
MIT ec3 hub
BEYOND DECARBONIZATION:
Material Agency and Multifunctionality
Frank Mruk, FAIA, Senior Director, NRMCA
Hessam AzariJafari, Ph.D., Executive Director of MIT ec3 hub
Concrete Innovation Webinar series
04/15/2026
CSHub
MIT CONCRETE SUSTAINABILITY HUB

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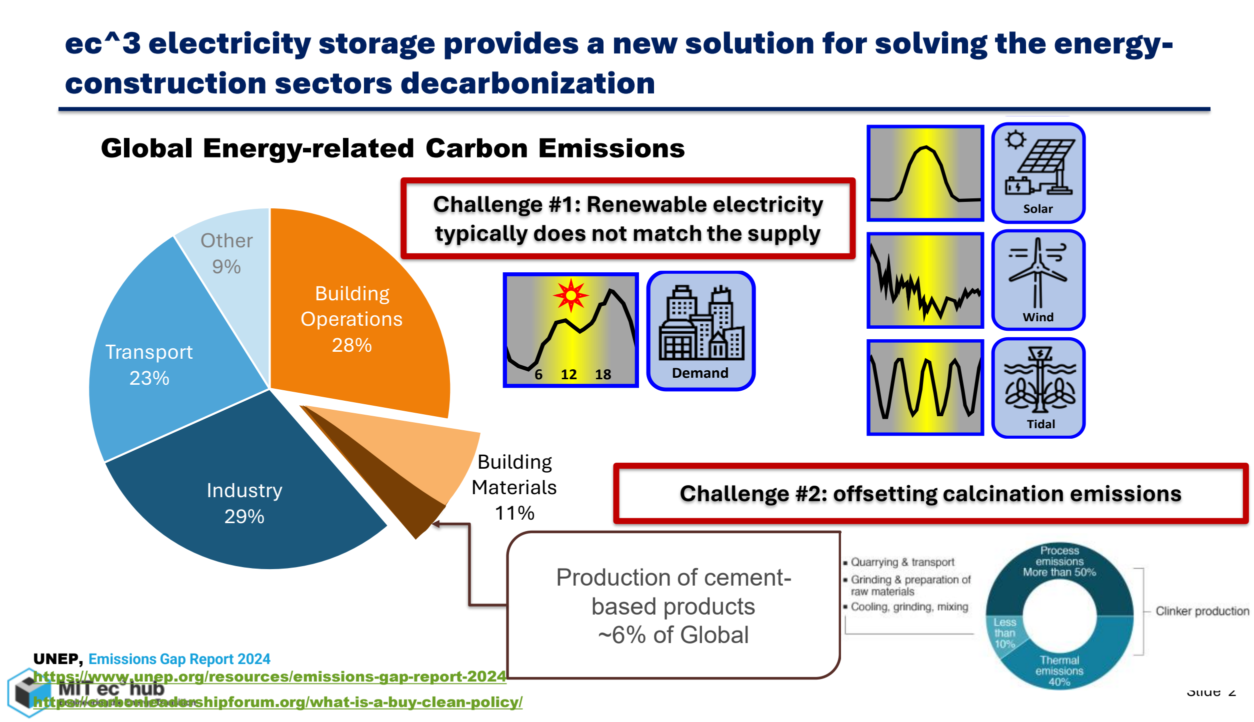
ec^3 electricity storage provides a new solution for solving the energy-construction sectors decarbonization
Global Energy-related Carbon Emissions
Other 9%
Building Operations 28%
Transport 23%
Industry 29%
Building Materials 11%
Challenge #1: Renewable electricity typically does not match the supply
6 12 18
Demand
Solar
Wind
Tidal
Challenge #2: offsetting calcination emissions
Production of cement-based products ~6% of Global
Quarrying & transport
Grinding & preparation of raw materials
Cooling, grinding, mixing
Process emissions More than 50%
Less than 10%
Thermal emissions 40%
Clinker production
UNEP, Emissions Gap Report 2024
https://www.unep.org/resources/emissions-gap-report-2024
https://carbonleadershipforum.org/what-is-a-buy-clean-policy/
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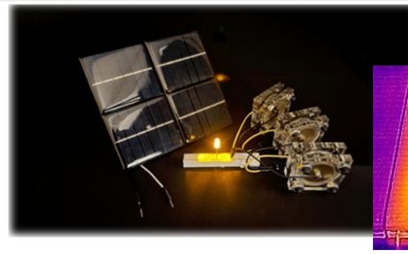
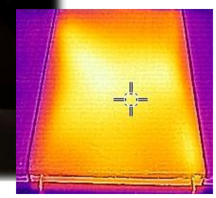
Mission and Vision Statement of ec^3 Hub

