NETL GASIFICATION SYSTEMS

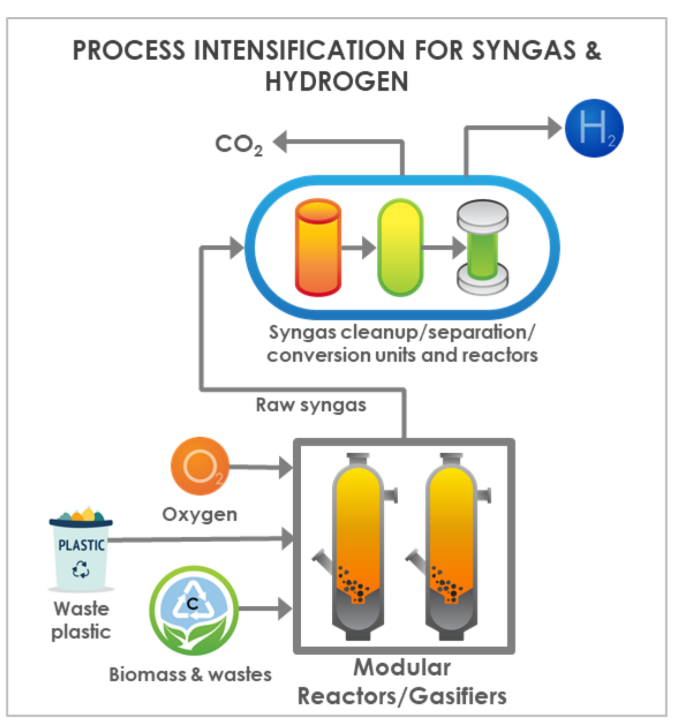
The Gasification Systems program at NETL focuses on efficient gasification systems enabling use of solid feedstocks for decarbonized syngas and clean hydrogen production through a diverse and cutting-edge research portfolio.

Gasification for A Decarbonized Economy

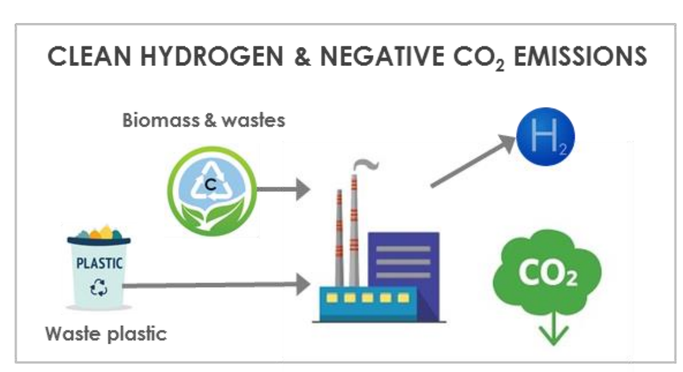
The DOE Gasification Systems program is developing innovative designs and technologies for converting diverse types of solid feedstocks into clean synthesis gas to enable the low-cost production of hydrogen, transportation fuels, chemicals, electricity, and other useful products to suit market needs. Advancements in this area will help enable syngas-based technologies and energy systems to be competitive in both domestic and international markets, and spur on the use of domestic resources towards increased energy security and emissions reduction goals of the United States.

Key Program Technology Areas

Improving gasifier designs to increase **syngas heating values, reduce reactor size,** and lower **oxygen demand for decarbonized energy systems and hydrogen production.**



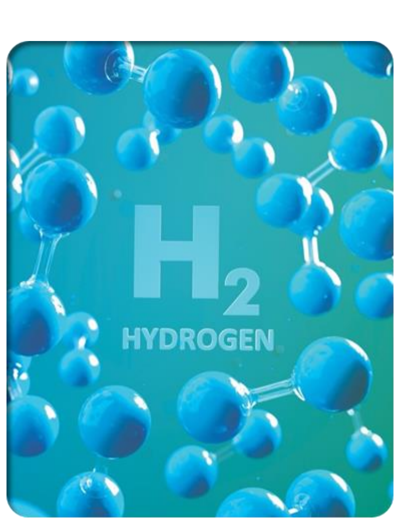
Innovative new methods for **oxygen production,** including **membranes, cryogenics,** and **oxygen carriers, enabling lowest cost carbon capture.**



Innovative technology for clean hydrogen production using **carbon-neutral** biomass with carbon capture, enabling net-negative carbon systems.

Clean Hydrogen

The gasification pathway enables deployment of clean hydrogen production with net-zero carbon or net-negative carbon capability in energy systems, and cost-effective decarbonization for U.S. industry. This helps to accomplish ambitious administration carbon reduction goals leading to complete decarbonization of the economy by 2050.



Environmental Justice

Gasification enables remediation of wastes (legacy waste disposal and more) to address environmental justice and job creation initiatives. Advanced co-gasification of wastes, biomass, and plastic with low-cost oxygen combine to form a viable net-zero energy system basis.

Decarbonized Economy

Process intensified gasification technologies with low-cost oxygen via advanced oxygen separation methods will enable lowest cost carbon capture, driving deployment and adoption of widespread carbon capture and storage as required for decarbonization.

GASIFICATION SYSTEMS

FY 2024 BUDGET REQUEST

$30,000k

CONTACTS

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TECHNOLOGY MANAGER:
Jonathan Lekse

TECHNICAL PROFOLIO LEAD:
Debalina Dasgupta

PERFORMERS

EPRI Electric Power Research Institute
The University of Utah
Clarkson University
ERCo Energy Research Company
NREL
Washington University in St. Louis, James McKelvey School of Engineering
parc Part of SRI International
University of Kentucky
UND University of North Dakota
EERC
NC State University
Oak Ridge National Laboratory
Auburn University
SUSTEON
West Virginia University
SUNY The State University of New York
RTRC RTX Technology Research Center
OSMOSES
Pacific Northwest National Laboratory
TDA Research
Los Alamos National Laboratory
INL Idaho National Laboratory

U.S. DEPARTMENT OF ENERGY
NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Process Intensification of Hydrogen Production through Sorption-Enhanced Gasification of Biomass

Demonstrate the feasibility of sorption-enhanced biomass gasification for production of H_2-rich syngas in a dual fluidized bed reactor operating under industrially-relevant conditions

Overview

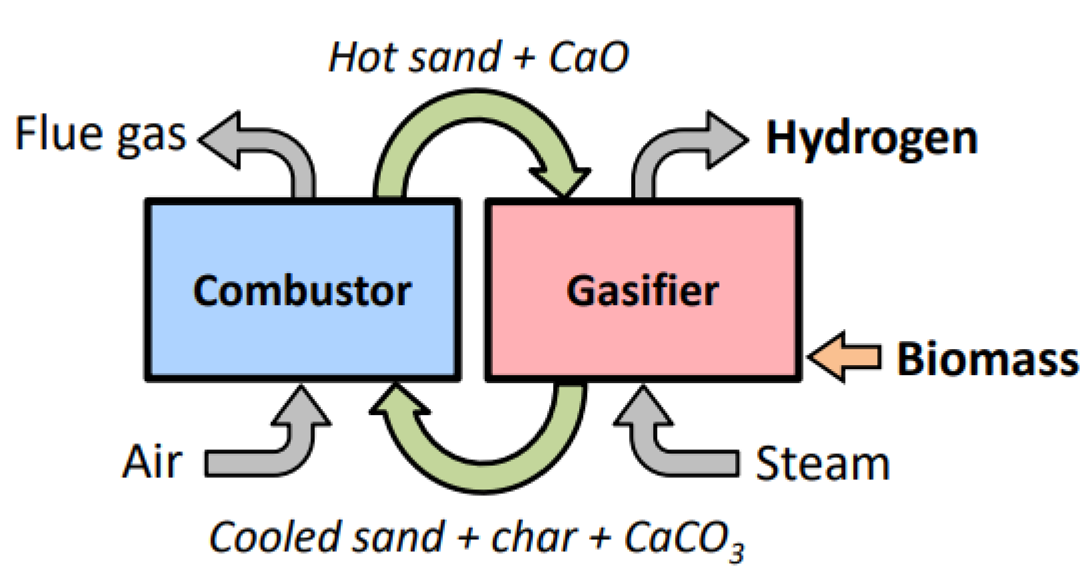
The University of Utah is demonstrating the feasibility of sorption-enhanced biomass gasification for production of H_2-rich syngas in a dual fluidized bed reactor operating under industrially-relevant conditions. This will be achieved by preprocessing the biomass feedstock to ensure consistent composition and trouble-free feeding, combined with operation of an existing dual fluidized bed process development unit with addition of limestone to achieve in situ removal of CO_2 from the gasifier to create a clean, high-hydrogen syngas. Objectives include demonstration that waste biomass can be pre-processed to promote the sorption-enhanced gasification, understanding & modeling the fundamental processes involved, evaluating sorption-enhanced gasification performance and syngas quality over a range of operating conditions, and demonstrating an oxygen-blown variant that can produce separate H_2- and CO_2-rich streams from this gasification process.

Benefits

The technology being developed applies process intensification to reduce the complexity and number of unit operations compared to the conventional multi-step process for conversion of biomass to hydrogen. As such, it potentially increases efficiency and reduces costs, simplifying production of H_2 from biomass and advancing clean hydrogen production technology toward the goal of achieving \$1/kg of H_2 per Hydrogen Shot goals.

Recent Results

- Gasification temperature is limited to T <720°C due to the chemical equilibrium of the capture reaction
- Sorption capacity is enhanced with steam, holds true over multiple cycles
- CO_2 sorption performance is limited by CO addition and presence of H_2
- Sorbent decay increased with syngas introduction



$$C + O_2 \rightarrow CO_2$$
$$CaCO_3 \rightarrow CaO + CO_2$$

$$C + H_2O \rightarrow CO + H_2$$
$$CO + H_2O \rightarrow CO_2 + H_2$$
$$CaO + CO_2 \rightarrow CaCO_3$$

QUICK FACTS

AWARD NUMBER:

DE-FE0032174

PROJECT BUDGET

DOE Share:
\$1,596k

Performer Share:
\$399k

Total Award Value:
\$1,995k

CONTACTS

HQ PROGRAM MANAGER:
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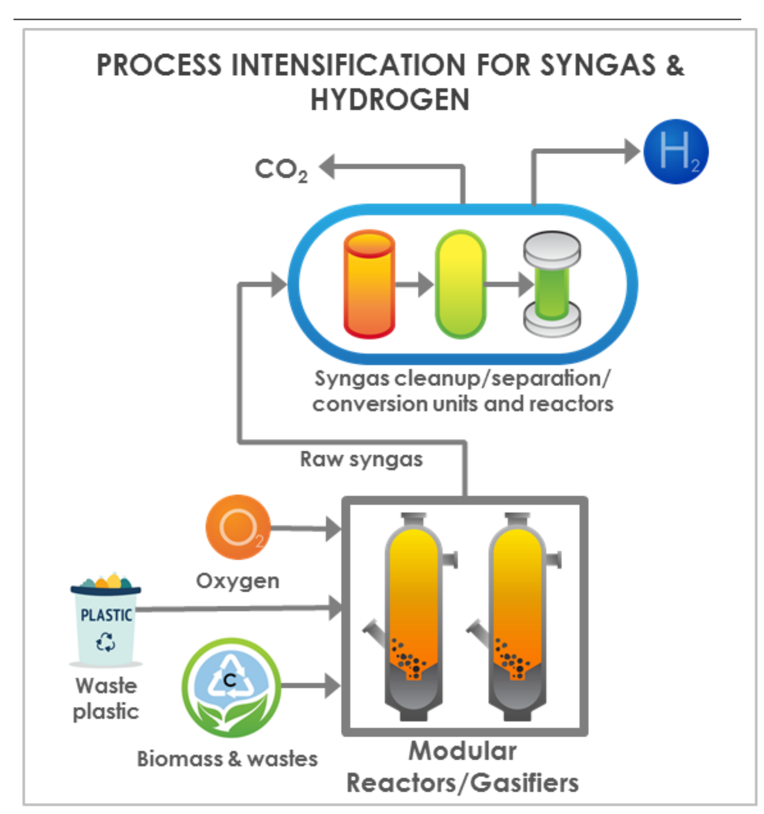
PRINCIPAL INVESTIGATOR:
Kevin J. Whitty

PERFORMER

The University of Utah

PARTNER

Idaho National Laboratory



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Modular Biomass Gasification for Co-Production of Hydrogen and Power

Demonstrate the technical and economic feasibility of a novel, process-intensified and modular Combined Hydrogen Heat and Power technology, targeting scales less than 50 MWe (~60 MTPD hydrogen)

Overview

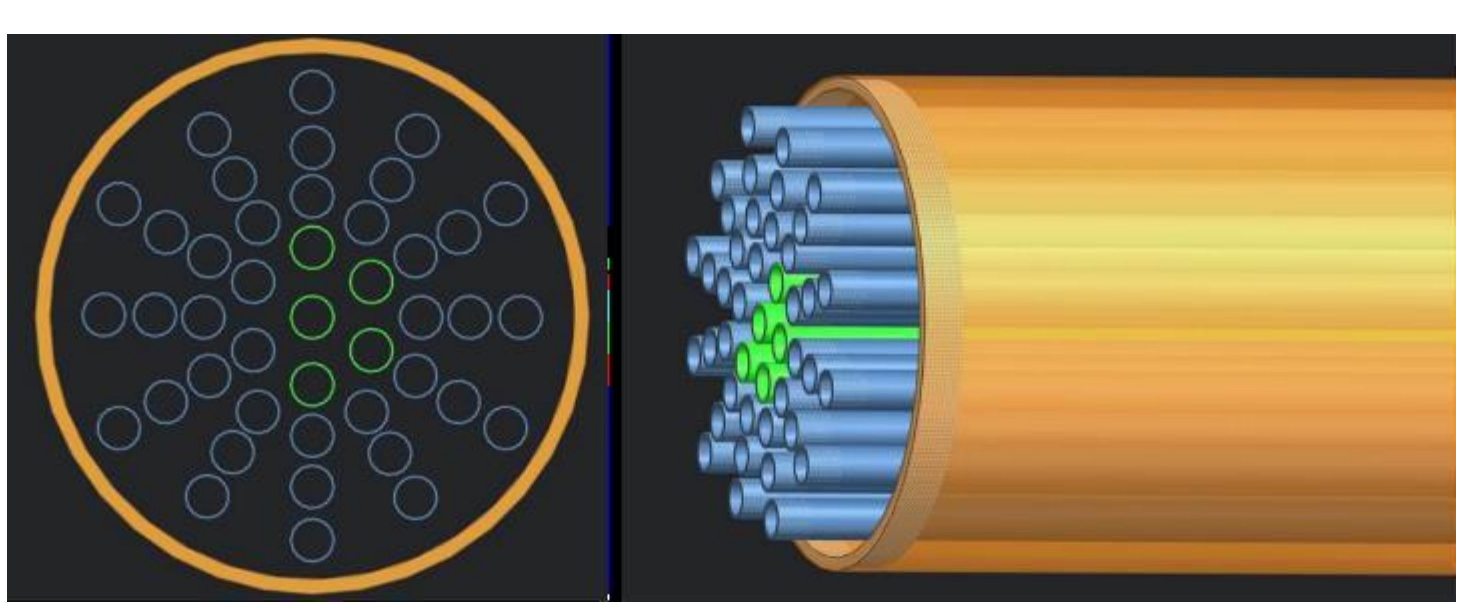
The University of North Dakota is developing a novel process-intensified and modular Combined Hydrogen, Heat, and Power (CH2P) production technology, integrating a novel adaptation of the steam-iron process to produce high-purity H_2 and a compression-ready CO_2 stream from the gasification of biomass and biomass blends. Key features include the use of a novel, iron-based material with multi-functionality oxygen carrier material that combines syngas purification, H_2 production, and CO_2 separation, use of a low-cost, modular bed gasification system known as the Sandwich™ Gasifier, and tightly integrating the gasification process and synthesis gas conversion process.

Benefits

Awards resulting from DE-FOA-0002400, “Clean Hydrogen Production, Storage, Transport and Utilization to Enable a Net Zero Carbon Economy,” are targeted toward developing technologies enabling clean hydrogen production, transport, storage, and use in the energy sector, including electricity, heat, transportation, and industrial use. These awards are focused on achieving overall cost reductions in clean hydrogen production from efficient gasification systems to make progress toward DOE’s Hydrogen Shot initiative’s cost goal of $1 per one kilogram of clean hydrogen.

Recent Results

- Perovskite oxygen carrier preparation methods successful
- Bench scale biomass gasification experimental results showing good agreement with ASPEN simulations



QUICK FACTS

AWARD NUMBER:
DE-FE0032182

PROJECT BUDGET

DOE Share:
$1,600k

Performer Share:
$520k

Total Award Value:
$2,120k

CONTACTS

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PRINCIPAL INVESTIGATOR:
Junior Nasah

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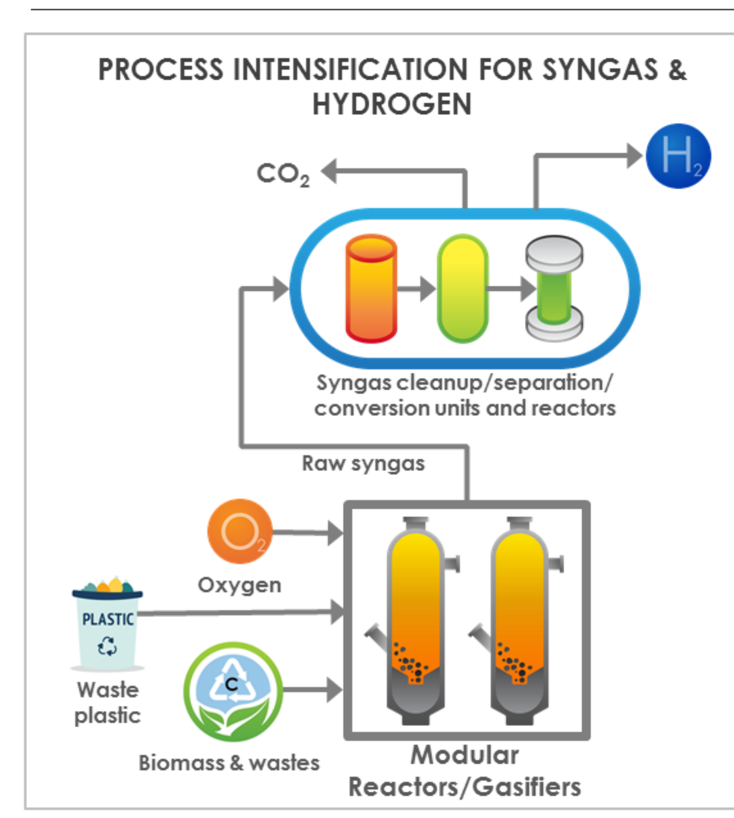
UND University of North Dakota



U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Producing Clean Hydrogen Using a Modular Two-Stage Intensified Membrane-Enhanced Catalytic Gasifier

Develop a process intensified two-stage bubbling fluidized bed gasifier for hydrogen production from biomass

