Geologic Storage of Hydrogen

Anna S. Lord, Peter H. Kobos, and David J. Borns
Sandia National Laboratories

May 21, 2009

pd_33_sniderlord

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000. SAND2009-1840C

Sandia National Laboratories

Overview

Timeline

Start – May 1, 2007

Finish – Sept. 30, 2009

75% complete

Barriers

Barrier - Geologic Storage

Target –Geologic Caverns

Geologic Caverns	2005 Status	FY 2017
Installed Capital Cost	Assumed equal to natural gas caverns	Equal to natural gas caverns

Budget

Total Project Funding

-DOE share ($200K)

-Contractor share (N/A)

Funding received in FY08
$100K

Funding received in FY09
$0K

Partners

None

Sandia National Laboratories

Relevance

Objectives

This project will present an understanding of the various types of underground geologic storage available and their suitability for the storage of hydrogen by developing a white paper.

An economic analysis will portray the probable costs entailed in developing and operating the most viable candidates for the underground storage of hydrogen. This information and analyses will help DOE achieve its technical target for geologic storage as presented in the table below.

Geologic Caverns	2005 Status	FY 2017
Installed Capital Cost	Assumed equal to natural gas caverns	Equal to natural gas caverns

Sandia National Laboratories

Relevance (cont.)

The white paper describes:

- Different storage types
- Advantages and disadvantages of the different storage types
- Includes maps of locations where storage is available
- Discusses operational issues specific to hydrogen

The economic analyses will address:

- Development costs
- Plant costs
- Operational costs

Sandia National Laboratories

Approach

Milestones

Milestone	% Complete	Comments
Overview of geologic storage	100	White paper written
Develop maps of available geologic storage in the U.S.	100	Maps are included in white paper.
Analyze issues related to geologic storage, specific to hydrogen	100	Included in white paper
Complete as SAND report	95	Pending formatting.
Develop cost models for: salt, depleted oil/gas reservoir, aquifer	40	Salt model complete. Other models in progress.

Sandia National Laboratories

Technical Approach

(A) Conduct an extensive literature search.

Collect information pertaining to

- the underground geologic storage options currently in use for natural gas,
- possible alternative storage options currently being tested,
- the advantages and disadvantages of each option,
- the location of these storage types,
- the possible problems that may arise with the storage of hydrogen versus natural gas,
- current examples of underground facilities storing hydrogen gas.

Sandia National Laboratories

Technical Approach (cont.)

(B) Perform an economic analysis on the three types of storage sites being considered for hydrogen.

An in depth analysis will include

- Site development costs
- Plant costs
- Operational costs

Sandia National Laboratories

Geologic Storage -Technical Accomplishments

Currently used for the storage of oil, natural gas, and compressed air.

Why underground storage?

Stored energy can be used to:

(1) meet seasonal energy demands and

(2) ensure continuity in supply during accidents or natural disasters

Sandia National Laboratories

Geologic Storage -Technical Accomplishments

Types of Underground Storage

Porous Media (e.g. sandstone)

Examples: depleted oil/gas reservoirs and aquifers

Cavern Storage

Examples: excavated or solution mined rocks, such as salt, coal, igneous, and metamorphic rocks.

Basic Storage Requirements

High porosity, high permeability, hold adequate volumes of gas, extract gas at high rates, contain and trap gas, and cushion gas

Sandia National Laboratories

Geologic Storage -Technical Accomplishments

Types of Underground Storage

Salt Caverns

Salt caverns are solution mined cavities within either salt domes or bedded salts that do not match reservoir volume capacity.

Depleted Oil/Gas Reservoirs

Depleted reservoirs are proven gas reservoirs that are easy to develop and operate due to existing infrastructure.

