Lynntech

2010 DOE Hydrogen Program
Annual Merit Review Meeting

Design, Optimization and Fabrication of Home Hydrogen Fueling System

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Lynntech Inc.

7th June 2010

Project ID # PD066



Overview

Timeline

- Start – July 2009
- Finish – April 2010
- Phase I completed.

Budget

- Total project funding
  - DOE - $100,000

Barriers

- Barriers
  - Cost
  - Safety
- Targets – Home H_2 production and dispensing

	2010	2015	Ultimate
H_2 cost $ per kg*	3-7	2-6	2-3

Partners

- None for Phase I
- Potential partner for Phase II reformer development – GTI, Innova Tek.
- Mid South Synergy

http://www1.eere.energy.gov/hydrogenandfuelcells/storage/pdfs/targets_onboard_hydro_storage_explanation.pdf

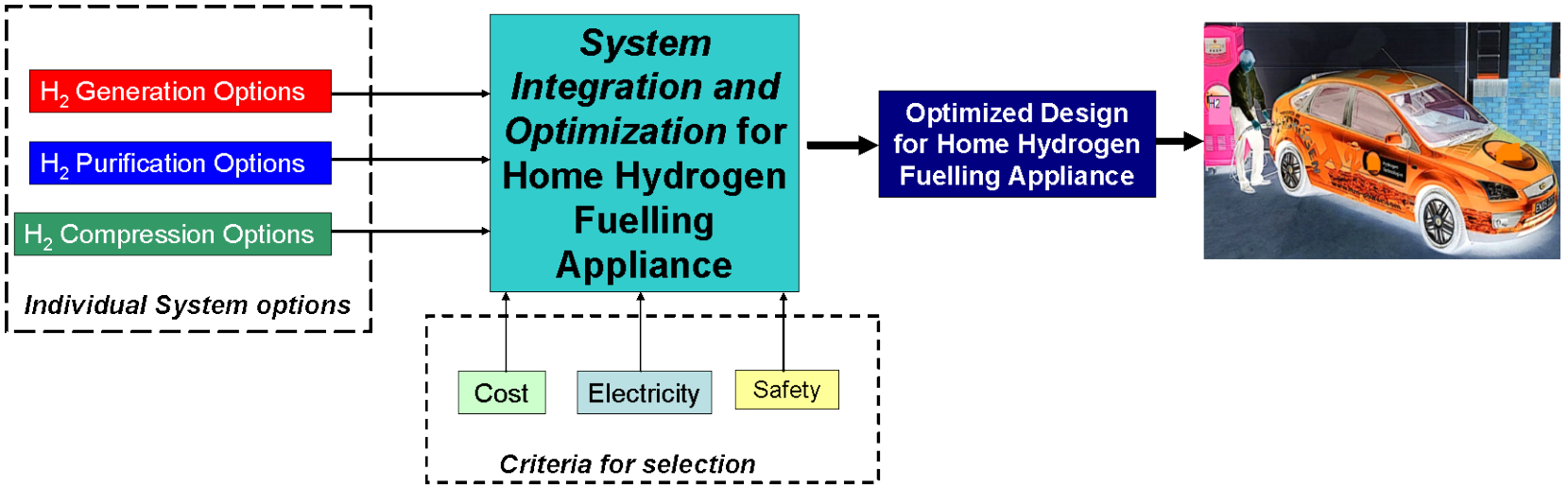
Objectives

Target : Affordable hydrogen for fueling a PEM fuel cell vehicle for domestic daily consumer that speeds up commercialization and general awareness of fuel cell technology.

Problem : Lack of system integration study for producing H_2 at required quality and pressure.

