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Presented by

Pilot Testing and Assessment of Safety and Integrity of Targeted Hydrogen Blending in Gas Infrastructure for Decarbonization

CEC-UCLA: PIR-22-003

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UCLA

Outline

- Background
  - Gas R&D Program
  - Solicitation Policy Drivers
- Project Overview
  - Goals and objectives
  - Primary Use Cases
  - Flow of Technical Tasks
  - Risk and Performance Assessment

Background: Gas R&D Program

- Research and development to support the transition to clean energy, greater reliability, lower costs, and increased safety for Californians
  - Benefits natural gas IOU ratepayers
  - Not adequately addressed by competitive or regulated entities
- $24 million annual budget, funded by a surcharge on gas consumption in California
  - Energy efficiency, renewable technologies, conservation, environmental issues, and transportation
  - Supports state energy policy

Policy Drivers

GFO-21-507 - Targeted Hydrogen Blending in Existing Gas Network for Decarbonization

- Renewable and zero-carbon electricity generation by 2045 (Senate Bill 100, 2018).
- Hydrogen Injection Standards (CPUC Rulemaking 13-02-008 Phase 4, 2019).
- Assessment of hydrogen delivery through existing gas pipeline network (CPUC Resolution G-3555, 2019).
- CARB, CEC, CPUC are required to develop a comprehensive report on the development, deployment, and use of hydrogen (SB 1075)

Project Goals and Objectives

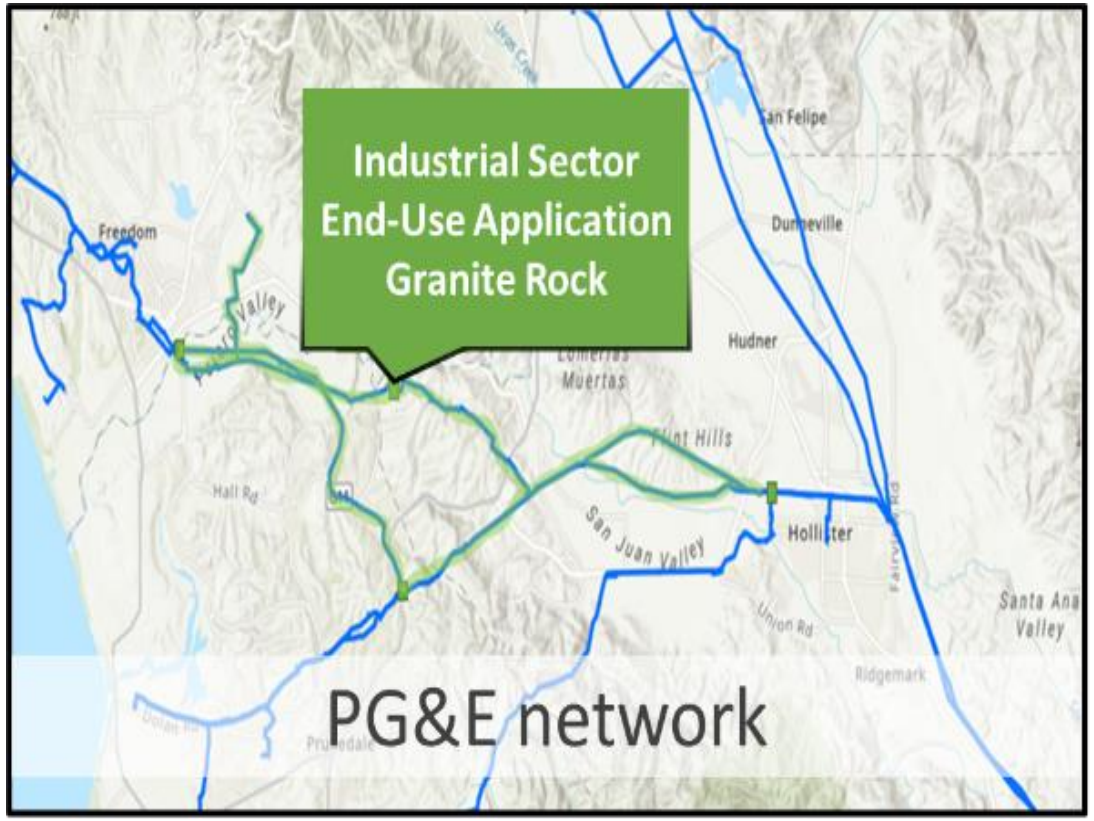
Pilot Testing and Assessment of Safety and Integrity of Targeted Hydrogen Blending in Gas Infrastructure for Decarbonization

