BrightLoop™ Technology

For hydrogen, steam or syngas production with CO_2 isolation

BABCOCK & WILCOX

RENEWABLE | ENVIRONMENTAL | THERMAL

Providing solutions for the low-carbon **energy transition**

As the world advocates for decarbonization, industry is responding by looking for innovative ways to optimize its processes for a cleaner tomorrow. Emerging technologies to support the continuous drive to reduce greenhouse gas (GHG) emissions can form a cornerstone of corporate stewardship.

The BrightLoop™ process from Babcock & Wilcox (B&W) is a versatile and flexible technology which can be used for a wide range of applications. We've demonstrated that BrightLoop can effectively separate carbon dioxide (CO_2) while producing hydrogen, steam and/or syngas, as well as being ready for commercial scale-up.

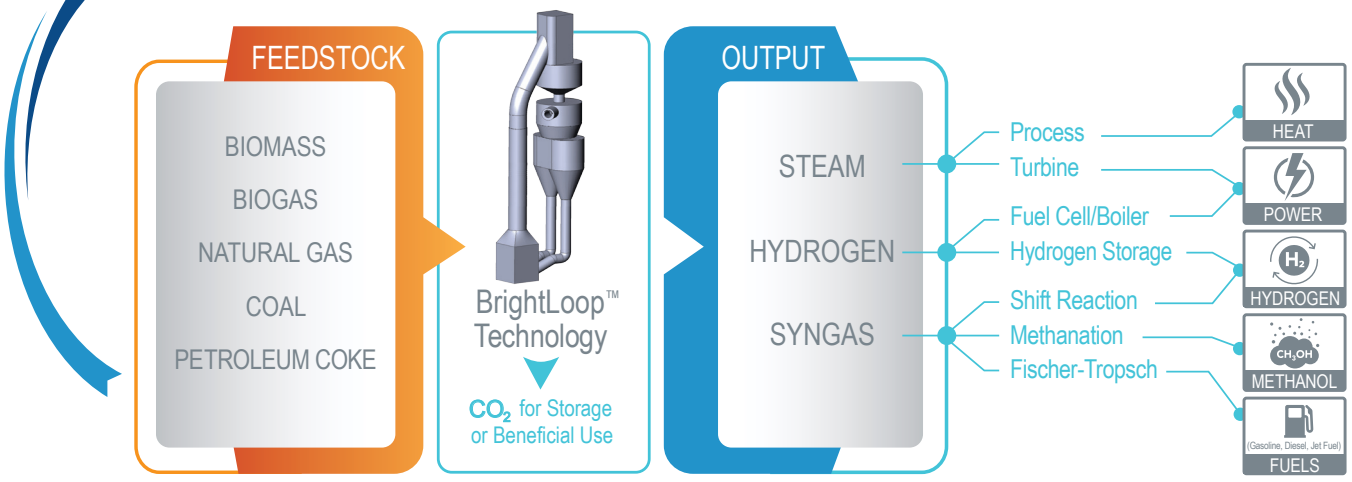
A particle breakthrough made it happen. Our proprietary particle is an extremely versatile oxide in terms of application, cost and abundance making chemical looping possible for practical implementation in a low-carbon world.

The ultimate in flexibility

The BrightLoop™ carbon capture system produces clean energy with complete in-situ CO_2 capture. You can simultaneously accomplish low carbon initiatives and energy transition objectives. Just as importantly, there is built-in flexibility to maximize its potential for your specific needs.

- **FLEXIBILITY OF FEEDSTOCK** — Works with a vast array of feedstock (raw material) — natural gas, biomass, biogas, petroleum coke (petcoke), coal, methane, municipal solid waste for waste-to-energy (WtE) and syngas.
- **FLEXIBILITY OF OFF-TAKE** — Suitable for a wide range of applications, through the production of hydrogen; synthesis gas (syngas) for transportation; and other uses including steam for power, process or heating.
- **FLEXIBILITY OF SCALE** — Highly scalable to accommodate both large and small applications, while applicable to a range of industrial processes capable of delivering a net zero outcome.
- **FLEXIBILITY OF CARBON UTILIZATION** — The process inherently isolates carbon dioxide for storage/sequestration, or for beneficial uses such as generating revenue by isolating the CO_2 stream.
- **FLEXIBILITY OF CONFIGURATION** — The BrightLoop system allows a modular deployment, from the feedstock to the off-take. Work with our system experts to configure an on- or off-site implementation designed specifically to your feedstock, scale and off-take requirements.