Phase I objectives

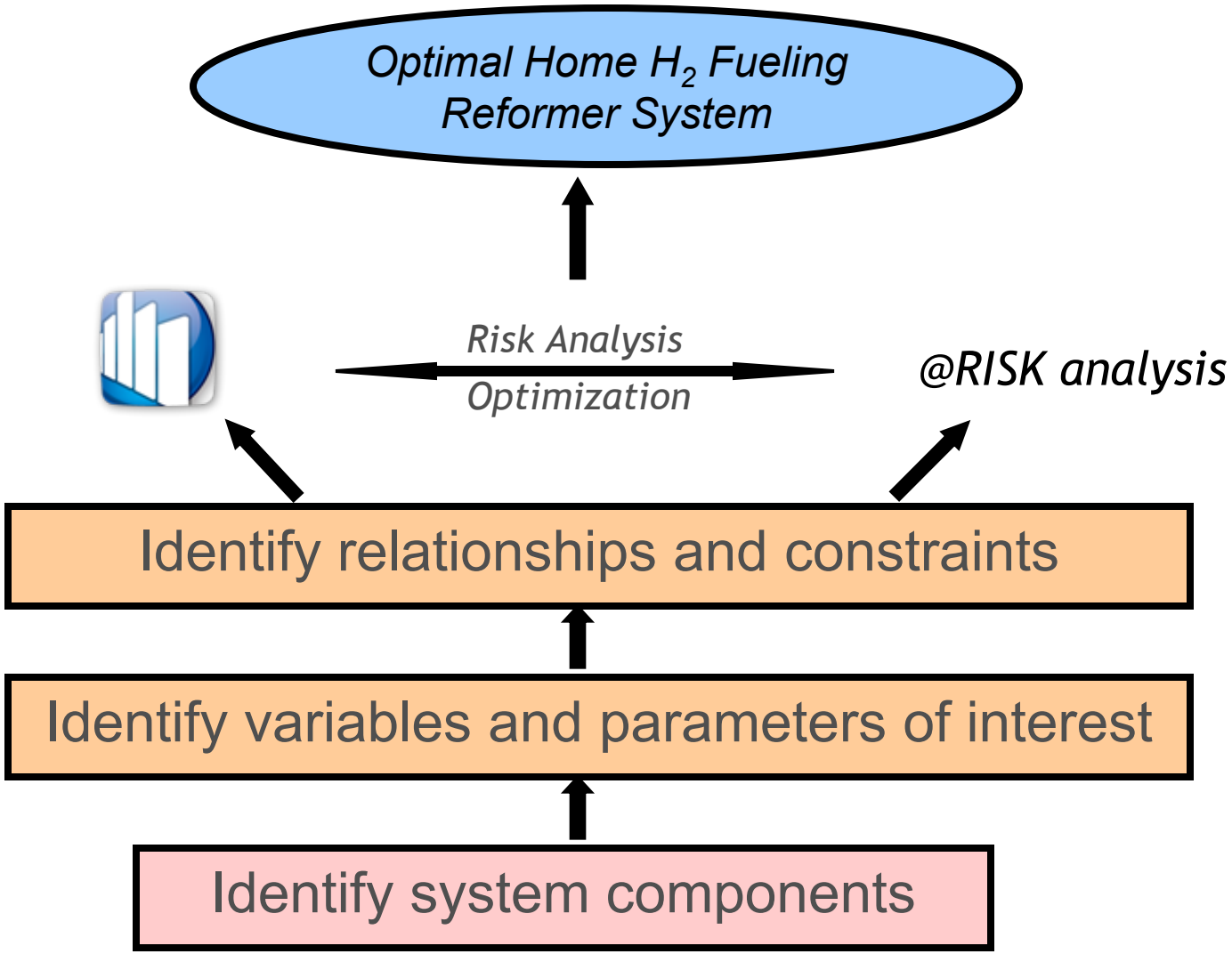
- Develop a multivariate model for system integration and optimization for a Home Hydrogen Fueling device based on natural gas reformation.
- Identify best options for H_2 generation, purification and compression for home hydrogen fueling device and provide an optimized system design.