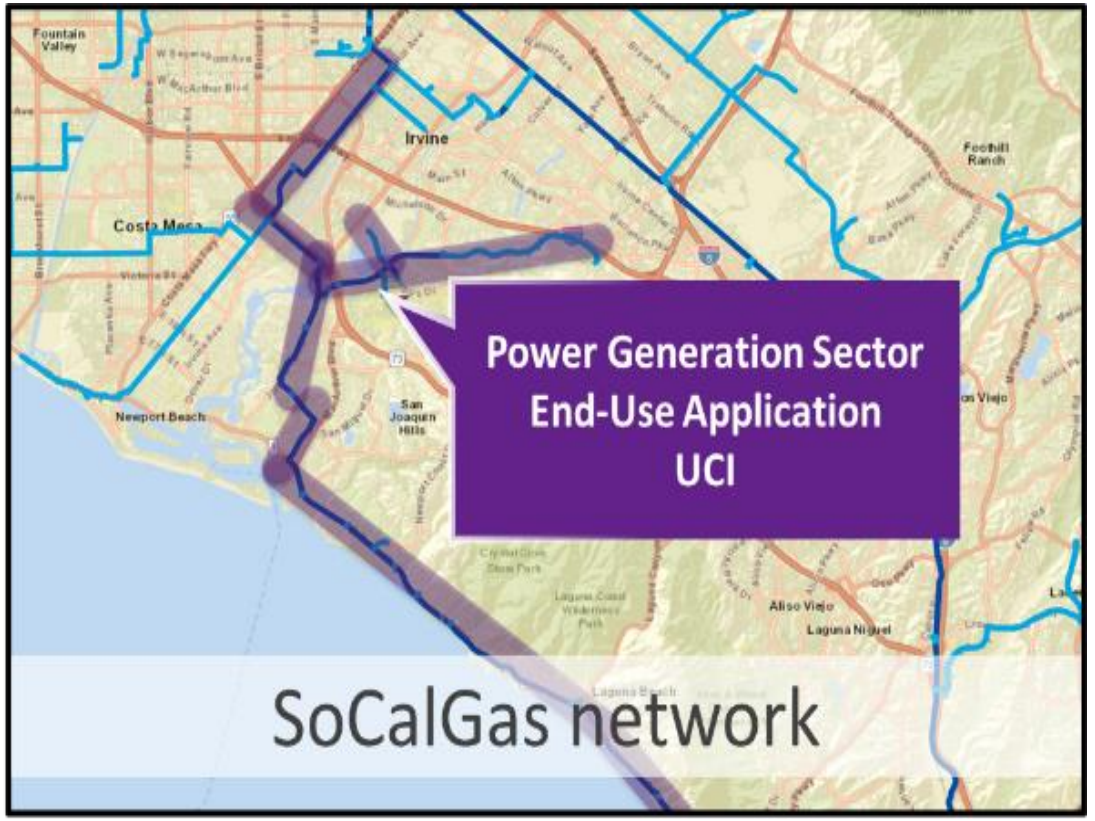
- Lead Organization: UCLA Risk Institute
- Sponsored by CEC, 3 years
- 4 industrial partners, 2 IOUs and 1 pipeline operator, UCI, SNL, DNV, GTI

Objectives

- Create a repository of available information
- Design and execute a hydrogen blending testing program
- Develop models to conduct risk and performance assessment
- Perform techno-economic analyses of various decarbonization pathways

Primary Use Cases: Graniterock and UCI Microgrid





From Laboratory Work to System Wide Risk & Performance Assessment

List of Materials
List of Impurities
Operating Conditions

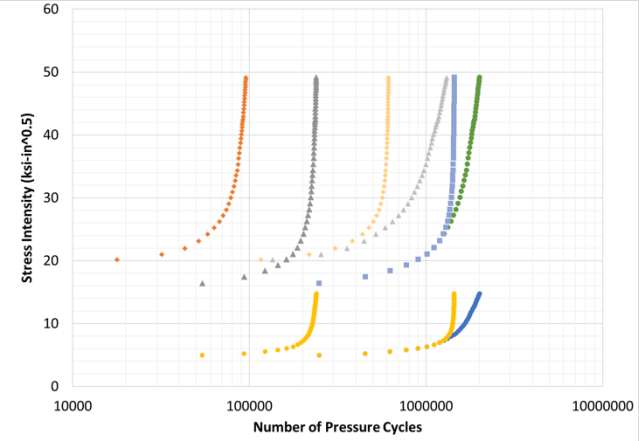
List of Components

Use Cases: Power Generation &Industrial

Pipeline Infrastructure System

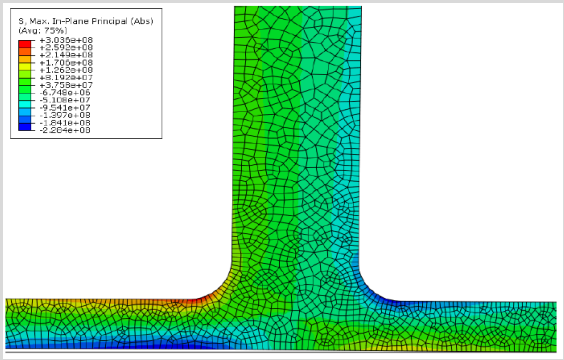
Laboratory Experiments

Objective: characterize materials behaviour in various hydrogen/methane/impurities mixtures



