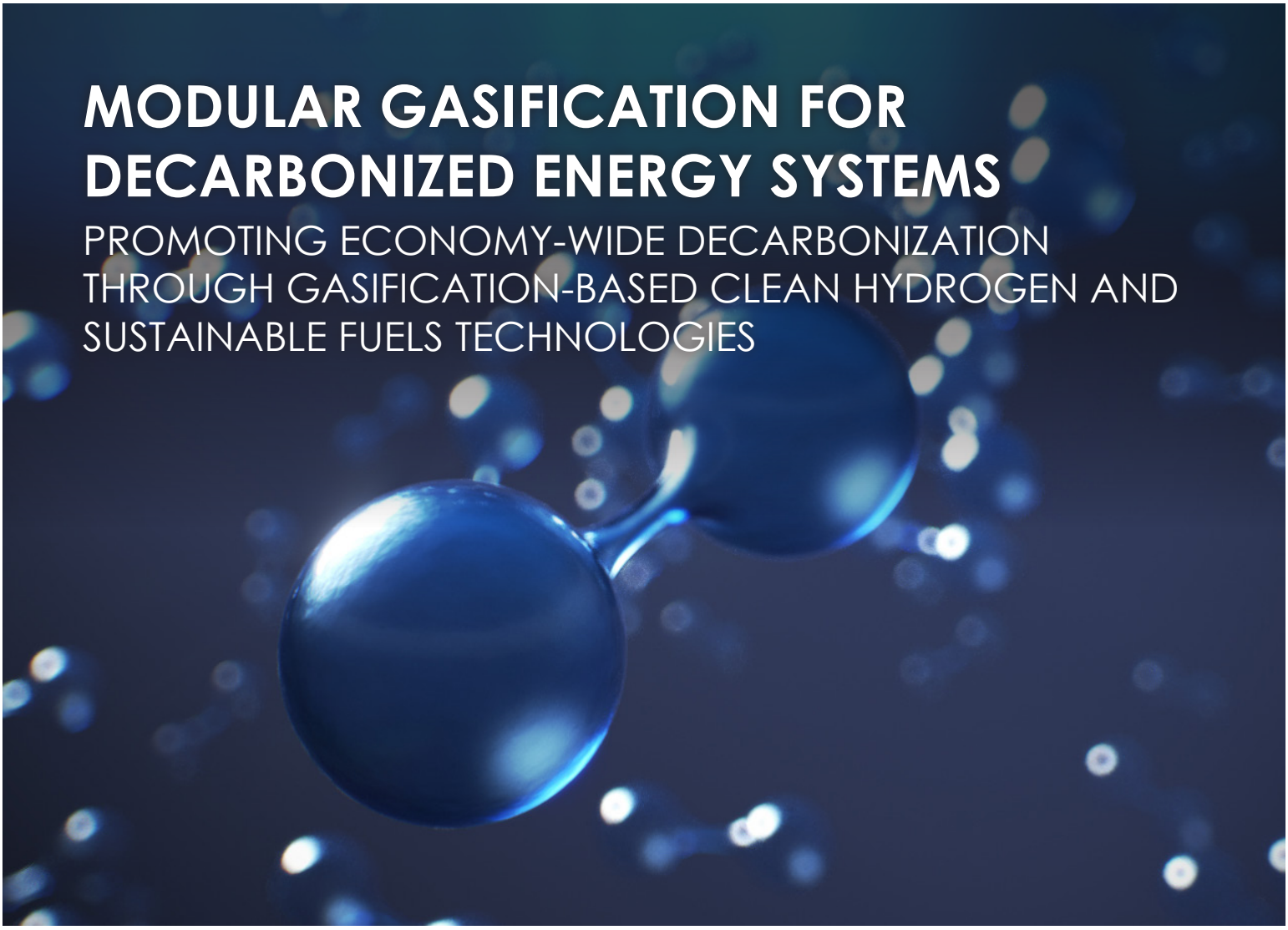
MODULAR GASIFICATION FOR DECARBONIZED ENERGY SYSTEMS

PROMOTING ECONOMY-WIDE DECARBONIZATION THROUGH GASIFICATION-BASED CLEAN HYDROGEN AND SUSTAINABLE FUELS TECHNOLOGIES



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NATIONAL ENERGY TECHNOLOGY LABORATORY

OVERVIEW

DOE's Gasification Program is revolutionizing the design and application of gasifiers and gasification systems using opportunity feedstocks such as biomass and wastes 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 liabilities. Modular gasification has the unique capability of accepting varied waste materials like municipal solid waste (including discarded plastics) and biomass and converting them into useful products (e.g., chemicals, fuels and power), keeping waste materials out of landfills. When retrofitted with appropriate carbon capture technology, gasification can also produce clean, carbon-neutral hydrogen. When blending biomass into feedstocks, gasification technologies enable Biomass Energy with Carbon Capture and Storage (BECCS) systems exhibiting net negative carbon-emitting performance, a key strategy needed to achieve the administration's goal for net zero-carbon economy by 2050.