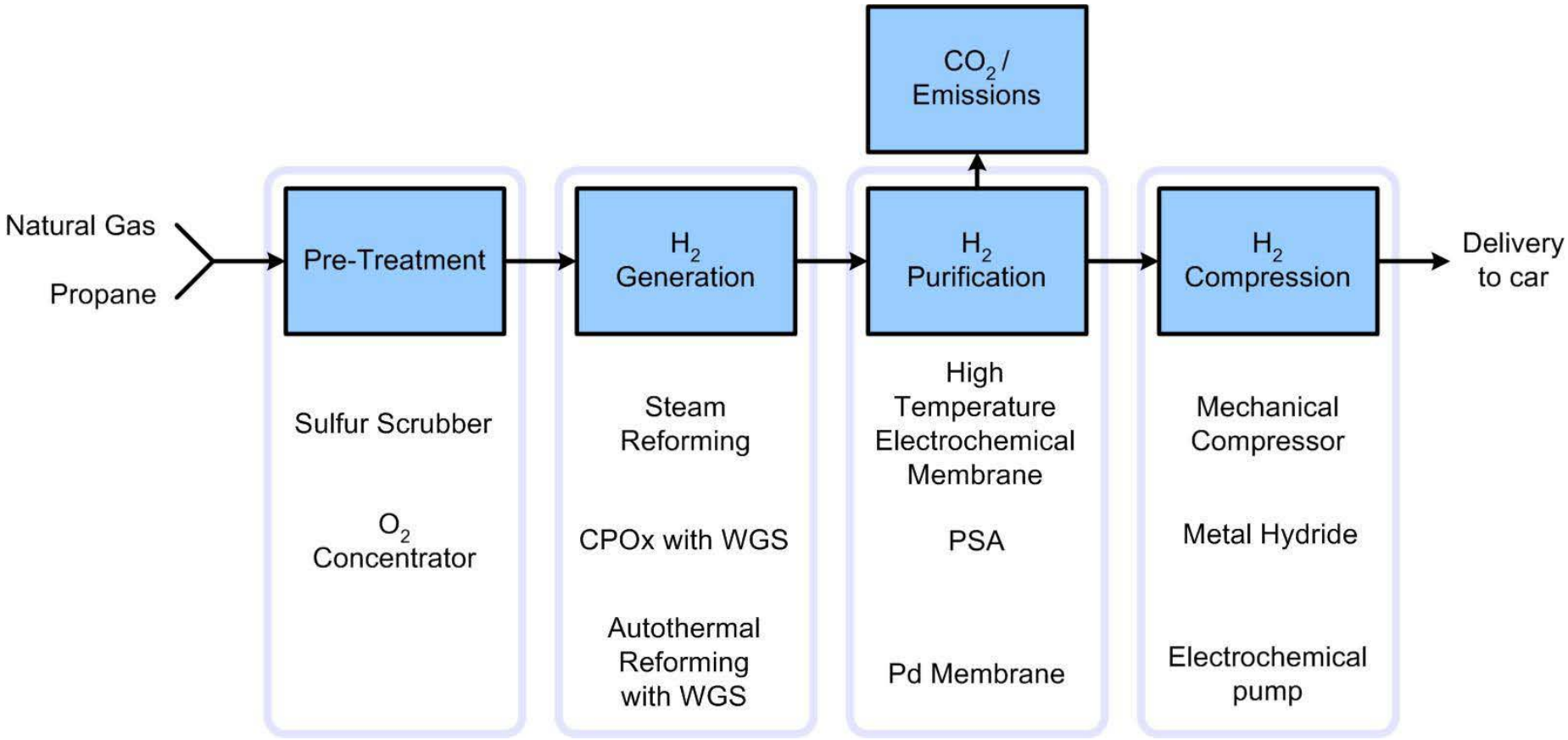
Milestones

Milestones	Progress Notes	Comments	% Comp
Identify requirements and specification for a reformer based Home H_2 Fueling Station	Identified safety codes and standards and developed operating guidelines.	Concise list of safety standards for individual subsystems (reformer, purifier and compressor) have been reviewed to create a user oriented safety instructions guidelines.	100
System optimization analysis	**Constructed a user friendly multivariate model** and identified best options for a Home Fueling Station for low H_2 production rates based on cost, CO_2 emissions and electricity consumption.	• **Compressor and purifier are the capital cost intensive systems driving H_2 cost at H_2 production rates < 5 kg/day (8 hr operation).** • Identified the least cost system design as a function of production rate. • Provided sensitivity analyses for the system designs.	100
Complete system design with the optimized design approach	Preliminary system design calculations completed.	Preliminary designs for individual subsystems identified are completed. Off-the-shelf components identified for the Phase II prototype.	100
Target for the Phase II prototype development	**Go/No Go milestones** for Phase II for the optimized system fabrication are identified.	**Specific target parameters identified to achieve the H_2 cost targets for the identified compression and purification technologies.**	100

