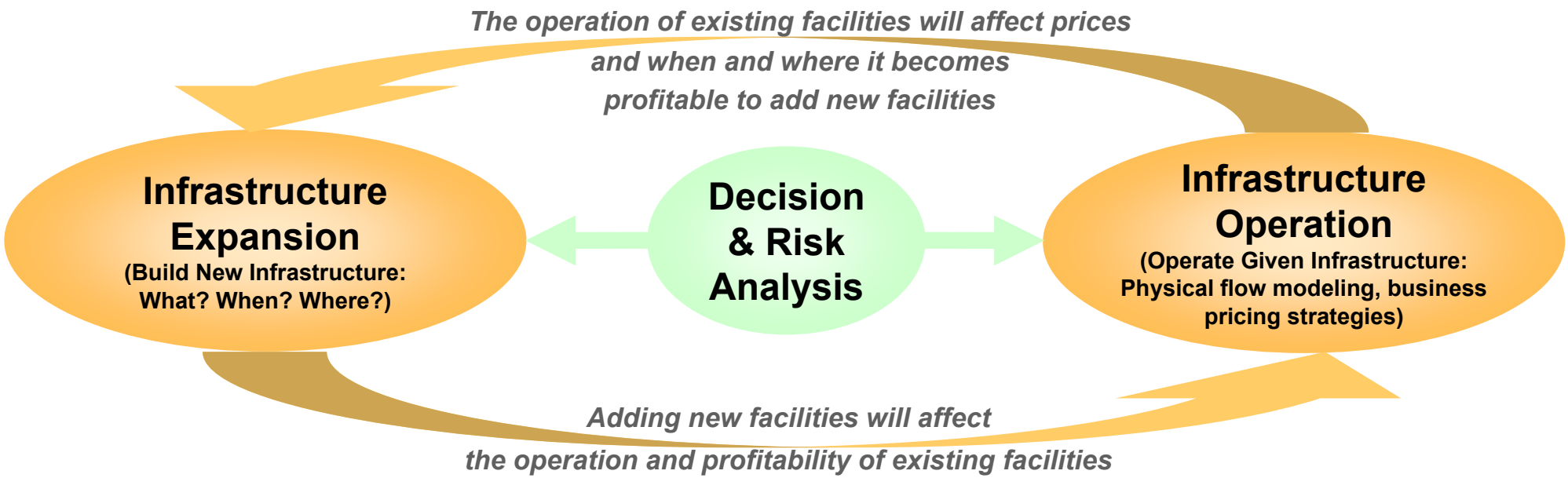
- Agent-based modeling and simulation (ABMS) simulates the behaviors and interactions of large number of individuals (*agents*) and studies the macro-scale consequences of these interactions

What is an Agent?