Overview

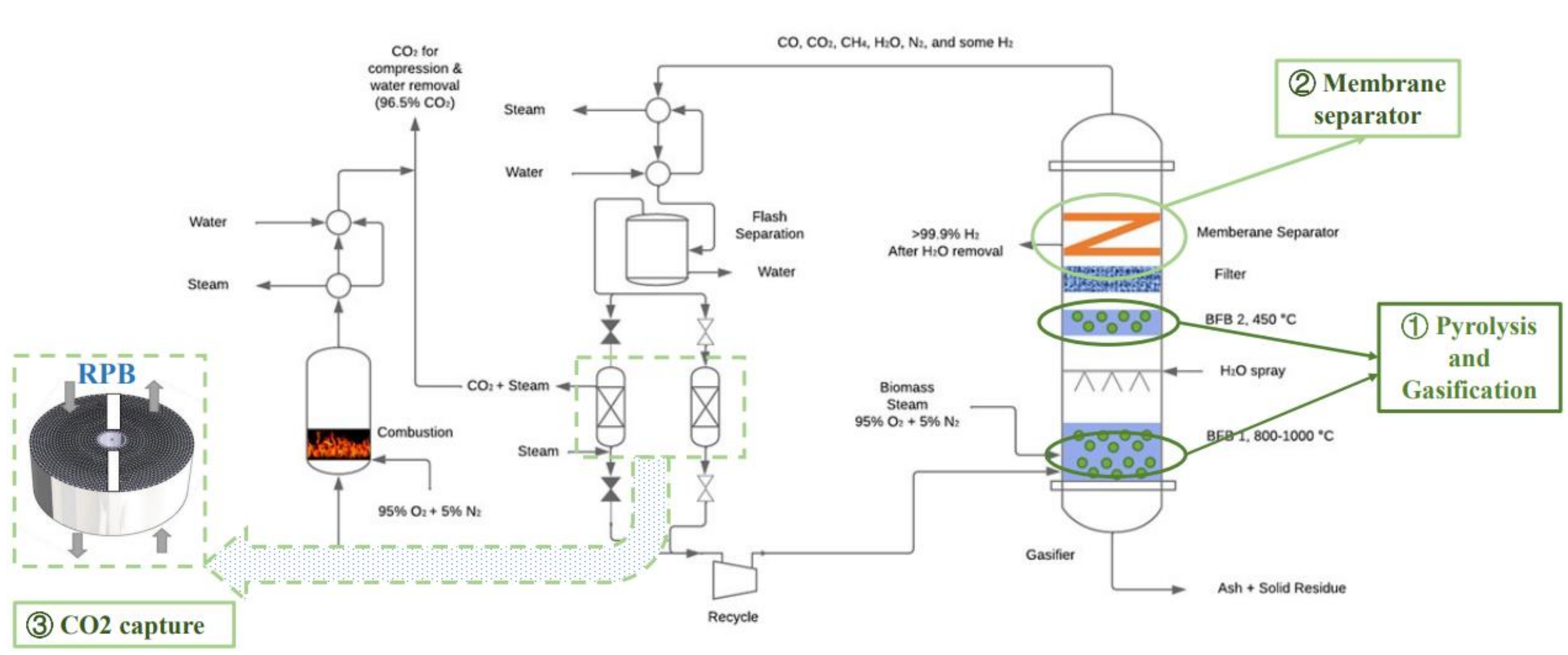
West Virginia University Research Corporation (WVURC) is developing a process intensified two-stage bubbling fluidized bed (BFB) gasifier for hydrogen production from biomass. The BFB gasifier system would be integrated with a membrane separator and pre-combustion carbon dioxide capture system with syngas recycle. The overall goal of the project is to reduce the costs of hydrogen production by developing a modular and highly efficient and intensified gasification system with significantly less equipment items than traditional systems.

Benefits

Awards resulting from DE-FOA-0002400, "Clean Hydrogen Production, Storage, Transport and Utilization to Enable a Net Zero Carbon Economy," are targeted toward developing technologies enabling clean hydrogen production, transport, storage, and use in the energy sector, including electricity, heat, transportation, and industrial use. These awards are focused on achieving overall cost reductions in clean hydrogen production from efficient gasification systems to make progress toward DOE's Hydrogen Shot initiative's cost goal of $1 per one kilogram of clean hydrogen.

Recent Results

- For catalytic fixed bed gasification of pine biomass, differences in syngas composition and carbon conversion quantified as function of high and low pressure operation
- Using defect curing for engineering the selective layer of the Matrimid hydrogen permeation membrane
- Process modeling parameters being defined/optimized



QUICK FACTS

AWARD NUMBER:
DE-FE0032191

PROJECT BUDGET

DOE Share:
$1,499k

Performer Share:
$375k

Total Award Value:
$1,874k

CONTACTS

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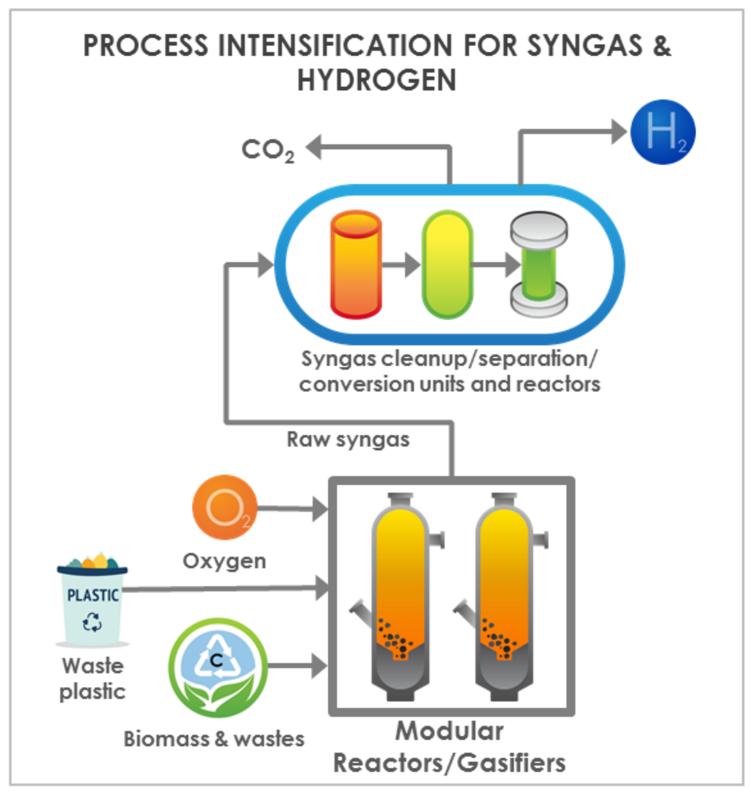
PERFORMER

West Virginia University



Metallic Membrane Reactors: An Intensified Process to Transforming the Production of Carbon-Neutral Hydrogen

Develop a process intensified biomass gasification process by the use an H_2-selective Membrane Assisted Water Gas Shift reactors (MAWGS)

Overview

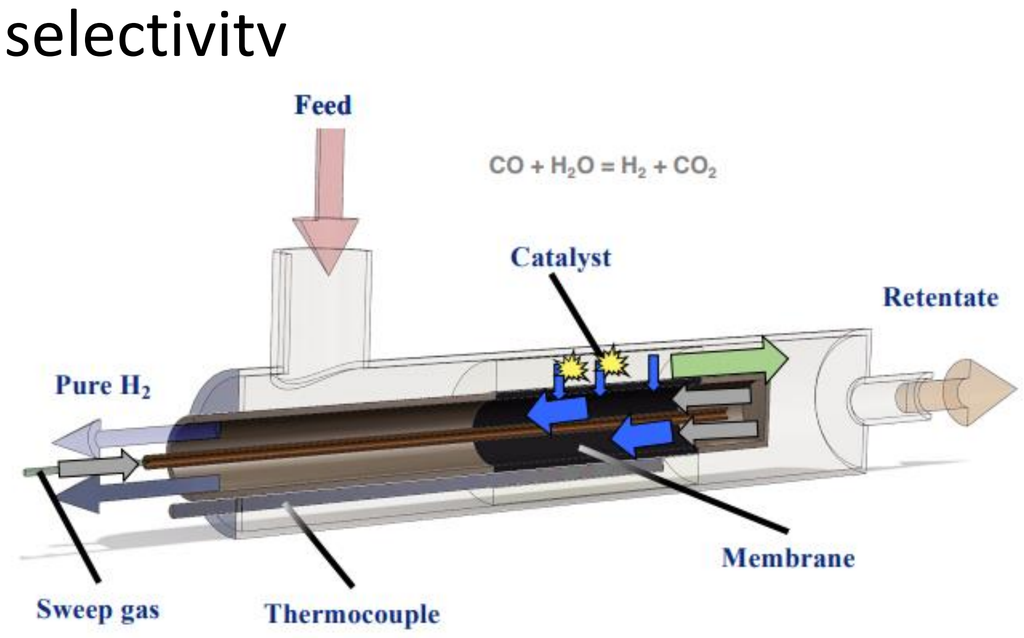
Clarkson University is demonstrating carbon-neutral hydrogen production from biomass gasification based on the use of metallic H_2-selective membrane assisted water gas shift reactors (MAWGS). As opposed to conventional practice of syngas upgrading/cleaning followed by hydrogen separation, this approach removes the hydrogen gas directly from the WSG reaction zone via the membrane. This results in significant process intensification, reducing the volume of the reactor and catalyst amount and increasing conversion, translating into lower capital, operating and maintenance costs.

Benefits

Awards resulting from DE-FOA-0002400, "Clean Hydrogen Production, Storage, Transport and Utilization to Enable a Net Zero Carbon Economy," are targeted toward developing technologies enabling clean hydrogen production, transport, storage, and use in the energy sector, including electricity, heat, transportation, and industrial use. These awards are focused on achieving overall cost reductions in clean hydrogen production from efficient gasification systems to make progress toward DOE's Hydrogen Shot initiative's cost goal of $1 per one kilogram of clean hydrogen. Advances in hydrogen technologies capable of improving performance, reliability, and flexibility of existing and novel methods to produce, transport, store, and use hydrogen will enable carbon footprint reductions associated with energy use, supporting the United States' goals to reduce greenhouse gas pollution by 2030 and to achieve economy-wide net-zero emissions by 2050.

Recent Results

- A ternary Pd-based membrane, Pd-Au-Ag (70-26-4 w/w%) on porous stainless-steel support shows good performance in terms of hydrogen permeation and ideal selectivity
- Membrane stable under multiple thermal cycles in reaction environment
- Membrane reactor performs better than a traditional reactor



QUICK FACTS

AWARD NUMBER:
DE-FE0032205

PROJECT BUDGET

DOE Share:
$535k

Performer Share:
$121k

Total Award Value:
$671k

CONTACTS

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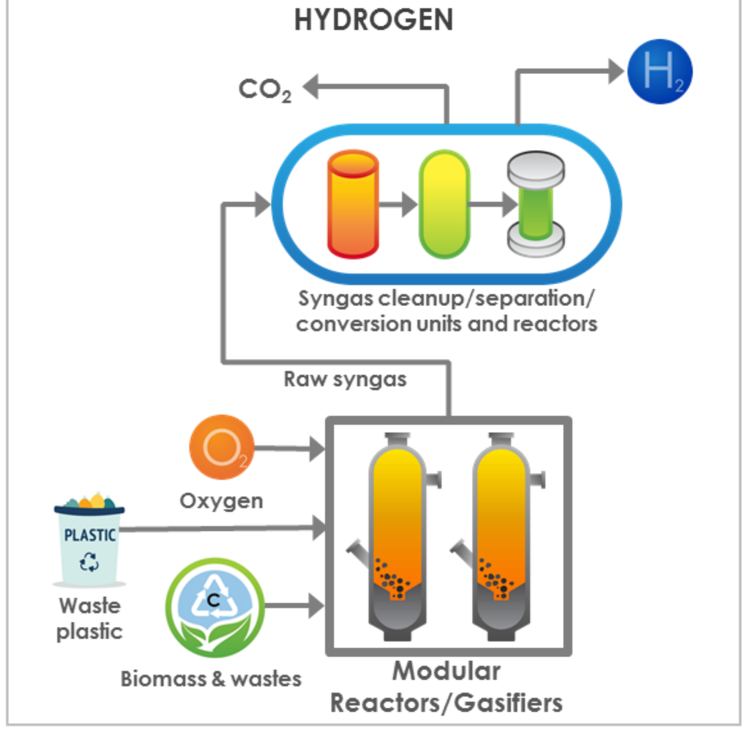
PRINCIPAL INVESTIGATOR:
Simona Liguori

PERFORMER

Clarkson University



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Catalytic Membrane Reactors Based on Carbon Molecular Sieve Hollow Fiber Membranes for Sustainable And Modular Hydrogen Production

- Demonstrate a process-intensified process for economically viable, modular H_2 production from waste biomass using catalytic membrane reactors (CMR) based on carbon molecular sieve hollow fiber membranes.

Overview

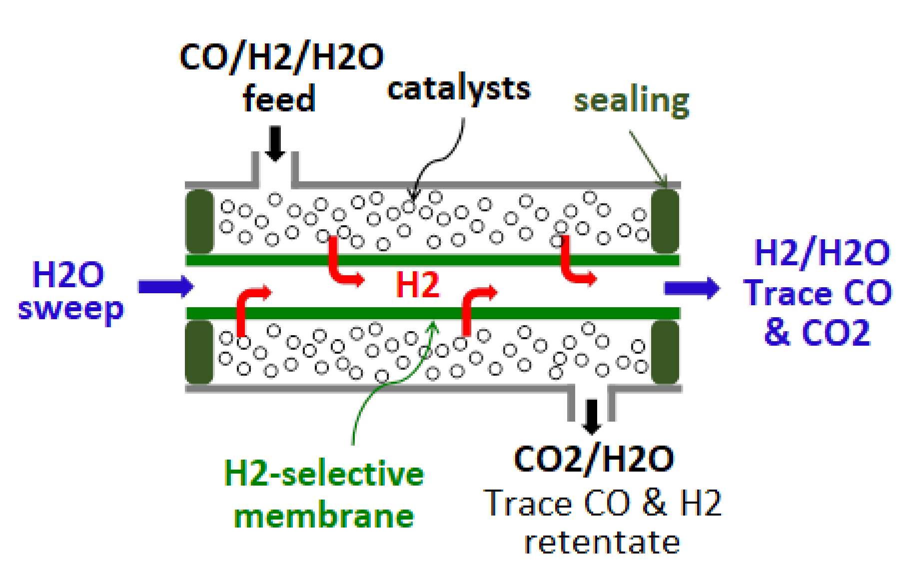
The Research Foundation for State University of New York (SUNY) on behalf of University at Buffalo is developing a process-intensified gasification system for economically viable, modular H_2 production from waste biomass using catalytic membrane reactors (CMR) based on carbon molecular sieve hollow fiber membranes. Specifically, the CMR will be developed to selectively remove H_2 during the high-temperature water-gas shift reaction to circumvent thermodynamic limitations on the conversion of CO to CO_2 and H_2. The endpoint of the program will be a 200-hour continuous test of the optimized CMRs for achieving high carbon conversion at high temperatures and a roadmap for technology demonstration, deployment, and commercialization.

Benefits

Awards resulting from DE-FOA-0002400, "Clean Hydrogen Production, Storage, Transport and Utilization to Enable a Net Zero Carbon Economy," are targeted toward developing technologies enabling clean hydrogen production, transport, storage, and use in the energy sector, including electricity, heat, transportation, and industrial use. These awards are focused on achieving overall cost reductions in clean hydrogen production from efficient gasification systems to make progress toward DOE's Hydrogen Shot initiative's cost goal of $1 per one kilogram of clean hydrogen.

Recent Results

- Simulations show that the primary advantage of CMR is to increase gas space velocities compared to conventional packed bed reactors
- Various Fe_2O_3-based nano-catalysts exhibit high CO conversion (~78%)
- Carbon molecular sieve hollow fiber membranes show excellent H_2/CO_2 separation performance meeting the target
- Base case CMRs using tubular membranes demonstrate higher CO conversion than packed bed reactors



Schematic of catalytic membrane reactors (CMRs)

QUICK FACTS

AWARD NUMBER:
DE-FE0032209

PROJECT BUDGET

DOE Share:
$1,600k
Performer Share:
$500k
Total Award Value:
$2,100k

CONTACTS

HQ PROGRAM MANAGER:
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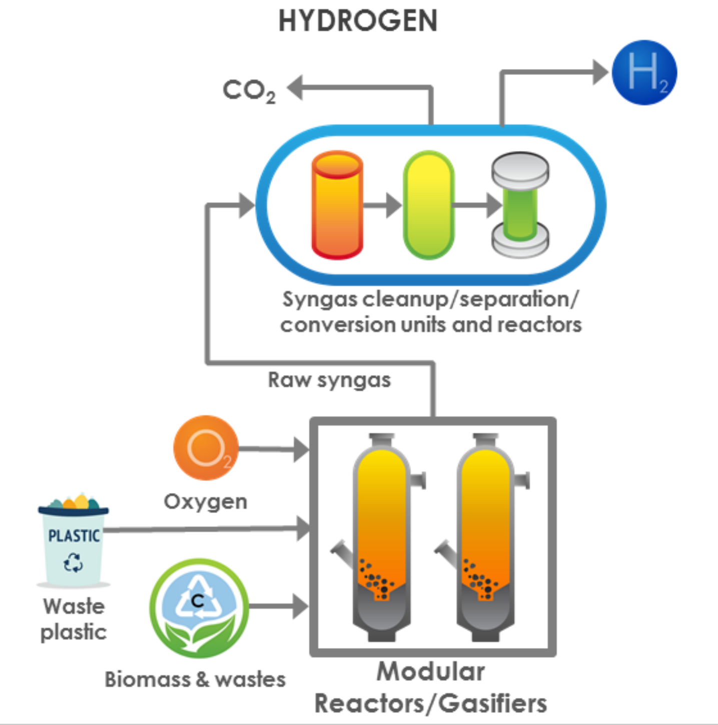
PRINCIPAL INVESTIGATOR:
Haiqing Lin

PERFORMER

SUNY The State University of New York



Intensification of Hydrogen Production Enabled by Electrochemical Pumping Module for Purification and Compression

Develop and demonstrate an innovative electrochemical hydrogen pump (EHP) technology that will significantly reduce the costs of clean hydrogen production, specifically from small-scale (5- 50MW) biomass gasification units

Overview

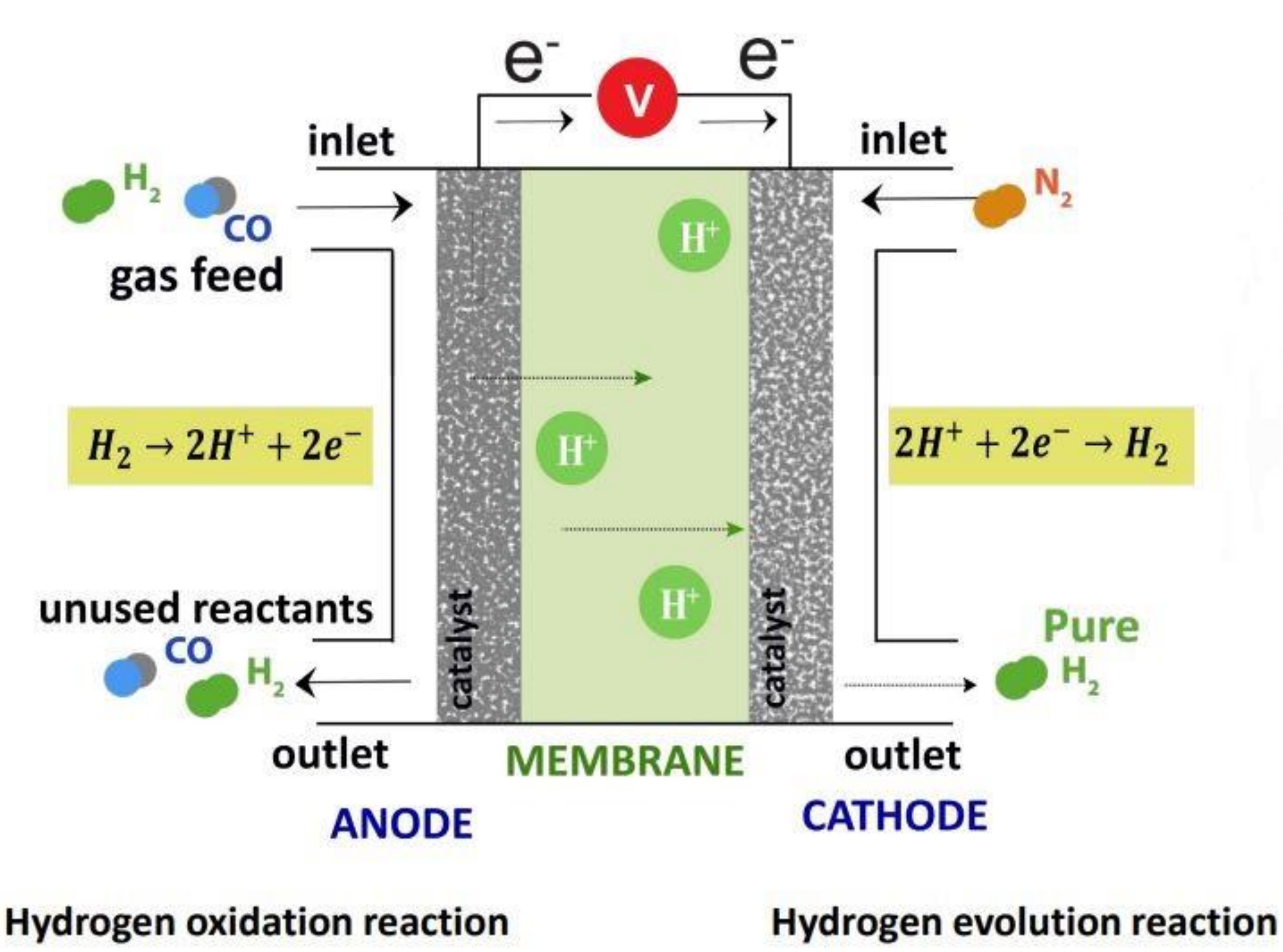
Washington University is developing and demonstrating an innovative electrochemical hydrogen pump (EHP) technology. It combines two energy-intensive process steps of hydrogen purification and compression into a single step, utilizing a small amount of electricity to simultaneously treat product gas from a standard water-gas shift reactor and selectively pump pure H_2 through an electrochemical cell to achieve high-purity and high pressure H_2 for subsequent storage/utilization or pipeline injection.