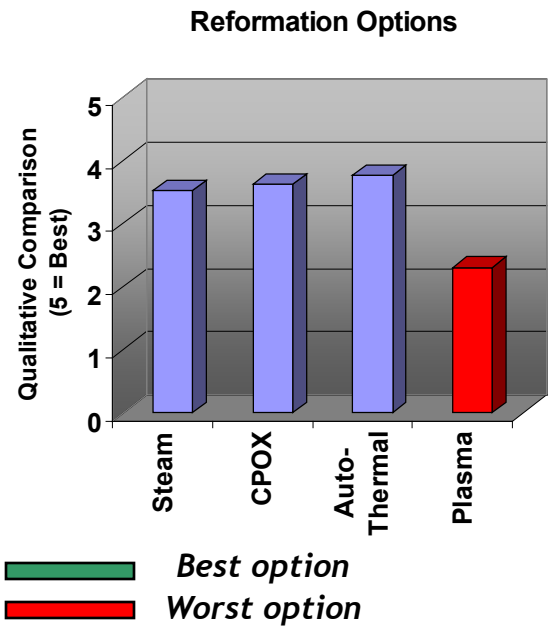
Multivariate Optimization Example

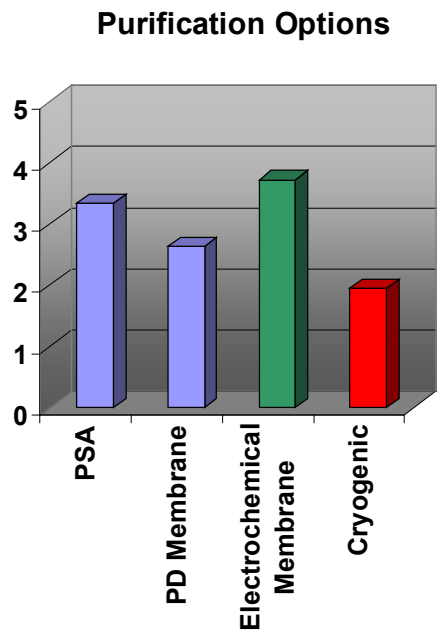


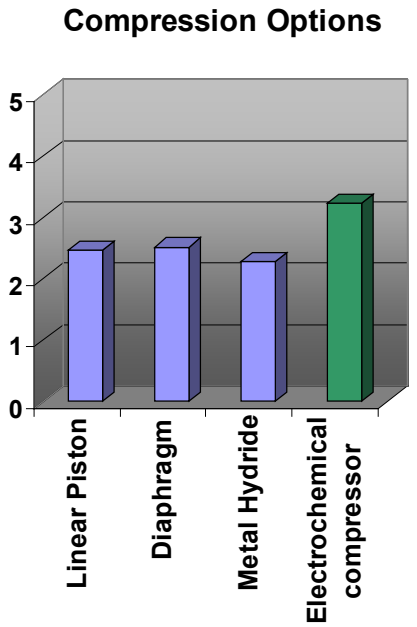
Lynntech's Home Hydrogen Reformer Component matrix



System selection analysis (Weighting factors)



