Early Career Researchers in Net-Zero Energy Systems

Sarah Finkeldei

Brian Tarroja

David Copp

Iryna Zenyuk

Bihter Padak

Erdem Sasmaz

Mo Li

Electric Energy Generation & Storage

Transportation

Negative Emissions

Difficult to Decarbonize Sectors

Building a Robust Clean Electricity System: Maximizing Co-Benefits of Power Decarbonization

Brian Tarroja
Civil and Environmental Engineering

Motivation

- Achieving deep decarbonization depends strongly on electrification of energy end-uses and meeting those electricity demands with zero-carbon electricity resources.

- A reliable zero-carbon electric grid, however, can take a multiplicity of different forms with regard to resource mix and infrastructure requirements.

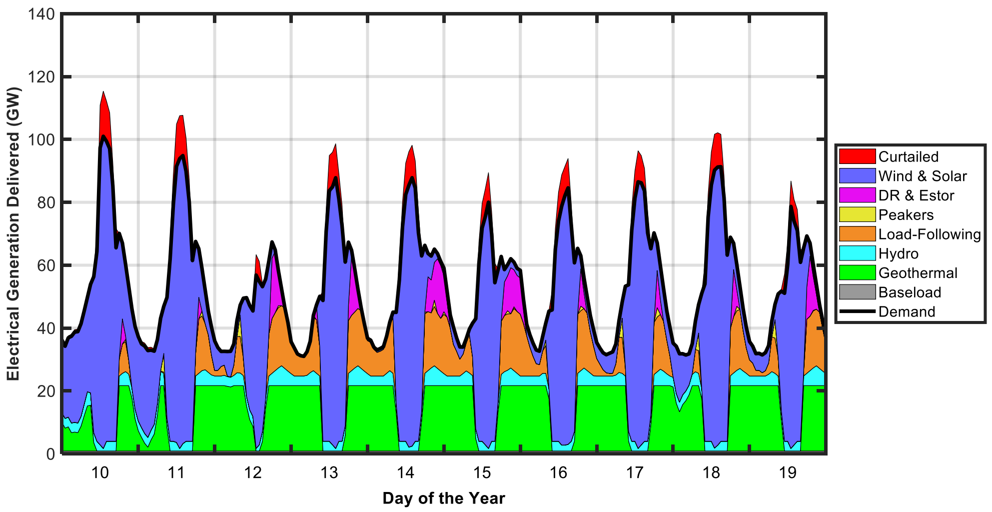
- These different forms can vary widely in their impacts to non-carbon environmental, health, and social outcomes.

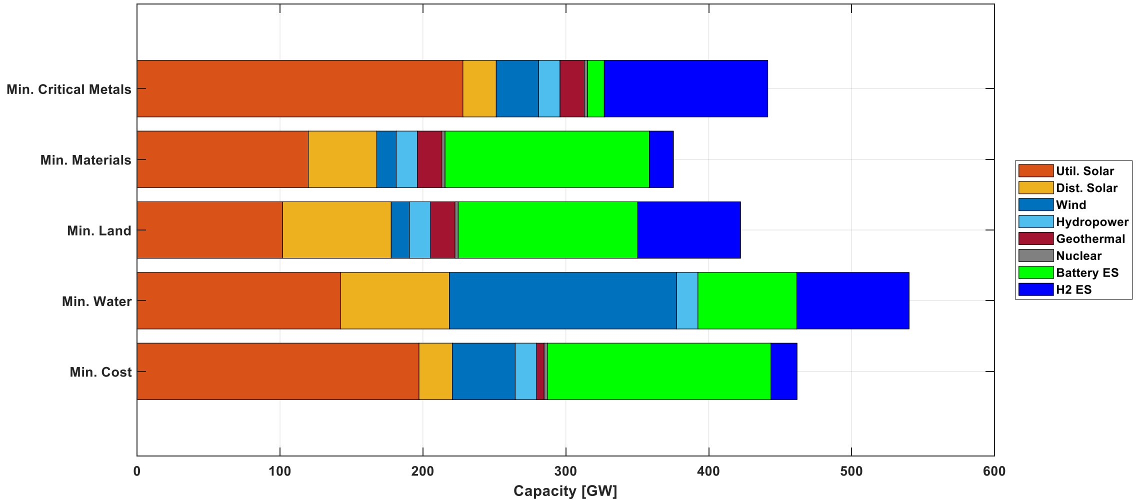
- These must be understood to build a durable transition to a clean electricity system.

Technical Approach

- Model how different realizations of a deeply decarbonized electricity system perform on non-carbon environmental, health, and social metrics

- Account for the technical & operational needs of the grid and feedbacks between electricity and other resource sectors





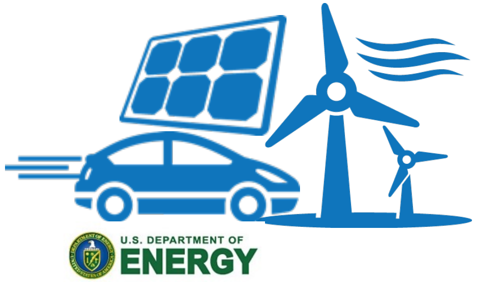
Potential Impact

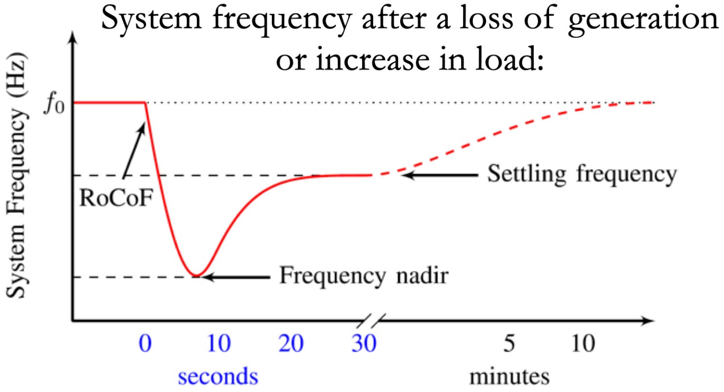
- Decarbonized electricity systems that also maximize non-carbon co-benefits will minimize unintended consequences and enable larger social and political support

