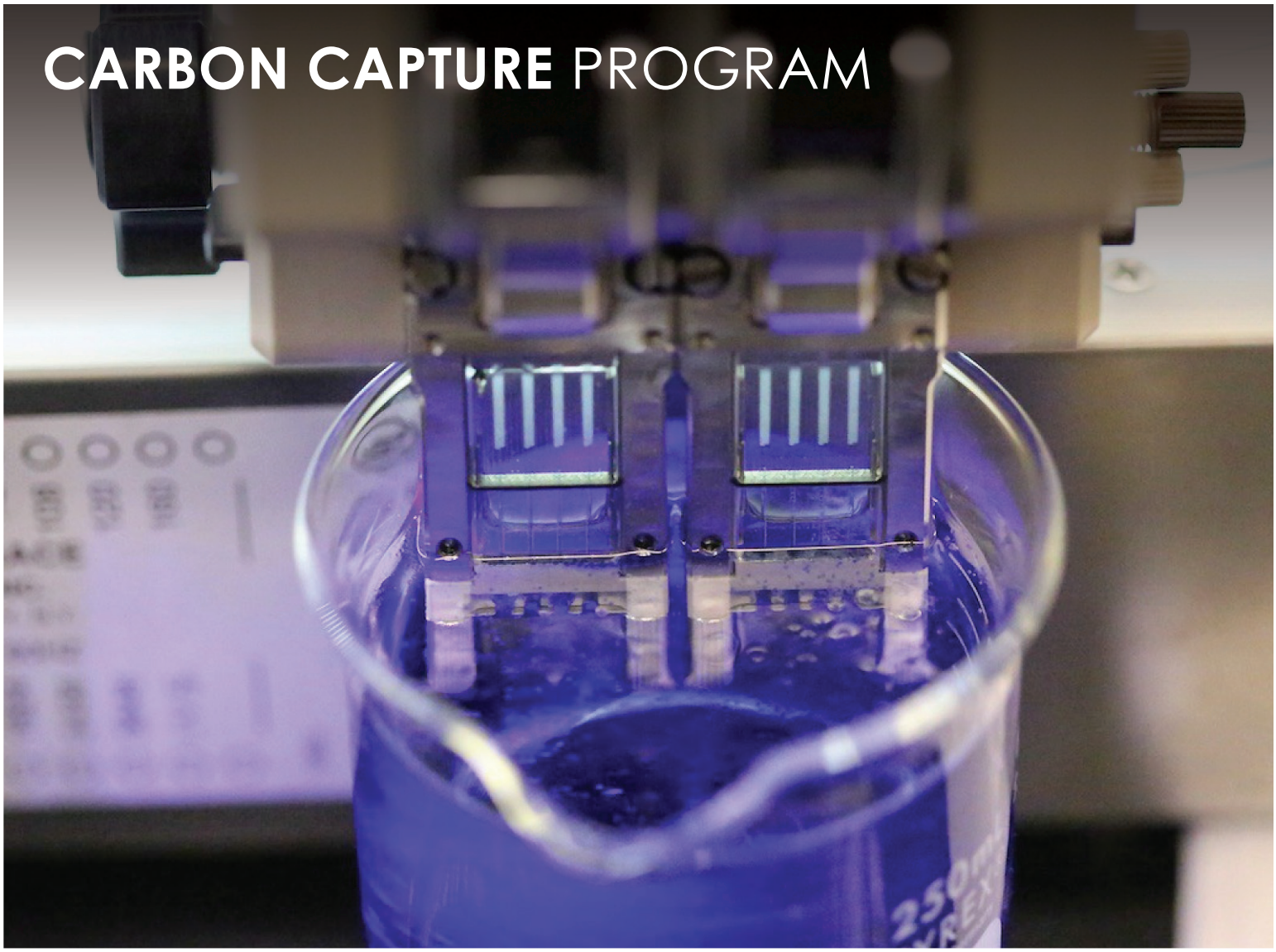
CARBON CAPTURE PROGRAM



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The **Carbon Capture Portfolio of Programs** is unique in its ability to advance a range of technology solutions aimed at step-change improvement in the economics, efficiency and reliability of carbon capture that are suitable to the unique environments of post-combustion and pre-combustion applications.