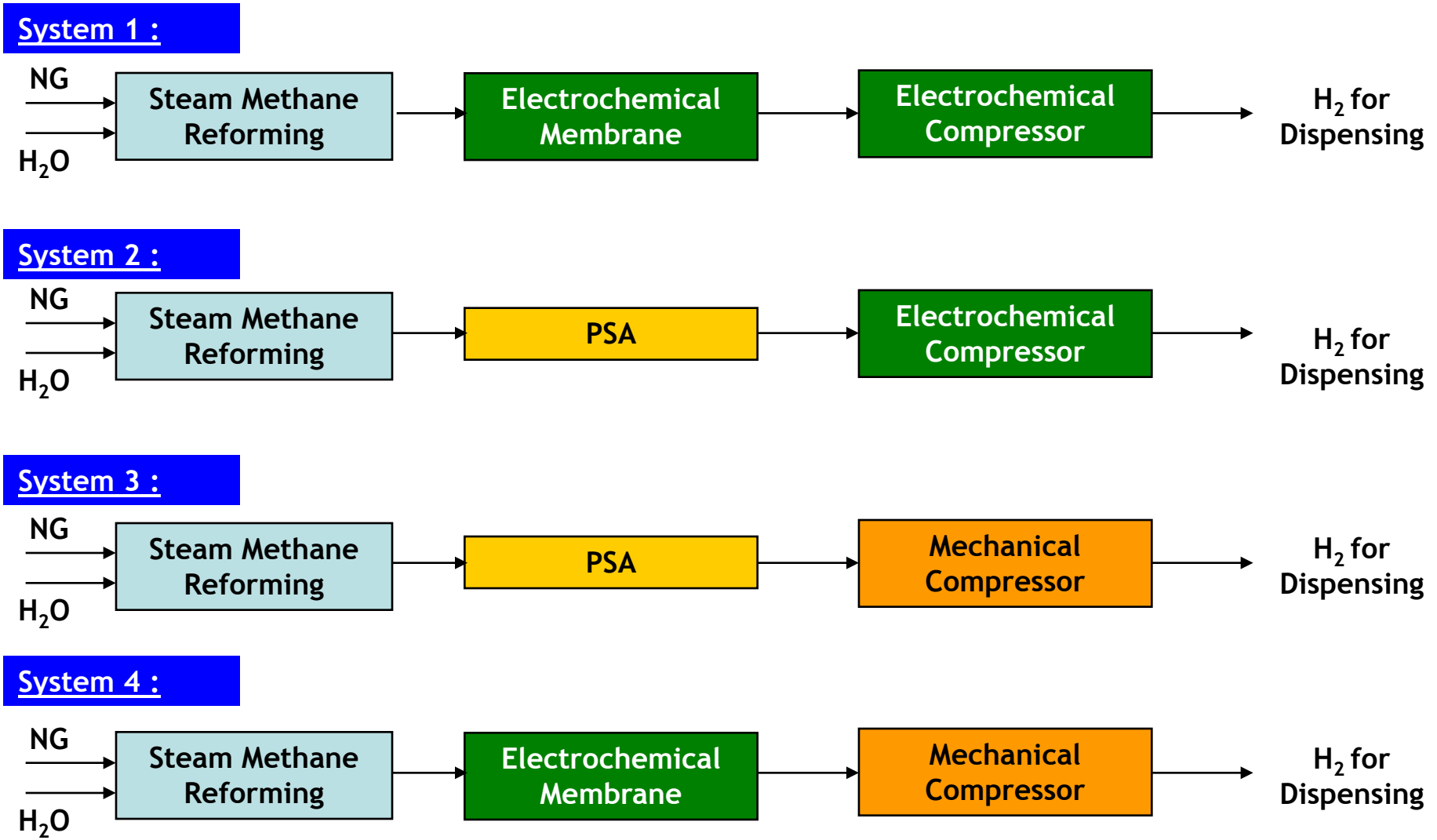




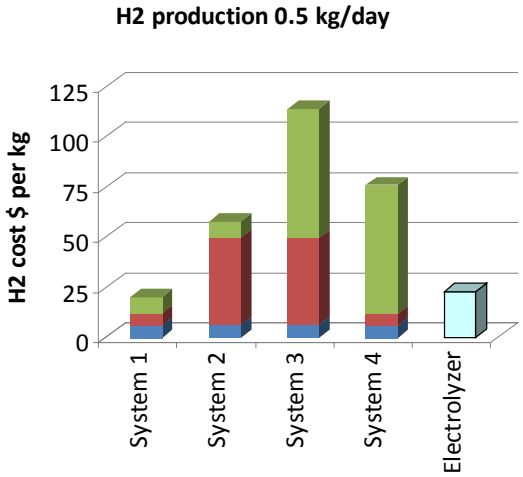
Parameter	Weightage
Cost	50 %
Safety	12.5 %
Technological maturity	12.5 %
Ease of operation	10 %
Maintenance	10 %
Ease of integration	5 %

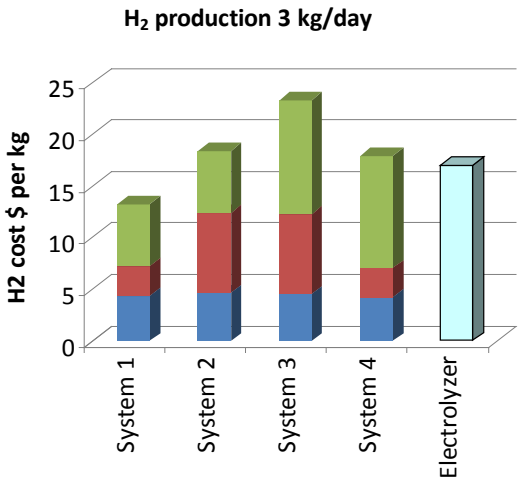
- The analysis is strictly for low hydrogen production rates of 0.5 kg/day to 5 kg/day.
- Cost was assumed the main driver for the technology.
- Pre-treatment options were not critical in final system analysis.