Benefits

Awards resulting from DE-FOA-0002400, “Clean Hydrogen Production, Storage, Transport and Utilization to Enable a Net Zero Carbon Economy,” are targeted toward developing technologies enabling clean hydrogen production, transport, storage, and use in the energy sector, including electricity, heat, transportation, and industrial use. These awards are focused on achieving overall cost reductions in clean hydrogen production from efficient gasification systems to make progress toward DOE’s Hydrogen Shot initiative’s cost goal of $1 per one kilogram of clean hydrogen.

Recent Results

- A CO-tolerant electrocatalyst has been identified (PtRu/C) that shows improved hydrogen recovery
- Thermally stable PBI membrane (doped with phosphoric acid) fabricated



QUICK FACTS

AWARD NUMBER:
DE-FE0032178

PROJECT BUDGET

DOE Share:
$1,600k

Performer Share:
$401k

Total Award Value:
$2,001k

CONTACTS

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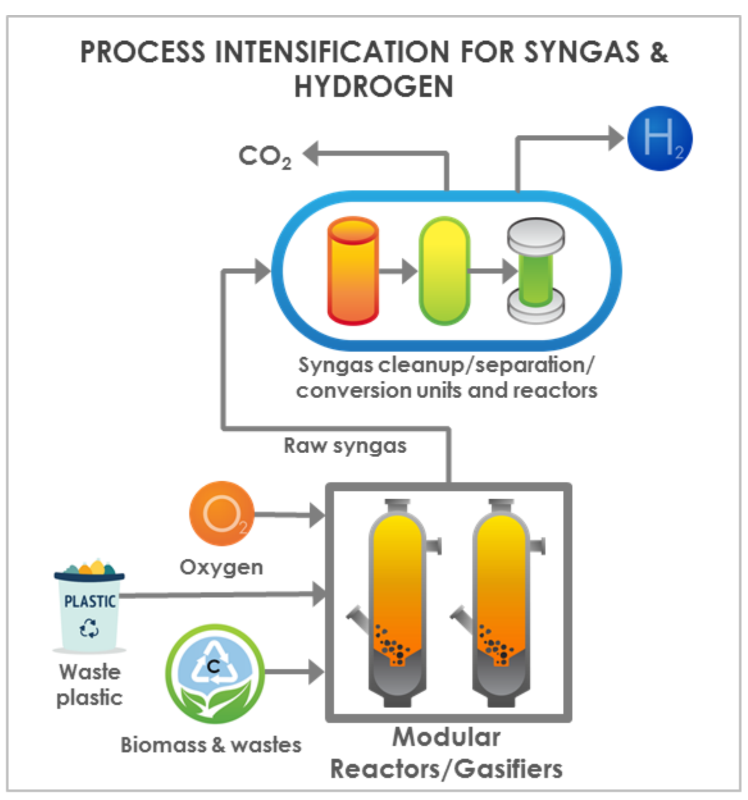
PRINCIPAL INVESTIGATOR:
Vijay Ramani

PERFORMER

Washington University in St. Louis
James McKelvey School of Engineering



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Hydrogen Production from Modular CO_2 Assisted Oxy-Blown Gasification of Waste Blends

Develop a process intensified two-stage bubbling fluidized bed gasifier for hydrogen production from biomass

Overview

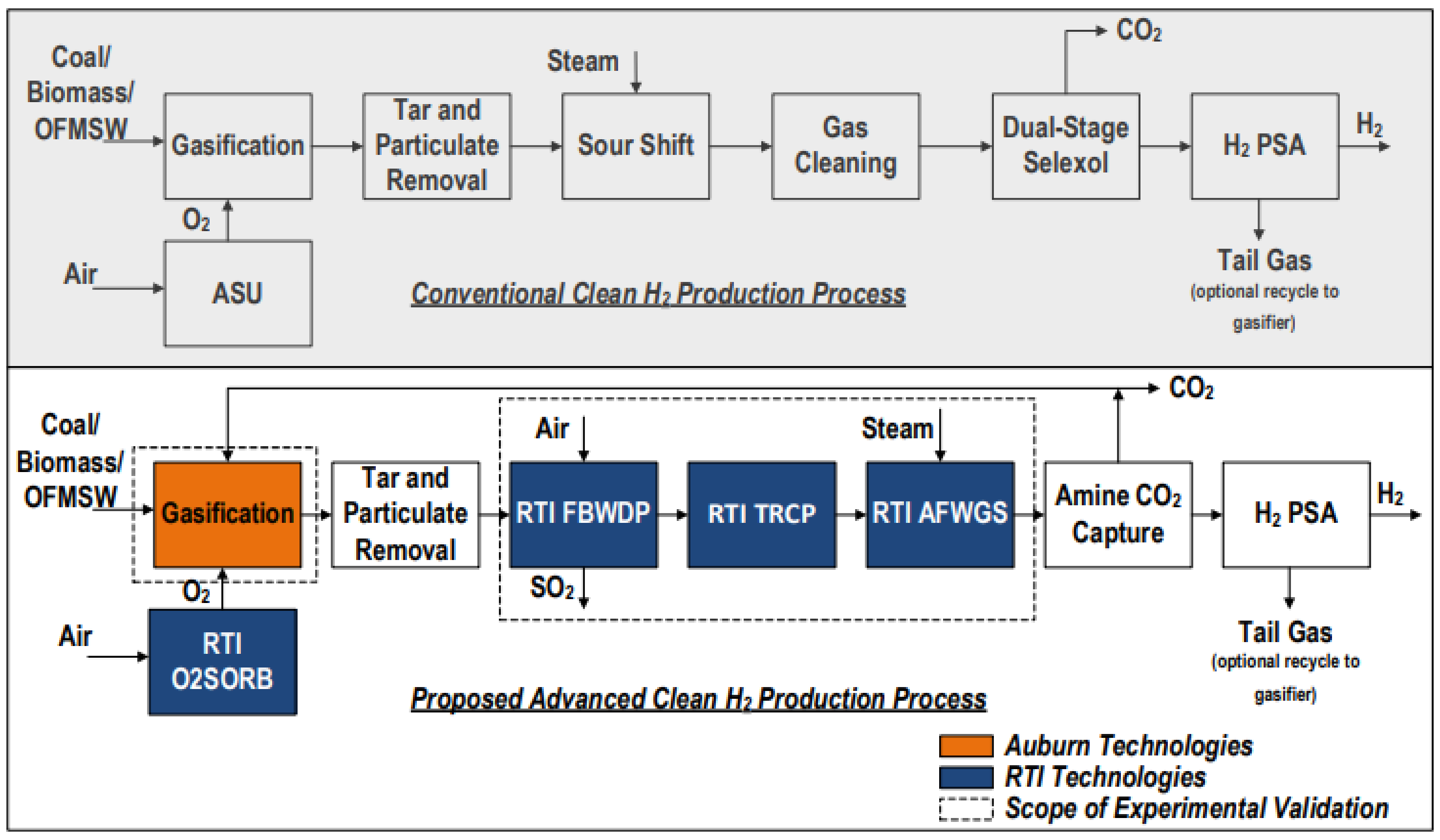
Auburn University is developing a novel process to produce H_2 from blended feedstock wastes via CO_2-assisted oxy-blown gasification. The proposed project will demonstrate the integration of CO_2-assisted oxy-blown gasification with novel, modular technologies for syngas cleanup and conditioning, including RTI's fixed-bed warm desulfurization process, trace contaminant removal process, and advanced fixed-bed water-gas shift (WGS).

Benefits

Awards resulting from DE-FOA-0002400, "Clean Hydrogen Production, Storage, Transport and Utilization to Enable a Net Zero Carbon Economy," are targeted toward developing technologies enabling clean hydrogen production, transport, storage, and use in the energy sector, including electricity, heat, transportation, and industrial use. These awards are focused on achieving overall cost reductions in clean hydrogen production from efficient gasification systems to make progress toward DOE's Hydrogen Shot initiative's cost goal of $1 per one kilogram of clean hydrogen.

Recent Results

- Preliminary TEA shows that emerging technologies can achieve about 16% reduction in hydrogen production cost (2.94$/kg to 2.47$/kg) with ~22% reduction in capital and ~23% reduction in operating costs (fixed and variable); feedstock cost can impact significantly



H_2 Production Scheme

QUICK FACTS

AWARD NUMBER:

DE-FE0032214

PROJECT BUDGET

DOE Share:

$1,574k

Performer Share:

$402k

Total Award Value:

$1,976k

CONTACTS

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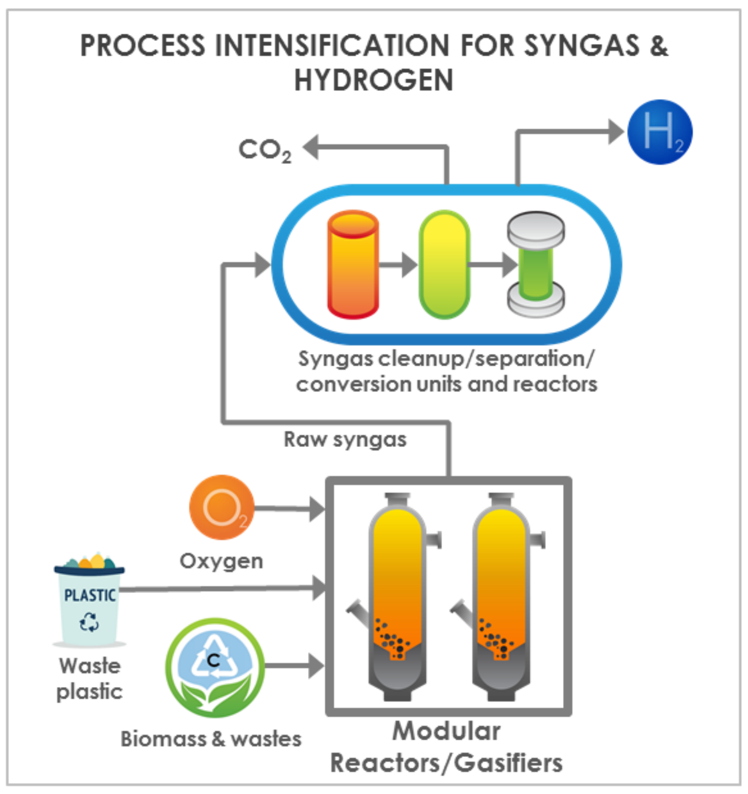
PERFORMER/PARTNER

RTI INTERNATIONAL

AUBURN UNIVERSITY



U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

Advanced Air Separation Unit (ASU) for Low-Cost H_2 Production via Modular Gasification

Develop a modular, novel, sorbent-based, advanced air separation unit (ASU) for oxygen production to support low-cost hydrogen production from the gasification of biomass and/or wastes

Overview

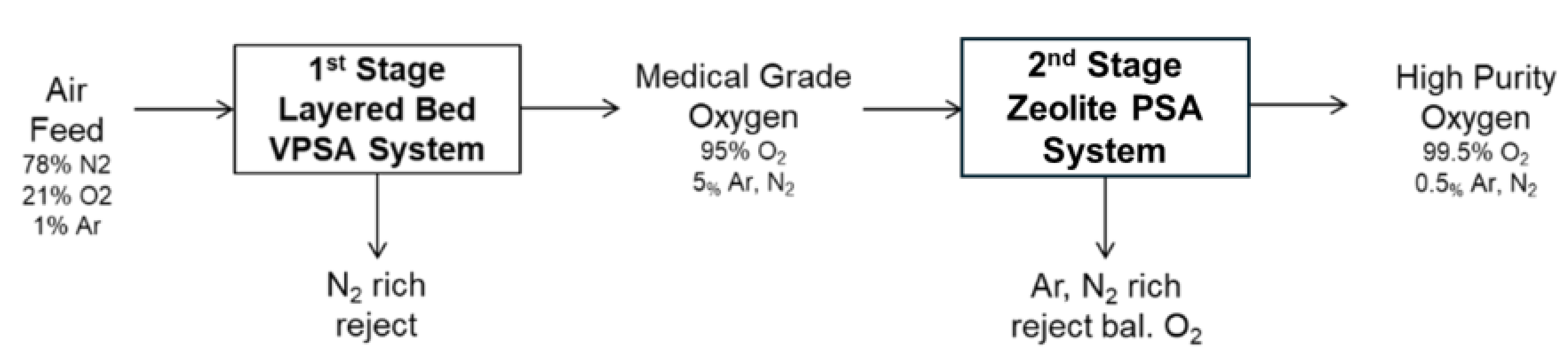
TDA Research Inc. is developing a high-purity oxygen separation process based on novel sorbents that will be utilized in a two stage, modular, vacuum pressure swing adsorption (VPSA) and pressure swing adsorption (PSA) system. The first stage consists of a layered bed VPSA unit using TDA's silver VPSA technology established for use in medical oxygen generators to produce 93-95% oxygen, which is upgraded to higher purity oxygen (98%+) by a zeolite PSA second unit.

Benefits

Successful development of the two-stage TDA process would allow its utilization in an efficient and low-cost small-scale modular ASU that could be incorporated in systems for gasification of alternative feedstocks to produce decarbonized syngas and clean hydrogen, supporting broad ranging goals for economy-wide decarbonization. Small ASUs enable distributed hydrogen production, providing an alternative to trucks or pipelines transferring hydrogen, providing a route to fuel diversification and energy resiliency, and bringing the clean energy economy and jobs to disadvantaged communities.

Recent Results

- Sorbents are being prepared in sufficient quantities for prototype testing (2 kg optimized sorbent)
- In-house synthesis of sorbents at TDA following the hydrothermal synthesis recipe



QUICK FACTS

AWARD NUMBER:
DE-FE0032328

PROJECT BUDGET

DOE Share:
$1,250k

Performer Share:
$312.5k

Total Award Value:
$1,562.5k

CONTACTS

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Gokhan Alptekin

PERFORMER

TDA RESEARCH

AIR SEPARATION TECHNOLOGY

High Purity Oxygen Generation through Modular Structured Rapid Pressure Swing Adsorption (RPSA))

Develop a novel single-stage dual-layer advanced air separation technology to produce high-purity oxygen that is needed for the efficient production of high-purity hydrogen

Overview

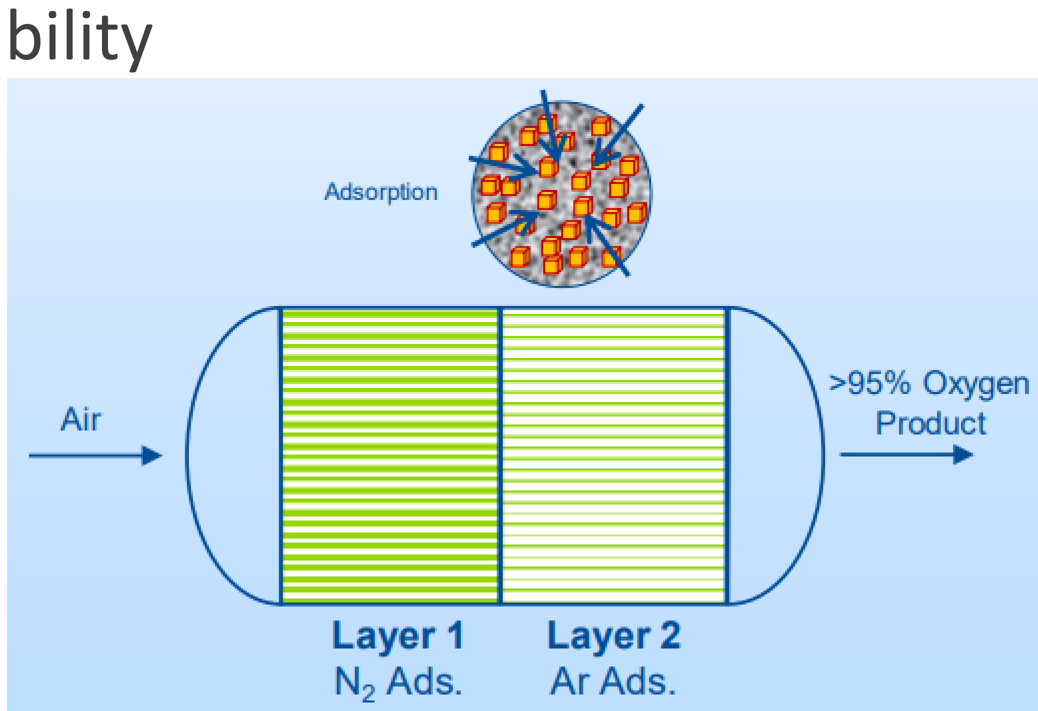
Susteon Inc. is developing the “OxygenPure” novel single-stage dual-layer advanced air separation technology for integration in a prototype fiber modular oxygen production system. The technology is based on a microporous nitrogen-selective lithium-exchanged X-type (LiX) zeolite-containing fiber adsorbent followed by an argon-selective carbon molecular sieve (CMS)-structured fiber adsorbent to separate nitrogen and argon from air via rapid pressure swing adsorption.