David Copp, PhD
Mechanical and
Aerospace Engineering

Motivation

- Address grid stability challenges related to renewables and electrification
- Realize firm and dispatchable electricity
- Lower inertia → faster rate of change of freq. (RoCoF) and lower nadir
- Steep ramps (currently accommodated with, *e.g.*, natural gas "peaker" plants)





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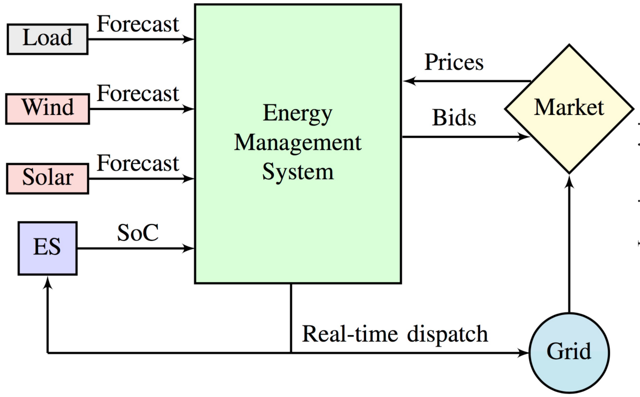
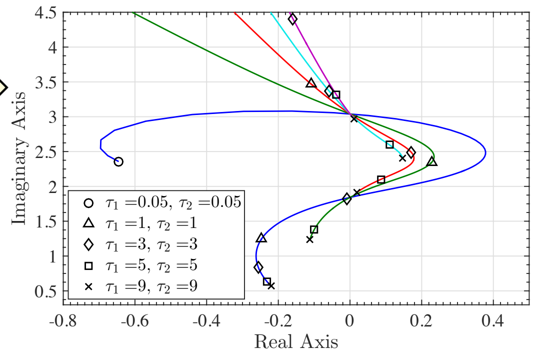
Technological Approach

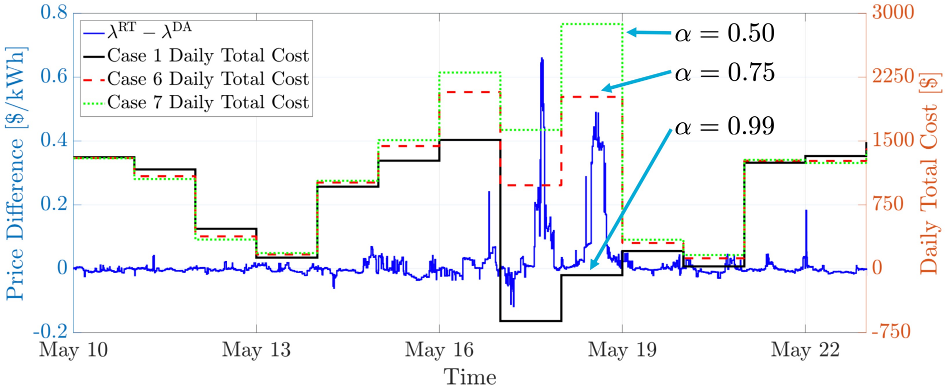
- Energy management algorithms
- Optimal estimation and control
- Utilization of real-time information and computation





Potential Impact

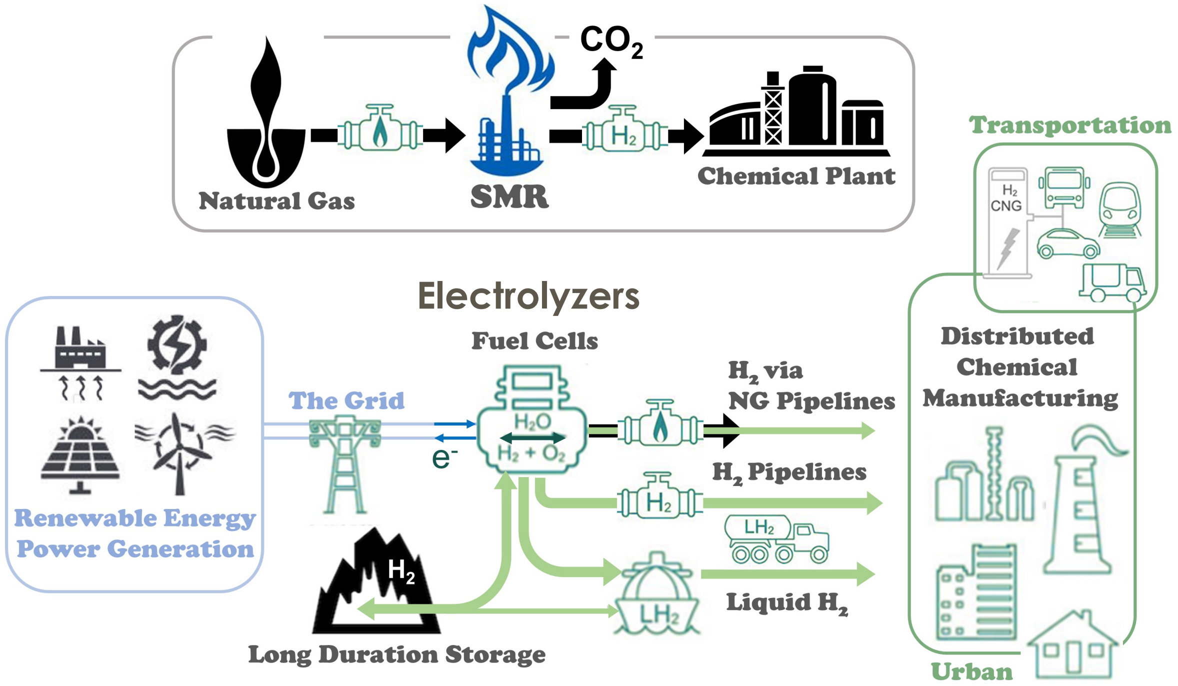
- Integration of more intermittent renewable generation
- Reliable and resilient grid with real-time situational awareness
- Value streams for new technologies