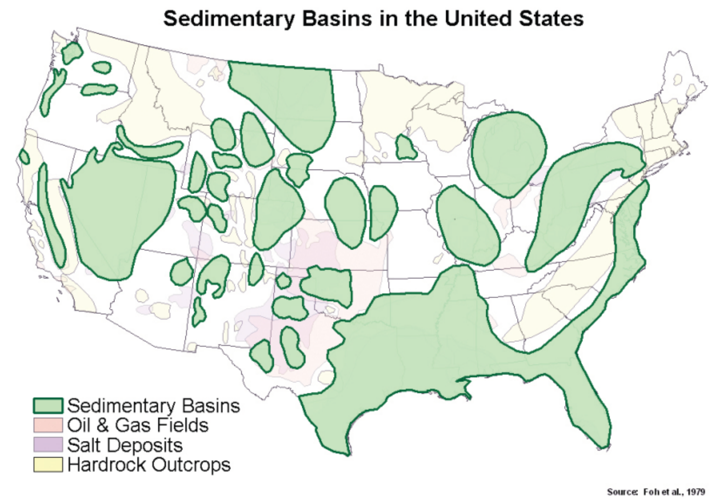
Aquifers

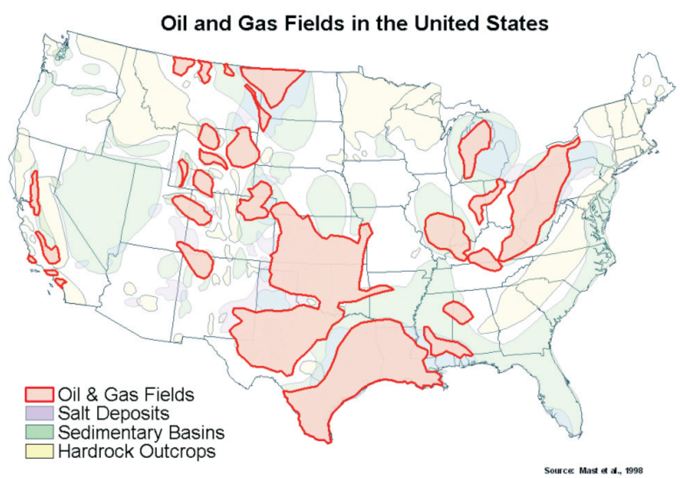
Aquifers are similar in geology to depleted reservoirs, but have not been proven to trap gas and must be developed.

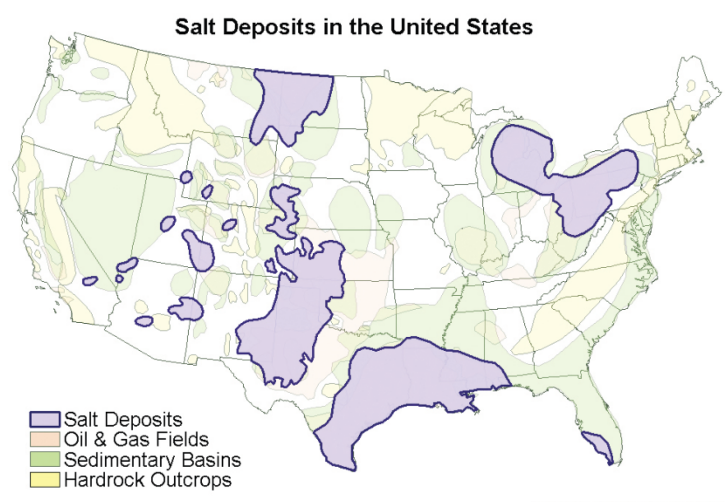
There are other storage options available currently and in the near future, such as abandoned coal mines, lined hard rock caverns, and refrigerated mined caverns.

Geologic Storage -Technical Accomplishments

Locations of available geologic storage







Sandia National Laboratories

Geologic Storage -Technical Accomplishments

Hydrogen is a light, small molecule

The molecule characteristics and the hydrogen purity demand may limit storage options. Future analyses may be needed to investigate possible issues with hydrogen storage.