Component Reliability Assessment

Objective: characterize and quantify each component behaviour and reliability



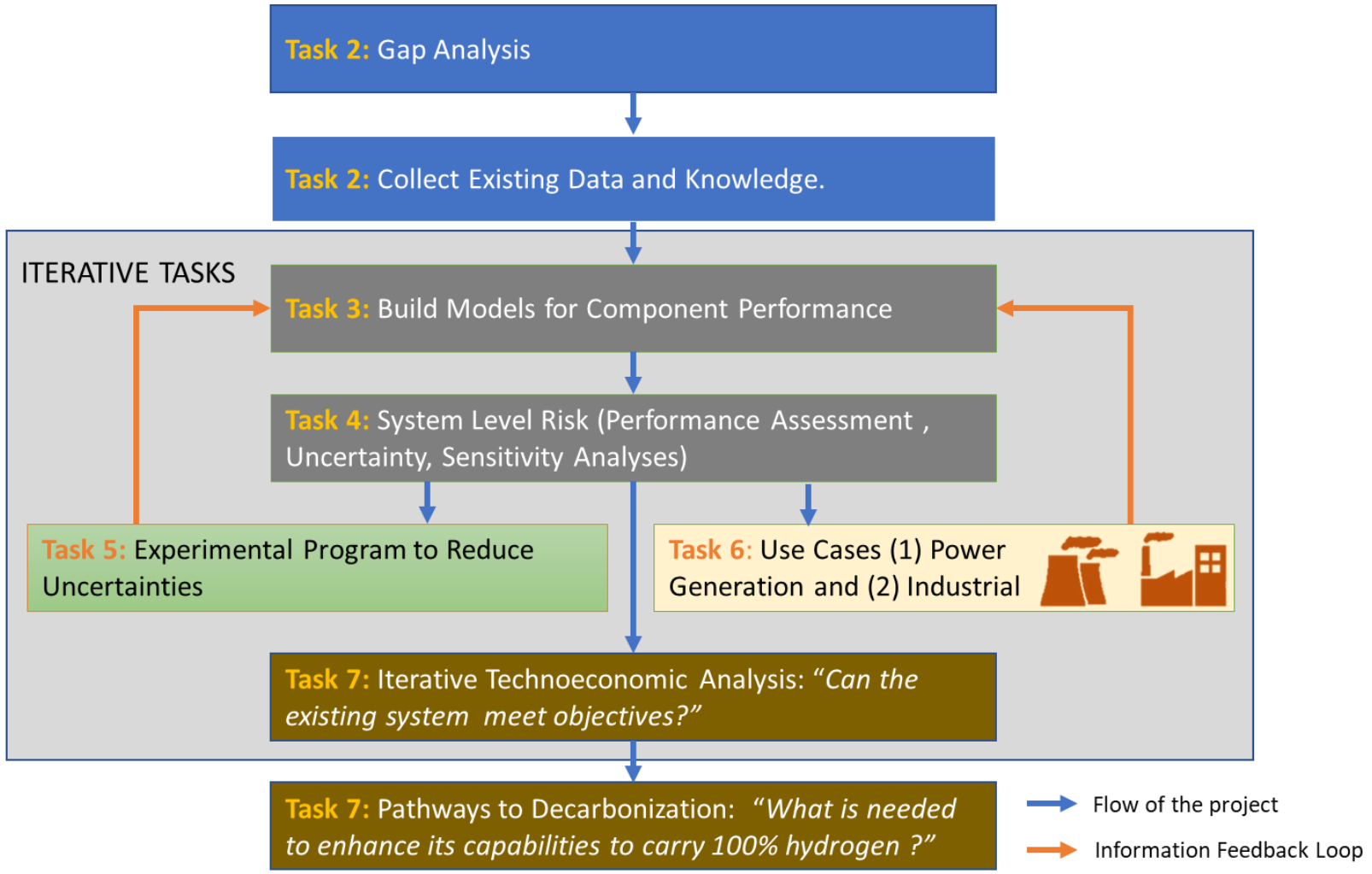
System Wide Risk Assessment

Objective: Quantify **System Level** Operational Risk for Various Blending Levels.
Basis to answer questions such as:

- Hydrogen blending roadblocks?
- What modifications, if any?
- Residual risks after modifications?
- Techno economic tradeoffs ?

