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STEEL & CEMENT MANUFACTURING
INNOVATIONS TO ENABLE A LOW CARBON ECONOMY

A Proposal to the National Science Foundation for an Engineering Research Center (ERC)

Webinar on Industrial Decarbonization to solicit Industry Interest and Collaboration

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School of Sustainable Engineering and Built Environment
Arizona State University

Engineering Research Centers of NSF

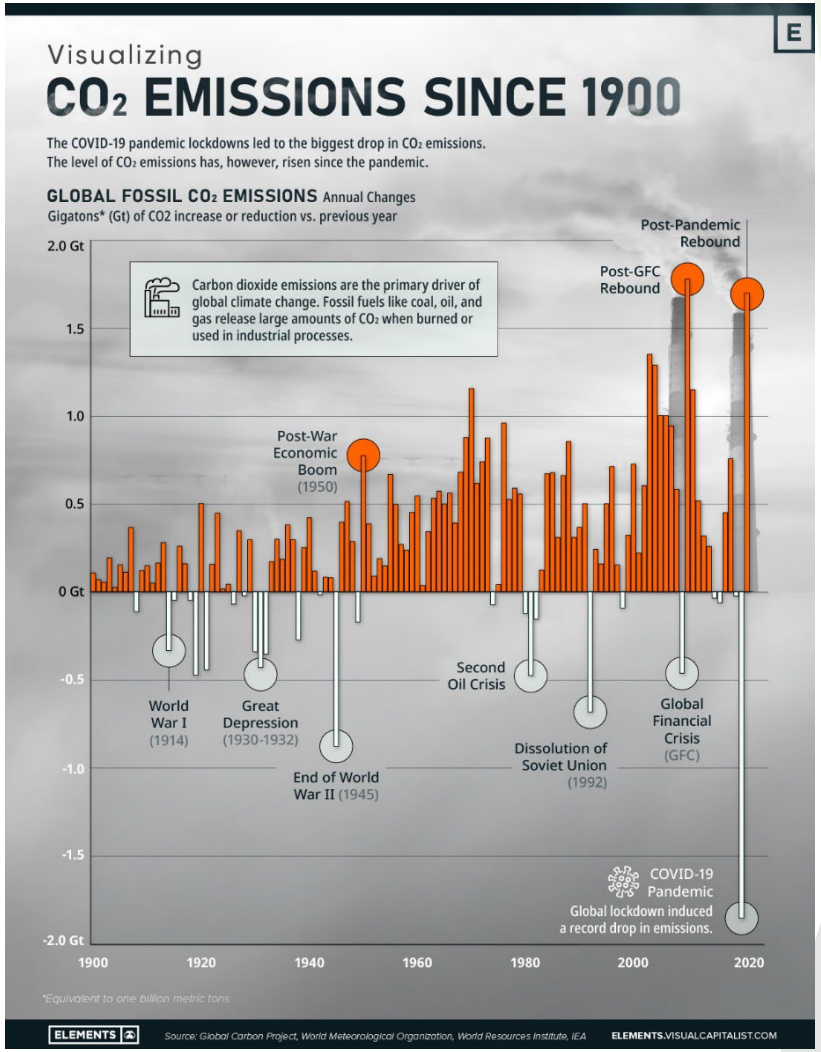
- NSF Engineering Research Centers (ERC) are signature investments of NSF
- Supports high-risk, high-payoff research centers focused on advancing engineered systems technology and education through multidisciplinary, cross-sector partnerships.
- Research, education, and partnerships that lead to strong societal impacts
- Research complemented by workforce development, diversity and a culture of inclusion (DCI), and value creation within an innovation ecosystem (IE) that will outlast the lifetime of the ERC.

Agenda

- **2.00 PM**: Welcome and Introduction to the Proposed Engineering Research Center – *Narayanan Neithalath (Professor, ASU)*
- **2.10 PM**: Roadmap for cement industry decarbonization – *Paul Tennis (Senior Director, Portland Cement Association (PCA))*
- **2.25 PM**: Steel industry and decarbonization efforts – *Brian Bliss (General Manager, Programs and Publications, Association for Iron and Steel Technology (AIST))*
- **2.40 PM**: Carbon-Neutral concrete – ACI NEU – *Dean Frank (Executive Director, American Concrete Institute (ACI) Center of Excellence in Carbon Neutral Concrete)*
- **2:55 PM**: Proposed efforts on decarbonization of cement manufacturing and concrete - *Prof. Gaurav Sant (Director, Institute of Carbon Management, UCLA)*
- **3.10 PM**: Proposed efforts on decarbonization of steel manufacturing – *Prof. Ron O'Malley (Director, Peaslee Steel Manufacturing and Research Center, Missouri S&T)*
- **3.25 PM**: Industrial collaboration and path forward - *Narayanan Neithalath (Professor, ASU)*