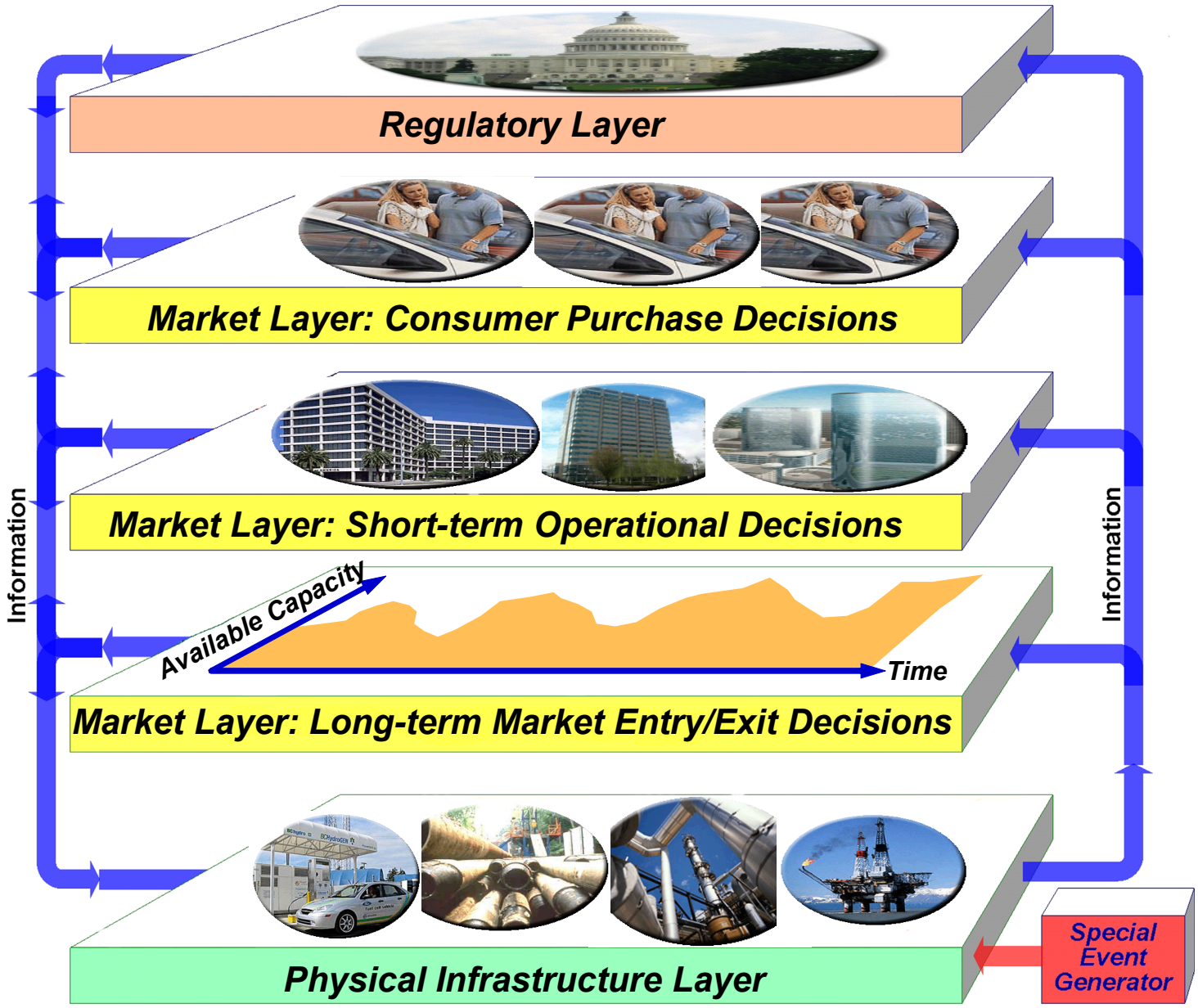
- An agent is an individual with a set of characteristics or attributes
  - A set of rules governing agent behaviors or “decision-making” capability, protocols for communication
  - Responds to the environment
  - Interacts with other agents in the system
- Agents are diverse and heterogeneous
  - Each agent has own internal decision model, strategies, and objectives that can vary in complexity (simple to elaborate)
  - Each agent tries to find its own optimum as compared to traditional models with a single decision maker trying to optimize the entire system (social optimum)

Conceptual H2-CAS Model

- **H2CAS concept distinguishes between three key components**
  - Infrastructure expansion (build-up) decision
  - Infrastructure operational decisions
  - Decision and risk analysis

