MODULAR GASIFICATION FOR FUEL-FLEXIBLE & WASTE REMEDIATION SYSTEMS

SYNERGIES IN DECARBONIZING POWER, FUELS, AND PROMOTING ENVIRONMENTAL JUSTICE

NETL

NATIONAL ENERGY TECHNOLOGY LABORATORY

MISSION

The National Energy Technology Laboratory's mission is to drive innovation and deliver solutions for an environmentally sustainable and prosperous energy future while achieving the following:

- Ensuring affordable, abundant and reliable energy that drives a robust economy and national security, while
- Developing technologies to manage carbon across the full life cycle, and
- Enabling environmental sustainability for all Americans.

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NETL implements this effort as part of DOE's Advanced Energy Systems Program.

Program 143, June 2021

NETL is revolutionizing the design and application of mixed feedstock chemical reactors, including gasifiers and plants, to create new opportunities for significant reductions in greenhouse gas (GHG) emissions. These technologies will also play an important role in achieving Environmental Justice for disadvantaged communities by providing jobs and remediating environmental waste. Modular gasification can reduce the disposal burden of waste materials like coal gob, coal fines, petroleum coke, biomass waste, and discarded plastics in landfills by converting them into useful products (e.g., fuels and power). When retrofitted with appropriate carbon capture technology, gasification can also produce hydrogen with carbon neutral potential. When blending biomass into feedstocks, gasification technologies enable Biomass Energy with Carbon Capture and Storage (BECCS) exhibiting negative carbon-emitting performance, a key strategy needed to achieve the administration's goal for zero-carbon economy by 2050.

New technologies under development will provide an opportunity to reduce carbon emissions across the board. These progressive technologies take into consideration the impacts of climate change, improvement of public health, and conservation our nation's air, land, and waters. Furthermore, through innovation, commercialization, and deployment of clean energy systems and infrastructure, the technologies will provide high-value products (e.g., hydrogen) and useful raw materials to thereby engender a circular economy and revitalize existing fossil fuel and power plant communities.

The primary outcomes of these modular systems will include the production of decarbonized fuels like hydrogen, as well as clean electricity. This will ultimately contribute to the revitalization of disadvantaged communities across the nation and help ensure energy security for America's future.

BACKGROUND

Gasification technologies can turn any carbonaceous feedstock or feedstock mixtures into syngas and other chemical building blocks that can be synthesized into a variety of valuable products, to include hydrogen, fuels, chemicals, and carbon products. Additionally, feedstock blends consisting of coal waste and biofuels (e.g., biomass or biogas) in combination with carbon capture technology may afford a net-negative carbon emissions profile. However, there is a need to improve cost, efficiency, reliability, and flexibility of existing conversion technologies and to devise innovative new gasification technologies for competitive processes in current and future markets. This is especially true for gasification and syngas technologies on modular or smaller scales, as needed to avoid huge capital investment liabilities and enable flexible deployment under changing market conditions.

In the anticipated hydrogen economy of the future, modular hydrogen production from locally available, low-cost materials could provide an invaluable alternative to pipeline or tanker delivery. Modular gasification of low cost feedstocks such as waste coal and other waste streams (including unrecyclable plastic destined for a landfill) might fill this niche with a viable, market-competitive alternative to large-scale conventional natural gas-based hydrogen, and help to revitalize communities and smooth out intermittent renewable energy-based hydrogen production.