Benefits

Successful development of the OxygenPure technology would allow its utilization in an efficient and low-cost small-scale modular ASU that could be incorporated in systems for gasification of alternative feedstocks to produce decarbonized syngas and clean hydrogen, supporting broad ranging goals for economy-wide decarbonization. Small ASUs enable distributed hydrogen production, providing an alternative to trucks or pipelines transferring hydrogen, providing a route to fuel diversification and energy resiliency, and bringing the clean energy economy and jobs to disadvantaged communities.

Recent Results

- Multiple LiX-polymer fibers were successfully prepared in the lab with LiX ≥ 80 wt%
- Both LiX/P-1 and LiX/(P-2 + Matrimid) fibers show promising N_2 uptakes and thermal stability
- Hybrid polymer binders with small addition of Matrimid improves performance, with potential to significantly reduce the overall fiber cost



QUICK FACTS

AWARD NUMBER:
DE-FE0032335

PROJECT BUDGET

DOE Share:
$1,250k

Performer Share:
$312.5k

Total Award Value:
$1,562.5k

CONTACTS

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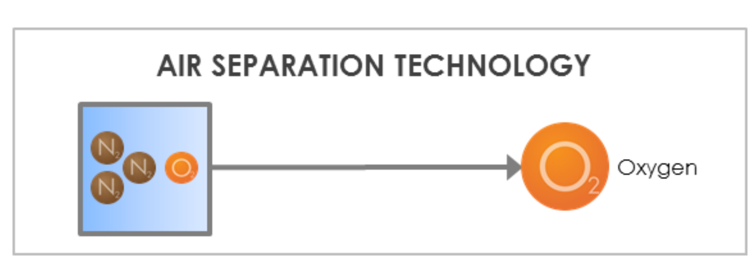
PRINCIPAL INVESTIGATOR:
Dr. Jian Zheng

PERFORMER

SUSTEON
Reimagining the carbon ecosystem



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Electrochemically Mediated Air Separation Modules (EM-ASM)

Develop a novel electrochemically mediated O_2 separation technology that generates O_2 of sufficient purity to enable high-quality syngas production and efficient precombustion carbon capture for H_2 production from gasification of biomass and wastes

Overview

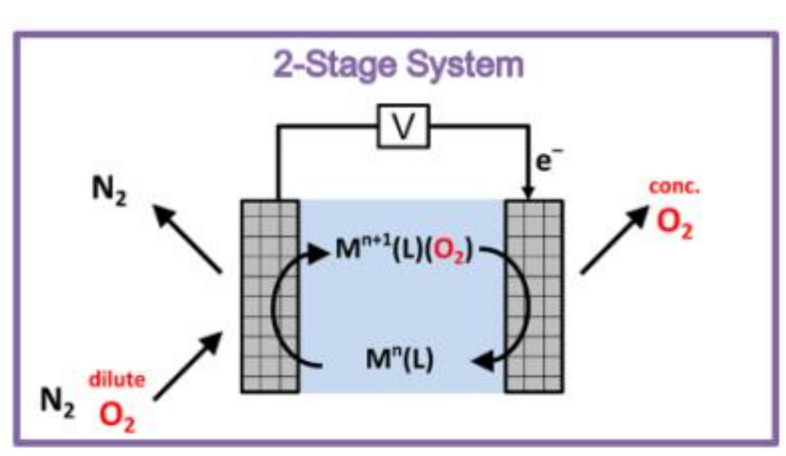
Raytheon Technologies Research Center is developing a novel sorbent/electrochemical looping technology based on electro-chemical flow cells fed tailored transition metal (TM) complexes. The approach involves computational methods to rapidly identify promising TM complexes, synthesize and rapidly screen promising TM complex sorbents, design/build/test small reactors for oxygen production, and evaluate a full-scale oxygen separation module in the context of a gasification process.

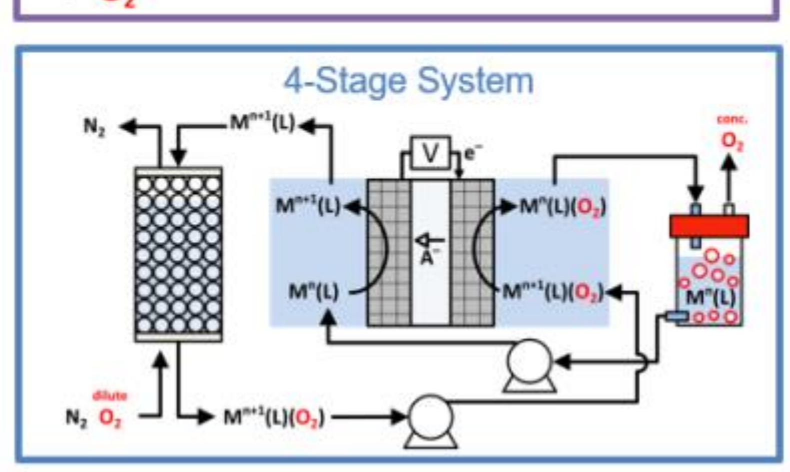
Benefits

Successful development of electro-swing oxygen sorption process would allow its utilization in an efficient and low-cost modular ASU that could be incorporated in systems for gasification of alternative feedstocks to produce decarbonized syngas and clean hydrogen, supporting broad ranging goals for economy-wide decarbonization. Small ASUs enable distributed hydrogen production, providing an alternative to trucks or pipelines transferring hydrogen, providing a route to fuel diversification and energy resiliency, and bringing the clean energy economy and jobs to disadvantaged communities.

Recent Results

- The TM complex Co-salen evidenced adequate binding constant for reversible oxygen separation
- Efficacy of the electro-swing sorption process is being tested, with preliminary thermodynamic and kinetic analyses promising





QUICK FACTS

AWARD NUMBER:
DE-FE0032348

PROJECT BUDGET

DOE Share:
$1,250k

Performer Share:
$369k

Total Award Value:
$1,619k

CONTACTS

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PERFORMER

RTRC
RTX Technology Research Center

PARTNERS

AIR SEPARATION TECHNOLOGY

Oxygen Integrated Unit for Modular Biomass Conversion to Hydrogen (OXIUM)

Develop a fast and high-capacity reversible oxygen sorbent enabling biomass gasification-based clean hydrogen production

Overview

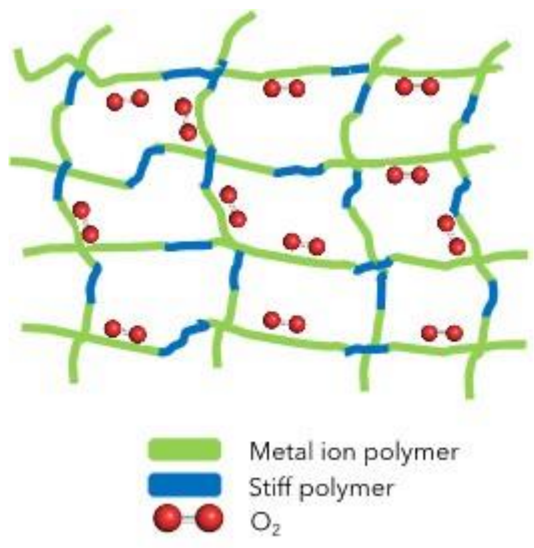
Palo Alto Research Center Inc. (PARC) is developing a reversible oxygen (O_2) sorbent consisting of a durable porous polymer with chemically bonded coordinated $Co^{2}+$ complexes that capture O_2 reversibly by vacuum pressure swing adsorption. High specific surface area (greater than 300 m^2/g) and pore tuning of mesopores 10 nanometers (nm) to 100s of nm in size will enable rapid rates of gas transport, bulk diffusion, and high O_2 uptake.

Benefits

Successful development of this sorbent would allow its utilization in an efficient and low-cost small-scale modular ASU that could be incorporated in systems for gasification of alternative feedstocks to produce decarbonized syngas and clean hydrogen, supporting broad ranging goals for economy-wide decarbonization. Small ASUs enable distributed hydrogen production, providing an alternative to trucks or pipelines transferring hydrogen, providing a route to fuel diversification and energy resiliency, and bringing the clean energy economy and jobs to rural and historically disadvantaged communities.

Recent Results

- PARC's method of modifying existing high-porosity, high-amine polymers for Co(II) chelation, and incorporating Co(II) into the polymer to form Co-sorb yielding superior uptake (>3.7 mmol Co/g sorbent)
- Reversible oxygen uptake in preliminary TGA testing showing promising adsorption/desorption of O_2 in multiple cycles



QUICK FACTS

AWARD NUMBER:
DE-FE0032350

PROJECT BUDGET

DOE Share:
$1,250k

Performer Share:
$312.5k

Total Award Value:
$1,562.5k

CONTACTS

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PERFORMER

parc
Part of SRI International

PARTNER

SIMACRO

AIR SEPARATION TECHNOLOGY

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Optimization and Scale-Up of Molecular-Sieve Membranes with Record Air Separation Performance

Develop a novel polymer membrane system for producing enriched oxygen from air for integration into modular gasification systems for low-cost hydrogen production

Overview

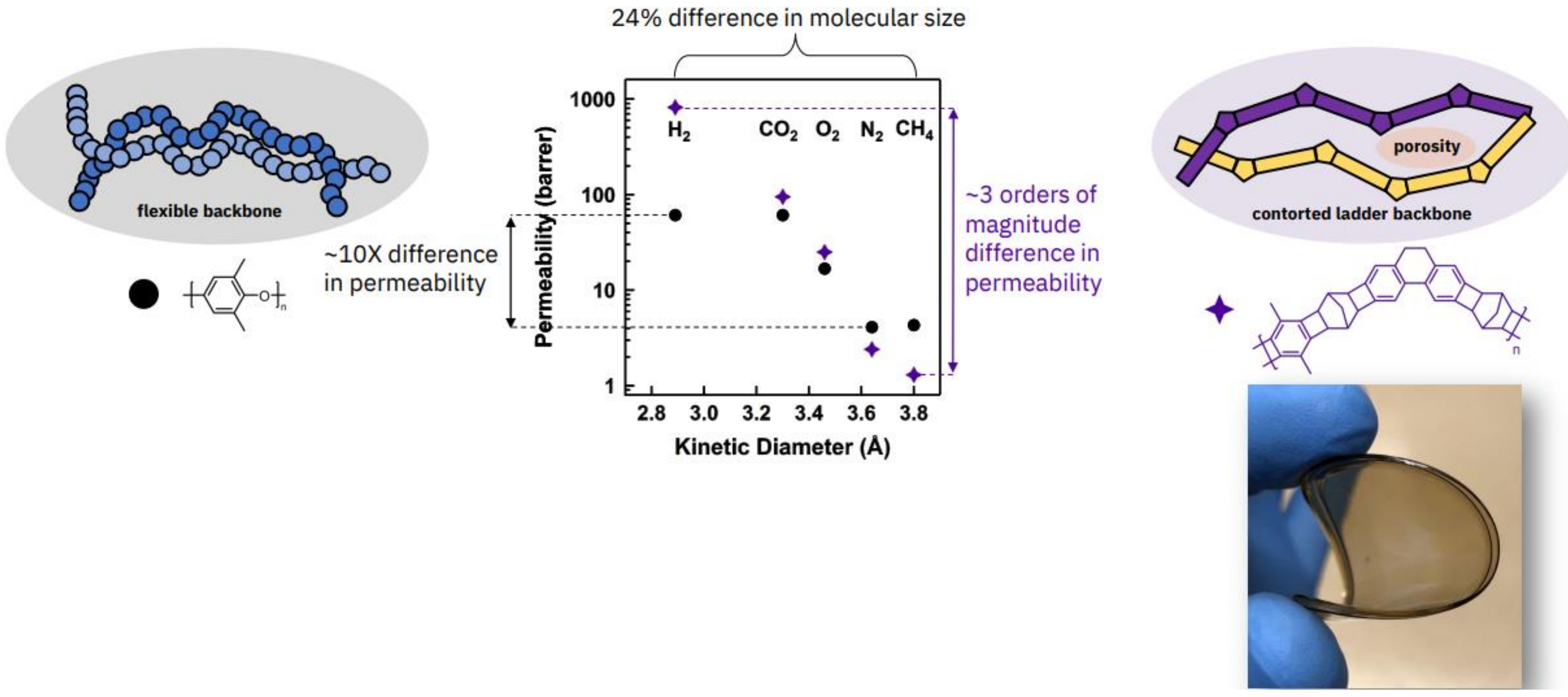
Osmoses Inc. is developing membranes made of hydrocarbon ladder polymers with ultrahigh permselectivity for membrane gas separations. The polymer membranes combine high selectivity with thermal stability up to 250°C, chemical resistance to water and H_2S, and operability under high pressure. The polymer membranes are targeted for incorporation in membrane modules for modular air separation units at low production cost and low energy consumption.

Benefits

Successful development of Osmoses' membrane technology would allow its utilization in an efficient and low-cost small-scale modular ASU that could be incorporated in systems for gasification of alternative feedstocks to produce decarbonized syngas and clean hydrogen, supporting broad ranging goals for economy-wide decarbonization. Small ASUs enable distributed hydrogen production, providing an alternative to trucks or pipelines transferring hydrogen, providing a route to fuel diversification and energy resiliency, and bringing the clean energy economy and jobs to disadvantaged communities.

Recent Results

- Polymer compositions being studied for best O_2/N_2 separation performance for the Osmoses hydrocarbon ladder polymer membrane



QUICK FACTS

AWARD NUMBER:
DE-FE0032352

PROJECT BUDGET

DOE Share:
$1,250k

Performer Share:
$578k

Total Award Value:
$1,828k

CONTACTS

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OSMOSES

PARTNER

GTI ENERGY

AIR SEPARATION TECHNOLOGY

An Advanced Modular Redox Air Separation System for Cost-Effective, Net-Zero Hydrogen Production

Develop a for low-cost hydrogen production

Overview

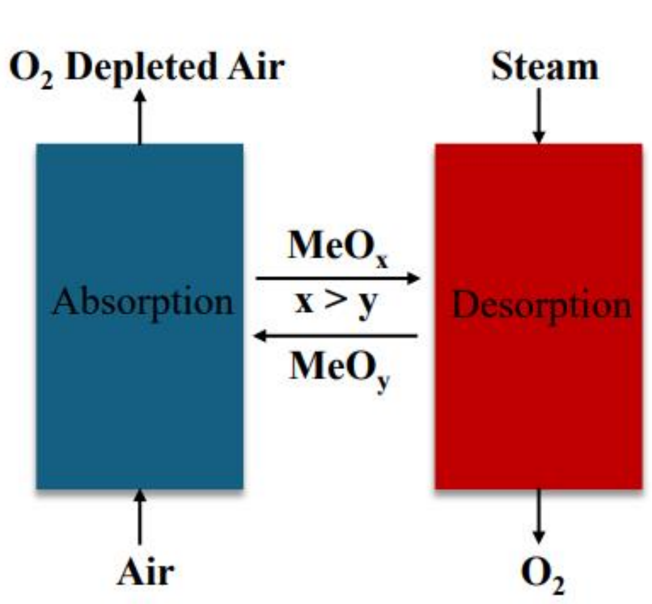
North Carolina State University (NCSU) is developing a redox-based air separation unit taking advantage of selected perovskite oxygen sorbents enabling continuous oxygen exchange, steam resistance, flexible thermodynamic properties and fast kinetics. Project focus will be on identifying superior performing sorbent formulations and testing them for long-term operational efficacy and durability, plus process modeling and technoeconomic analysis to determine systems feasibility.

Benefits

Successful development of chemical looping air separation would enable efficient and low-cost small-scale modular ASUs that could be incorporated in systems for gasification of alternative feedstocks to produce decarbonized syngas and clean hydrogen, supporting broad ranging goals for economy-wide decarbonization.

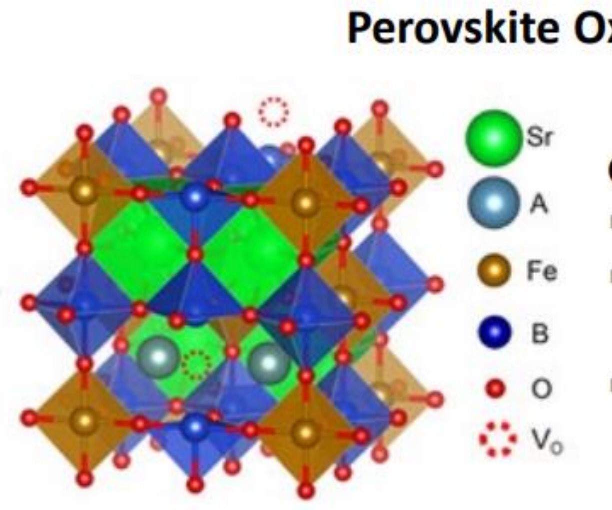
Recent Results

- Reactor modeling and preliminary TEA show oxygen cost as low as \$65/ton O2 at 5-10 MW gasifier scale
- Entropy stabilized perovskite sorbents synthesized and tested
- Improved density functional theory model developed



- 2-step redox loop at 400-600 °C
- Produce concentrated O_2 (up to 99%)
- Steam-resistant oxygen sorbent

Perovskite Oxides ($ABO_{3-\delta}$)



Great sorbent candidates:
- Continuous oxygen exchange
- Flexible thermochemical properties
- Fast kinetics

Absorption: $ABO_{3-\delta} + \delta/2O_2(g) \rightarrow ABO_3 + \text{Heat}$

Desorption: $ABO_3 + \text{heat} \rightarrow ABO_{3-\delta} + \delta/2O_2(g)$

QUICK FACTS

AWARD NUMBER:
DE-FE0032355

PROJECT BUDGET

DOE Share:
\$1,250k

Performer Share:
\$313k

Total Award Value:
\$1,563k

CONTACTS

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NC STATE UNIVERSITY

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Advancing Entrained-Flow Gasification of Waste Materials and Biomass for Hydrogen Production

Demonstrate the technical feasibility of gasifying blends of biomass and high-volume waste materials to produce hydrogen and improve feedstock preparation and feeding to enhance gasifier performance and conversion

Overview

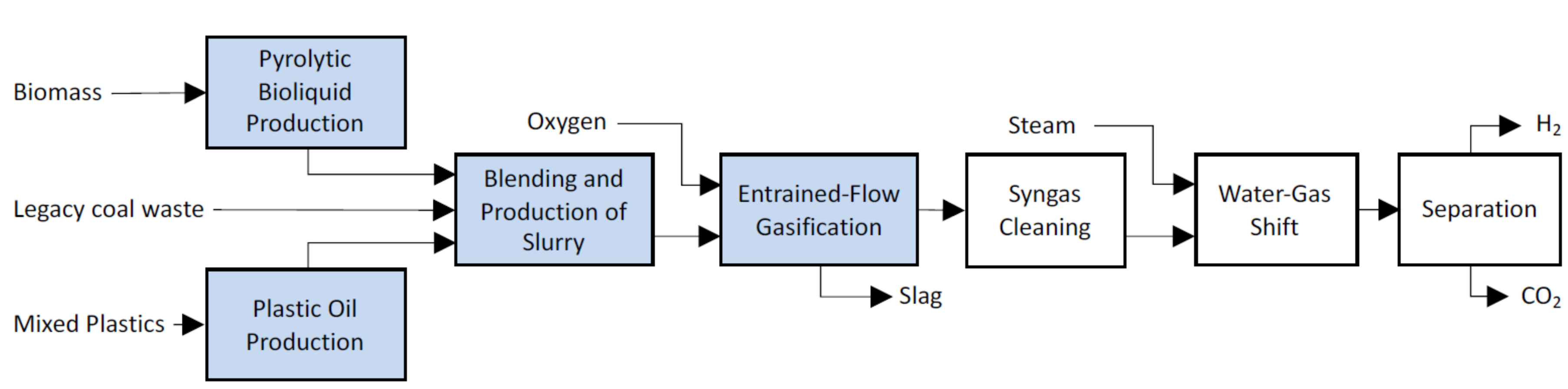
The University of Utah is exploring utilization of various slurried mixtures of coal, biomass liquid, and waste plastic oil in a 1-ton/day pressurized, oxygen-blown entrained-flow gasifier to characterize the influence of operating conditions on reactor performance, carbon conversion, and syngas quality. Focus is on biomass and plastic liquefaction processes and deployment of a new flexible fuel gasifier burner based on proven hot oxygen burner technology for flexible multiphase feeding. Specific objectives are to develop customized bioliquids and plastic oils for gasifier feed; create stable, pumpable slurries that maximize the concentration of waste materials; design a second-generation hot oxygen burner to improve performance and fuel flexibility; and acquire industrially relevant performance data for pressurized, oxygen-blown entrained-flow gasification of slurried blends of biomass and waste materials.

