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EPA Eyes “Burdensome” Rules

White House aims to ensure rules are properly designed to meet their goals

By Lynn L. Bergeson

On February 24, 2017, President Trump issued Executive Order (EO) 13777, Enforcing the Regulatory Reform Agenda. The EO offers opportunities for stakeholders to improve regulations. This article summarizes efforts to implement this EO, and identifies opportunities stakeholders may wish to pursue to eliminate or amend regulatory initiatives they feel have outlived their utility or were ill-conceived from the get-go.

IMPLEMENTING EO 13777

EO 13777 is intended to reduce the burdens that agencies impose through regulatory initiatives, and directs federal agencies to undertake activities to further this goal. The scope of the EO is unusually broad, and applies to regulations and rules that are defined under the Administra-

tive Procedure Act as “an agency statement of general or particular applicability and future effect designed to implement, interpret, or prescribe law or policy or describing the organization, procedure, or practice requirements of an agency.” This definition is broader than the definition of a rule or regulation in other EOs involving regulatory review. Existing EOs exclude “formal” rules, or rules that are the result of trial-like administrative procedures that require more process than standard notice and comment-type rulemaking initiatives. The EO excludes regulations issued with respect to military, national security, or foreign affairs functions of the United States, regulations related largely to agency organizational or management functions, and regulations exempted by the Office of Management and Budget (OMB).

On March 24, 2017, Administrator Pruitt of the U.S. Environmental Protection Agency (EPA) issued a memorandum intended to expand and improve the EPA's internal mechanisms for information sharing and to comply with the EO. It requires the EPA's programs and regional offices "report all regulatory actions in the agency's regulatory management system and adopt such reporting as common practice moving forward." Actions that must be reported include "those related to any statutory or judicial deadlines, petitions, pesticide tolerances, significant new use rules, national priority listings or de-listings, permits, federal implementation plans and state implementation plans." Officials entering the information must certify its accuracy. This new directive will ensure that few, if any, regulatory decisions escape the scrutiny of the EPA's political appointees, and allow them to identify any and all regulations that can be repealed, replaced or modified to make them less "burdensome."

Also on March 24, 2017, Pruitt, in another memorandum tasked Samantha Dravis, senior counsel and associate administrator for the Office of Policy, to serve as the EPA's regulatory reform officer (RRO). That memorandum also assigns Ryan Jackson, Pruitt's Chief of Staff, to chair the Regulatory Reform Task Force (RRTF) that the EPA is required to establish, as are all federal agencies, under the EO.

The RRTF charge is broad and its work could have a significant impact. The task force evaluates existing regulations and recommends "those that can be repealed, replaced or modified to make them less burdensome." As a first step, the EO memorandum states that by May 15, 2017, "the Offices of Air and Radiation, Land and Emergency Management, Chemical Safety and Pollution Prevention, Water, Environmental Information, Congressional and Intergovernmental Relations, and Small and Disadvantaged Business Utilization should provide the Task Force with recommendations regarding specific rules that should be considered for repeal, replacement or modification."

Under the EO, the EPA's RRTF is required to seek input from entities significantly affected by the EPA's regulations — such as those that are potential candidates for repeal, replacement, or modification. The EO memorandum goes further and directs the EPA's offices to hold public meetings to seek input directly from affected stakeholders. The EPA has convened several such meetings. Over 45,000 comments have been filed in response to the EPA's request for regulatory reform suggestions.

DISCUSSION

The public meetings the EPA convened and the request for comment provide unique opportunities for stakeholders to

The EPA will focus on rules flawed from the get-go.

call attention to regulations and policies they feel should be revised or repealed, or are being implemented or enforced incorrectly. The EPA likely will focus on rules most deserving of serious consideration because they have outlived their utility, were flawed from the get-go, or need adjusting to reflect the passage of time. Stakeholders are urged to keep the momentum going and ensure rules are de-

signed to achieve their intended purpose efficiently. ■

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Interest in Carbon Capture Intensifies

New installations and technology development promise continuing progress

By Seán Ottewell, Editor at Large

The implications of the U.S. government's decision to pull out of the Paris Climate Accord stir heated debate. Regardless, many American chemical companies — driven by shareholder demands, concerns over public image and, sometimes, pure economics — likely will continue to pay significant attention to greenhouse gas emissions. (See: “Look Beyond the Paris Accord Pullout,” <http://goo.gl/U52aET>) In addition, the worldwide focus on developing carbon dioxide capture and storage (CCS) technologies remains strong.

