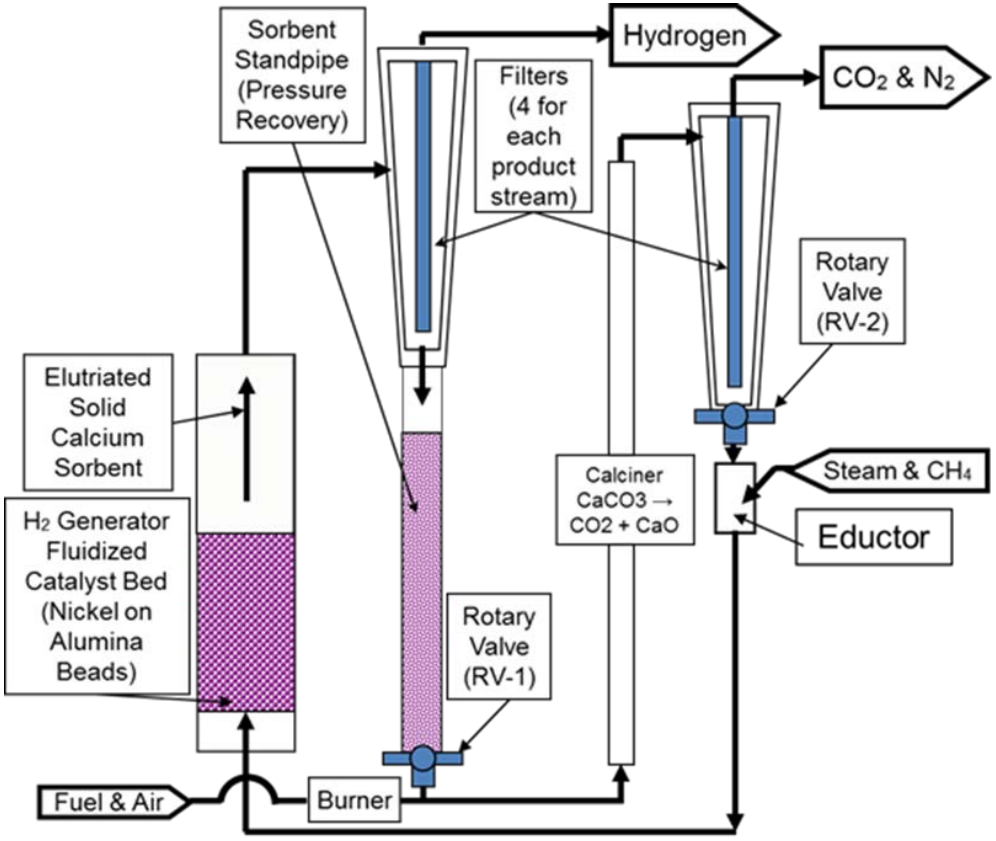
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# Advanced Manufacturing Office R&D Projects H2 at Scale

November 16, 2016

# One Step Sorption Aided Hydrogen Generation

**Project Prime:** Gas Technology Institute
**Project Partners:** Energy & Environmental Research Center (EERC)
**Technology:** Develop low-cost hydrogen production technology using Sorption Enhanced Reforming (SER) that combines the reforming and water-gas shift processes into one-step. Calcium oxide sorbent is elutriated through a bubbling fluidized catalyst bed with methane and steam. Hydrogen end-users benefit from process intensification and reduced hydrogen cost (15% – 20%) through lower capital cost, improved efficiency, and smaller footprint. In addition, a separate $CO_2$ stream arising from calcination reduces $CO_2$ capture costs.




## Technology Update

- Earlier development efforts constructed a 20,000 scfd Feasibility Demonstration Unit (FDU) demonstrating over 60 hours of $H_2$ production at 80% - 90% purity.
- The FDU was successfully started again in August and operated for 12 hours without any reduction in catalytic activity.
- Researchers are investigating alternate catalyst substrate compounds better able to withstand SER conditions, improving catalyst life and reducing the frequency of replacing the catalyst and sorbant.

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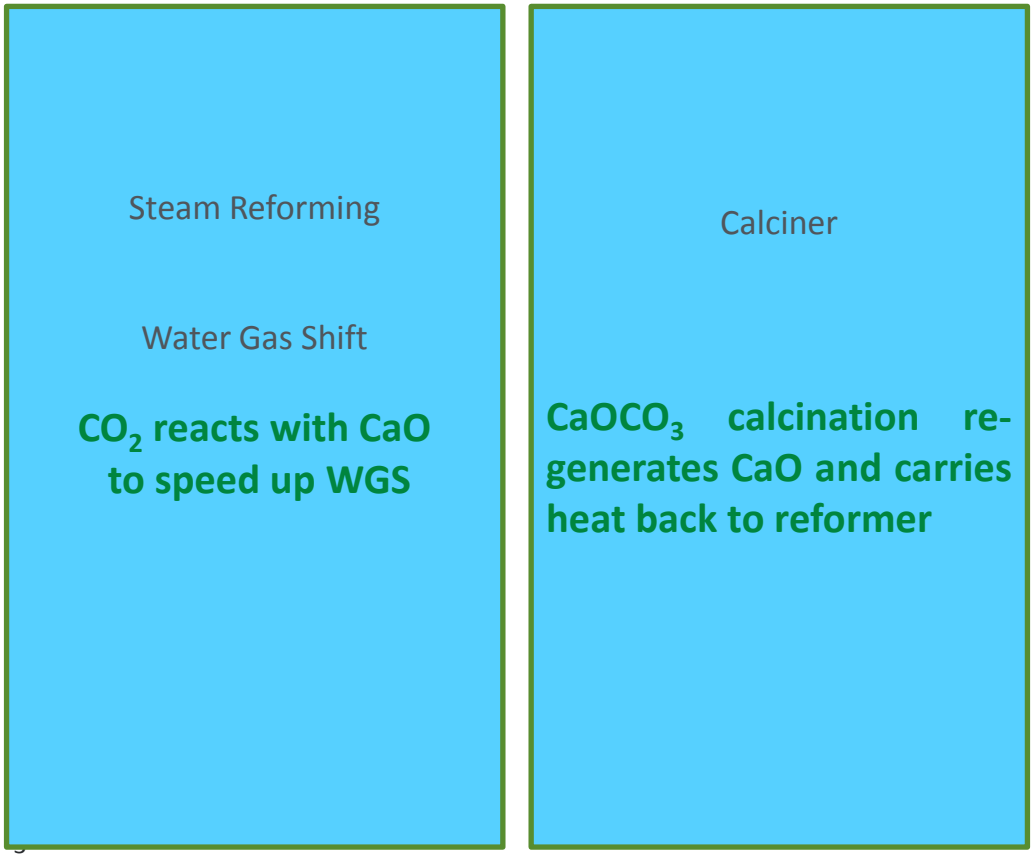