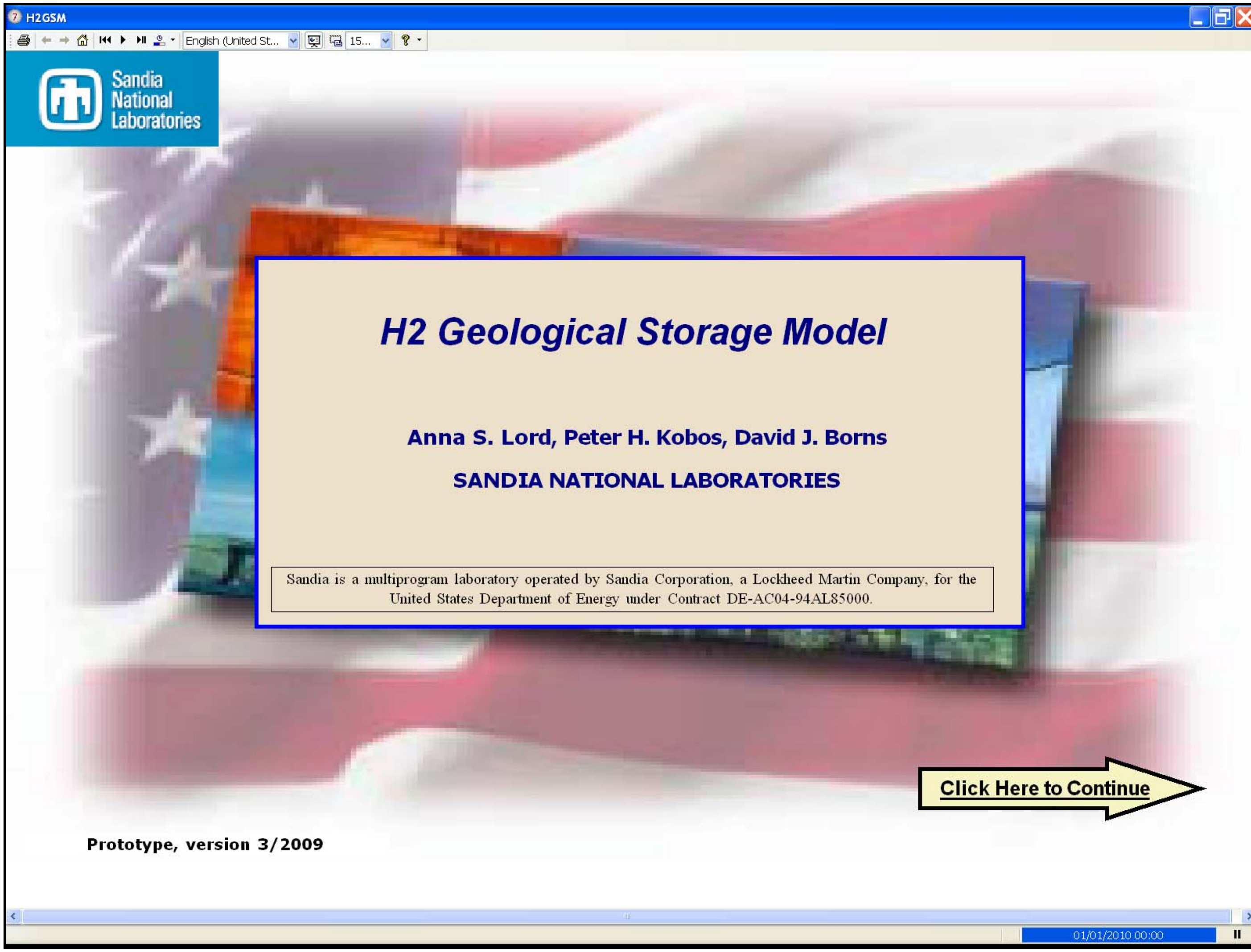
Issues?

- Mixing of hydrogen with natural gas? –depleted gas/oil reservoirs
- Flow, diffusion and fingering of hydrogen into water-bearing units? – depleted gas/oil reservoirs and aquifers?
- Hydrogen embrittlement? –all storage options?
- Chemical reactions? –depleted gas/oil reservoirs and aquifers?

Hydrogen storage in Salt caverns does not pose significant issues.