Iryna Zenyuk
Chemical and Biomolecular Engineering

Motivation

- Difficult to decarbonize sectors, such as long-duration grid energy storage, heavy-duty trucks, ships & chemical manufacturing (cement)
- Electrochemical technologies that are based on electrolyzers have potential to fill in this gap
- Hydrogen as a clean fuel for transportation and chemical manufacturing

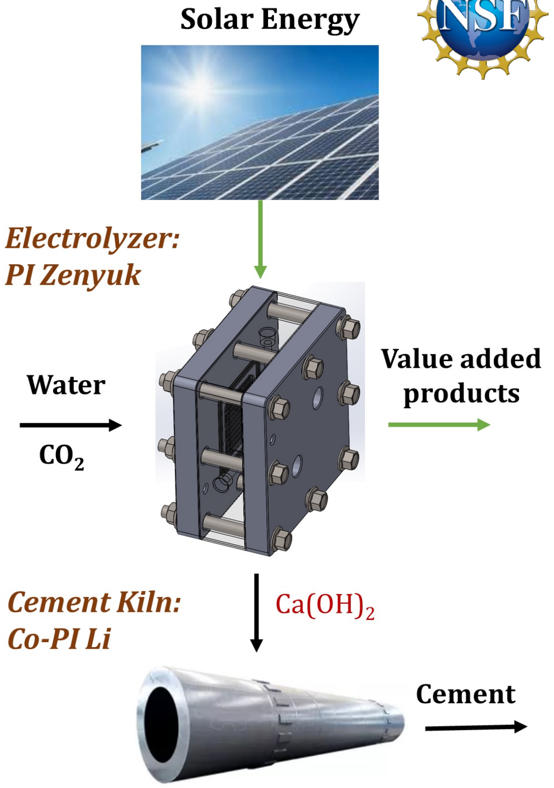


Technological Approach

- Design of novel materials, integration into actual devices and scale up
- Advanced characterization using synchrotron x-rays
- Activity, durability and cost all need to be balanced
- Advancing manufacturing technologies through fundamentals

Potential Impact

- Net-zero emissions energy systems that are difficult to decarbonize
- Long-duration, seasonal energy storage;
- Heavy-duty trucks electrification;
- Clean cement manufacturing
- Negative emission technologies with CO_2 reduction to value added chemicals



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Combustion and Emission Control Technologies

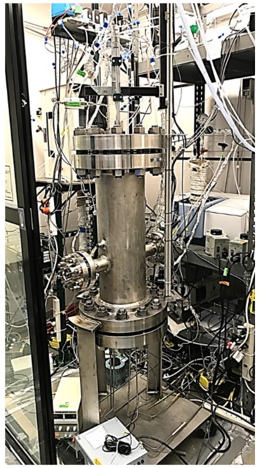
Bihter Padak
Mechanical &Aerospace Engineering

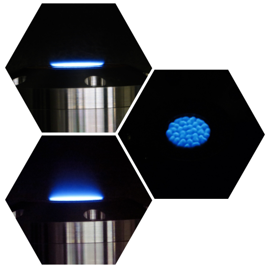
Objective: Reduce pollutant emissions from stationary and mobile sources by developing novel materials while trying to understand the combustion chemistry at a fundamental level

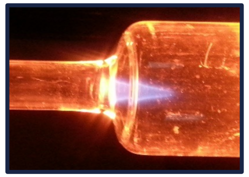
Utilization of Carbon-free Fuels in Combustion Processes:

Adding renewable H_2 and NH_3 to natural gas

- Stationary power systems
  - Gas-fired utility boilers
  - Gas turbines
  - Process heaters
  - Gas-fired reciprocating engines
- Transportation
  - Medium/heavy-duty vehicles
  - Ocean going vessels
- Residential and commercial appliances

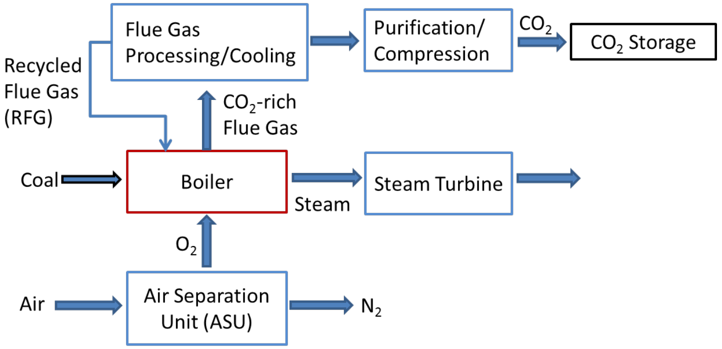




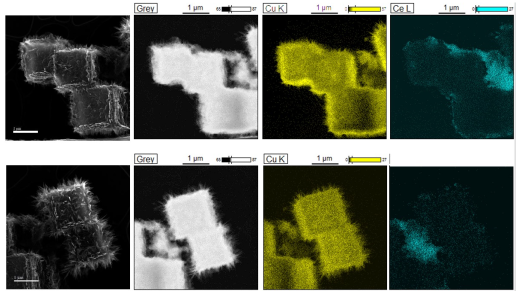


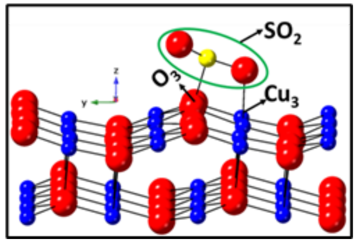
Carbon Capture and Storage Technologies:

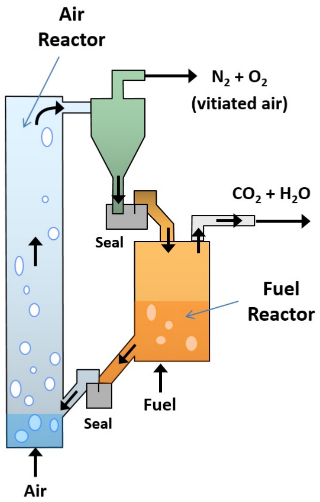
- **Oxy-combustion**
  - Combustion in O_2 rather than air
  - Results in reduction of NO_x and SO_x emissions



- **Chemical looping combustion**
  - Combustion of fuel by metal oxide reduction instead of direct oxidation with air







faculty.sites.uci.edu/padaklab

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UCIrvine University of California
Advanced Power & Energy Program
University of California · Irvine

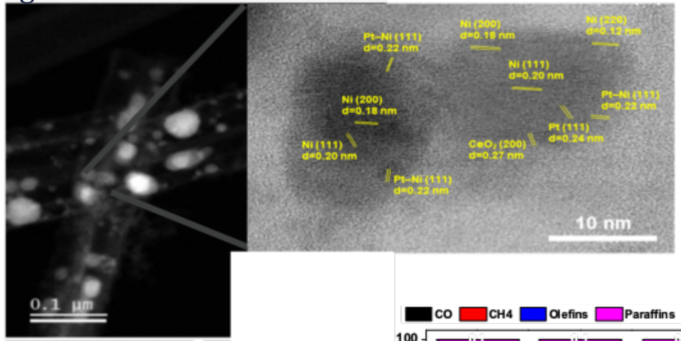
Heterogenous Catalysis for Net-Zero Carbon Reduction

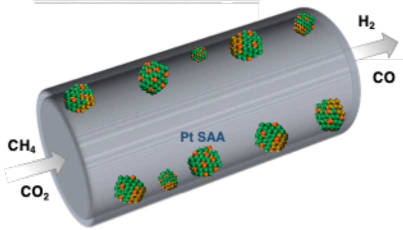
Erdem Sasmaz
Chemical and Biomolecular Engineering

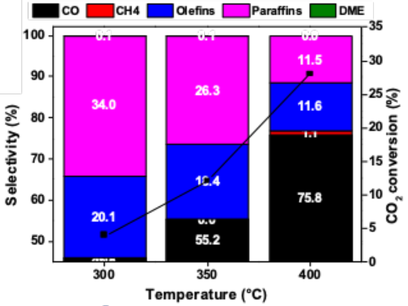
Motivation : Develop sustainable technologies to decarbonize the transport and manufacturing sectors

CO_2 reduction to value-added chemicals

Confined yolk-shell morphologies
Pt-Ni single atom alloy catalysts



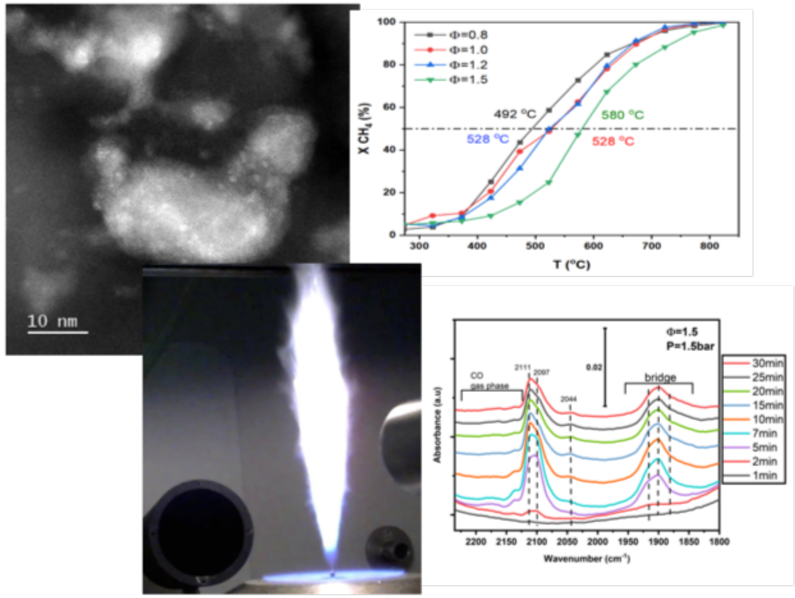




- **Minimized coke formation**
- **Enhanced oxygen transfer**
- **Improved reaction kinetics**

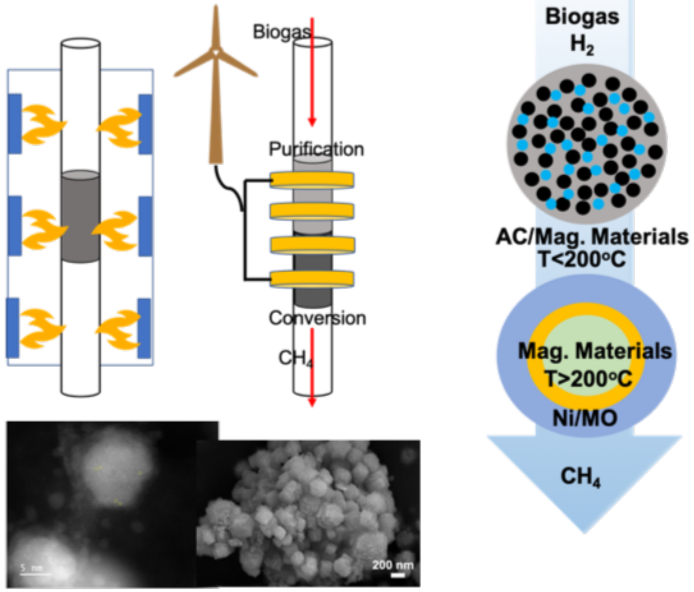
Control of Methane Emissions

634 MM ton CO_2 equivalent in 2018



Automated nanomaterial synthesis

Biogas Conversion Conversion and Sustainable Hydrogen Production



Novel ferromagnetic materials for radio frequency heating

- Direct use of renewable sources for energy production
- Up to 90% energy efficiency
- Instantaneous on/off switching
- Elimination of hot-spots