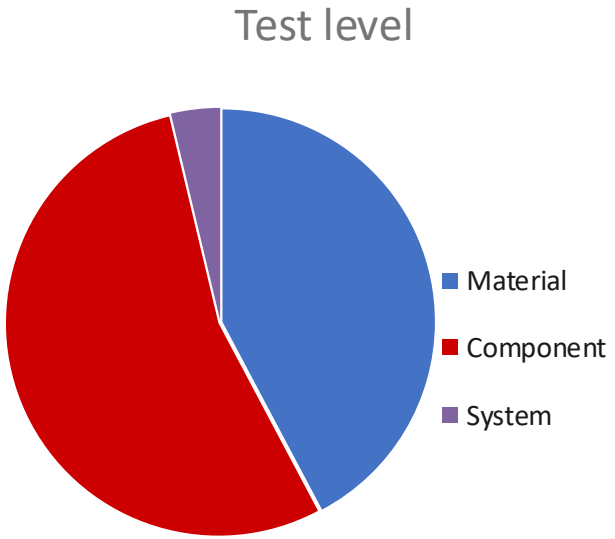
Source: UCLA

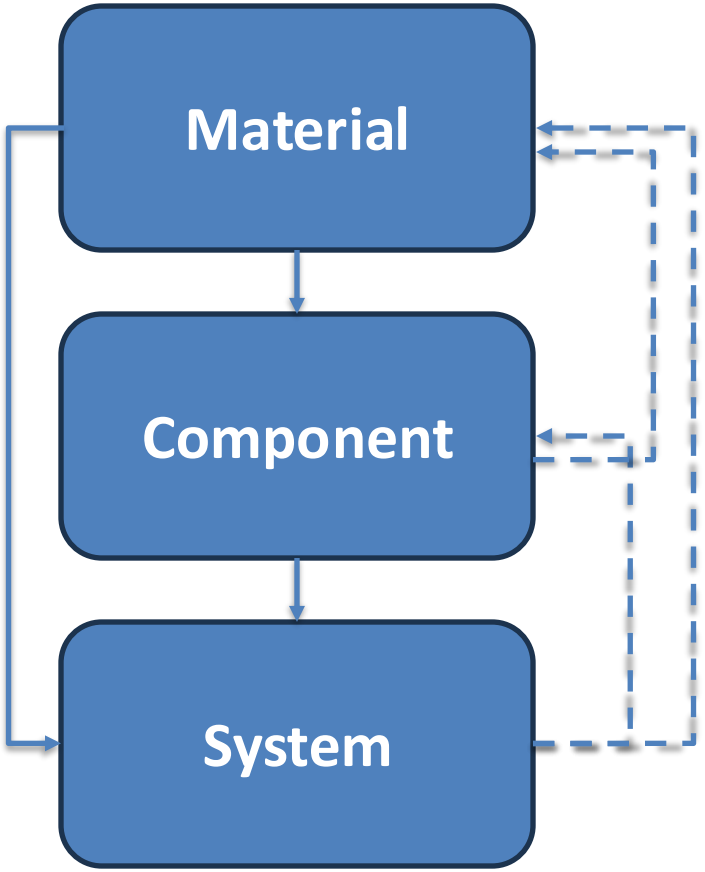
Flow of Technical Tasks



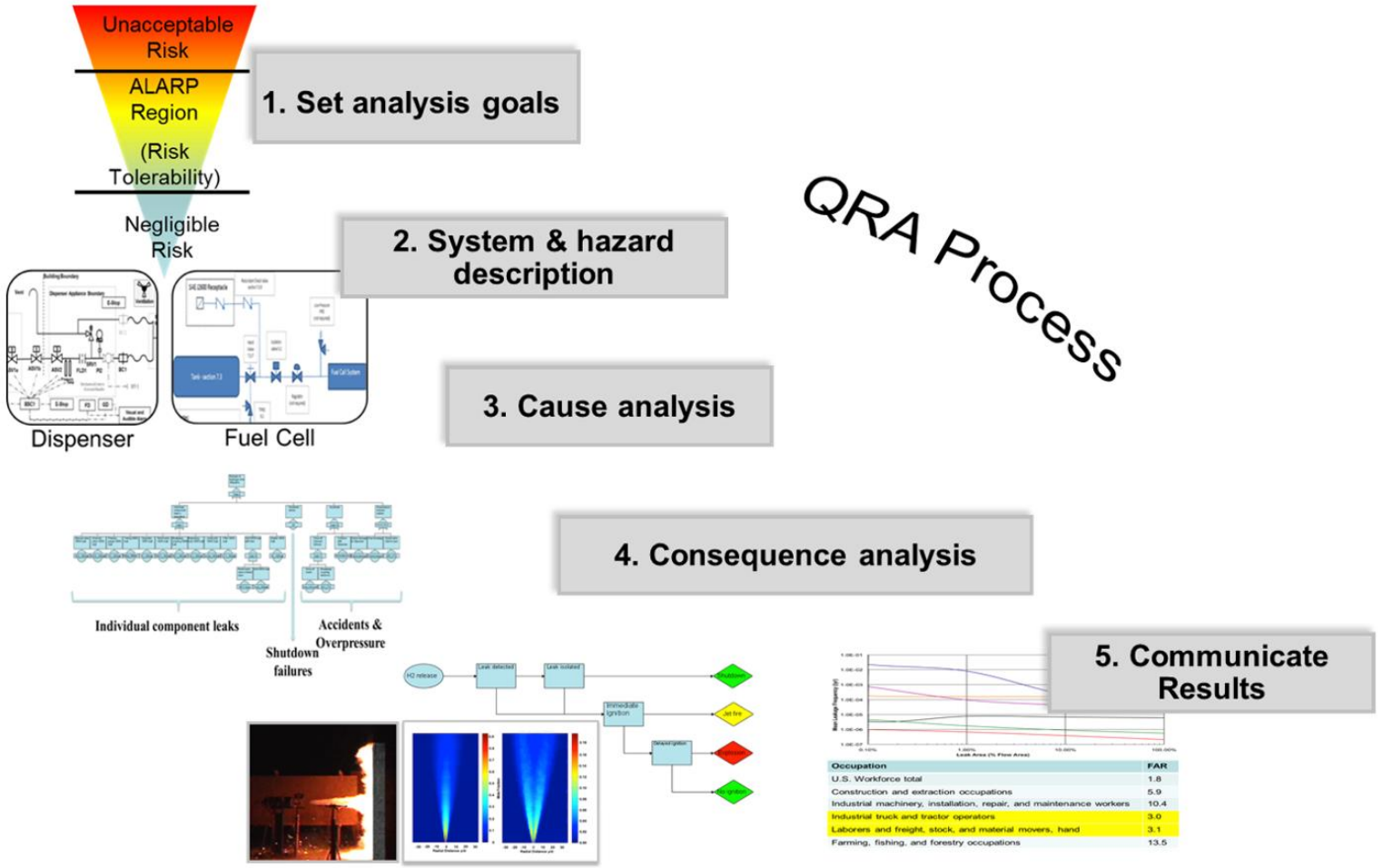
Example Results: Gap Analysis

- Fast evolving landscape
- System gaps are pervasive
- Examples:
  - Effect of contamination
  - Flow and heat transfer problems
  - H2 effects on polymers and elastomers
  - H2 effects on non-ferrous alloys
  - Sensing and metering
  - Technoeconomic analysis gaps