According to the Global CCS Institute, Melbourne, Australia, 40 large-scale CCS facilities are in various stages of development, including 17 already in operation. In fact, notes the institute, over 200 million metric tons of CO₂ have been injected

securely into the sub-surface since the early 1970s — a powerful counter to those arguing the technology is experimental or untried, it contends.

Tellingly, two of the major CCS projects to come onstream in 2017 are based in the United States.

MAJOR STEP

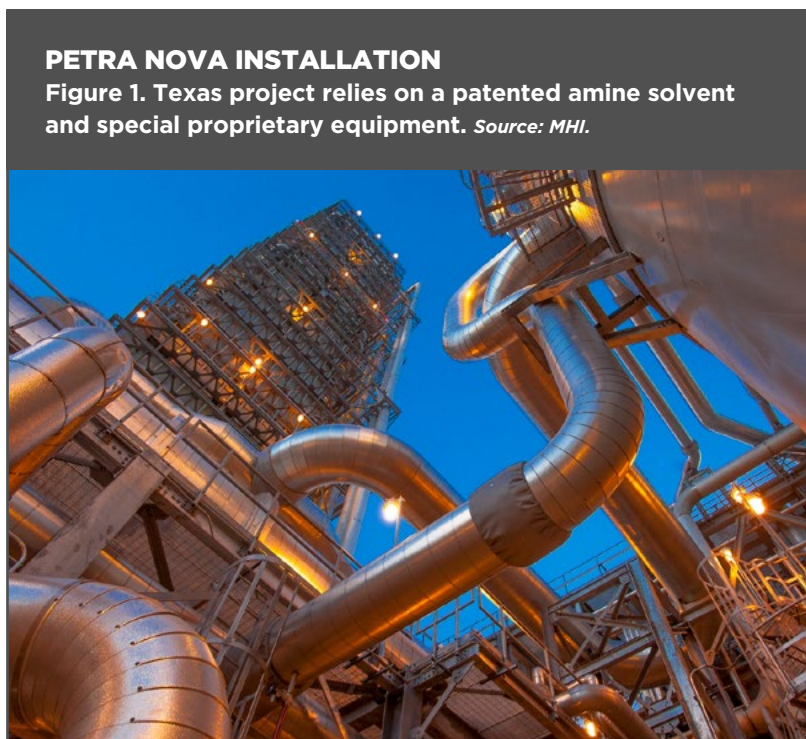
In January, Petra Nova, a joint venture between NRG Energy, Houston, and JX Nippon Oil & Gas Exploration, Tokyo, started CO₂-capture operations at the W.A. Parish power plant near Houston. The project can capture more than 5,000 t/d of CO₂, which then is used to boost production at the West Ranch oilfield that is jointly owned by NRG, JX Nippon and Hilcorp, Houston. Petra Nova estimates oil production in the

field will rise over the next few years from 300 bbl/d to 15,000 bbl/d once CO₂-driven enhanced oil recovery gathers pace.

Key to the whole project is the Kansai Mitsubishi CO₂-recovery process developed by Mitsubishi Heavy Industries (MHI), Tokyo. This includes patented KS-1 amine solvent and special proprietary equipment (Figure 1).

“KS-1 is a sterically hindered amine, while the most common amine used for carbon dioxide capture, monoethanolamine, is a primary amine. KS-1 provides higher absorption capacity, lower energy requirement and more oxidation and corrosion resistance as compared to conventional amines. Less amine makeup and steam consumption are required,” says an MHI spokesman.

The Petra Nova plant also features proprietary equipment and process innovations developed by MHI, he adds. For example, adaptations made to reduce sol-



vent oxidation and amine emissions from the absorber effectively decrease amine loss. In addition, an energy-saving process around the regenerator cuts steam consumption.