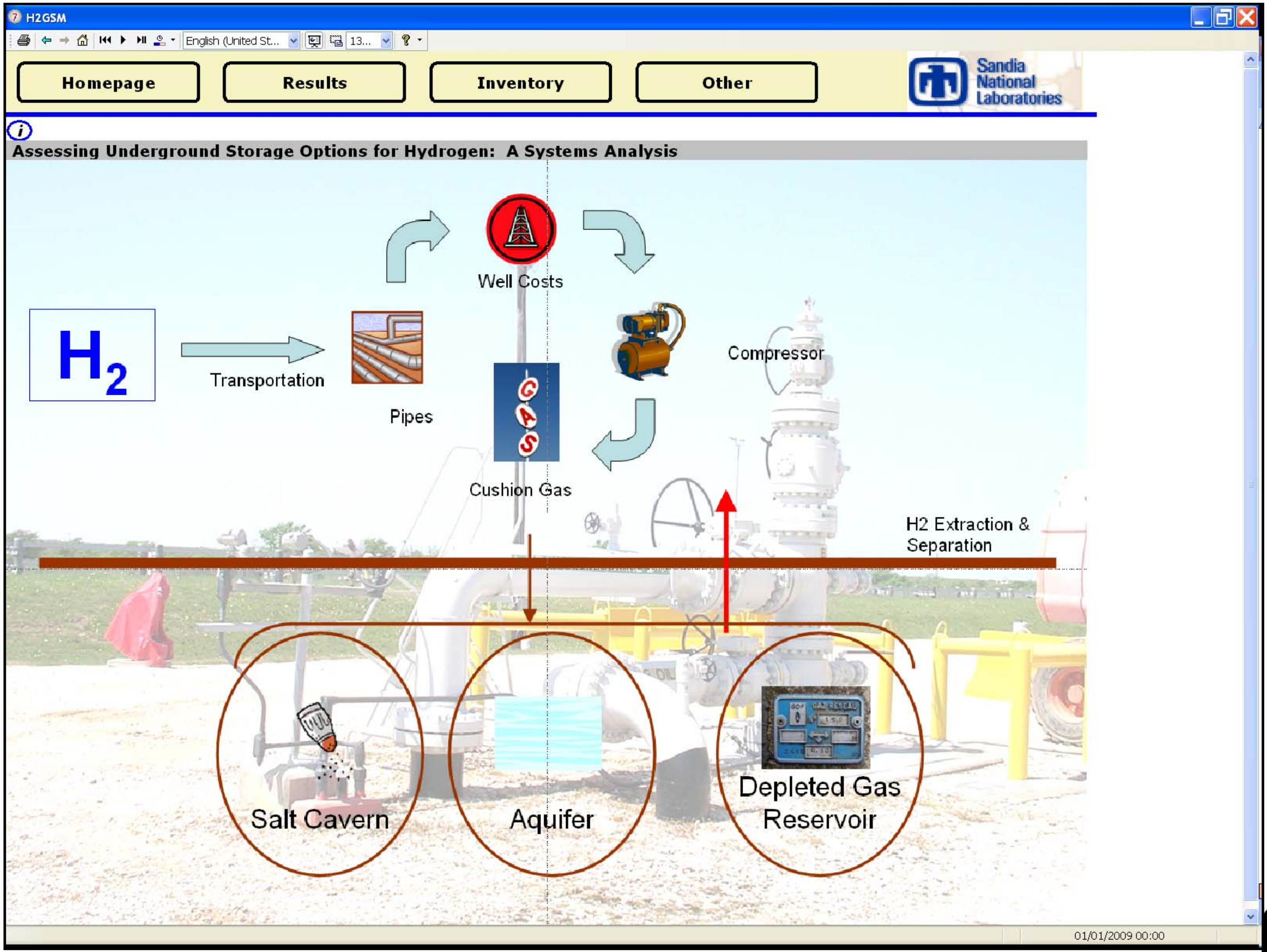
Sandia National Laboratories

Economic Model -Technical Accomplishments



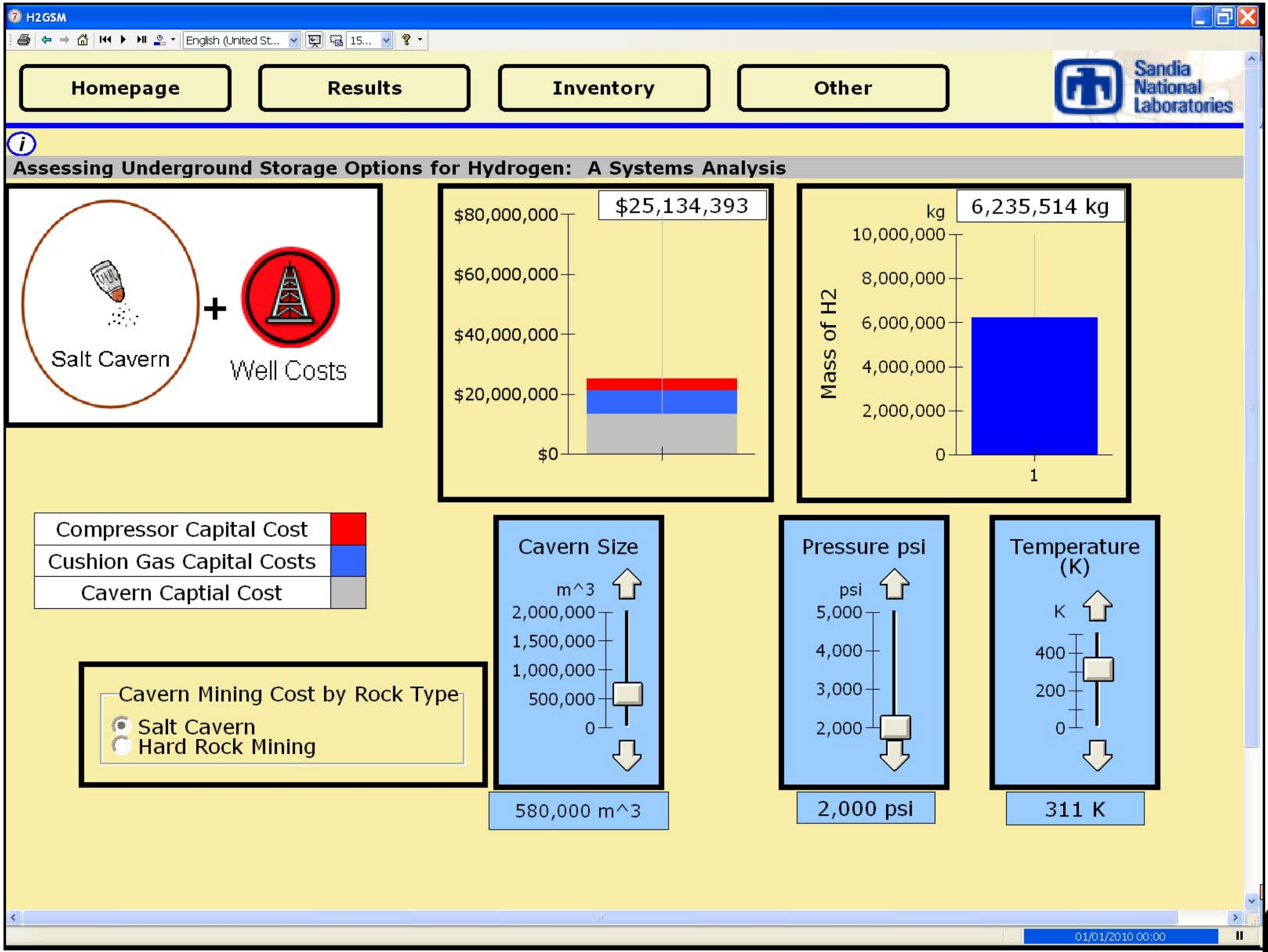
Sandia National Laboratories

Economic Model -Technical Accomplishments



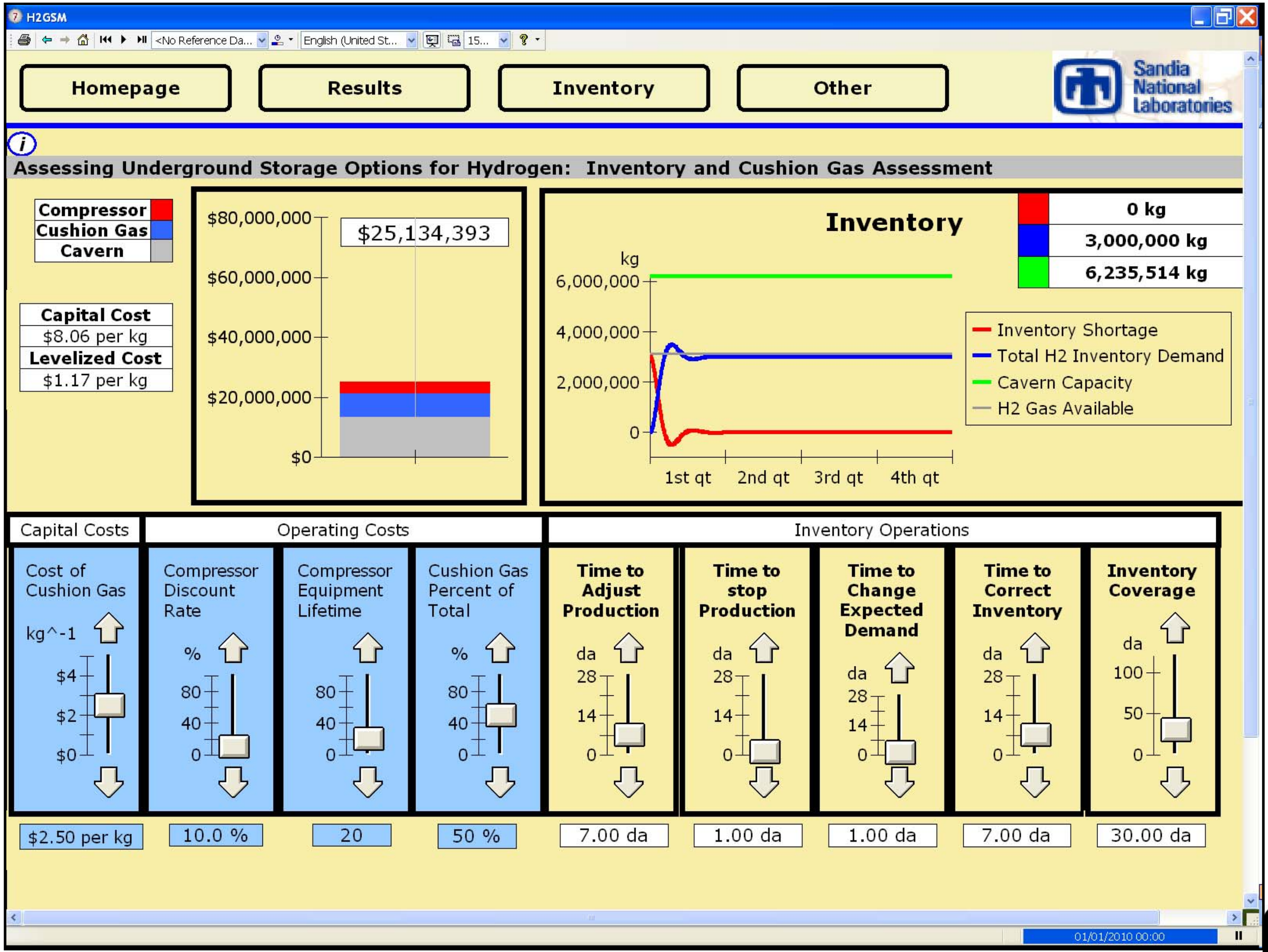
Sandia National Laboratories

Economic Model -Technical Accomplishments



Sandia National Laboratories

Economic Model -Technical Accomplishments



Working, Illustrative Prototype Results as of 3/2009

Sandia National Laboratories

Collaborations

Looking to incorporate the economic model, which is modular by design, with other larger hydrogen infrastructure assessment models, such as, Argonne National Labs “Wheels to Wells” model.

Future Funded Work

Timeline	