Hydrogen Quantitative Risk Assessment



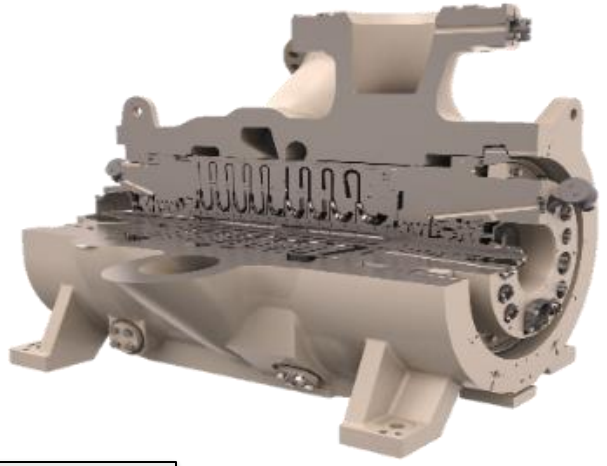
Source: UCLA

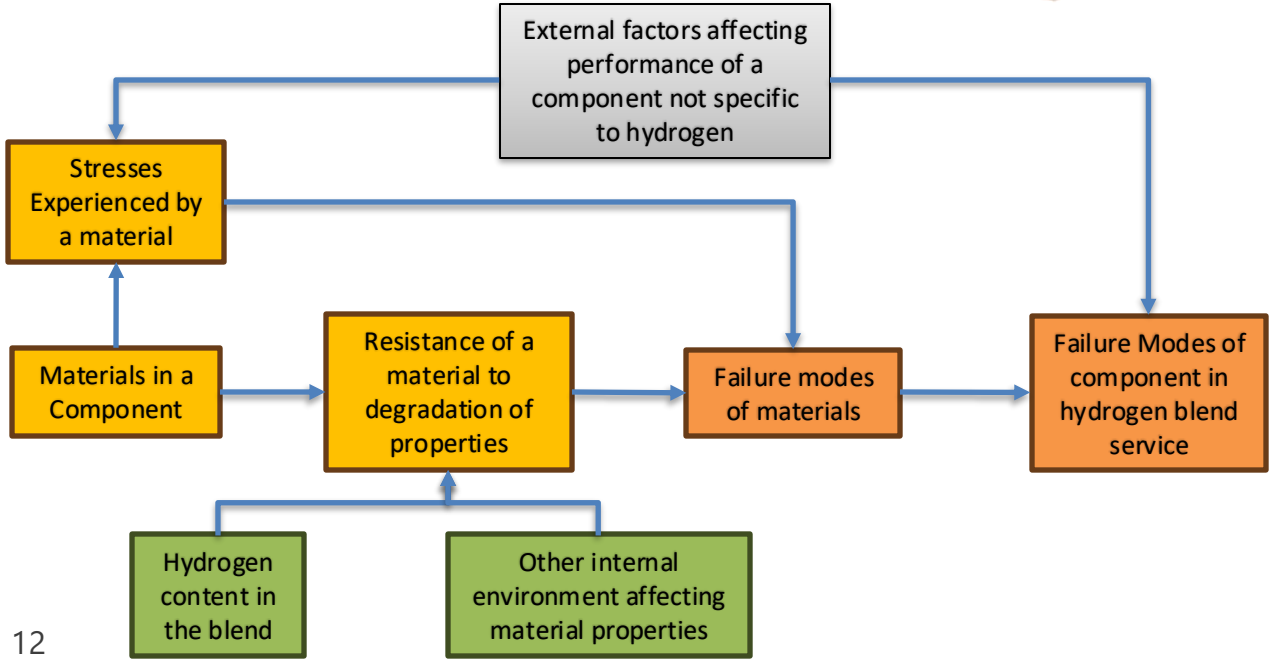
Example Results: Component Modeling

Bayesian Belief Network Rationale

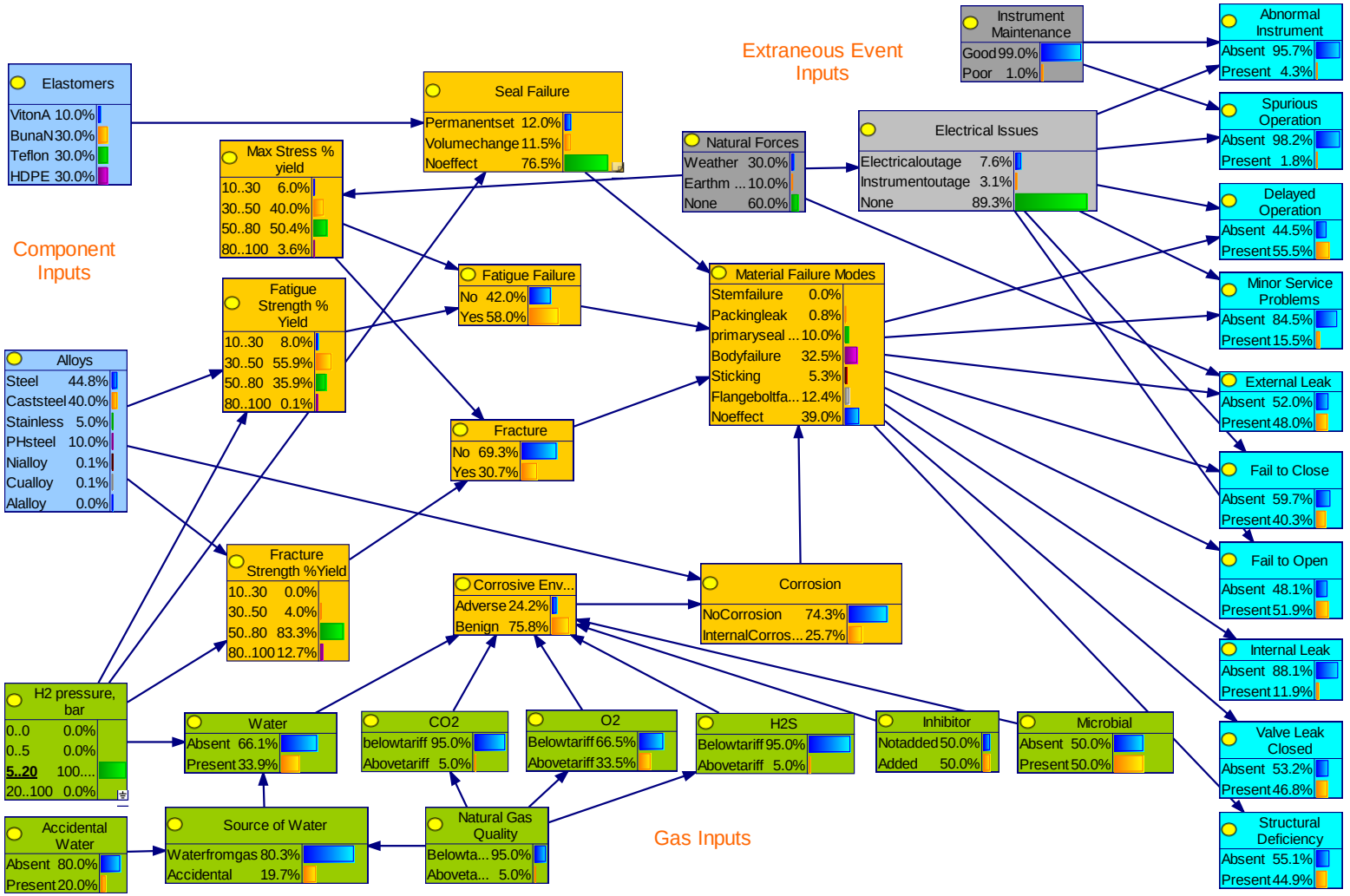
- Compressor and regulator stations have many components each made of many parts and materials
- Failure statistics of some components used in oil & gas industry exists (OREDA database), but not in hydrogen service
- Bayesian network is a convenient way to include knowledge of hydrogen effects