The process itself underwent small-scale pilot plant testing at MHI's R&D center in Hiroshima, Japan, before being scaled up at a larger pilot plant in Osaka.

A major stepping stone from this to the Petra Nova application came in 2011 with a project at Alabama Power's Plant Barry, Bucks, Ala. The

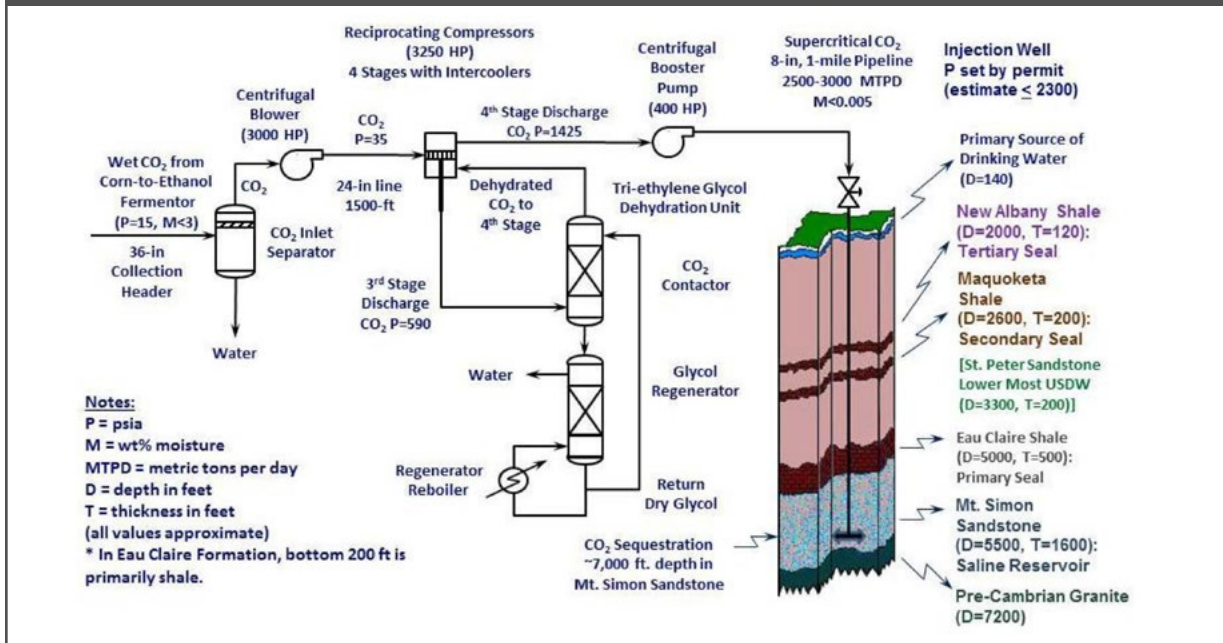
world's first fully integrated coal power and geological storage project, it captures over 500 t/d of CO₂.

“All the MHI technologies applied to Petra Nova plant were successfully demonstrated at the Plant Barry, showing high operability and high efficiency of CO₂ capture while minimizing energy consumption,” notes the spokesman.

The flue gas at the Alabama plant was challenging because it contained SO_x, NO_x and particulates that typically exacerbate amine losses

PIONEER PLANT

Figure 2. New facility in Illinois is the first in the U.S. to store substantial quantities of CO₂ in a geological formation. Source: ADM.



and degrade CO₂ capture efficiency, he explains.

“The countermeasures developed by MHI significantly reduced the impact caused by such impurities contained in dirty flue gas. As a result, MHI applied the experiences and lessons learned from the Plant Barry project and successfully scaled up by ten times at Petra Nova.”

Meanwhile, April saw the launch of the world's first large-scale bio-energy with CCS project. The facility in

Chicago can capture and store approximately 1 million t/y of CO₂; it is operated by bio-ethanol producer Archer Daniels Midland (ADM), Chicago, and administered by the U.S. Department of Energy's (DOE) Office of Fossil Energy. Known as the Illinois Industrial CCS (ICCS) project, it's also the first U.S. CCS facility to store substantial quantities of CO₂ in a geological formation (Figure 2). ICCS project partners handled the design, construction, demonstration and integrat-

ed operation of all the CCS processes involved.