The BrightLoop™ system



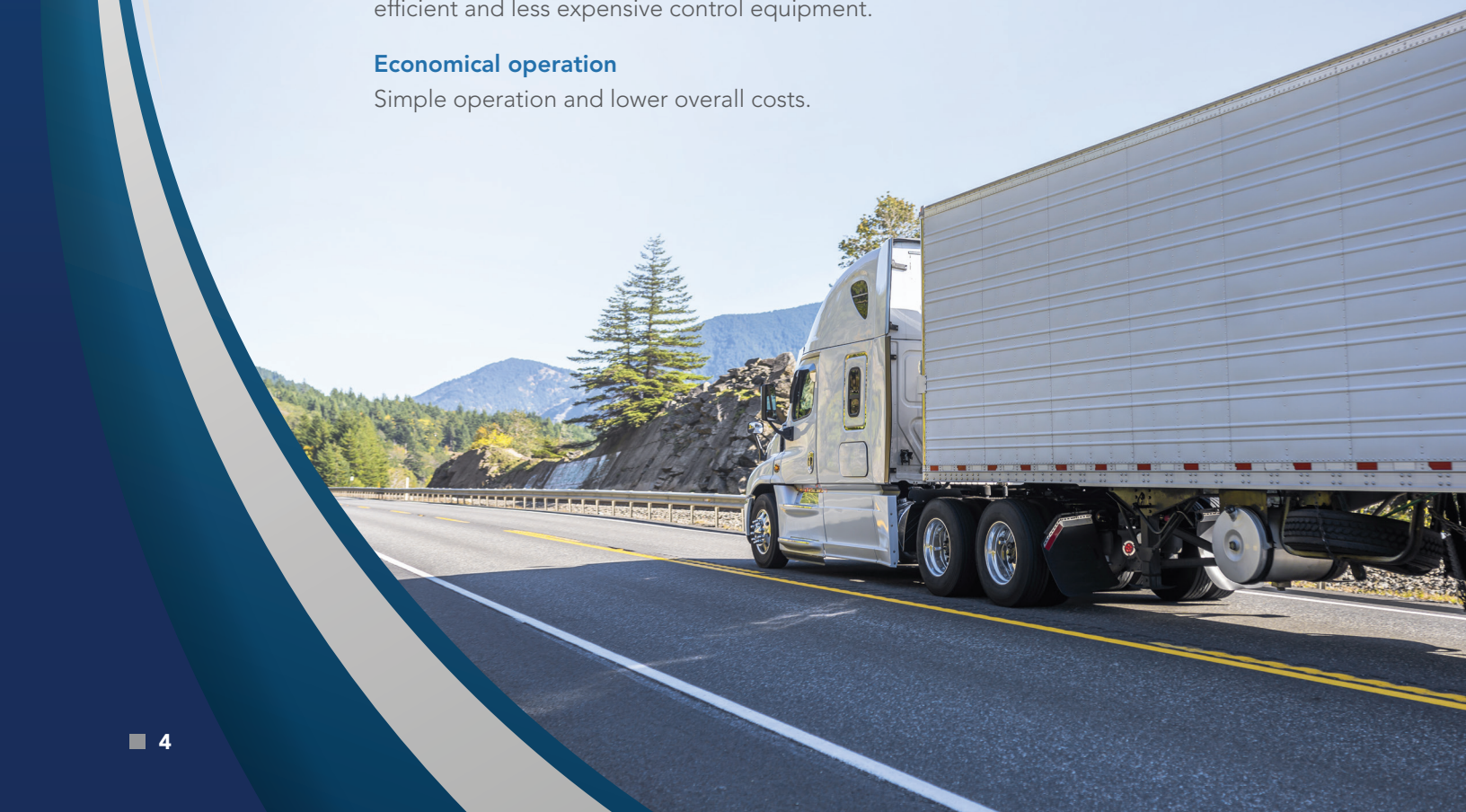
Other BrightLoop™ chemical looping **advantages**

In-situ CO_2 capture
BrightLoop enables CO_2 isolation of up to 95% or higher. There is no need for post-combustion scrubbing. Our design significantly reduces both capital expenses and operating costs to achieve a low carbon footprint.

