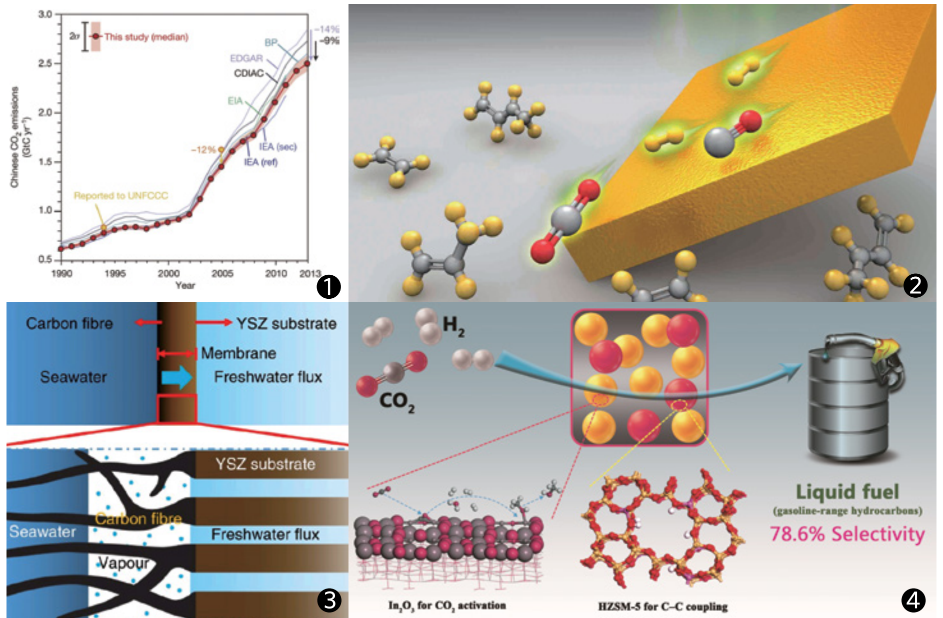
Taking green energy to the next level

Developing next-generation technologies to exploit varied energy resources, A RESEARCH INSTITUTE IN SHANGHAI supports national sustainability strategies.



SARI's research accomplishments include diverse fundamental studies on clean energy. (**1**. *Nature* 524, 335–338 (2015). **2**. *Nature* 538, 84–87 (2016). **3**. *Nature Nanotech* 13, 345–350 (2018). **4**. *Nature Chem* 9, 1019–1024 (2017).)

Accurate estimation of carbon emissions, needed for developing clean energy innovations, relies on big data. Committed to supporting low-carbon development strategies, and providing technical solutions for industry, the Shanghai Advanced Research Institute (SARI), Chinese Academy of Sciences (CAS), is developing an integrated system combining satellite and ground observation to monitor carbon emissions, supporting multi-level research on energy, the economy, and the environment.

Based on a big data system they built, SARI is also developing visualization techniques, analytical platforms, and energy technology evaluations to judge the feasibility and emission reduction potential of different technologies. Their results are summarized in a series of policy reports on low-carbon energy development.

SARI's energy science studies are the culmination of its strategies integrating basic and applied research with industry. Jointly established by CAS and the Shanghai Municipal Government in 2012, SARI focuses on cutting-edge research and core technologies to support important emerging industries. "Addressing national strategies for energy development, we develop clean technologies for sustainable use of carbon, methods for comprehensive use of CO_2, and equipment or techniques for efficient use of clean energy," said Ruxin Li, SARI's president. "We aim to build a complete innovation chain to provide solutions for industry."

Green carbon conversion technologies

Developing ways to efficiently use carbon-containing resources is a focus of SARI's energy research. Their basic studies revealing the rules and mechanisms of C-H, C-O, and C-C bond breakage and reconstruction have led to approaches for more efficient use of compounds, like methane and CO_2, reducing their environmental impact.

A notable example is SARI's development of a highly efficient nickel-based catalyst for CO_2 reforming of methane, a reaction that converts major greenhouse gases, such as CO_2 and CH_4, into high-value syngas that has broad industrial uses. The catalyst is more stable, and can better prevent carbon deposition, enabling more efficient use of CO_2, while reducing emissions. The technology has been demonstrated in an industrial pilot.

Syngas was also studied in relation to cobalt carbide nanoparticles in a process where it is converted into chemicals. Here, SARI researchers showed a promising new catalyst system for directly converting syngas into olefins in mild reaction conditions, offering alternative feedstocks for producing these petrochemical derivatives useful in the chemical industry.

Using coal-based olefins as raw materials allows for the production of metallocene polyalphaolefin (mPAO), a high-grade base oil widely used in synthetic lubricants.