NORWEGIAN INITIATIVE

Also this year, Aker Solutions, Fornebu, Norway, won contracts for conceptual studies for carbon capture at an ammonia plant in Porsgrunn, Norway, of Yara International, Oslo, and a cement production facility in Brevik, Norway, of Norcem, Oslo.

Yara and Norcem are among three companies in the running to receive Norwegian

government funding to build and operate a full-scale carbon capture plant. The government aims to fund at least one of the plants, which would be operational by 2022, as part of an overall NOK 1.3-billion (\$156-million) investment in CCS technologies.

The Yara study will involve designing and developing a capture plant for the reformer flue gas and also will include liquefaction. The study for Norcem will focus on designing a carbon capture plant that's integrated with the cement factory, including a process to turn the CO₂ into liquid, together with storage facilities that can be used before shipping; the plant will have a capacity of about 400,000 t/y of CO₂. Both conceptual studies should be completed in September.

Aker's proprietary ACC carbon capture process uses a mixture of water and organic amine solvents to absorb the CO₂. The company says its process gives high capture rates with low energy consumption while the solvent is robust and requires minimum makeup.

Following the conceptual studies, efforts will turn to front-end engineering design until around mid-2018. The Norwegian government expects to make an investment decision in the first half of 2019.

Much of Aker's experience with the design, construction and operation of amine plants

has come at the Technology Centre Mongstad (TCM), Mongstad, Norway, together with extensive tests in the U.S., the U.K. and Norway using its mobile carbon capture plant.

TCM, which plays a key role in the Norwegian government's CCS efforts, has received a boost with the announcement that Norway's Gassnova, Porsgrunn, and Statoil, Stavanger, as well as Shell, The Hague, The Netherlands, are continuing their participation in test operations there until 2020. Total, Paris, now is joining this work, too.

"Test operations on TCM have played a very important role in uncovering areas for technology improvements that have helped to drive the cost of CCS down, and we see that such learning takes place in every test campaign. We believe that this will also be the case in the coming years and this is therefore an important contribution to achieving the objectives of Shell's strategy in the CCS," says Tor Arnesen, Norske Shell CEO.

"This is a strategic investment for Total and in keeping with our commitment to combat climate change in two ways: by enhancing our expertise in CCUS [carbon capture, utilization and storage] technologies, and reducing carbon emissions from our production plants. Therefore, we believe it is important to be involved in this project, which is the only industrial-scale one in Europe," adds Philippe Baptiste, Total CTO.

BRITISH PROJECT

Meanwhile in May, CCS technology development in the U.K. took a step forward with the announcement that the Acorn project in northeast Scotland has won support in the latest funding round for the European Union's "Advancing CCS Technologies" initiative.

The funding will enable a small-scale project from which a more-extensive CCS network could evolve. The project itself will capture CO₂ emissions from the St. Fergus gas processing plant and transport them for permanent storage deep beneath the North Sea in existing redundant oil and gas infrastructure that currently is under threat of decommissioning. The plan is for St. Fergus to serve as a future hub for CCS, getting gas from central Scotland via multiple pipelines as well as imports shipped in to nearby Peterhead harbor. Already £100 million (\$129 million) of public money has been spent on an evaluation of the strategy being pursued.

"There were two parallel trains of gas processing there for 25 years and an existing amine plant. The plan is to re-use infrastructure like this. The CO₂ will be dried, compressed and then sent to the storage sites," explains Sam Gomersall, commercial director at Pale Blue Dot Energy, Banchory, Scotland, a management consultancy with over a decade's experience with CCS projects.

One of these involves a prospective CCS operation in Teesside, northeast England, a heartland of U.K. chemical production. There, the Teesside Collective, a consortium including companies in energy-intensive industries, aims to create the U.K.'s first CCS-equipped industrial zone.

The project targets emissions from collective member, Lotte Chemical, Wilton, which makes PET resin. Its site produces about 55,000 metric tons of CO₂ annually; a CCS plant would capture 90% of that.