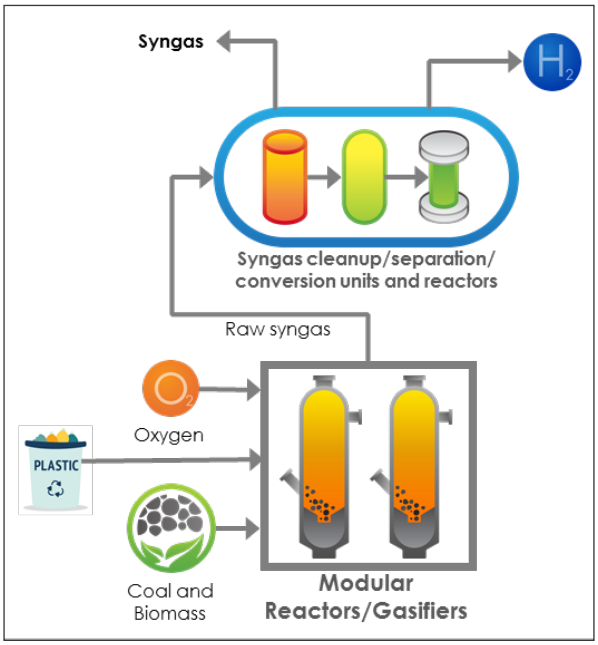

FIGURE 1. A Gasification Production Key Technology—Process Intensification for Hydrogen and Syngas Production

APPROACH

NETL's approach for gasification technology development will focus on modularization, intensification, and solutions for process issues arising when wider feedstock combinations are deployed for hydrogen production. Holistic approaches with gas separation/pollutant removal technologies are critical to these endeavors. In all cases, these should apply at modular scale (5–50 MWe equivalent) so that these small-scale gasification-based plants/systems will have improved efficiency and reduced costs to make these types of plants more attractive in the marketplace.

PROCESS INTENSIFICATION

"Technologies that replace large, expensive, energy-intensive equipment or process with ones that are smaller, less costly, more efficient, or that combine multiple operations into fewer devices."

NETL is looking at microwave/plasma driven reactors, non-traditional thermal reactors, oxygen carrier development and innovative catalyst design for **process intensification** of gasification systems.

A growing interest in utilizing mixed plastic waste as gasification feedstock is likely to create issues with feed preparation, conveyance to the gasifier, syngas cleanup, and materials degradation. Degradation is a particular concern with refractories in the high-temperature zones of gasification vessels and other unit operations. NETL is addressing the need for greater understanding of waste plastic gasification by investing in R&D to adapt or leverage known gasifier technology. Utilizing a preponderance of waste plastics and municipal waste with coal waste to make useful products diverts wastes away from landfills, and thereby helps to support a circular economy and provides clean power and fuels to lower income/disadvantaged communities.

Ultimately, gasification systems will need to be customized for each application —focused on locally available coal waste and other opportunity fuels such as other waste materials, biomass, natural gas, and renewable energy resources. These resources include, but are not limited to, hydropower, geothermal power, wind energy, and solar energy. The most economically competitive products would be considered, and techno-economic systems analysis would be performed periodically during development to refine the slate of created products, evaluate potential performance and associated costs, and identify key research aspects and targets to show where more development work would be most beneficial.

FIGURE 2. An example of Circular Economy

SIMULATION & PROTOTYPING

NETL's expertise in modeling and simulation in concert with experimental validation can be powerfully applied to accelerate and save costs on technology and systems development. Simulation-based reactor design will be used to predict reactor behavior and results, and advanced manufacturing techniques will enable rapid prototyping of concepts. This approach should lead to significantly reduced times for new reactor development.

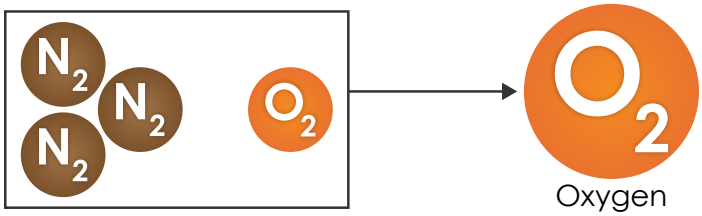

FIGURE 3. A Gasification Production Key Technology—Air Separation/Oxygen Production

The high-fidelity multiphase and kinetic modeling tools supported by experimental data will provide accurate predictions of the reactor operation, and details about where and why desired and undesired reactions occur. This unique capability will allow researchers to virtually test both feed-specific and product-specific reactor designs.