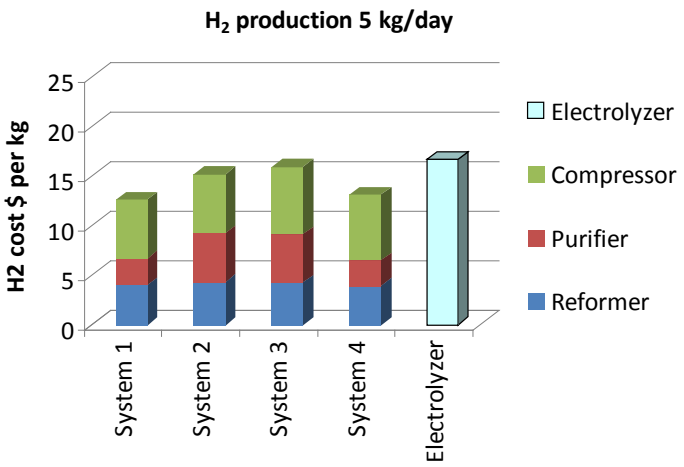
System integration choices



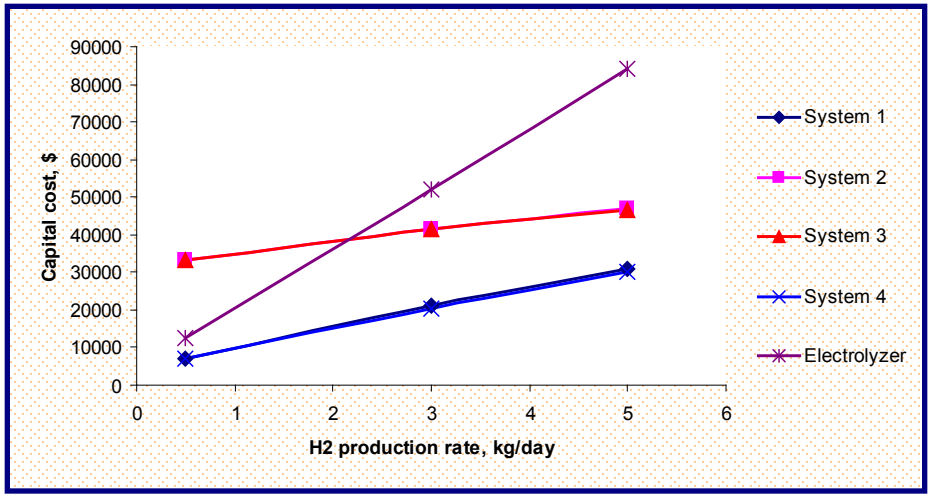
Cost of hydrogen vs. System Designs (single system assumed)







- Purification and compression are the critical cost components at low hydrogen production rates.
- Capital cost of Electrolyzers depend strongly on H_2 production rate as compared to Reformer systems.
- Electrochemical techniques for purification and compression can be scaled down in a cost effective way as compared to conventional PSA and mechanical compressor options.



Capital cost of fuel processors (excluding compression)