"We delivered a project on a capture plant on the Lotte site and we are now into a more detailed design and costing phase. The company is very enthusiastic about moving it forward. The challenge now is getting funding for the next stage," notes Gomersall.

EMERGING DEVELOPMENTS

Other parties are moving to commercialize novel technologies they believe will play an important role in future CCS strategies.

One of these is Air Products, Allentown, Pa., which is working closely with the Norwegian University of Science and Technology (NTNU), Trondheim, to commercialize the latter's fixed site carrier (FSC) membrane technology. This allows highly energy efficient capture of CO₂ from flue gases and biogases. The two signed an exclusive license agreement in February.

The NTNU technology uses a process called facilitated transport to remove the CO₂ from other gases. Instead of a filter effecting the separation, an agent acting as fixed carrier within the membrane helps to convert the CO₂ — in combination with moisture — into bicarbonate that is quickly transported through the membrane.

Air Products and NTNU researchers already have achieved good results in tests in industrial plants. They also found the technology can serve to upgrade biogas to methane.

A spokeswoman for Air Products adds that previous testing was mainly lab-scale and the focus now is on scaling up to a commercial product.

At the research level, every aspect of CCS technology is receiving close scrutiny. For example, scientists at King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia, are focused on developing new materials that can capture CO₂ at very low concentrations.

A team led by professor Mohamed Eddaoudi, associate director of the university's Advanced Membranes and Porous Materials Research Center, points to a breakthrough in metal organic frameworks (MOFs). Its latest MOF can take up CO₂ even when present at concentrations as low as 400 ppm.

The key to the new MOF's performance is its structure: square-grid layers encompassing Ni(II) metal centers and pyrazine linkers, bridged via pillars composed of niobium, oxygen and fluorine atoms.

"The ability to control the distance between the fluorine atoms allowed us to create the ideal square-shaped pockets for trapping CO₂ molecules effectively and efficiently and giving our material such impressive performance," explains Eddaoudi.

He believes the MOF might suit a wide range of static industrial applications that produce CO₂, including direct capture from air.

The team now is working to scale up the use of its new MOF and looking for industry collaboration as the next step towards commercialization.

Meanwhile, researchers at the University of Amsterdam (UvA), Amsterdam, the Netherlands, have stumbled upon a catalyst that could make the conversion of CO₂ into useful chemicals a commercial proposition.

Working within UvA's sustainable chemistry research priority area, chemists Edwin Gnanakumar and Shiju Raveendran have invented an enzyme that can efficiently convert CO₂ into CO under relatively mild conditions.

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“It was an accidental discovery,” admits Raveendran. “We were experimenting for a different product but the catalyst turned out to be highly selective for CO₂, better than any reported ones.”

Longer-term tests in a flow reactor confirmed the catalyst remains active — pointing up its promise for scaleup for applications such as industrial flue gas conversion. The technology is readily adaptable to handle large amounts

of gases, according to the researchers.

The new catalyst is easily prepared and inexpensive, and converts CO₂ at ambient pressure and low temperatures, Raveendran adds.

The researchers now are in the process of commercializing the catalyst with help from UvA’s in-house technology transfer office. ■

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Rethink Carbon Capture

Two much-less energy intensive processes target carbon dioxide emissions

By Seán Ottewell, Editor at Large

Two new processes, one lab-based and the other operating commercially, are forcing engineers and scientists to rethink their strategies for dealing with carbon dioxide (CO₂) emissions.

The first, developed by a team of scientists at the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL), Oak Ridge, Tenn., is described as a simple, reliable process to capture the gas directly from ambient air.

Initially, the scientists weren't considering CO₂ removal at all; rather, they were looking for methods to remove contaminants such as sulfates, chromates and phosphates from water. To achieve this, they synthesized a version of the strong base guanidine. This, in turn, bound strongly with the negatively-

charged contaminants to form insoluble crystals that are easily separated from water.

"When we left an aqueous solution of the guanidine open to air, beautiful prism-like crystals started to form," says Radu Custelcean of ORNL's chemical sciences division. He adds, "After analyzing their structure by X-ray diffraction we were surprised to find the crystals contained carbonate, which forms when carbon dioxide from air reacts with water."