Benefits

Gasification Systems program efforts to generate data and experience for co-gasification of mixed solid feedstocks like biomass, coal, and carbonaceous mixed wastes such as plastics and municipal solid waste enable and encourage the advancement of clean hydrogen technologies. Integration of pre-combustion carbon capture and storage (CCS) into gasification processes and utilization of biomass in the feedstock mix enable net-zero or net-negative carbon emissions. Advances in alternate feedstocks gasification can provide significant benefits towards reduction of carbon emissions from multiple sectors of the U.S. economy in accordance with the DOE's Hydrogen Energy Earthshot initiative.

Recent Results

- Bio-liquid produced by rapid thermal treatment provides good basis for mixed feedstock slurries
- Slurries are pumpable and stable and most show limited separation
- Hot oxygen burner (HOB) achieves high conversion, good syngas, little soot



QUICK FACTS

AWARD NUMBER:

DE-FE0032175

PROJECT BUDGET

DOE Share:

$1,593k

Performer Share:

$389k

Total Award Value:

$1,992k

CONTACTS

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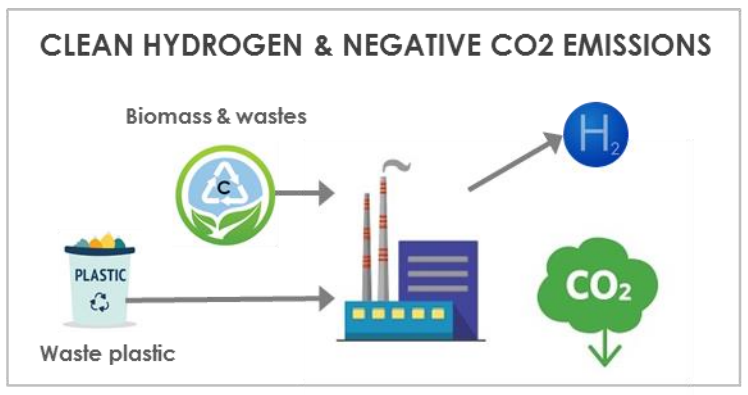
THE UNIVERSITY OF UTAH

PARTNERS

Linde

ENSYN



U.S. DEPARTMENT OF ENERGY

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Performance Testing to Advance Modular, Moving-Bed Gasification for the Generation of Low-Cost, Clean Hydrogen from Biomass Mixed with Legacy Coal Waste, Waste Plastic, and/or Other Waste

To qualify coal, biomass, and plastic waste blends based on performance testing of selected pellet recipes in an updraft moving-bed gasifier

Overview

Electric Power Research Institute Inc. (EPRI) will qualify blended feedstocks of biomass mixed with legacy coal wastes, plastic wastes, and refuse-derived fuel (RDF) as feedstocks for moving-bed gasification for modular production of high hydrogen content raw syngas that can be shifted to produce clean hydrogen. In particular, the effects of the various fuels on syngas compositions, organic condensate production, ash characteristics, and impacts on gasifier operations will be the focus of the project.

Benefits

- Support developing technologies enabling clean hydrogen production and contribute towards efficiency and cost reductions to help make progress towards the U.S. Department of Energy's (DOE) Hydrogen Energy Earthshot.
- Advance innovative and flexible modular (5–50 MWe equivalent) gasifier technology and gasification processes using alternative feedstocks.
- Improving the performance of gasification unit operations, addressing issues with feedstock preparation and feeding to the gasifier vessel, syngas cleanup, and corrosion.

Recent Results

- Identified fuel sources for all proposed pellet formulations, along with a change of waste plastic from auto shredder residue to wire insulation tailings
- Finalized agreements with pelletization and transport vendors and shipped the fuels
- Incorporated learnings from recently completed gasification testing at Sotacarbo facility
- Identified opportunities for key equipment upgrades at Sotacarbo test facility to improve operations and quality of test results

QUICK FACTS

AWARD NUMBER:
DE-FE0032180

PROJECT BUDGET

DOE Share:
$1,128k

Performer Share:
$282k

Total Award Value:
$1,410k

CONTACTS

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PRINCIPAL INVESTIGATOR:
George Booras

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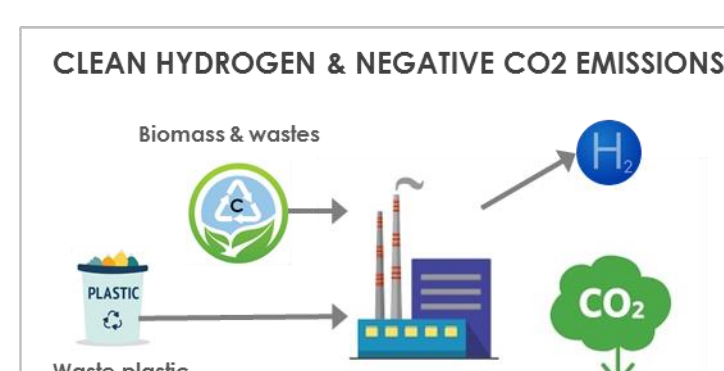
EPRI ELECTRIC POWER RESEARCH INSTITUTE

PARTNERS

NexantECA

Hamilton Maurer International

SOTACARBO SUSTAINABLE ENERGY RESEARCH CENTRE



U.S. DEPARTMENT OF ENERGY | NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Hydrogen Production from High Volume Organic Construction and Demolition Wastes

Develop integrated gasification & gas cleanup process to produce 99% hydrogen from highly contaminated construction and demolition (C&D) waste feedstock

Overview

The University of North Dakota/EERC is innovating gasification of waste materials with storage of key contaminants to make clean hydrogen. The project is showing how construction and demolition (C&D) debris-containing treated lumber can be converted sufficiently and economically to store arsenic and make a clean hydrogen stream. The project is using genuine C&D waste feedstock in multiple trials using EERC's high pressure fluidized bed pilot gasifier, in which improving shift catalyst performance, tar cracking, and long-term steady state hydrogen generation will be evaluated/demonstrated.

Benefits

Awards resulting from DE-FOA-0002400, "Clean Hydrogen Production, Storage, Transport and Utilization to Enable a Net Zero Carbon Economy," are targeted toward developing technologies enabling clean hydrogen production, transport, storage, and use in the energy sector, including electricity, heat, transportation, and industrial use. These awards are focused on achieving overall cost reductions in clean hydrogen production from efficient gasification systems to make progress toward DOE's Hydrogen Shot initiative's cost goal of $1 per one kilogram of clean hydrogen. Advances in hydrogen technologies capable of improving performance, reliability, and flexibility of existing and novel methods to produce, transport, store, and use hydrogen will enable carbon footprint reductions associated with energy use, supporting the United States' goals to reduce greenhouse gas pollution by 2030 and to achieve economy-wide net-zero emissions by 2050.

Recent Results

- Hydrogen production from gasification of C&D waste appears commercially viable for modular systems
- Successful control of arsenic and other trace metals has been demonstrated
- High level of tar cracking achieved with oxygen-injected high temperature stage, indicating technical feasibility for C&D waste

QUICK FACTS

AWARD NUMBER:

DE-FE0032183

PROJECT BUDGET

DOE Share:
$1,600k

Performer Share:
$400k

Total Award Value:
$2,000k

CONTACTS

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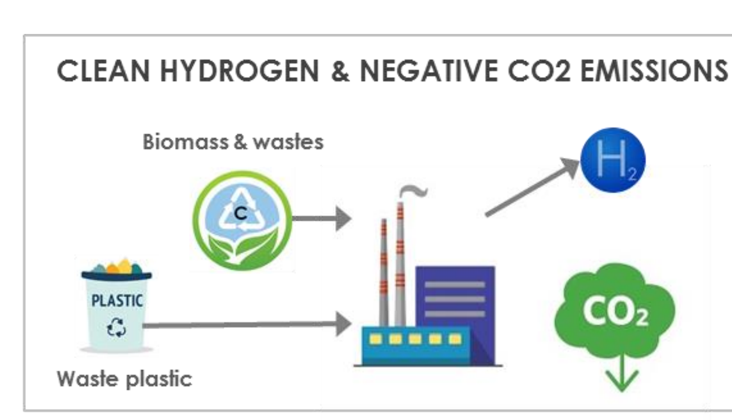
Michael Swanson

PERFORMER

EERC

UND UNIVERSITY OF NORTH DAKOTA



U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Advanced Gasifier Design

Leveraging NETL's multiphase computational modeling expertise in reactor design problems, and utilizing MFiX and other key software tools

Overview

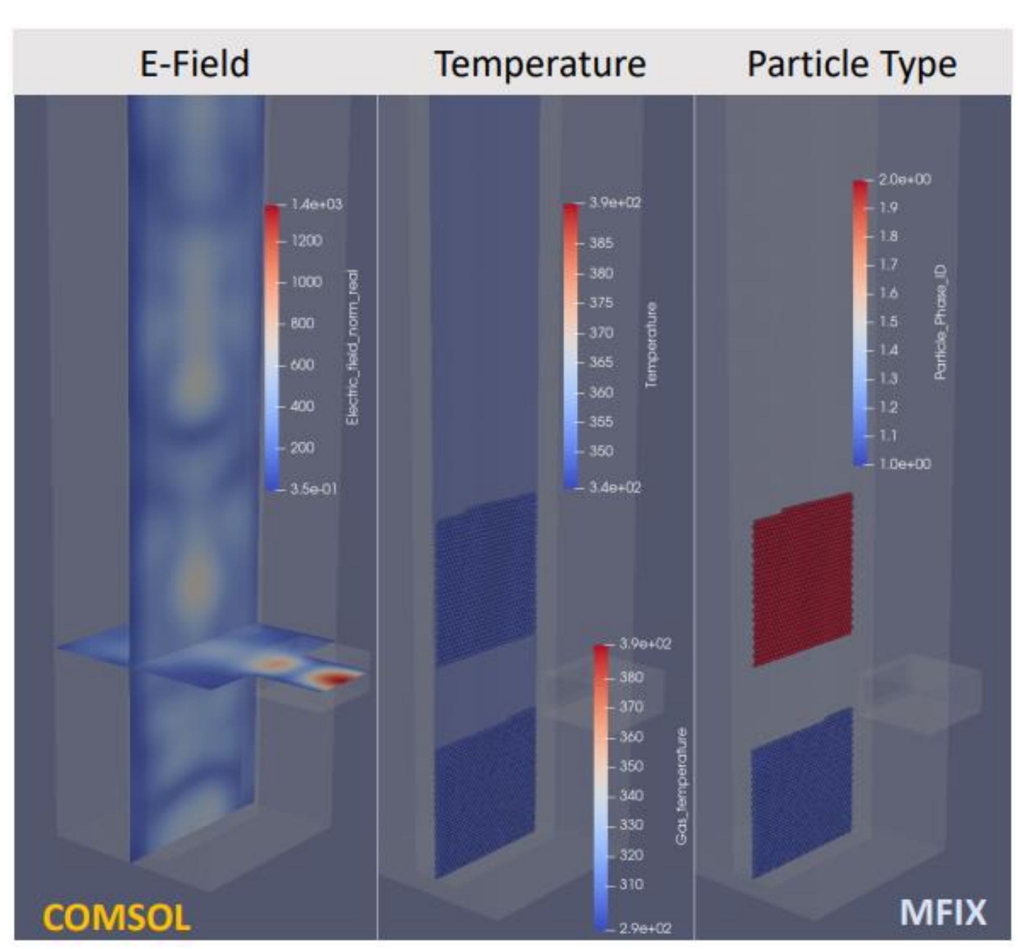
NETL's simulation-based engineering tools (MFiX, Optimization Toolset) are being used in design and optimization of novel pyrolysis and gasification reactor designs (a novel O_2-blown, pilot-scale pyrolyzer and gasifier for use in carbon negative H_2 production) supporting FECM's mission. Simulations guide design and scale-up of gasification reactors for mixed feedstocks, including biomass, plastics, and MSW. Simulations verify that the pilot-scale system meets the design parameters and help guide reactor optimization. The gasifier models are evaluated over a range of operating conditions and feed rates to provide information on flows, temperatures, and solid and gas compositions in the reactor. Geometric design and operating parameters can be optimized in this approach.

Benefits

NETL is providing an advanced capability to use reactor performance predictions from multiphase flow CFD simulations to optimize reactor performance. In contrast to proprietary commercial CFD software, the MFiX Suite and associated toolsets are open-source codes, freely available to FECM stakeholders from industry and universities. Furthermore, the codes are developed, validated, and supported for FECM applications by NETL's software development and application specialists, who have expertise in the application of CFD tools to FECM technologies. As an open-source code, the MFiX Suite can be customized for novel applications.

Recent Results

- Combined computational electromagnetics (CEM) and computational fluid dynamics (MFIX) help in predicting interactions in microwave-heated fluidized bed reactors.
- Agglomeration of bed material from fused (melted) plastic during pyrolysis of municipal solid waste can cause defluidization of the bed. NETL is developing a liquid bridge model for agglomeration of melted plastic to aid in understanding and tackling this problem.



QUICK FACTS

AWARD NUMBER:
NETL FWP 1022405, Task 3

PROJECT BUDGET

DOE Share:
$1,150k

Total Award Value:
$1,150k

CONTACTS

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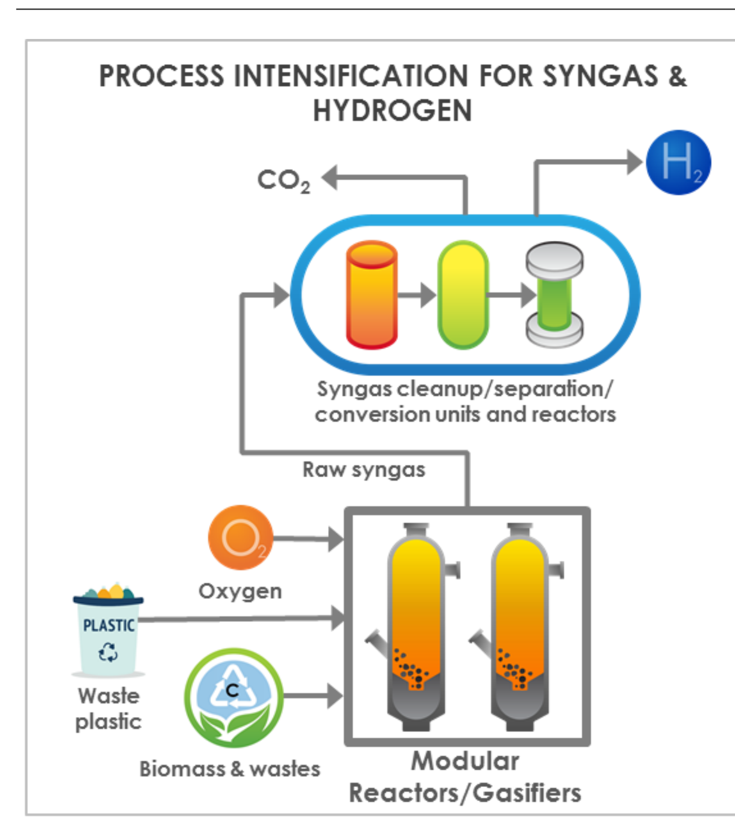
Mehrdad Shahnam

PERFORMER



Refractory Materials for Multi-Fuel Gasification

Develop novel refractory materials that enable multi-fuel gasification

Overview

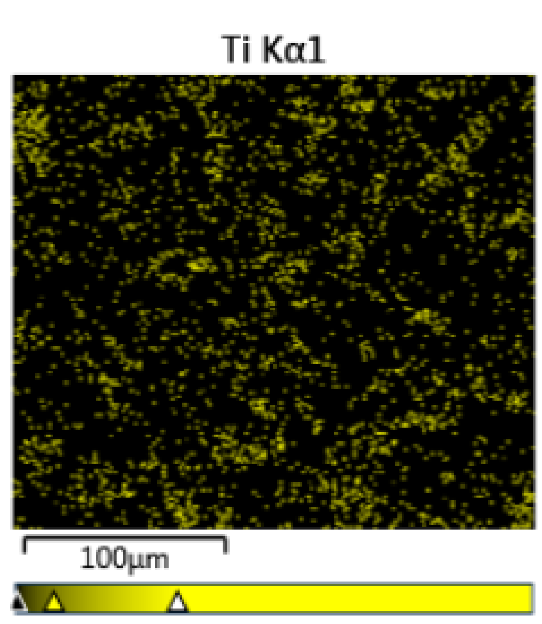
NETL is identifying refractory materials of construction and demonstrating extended service life in a co-gasification environment to enable diversified carbon feedstock options, including coal, biomass, and plastics. Refractories are subjected to severe gasification conditions and structures must: resist temperatures ranging from room to at least 1200°C; be resistant to both reducing and oxidizing environments; resist carbon and mineral impurities from the feedstock material (ash), including their abrasion as high-velocity particulates; be flexible to changes in their carbon feedstock makeup; and resist thermal cycling. During service, systems must be quickly adaptable to redesign and rapid repair/replacement.

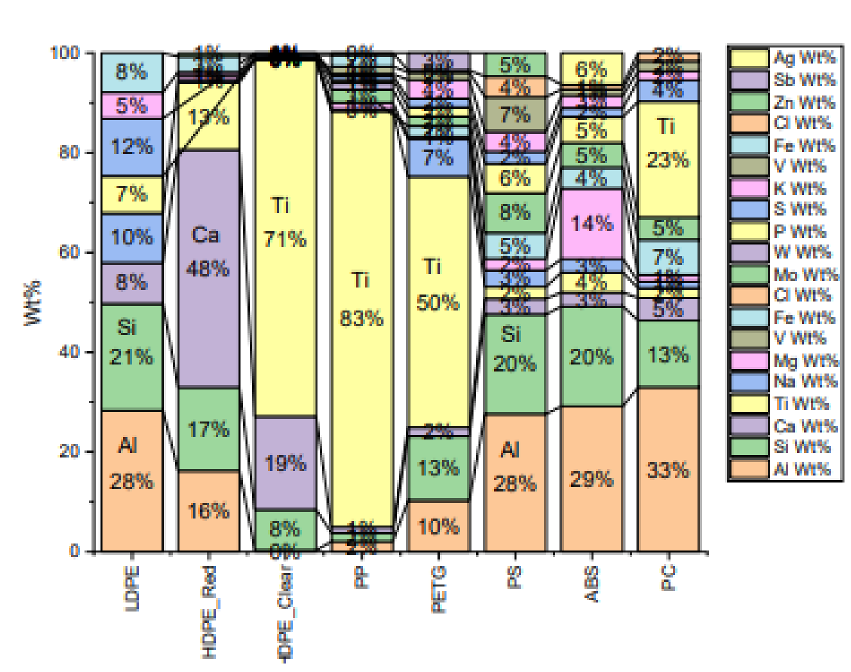
Benefits

Conventional gasifier refractories are formulated to resist coal ash and slag. Introducing alternative feedstocks results in much different ash and slag chemistry which may cause accelerated refractory degradation. This work addresses this challenge with development of tailored refractory formulations. This helps with accommodating diversified carbon feedstocks in decarbonized gasification systems, which in turn will help achieve lower carbon emissions and economy-wide goals.

