Hydrogen Strategy
Office of Clean Coal and Carbon Management

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Mission:
Discover and develop advanced coal technologies that ensure America’s access to resilient, affordable, reliable, and carbon neutral emitting coal energy resources

R&D Priorities:
1. Advancing small-scale modular coal plants of the future, which are highly efficient and flexible, generate electricity and hydrogen, with carbon-neutral emissions
2. Creating new market opportunities for coal
3. Reducing the cost of carbon capture

HOLISTIC APPROACH TO ENERGY GENERATION FROM FOSSIL FUELS
Carbon neutral, including net negative CO₂ emissions with co-firing coal and biomass, power plant R&D effort in the world

Capable of producing power and/or hydrogen for polygeneration

Coal, biomass, and plastics with CCUS excellent and economical feedstocks for hydrogen

Contributes to IEA minimum cost scenario for deep CO₂ emissions -- carbon capture

Provides low cost power generation; economically competitive

Potential to sustain U.S. coal communities; provide a source of high value exports

Flexible coal plant operations to meet the needs of the grid

Innovative and cutting-edge components; improved efficiency and carbon neutral emissions

Transforms how coal technologies are designed and manufactured

Smaller than conventional utility-scale coal plants

Resilient power generation

Carbon neutral Emissions
Negative CO₂ emissions when co-firing biomass
Existing Gasification R&D—H₂ Production

Recent DOE/NELT supported work—innovative WGS & process integration focus

- TDA developed integrated water-gas shift with pre-combustion CO₂ capture technology (alternative to conventional multi-stage WGS with inter-stage cooling followed by CO₂ removal)

- RTI developed Warm Syngas Cleanup (WGCU) integrated with novel water-gas shift technology (for high H₂ syngas production)

- Alstom’s limestone chemical looping gasification (LCL-G™) process (for H₂ or high H₂ syngas generation) using limestones

- Ohio State’s syngas chemical looping for H₂ production using iron oxide based oxygen carrier

- Praxair’s advanced H₂ transport membranes for coal gasification

- Kentucky CAER chemical looping with spouting fluidized bed for H₂-rich syngas production from catalytic coal gasification

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- GTI’s Hybrid Molten Bed (HMB) gasifier for high H₂ syngas production

- Small modular gasifier design and Air separation
Pre-Combustion Capture Technologies – Reduce Cost of Capture in Gasification

DOE has been working on cleanup of syngas streams for many years. Numerous tests have been conducted at the NCCC, a recent shift in focus is toward polygen and H₂.

Recent example of R&D activities:

- **TDA**  Sulfur & carbon capture process based on WGS with a physical adsorbent to eliminate CO₂ emissions from a coal-based polygen system.

- **MPT**  Microporous ceramic membranes have been proven to be low cost, stable material for high temp. application.

- **Air Products** – Port Arthur PSA sorbent modules - Commercial Demonstration
Future of Gasification with MSW and Plastics

Alternative feedstock & blending possibilities
• Low-cost localized sources

Syngas can:
• Produce heat and/or power
• Provide higher value products

Environmental Benefits
• Reduce landfill burden
• Sustainable waste to energy
Low cost oxygen enables:

- Low cost pre-combustion carbon capture
- Low cost feedstock (e.g. MSW)

Future work – where are we heading?

- Waste Plastics as Gasifier Feedstock
- Pre-combustion carbon capture technologies
- Negative CO$_2$ w/ Biomass Blending
- Ultra High-Pressure Gasifier
- Microwave assisted gasification systems
- Materials development (extreme materials and catalysts)
Hydrogen Turbine Systems Affected

These combustion turbine systems are affected by firing with H₂ instead of natural gas.

Technical challenges are due in part to H₂ characteristics:

- High flame speed
- Broad flammability limits
- Low density
- Low volumetric energy content (Btu/ft³)
- High mass energy content (Btu/lb)
- Low ignition energy
Hydrogen Turbine R&D Planned by FE

• Science and engineering knowledge of stable high temperature, low NO\textsubscript{x} hydrogen combustion.

• Combustion of carbon neutral fuels (i.e. NH\textsubscript{3}, ethanol vapor).

• Apply H\textsubscript{2} combustion engineering to utility scale and aero derivative machines.

• Develop and test hydrogen combustion retrofit packages.

• Apply advanced manufacturing for hydrogen combustors.

• Apply and develop advanced CFD with reacting flows.

• Develop control strategies and instrumentation.

• Assess and mitigate moisture content effects on heat transfer and ceramic recession.

• Aim for 100% hydrogen machine.
Reversible Solid Oxide Electrolysis Cell (SOEC)-RSOFC

• Attractive option to produce hydrogen at high efficiency – higher the operating temperature, higher the efficiency

• Reversing the operation of a solid oxide fuel cell (SOFC) system

• SOEC system is supplied with electricity and water (steam) to produce hydrogen, oxygen and heat

• Hydrogen in turn, can be used to produce power again - potential to provide a significant means for energy storage
SOECs have similar materials set as SOFCs
- Dense, thin and chemically stable ionic conductor as electrolyte
- Porous electrodes
- Dense, thin and chemically stable electronic conductor as interconnect between cells

SOECs share the similar stack design as SOFCs
- Potential for hybrid systems to produce hydrogen in SOEC mode and electricity in SOFC mode

Prior and on-going SOFC R&D supported by FE will provide the technology basis for SOEC development going forward
Benefits of Storage: Reliable, Affordable, Clean

- **Reliability** in a changing grid
- **Resiliency** in unplanned events
- **Secure** energy supply
- **Reduced** customer cost
- **Clean** infrastructure & end use
- **Optimal** asset utilization

Image Source: Adobe Stock
Hydrogen Storage Technologies

Generalized groups of hydrogen storage technologies

- Physical Storage
  - $\text{H}_2(\text{g})$
  - $\text{H}_2(\text{l})$

- Adsorption

- Chemical Storage
  - Metal Hydrides
  - Chemical Hydrides
    - Elemental Hydrides
    - Intermetallic Hydrides
    - Complex Hydrides

Example: Gasification/Poly-generation

Energy.gov/fe
Request for Information—Hydrogen Technologies DE-FOA-0002369

Seeking input from stakeholders about hydrogen technology opportunities and research needs that could lead to technological advances

Topic Areas

1. Natural Gas Hydrogen Production, Transport, and Storage
2. Hydrogen Production from Coal, Biomass, and Waste Plastics Gasification
3. Hydrogen Turbines
4. Hydrogen Storage
5. Hybrid Energy Systems with reversible solid oxide fuel cells to produce hydrogen

Responses Due: August 24th, 2020 to DOE FE National Energy Technology Laboratory

https://netl.doe.gov/business/solicitations
Questions?

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