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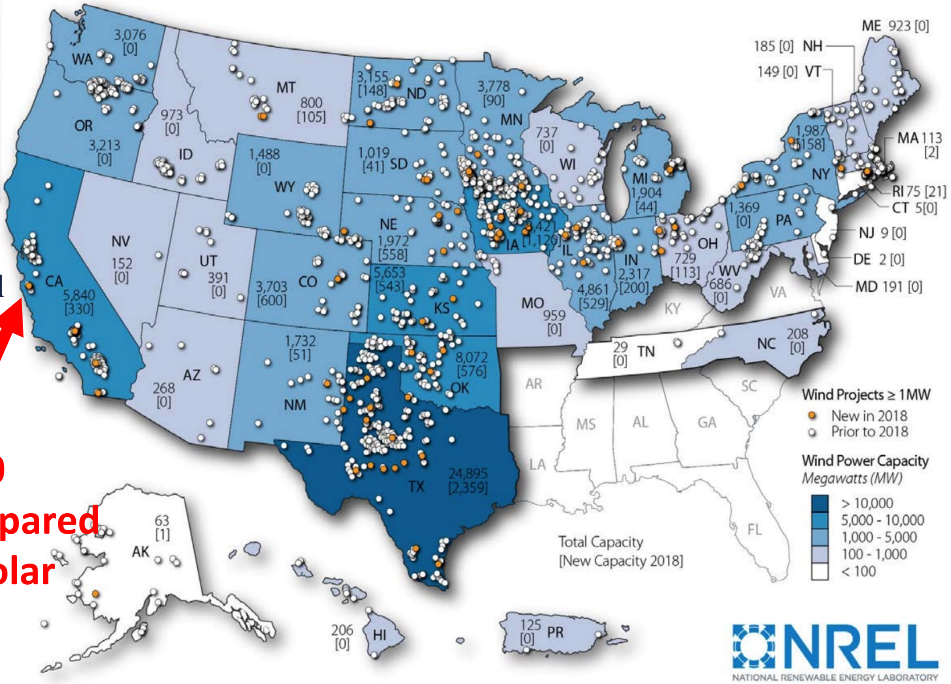
Civil & Environmental Engineering

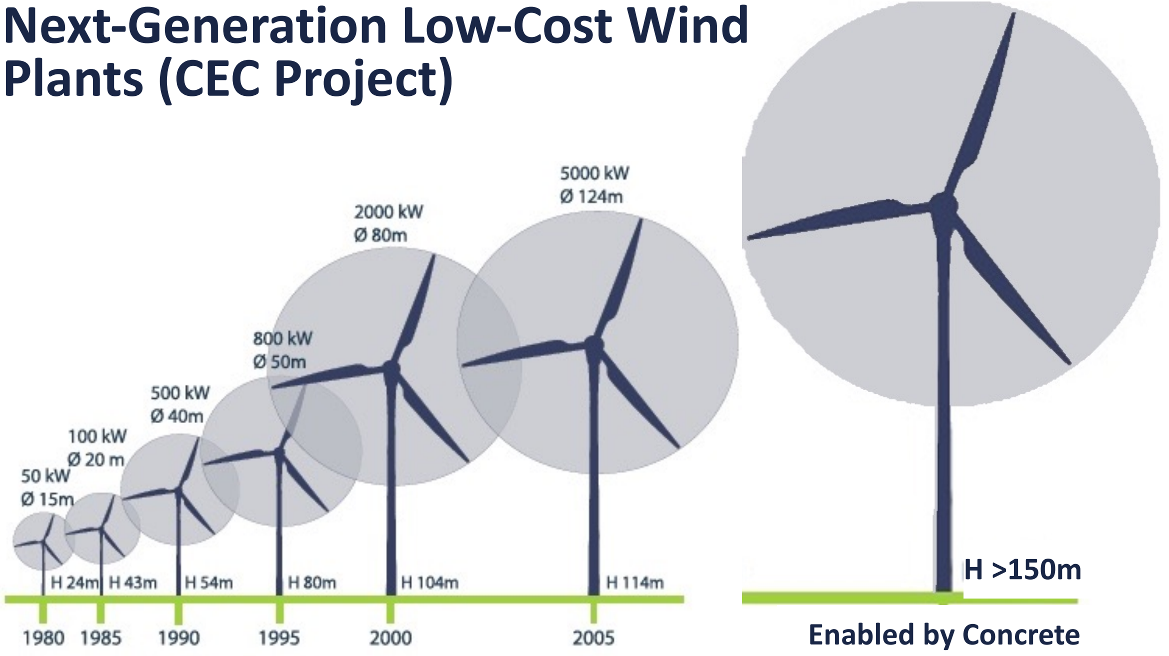


1/10 compared to solar

Source: DOE/LBNL 2018 Wind Technologies Market Report

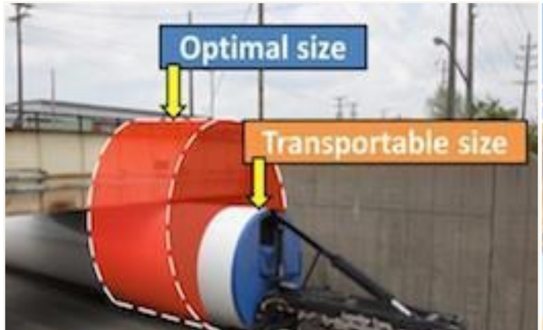
On-Site 3D Concrete Printing for Next-Generation Low-Cost Wind Plants (CEC Project)