Effect of electricity and natural gas price

Effect of electricity price

Effect of natural gas price

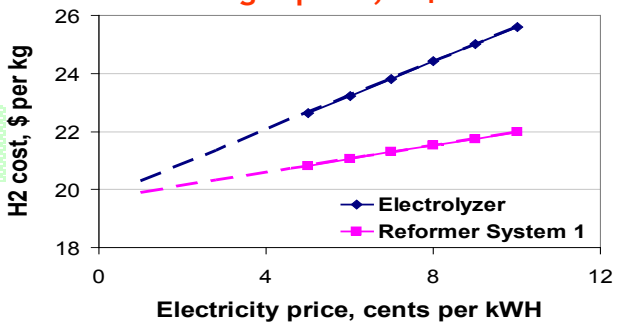
H_2 production

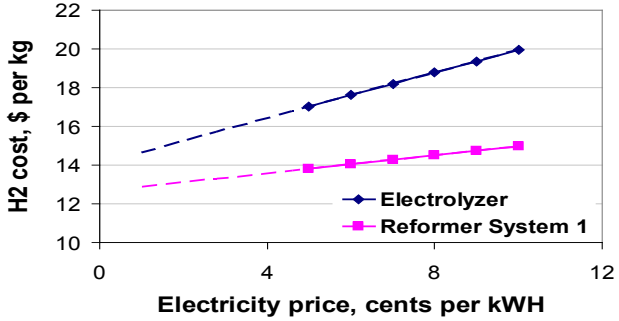
0.5 kg/day

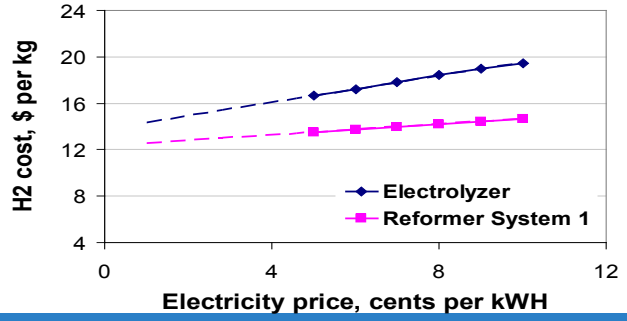
3 kg/day

5 kg/day

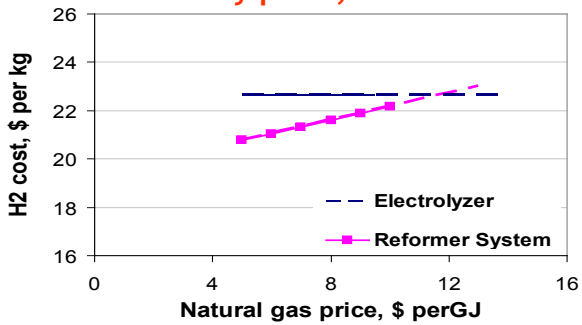
Natural gas price, 7 $/GJ

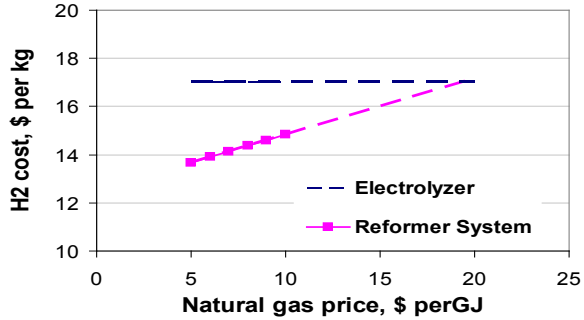


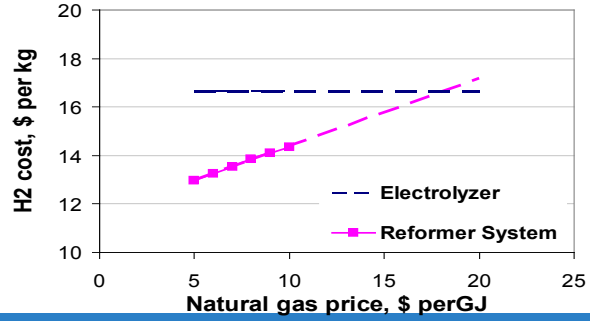




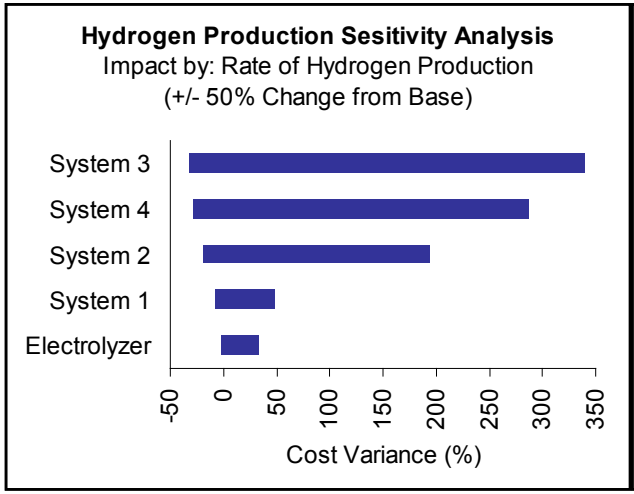
Electricity price, 5 cents/kWH

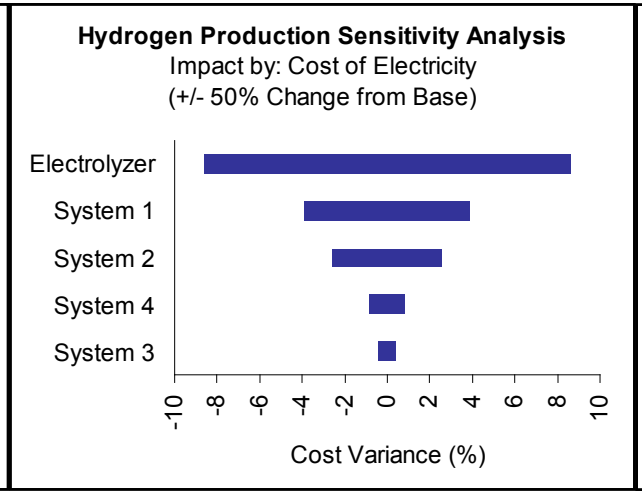


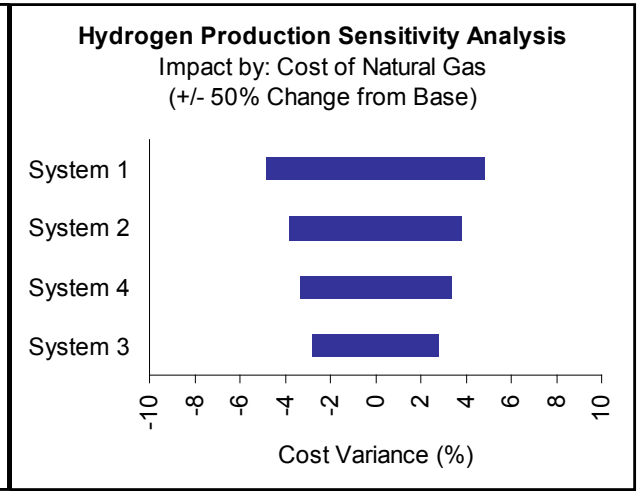




Sensitivity analysis for H_2 cost







- **For hydrogen production variation, System 1 and Electrolyzer have the least variation in the cost.**
- **As expected, the impact of variation in cost of electricity is pronounced for Electrolyzer and followed by the Reformer Systems with more electrochemical technologies.**
- **Effect of natural gas on the four Reformer Systems is comparable and low.**

Collaborations

- **Partners**
  - Potential collaboration for Reformer reactor development in Phase II :
    - Gas Technology Institute (GTI)
    - Innova Tek Inc.
  - Mid South Synergy for field testing of prototype that will be developed in Phase II.

Future work (Phase II)

- Develop and demonstrate cheap (low capital cost) electrochemical membrane purifier technology for hydrogen reformate purification.
- Develop and demonstrate cheap (low capital cost) electrochemical compression technology for hydrogen.
- Development and / or fabrication of fuel processor (subcontract to reformer partner).
- Integrate the systems to produce a prototype.
- Field testing of the system with the help of **Mid South Synergy**, a local electrical co-operative.

Conclusions

- **A multivariate model was developed** for system optimization of home hydrogen fueling systems.