- **Mission:**

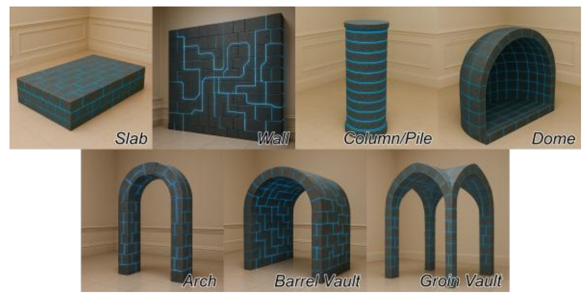
To provide novel research and implementation resources on multifunctional cement-based solutions that foster transition and empower communities to achieve a low-carbon future at scale.





- **Vision:**

Multifunctional cement-based materials will be the cornerstone of resilient, equitable, and low-carbon infrastructure systems and buildings.



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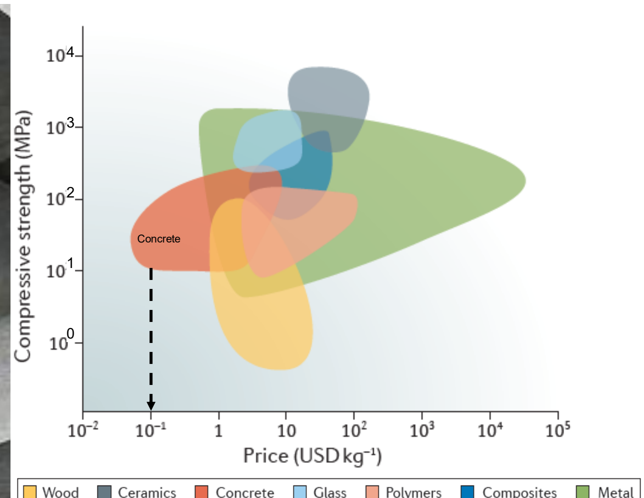

Bechthold, M. & Weaver, J. C. Materials science and architecture. Nat. Rev. Mater. 2, 17082 (2017).

Concrete is a

STRONG, DURABLE, VERSATILE, INEXPENSIVE

construction material

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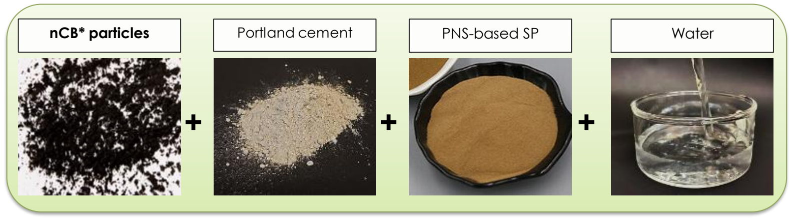
How do we make Electron-Conducting Concrete

TAKE:

1. A Hydrophobic CONDUCTOR: NanoCarbon Black
2. A Hydrophilic INSULATOR: Concrete = Cement + Water + Sand + Stones

MIX – WHAT HAPPENS?



*nCB – nano Carbon Black

- **Carbon-Black**
- **Cement Composite**

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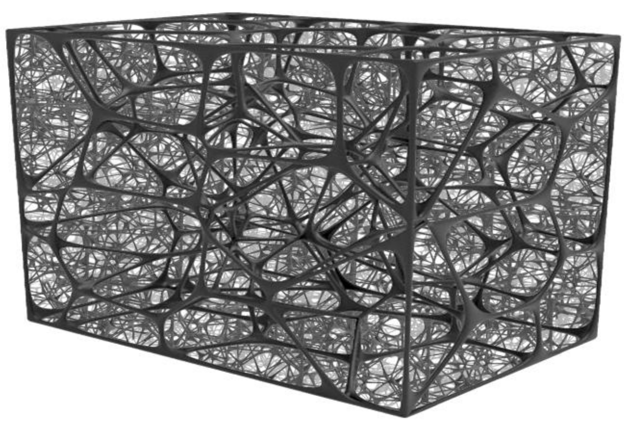