Higher Capacity



Enabled by Concrete Additive Manufacturing

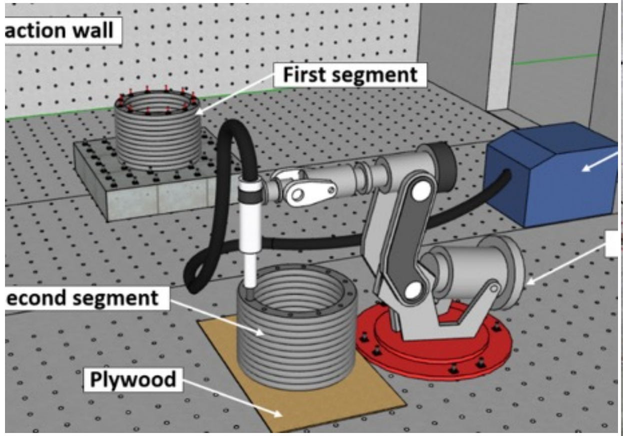
Challenges



Transportation constrains (Keystone Tower Systems)

Formwork (Siemens Wind)

New Approach



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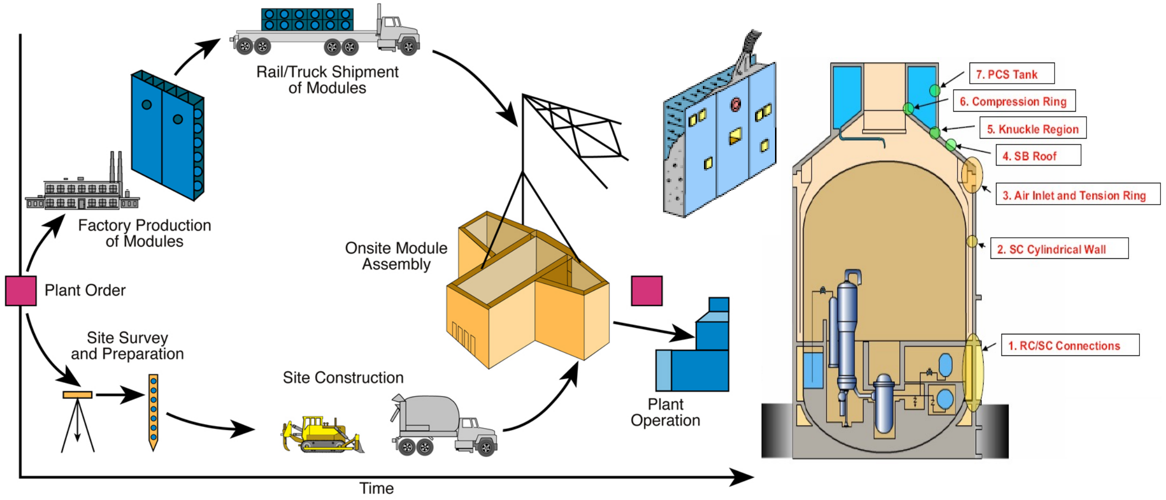
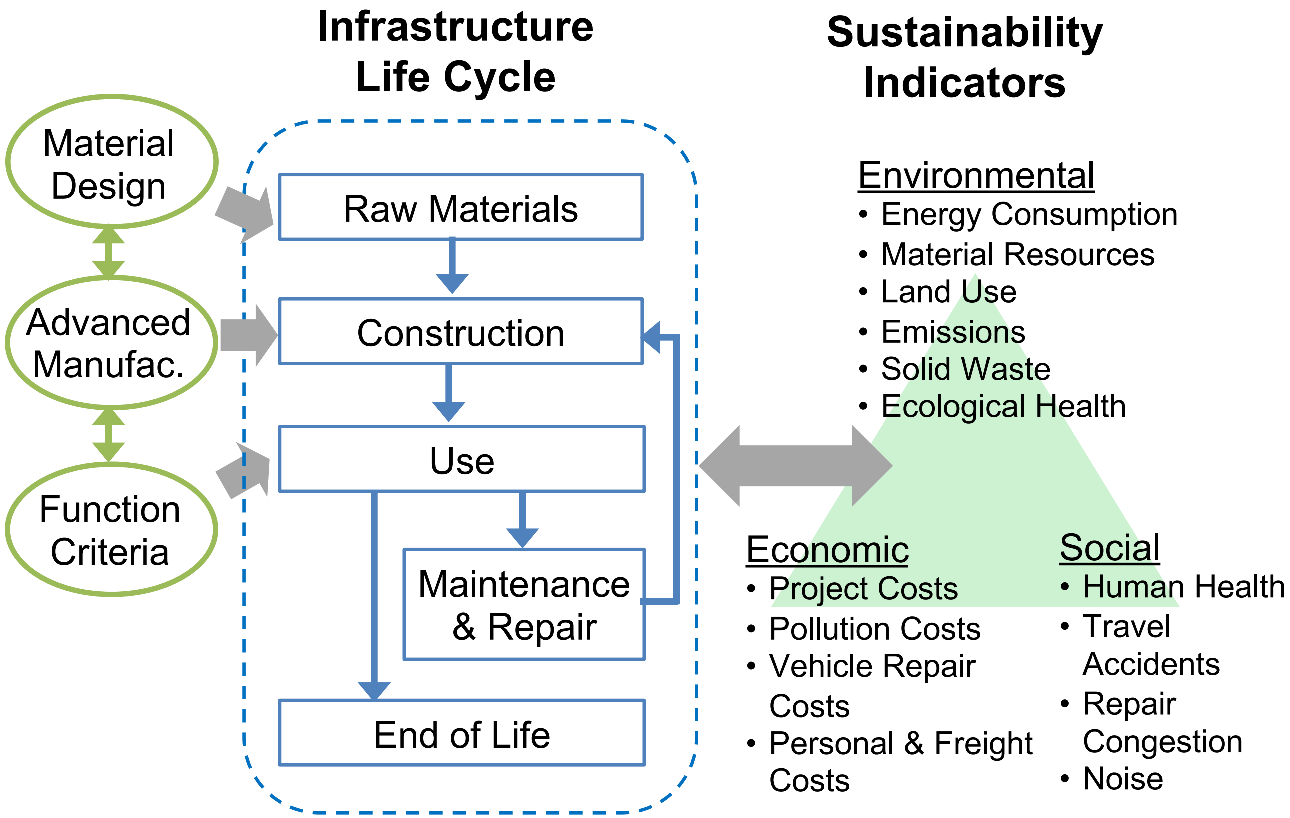
Lean cement manufacturing by renewable energy (NSF)