In most current capture technologies, once the CO₂ is released from a binding compound, it is transported through a pipeline to underground storage. However, the capture materials must be heated to 900°C to release the gas in the first place and this, in turn, can emit yet more CO₂.

The ORNL process is much less energy intensive. Custelcean explains: “We were able to release the bound carbon dioxide by heating the crystals at 80–120°C, which is relatively mild when compared with current methods.” After heating, the crystals reverted to the original guanidine material. The recovered compound was then recycled through three consecutive carbon capture and release cycles.

Custelcean believes such air capture methods are gaining traction, but the ORNL process needs further development followed by aggressive implementation to be effective against global warming. Also, he says a better understanding is needed of the guanidine material and how it could benefit both existing and future carbon capture and storage applications.

To understand the guanidine material's crystalline structure and properties, the scientists are making use of the ORNL's spallation neutron source (SNS) to analyze carbonate binding in the crystals. Getting a better understanding of the molecular mechanism behind carbon capture and release will, they say, help in the design of the next generation of sorbents.

The scientists also plan to evaluate the use of solar energy as a sustainable heat source to release the bound CO₂ from the crystals.

More on their work can be found in the journal *Angewandte Chemie International Edition*.

Meanwhile Carboclean, formed in India but now operating from London, U.K., has made what it describes as a breakthrough in treating CO₂ with its new carbon capture and utilization (CCU) technology.

At its heart is a new — unnamed — CO₂-stripping chemical that's slightly more efficient than the amine used in current carbon capture and storage (CCS) technologies. However, Carboclean maintains that CCU technology needs less energy, is less corrosive and requires much less investment in new plant than the CCS alternative.

The new process has been installed on the coal-fired boiler at Tuticorin Alkali Chemicals, Bengal, India. That firm now is using the CO₂ from its own boiler to make baking soda — a base chemical with a wide range of uses including glass manufacture, sweeteners, detergents and paper products.

In an interview with BBC Radio 4, Tuticorin managing director Ramachandran Gopalan said, “I am a businessman. I never thought about saving the planet. I needed a reliable stream of carbon dioxide, and this was the best way of getting it.” He added that the

Initially, the scientists weren't considering CO₂ removal at all.

plant now has virtually zero emissions to air or water.

Crucially, says Carboclean CEO Aniruddha Sharma, the technology is running without subsidy and therefore is a major advance for carbon capture technology which as a whole has languished for decades under high costs and lukewarm government support.

He adds: "So far the ideas for carbon capture have mostly looked at big projects and the risk is so high they are very expensive to finance. We want to set up small-scale plants that de-risk the technology by making it a completely normal commercial option." ■

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Projects Target Carbon Dioxide Emissions

In one project, computer simulations tackle the amine chemical scrubber conundrum

By Seán Ottewell, Editor at Large

Researchers at North Carolina State University (NCSU), Raleigh, N.C., have used computer simulations to develop new molecular models that could be used to design cheaper and more efficient versions of the amine chemicals currently used in scrubbers to reduce carbon dioxide emissions.

In 2014, coal-fired power plants produced more than 14 billion mt of CO₂, representing 40% of the total amount generated by human activity worldwide, according to the International Energy Agency (IEA), Paris, France. At the same time, new environmental regulations and public incentives are progressively being put in place to limit the amount of CO₂ emissions from industry and to encourage new research for its storage and recycling.

However, as the IEA points out, with the average cost of capturing and storing CO₂ ranging between \$50 and \$100/mt, current scrubbing technology is too expensive to become a sustainable solution.

Part of the problem here is the inefficient amine-based solutions still used in industrial scrubbing applications require very costly absorbent regeneration. Even those that are considered good candidates, such as tertiary amines, can have CO₂ properties that differ drastically from one analogue to another despite apparently high structural similarity.

To tackle this issue, NCSU researchers are looking for new amine chemicals with better qualities such as faster absorption rates, higher CO₂ capacity and lower heats of reaction. Denis Fourches, assistant profes-

This is a game changer for designing and prioritizing new compounds.

sor of chemistry at NCSU, and postdoctoral researcher Melaine Kuenemann, worked to create computer models that could predict an amine's absorption properties based on its chemical structure.