Lessons learned from computational simulation, fundamental research, technology development and large-scale testing (in both pre- and post-capture environments) is informing investment in new chemical production methods, novel process equipment designs and new equipment manufacturing methods – with a focus on the seamless integration of these new capture processes, equipment, and designs with balance-of-plant operating systems.

Post-combustion capture and pre-combustion capture, the two-main carbon capture methodologies being pursued within this Portfolio of Programs are briefly discussed below.

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POST-COMBUSTION CARBON CAPTURE

Post-combustion capture is applicable to conventional pulverized coal-fired power plants where fuel is burned to generate electric power. CO_2 is captured from flue gas after complete fuel combustion. The principal challenge is separating the CO_2 generated during combustion (12-15 percent) from the large amounts of nitrogen (from air) found in the flue gas.

Within the **post-combustion capture** environment, advanced gas separations processes are under investigation in the following four core research areas: **solvents, sorbents, membranes and novel concepts.**

SOLVENTS — Involve chemical or physical absorption of CO_2 from flue gas into a liquid carrier. Research projects focus on the development of durable, low-cost, non-corrosive solvents that can effectively capture CO_2 using as little energy as possible.

SORBENTS — Use physical adsorption by solid sorbents to capture CO_2 from flue gas. Research is focused on developing highly effective CO_2 capture sorbents with low raw material costs, strong thermal and chemical stability and low rates of sorbent losses over time.

MEMBRANES — Use permeable or semi-permeable materials that allow for the selective transport and separation of CO_2 from flue gas. Research focus includes developing low-cost, durable membranes with improved permeability and selectivity, thermal and physical stability and tolerance to contaminants in combustion flue gas.

NOVEL CONCEPTS — Includes hybrid systems that combine attributes from multiple technologies, electrochemical membranes, cryogenic capture, and advanced manufacturing to reduce the cost and improve performance by eliminating conventional manufacturing constraints.

PRE-COMBUSTION CARBON CAPTURE

Pre-combustion capture is applicable to integrated gasification combined cycle (IGCC) power plants, where solid fuel is converted into gaseous fuel – syngas – by applying heat under pressure in the presence of steam and oxygen. CO_2 is captured from the syngas and remaining hydrogen is combusted to generate electric power.

The higher concentrations of CO_2 in syngas facilitate less complicated capture due to the higher CO_2 partial pressure.

Within the **pre-combustion capture** environment, advanced gas separations processes are under investigation in the following four core research areas: **solvents, sorbents, membranes and novel concepts.**

SOLVENTS — Involve chemical or physical absorption of CO_2 from syngas into a liquid carrier. Challenges include recovering CO_2 at high pressure, improving solvents to reduce H_2 losses and developing solvents that are effective at higher temperatures to improve IGCC efficiency.

SORBENTS — Use physical adsorption by solid sorbents to capture CO_2 from syngas. Research of interest includes sorbents with acceptable performance at the high temperatures encountered in IGCC systems to avoid the need for syngas cooling.

MEMBRANES — Use permeable or semi-permeable materials that allow for the selective transport and separation of CO_2 from syngas. Research focus includes developing low-cost, durable membranes with improved permeability and selectivity as well as thermal and physical stability.

NOVEL CONCEPTS — Novel Concepts under investigation include hybrid systems that combine attributes from multiple technologies, improve process intensification or integrate CO_2 capture directly with the creation of syngas fuel for lower costs.

POST-COMBUSTION AND PRE-COMBUSTION CARBON CAPTURE ARE DEVELOPING TECHNOLOGIES TO PROVIDE STEP-CHANGE REDUCTIONS IN BOTH COST AND ENERGY PENALTIES COMPARED TO CURRENTLY AVAILABLE TECHNOLOGIES:

- Carbon capture R&D can increase new coal generation capacity by 45 GW, create an additional 1.9 million jobs and add over $200 billion to GDP between now and 2040.
- Carbon capture R&D has developed solvents with reduced energy penalty, membrane materials with lower capital costs, process designs that reduce capital costs, and analytical methods to accelerate and de-risk CO_2 capture technology development.
- The National Carbon Capture Center (NCCC) has facilitated maturation of technologies from laboratory- to bench- to pilot-scale testing, allowing the most promising technologies to be tested on actual flue gas or syngas.
- Using captured CO_2 for enhanced oil recovery can generate over 2 billion barrels of domestic oil production.

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