Percolation of a Volumetric Wire through a load-bearing cement skeleton

A Physical Chemistry Driven Process = Highly Repetitive

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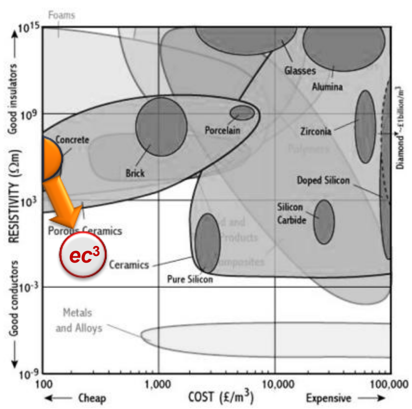
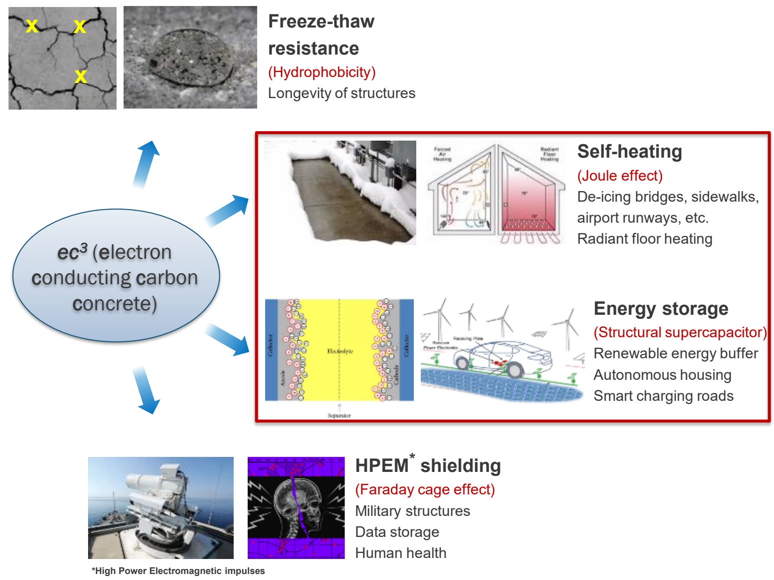
ec^3 = ELECTRON CONDUCTING CARBON-CEMENT BASED MATERIALS

Resistivity vs. cost



http://www-materials.eng.cam.ac.uk



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ec^3 for Self-heating

ec^3 = ELECTRON CONDUCTING CARBON-CEMENT BASED MATERIALS

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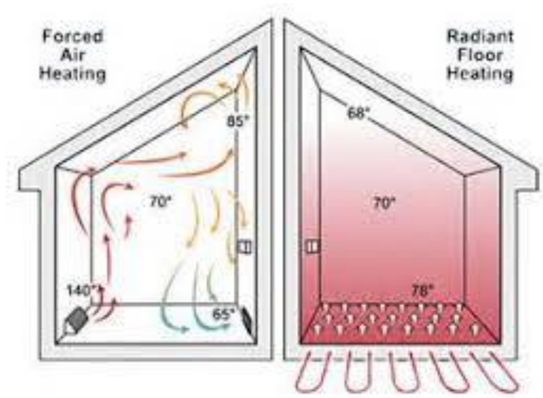
Self-heating ec^3 provides opportunities to reduce the maintenance, improve thermal comfort, and extend the service life of outdoor concrete