Need and Rationale for SCIENCE ERC

- Global CO_2 emissions are rising
- Emissions from fossil fuels and cement have increased by 1.0% in 2022, hitting a new record high of **36.6 billion tons** of CO_2 ($GtCO_2$)
- Steel and cement production are among the ***hardest-to-decarbonize*** industries
- Accounts for 50% of all industrial emissions
- Accounts for ~16% for global anthropogenic CO_2 emissions
- Transforming cement, steel, and concrete manufacturing influences a number of allied industries (admixtures, fibers, construction, fabrication, sensors, IoT…)



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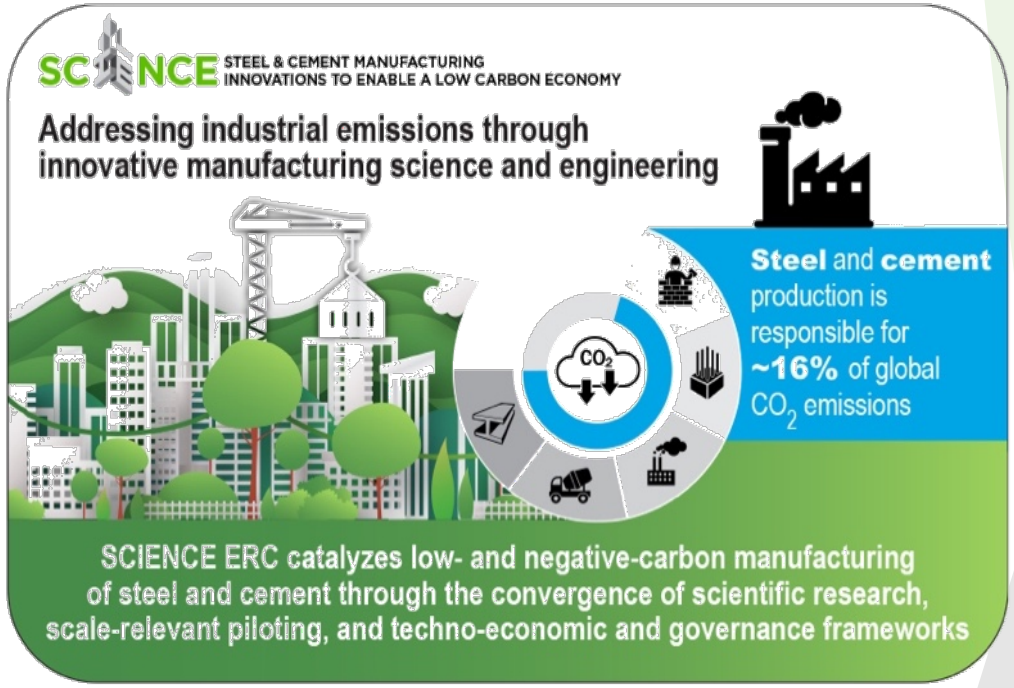
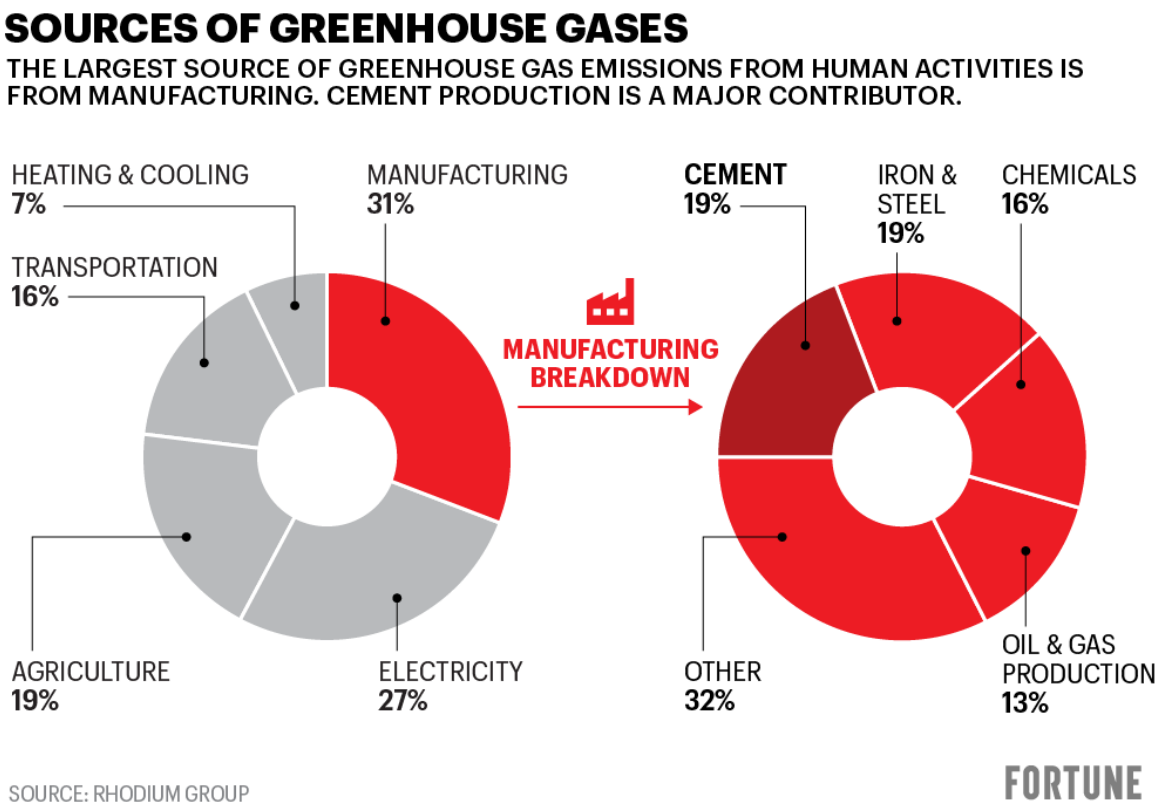
Steel and cement are critical components of modern society