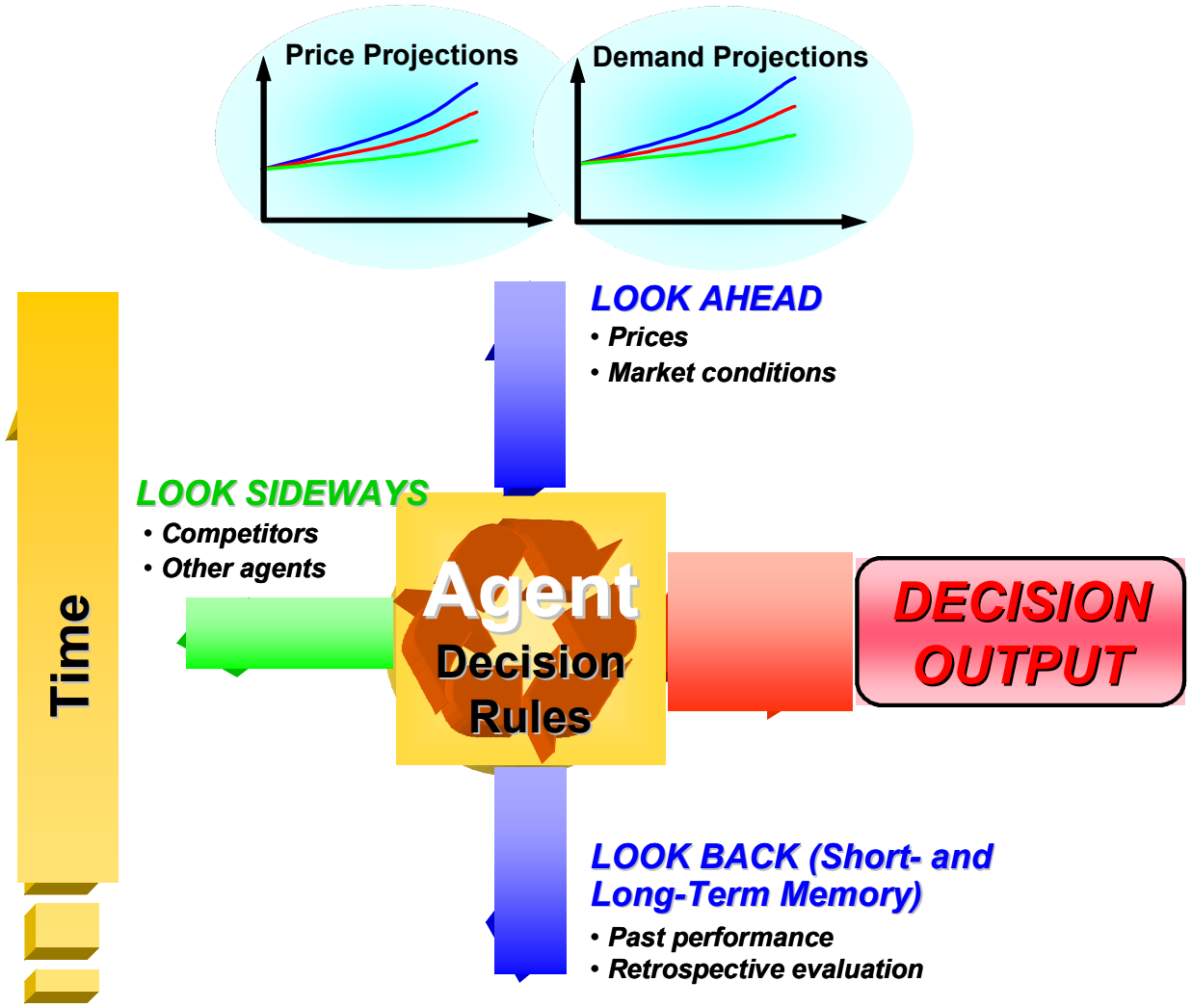


H2-CAS Agents Make Decisions in a Complex and Multidimensional Environment



H2-CAS Agents Consider Information on the Past, Present, and Future in their Decisions

- Agents make decision using local and public information
- Agents develop demand and price expectations by market segment/region
- Agents consider fossil fuel price uncertainties
- Agents consider actions of competitors
- Agents consider past performance in making their decisions



Technical Accomplishments/ Progress/Results

- Project is starting in June 2005
- No accomplishments yet

Future Work

- FY05: Finalize scoping, initiate data collection and agent definitions, start development of conventional and ABMS model
- FY06: Continue ABMS model development and conduct initial test runs

	YEAR 1				YEAR 2				YEAR 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Develop Preliminary Hydrogen Infrastructure Description												
2. Assemble Data on Alternatives												
3. Assemble Results of Conventional Modeling of H2 Infrastructure												
4. Develop Agent-Based Simulation Model												
5. Conduct Base Case Analysis												
6. Conduct Analysis of Alternative Cases												
7. Conduct Model Validation												
8. Prepare Reports on Analyses												

Publications and Presentations

As the project has not started yet, no publications or presentations have resulted from work on this project.

Hydrogen Safety

The most significant hydrogen hazard associated with this project is:

As the focus of this project is transition analysis, no safety hazard has been identified.

Hydrogen Safety

Our approach to deal with this hazard is:

Not applicable.