Recent Results

- Collaboration with HarbisonWalker ongoing to evaluate ceramic bonded refractories for waste plastic gasification feedstock.
- Computed tomography evaluated to determine slag penetration into refractory liner material.





QUICK FACTS

AWARD NUMBER:

NETL FWP 1022405, Task 4

PROJECT BUDGET

DOE Share:

$400k

Total Award Value:

$400k

CONTACTS

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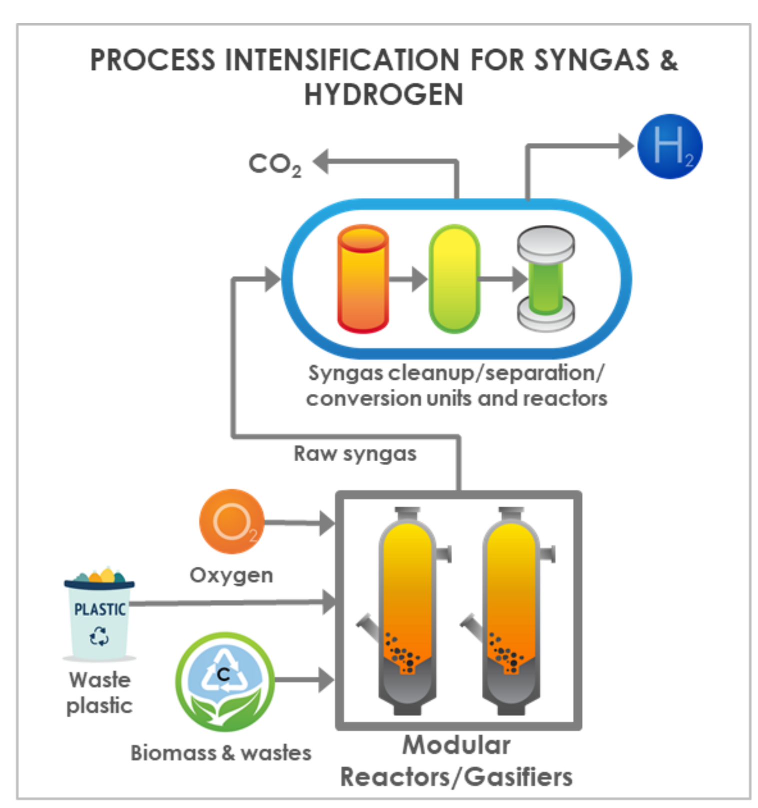


U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Microwave Reactions for Gasification

Develop microwave technology for fuel-flexible gasification at a modular scale

Overview

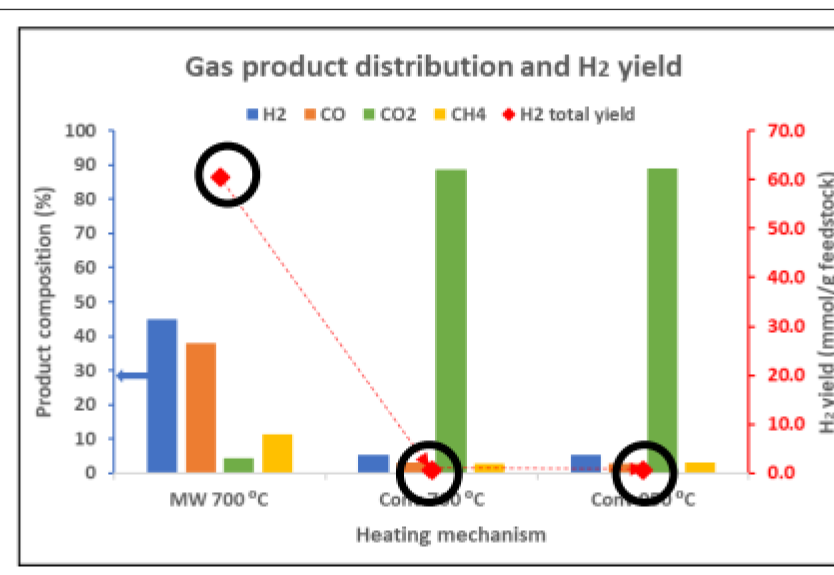
NETL is developing microwave-based concepts for feedstock-flexible gasification at a modular scale for H_2-rich syngas production. Co-production of energy, value-added chemicals, and carbon materials at low temperature is enhanced with microwave application to blended feed streams of biomass, waste plastic, coal fines, and/or MSW. This task focuses on efficient microwave gasification processes for H_2-rich syngas production that can handle heterogeneous feedstock and quantifying energy efficiency and economic benefits. Microwave technology integration into different steps in the gasification process (e.g., feed pretreatment, tar conversion) is also under consideration. Scope includes scale up of a microwave reactor through numerical modeling and laboratory testing, system analysis studies to understand the economic feasibility of the microwave reaction systems, and development of a larger scale continuous reactor prototype. Mechanistic studies will be taken to evaluate the effect of catalysts on the reaction pathways in microwave-assisted gasification of waste plastic/biomass.

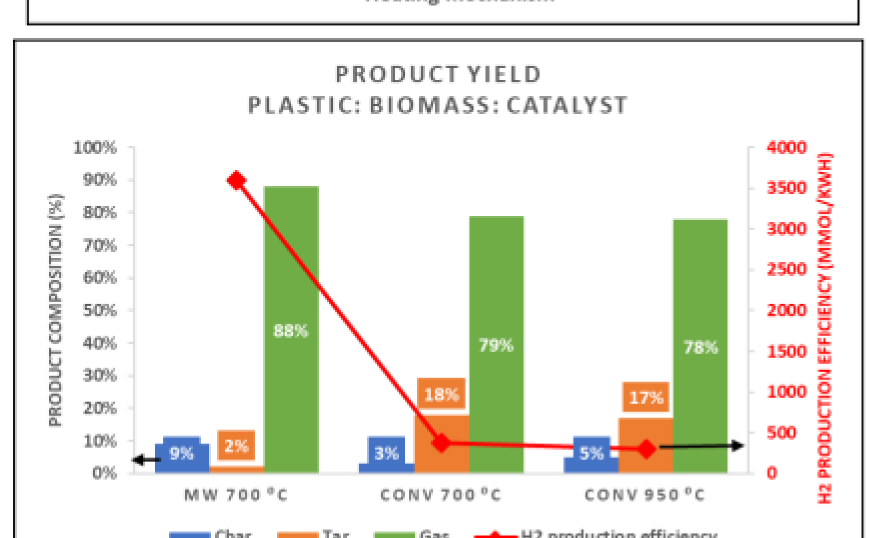
Benefits

Chemical conversion can be enhanced by applying microwave fields to the reaction zone. The high-frequency microwave fields can selectively stimulate active sites in metals through dielectric and magnetic interactions without increasing the bulk gas temperature and solid medium. These conditions can result in product yields that are significantly higher than predicted by thermodynamics, which can provide savings in both energy and feed costs.

Recent Results

- 4 times higher hydrogen yields and ~20% higher syngas yields with microwave heating
- Tar generation < 2%
- Fe oxide catalyst enhances MW synergy between plastics and biomass





QUICK FACTS

AWARD NUMBER:

NETL FWP 1022405, Task 6

PROJECT BUDGET

DOE Share:

$1,000k

Total Award Value:

$1,000k

CONTACTS

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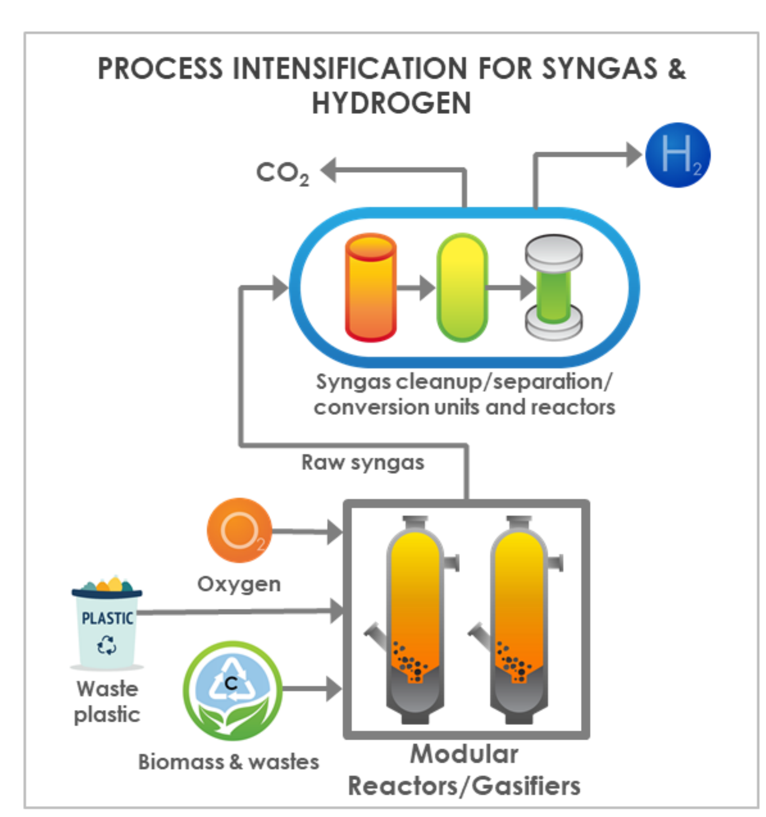
PRINCIPAL INVESTIGATOR:
Mark Smith

PERFORMER



U.S. DEPARTMENT OF ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Process Development to Mature Oxygen Sorbent-Based Technology

Develop a computational model of oxygen storage/release potential of NETL designed materials and to leverage simulation to design a pilot-scale fixed bed, perovskite sorbent oxygen separation reactor

Overview

NETL is advancing technology towards a pilot-scale prototype of a fixed bed, perovskite sorbent-based O_2 separation unit. This task supports that effort with modeling/simulation of the unit, developed using simulation-based engineering tools. The model includes both O_2 capture and regeneration modes of operation with thermal management of the system using heat exchange surfaces in fixed beds. Model predictions are being validated with experimental data, and model will be thoroughly tested over a range of operating conditions, including varying flows and operating temperature.

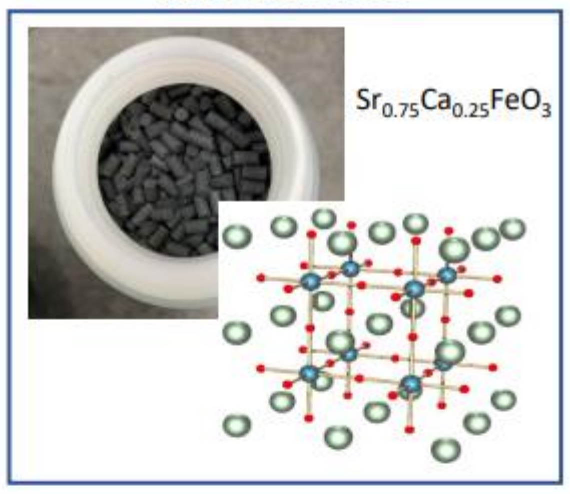
Benefits

In this research effort, NETL is providing an advanced capability to use reactor performance predictions from multiphase flow computational fluid dynamics (CFD) simulations to optimize design and performance of an oxygen separation process. Simulations better capture kinetics and produce improved device performance metrics. Simulations serve to demonstrate O_2 production from perovskite materials, that may effectively supplant some cryogenic air separation processes. Risk is reduced through examining processing scenarios virtually, greatly reducing experimental trials cost.

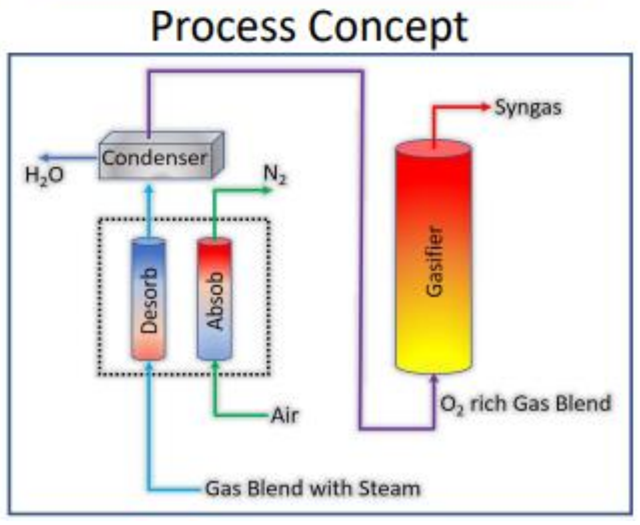
Recent Results

- Iso-conversional desorption kinetic analysis reveals a three-stage desorption mechanism related to conversion extent (surface reaction→ diffusion → random nucleation).
- Quantified effective activation energy dependence on conversion extent.
- Experiments indicate that steam is an effective effluent for desorption mechanism and results in near equivalent oxygen production as N_2.

Test Material



Process Concept



QUICK FACTS

AWARD NUMBER:

NETL FWP 1022405, Task 7

PROJECT BUDGET

DOE Share:
$527k

Total Award Value:
$527k

CONTACTS

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Mary Ann Clarke

PERFORMER

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Gasification of Waste Plastic to Enable a Circular Economy

Explore the gasification of alternative feedstocks, such as waste plastics, waste coal, and biomass, to generate H_2/syngas with minimal CO_2 emissions

Overview

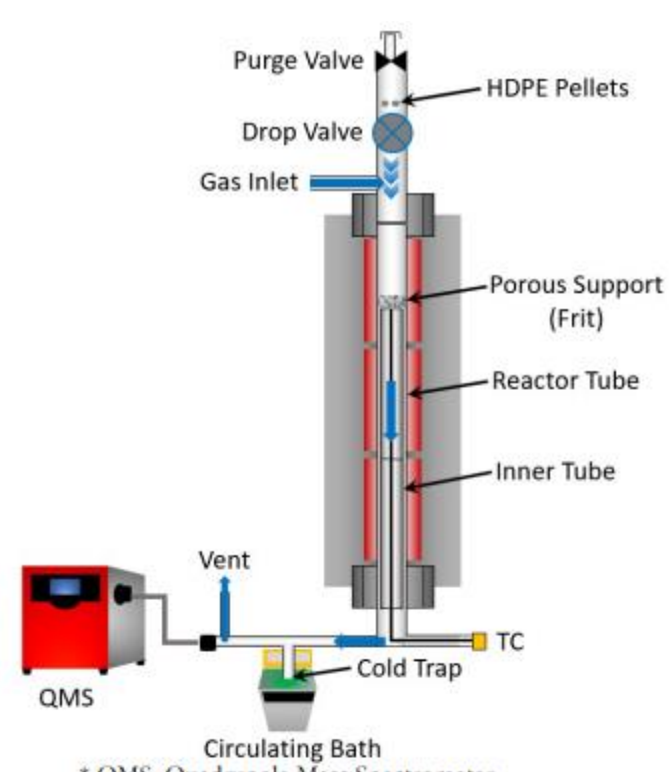
NETL is exploring the gasification of alternative carbonaceous feedstocks (waste plastic, waste coal, biomass) to generate H_2 with minimal CO_2 emissions. Co-gasification of waste plastic and waste coal is being studied, specifically as regards the effects of operating conditions and catalyst compositions on H_2/syngas production and tar mitigation. The pyrolysis of waste plastic/biomass at different operation conditions (like temperature and residence time) is also in scope to support model development and validation.

Benefits

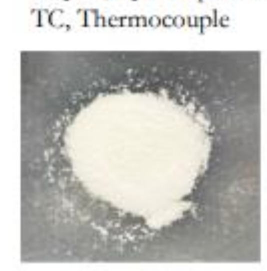
Gasification for H_2 production has advantage due to the possibility of using feeds with different compositions. The production of H_2 from waste coal/plastics/landfill wastes/MSW/biomass enhances the sustainable usage of waste plastic/coal and offers significant environmental benefits. Furthermore, additional environmental benefits may potentially be realized when integrated with CCUS. Using carbon capture technology, the net CO_2 emissions of H_2 production can be greatly reduced or eliminated, and possibly rendered carbon negative if biomass feedstock is blended.

Recent Results

- Accomplished co-gasification of pelletized low-density polyethylene and coal refuse/biomass with 10% H_2O/Ar in the drop tube reactor
- Completed investigation of pyrolysis of high-density polyethylene (HDPE) pellets and MSW in the drop tube reactor
- Determined pyrolysis kinetic parameters (heat of fusion and activation energy) using a non-isothermal simultaneous thermogravimetric analyzer- differential scanning calorimeter
- Co-gasification and pyrolysis findings presented in ACS and AIChE



* QMS, Quadrupole Mass Spectrometer
TC, Thermocouple


LDPE Powder


Coal refuse

QUICK FACTS

AWARD NUMBER:
NETL FWP 1022405, Task 8

PROJECT BUDGET

DOE Share:
$500k

Total Award Value:
$500k

CONTACTS

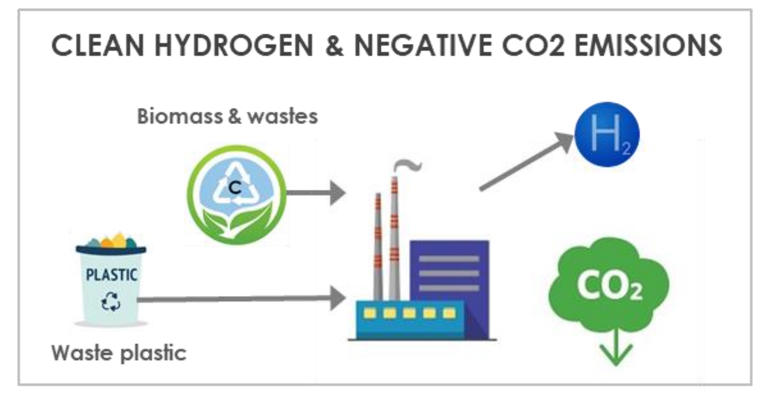
HQ PROGRAM MANAGER:
Jai-Woh Kim

TECHNOLOGY MANAGER:
Jonathan Lekse

FEDERAL PROJECT MANAGER:
Aaron Lyons

PRINCIPAL INVESTIGATOR:
Ping Wang

PERFORMER



U.S. DEPARTMENT OF ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Maturing Oxygen Carrier and Catalyst Technologies for Hydrogen Production

- Development of optimized systems with inherent carbon capture that can be used in H_2 production from solid fuels such as biomass, plastics, coal, and municipal solid waste (MSW) via two novel patented and patent pending processes

Overview

NETL is developing optimized systems with carbon capture that can be used in H_2 production from solid fuels, such as biomass, plastics, or MSW. Two novel patented/patent-pending processes are being pursued: a Fe-based catalytic process and a metal ferrite-based non-catalytic process. Information and parameters are being identified for use in developing integrated H_2 production systems, a scaled-up reactor design based on sub-pilot scale and pilot scale test data, and for supporting technoeconomic analyses and commercialization.