- Globally, all of the 4.5 billion tons of cement (which produces >30 billion tons of concrete), and >50% of the 2.5 billion tons of steel produced each year, are used in construction
- Infrastructure construction and repair are projected to increase annual global production of steel and cement by >30% by 2050
- Carbon impacts of steel, cement (and concrete) manufacturing need to be significantly curtailed



Carbon impact of infrastructure materials



Paris Climate Agreement - Limit global warming to **well below 2°C, preferably to 1.5°C**, compared to pre-industrial levels; reduce global greenhouse gas ***(GHG) emissions by 45% by 2030*** and to reach ***net zero by 2050***

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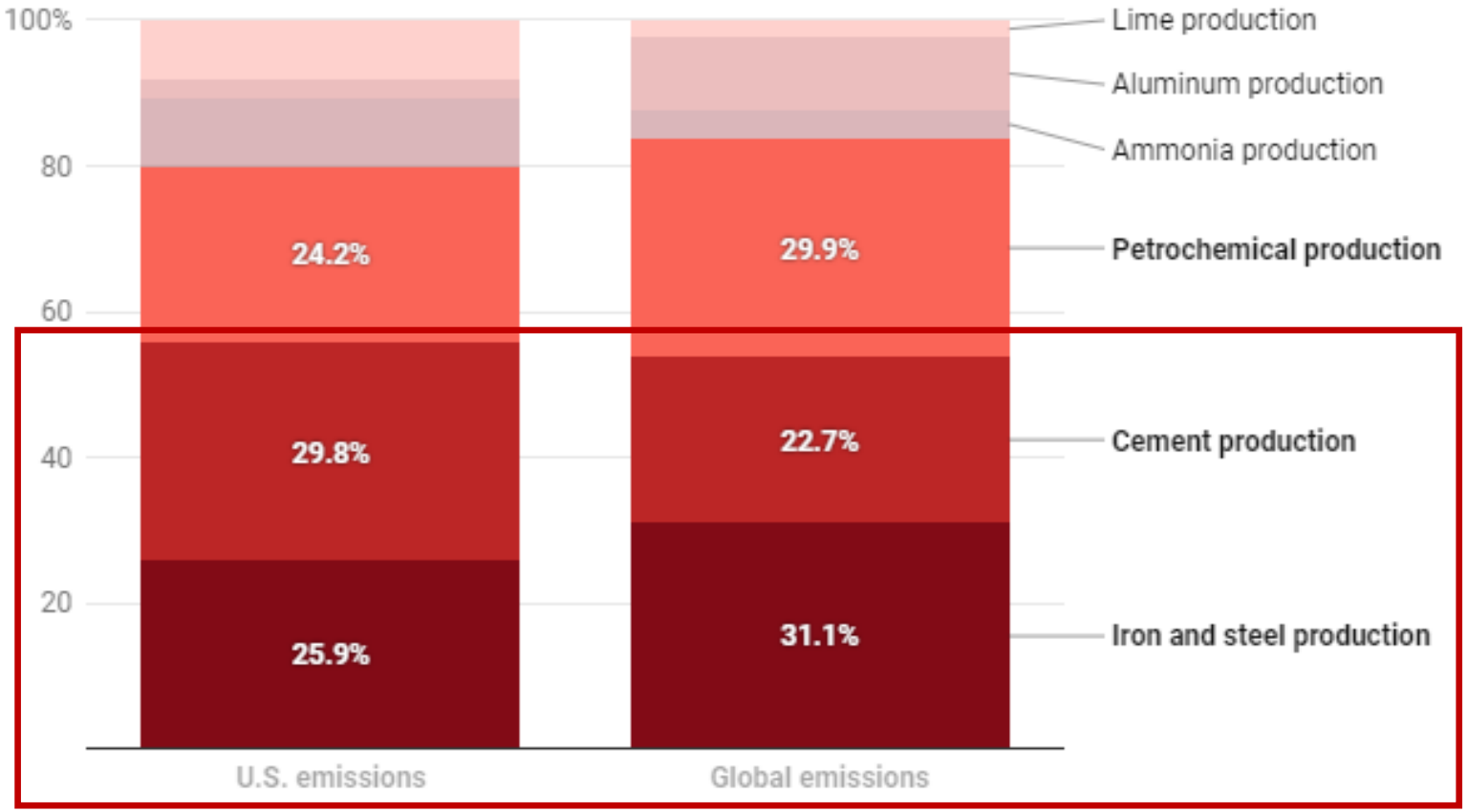
The top 3 emitters of greenhouse gases (GHGs) are iron and steel, cement, and petrochemical production