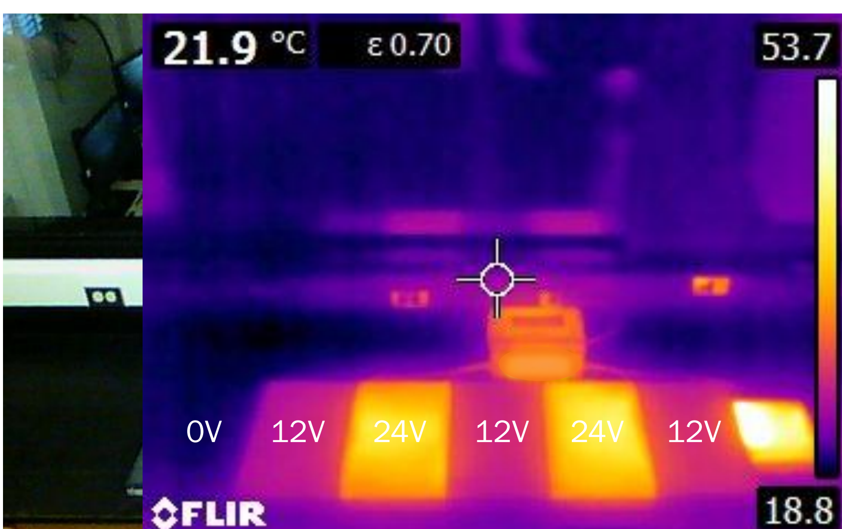
Self-heating sidewalk

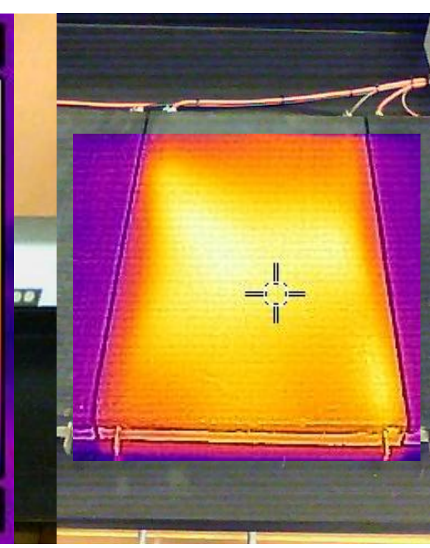
Radiant Floor Heating



CY. Tuan, J. Cold Reg. Eng., 2008, 22(1): 1-15

Experimental study of self-heating slab demonstrated a uniform distribution of heat: ensuring structural integrity, durability, energy efficiency, and safety






Sapporo Odori Park, J
ec^3
Positive electrodes
Negative electrodes
Electric power
Subbase
Subsoil
発熱するコンクリートで、雪を溶かしています。
雪が溶けちゃう コンク
電子伝導性コンクリートパネルによる融雪実証試験
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実証実験
特殊コンクリートで
ロードヒーティング
札幌 大通公園
December 2024

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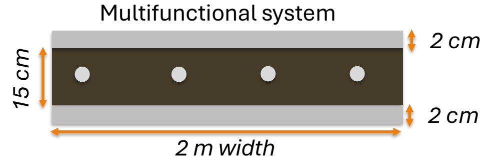
Role of multifunctional (self-heating) concrete in the decarbonization of built environment

Case study of sidewalk in a cold climate region (Canada)

Conventional system

- **Maintenance:** Deicing salt: 2.8 kg/m^2/year
- **Repair:** Replacement of the whole slab every 15 years due to freeze-thaw cycles
- **Mix design:** conventional concrete

Multifunctional system



- **Maintenance:** no salt
- **Repair:** Replacement of the top layer slab every 20 years due to wear and tear
- **Energy consumption:** 110 kWh/year
- **Electrode (Steel):** 4 @ 0.56 kg/m
- **Mix design:** conventional concrete + 10% carbon black

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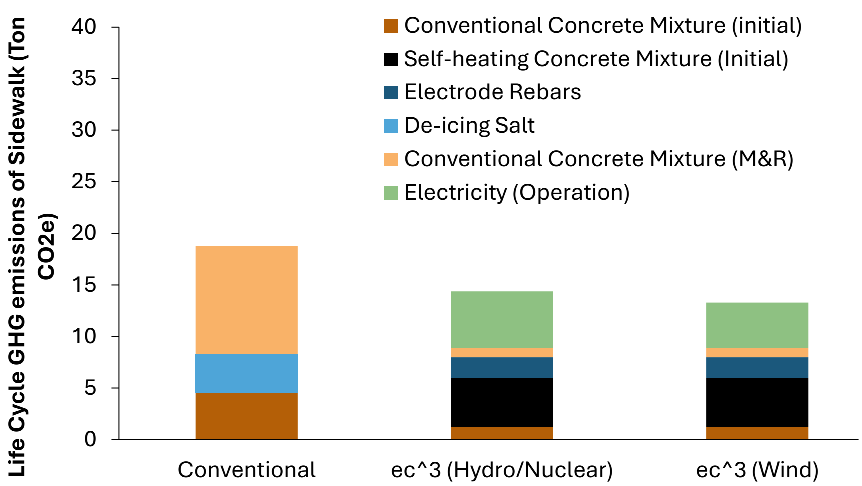
Depending on the electricity source, ec^3 self-heating slab can reduce the life cycle emission of concrete sidewalk by up to 24%