Source: UCLA





Example: BBN Model for Valves



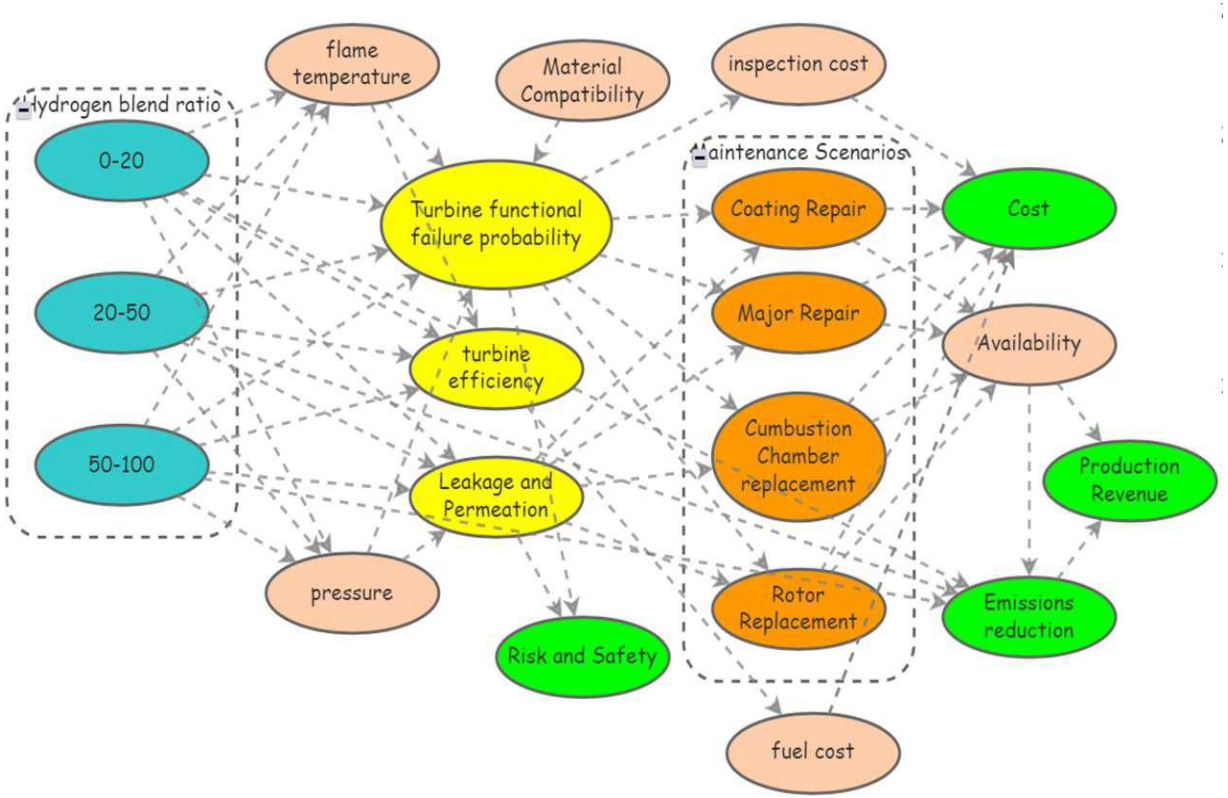
Failure Modes Corresponding to OREDA Data (Note: The "other" and "Unknown" categories are removed))

