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CARBON UPCYCLING: TURNING CARBON DIOXIDE (CO_2) INTO CO_2NCRETE

WRITTEN TESTIMONY:

GAURAV N. SANT
ASSOCIATE PROFESSOR AND HENRY SAMUELI FELLOW: CIVIL AND ENVIRONMENTAL ENGINEERING, MATERIALS SCIENCE AND ENGINEERING, AND THE CALIFORNIA NANOSYSTEMS INSTITUTE
UNIVERSITY OF CALIFORNIA, LOS ANGELES (UCLA)

Introduction

Thank you, Chairman Smith, Ranking Member Johnson and Members of the Committee for inviting me to appear before you as you review private sector leadership in next generation energy technology to increase efficiency, environmental benefits and consumer savings, and associated research and regulatory hurdles. As requested by the committee, I am focusing my testimony on research that we have been engaged in that seeks to convert carbon dioxide (CO_2) into a novel building material, CO_2NCRETE.[1,2] The views expressed herein are my own, and do not necessarily represent those of UCLA.

I am an Associate Professor and Henry Samueli Fellow in the Henry Samueli School of Engineering and Applied Science at the University of California, Los Angeles (UCLA). I am a civil engineer, and a materials scientist with broad ranging expertise in materials synthesis, characterization and simulation.[3]

Summary

My testimony today can be summarized as follows:

Motivation: Electricity generation from coal-fired power plants alone represents 25% of CO_2 emissions from the United States (1.2 billion tons of CO_2 emitted in 2016).[4] Carbon capture and storage (CCS) has been proposed as a solution to mitigate CO_2 emissions caused by industrial activities.[5] However, CCS is not always viable due to: (i) its high cost, (ii) uncertainty in the permanence of the sequestration solution, and/or, (iii) the lack of suitable geological features in the local vicinity where CCS can be achieved.[5,6,7] Therefore, it is necessary to identify and create new pathways for the beneficial utilization of CO_2 while simultaneously yielding a permanent CCS solution.

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[1] Vance, K.; Falzone, G.; Pignatelli, I.; Bauchy, M.; Balonis, M.; Sant, G. *Ind. Eng. Chem. Res.* **2015**, *54* (36), 8908–8918.
[2] www.co2upcycling.com
[3] https://scholar.google.com/citations?user=p_kytiYAAAAJ&hl=en&oi=ao
[4] U.S. Energy Information Administration. *Monthly Energy Review*; DOE/EIA-0035(2017/06); Office of Energy Statistics, U.S. Department of Energy: Washington, DC 20585, June 2017; p 232.
[5] Haszeldine, R. S. *Science* **2009**, *325* (5948), 1647–1652.
[6] Kulichenko, N.; Ereira, E. *Carbon Capture and Storage in Developing Countries: A Perspective on Barriers to Deployment*; Energy and Mining Sector Board Discussion Paper, No. 25; World Bank Publications, 2012.
[7] Bachu, S. *Energy Conversion and Management* **2000**, *41* (9), 953–970.

Technical approach: A novel approach to mitigate CO_2 emissions is by *upcycling* or beneficially utilizing industrial wastes that may be in the form of solids, liquids, or vapors to create new materials, e.g., CO_2NCRETE. As an example, in the case of flue gas borne CO_2, this is accomplished by converting gas borne CO_2 (i.e., by mineralization[8,9]) into stable carbonate compounds which may offer cementitious character into building materials. Not only do such innovative technologies yield environmental benefits, but they also have the potential to reduce the environmental impact of the construction sector as follows:

- *OPC production:* The production of ordinary portland cement (OPC) – the primary binding agent used in traditional concrete – results in nearly 9% of global CO_2 emissions (N.B.: 0.9 t of CO_2 are emitted per ton of OPC produced).[10,11] Therefore, the development of new cementation agents that take-up CO_2 will help reduce the CO_2 emissions associated with OPC (and concrete) production, and
- *Material recycling:* The simultaneous reuse of CO_2 and industrial byproducts (solid wastes) resulting from coal combustion creates a new paradigm in waste-to-resource recycling of materials. This creates a circular economy[1213] paradigm between the energy and construction sectors and thus greatly enhances the sustainability metrics of both industries.