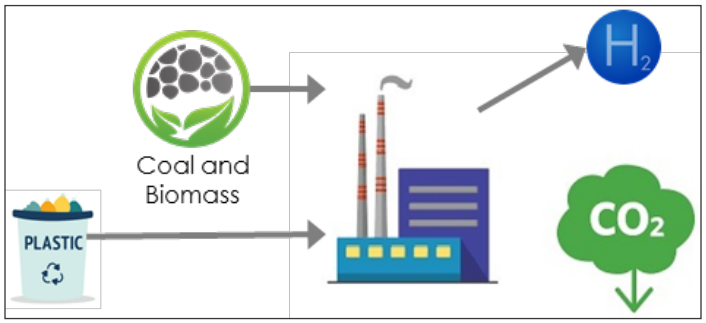

FIGURE 4. A Gasification Production Key Technology—Blue Hydrogen & Negative CO_2 Emissions

Rapid prototyping, such as inexpensive 3D plastics printing of cold flow reactors, will be used to quickly test the novel designs. Artificial intelligence and machine learning (AI/ML) along with additive manufacturing and other advanced manufacturing techniques for metals and ceramics will be used to rapidly translate proven cold-flow reactor designs into reactors for hot-flow validation, and for final manufacturing of multi-fuel reactors for deployment.

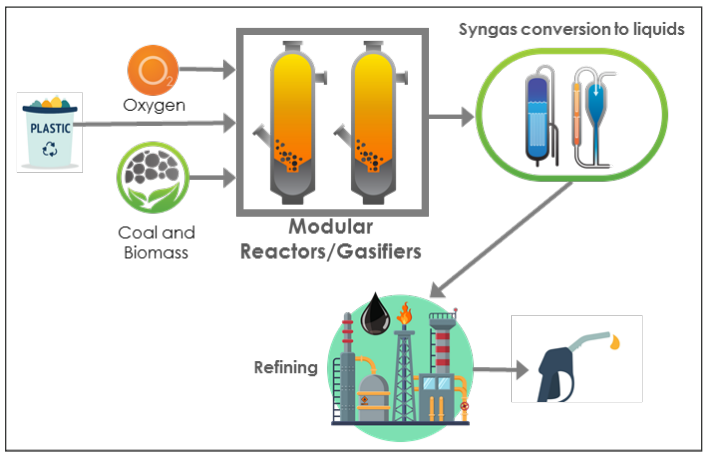

FIGURE 5. A Gasification Production Key Technology—Coal & Biomass to Liquids and Polygeneration

GASIFICATION SYSTEMS

VISION

NETL envisions transformative gasification systems producing hydrogen and other high value products such as liquid fuels from mixtures of low-cost waste coal, environmentally beneficial biomass, and even liability waste materials, simultaneously creating cost advantages for these systems while addressing climate change and environmental justice requirements. They would be modular, overcoming the traditional economies of scale constraints facing gasification plants and flexibly tapping into new markets. They would intrinsically include carbon capture and enable biomass cofeeding to enable net negative greenhouse gas emissions performance. Gasification Program Key Technologies being pursued are shown in Figures 2-5.

Outreach and communication to foster collaboration of R&D in multiple relevant technical areas, as well as leveraging and extending commercial technologies will be an active and ongoing part of NETL R&D. Reaction engineering, energy conversion engineering, materials engineering, use of AI/ML and novel computational modeling, and manufacturing are all significant contributors to current research in this area.

Finally, while initiatives continue to improve cost and environmental footprint of fossil fuel utilization in the short-term, NETL is working with our partners in industry and academia to achieve a responsible transition to renewable energy resources as synergies of fossil and renewable energy technologies are also of interest in gasification systems development moving forward.

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