Source: UCLA

Techno-Economic Analysis Framework

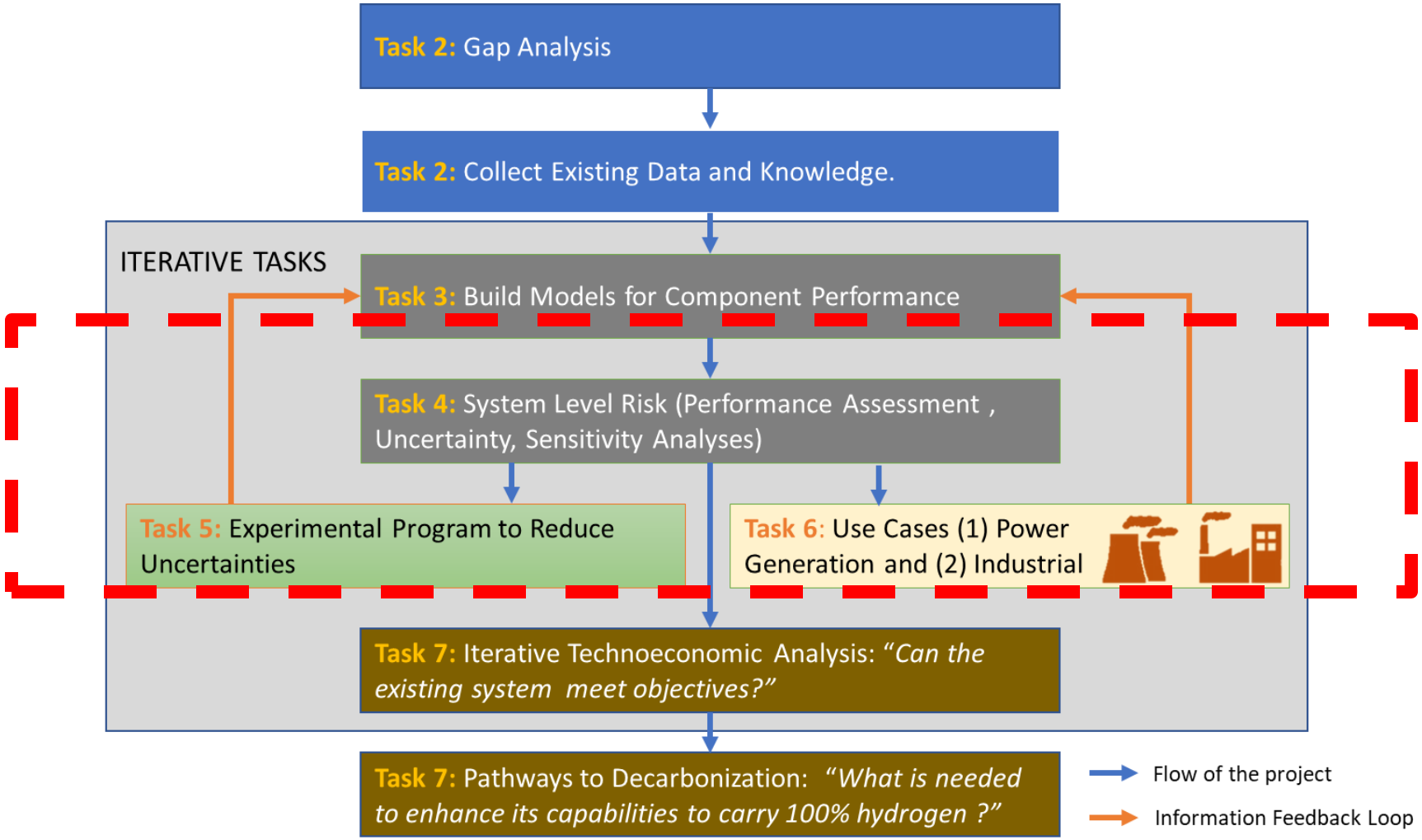
- Model to consider various blending levels and operational factors
- produce projected **risk**, **availability, efficiency**, **emission**, and **cost.**
- Built based on extensive literature review
- Major Steps
  - Develop component-level model.
  - Combine component-level into system-level model
  - To be applied to several pathways (scenarios)
  - Optimum pathway will be identified via multivariate optimization

Conceptual TEA Nodal Model



Source: UCLA

Immediate Next Tasks



Source: UCLA

Thank you

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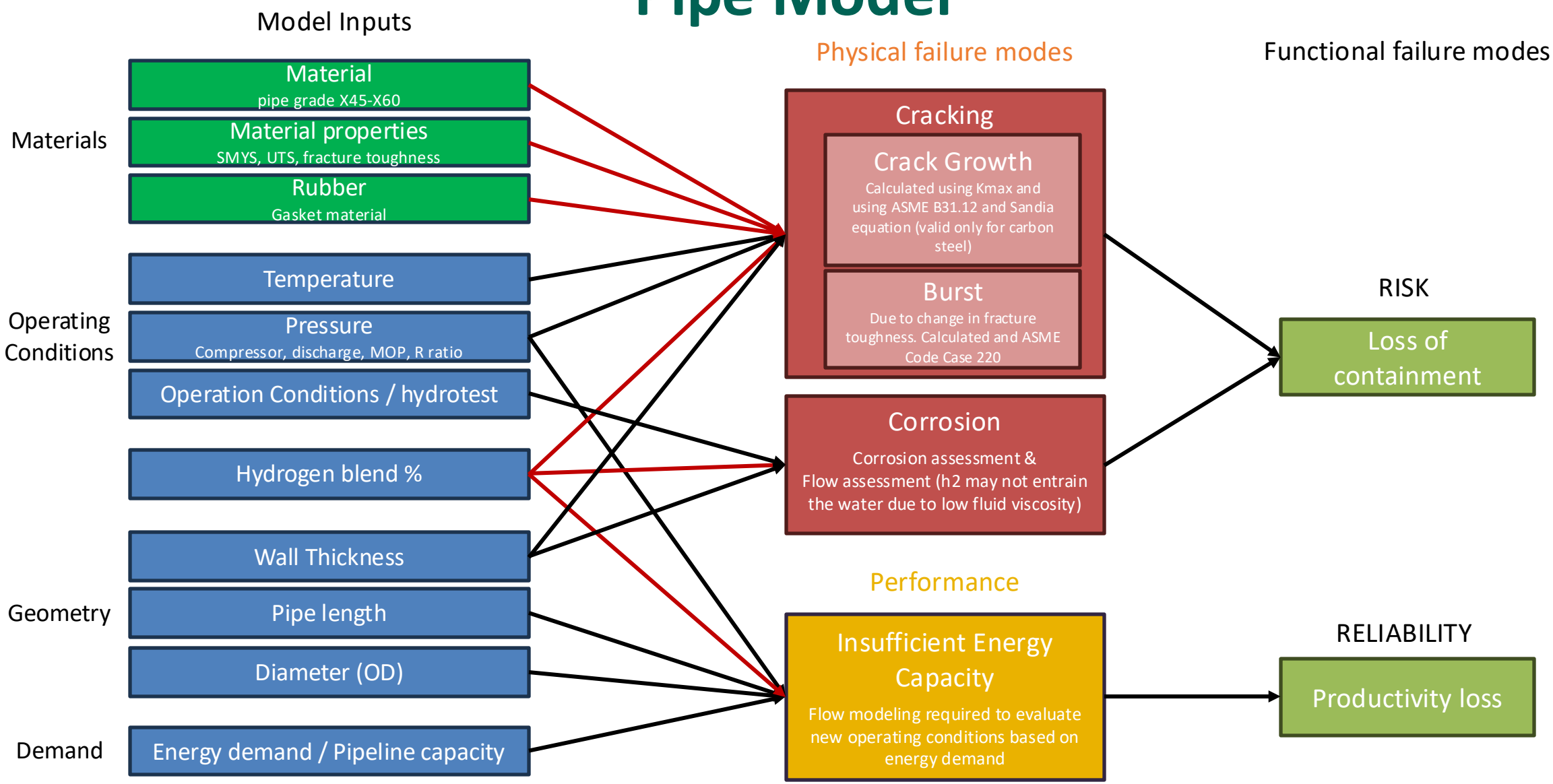
Additional Project Information: https://www.energizeinnovation.fund/projects/pilot-testing-and-assessment-safety-and-integrity-targeted-hydrogen-blending-gas