The upcycling process is accomplished by contacting calcium hydroxide ($Ca(OH)_2$, also known as portlandite) with flue gas borne CO_2.[1,2] Such portlandite may be secured by: (a) calcining limestone and hydrating the lime that results,[1415] or (b) by leaching calcium species from alkaline industrial wastes such as slags and coal combustion residuals to produce $Ca(OH)_2$.[16,17] Following combination with fine and coarse mineral aggregates, chemical additives, water, and suitable binding agents (if needed) – similar to traditional concrete – this mixture containing $Ca(OH)_2$ forms a slurry that can be shaped into common construction elements, such as beams, columns, and slabs.

The upcycled concrete (CO_2NCRETE) production process is designed to "bolt-on" to large point-source CO_2 emitters including: petrochemical facilities, coal- and natural gas-fired power plants, and cement plants. In each case, emitted flue gas is used to both provide waste heat to hasten chemical reactions, and to provide CO_2 to ensure mineralization without imposing any additional need for emissions control. The process cycle is being designed for scalable operations to accelerate the R&D pathway towards pilot-scale trials, technology commercialization and deployment.

Impacts and benefits: CO_2NCRETE offers a transformative route for the beneficial utilization of flue gas borne CO_2 in the cementation cycle. This creates pathways to produce construction materials with up to 50% or lower CO_2 intensity than OPC.[1,2,18] Furthermore, by creating a robust CO_2 (and solid waste) off-take partnership between the energy and construction sectors, the outcomes of this work create new *sectoral* synergies which would be difficult to realize otherwise. Significantly, this CO_2 upcycling

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[17] Iyer, R. *Journal of Hazardous Materials* **2002**, *93* (3), 321–329.
[18] Green Chemistry: The Nexus Blog: Green CO2NCRETE(TM) for Sustainable Construction https://communities.acs.org/community/science/sustainability/green-chemistry-nexus-blog/blog/2017/02/16/green-cosub2subncretetm-for-sustainable-construction (accessed Jul 15, 2017).

approach can reduce the environmental impact of electricity generation from fossil fuels, while simultaneously advancing the materials, methods and processes utilized by the construction sector.

The Role of Federal R&D Support

Financial support secured from federal agencies including the: (i) Department of Energy, (ii) Department of Transportation, and, (iii) National Science Foundation has been instrumental in enabling our work. The support of federal agencies such as those noted above, and others, is critical for enabling basic and applied R&D, technology creation and development. Broadly, with significant (competitive) international investments in R&D around the world, federal support of basic and applied R&D, in core and emerging domains such as CO_2 utilization and reuse is more important now than ever. This is because federal R&D support is vital to enable the continued creation of knowledge and technology – within universities, and national laboratories – the reservoirs of knowledge that have ensured U.S. intellectual leadership globally.

Furthermore, federal support of R&D is especially important in the case of technologies which benefit conventional industries which are unlikely to being offshored – e.g., fossil-fuel based electricity generation, and the construction sector – which feature reduced appetite for technical and commercial risk due to uncertainty in revenue, profit pressures, substantial regulatory and compliance burdens, and/or very high costs associated with the development of greenfield facilities with long operating horizons. Therefore, it becomes necessary for the government to underwrite a larger proportion of the costs associated with R&D that has the potential to benefit such industries, and in turn, the general public, until sufficient (technology) maturity is achieved.

However, once such maturity is achieved, and industry is assured of the commercial value and potential of new technology, it is expected that industry will take-over and accelerate the residual R&D pathway including commercial trials that results in market penetration, and diffusion of new technology.

Thank you again for the opportunity to testify on this important topic.