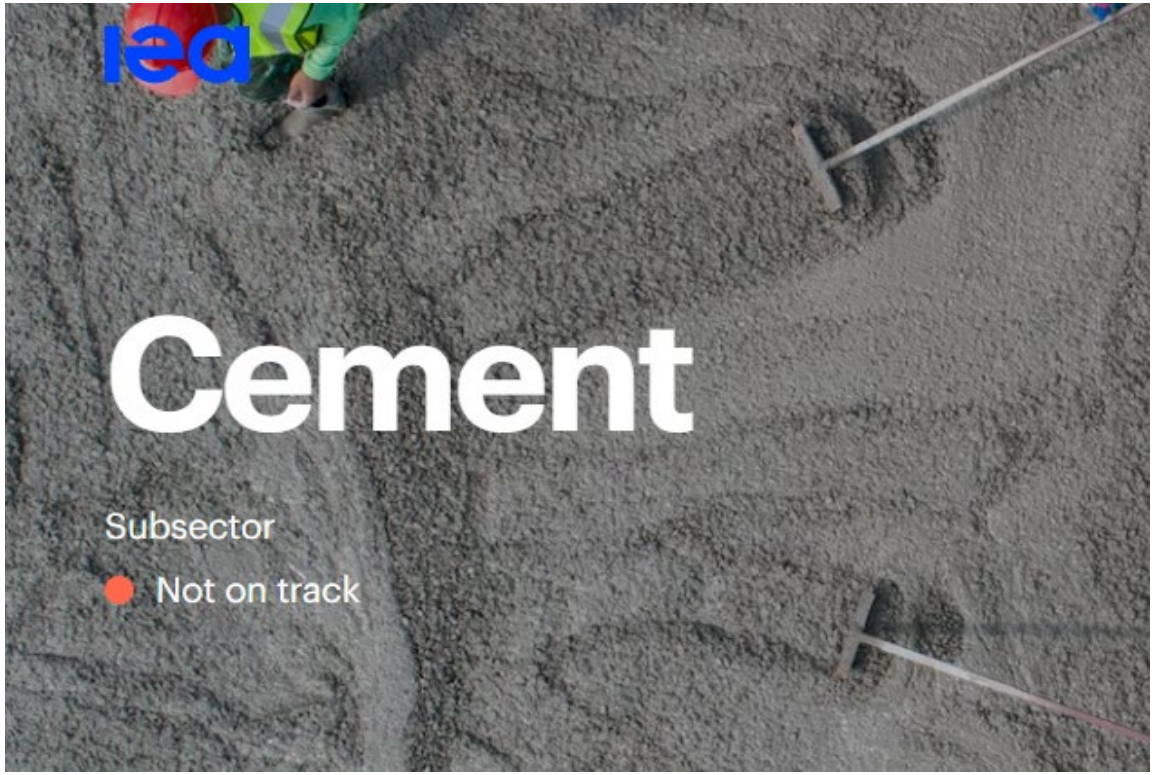
U.S. and global GHG emissions by industrial sector, as percentages of total emissions and in million metric tons of carbon dioxide equivalent