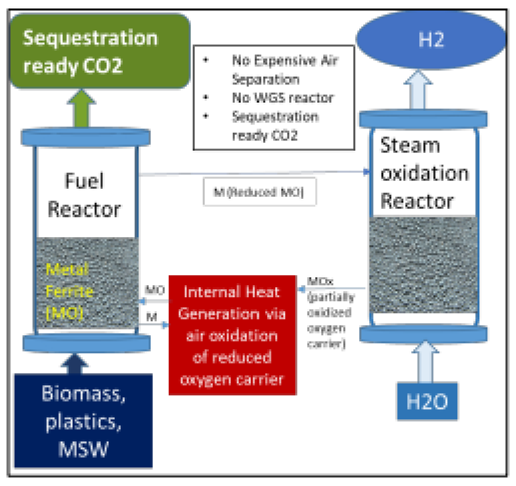
Benefits

These processes inherently combine carbon capture and sequestration enabling H_2 production with negative CO_2 emissions when biomass is used as fuel. In the non-catalytic process, metal acts as an oxygen carrier, which eliminates the need for an air separation unit to provide high purity O_2 (and all its associated costs). The high-thermal conductivity of the metal also makes it an excellent heat transfer medium. In the catalytic H_2 production process, catalysts and steam are used to produce H_2—alleviating the air separation unit requirement. The solid fuel can be added separately and continuously into the catalyst containing the reactor to produce H_2, making the process simple and commercially viable.

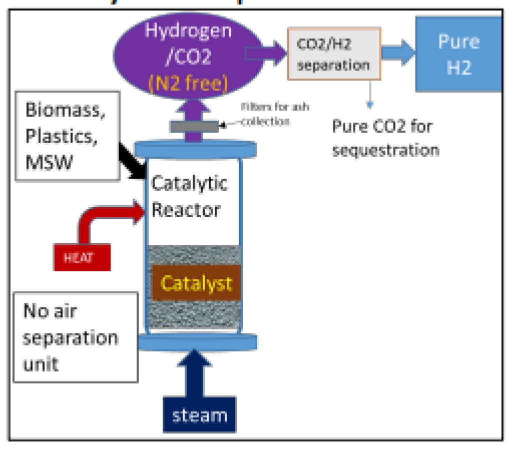
Recent Results

- Multi-cycle H_2 production with Ca ferrite oxygen carrier using polypropylene (plastic) as fuel
  - Stable H_2 production during 20 cycle test at a rapid rate with steam to H_2 conversion rate of about 85%.
  - Polypropylene is suitable fuel for the process
- Sub-pilot scale tests of Ca ferrite oxygen carrier with woody biomass
  - Initiated H_2 production with oxygen carrier tests with woody biomass in sub-pilot scale unit (2-5 kg material processing)

Non catalytic H2 production



Catalytic H2 production



QUICK FACTS

AWARD NUMBER:

NETL FWP 1022405, Task 11

PROJECT BUDGET

DOE Share:

$500k

Total Award Value:

$500k

CONTACTS

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Ranjani Siriwardane

PERFORMER

NETL

Feedstock Control for Gasification

Support the development of intelligent systems capable of controlling blends of mixed plastic waste, biomass, MSW, and waste coal supplied to a modular gasification system for production of H_2 with CCS

Overview

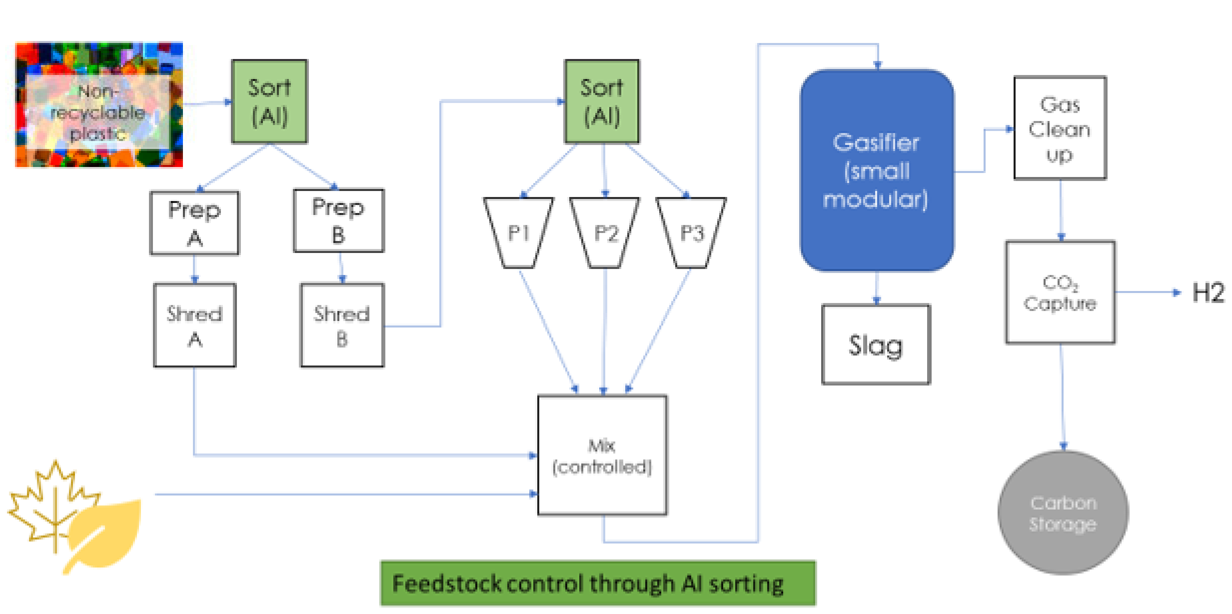
NETL is developing intelligent systems capable of controlling the blend of mixed plastic waste, biomass, MSW, and waste coal supplied to a modular gasification system for production of H_2 with CCS. Actively controlling the blend of waste plastics and other materials fed to a gasifier will make its operation more stable and enable the optimization of its operation based on the feed stream composition.

Benefits

Initiatives to reduce solid waste generation and to increase recycling in the U.S. have been in place for many years and are having some positive impact. However, the disposal of significant amounts of waste is still required under increasingly stringent regulations and using decreasing landfill space. Plastics are a significant part of the solid waste stream and become a liability if recycling is not possible and must be landfilled or incinerated, with varying degrees of pollution potential and costs incurred. This work focuses on aiding development of energy systems which can consume large quantities of waste plastics for clean utilization/conversion.

Recent Results

- NETL has worked with NREL to develop the State-of-Technology Report



QUICK FACTS

AWARD NUMBER:

NETL FWP 1022405, Task 14

PROJECT BUDGET

DOE Share:

$400k

Total Award Value:

$400k

CONTACTS

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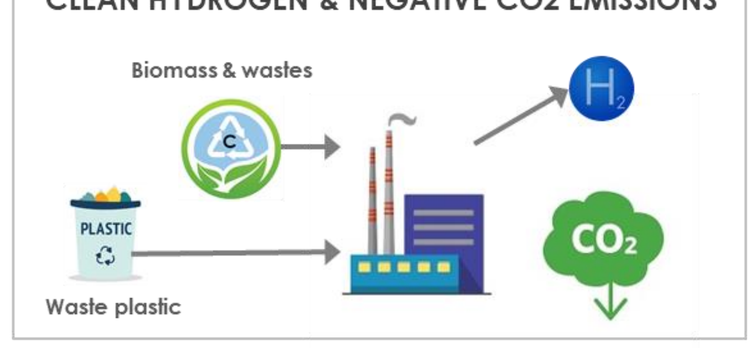
PERFORMER

CLEAN HYDROGEN & NEGATIVE CO2 EMISSIONS



U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Enabling Low Carbon Feedstocks for Gasification

- Characterize the physical and chemical transformation of feedstocks for gasification to enable reliable low-cost hydrogen (H_2) and power generation from low-carbon life-cycle and low-cost feedstocks

Overview

Oak Ridge National Laboratory (ORNL) is developing methods to characterize the physical and chemical transformation of feedstocks for gasification to enable reliable low-cost H_2 and power generation from low-carbon life-cycle and low-cost feedstocks. Specific feedstocks of interest include:

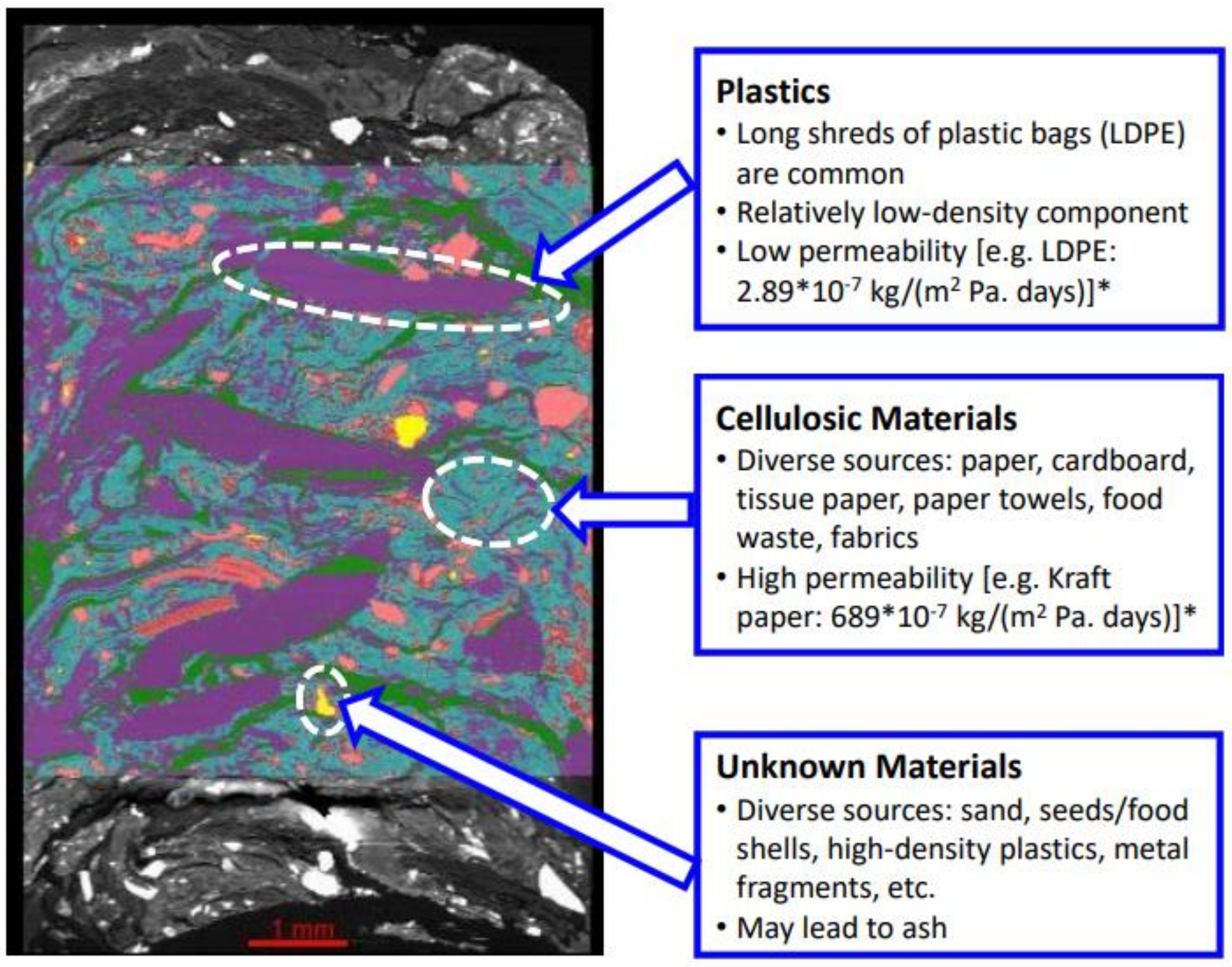
- Municipal Solid Waste (MSW) [and associated sub-components]
- Sustainable Biomass
- Waste Plastics
- Food Waste
- Waste Coal

Benefits

This work is intended to enable use of low-cost feedstocks (low OpEx) and optimize reactor designs (low CapEx) for gasification systems utilizing low-carbon waste and biomass feedstocks. With CCUS, low (even negative) CO_2 Emissions can be achieved. The technology advancement pursued in feedstocks characterization helps enable a modular gasification approach to co-locate H_2/power generation with distributed feedstocks, maximizing efficiency and minimizing transportation cost.

Recent Results

- Initial results on neutron imaging of realistic pyrolyzed MSW samples obtained—in construction phase of in situ TGA for future neutron studies
- Initial results on neutron imaging of realistic pyrolyzed MSW samples/pellets obtained
- Porosity and permeability measurements in progress
- Preliminary catalytic gasification data shows promising results



QUICK FACTS

AWARD NUMBER:
FWP-FEAA437

PROJECT BUDGET

National Laboratory Share:
$2,571k

Total Award Value:
$2,571k

CONTACTS

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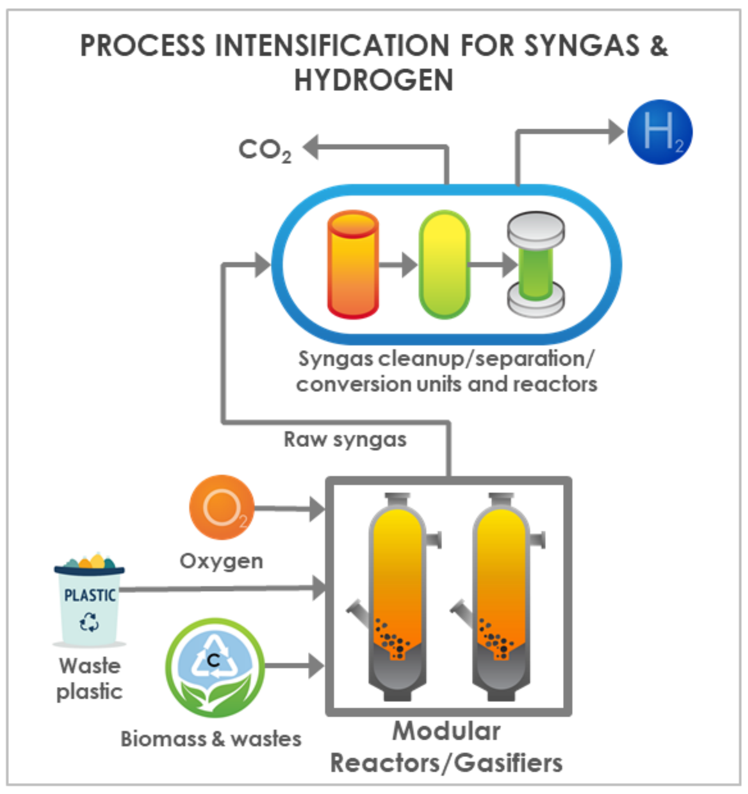
James E. Parks II

PERFORMER

Oak Ridge National Laboratory



U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Pressure Driven Oxygen Separation

Develop a small scale and modular air separation unit providing 10 T/day of high purity oxygen to a 1-5 MW gasifier at low cost and high efficiency

Overview

Pacific Northwest National Laboratory (PNNL) is developing air separation technology based on mixed ion-conducting membranes in planar architecture and stacks, employing doped CeO_2 as the ion conductor and $LaMnO_3$ as the electronic conductor supported on a low-cost porous substrate of MgO-Al_2O_3 composites. This technology utilizes the difference in oxygen partial pressures across the membrane to drive the separation of oxygen (no electrical energy required).

PNNL is focusing on multiple technological aspects for increasing performance efficiency and reducing costs of this technology, including best use of low-cost materials, planar stack architecture design allowing reliable and low-cost fabrication/processing and stack/seal performance, minimizing interactions between ionic and electronic conducting phases during sintering to maximize oxygen permeability in the composite membranes, and controlling sintering so as to minimize warping and cracking of the planar composite membranes.

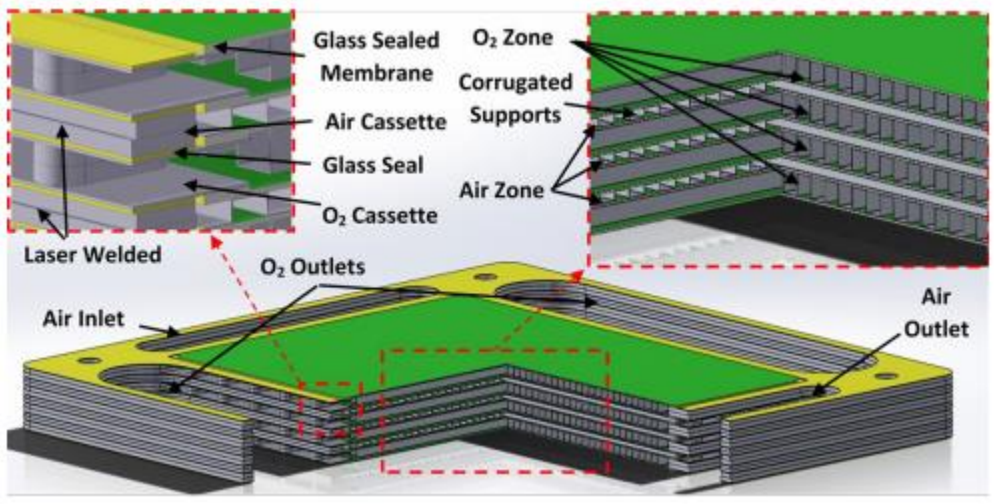
Benefits

This membrane-based oxygen separation approach is intended to enable small-scale, modular air separation units providing 10 to 40 tons of high-purity oxygen to 1- to 5-MWe gasifiers at low cost and high energy efficiency.

Because the air separation membrane is of the ion transport type, it provides extremely high oxygen selectivity. But unlike conventional ion transport membranes that require operating temperatures of 1,450 to 1,650°F, PNNL's membrane is targeted for operation at 1,100 to 1,300°F. At these milder conditions, energy demand for heating input gases is lower, and equipment durability should be improved.

Recent Results

- Thermal expansion match attained between all components (composite membrane, composite support, glass ceramic seal, 400 series stainless steel frame)
- Ability to scale up bilayers to different sizes and shapes using traditional inexpensive techniques; efficient infiltration of catalysts into porous barriers with an ultrasonic dispenser



QUICK FACTS

AWARD NUMBER:
FWP-73130

PROJECT BUDGET

National Laboratory Share:
$4,100k

Total Award Value:
$4,100k

CONTACTS

HQ PROJECT MANAGER:
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PRINCIPAL INVESTIGATOR:
David Reed

PERFORMER

Pacific Northwest National Laboratory

AIR SEPARATION TECHNOLOGY

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Rotary Magnetocaloric Liquefier for Air Separation

Development of an efficient, compact cryogenic air separation unit (ASU) for production of distributed, low-cost LO_2 and LN_2 at engineering scale

Overview

Pacific Northwest National Laboratory (PNNL) is leveraging their previously developed magnetocaloric liquefier technology in this project to realize an efficient, compact cryogenic ASU. The goal is to replace two of the three modules of a conventional cryogenic ASU with two innovative technologies:

1. Replace turbo-Brayton cycle air liquefiers with magnetocaloric liquefiers (MCLs), which should increase ASU energy efficiency by ~40% and decrease CAPEX by ~25%.
2. Replace conventional distillation columns with microchannel distillation columns (MCDs), which should reduce the distillation footprint by ~10 times.

