Carbon Capture, Utilization and Storage (CCUS) and Negative Emission Technologies in Urban Cities

A.-H. Alissa Park
Department of Earth and Environmental Engineering
Department of Chemical Engineering
Lenfest Center for Sustainable Energy
Columbia University in the City of New York

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We need “… substantial multi-century climate change commitment created by past, present and future emissions of CO₂.” (IPCC, 2013)
Mission Innovation aims to reinvigorate and accelerate global clean energy innovation with the objective to make clean energy widely affordable.
Potential Annual Revenue (dollars)

What should we make using CO₂?

Concrete
- 2020: $10B–$60B
- 2025: $50B–$200B
- 2030: $150B–$400B

Fuels
- 2020: $1B–$5B
- 2025: $4.5B–$60B
- 2030: $10B–$250B

Aggregates
- 2020: $0.1B–$0.6B
- 2025: $0.4B–$2.5B
- 2030: $2B–$25B

Polymers
- 2020: $0.1B–$0.2B
- 2025: $0.2B–$5B
- 2030: $1B–$12B

Methanol

(CO₂ Sciences & The Global CO₂ Initiative, Nov. 2016)
Potential Reduction in CO$_2$ Emissions (tons)

What should we make using CO$_2$?

(CO$_2$ Sciences & The Global CO$_2$ Initiative, Nov. 2016)
The experiment injected 220 tonnes of carbon dioxide several hundred meters underground (J. MATTER)

https://www.or.is/en/projects/carbfix/news/carbfix-paper-science
Carbonation of industrial wastes results in reclassification of these materials as non-hazardous hence **safe for long-term carbon storage** or for **sustainable utilization**.
A.-H. Alissa Park, Director of Lenfest Center for Sustainable Energy

Sustainable Transformation of Unconventional Resources using CO₂

Carbonation of Industrial Wastes

Baotou Steel in China
500-600 metric tons of slag per year
GreenOre and Baotou Steel Joint Venture
Sustainable Construction Materials: Integrated Upcycling of Waste Materials and Carbon Sequestration (NYSERDA)

1 ton of cement leads to approx. 1 ton of CO₂ emissions. In 2015, NYS cement consumption was approx. 2.8 million metric tons. Therefore, finding an alternative material to replace cement (even partially) can help to lower CO₂ emissions.

Construction materials applied to Buildings in NYC – NSF Connected Communities

Carbon Mineralization applied to Materials distillation – WTM&E (DOE ARPA-E)

Waste concrete → New construction materials

Capture and store/utilize CO₂ from municipal solid wastes
BioEnergy with Carbon Capture and Store (BECCS): Negative Emission Technology

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Alkaline Thermal Treatment of biomass with in-situ CO₂ capture

Biomass($C_nH_{2n}O_2$) + NaOH $\rightarrow$ H₂ + Na₂CO₃

CH₄ + H₂O $\xrightarrow{\text{Ni/ZrO}_2}$ CO + 3H₂
CO + H₂O $\xrightarrow{\text{Ni/ZrO}_2}$ CO₂ + H₂
CO₂ + Ca(OH)₂ $\rightarrow$ CaCO₃

Minerals and alkaline Industrial wastes
Recycle
Industrial use or carbon storage

Wet & Salty Seaweed

Rain + NO₃⁻ + SO₄²⁻; low pH

CO₂ Neutralized with alkaline solution
Biochar

373 K
423 K
473 K
523 K
573 K
Carbon Capture and Conversion to Chemicals and Fuels

Novel Nano-scale Hybrid Materials have unique electrolyte behaviors with high CO₂ loading capacity.

We need to develop new pathways to existing chemicals and even new pathways to new chemicals and materials.