Product purity
Proprietary moving bed design allows for high product purity.

Emissions control
A concentrated exhaust stream results in more efficient and less expensive control equipment.

Economical operation
Simple operation and lower overall costs.



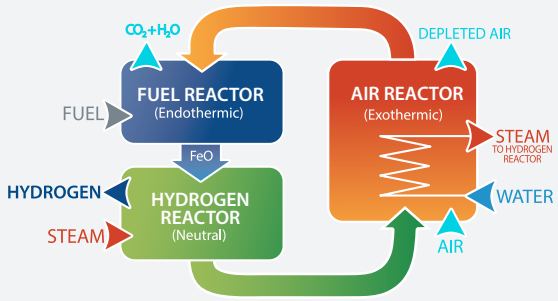
The BrightLoop™ process

In the BrightLoop process, the fuel reacts with oxygen-carrier particles in a reducer reactor (fuel reactor), forming combustion byproducts, predominantly CO_2 and H_2O, while reducing the oxygen-carrier particles. The reduced oxygen-carrier particles then move to a partial oxidizer (hydrogen reactor) where they react with steam to partially oxidize the particles and generate a stream of hydrogen.

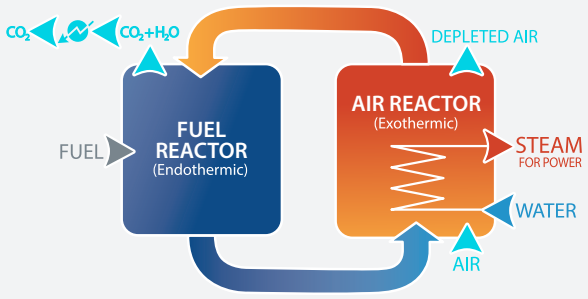
The oxygen-carrier particles are then transported to a combustor reactor (air reactor) where they are regenerated with air back to their original state. The exothermic oxidation reaction of the oxygen-carrier particles with air releases heat that both reheats the particles for their return to the reducer reactor and heats the air which can be used to heat water and produce steam for power generation or as a heat source for various other processes.

The process can be optimized to produce hydrogen, steam or both products by adjusting the conversion in the partial oxidizer reactor (System A). If hydrogen is not needed, the oxidizer can be removed (System B). Systems C and D below show similar configurations for the generation of syngas for hydrogen, liquid fuel or methanol production, all with CO_2 isolation.

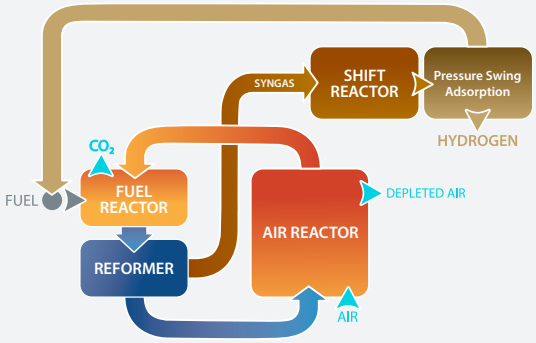
BrightLoop Applications with Various Product Outputs