Case study of the City of Montreal in Canada (50-year period)



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ec^3 for Energy Storage

ec^3 = ELECTRON CONDUCTING CARBON-CEMENT BASED MATERIALS

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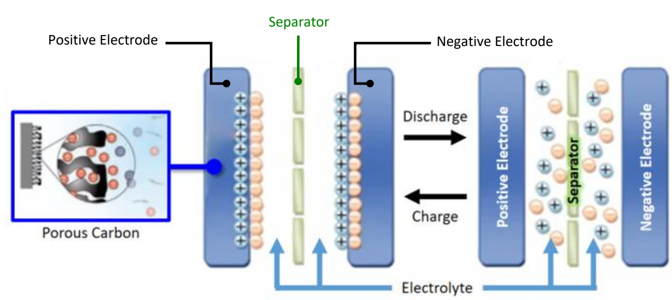
Cement + Carbon + Porosity = Supercapacitor

Battery = Change electrical energy into chemical energy

Supercapacitor = Electrical Charge stored in a shell around the carbon (no chemical reaction)

ec^3 decarbonizes the grid by reducing stress through renewable energy storage and mitigates cement/concrete emissions via multifunctionality



- **CONCRETE AS "structural" SUPERCAPACITOR:**
  - **Porosity of cement paste (for Electrolyte)**
  - **Carbon-Cement Composite for Energy Storage**

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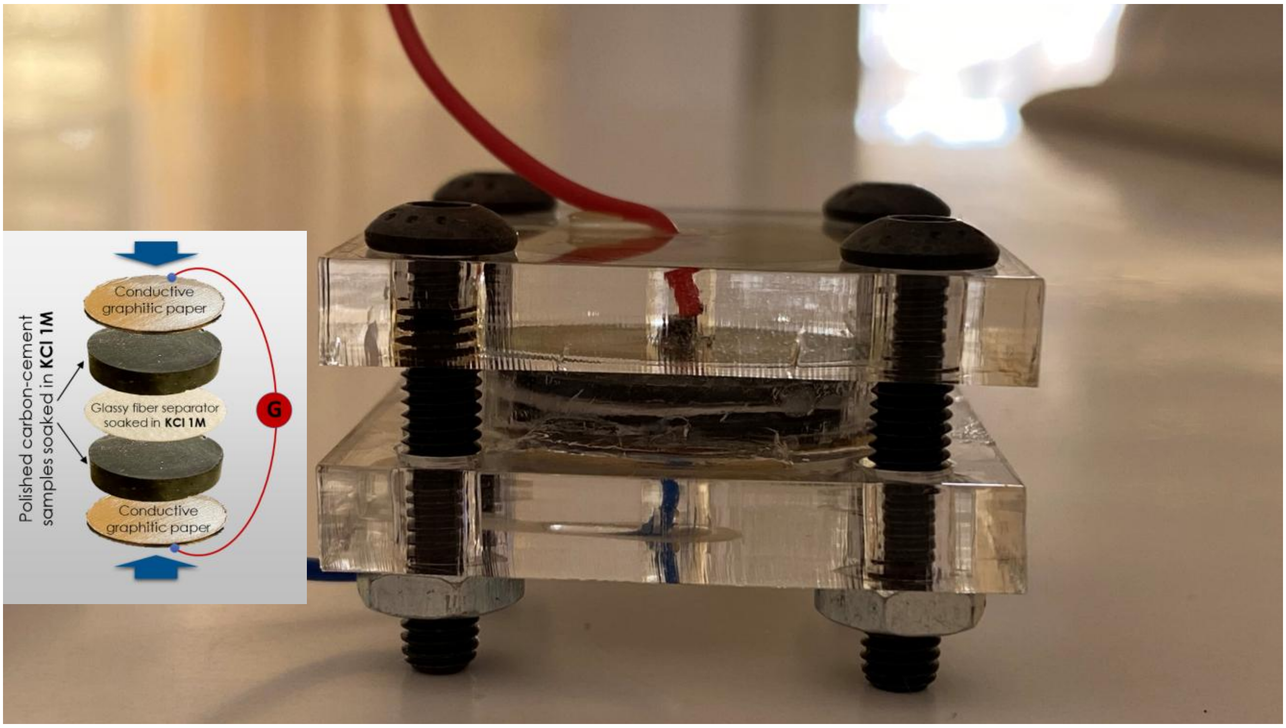