Pipe Model


Model Inputs
Materials
Material
pipe grade X45-X60
Material properties
SMYS, UTS, fracture toughness
Rubber
Gasket material
Operating Conditions
Temperature
Pressure
Compressor, discharge, MOP, R ratio
Operation Conditions / hydrotest
Hydrogen blend %
Geometry
Wall Thickness
Pipe length
Diameter (OD)
Demand
Energy demand / Pipeline capacity
Physical failure modes
Cracking
Crack Growth
Calculated using Kmax and using ASME B31.12 and Sandia equation (valid only for carbon steel)
Burst
Due to change in fracture toughness. Calculated and ASME Code Case 220
Corrosion
Corrosion assessment & Flow assessment (h2 may not entrain the water due to low fluid viscosity)
Performance
Insufficient Energy Capacity
Flow modeling required to evaluate new operating conditions based on energy demand
Functional failure modes
RISK
Loss of containment
RELIABILITY
Productivity loss

Calculation Results

	Abnormal instrument reading	Delayed opeartion	External Leakage - Process	External Leakage - Utility	Fail to Close on Demand	Fail to Open on demand	Internal Leakage	Valve leakage in closed position	Other	Minor in service problems	Spurious operation	Structural deficiency	Unknown
Percentage of failures from OREDA	3.41	9.1	21.59	5.68	2.28	36.38	4.55	1.14	5.68	6.83	1.14	1.14	1.14
BN Probabilities													
No hydrogen	4.3	12.5	12.3		15.8	19.1	4.4	13.1		8.9	1.8	9.3	
0 - 5 bar H2	4.3	32.9	29.6		25.9	34.7	8.3	29.1		13.7	1.8	26.6	
5 - 20 bar H2	4.3	62.5	48.8		42.5	51.1	19.4	48.1		15	1.8	43.8	
20 - 100 bar H2	4.3	67.5	57.6		47.8	61.2	13.9	55.8		16.9	1.8	54.5	
Number of failures reported in OREDA	3	8	24		2	32	4	1	4	6	1	1	2

Hydrogen increases the likelihood of various valve failure modes involving materials interactions

The failure probabilities for various modes do not add to 100% because in the BN, they are independent (but affected by some common factors)

Project Team and Primary Responsibilities

Institution	Type	Form of Participation	Primary Role	CEC Funds	Match Fund
Univ Calif Los Angeles (UCLA)	Research and Education	Lead	Project Mgt, Test/Analysis	x	x
Sandia National Lab (SNL)	Research and Development	Partner	Test Program	x	
DNV	Research/Development/Service	Partner	Test and Analysis	x	x
Gas Technology Institute (GTI)	Research and Development	Partner	Test and Analysis	x	x
Univ Calif Irvine (UCI)	Research and Education	Partner	Test / Power Use Case	x	x
MCC	Consulting	Partner	Test and Analysis	x	x
System Safety LLC	Hydrogen Energy Consulting	Partner	Analysis	x	
Calif Steel Industries (CSI)	Industry	Support/Participation	Candidate Use Case		
Solar Turbine	Industry	Support/Participation	Candidate Use Case		x
CalPortland	Industry	Support/Participation	Candidate Use Case		
GraniteRock	Industry	Support/Participation	Industry Sector Use Case		
Emerging Fuels Institute (EFI) Pipeline Research Council International	Research and Development	Support/Participation	Domain Expertise		
SoCalGas	IOU	Support/Participation	Pipeline System/Blending		
PG&E	IOU	Support/Participation	Pipeline System/Blending		
Williams	Gas Pipeline Operator	Support/Participation	Data /Domain Expertise		x
Sacramento Municipal Utility District (SMUD)	Community-owned Electric Service	Support/Participation	Data /Domain Expertise		x

Relevant Policies, Applications & Decisions since

- D.21-07-005: Directing California's four large gas utilities to propose system testing on the effects of hydrogen blended into methane at concentrations ranging from 0.1% to 20%
- A.22-09-006**:** Application from SoCalGas, SDG&E, and SWG for the creation of hydrogen blending demonstration projects by each utility.

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