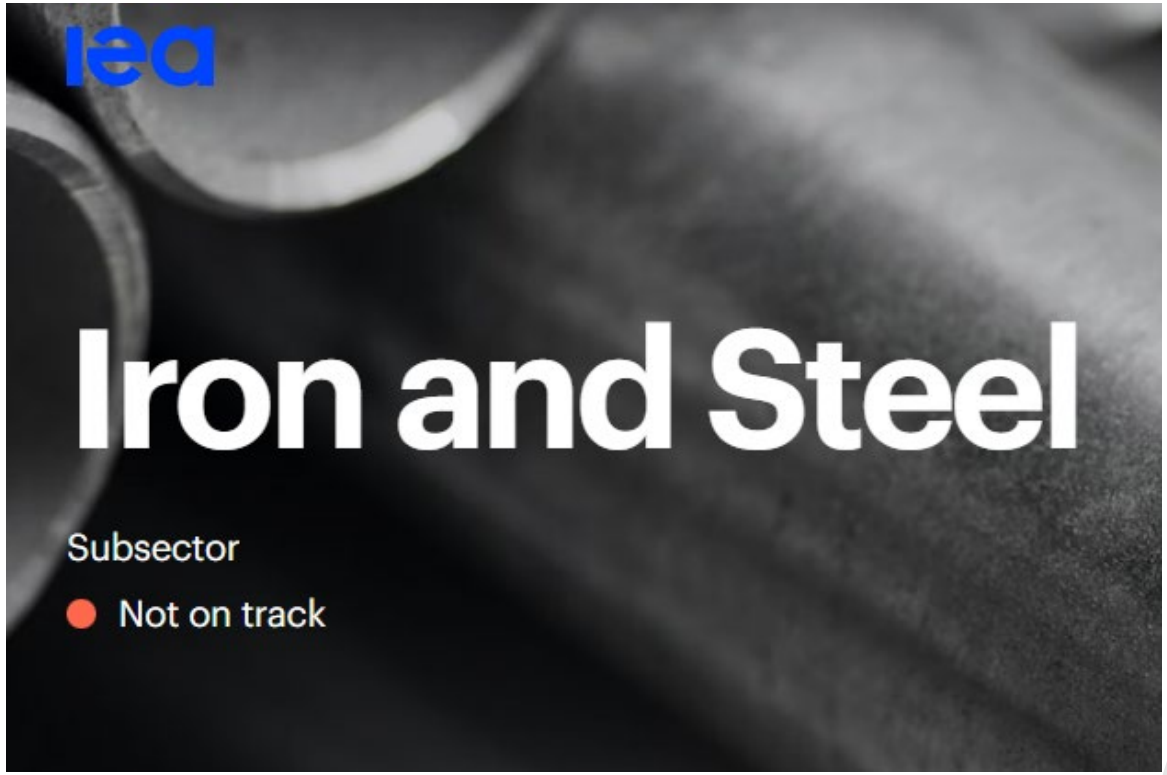


As a % of total industrial emissions

The Pathway to Industrial Decarbonization
https://www.americanprogress.org/article/the-pathway-to-industrial-decarbonization/

The cement and steel industries are not on track to meet the Paris Agreement climate targets by 2030, according to IEA





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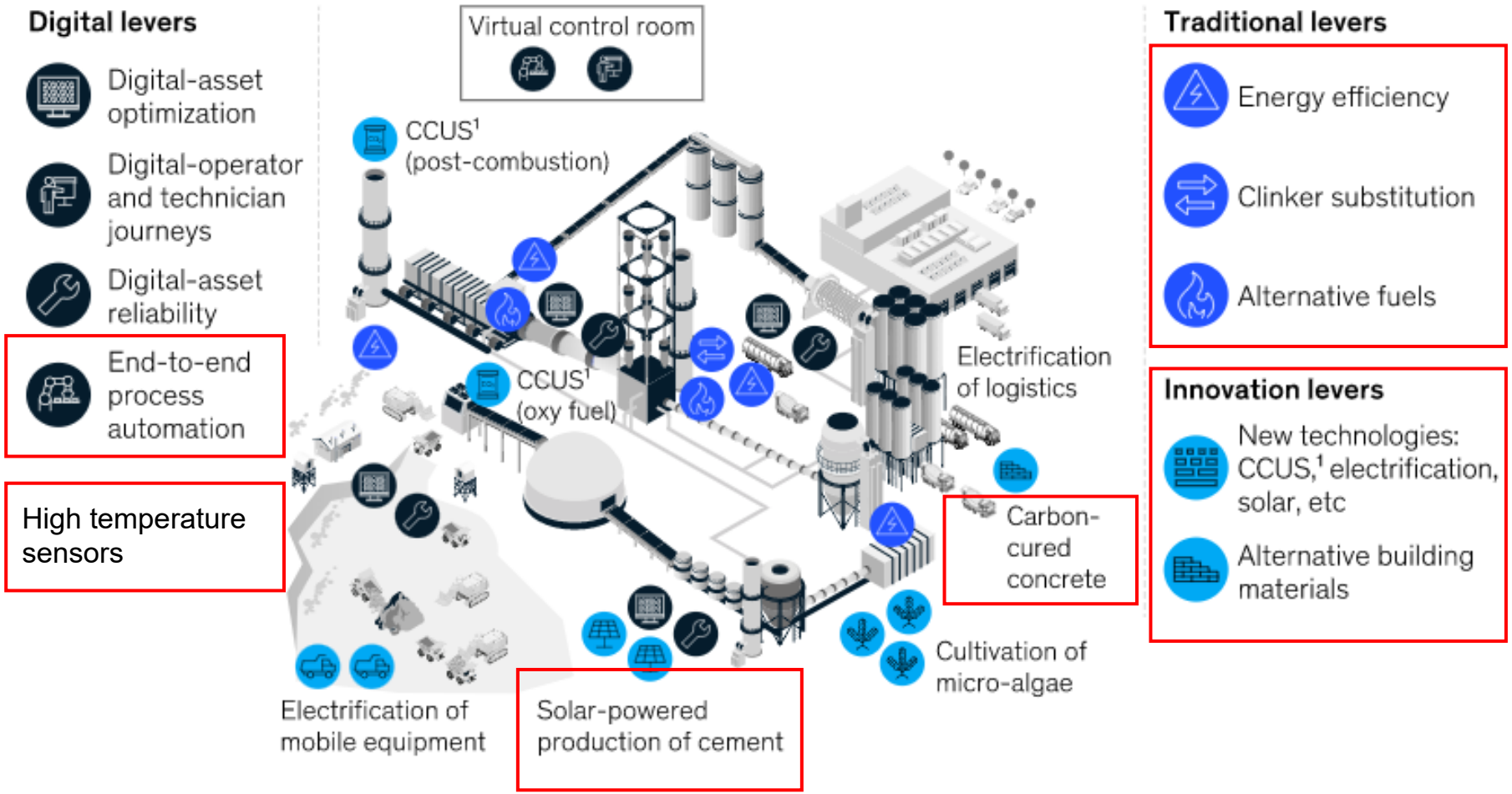
Cement decarbonization trends