2008	• Complete: Salt cavern cost model – Developed ‘H_2 Geological Storage Model’ in PowerSim Studio – Included capital and operating costs
2009 Spring	• Ongoing: Salt Cost Model – Purification/Dehydration units – Leaching plant – Pipes – Brine disposal – Cycle frequency related to demand requirements
2009 Summer +	• Future: Develop similar models for geologic underground storage. – Depleted Oil/Gas Reservoir – Aquifers

National Laboratories

Proposed Future Work

(1) Modularize the existing hydrogen storage model

- Integrate with surrounding infrastructure
- Determine how the existing infrastructure could be used to support the initial transport of hydrogen to fuel a trial fleet of H_2 vehicles

(2) Investigate further possible operational challenges

- Due to the possibility of reservoir mixing, hydrogen loss through chemical reactions, and the occurrence of hydrogen embrittlement

(3) Incorporate GIS information into the H_2 storage model

- Allows map data to be extracted that could aid in optimizing suitable geographic locations for storage

Summary

Relevance – To understand the various types of geologic storage available for hydrogen and portray the potential costs.

Approach – To develop a white paper and storage cost model.

Technical Accomplishments- Described the advantages and disadvantage of various geologic storage options; created a tool that will be used to develop the costs of salt cavern storage facilities.

Future work – develop similar cost models for depleted oil/gas reservoirs and aquifers.