- **Model Results** for **0.5 to 5 kg/day hydrogen production rate**
  - Reformation of natural gas is the cost effective way to produce hydrogen gas as compared to water electrolyzers.
  - Capital cost of purification and compression are the critical cost drivers for the reformer based hydrogen production systems.
  - Electrochemical purification and compression technologies offer the most cost effective route as compared to conventional PSA and mechanical compression technologies.
  - Combination of reformation for H_2 production with electrochemical purification and compression offers the most economical system design.
- Fundamentally new information has been uncovered on how to design small hydrogen refueling stations.
- **The commercial benefits are multiple and include**
  1. Small scale hydrogen refueling stations offering significant cost and process advantages over existing designs and
  2. Modeling and simulation tools for implementation of future hydrogen economy equipment items and infrastructure.

Project summary

- **Relevance :** The Phase I project identified the critical components for an affordable home hydrogen fueling device and identified critical technology pathways to achieve the best H_2 cost.
- **Approach :** Develop a multivariate model to identify and optimize the reformer based home hydrogen fueling system.
- **Technical Accomplishments and Progress :** Identified the critical technologies for a cost and energy effective home hydrogen fueling system through a multivariate optimization approach.
- **Technology Transfer/Collaborations :** Active communication with GTI and Innova Tek for reformer development in possible Phase II effort. Support from Mid South Synergy for field testing of Phase II prototype.
- **Proposed Future Research :** Develop cheap technologies for purification and compression of hydrogen.

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