Reduce GHG emissions from buildings and transportation infrastructure (DOE, DOT)



New materials and advanced manufacturing for small nuclear reactors, and nuclear waste storage (DOE NEUP & NEET)



Assess how new technologies impact system sustainability (NSF, ARPA-E, CEC)

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Sarah Finkeldei
Department of Chemistry

Nuclear Energy towards zero-Carbon Emission

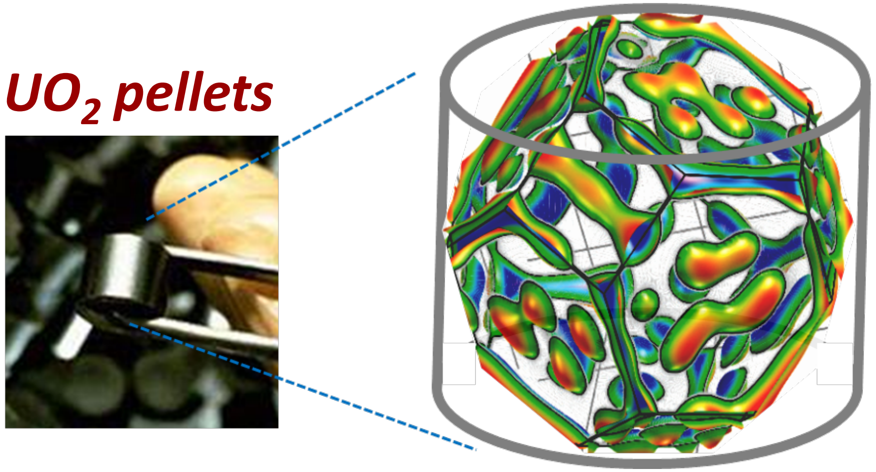
High energy density of nuclear fuel: 20% of U.S. electricity

Perpetual improvements of operating reactor fleet
(efficiency & safety)

Design of advanced reactor systems:

- **Small modular reactors**
- **Advanced fuel forms**

UO_2 pellets



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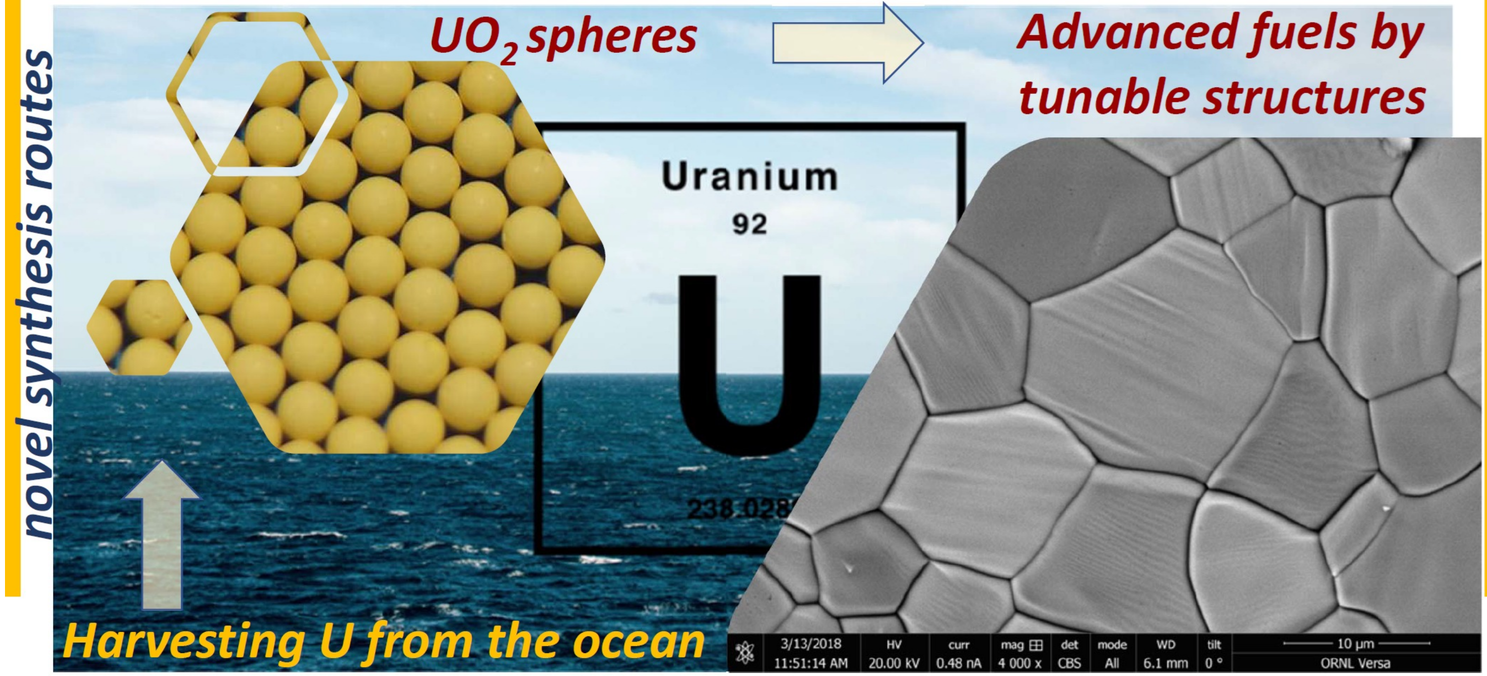