- Direct CO_2 intensity of cement production increased ~ 1.5% per year during 2015-2021
- 3% annual declines until 2030 are necessary to get on track with the Net Zero Emissions by 2050 Scenario
- Global clinker-to-cement ratio increased by 1.6% per year from 2015-2021, to 0.72
- This ratio needs to drop to 0.65 by 2030
- CCS captures < 1 Mt of CO2 today – needs to be at 180 Mt in 2030
- Alternatives strategies for making clinker are necessary to avoid these emissions altogether
  - Process changes (electrification, alternate routes); material changes (other than carbonates)

https://www.iea.org/reports/cement

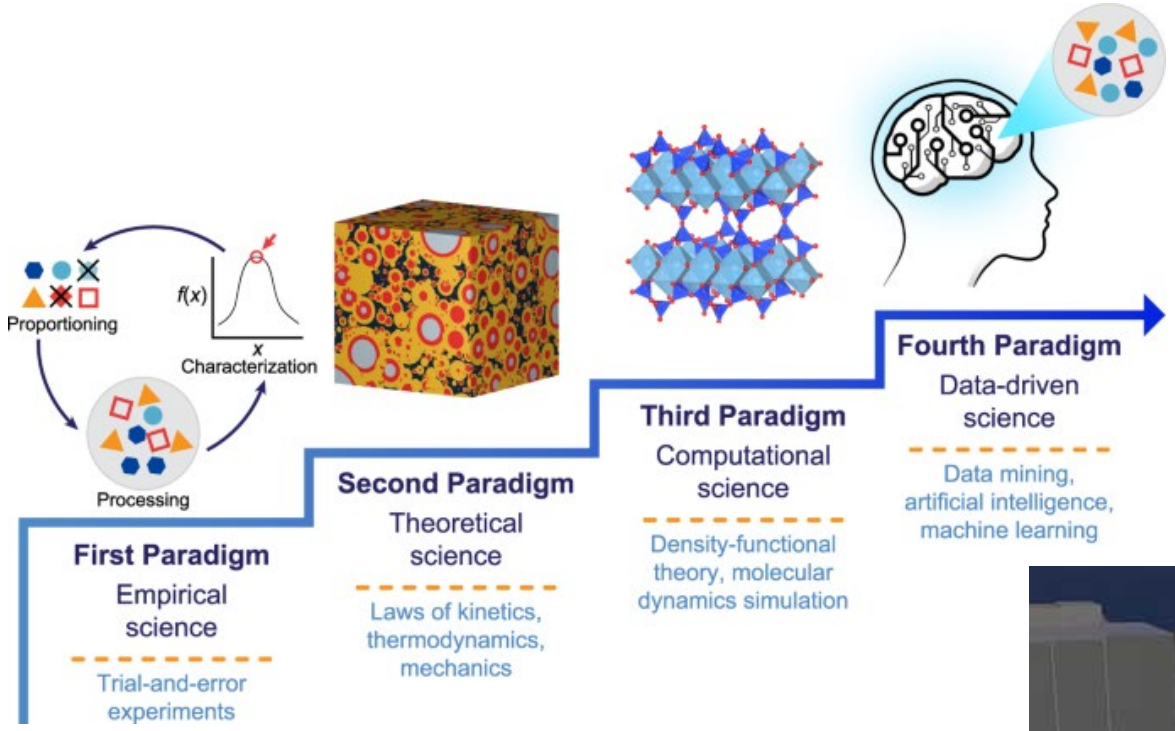
Digitization to improve outcomes

Integrated digital twin of cement plant enabling steering and optimized operations from end to end