They collected and curated experimental data from the literature and built a modeling set based on 41 publicly available amine solutions together with all their chemical and absorption properties.

Then they analyzed the chemical and structural characteristics of each amine and grouped them into families of chemicals with similar structural properties. Next, they looked at how well and how quickly these amines could absorb carbon. Using these data, the researchers created a series of models known as quantitative structure-property relationships models that can predict the amines' CO₂ absorption properties solely based on their structural characteristics.

These models utilize machine-learning techniques to predict which chemical structures are likely to have the best overall absorp-

tion properties. The researchers found the models to be reliably discriminating between amines with high absorption properties versus those that were less efficient.

"This work is the first attempt to develop computer models for fully evaluating and predicting carbon dioxide absorption properties of amine solutions," Fourches says. "The next step for us is to utilize these computer models to screen a virtual library of hundreds of thousands of new amines, and identify some new amine candidates predicted to have way better carbon absorption properties."

He adds, "If you had to test all of these thousands of compounds experimentally, it would take decades of work. With the powerful computers we have access to, this virtual screening can be done in a matter of days and is very inexpensive. This is a game changer for designing and prioritizing new compounds."

Meanwhile, the U.S. Department of Energy's Office of Fossil Energy (FE) has selected seven projects to receive \$5.9 million in

funds to focus on novel ways to use CO₂. The seven will directly support FE's carbon use and reuse R&D portfolio, which in turn will develop and test novel approaches to convert captured CO₂ into usable products.

The projects fall into three technical areas: biological-based concepts for beneficial use of CO₂; mineralization concepts utilizing CO₂ with industrial wastes; and novel physical and chemical processes for beneficial use of the gas.

Five of the projects fall in the third category, with each getting nearly \$800,000 in FE funding. Among them, the University of Delaware, Newark, is to develop and test a two-stage electrolyzer process for converting flue-gas-derived CO₂ into C₂ and C₃

alcohols such as ethanol and propanol. The Gas Technology Institute, Des Plaines, Ill., is working on a direct, high-energy electron beam synthesis process to produce chemicals such as acetic acid, methanol and carbon monoxide from CO₂. Development of a sorbent-based, thermocatalytic process to convert captured CO₂ into syngas is the focus for TDA Research, Wheat Ridge, Colo.

In another development, Emissions Reduction Alberta has announced the Round Two winners of its competition for technology to productively use CO₂. For details, see "Carbon Contest Chooses Winners," <http://goo.gl/pQgCE4>. ■

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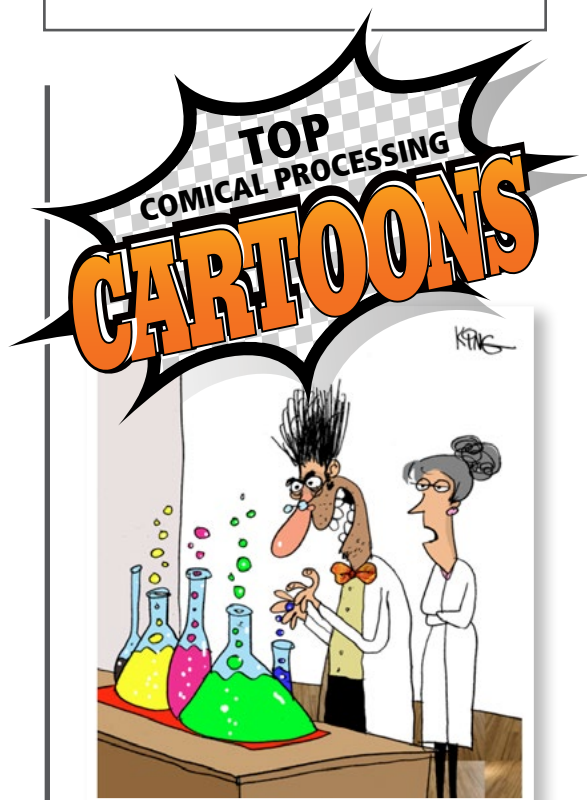
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