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# SBIR Projects: $H_2$ Production and Purification

SBIR projects on H2 production and purification.

| Phase | Title | Institution |
|---|---|---|
| I | High efficiency reformer for hydrogen production | Precision Combustion, Inc |
| Demonstrate concept feasibility of using a novel catalyst and reactor technology, the proposed Microlith Technology, that will allow processing and reforming of still gas over a wide range of composition. Native sulfur from still gas will be effectively removed as $H_2S$, followed by steam reforming to produce $H_2$-rich syngas. $H_2$ is recovered via adsorption. | | |
| I | $H_2$ Production from Still Gases on Structured Catalysts for Refineries | Nexceris, LLC/ NexTech Mat |
| Researchers propose to convert still gas to hydrogen by engineering novel structured catalysts for steam reforming (STR) and water gas shift (WGS) reactions. Increased catalyst loading and adhesion on the substrates will be attempted by tailoring the substrate/catalyst interface with a coating technology. In the Phase I effort, powder catalysts will be synthesized, characterized, wash-coated on small substrates, and tested for the STR and WGS reactions. | | |
| IIB* | Improved Hydrogen Purification | Compact Membrane Systems, Inc. |
| Develop high performance, robust membranes for the purification of hydrogen from natural gas and hydrocarbon feedstocks by utilizing a novel material with a high permeability for $CO_2$, the major contaminant. While this material can easily be formed into a membrane, making the material thin enough to provide high $CO_2$ permeance is much more difficult. A membrane fabrication method will be developed to enable fabrication of prototype membranes for pilot tests. | | |

# A Novel Flash Ironmaking Process

**Project Prime:** American Iron and Steel Institute
**Project Partners:** University of Utah; Berry Metal Company; ArcelorMittal, USA; United States Steel Corp.; TimkenSteel
**Technology:** Develop a novel ironmaking process that directly converts a vertical stream of iron ore particles to metal in just seconds using low cost natural gas, hydrogen, other syngas, or a combination thereof. This process uses less energy and reduces greenhouse gas emissions compared with conventional blast furnaces, coke ovens, and ore preparation. The project seeks to demonstrate the scaleup feasibility of the process allowing for new ironmaking capacity at a significantly lower capital cost. than with competing systems.

**Large-scale bench reactor**
*Image courtesy of Berry Metal Company*

## Technology Update

- Large-scale bench reactor (LSBR) was installed and successfully commissioned in November 2015. Experimental runs are identifying equipment issues/adjustments.
- Goal is to achieve >95% metallization with 1.5 times stoichiometric reducing gas volume.
- Conducting reaction kinetics experiments of magnetite reduction at high operating temperature and conditions expected in the LSBR.
- Developing CFD model based on LSBR results. CFD model will be applied to the design of an industrial scale reactor.

# Ultra Efficient Combined Heat, Hydrogen, and Power System

**Project Prime:** FuelCell Energy, Inc.

**Technology:** Develop a combined heat, hydrogen and power tri-generation system (CHHP) to utilize reducing gas produced by a high-temperature fuel cell to directly replace hydrogen and nitrogen used in a metal annealing process, greatly improving the efficiency of the system and reducing annealing costs. The addition of hydrogen provides additional value for the technology, and improves payback.

## Technology Update

- The combined heat, hydrogen and power tri-generation system was successfully commissioned at the FuelCell Energy manufacturing plant in CT.
- System is fully operational at greater than 75% efficient at generating heat and power. The system also provides a stream of high purity hydrogen to the fuel cell anode manufacturing line.
- Additional application areas include metals (e.g. powdered copper) process industries that use a reducing atmosphere in manufacturing.


**The high efficiency packaged CHHP system in operation at FuelCell Energy's manufacturing plant in CT .**

# Clean Energy and Manufacturing: A Mission for Innovation

## Clean Energy Manufacturing

**Making Products which Reduce Impact on Environment**

- **Alternative to carbo-thermic reduction**
- **Alternative to NG combustion based heating for thermal processes**

## Advanced Manufacturing

**Making Products with Technology as Competitive Difference**

- **Affordable alloys that can withstand H (pipe lines for mixed atmospheres?)**
- **Systems that can withstand intermittent use of NG/$H_2$ to compensate for variations in renewables**
- **Catalysts for $H_2$ generation**
- **Membranes for $H_2$ purification**