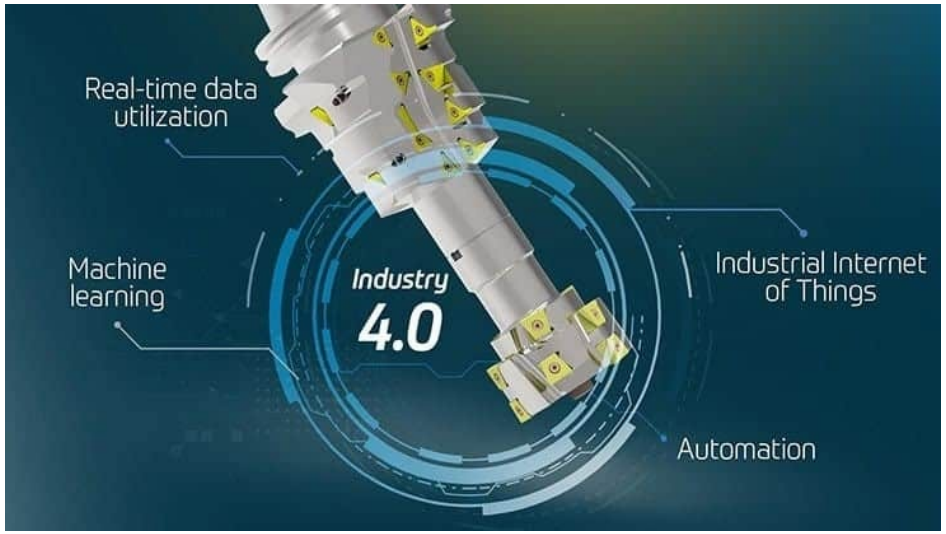


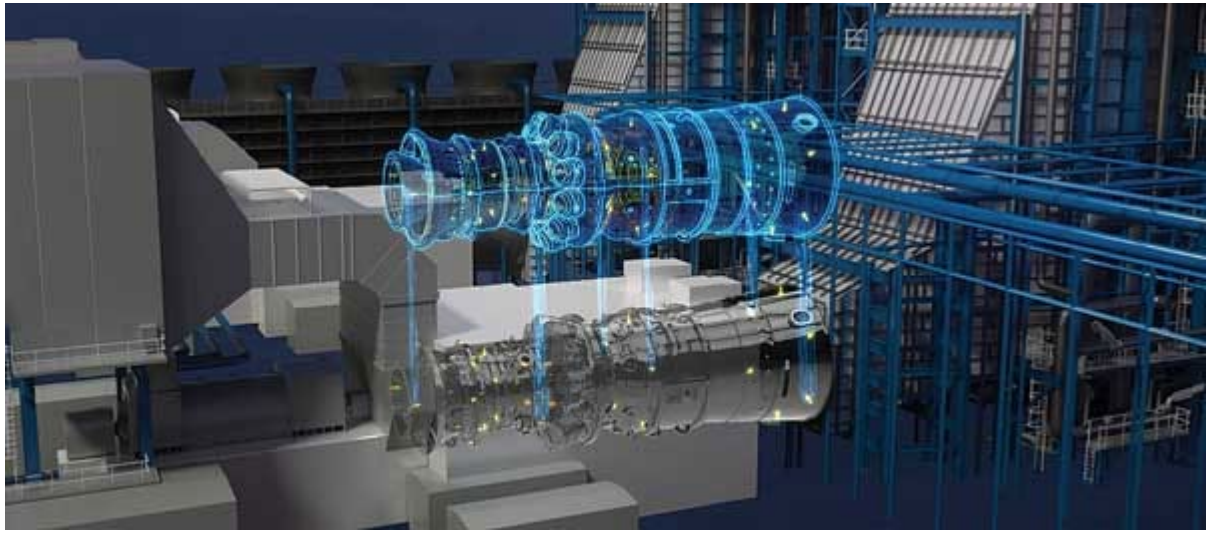
https://www.mckinsey.com/industries/chemicals/our-insights/the-21st-century-cement-plant-greener-and-more-connected

Modeling and Industry 4.0 tools enabling decarbonization



https://www.nature.com/articles/s41524-022-00810-x





https://www.cemnet.com/Articles/story/166427/digital-twins.html

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SCIENCE ERC envisions disruptive transformations in steel, cement, and concrete production

- Pioneer new technologies to eliminate carbon emissions from steel and cement manufacturing
- Develop waste upcycling and unique synthesis processes
- Increase process efficiency
- Enhance carbon capture/mineralization strategies
- Industry 4.0 tools – sensors and digital twinning enabling decarbonization
- Educate a new generation of engineers and technicians
- Lead global awareness in carbon-lean manufacturing

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The Team

Arizona State University

Narayanan Neithalath (Cement/Concrete)
Sridhar Seetharaman (Steel)
Barzin Mobasher (Fiber reinforced concrete)
Pat Phelan (Renewable Energy)
Diana Bowman (S&T policy)

University of California Los Angeles

Gaurav Sant (Cement/Concrete)
Mathew Bauchy (Cements/ML-AI)
David Jassby (Membranes/Nanotechnology)
Dante Simonetti (Process intensification)
Sriram Narasimhan (Sensors/IoT)

Missouri Univ. of S&T

Ron O' Malley (Steel)
Aditya Kumar (Cement, ML-AI)
Jie Huang (Sensors/IoT)
Jagannath Sarangapani (ML/AI)

Navajo Technical Univ.