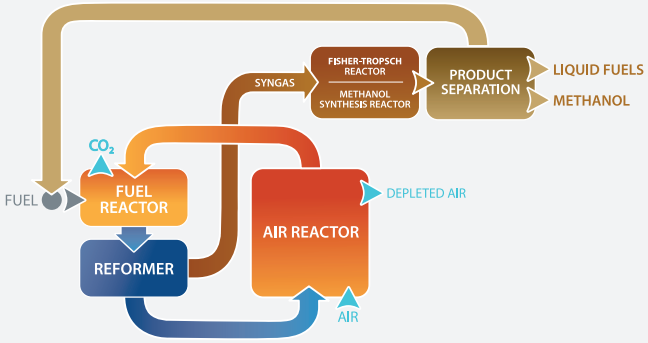
System A: Hydrogen Generation



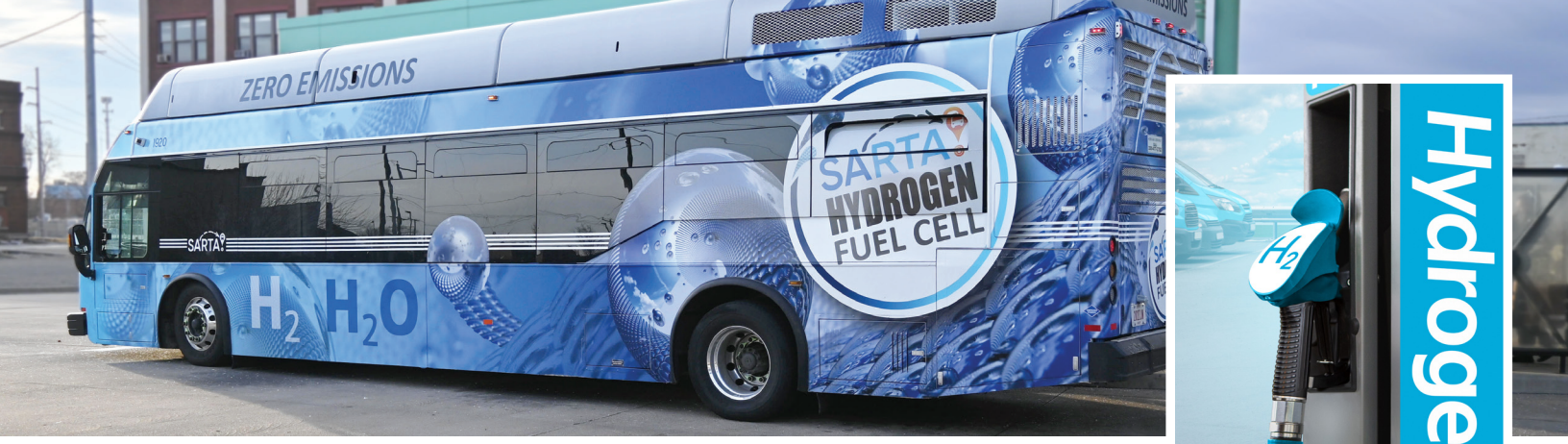
System B: Steam Generation



System C: Syngas Generation with CO_2 Isolation for Hydrogen Production



System D: Syngas Generation with CO_2 Isolation for Liquid Fuel or Methanol Production



Example scenarios

The three examples below (depicted on the following page) illustrate some of the advantages of B&W's BrightLoop technology, comparing typical current configurations with configurations using BrightLoop technology. Each example includes carbon capture/isolation in a low-carbon environment.

Hydrogen Production

This scenario compares hydrogen production using the steam methane reforming (SMR) process to BrightLoop technology. The SMR process includes a boiler for steam production, a water shift reactor and pressure swing adsorption, along with CO_2 capture and boiler nitrogen oxides (NO_X) control. The unsold or unutilized petcoke stream from oil cracking and refining process is shown as a waste product that is commonly landfilled. BrightLoop technology can use waste petcoke as the feedstock to produce hydrogen while inherently isolating CO_2 without the need for separate carbon capture equipment.

Oil & Gas

In this scenario, adding post-combustion carbon capture onto an existing boiler means a significant capital outlay and significant ongoing operating costs. Replacing the boiler with BrightLoop technology provides a concentrated CO_2 stream; steam for process; and the capability to use the waste stream, in this case petcoke, back into BrightLoop, lowering both fuel and waste disposal costs.