New technologies under development will provide an opportunity to reduce carbon emissions across multiple economic sectors, helping to reduce impacts of climate change while improving public health and conserving our nation's air, land and waters. DOE's Gasification Program's activities in this area are intended to support both the Hydrogen Shot™ and the Clean Fuels & Products Shot™ for low-cost hydrogen generation technologies and sustainable fuels and chemicals production. Furthermore, through innovation, commercialization and deployment of clean energy systems and infrastructure, the technologies will engender a circular economy and revitalize existing fossil fuel and power plant communities, helping to 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, including hydrogen, fuels, chemicals and carbon products. Additionally, feedstock blends consisting of waste and biofeedstocks (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 wastes (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.

APPROACH

DOE's approach for gasification technology development focuses on modularization, process intensification, air separation/oxygen production technology development to support high-efficiency oxygen-blown gasification processes and solutions for process issues arising when challenging feedstock compositions 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.

A growing interest in utilizing mixed municipal solid waste, waste plastics and biomass 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. DOE's Gasification Program is addressing the need for greater understanding of biomass and/or waste plastic gasification by investing in R&D to adapt or leverage known gasifier technology. Utilizing a preponderance of biomass, waste plastics and municipal solid 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. They will be focused on locally available feedstocks and resources, even including renewable energy sources (hydropower, geothermal power, wind energy and solar energy), which might afford hybrid energy system realization. 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.

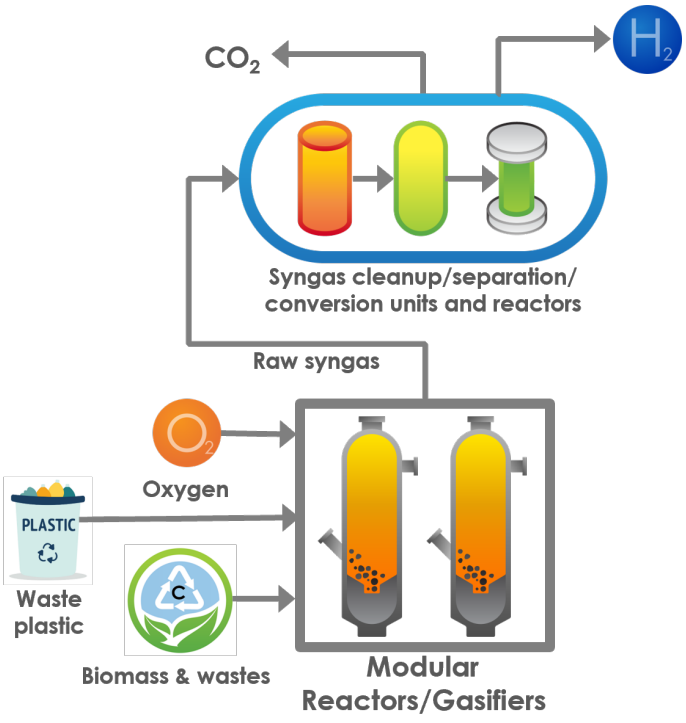

Figure 01. A Gasification Production Key Technology—Process Intensification for Hydrogen and Syngas Production

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.

Figure 02. 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 gasifier and 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.

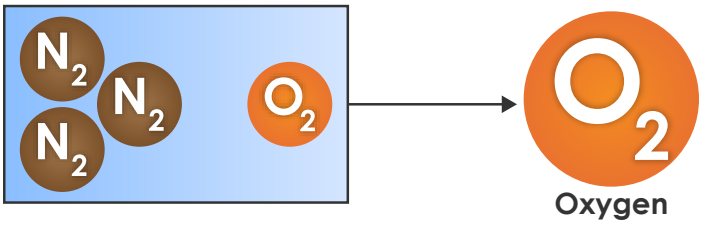

Figure 03. A Gasification Production Key Technology—Air Separation/Oxygen Production

The high-fidelity multiphase and kinetic modeling tools supported by experimental data will provide accurate predictions of gasifier and 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.

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.

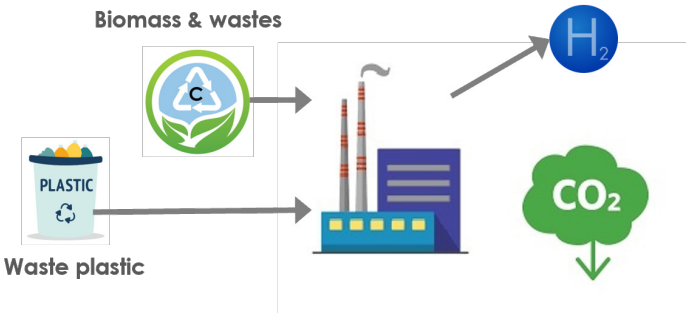

Figure 04. A Gasification Production Key Technology—Clean Hydrogen & Negative CO_2 Emissions

VISION

DOE's Gasification Program envisions transformative gasification systems producing hydrogen and other high value products such as liquid fuels from mixtures of low-cost carbonaceous waste materials and environmentally beneficial biomass, 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 co-feeding to enable net negative greenhouse gas emissions performance. Gasification Program Key Technologies being pursued are shown in Figures 1, 3 and 4.

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. NETL is working with our partners in industry, national laboratories and academia to achieve a responsible transition to decarbonized energy systems through concerted initiatives and approaches.

NETL is a U.S. Department of Energy national laboratory that drives innovation and delivers technological solutions for an environmentally sustainable and prosperous energy future. By leveraging its world-class talent and research facilities, NETL is 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, enabling environmental sustainability for all Americans.

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