Colleen Bowman (Education and Tech)
Ragavanatham (Adv. Manufacturing)
Arup Dey (Industrial Engineering)

Industrial Partner Collaboration

- Develop an Innovation Ecosystem as part of this effort
- A wide range of partners to ensure success and transformation
- Industry-relevant (Use-inspired) research, development, and demonstration
- Leading industry members in: Cement, Steel, Concrete, Chemical and mineral admixtures, Resource recovery/utilization, Construction, Sensors, Digitization, IoT
- Professional societies (PCA, ACI, AIST, CRSI, PCI, ASCE…)
- Industry/practitioner advisor board (IPAB) to guide RD&D of the center

Membership Benefits

- Benefits far outweigh the relatively small annual membership fees
- Leverage research funds from NSF and other center members – consolidated funding (via membership fees) enable 5-6X the individual investment to address significant decarbonization needs of cement, concrete, and steel
- Get research results early – members avail early look at research at all 4 partners
- Influence research directions
- Low overhead rate on joint research projects
- Pipeline of qualified scientists and engineers to the industry

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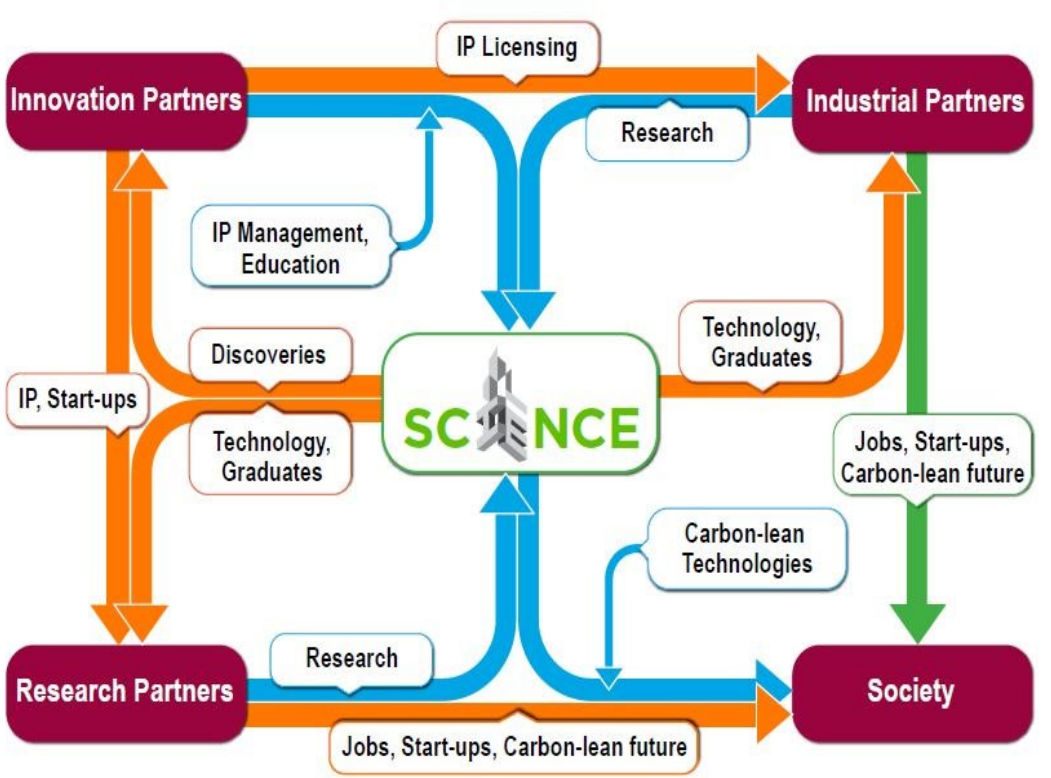
Industrial Partner Collaboration

- Tiered membership in the center
- Provides access to research, testing, and innovation infrastructure of partner universities
- Opportunity to engage on a pre-competitive basis with customers, peers
- Test beds (at partner as a resource for industrial partners to examine technology before scale-up
- Jumpstart on tech transfer – influence applied research aligned with overall industry interests
- Licensing rights
- Partnerships to pursue major federal funding



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