Waste- or Biomass-to-Energy

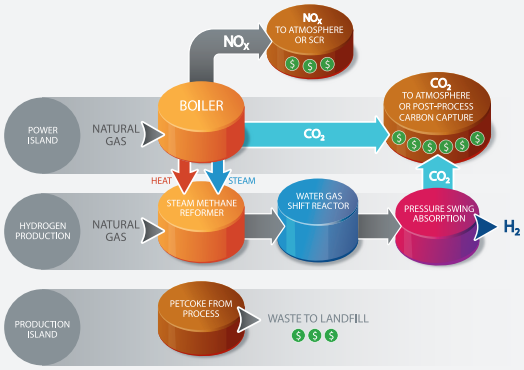
Similar to the oil & gas example, this scenario shows that including post-combustion carbon capture onto a waste- or biomass-to-energy installation, as well as NO_X control, adds considerable capital and operating expenses. Utilizing BrightLoop technology for steam generation isolates the CO_2 while producing zero NO_X emissions.

Comparisons of Typical Scenarios with BrightLoop Technology in a Low-Carbon Environment

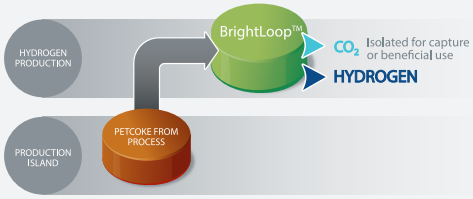
CURRENT CONFIGURATION

CONFIGURATION IN A LOW-CARBON ENVIRONMENT

Hydrogen Production



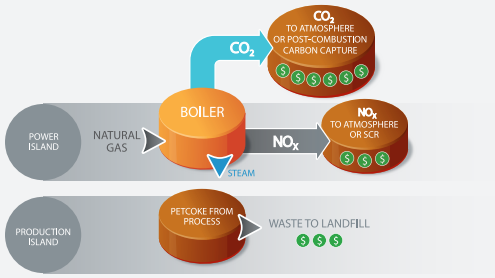
Hydrogen production using Autothermal Reforming would have a similar configuration and benefit using BrightLoop.

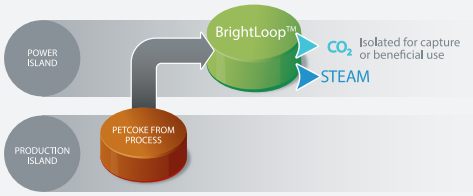


Benefits

- Potential for natural gas savings when replaced with waste product (petcoke)
- No waste (petcoke) to landfill
- BrightLoop CO_2 isolation saves energy

Oil & Gas





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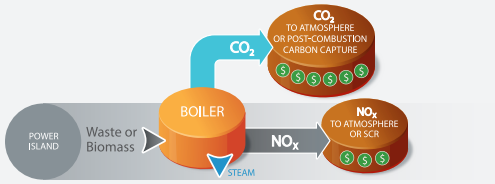

Benefits

- BrightLoop CO_2 isolation and capture while still producing steam
- Potential for carbon negative emissions
- Sales of carbon credits

BrightLoop™ Technology

The bright way to an energy transition

Technology Status

Under a DOE-sponsored project, B&W successfully built a 250 kW_t coal-based chemical looping pilot facility to demonstrate the reducer and combustor operation for application to steam and power generation. On another project, our university partner demonstrated full conversion of syngas to hydrogen at its 250 kW_t pilot unit constructed and tested at the National Carbon Capture Center.

Given the success of the 250 kW_t pilot units for application to hydrogen and steam for power generation, B&W is ready to demonstrate the technology at a larger scale, with a thermal input of between 2.5 and 25 MW_t while utilizing the most applicable fuel feedstock.

B&W's BrightLoop technology can combine carbon capture with energy production while reducing or eliminating unused waste. It can help reduce the risk of operating within the uncertainty of a carbon-constrained world.

Each day is another opportunity to:

CO_2llaborate, CO_2operate, CO_2mmunicate and CO_2nserve.

We have the *clean* energy ready for the energy transition.

babcock-decarbonization.com

Babcock & Wilcox
1200 E Market Street, Suite 650
Akron, Ohio, U.S.A. 44305
Phone: +1 330.753.4511

www.babcock.com

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Established in 1867, Babcock & Wilcox is a global leader in renewable, environmental and thermal technologies and services for power and industrial applications.

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