Given the growing demand for this synthetic hydrocarbon, SARI researchers have improved techniques and constructed an innovative catalytic system for mPAO production, leading to a production unit capable of producing 3,000 tonnes of low-viscosity mPAO per year.

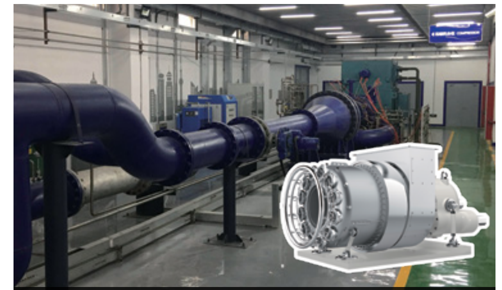
Working with businesses, the SARI team has piloted the technology for industrial use, demonstrating its potential for lowering costs. The technology provides high-quality lubricants to support advanced manufacturing, while offering a clean solution to high-value application of coal.

Comprehensive CO_2 use strategies

Promoting the integration of carbon capture, utilization, and storage (CCUS) technologies with traditional processes to more efficiently use CO_2 and reduce emissions is another major research direction at SARI. Among its many innovations is the direct conversion of CO_2 into liquid fuels with high selectivity. Key to the SARI team's success is the design of a bifunctional catalyst that enables CO_2 activation and C-C coupling to produce gasoline-range hydrocarbons. The reaction platform they developed for CO_2 hydrogenation is being tested for large-scale production.

ADVERTISEMENT FEATURE

SARI's big data platform for energy and carbon management



Helium-based Brayton cycle gas turbine testing platform, and ZK2000 2MW gas turbine co-developed by SARI

An industrial plant used as a demonstration project for CO_2 reforming of methane

Pilot plant for low-viscosity mPAO base oil

In addition to converting CO_2 to high-value chemical products via hydrogen, photo/electroreduction of CO_2 is also promising. However, efficient CO_2 reduction to high value-added chemicals is still challenging. After exploring various metals and alloys, SARI researchers identified a Pd-Sn alloy showing strong potential as an electrocatalyst for converting CO_2 into formic acid with high efficiency. Researchers have also developed a nitrogen-doped mesoporous carbon as an electrocatalyst for efficient conversion of CO_2 to ethanol, shedding light on electroreduction to multi-carbon products.

CO_2 can also be used in the recovery of unconventional oil and gas resources, where, because of low porosity and permeability, water fracturing is typically employed for reservoir stimulation, raising issues of pollution and water shortages. In the search for alternative fracturing fluids, a SARI team demonstrated CO_2 fracturing as a more effective reservoir stimulating technology. Using CO_2 can lower the fracturing pressure, and generate complex networks, leading to greater stimulated reservoir volume and enhanced production of unconventional resources.

CO_2 can also be converted to biomass via photosynthesis of microalgae. Focusing on its downstream uses, SARI researchers are exploring using biomass to replace chemical fertilizers, coupling CO_2 capture with wastewater treatment, and converting biomass to chemicals.

Advanced energy systems

Focusing on thermal and electrochemical energy conversion to electricity, SARI is keen to develop efficient, clean technologies to support growing energy demand. In addition to developing the MW class simple cycle industrial gas turbines with high efficiency and ultra-low NOx emission with industrial partners, SARI has also led the development of helium turbine based on closed Brayton cycle, which has the potential to serve as a power conversion system, such as for high temperature nuclear power plants and concentrated solar power plants. With a MW class test facility, a 10MW prototype helium turbine system is under construction.

SARI's innovative energy system R&D activities also include cost-effective, high-performance fuel cell and water electrolysis technologies. The nitrogen-doped, Pt-based electrocatalysts show high catalytic activity and excellent durability. The nanostructured membrane electrode enables efficient electrolytic water splitting for hydrogen production with outstanding performance, low use of noble metals, and high stability.

SARI researchers have also contributed to the preparation of heterojunction and passivating contact solar cells, which combine the advantages of crystalline silicon and thin film technologies to improve performance. Supporting China's first 100MW production line for high-efficiency heterojunction solar cells, they developed technologies boosting production efficiency by more than 24%.

Improving the efficiency of energy conversion in chemistry demands highly specific catalysts, making accurate characterization of material structures increasingly important. SARI is fortunate to house the Shanghai Synchrotron Radiation Facility (SSRF), an advanced third-generation synchrotron light source, which supports many of SARI's energy material discoveries and breakthroughs. Since its opening in 2009, SSRF has constructed multiple beamlines and end stations devoted to energy related research, prompting numerous publications. With more beam lines and end stations planned at SSRF and other advanced research platforms for energy material research, SARI is poised for more innovations.

"With construction of big science facilities at the centre of plans, we will be conducting cutting-edge research, developing key technologies, and facilitating international and industry-academia collaborations to pioneer sustainable solutions," says Li. ■

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