Impact:

- **Diminish reliance on fossil fuels/zero carbon emission**
- **Hydrogen production**
- **Advanced nuclear waste management**
- **Uranium extraction from seawater**

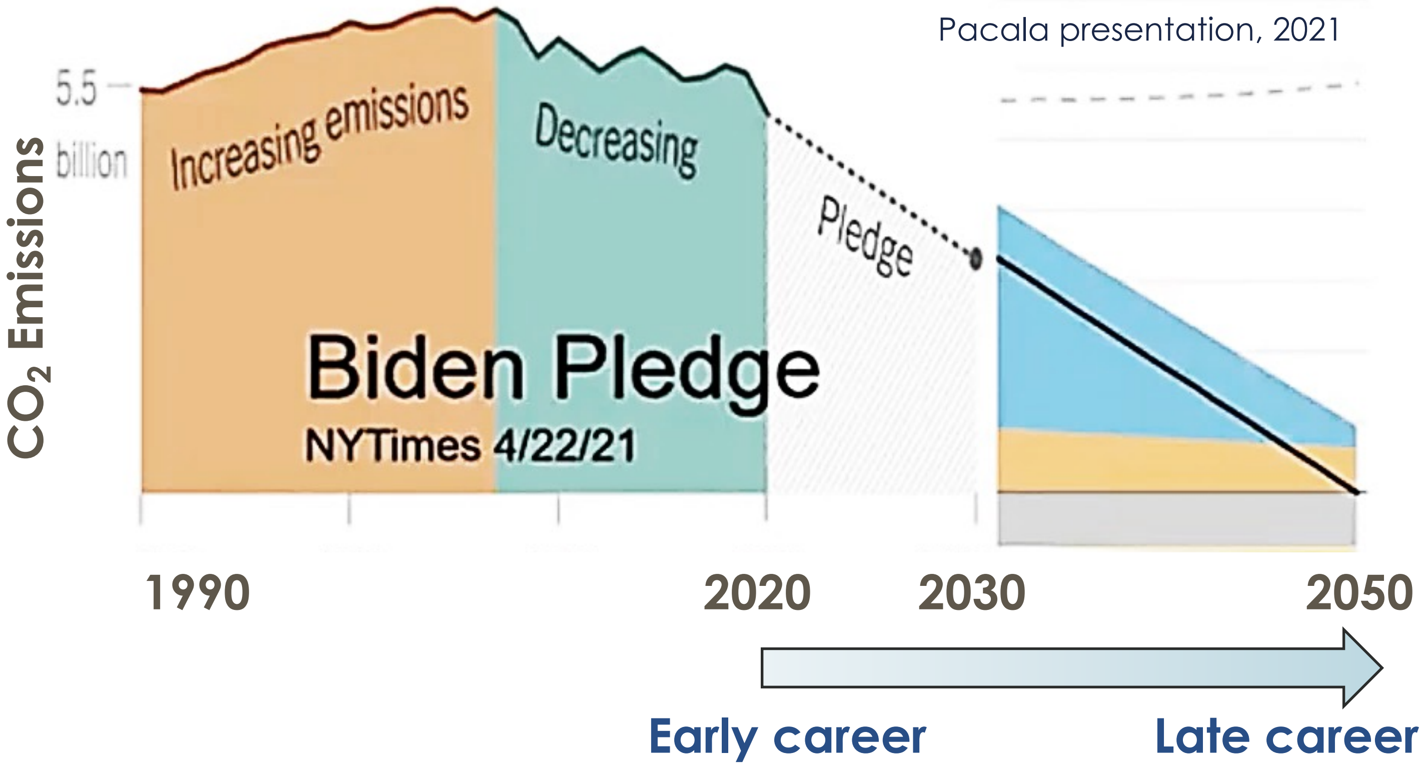
Panel Discussion: Focus on Early Career & Decarbonization

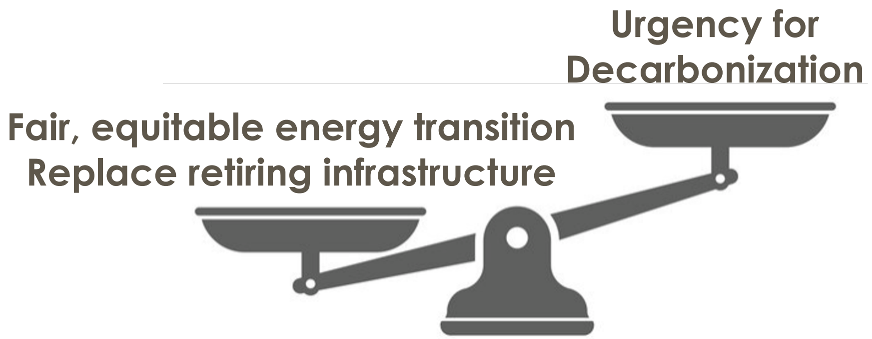
NASEM Accelerating Decarbonization of the US Energy System Goals to Reach by 2030:

- Producing carbon-free electricity
- Electrifying energy services in transportation, buildings and industry
- Investing in energy efficiency and productivity
- Planning, permitting and building critical infrastructure
- Expanding the innovation toolkit
- Strengthening the US economy
- Promoting equity and inclusion
- Supporting communities, businesses, & workers
- Maximizing cost-effectiveness

50 % reduction in greenhouse-gas emissions by 2030 from where we were in 2005

Pacala presentation, 2021





How to balance the "life plan" advise: *work to become the best possible scientist for the first stage of their life before transitioning to deliver on the "social contract" with the urgency for action*

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