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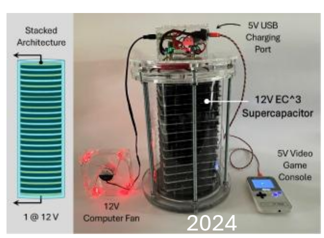
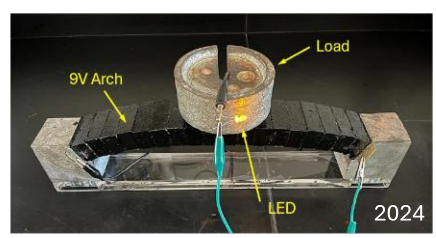
MIT ec^3 team has been working on two main applications: energy storage for roads and self-heating panels





- Energy density = 0.3 -0.4 kWh/m3
- Compressive strength = 20-30 MPa

Demo date: September 25th, 2025, Japan

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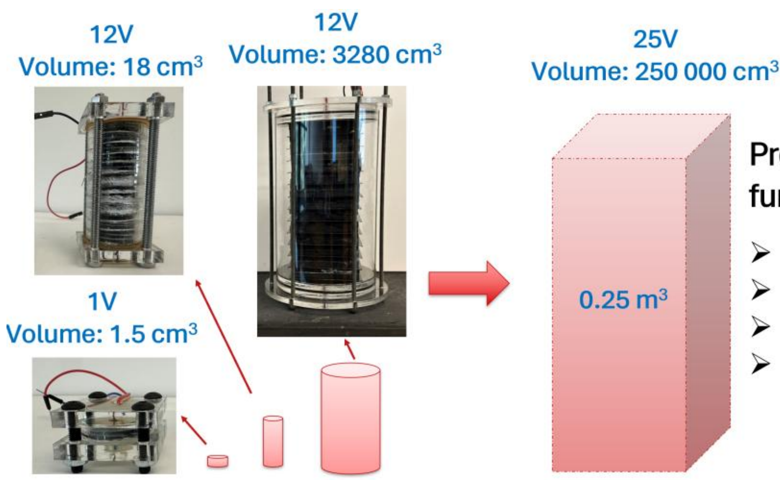
Evolution of the ec^3 technology 2022-2025

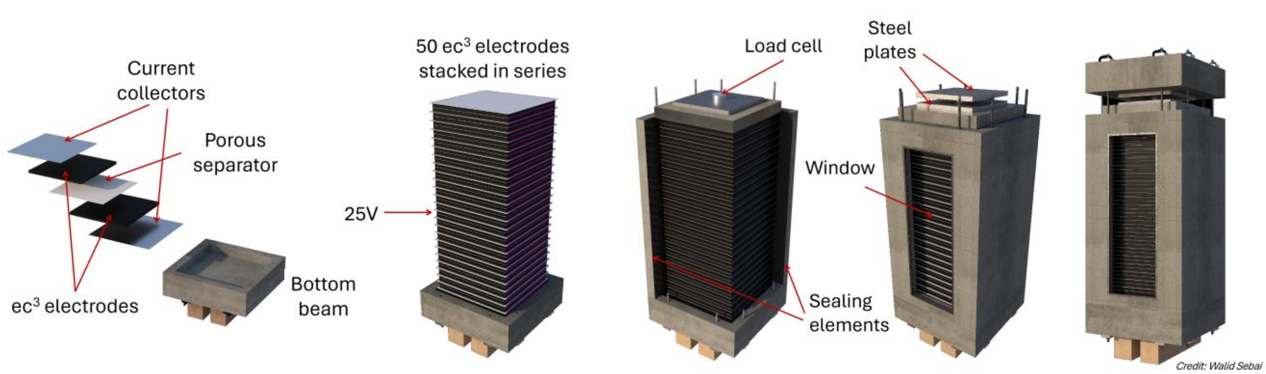


Prototype functions:

- Scaling
- Prestressing
- Sealing
- Operational safety

25V Prestressed Prototype

Assembly of the prototype



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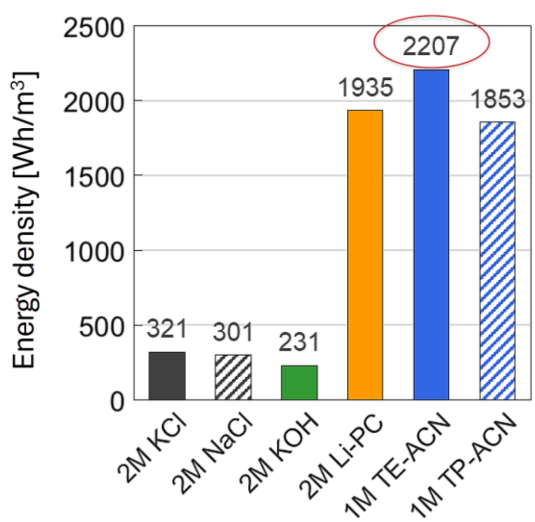
Progress in ec^3 research results in a 10x increase in the energy storage capacity



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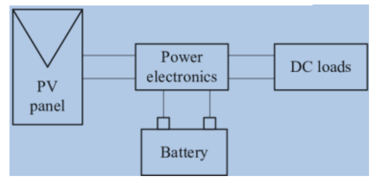
Case study of single family home to assess the environmental impact of ec^3 for energy storage application

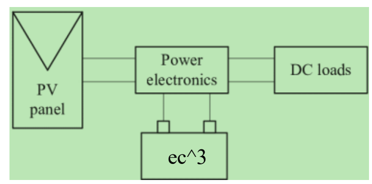
ec^3 volume = 35 m3
Location = Boston, USA
PV power = 10 kW
Scenario:

- ec^3 energy density = 2.2 kWh/m3

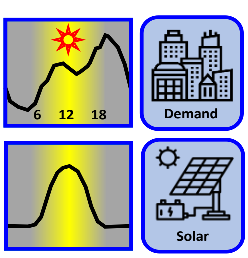
Scenario 2: PV + Li-Ion battery

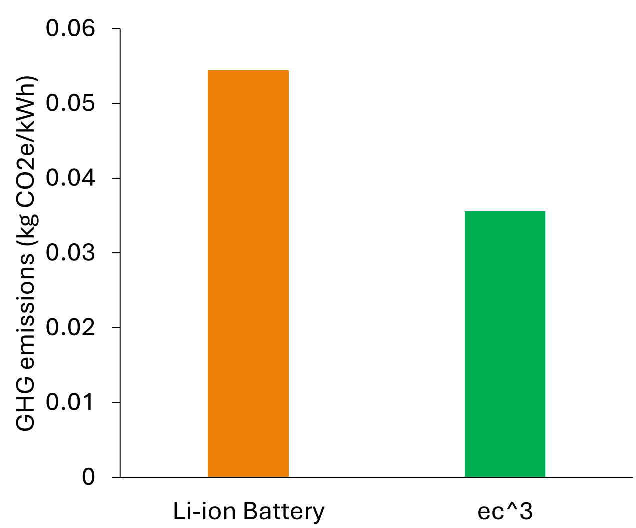


Scenario 3: PV + ec^3

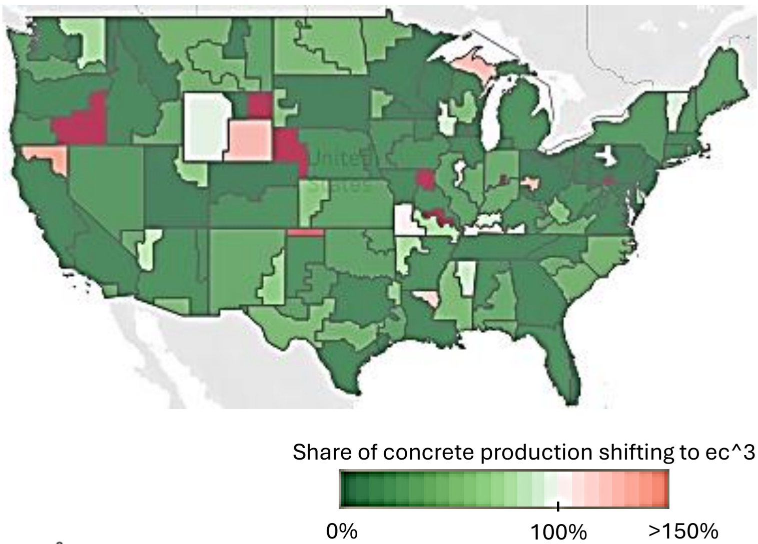


Enhancing the energy density of ec^3 results in a 35% reduction in the climate change impact associated with energy storage





ec^3 technology can cover 90% of the United Stated battery needs by 2050



In 70% of U.S. regions, battery demand can be fully met by converting less than 40% of concrete production to ec^3

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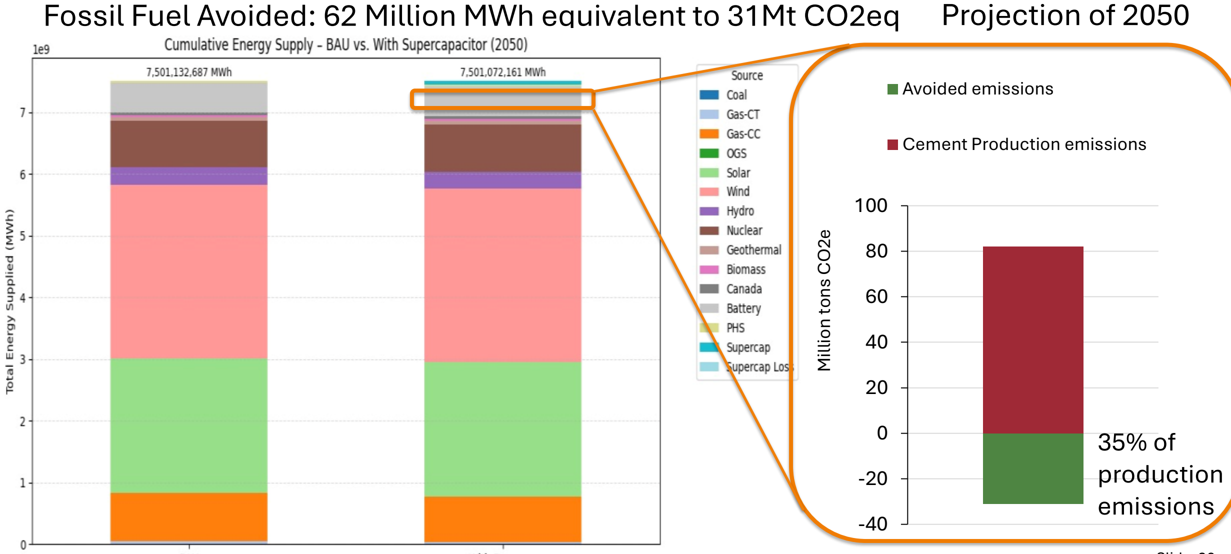
Annual environmental benefits of using concrete as an energy storage means is 35% of cement production emissions in only one year

Fossil Fuel Avoided: 62 Million MWh equivalent to 31Mt CO2eq   Projection of 2050



Effective communication is a key to the success of ec^3 implementation

- Weekly (Zoom) meetings with the Technical collaborative group

- Technical and Strategy meetings (in-person and remote)
- Monthly Research Brief Updates

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How to get involved with ec^3 hub activities?

"If you like ~~her~~ ec^3, just ask ~~her out~~ for ec^3. Always works for me"
— Henry Cavill

Collaboration for specific applications:

1) Need to license currently developed IPs (example: self-heating)

2) Need to define a new applications (open to ideas)

Organization Features Features

Technology needs	Collaborator image and vision	Scope of operation

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Acknowledgments

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CSHub MIT Concrete Sustainability Hub

Concrete Advancement Foundation

MIT ILP Industrial Liaison Program

ACA American Cement Association — Sustainable Cement for Resilient Concrete

Thank you!

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