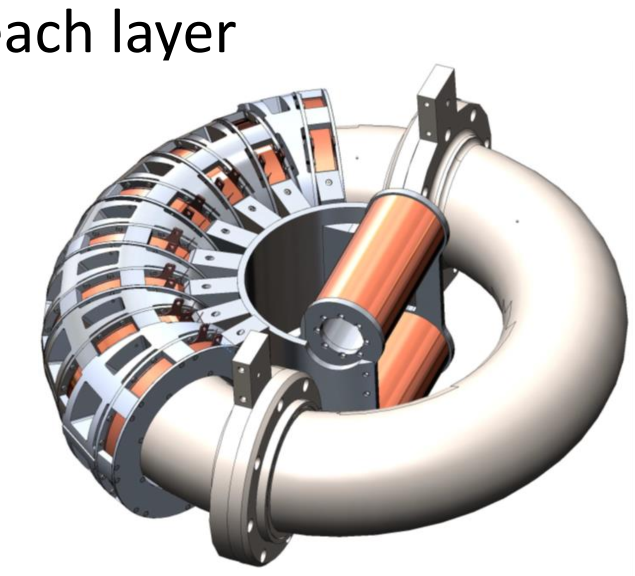
The original reciprocating MCL concept was found to have inherent technical barriers for scale up, so a thermodynamically simpler 2-stage rotary MCL was devised that will reduce/eliminate AC losses in magnets, utilize less refrigerant, operate at higher frequencies, simplify heat transfer process flows, and readily scale.

Benefits

Gas compressors and expanders in cryogenic ASUs are the major cost drivers of conventional air separation. The MCL concept would eliminate the need for conventional gas compression in cryogenic-based air separation. Preliminary cost analysis indicates that MCL will be no more or even less expensive than the conventional liquefaction technologies used in cryogenic ASUs. Moreover, MCL will be highly modular, providing good cost performance for smaller amounts of oxygen production at which conventional cryogenic ASUs would have poor cost performance.

Recent Results

- TEA quantifies reductions in capital costs and operational costs: low-cost LOX is achievable
- Regenerator fabrication methods devised; will be formed of refrigerant layers with a thermal break between each layer



QUICK FACTS

AWARD NUMBER:
FWP-82796

PROJECT BUDGET

National Laboratory Share:
$1,330k

Total Award Value:
$1,330k

CONTACTS

HQ PROJECT MANAGER:
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PRINCIPAL INVESTIGATOR:
Corey Archipley

PERFORMER

Pacific Northwest
NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

High Selectivity and High Throughput Carbon Molecular Sieve Hollow Fiber Membrane Based Modular Air Separation Unit for Producing High Purity O_2

Development of air separation technology to be utilized in advanced coal-based modular energy systems, making substantial progress toward enabling cost-competitive, coal-based power generation with near-zero emissions

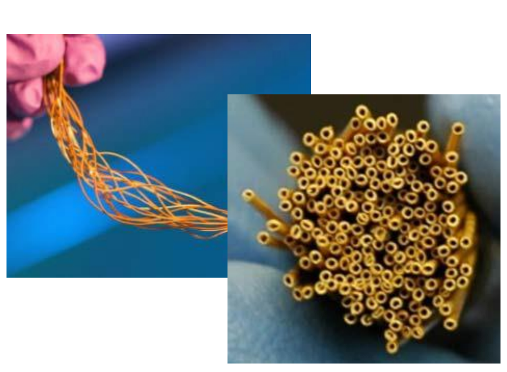
Overview

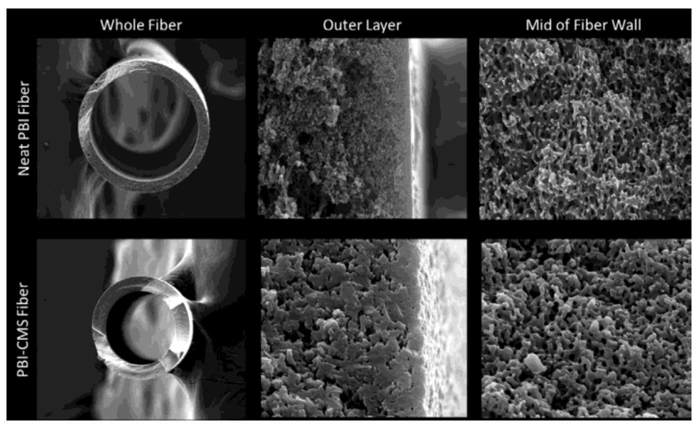
Los Alamos National Laboratory (LANL) is developing carbon molecular sieve (CMS) hollow fiber membranes for a modular air separation unit for high purity O_2 production. A two-stage membrane process is envisioned and will be optimized to achieve the O_2 purity target while minimizing the energy consumption. Core to the proposed work is development of polybenzimidazole (PBI)-derived CMS (PBI-CMS) hollow fiber membranes having exceptional O_2/N_2 selectivity and high O_2 permeance. The PBI-CMS hollow fiber membranes will be obtained via controlled pyrolysis of PBI hollow fibers having microstructures tailored for gas separations (PBI HF manufacturing methods recently discovered/patented by the LANL team).

Benefits

Membrane-based ASUs have better energy efficiency than industry-standard cryogenic methods, provided materials having high O_2/N_2 selectivity and high productivity membrane systems based on these materials are developed. PBI-CMS membranes have expectational separation performance potential, and when deployed in high packing-density and low-cost hollow fiber membrane modules familiar in industrial application, should enable energy-efficient high-purity O_2 production at modular scales.

Recent Results





- Mitigation of structural collapse during pyrolysis process achieved.
- Thinner selective layer (< 1 µm) was achieved
- Project goal of high O_2/N_2 selectivity (~15) was achieved.
- Demonstrated scaled-up process to commercialize CMS HFMs.
- Developed CMS HFMs with extremely high mechanical strength.
- High temperature epoxy was found.

QUICK FACTS

AWARD NUMBER:

FWP-FE-1049-18-FY19

PROJECT BUDGET

National Laboratory Share:

$3,322k

Total Award Value:

$3,322k

CONTACTS

HQ PROJECT MANAGER:
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PRINCIPAL INVESTIGATOR:
Rajinder P. Singh

PERFORMER

Los Alamos NATIONAL LABORATORY EST. 1943

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Gasification of Blended Feedstocks Coupled with Carbon Capture and Sequestration to Achieve Net-Zero or Net-Negative Emissions H_2

- Identify the viability of low- and zero-carbon H_2 based on economic and sustainability assessments and demonstrate operational feasibility with emerging feedstock characterization technologies and coupled gasification reactor modeling

Overview

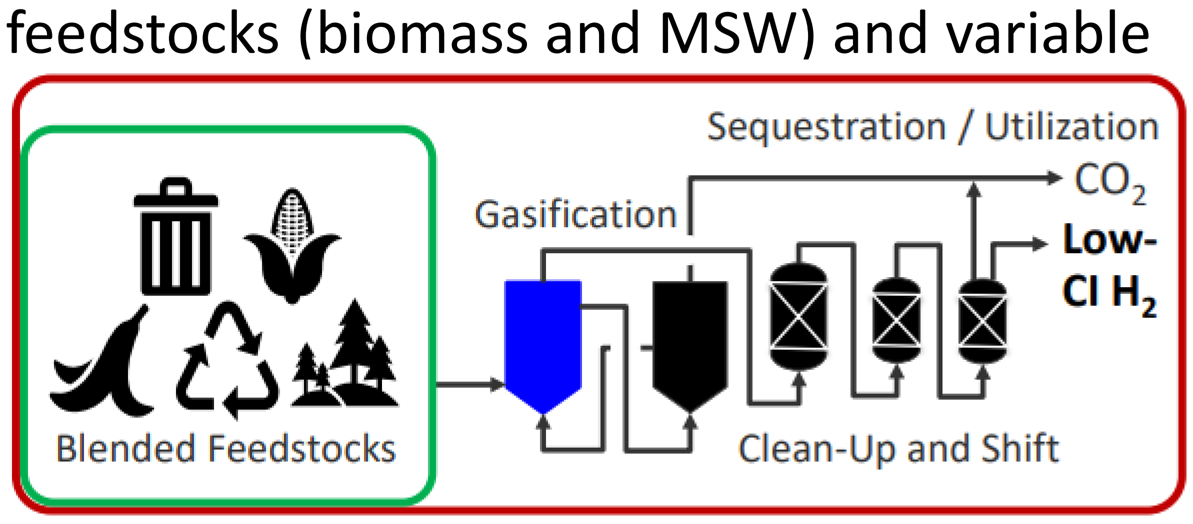
In this project, the National Renewable Energy Laboratory (NREL) is investigating the production of low-carbon H_2 through four related core areas focused on Systems Analysis, Gasification Reactor Modeling, Real-Time Feedstock Characterization, and Gasification Experiments. Systems analysis comprises TEA, LCA, and resource analysis on gasification of blended carbonaceous resources (i.e., sustainable biomass, mixed plastics waste, coal waste) to produce a low-cost and low-carbon H_2 product. Gasification mesoscale modeling produces high-fidelity particle-scale simulations of gasification, augmented with machine learning methods to produce fast-solving sub-grid models that account for feedstock-specific behavior in MFiX reactor simulations. Real time feedstock characterization work involves measurement of the chemical and physical attributes of mixed gasifier feedstocks in real-time to enable feed-forward control, ensure stable operation of the gasifier, and optimize H_2 production. Gasification experiments are proposed for the NREL Single Particle Rector (SPR) and the NREL Research Gasifier (NRG).

Benefits

This work will help define the minimum viable scale of a net-zero gasification to H_2 facility, help answer where these facilities could be sited based on feedstock availability, H_2 distribution/off-take, and CO_2 transport/sequestration considerations, how the systems could be designed to approach the $1/kg H_2 target from the Hydrogen Shot, how feedstocks selection/blending impact final carbon intensity, and help inform targets for the commercialization of a low-carbon H_2 facility and support the goals of the Hydrogen with Carbon Management program within FECM.

Recent Results

- NREL and NETL researchers collaborating on generating well-curated datasets using multiple sensing modalities of well-characterized feedstock mixtures.
- Demonstrated integration of Aspen Plus model with TEA and CI quantification with different feedstocks (biomass and MSW) and variable plant scales



QUICK FACTS

AWARD NUMBER:
FWP-OMS27850

PROJECT BUDGET

National Laboratory Share:
$2,010k

Total Award Value:
$2,010k

CONTACTS

HQ PROJECT MANAGER:
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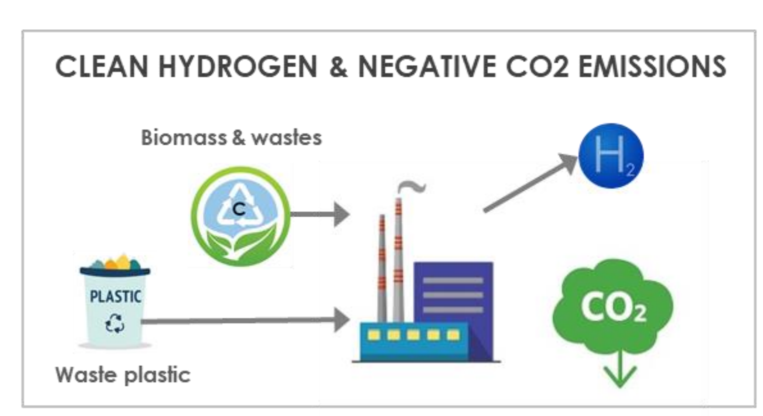
PRINCIPAL INVESTIGATOR:
Michael Talmadge

PERFORMER

NREL Transforming ENERGY



U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

MSW and Biomass Reference Materials for Gasification

- Increase understanding of how MSW, waste biomass, unrecyclable plastics, automotive shredder residues, waste tires, etc. impact gasifier operation and conversion kinetics with respect to material type and variability

Overview

In this project, Idaho National Laboratory seeks to establish a partnership between NETL, the Office of Fossil Energy and Carbon Management (FECM), and the Bioenergy Technologies team at Idaho National Laboratory (INL) that has expertise in the areas of feedstock supply, logistics, characterization, and preprocessing. The primary objective of this project is to understand how waste, such as MSW, waste biomass, unrecyclable plastics, automotive shredder residues, waste tires, etc. impacts gasifier operation and conversion kinetics with respect to material type and variability. Dedicated production, feedstock analysis, and conversion testing of standardized and reference materials will lead to a handling and conversion quality framework with critical material attributes and will be validated with test cases at the pilot scale.

Benefits

Over the multi-year project, a major benefit of establishing a framework for characterizing standardized feedstocks and determining relevant feedstocks for FECM/NETL gasification research is targeted. This will foster using gasification as an end-of-life solution for municipal solid waste (MSW), unrecyclable plastics and waste biomass feedstock, providing attractive pathways for hydrogen (and energy more broadly) and chemical production.

Recent Results

The project was recently commenced (mid-2024) and as of December 2024, initial findings and reporting are still pending.

QUICK FACTS

AWARD NUMBER:

FWP-INL-24-FECM24-004

PROJECT BUDGET

National Laboratory Share:
$2,607k

Total Award Value:
$2,607k

CONTACTS

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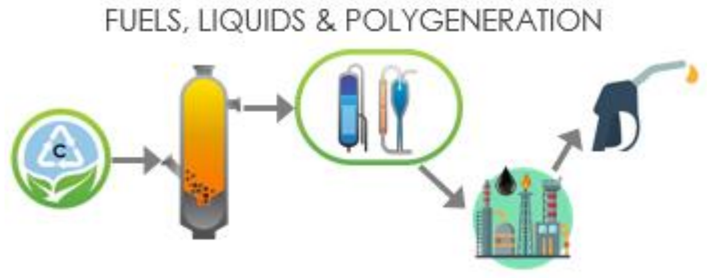
Idaho National Laboratory



U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Machine Learning Enhanced LIBS to Measure and Process Biofuels and Waste Coal for Gasifier Improved Operation

- In situ and near real time gasifier feedstock measurement, resulting in immediate and time sensitive fuel data that gasifier operators can use to maximize performance and avoid negative effects of ash in feedstocks

Overview

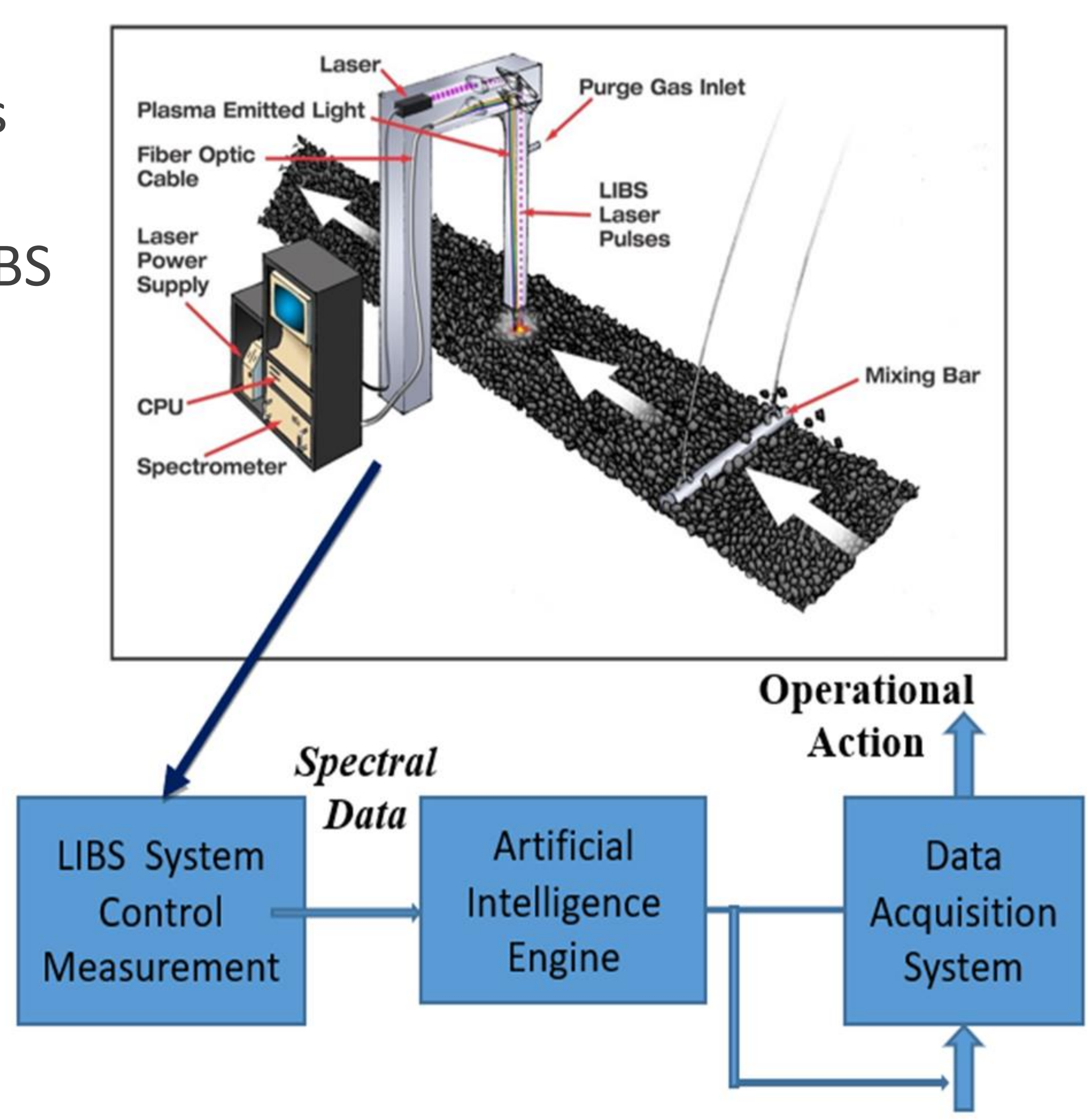
Energy Research Company is collaborating with Lehigh University to develop an instrument to measure the feedstock to a gasifier in-situ and in near real time, resulting in immediate and time sensitive fuel data that gasifier operators can use in a feedback or feedforward control scheme to maximize performance and avoid negative effects of ash in feedstocks. The instrument combines Laser Induced Breakdown Spectroscopy (LIBS) with Artificial Intelligence. Current objectives are to extend prior measurement success by better simulating a commercially operating gasifier and determining the exact gasifier performance from measurements using the Machine Learning (ML)-LIBS data as an input to GTI's gasifier simulator.

Benefits

Technological advancement in this area would provide better control of gasification and ash/slag issues arising with complex mixed feedstocks. This would tend to help increase value from utilization of waste and biomass feedstocks as environmental justice and legacy waste remediation are pursued.

Recent Results

- All feedstocks' properties accurately measured
- Signal to noise ratio of LIBS data excellent for all chemical elements
- Success in high precision measurements on varied feedstocks regarded as a technical breakthrough



QUICK FACTS

AWARD NUMBER:
SC0022696

PROJECT BUDGET

DOE Share:
$1,895k

Total Award Value:
$1,895k

CONTACTS

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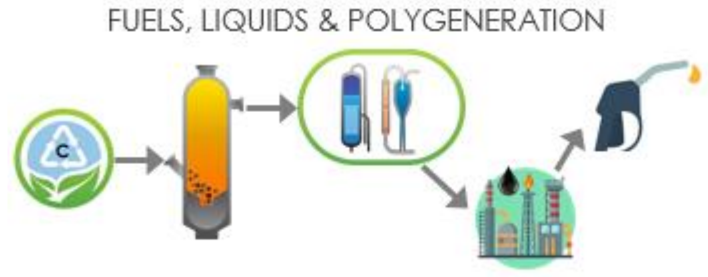
PRINCIPAL INVESTIGATOR:
Robert De Saro

PERFORMER

ERCo ENERGY RESEARCH COMPANY



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